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SUMAR

BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
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Section

MATERIALS SCIENCE AND ENGINEERING

CONTENTS

Pp.

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THE IMPORTANCE OF SURFACE ACTIVATION IN THE PHOSPHATING CHEMICAL CONVERSION PROCESS

BY

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Abstract: The process of depositing thin layers of phosphate through chemical conversion (phosphating), is widely used in industry due to its ability to improve the corrosion and wear resistance of the base material. Regarding phosphating in biomaterials, the layers deposited by this process began to be studied in the last decade. They are of real interest due to the previously mentioned properties as well as their ability to control and efficiently design phosphating solutions. Currently, most metal implants on the market are made of titanium or alloys. But, in the literature, there are few studies reported on the deposition of phosphate layers by chemical conversion on titanium surfaces. This is because its surface activation is challenging. Research on the deposition of phosphate layers on different materials shows several methods to activate their surfaces. The simplest and most common method is the mechanical one, by grinding or sandblasting, while the activation of the surface with pickling or activation solutions requires greater attention in terms of the concentrations of the substances used as well as the time of immersion of the material in the solution. Regarding the surface activation of titanium and its alloys, this is an extremely significant step in the phosphating process. Grinding and activation solutions influence the phosphate layers morphology. Therefore, to highlight the importance of surface

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activation as well as study the influence of the type of activation on the formation of phosphate layers, a zinc phosphate layer was deposited on the surface of Ti6Al4V alloys. It was analyzed how both the grinding of the surface and the immersion time in the activation solution influence the morphology of the deposited phosphate layers. This was done using scanning electron microscopy (SEM) equipped with Energy-dispersive X-ray spectroscopy (EDX) detector.

Keywords: phosphate coatings, surface activation, titanium alloy, biomaterial, SEM.

1. Introduction

Chemical conversion coating is a metal surface treatment that involves a chemical reaction at the surface of the metal (Darband and Aliofkhazraei, 2017). Phosphate layers are formed on the surface of several materials, including titanium and its alloys, using the phosphating process (Rumyantsev *et al.*, 2022). It is a substantial conversion deposition method that is widely used in a variety of industries for corrosion protection, wear resistance, and subsequent coatings (Burduhos-Nergiș *et al.*, 2019). It is distinguished by the formation of a phosphate layer on the surface of the metal. To do this, a chemical reaction occurs between the metal surface and the phosphate solution. The phosphate layer not only coats the entire surface of the material, but it also forms bonds with the substrate (Bejinariu *et al.*, 2019).

For nearly a century, phosphate chemical conversion (phosphating) has been employed in the military and automotive industries, particularly for metal anti-corrosion treatment (Burduhos-Nergis *et al.*, 2020). In the last four years, it has attracted a lot of interest in the field of surface modification of biomaterials such as titanium (Ti) (Zhao *et al.*, 2021a), magnesium (Mg) (Phuong *et al.*, 2013), and zinc (Zn) (Gao *et al.*, 2018), among others (Liu *et al.*, 2015).

Development of materials and production methods in the medical industry remains a critical therapeutic strategy for bone defects (Koons *et al.*, 2020). Despite the fact that more than 60% of orthopedic implants produce complications, the most commonly used orthopedic implants are constructed of metals such as titanium alloys, zinc alloys, magnesium alloys, cobalt-chrome alloys, and stainless steel (Baltatu, 2022; Prasad *et al.*, 2017). Ti implants, in particular, are commonly employed due to their superior mechanical characteristics and biocompatibility. However, it has some drawbacks, including a bio-inert surface and unsatisfactory corrosion and wear resistance. Taking all of this into account, numerous surface treatments can increase titanium properties (Kazantseva *et al.*, 2022; Zhao *et al.*, 2021b). The phosphate coatings deposited by titanium are one of them that can be used to improve those characteristics. However, because the titanium surface is inert, it is extremely difficult to form a phosphate layer on its surface using a chemical conversion process. As a result, it is critical to carefully select the process phases, most important being the mechanical preparation and the surface activation steps (Burduhos-Nergis *et al*., 2023).

Considering the advantages of the phosphating process for the characteristics of titanium, the present paper aims to analyse the importance of surface activation and mechanical preparation in the phosphating process of titanium by using a scanning electron microscope (SEM) equipped with an Energy-dispersive X-ray spectroscopy (EDX) detector.

2. Materials and methods

The material used as a substrate in this study is Ti6Al4V. On its surface, a zinc phosphate layer was deposited. The process used is presented in Fig. 1.

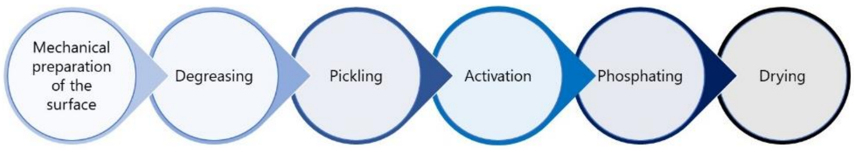


Fig. 1 – The phosphating process steps.

Metal phosphating begins with mechanical surface preparation. This can be achieved by grinding or sandblasting ceramic particles (Herbáth *et al*., 2023). Regarding titanium alloys, it has been observed that their surface can be activated by grinding, gradually from 400 grit to 1200 grit.

Before phosphating, the titanium surface must be free of grease particles. This step is critical to avoiding partial coverage of the material surface. Oily surfaces can lead to incomplete pickling. As a result, only a part of the surface is activated. Degreasing is done to remove some oils or greases used during the processing and storage of the material and to remove other residues (Darband and Aliofkhazraei, 2017). Therefore, degreasing can be done by immersing the metal in an alkaline solution based on NaOH at a temperature between 60° and 90° or by sonication in acetone, ethanol, and distilled water. In this case, the second method was used (Burduhos-Nergis *et al*., 2021a; Luk *et al*., 1999).

The following step is pickling, which removes inorganic substances and oxides from metal materials. This step prepares the surface for depositing upcoming layers on the sample surface. Titanium alloys can be pickled in hydrofluoric acid (HF), nitric acid, phosphoric acid, and sulfuric acid (Burduhos-Nergis *et al*., 2021b; Liu *et al*., 2020). The most promising is HF, while nitric acid can passivate the surface at low temperatures. In this instance, 2% HF was used for pickling.

The fourth step is one of the most critical steps in the phosphating process. This is done by immersing the metal in a titanium colloidal solution. The colloidal solution contains disc-shaped particles that are adsorbed to the metal surface during the activation period. When exposed to the zinc phosphate solution, sodium ions on the surface of the titanium phosphate particles interact with zinc ions. The ion-exchanged particles act as nucleation agents during zinc phosphating. This causes the orientation of the zinc phosphate crystals nucleated on the titanium phosphate particles. Adsorbed titanium phosphate particles can also affect the composition of the zinc phosphate layer. The mechanism of activation is not very well understood. However, it is believed that titanium phosphate particles are absorbed on the metal surface during activation and then act as nucleation agents during phosphating (Li *et al*., 2022; Tegehall, 1990; Tegehall, 1989).

The penultimate step consists of the immersion of the sample in the phosphating solution for 60 minutes at 95°C. The phosphating solution used contains Zn, Fe, NaOH, $NaNO_2$, $Na_5P_3O_{10}$, H_2PO_4 and HNO_3. After the formation of the phosphate layer, the sample is left to dry at room temperature.

The effect of the grinding and immersion time in the activation solution on the morphology of the zinc phosphate layer was study using a scanning electron microscope (Vega Tescan LMH II), equipped with Energy-dispersive X-ray spectroscopy (EDX) analysis equipment

3. Results and Discussions

In this study, we examined the difference in layer morphology obtained depending on the grinding and activation times.

In order to observe the effect of griding on the phosphate layer formation, the immersion time in the activator was set at 60 seconds.

In Fig. 2, SEM micrographs of the phosphate layer, obtained after sanding with metallographic paper of 400 grit as well as 1200 grit, can be observed.

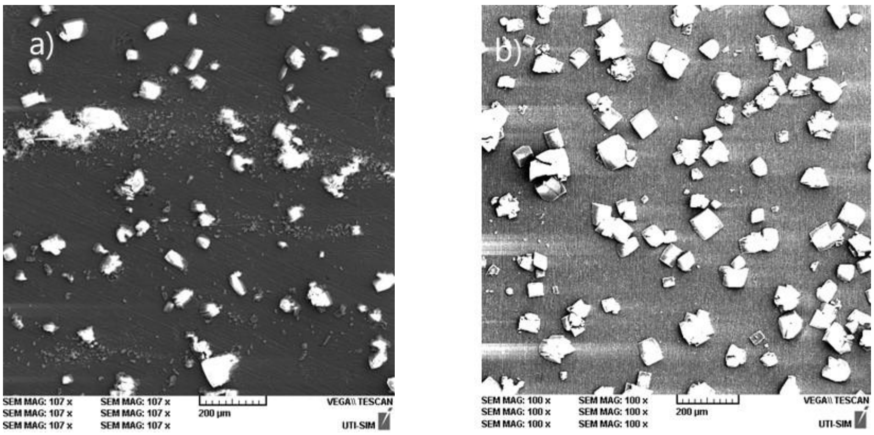
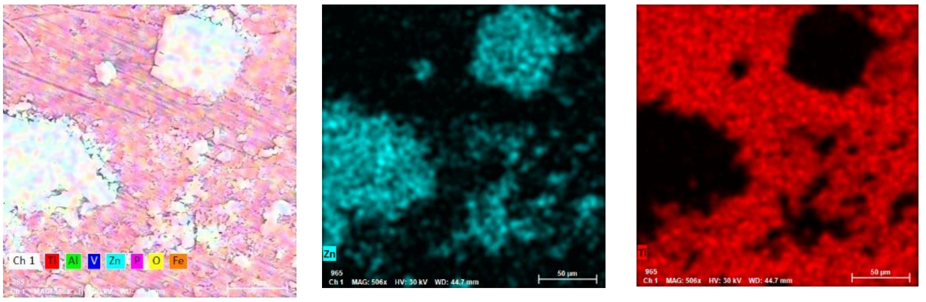
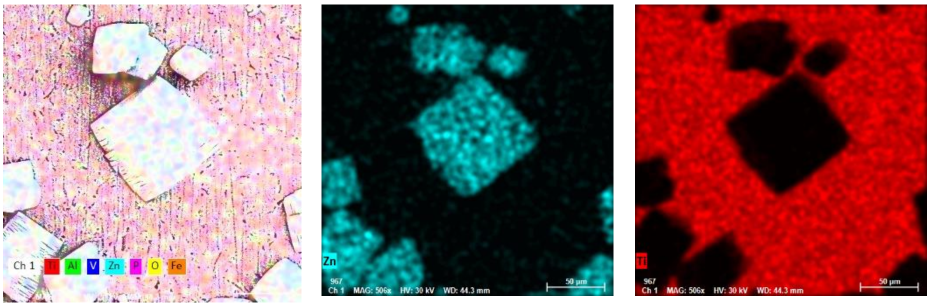


Fig. 2 – SEM micrographs of the phosphate layer grinded with a) 400 grit; b) 1200 grit.

As can be observed from Fig. 2, the number of crystals is different depending on the grinding. The largest number of crystals was obtained from the 1200-grit sample. In addition, Fig. 3 shows the elemental mapping of the zinc phosphate layer in both cases, highlighting zinc and titanium as the predominant elements. According to the EDX results, titanium is present all over the sample except on the crystals, where zinc is present. In both cases, the crystals of zinc phosphate are not covering the entire surface of the material, which can be attributed to the prolonged immersion in the activation solution. Also, the crystals for the 1200-grit sample show a more well-defined shape compared to the sample grinded with 400 grit.



The sample grinded with 400 grit



The sample grinded with 1200 grit

Fig. 3 – The elemental mapping of the main elements.

After these observations, the grinding with 1200 grit was kept, while the immersion time in the activator was changed from 60 seconds to 30 seconds. Fig. 4 shows the morphology of the phosphate layer obtained.

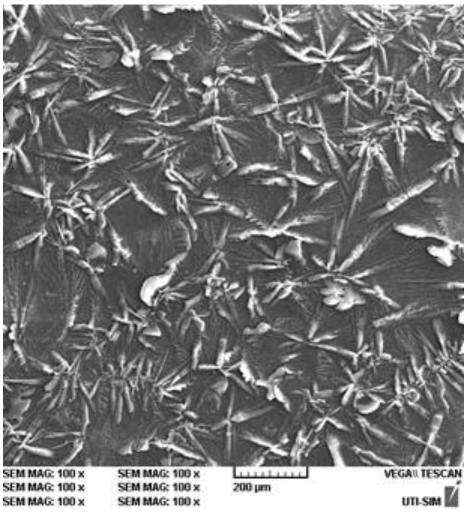


Fig. 4 – SEM micrographs of the phosphate layer after 30 seconds of immersion in activator.

As can be observed, the phosphate layer crystals changed their shape, approaching the specific form of zinc phosphate, namely the flower shape. From the point of view of the EDX results presented in Fig. 5, the zinc phosphate layer is formed over the titanium alloy surface. As a result of the thin zinc phosphate layer, titanium can be detected in some areas.

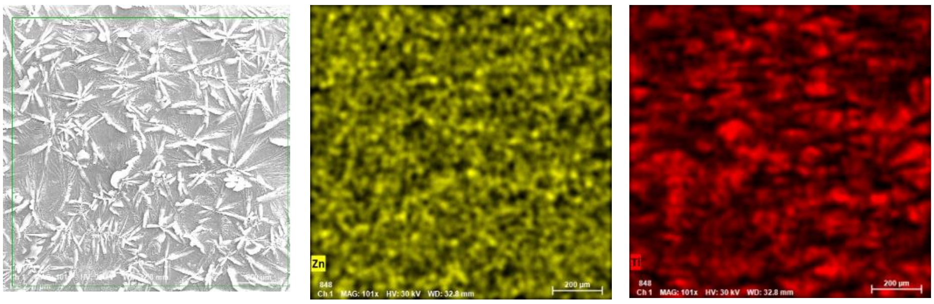


Fig. 5 – The elemental mapping of the main elements after 30 seconds of immersion in activator.

Even if the phosphate layer is obtained on the entire surface, the morphological characteristics of the phosphate layer can be improved. Therefore, the adjusting of the immersion time in the activator, the grinding, and the phosphating parameters (time and temperature) can change the morphology of the obtained layer. Also, the chemical composition of the phosphating solution is significant and must be taken into account the chemical composition of the substrate when the quantities and substances used are chosen.

4. Conclusions

The paper presents a study regarding the effect of surface activation on the formation of a zinc phosphate layer on the surface of the titanium alloy Ti6Al4V. Therefore, the following conclusions can be highlighted:

- During the grinding process, the number of crystals on the Ti surface is influenced by the mechanical preparation. Therefore, the higher the grit, the more crystals are formed on the surface;
- Mechanical preparation of the Ti surface can also be done for surface activation;
- The immersion time in activation must be lower than 60 seconds to form the phosphate layer on the entire surface of the material;
- The activation effect of colloidal titanium phosphate solutions is caused by the adsorption of colloidal particles on the metal surface. The particles can serve as nucleation agents in the zinc phosphating process.

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IMPORTANȚA ACTIVĂRII SUPRAFEȚEI ÎN PROCESUL DE FOSFATARE PRIN CONVERSIE CHIMICĂ

(Rezumat)

Procesul de depunere a straturilor subțiri de fosfat prin conversie chimică (fosfatare), este utilizat pe scară largă în industrie datorită capacității sale de a îmbunătăți rezistența la coroziune și la uzură a materialului de bază. În ceea ce privește fosfatarea biomaterialelor, straturile depuse prin acest proces au început să fie studiate în ultimul deceniu. Acestea prezintă un real interes datorită proprietăților menționate anterior precum și capacității de a controla și proiecta eficient soluțiile de fosfatare. În prezent, majoritatea implanturilor metalice de pe piață sunt realizate din titan sau aliaje sale. Însă, în literatura de specialitate, există puține studii raportate cu privire la depunerea straturilor de fosfat prin conversie chimică pe suprafețele de titan. Acest lucru se datorează faptului că activarea suprafeței sale reprezintă o provocare. Cercetările privind depunerea straturilor de fosfat pe diferite materiale prezintă mai multe metode de activare a suprafețelor acestora. Cea mai simplă și comună metodă este cea mecanică, prin șlefuire sau sablare, în timp ce activarea suprafeței cu soluții de decapare sau de activare necesita o atenție mai mare în ceea ce privește concentrațiile substanțelor folosite precum și timpul de imersare a materialului în soluție. În ceea ce privește activarea la suprafață a titanului și a aliajelor sale, acesta este o etapă extrem de importantă în procesul de fosfatare. Șlefuirea și soluțiile de activare influențează morfologia straturilor de fosfat. Prin urmare, pentru a evidenția importanța activării suprafeței, precum și pentru a studia influența tipului de activare asupra formării straturilor de fosfat, pe suprafața aliajelor de Ti6Al4V a fost depus un strat de fosfat de zinc. Așadar, s-a analizat modul în care atât măcinarea suprafeței, cât și timpul de scufundare în soluția de activare influențează morfologia straturilor de fosfat depuse. Acest lucru a fost realizat folosind microscopul electronic cu scanare (SEM) echipat cu un detector de spectroscopie cu raze X cu dispersie de energie (EDX).

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BIBLIOGRAPHIC APPROACH REGARDING ORGANIZATIONAL INTEGRATION OF HUMAN RESOURCE WITH SPECIAL NEEDS

BY

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Abstract. People with special needs represent an important "issue" around the world as over one in ten persons has a disability. An increased risk of unemployment is observed among people with disabilities in comparison with able individuals. The purpose of this paper is to clarify the organizational integration process of the human resource with special needs by developing, based on a bibliographic study, a research framework associated with this issue. The paper research working plan was to consult existing data and information (peer reviewed articles, specialty books, national and international databases, private and public institutions data, regulations, and so on) regarding the human resources with special needs. On the basis of these, the following research goals and stages were identified: (i) associated concepts regarding human resources with special needs and their integration within Romanian organizations, (ii) education process particularities of the human resources with special needs integration (factors associated to the education process of human resource with special needs), respectively the endorsed skills (systemically) and acquired process of the human resource with special needs, (iii) the need, impact and strategies of organizations employing human resources with special needs. It was identified that there are policies that are aimed at integrating people with special needs on the workforce,

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especially for preventing their discrimination. In addition, in Romania, there is a percentage level associated with the proportion of employees in a company that must be individuals with disabilities. However, people with special needs are in various predicaments regarding labor (such as scarce use of their potential, inadequate arrangements to support their needs, along with others) that are not necessarily due to their disability, but rather due to shortcomings around coordination, organization and communication of the employees and employers, as well as relevant institutions. This paper highlights the importance of further developing methods and instruments to promote and aid better workforce integration and utilization of the human resource with special needs.

Keywords: human resources, special needs, workforce integration, discrimination, disability policies.

1. Introduction

People with special needs (PWSN) represent an important topic worldwide, as more than one in ten individuals has a disability (WHO, 2011). An increased risk of unemployment is observed among people with disabilities (PWD) compared to able-bodied individuals (Barlow *et al.*, 2002). The purpose of this paper is to clarify the organizational integration process of the human resource with special needs.

Currently, the approach to people with special needs (PWSN) focuses on integration and harnessing their potential, benefiting both individuals and society. This perspective was not always prevalent. In 1981, the United Nations declared the "International Year of Disabled Persons", promoting full participation and equality for PWSN. In 1982, the General Assembly adopted Resolution 37/52, which significantly defined disability as a relationship between a person and their environment.

2. Methodology

The paper research working plan was to consult existing data and information (research studies, peer reviewed articles, specialty books, national and international databases, private and public institutions data, regulations, and so on) regarding the human resources with special needs.

On the basis of these, the following research goals and stages were identified: (i) associated concepts regarding human resources with special needs and their integration within Romanian organizations, (ii) education process particularities of the human resources with special needs integration (factors associated to the education process of human resource with special needs), respectively the endorsed skills (systemically) and acquired process of the human resource with special needs, (iii) the need, impact and strategies of organizations employing human resources with special needs.

3. Data and Results

3.1. Associated Concepts Regarding People with Special Needs

According to the latest World Health Organization - World Report on Disability (WHO, 2011), roughly 15% of the global population has a disability. This figure increased compared to the previous reports of about 10%, mainly due to aging of the population. The European Commission sets an expected disability percentage at 20% of the European population by 2020 (European Commission, n.d.). In Romania, the National Authority for Persons with Disabilities (ANPD) records 797 104 Romanians with disabilities, a total of 3.59% of the population (ANPD, 2016). (Whereas it is not certain why this observed percentage is so low in comparison with the global numbers, it is sensible to assume it is due to differences in what is counted as a disability. WHO sets the number of Romanians with disabilities at 19%, based on data from the Statistics annual book, 2008 (WHO, 2011). Therefore, it is reasonable to say that disability is part of the human experience and will in a way or another touch everyone's life (WHO, 2011).

The concept of special needs has long evolved. Before the 1970s, it was seen as a disease, often referred to as handicap, putting the individual in a rather rigid category. As of then, it made strides to be seen as a social construct (Bauman and Shaw, 2016), disability is no longer an attribute of an individual but created by the social environment, and thus requires social changes (Mitra, 2006). So, the term disability started being used and promoted instead of the term handicap.

Disability encompasses numerous definitions and categorizations, complicating consistent and clear treatment across institutions and countries. The International Classification of Functioning, Disability and Health (ICF) is a framework developed by the WHO, endorsed by all 191 Member States as of May 2001 (resolution WHA 54.21), establishing it as the international standard for describing and measuring health and disability. Figure 1 illustrates the disability model upon which the ICF is built, notable for its emphasis on the environment and the nuanced depiction of disabilities arising from the interaction between various factors.

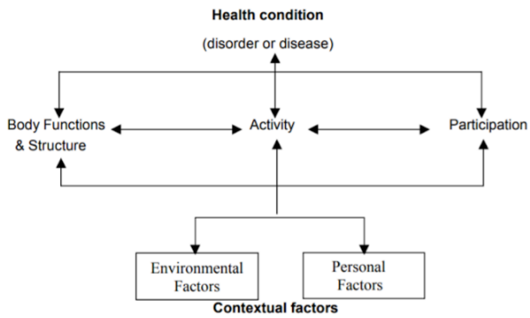

Fig. 1 − Model of Disability (Source: WHO, 2002).

Three interconnected areas are identified: impairments, activity limitations and participation restrictions (WHO, 2002). Disability results from the interaction of these areas and serves as an umbrella term encompassing impairments, activity limitations, and participation restrictions, as defined by the biopsychosocial model. Figure 2 illustrates an example of this framework in practice.

HEALTH CONDITION	IMPAIRMENT	ACTIVITY LIMITATION	PARTICIPATION RESTRICTION
Leprosy	Loss of sensation of extremities	Difficulties in grasping objects	Stigma of leprosy leads to unemployment
Panic Disorder	Anxiety	Not capable of going out alone	People's reactions leads to no social relationships
Spinal Injury	Paralysis	Incapable of using public transportation	Lack of accommodations in public transportation leads to no participation in religious activities
Juvenile diabetes	Pancreatic dysfunction	None (impairment controlled by medication)	Does not go to school because of stereotypes about disease
Vitiligo	Facial disfigurement	None	No participation in social relations owing to fears of contagion
Person who formally had a mental health problem and was treated for a psychotic disorder	None	None	Denied employment because of employer's prejudice

Fig. 2 − Examples of Disability (Source: WHO, 2002).

Considering the previous points, the goal in face of disability is to obtain independence of the PWSN, as humans have a fundamental human right of autonomy, or “self-rule”. This is done with a double approach: one, seeing PWSN as normal human beings with the same dreams and aspirations as anyone else; two, creating accessibility for PWSN (Gherguț, 2008).

In this regard, the European disability strategy 2010-2020 focuses on actions in eight priority areas:

- accessibility: ensure goods and services are accessible to people with disabilities and promote the market for assistive devices.
- participation: ensure that people with disabilities enjoy all benefits of EU citizenship, remove barriers to equal participation in public life and leisure activities, and promote the provision of quality community-based services.
- equality: combat discrimination based on disability and promote equal opportunities.

- employment: increase the participation of people with disabilities in the labor market, where they are currently under-represented.
- education and training: promote inclusive education and lifelong learning for students and pupils with disabilities. equal access to quality education and lifelong learning enables people with disabilities to participate fully in society and improve their quality of life.
- social protection: promote decent living conditions and combat poverty and social exclusion.
- health: promote equal access to health services and related facilities.
- external action: promote the rights of people with disabilities in the EU enlargement and international development programs.

Another framework sees integration from six perspectives (Meijer *et al.*, 1994): physical integration, integration at the level of terminology, integration at the administrative level, social integration, integration at the curriculum level, psychological integration.

Because the chances of PWSN are not naturally equal, there is a need for legislation to protect them. There are plenty of legislations, from national to supranational levels. Ecosoc, United Nation's Economic and Social Council, underlined the need for juridical instruments, so in 1993 the first rules regarding standard practices for egalization were adopted. This was followed by the EU in 1996.

Discrimination is when a person cannot find work not because of its inability to work but as a repercussion of no accesibility (WHO, 2001).

According to a study by Gherguț (2008), the attitudes of Romanians towards PWSN are affected by how they were treated in the communist times, when PWSN were hidden. In the West, PWSN were treated with compassion, in line with religious values, which Romania has as well. Nowadays, the attitudes are improving, PWSN are seen as different but equal with anyone else.

3.2. Education of People with Special Needs

Education of PWSN can be approached in two ways: in special schools, segregated by disability type, or in integrated schools, where all students are welcome, with PWSN having special teams that help them have needed accessibilities.

There is a consensus that the best approach is integrated education. The phrase "School for Diversity" means school for all and signifies a maximum of tolerance. An individual approach is preferred, allowing each student to perform according to its rhythm, capacity and personal needs (Popovici, 1998).

In regards to the constitutional aspects, in some countries such as Germany, inclusion is mandatory in schools, whereas in North America it is a principle, not an obligation (Kraus de Camargo, 2011). In Romania, there are laws underlying principles of evaluations and integrating students but segregation still exists.

In 2001, in a book, Gherguț highlights the process of moving away from segregation in education and truly integrating the student with special needs. The result of integration and inclusion programs in the last two decades is more openness and flexibility. In a 2011 article, Gherguț assesses the current situation. He states that only a small proportion of children with special needs have the opportunity to attend a regular community school, even if there is growing evidence that they learn better when they are allowed to go to a public school within their neighbourhood. Examples of good practice exist, but the models need to be strengthened and made more systemic.

Education forms the ability to integrate on the workforce and for the adult, a great part of life is the field of work. Transition is a complex process that needs interdisciplinary and transdisciplinary teams and approaches. A recent coordination is observed between systems of education, health care and justice (Kraus de Camargo, 2011). Despite the complexity and difficulties arising from that, it is valuable to continue and advance. One, because experience and knowledge is accumulating. Two, because PWSN might benefit from more independence.

The 1983 American law regarding education for PWSN was amended with clear models of transition between school and work, and transition made a national priority (Rusch and Phelps, 1987).

In Europe, the European Commission adopted a directive named EQUAL (1995-2011) that touches on transition by suggesting the formation of multidisciplinary teams, which should include on top of education professionals, doctors. In 2005, Hohn analyses the main results of the transition:

- transition processes needed to be individualised based on personal factors;
- PWSN have to be included and participate directly in the process;
- lowering the social barriers in order to access unemployment benefits;
- PWSN should be made sovereign over their own needs and be able to live as independently as possible.

3.3. People with Special Needs in the Workforce

Discrimination against people with special needs (PWSN) is illegal in both the private and public sectors in most countries worldwide. The Americans with Disabilities Act (ADA) in the USA was a pioneering law in the 1990s, and the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) has been universally adopted by all UN member states, totaling 193 countries.

A commonly used instrument to promote employment of PWSN is the quota system, which mandates a specific percentage (usually between 4-6%) of employees to be PWSN. Employers who do not meet this quota must pay a fee, which is directed to a fund supporting activities and programs for PWSN. Quotas are important as they clearly hold employers accountable and raise awareness even among those who do not meet the quota. In Romania, a quota was introduced in 1992 requiring organizations with over 250 employees to have 3% PWSN. This law was amended in 2002 and 2006 to include companies with over 50 employees and to raise the quota to 4% (OECD, 2007; Alpha MDN, 2010).

The proportion of PWSN in the labor market remains unclear. A World Health Survey (conducted in 51 countries) reported employment rates of 52.8% for men with disabilities and 19.6% for women with disabilities, compared to 64.9% for non-disabled men and 29.9% for non-disabled women. The OECD, based on an analysis of 27 countries, estimated the employment rate of PWSN at 44%, compared to 75% for people without disabilities (WHO, 2011). In the USA, the rates are 18% for PWSN compared to 64% for non-disabled individuals (U.S.B.L.S, 2013).

In Romania, the rate of employment of PWSN aged 18-55 is 12.7%, compared to 70% of the general population of the same age, being one of the lowest in Europe. Over the last years, there is positive growth of PWSN employment, with the rates doubling from 2003 to 2009, and in absolute numbers, there are three times more workers with special needs (Alpha MDN, 2010).

Accurate estimates of the impact of having a disability on the workforce are challenging. This is likely understated due to more inactivity on the workforce, the inactivity rate was about 2.5 times higher among PWSN (OECD, 2007); less chances at fulfilling their full potential (Bobko and Colella, 1994); and being promoted or in higher positions (U.S.B.L.S, 2013).

There are various theories in regards to the disadvantages of PWSN of the labour market. The explanations vary from general criticism of the capitalist system and economics recessions, to institutional and political failure (Acemoglu and Angrist, 2001; Lee, 2003). Especially in Europe, a continent of welfare states, there is the theory that PWSN are dependent on social benefits and so, less likely to have strong enough incentives to work (Acemoglu and Angrist, 2001). The nature of the work can also be a factor (Beegle and Stock, 2003; Jones and Sloane, 2010; Unger, 2002). Occupational inequality on the labour market in regards to PWSN, meaning the trends of occupation of certain jobs across different groups of workers, has been limited (Maroto and Pettinicchio, 2014).

Regarding the most important characteristics of potential employees, research underlines work experience and education as the fundamental variables that predict labour market outcomes of the human resource. The nature of disabilities can contribute to inequality by limiting productivity, work capacity, and other factors such as level of education and access to networking (Maroto and Pettinicchio, 2014). However, of most important is not to hire people as a social benefit but to hire them because of their skills. So, discrimination is rejecting them because of the needs they have and should be made accessibilities.

Regarding integration on the workforce, there are theories trying to explain discrimination on the labour market. One of them is expectancy theory, meaning that when facing a hiring decision, employers, lacking information, will choose employees based on observable characteristics (Reskin and Roos, 1990; Thurow, 1975). Another theory is statistical discrimination, that explains choices in regards to a person based on placing them in a category and then assessing their skills as the average of that group (Arrow, 1973; Lundberg and Startz, 1983).

These theories highlight that people will have certain expectations and attitudes towards PWSN, not necessarily based on reality. This is of most importance as PWSN are not a homogenous category, even when sharing a common diagnosis.

In relation to the type of disability, the results are inconclusive, however the attitudes will be dependent on the type of disability (Maroto and Pettinicchio, 2014).

According to the Report Regarding Invalidity, 2007, there are higher rates of employment among people with physical disabilities compared to mental ones, confirming previous studies stating that employers are more open to hiring people with physical disabilities compared to mental ones. It is likely to have different stereotypes, attitudes and expectations to different disabilities.

Numerous policies did not necessarily improve attitudes (Marotoa and Pettinicchio, 2014), some even have negative attitudes towards PWSN because they associate them with less productivity and higher costs (Schwochau and Blanck, 2000; Unger, 2002). However, it was seen that once a firm had an employee with a certain disability, it was more likely to have other employees with the same disability (Unger, 2002). To conclude, this discrepancy suggests that previous experience can eliminate myths about PWSN, reducing the uncertainty of hiring and promoting them in the workforce (Maroto and Pettinicchio, 2014).

4. Conclusions

It was identified that there are plenty of policies that are aimed at integrating people with special needs on the workforce, especially for preventing their discrimination. Furthermore, in Romania, there is a quota for a proportion of employees in a firm to be people with disabilities. However, people with special needs are in various predicaments regarding labour (such as scarce use of their potential, inadequate arrangements to support their needs, along with others) that are not necessarily due to their disability, but rather due to shortcomings around coordination, organization and communication of the employees and employers, as well as relevant institutions. This paper highlights the importance of further developing methods and instruments to promote and aid better workforce integration and utilization of the human resource with special needs.

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ABORDARE BIBLIOGRAFICĂ PRIVIND INTEGRAREA ORGANIZAȚIONALĂ A RESURSELOR UMANE CU NEVOI SPECIALE

(Rezumat)

Persoanele cu nevoi speciale reprezintă o „problemă" importantă la nivel mondial, având în vedere că mai mult de una din zece persoane are o dizabilitate. Se observă un risc crescut de şomaj în rândul persoanelor cu dizabilități, comparativ cu celelalte persoane. Scopul acestei lucrări este de a clarifica procesul de integrare organizațională a resurselor umane cu nevoi speciale, dezvoltând, pe baza studiului bibliografic, un cadru metodologic de cercetare asociat acestei probleme. Planul de lucru

al cercetării a fost să se consulte datele și informațiile existente (articole științifice, cărți de specialitate, baze de date naționale și internaționale, date ale instituțiilor private și publice, reglementările etc.) referitoare la resursele umane cu nevoi speciale. Pe baza acestora, au fost identificate următoarele obiective și etape de cercetare: (i) conceptele asociate resurselor umane cu nevoi speciale și integrarea acestora în organizațiile românești; (ii) particularitățile procesului educațional al integrării resurselor umane cu nevoi speciale (factori asociați procesului educațional al resursei umane cu nevoi speciale), respectiv abilitățile acceptate (sistematic) și procesul dobândit al resursei umane cu nevoi speciale; (iii) necesitatea, impactul și strategiile organizațiilor care angajează resurse umane cu nevoi speciale. S-a identificat că există anumite politici care vizează integrarea persoanelor cu nevoi speciale în forța de muncă, în special pentru prevenirea discriminării acestora. În plus, în România există un nivel procentual asociat angajaților într-o firmă ce trebuie să fie persoane cu dizabilități. Totuși, persoanele cu nevoi speciale se confruntă cu diferite probleme legate de muncă (cum ar fi utilizarea insuficientă a potențialului lor, aranjamente inadecvate pentru a le susține nevoile etc.) care nu sunt neapărat cauzate de dizabilitatea lor, ci mai degrabă de deficiențe în coordonarea, organizarea și comunicarea dintre angajați și angajatori, precum și instituțiile relevante. Această lucrare subliniază importanța dezvoltării ulterioare a metodelor și instrumentelor pentru promovarea și facilitarea unei mai bune integrări și utilizări a resursei umane cu nevoi speciale.

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BIODEGRADABLE MATERIALS BASED ON Zn-Mg-Ti IN MEDICINE: A PROMISING SOLUTION FOR SUSTAINABLE MEDICAL APPLICATIONS

BY

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Abstract. In the field of medicine, the development of biodegradable materials (BM) has become a priority, considering concerns related to pollution and the negative impact of medical waste on the environment. Titanium biomaterials are most commonly used in medical applications because of their exceptional characteristics, such as high corrosion resistance and biocompatibility. In recent years, three classes of BMs have been extensively investigated, including magnesium (Mg)-based, iron (Fe)-based, and zinc (Zn)-based BMs. Among these three BMs, Mg-based materials have undergone the most clinical trials. However, Mg-based BMs generally exhibit faster degradation rates, which may not match the healing periods for bone tissue, whereas Fe-based BMs exhibit slower and less complete in vivo degradation. Zn-based BMs are now considered a new class of BMs because of their intermediate degradation rates, which fall between those of Mg-based and Fe-based BMs, thus requiring extensive research to validate their suitability for biomedical applications. Zn-Mg-Ti-based materials have attracted the attention of the medical community because of their unique properties such as biodegradability and biocompatibility. This article explores the potential and applications of biodegradable Zn-Mg-Ti-based materials in medicine, highlighting

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their benefits and prospects for the sustainable development of medical technologies.

Keywords: Zn-Mg-Ti biodegradable, medical applications, implants.

1. Introduction

One of the most important characteristics of biodegradable Zn-Mg-Ti-based materials used in medicine is their biocompatibility, which refers to their ability to interact favorably with the human body without causing adverse reactions. This is a crucial property in the development of medical materials because they need to be integrated into human tissues and organs without triggering inflammation, immune rejection, or other negative effects.

Zn-Mg-Ti-based materials exhibit excellent biocompatibility, making them suitable for various medical applications (Fig. 1). This is because these materials are predominantly composed of elements naturally present in the human body, such as zinc, magnesium, and titanium. This significantly reduces the risk of adverse reactions and increases the likelihood of acceptance and tolerance of these materials by the body (Roohani *et al*., 2013).

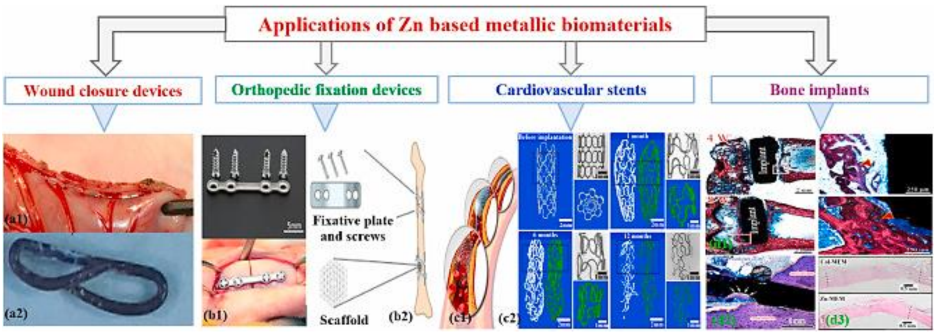

Fig. 1 – Potential applications of Zn-based biodegradable materials (Kabir *et al*., 2021).

In addition to biocompatibility, Zn-Mg-Ti-based BM are also non-toxic. This means that as they degrade in the body, they do not release toxic substances that could negatively affect the patient's health. This property is particularly important in the case of materials used in medical implants, where any release of toxic substances could hinder the healing process and overall health of the patient (Roohani *et al*., 2013).

The biocompatibility and non-toxicity of Zn-Mg-Ti-based biodegradable BM in medicine represent significant advantages compared with conventional materials. They allow for their safe and efficient use in various medical applications, contributing to superior therapeutic outcomes and minimizing risks for patients. Moreover, these properties open up new opportunities for the use of Zn-Mg-Ti-based BM in the field of regenerative medicine and personalized therapies, where biocompatibility and non-toxicity are essential factors for treatment success (Roohani *et al*., 2013).

2. Biodegradability control

The control of biodegradability in Zn-Mg-Ti-based materials can be achieved by adjusting their chemical composition and structure (Fig. 2). The percentage of magnesium and titanium in the Zn-Mg-Ti alloy can be modified to influence the degradation rate. For example, increasing the magnesium content in the alloy can accelerate the biodegradation process, whereas the addition of titanium can slow down this process. This approach allows for the customization of materials based on the specificity of the application, ensuring appropriate biodegradability and controlled release of active substances (Hutmacher *et al*., 2001).

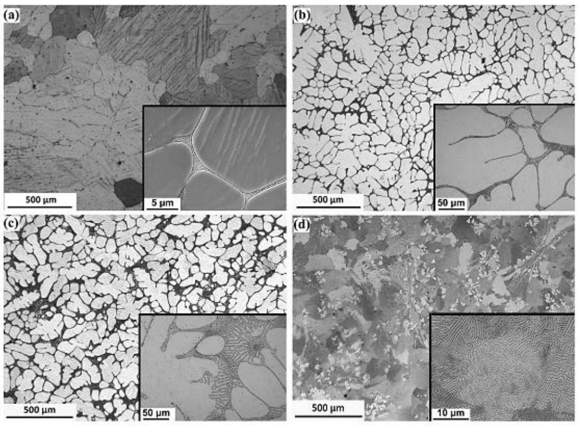

Fig. 2 − Optical microstructures of as-cast Zn-Mg alloys: (a) Zn-0.15 Mg, (b) Zn-0.5 Mg, (c) Zn-1Mg, (d) Zn-3Mg (Mostaed *et al.*, 2016).

The control of biodegradability in Zn-Mg-Ti-based materials in medicine has significant implications for medical treatments (Bowen *et al*., 2016). For instance, in the case of implants, it is crucial for the material to degrade at a rate compatible with the healing and tissue regeneration around the implant. Too rapid biodegradability could compromise the stability and structural support of the implant, whereas too slow biodegradability would require secondary surgical interventions for implant removal (Li *et al*., 2020).

Regarding BM used in medicine, it is essential that it provides adequate mechanical properties and maintains structural stability during the biodegradation process. These characteristics are particularly important in medical applications where materials must withstand the specific mechanical demands of the physiological environment and support the structural integrity of medical devices or implants (Witte, 2010). Tissue regeneration must be in accordance with the degradation rate of the implant and the maintenance of its mechanical integrity (Hermawan *et al*., 2010) for as long as necessary until complete healing (Fig. 3).

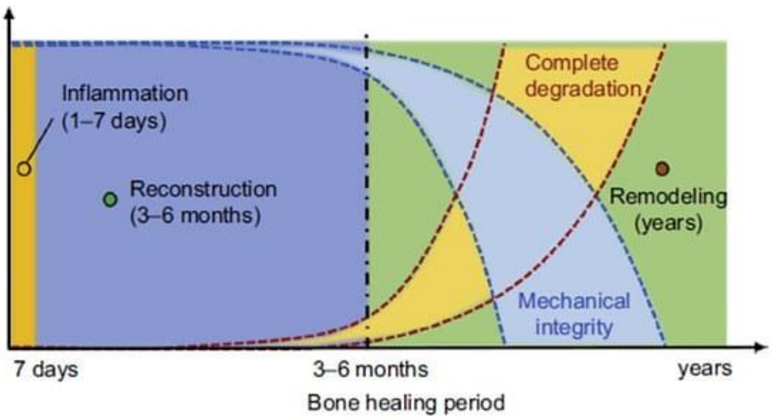

Fig. 3 − The correlation between the degradation rate and the mechanical resistance of a biodegradable metal implant (Paramitha *et al*., 2017).

The presence of adequate mechanical properties and stability during biodegradation provides significant advantages for Zn-Mg-Ti-based BM in the field of medicine. These materials can be used to create durable medical devices and implants capable of withstanding physiological demands and providing structural support during the healing process. By combining suitable mechanical properties with biodegradability and biological compatibility, Zn-Mg-Ti-based materials have emerged as an attractive option for various medical applications, contributing to the improvement of treatment quality and promoting rapid and efficient recovery for patients (Hermawan, 2012).

3. Medical implant applications

3.1. Orthopedic implants and osteosynthesis

One of the important applications of Zn-Mg-Ti-based BM in medicine is in the field of orthopedic implants. Orthopedic implants are used to replace or repair joints, bones, or soft tissues affected by trauma, degenerative diseases, or other conditions.

Zn-Mg-Ti-based BMs are particularly suitable for orthopedic implants because of their unique combination of properties. They provide adequate mechanical strength to support the loads and stresses applied during the healing period while gradually degrading into the human body. This aspect is essential to allow the tissues to gradually assume the load and regenerate around the implant without the need for additional surgical intervention to remove the implant.

In addition, Zn-Mg-Ti-based BM exhibits biological compatibility and stimulates tissue growth and regeneration. They can promote the formation of new bone around the implant, facilitating its integration into the existing bone tissue. As the material gradually degrades, the newly formed bone gradually takes over the load-bearing function, rendering the implant unnecessary.

The use of Zn-Mg-Ti-based BM in orthopedic implants offers multiple advantages. These include avoiding secondary surgeries for implant removal, reducing the risk of infections and adverse reactions associated with permanent implants, and promoting natural healing and tissue regeneration process (Fig. 4). Moreover, Zn-Mg-Ti-based BM contributes to faster recovery and restoration of normal functionality in patients (Sheikh *et al.*, 2015).

Fig. 4 − Orthopaedic fixation device (Punjabi *et al.*, 2015).

However, there are still challenges to overcome in the use of Zn-Mg-Ti-based BM in orthopedic implants. These challenges include optimizing the mechanical properties and degradability of the material to match the specific requirements of each case and ensuring proper integration of the implant into the surrounding tissues. Despite these challenges, the use of Zn-Mg-Ti-based BM in orthopedic implants represents a promising direction for research and development with the potential to significantly improve the life quality of patients and orthopedic treatment outcomes (Li *et al.*, 2022).

3.2. Cardiovascular implants

BM based on Zn-Mg-Ti have particular importance in the field of cardiovascular implants and stents. These devices are used to treat cardiovascular conditions and to keep the arteries open in cases of stenosis or blood vessel obstruction (Fig. 5). BM in this context offers significant advantages over permanent implants and stents (Li *et al*., 2020).

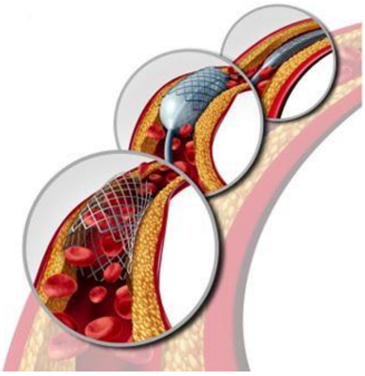

Fig. 5 − Coronary artery stent illustration (Mostaed *et al*., 2018).

An important advantage of biodegradable cardiovascular implants based on Zn-Mg-Ti is their ability to support the normal function of blood vessels during the healing period. These implants provide adequate mechanical support and keep the arteries open until the blood vessels heal and regain their elasticity and normal functionality. As the biodegradable material degrades, the blood vessels gradually take over the load-bearing function, ensuring optimal long-term functionality (Li *et al*., 2022).

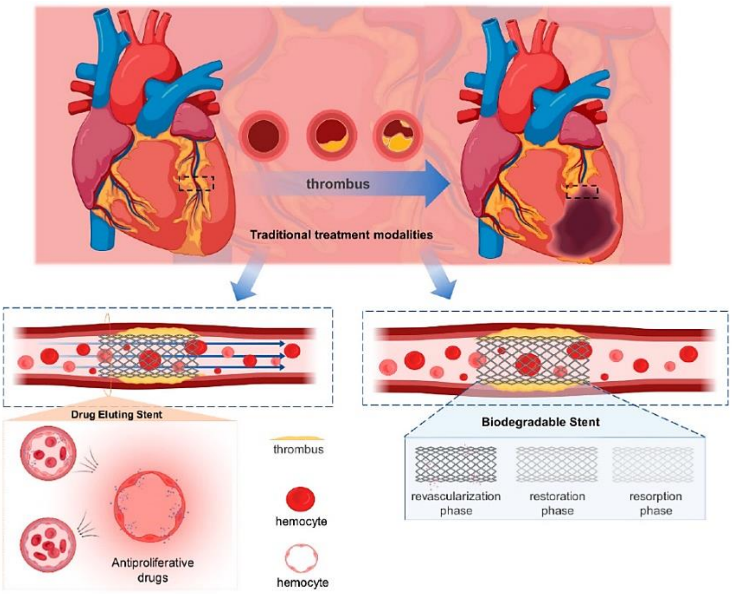

Fig. 6 − The schematic principle of drug-eluting stents and degradable stents (Zhang *et al*., 2023).

An important aspect of biodegradable Zn-Mg-Ti-based stents is their ability to release controlled amounts of drugs during the degradation process (Fig. 6). These substances can be incorporated into the material matrix or coated on the surface of the stent, gradually releasing into the affected area, thereby reducing inflammation and restenosis. After the complete release of the medicaments, the stent naturally degrades, thus avoiding complications associated with permanent stents (Moravej *et al*., 2010).

However, there are challenges and considerations in the use of biodegradable cardiovascular implants and stents based on Zn-Mg-Ti. Optimization of the degradation rate of the material according to the specific needs of each patient and condition is necessary (Li *et al*., 2020).

3.3. Scaffolds for Tissue Regeneration

Another field in which BM based on Zn-Mg-Ti are used in medicine is tissue regeneration. Scaffolds are three-dimensional structures used to support and guide the growth and regeneration of tissues in cases of tissue injuries or defects (Fig. 7). They can be used in various applications such as bone, cartilage, nerve, and skin tissue regeneration (Li *et al*., 2022).

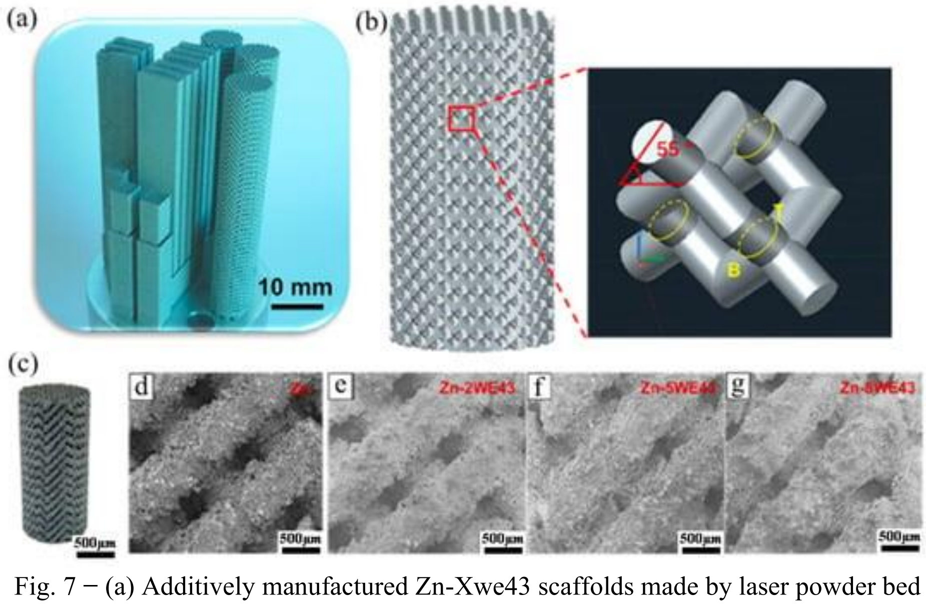

Fig. 7 − (a) Additively manufactured Zn-Xwe43 scaffolds made by laser powder bed fusion (L-PBF): (b) shape of porous scaffolds, (c) macro image, (d–g) enlarged parts of Zn-xWE43 (Kong *et al*., 2023).

BMs based on Zn-Mg-Ti are considered ideal for manufacturing scaffolds because of their unique properties. They provide a stable mechanical structure and sufficient strength to support the tissues during the regeneration process while gradually degrading into the body. The degradation process is synchronized with tissue formation and regeneration, allowing the scaffold to serve its temporary function and facilitate healing and natural regeneration of the affected tissue (Li *et al*., 2022).

An important aspect of biodegradable scaffolds based on Zn-Mg-Ti is their ability to promote cell adhesion and stimulate the proliferation and differentiation of stem cells into the desired tissue. The biodegradable material can be modified to provide an appropriate surface for cell attachment, thereby promoting cell interaction and growth. In addition, the scaffold can be functionalized with growth factors or bioactive substances to enhance the regeneration process and improve therapeutic outcomes (Paiva *et al*., 2022).

4. Advantages of Zn-Mg-Ti BM in medicine

4.1. Avoidance of secondary surgical interventions for implant removal

One of the main challenges in using permanent implants in medicine is the need for additional surgical interventions to remove them after they have fulfilled their therapeutic purpose. In many cases, this involves discomfort for the patient, increases the risk of complications, and requires additional medical resources. The use of BM based on Zn-Mg-Ti eliminates the need for secondary surgical removal interventions, bringing significant benefits to patients and medical professionals (Bowen *et al*., 2016).

Biodegradable implants based on Zn-Mg-Ti are characterized by their ability to gradually degrade in the body as they fulfill their therapeutic function. This controlled degradation process is synchronized with the healing and regeneration processes of the tissues surrounding the implant. As the biodegradable material decomposes, it is replaced by the patient's natural tissues, rendering the implant unnecessary (Wang *et al*., 2022).

The advantages of using biodegradable implants to avoid secondary surgical interventions are manifold. First, it eliminates the need for a surgical procedure to remove the implant, thereby reducing patient discomfort and the risk of complications associated with surgical procedures. Instead of requiring a second surgery, the biodegradable material naturally degrades and is absorbed by the body, thus avoiding the trauma and additional costs associated with implant removal (Zhang *et al*., 2021).

Another important advantage is the conservation of medical resources. Eliminating the need for secondary surgical interventions reduces the time and resources required for patient treatment. These resources can be allocated to other patients or used in other medical procedures, thus contributing to the efficiency and sustainability of the healthcare system.

Furthermore, avoiding secondary surgical interventions can have a positive impact on patients' quality of life. Patients recover faster and experience fewer side effects and complications associated with repeated surgical procedures. It can also lead to a reduction in the recovery period and a quicker return to normal daily activities (Roohani *et al*., 2013; Mbogori *et al*., 2022).

4.2. Reducing the risk of infections and adverse reactions

An important aspect in reducing the risk of infections is the fact that Zn-Mg-based biodegradable implants can be manufactured with antimicrobial properties (Fig. 8). The material can be modified to release antimicrobial substances in a controlled manner, inhibiting bacterial growth and thus reducing the risk of infections. This is a valuable feature, especially in the case of implants that are directly exposed to the external environment or placed in areas with a higher risk of contamination (Jana *et al*., 2022).

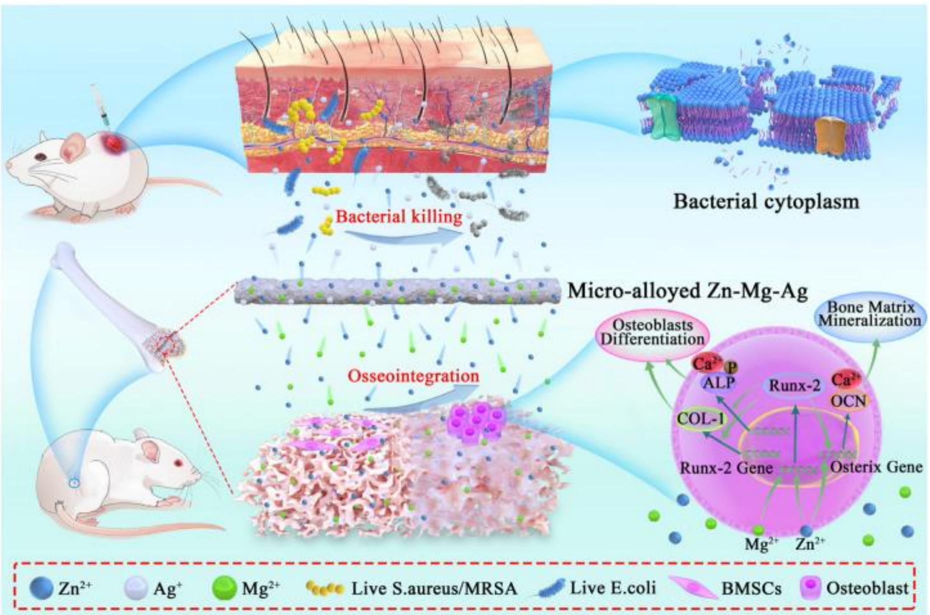

Fig. 8 − Scheme showing the autoantibacterial and osseointegration mechanisms of microalloyed Zn-Mg-Ag alloys (Chen *et al*., 2023).

Furthermore, Zn-Mg-Ti-based BM are well tolerated by the body and has a low risk of adverse reactions or immune rejection. They are biologically compatible and do not cause excessive inflammatory reactions or material rejection compared with permanent implants made from foreign materials. This reduces the risk of complications and contributes to a faster and more comfortable recovery for the patient (Sarian *et al*., 2022; Unune *et al*., 2022).

4.3. Stimulation of tissue regeneration and accelerated healing

Another significant benefit of Zn-Mg-Ti-based BM in medicine is its ability to stimulate tissue regeneration and accelerate the healing process. This aspect is particularly important for treating injuries and tissue defects, where the main goal is to restore the normal structure and function of the affected tissue (Wang *et al*., 2022).

Biodegradable implants based on Zn-Mg-Ti can be designed and functionalized to stimulate tissue regeneration. The biodegradable material can be modified to release growth factors, bioactive substances, or other bioactive molecules that support and promote healing and regeneration processes. These substances can activate stem cells, stimulate cell proliferation and differentiation, promote angiogenesis (the formation of new blood vessels), and support the formation of new tissue.

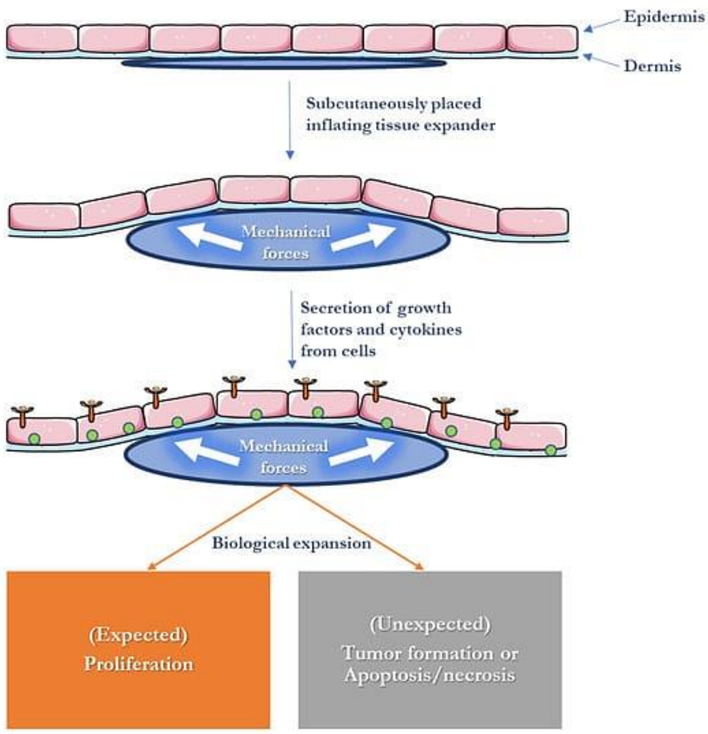

Fig. 9 − The sequence of tissue expander inflation depicted schematically (Hassan *et al*., 2023).

In addition, the biodegradable material based on Zn-Mg-Ti can provide structural support for tissue growth. Scaffolds made from this material can have a porous structure that allows cell infiltration and the formation of new tissue within the pores (Fig. 9). This facilitates cell adhesion, cell growth, and differentiation and the formation of an adequate extracellular matrix to support and organize the regenerated tissue (Xing *et al*., 2022).

Another important aspect is that Zn-Mg-Ti-based BM biodegradable materials have suitable mechanical properties to support tissues in the regeneration process. They provide sufficient strength and stability, allowing tissues to develop and regenerate safely and efficiently (Fig. 9). As the implant gradually degrades, the tissues consolidate and regain their normal function (Paiva *et al*., 2022).

Another advantage of using biodegradable implants in stimulating tissue regeneration and accelerating healing is that they can be personalized and adapted to meet the specific needs and requirements of each patient and type of injury. Scaffolds can be manufactured in various shapes and sizes and tailored to individual tissue defects. In addition, the controlled release of bioactive substances can be adjusted on the basis of the healing stage and the specific needs of the patient (Moravej *et al*., 2010).

5. Perspectives and challenges in the use of Zn-Mg-Ti-based biodegradable materials in medicine

5.1. Optimization of mechanical properties and degradability

In the development of Zn-Mg-Ti-based BM biodegradable materials used in medicine, optimizing mechanical properties and degradability is a crucial aspect. This is important to ensure that implants are sufficiently strong and stable to fulfill their intended function during the healing period, while also degrading in a controlled and safe manner within the body (Hermawan *et al*., 2010).

The mechanical properties of biodegradable implants, such as strength, hardness, and flexibility, need to be balanced to provide structural support and stability during the healing process. The implants should be able to withstand specific loads and mechanical stresses in the targeted area. Simultaneously, they should not be too rigid or exhibit excessive strength that could cause undue stress on the surrounding tissue or hinder the regeneration process (Li *et al*., 2020).

To optimize the mechanical properties and degradability of Zn-Mg-Ti-based implants, various techniques and strategies are employed. One of these is to adjust the chemical composition of the material. Adding other elements such as aluminum (Al), lithium (Li), or other metals can improve the mechanical properties and degradability of the material (Fig. 10). In addition, controlling manufacturing parameters, such as processing and heat treatments, can influence the material's properties.

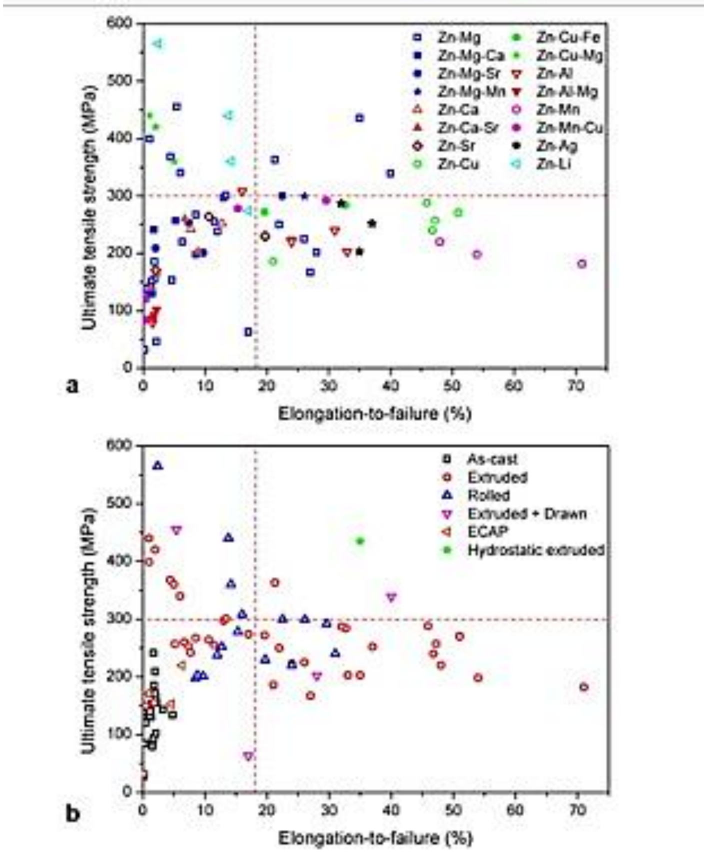

Fig. 10 – The ultimate tensile strength vs. elongation-to-failure plot of binary and ternary absorbable Zn-based alloys (Hernández-Escobar *et al.*, 2019).

Developing scaffolds with a porous structure is another strategy for optimizing the mechanical properties and degradability of implants. These allow for cell infiltration and tissue growth within the pores, thereby ensuring good integration and regeneration of the surrounding tissue. In addition, the porous structure can be tailored to provide the necessary strength and stability while also enabling controlled material degradation (Hermawan *et al.*, 2010).

5.2. Stimulation of tissue regeneration and accelerated healing

Another important aspect of Zn-Mg-Ti-based BM in medicine is their ability to be used for controlled drug delivery. This functionality provides an efficient means of delivering active substances to specific locations in the body (Fig. 11), with gradual and controlled release over a period of time (Jana *et al.*, 2022).

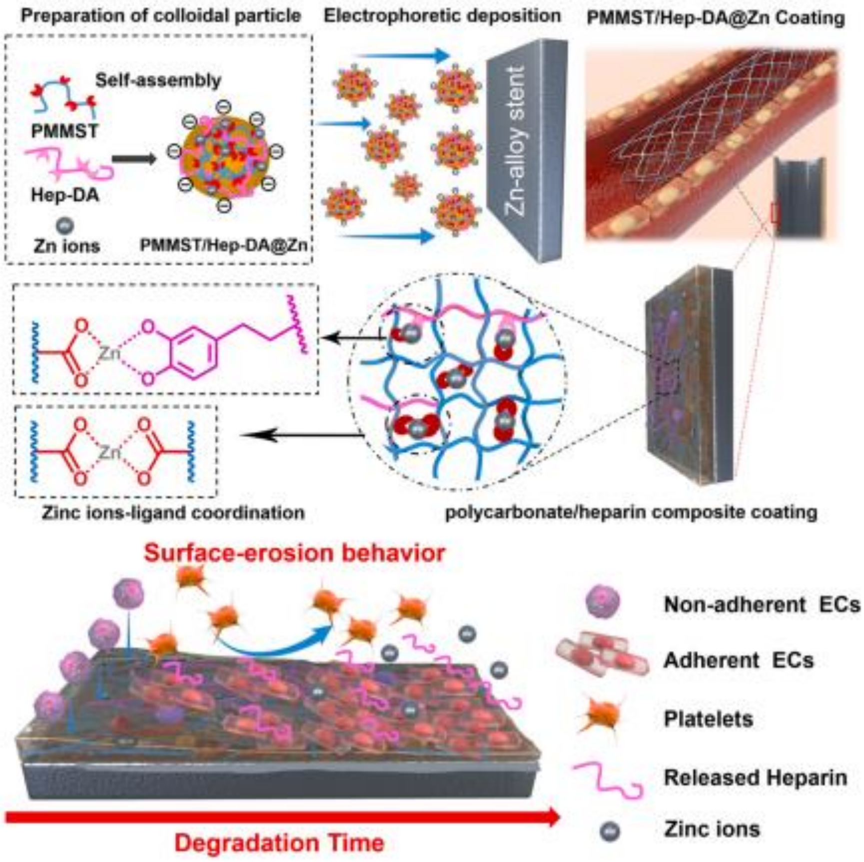

Fig. 11 – Electrophoretic deposition used to create a Zn-ion cross-linked polycarbonate/heparin composite layer on a Zn-alloy stent with heparin release for anticoagulation (Pan *et al*., 2022).

Using Zn-Mg-Ti-based implants for controlled drug delivery offers multiple advantages. It allows for the localized administration of active substances directly to the target area, thereby reducing side effects on other tissues and minimizing the patient's overall exposure to drugs. In addition, controlled drug delivery can enhance therapeutic efficacy by maintaining the appropriate therapeutic concentration in the affected area over a longer period of time (Li *et al*., 2022).

Various strategies and techniques have been employed to develop controlled drug delivery systems using Zn-Mg-Ti-based biodegradable materials. One of the most common approaches is to incorporate drugs into the biodegradable material matrix. Drugs can be added during the manufacturing process or incorporated later, depending on the specific requirements and characteristics of the active substance. Drug release is controlled by the material’s degradation rate, allowing for the gradual and consistent release of the active substance into the body (Hermawan *et al*., 2010).

Nanoparticle- or microsphere-based drug delivery systems can also be used. These involve encapsulating the drug within small particles, which are then incorporated into the matrix of the biodegradable material. These nanoparticles or microspheres provide additional protection for the drug, ensuring controlled and targeted release at the desired location (Hermawan, 2012).

Another strategy is the use of a coating or polymeric layer around the biodegradable implant. These layers can control the release of drugs through diffusion or specific chemical reactions, such as hydrolysis. This allows for gradual drug release based on therapeutic requirements and the necessary healing period (Sheikh *et al*., 2015).

5.3. Long-term testing and regulatory adaptation

Regarding the use of Zn-Mg-Ti-based implants in medicine, long-term testing and regulatory adaptation are essential to ensure the safety and efficacy of these biodegradable materials. These processes are crucial for evaluating the behavior of implants in the human body over an extended period and for developing appropriate standards and regulations for their use in medical practice (Roohani *et al*., 2013).

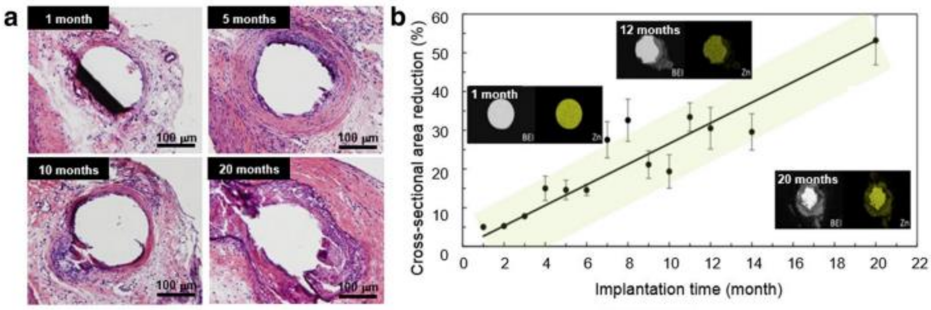

Fig. 12 – In vivo study of biodegradable zinc wires: a) murine artery appearance at different implantation times, b) rate of cross-sectional reduction of implanted zinc wires as a function of time (Drelich *et al*., 2017).

In a prolonged implantation investigation in vivo, Drelich et al. (2017) showed that persistent inflammation associated with the corrosion activity of zinc wires implanted in the murine artery decreased between 10 and 20 months (Fig. 12a). Despite a constant accumulation of passive corrosion compounds and considerable fibrous encapsulation of the wire, the wires maintained a constant corrosion rate for up to 20 months after implantation (Fig. 12b) without causing local toxicity. The results indicated that zinc stents could degrade effectively over a period of about 1-2 years (Drelich *et al*., 2017).

6. Conclusions

The use of Zn-Mg-Ti-based BM in medicine presents a promising solution for sustainable medical applications. Their unique properties, such as controlled biodegradability and biocompatibility, make them suitable for a wide range of applications, including orthopedic implants, dentistry, cardiology, and tissue regeneration. The benefits offered by these materials include avoiding secondary surgical interventions for implant removal, reducing the risk of infections and adverse reactions, as well as promoting tissue regeneration and accelerated healing.

However, there are still challenges to overcome in optimizing the mechanical properties and degradability of Zn-Mg-Ti-based materials, as well as developing controlled drug delivery strategies. Long-term testing and regulatory adaptation are also important aspects for the safe and efficient use of these materials in the medical field.

Nevertheless, the perspective of using Zn-Mg-Ti-based BM in medicine is encouraging, as they can contribute to a more sustainable medical practice, reducing the impact on the environment and providing more efficient therapeutic solutions to patients. With ongoing research and development in this field, these materials are expected to play an increasingly important role in improving the quality of life and clinical outcomes for patients.

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MATERIALE BIODEGRADABILE PE BAZĂ DE Zn-Mg-Ti ÎN MEDICINĂ: O SOLUȚIE PROMIȚĂTOARE PENTRU APLICAȚII MEDICALE DURABILE

(Rezumat)

În domeniul medicinei, dezvoltarea de materiale biodegradabile a devenit o prioritate, având în vedere preocupările legate de poluare și impactul negativ al deșeurilor medicale asupra mediului. La nivel mondial, mai mulți cercetători depun eforturi considerabile pentru dezvoltarea de polimeri biodegradabili care să conducă la fabricarea de compozite polimerice biodegradabile pentru diverse aplicații inginerești. Ca un nou tip de metal biodegradabil, Zn posedă caracteristici promițătoare, și anume: biodegradabilitate și biocompatibilitate adecvate, consum mai mic de energie pentru elaborare, o mai bună reciclare și toleranță la dimensiunea de prelucrare. Biomaterialele din titan sunt utilizate cel mai frecvent pentru aplicații medicale datorită caracteristicilor lor excepționale, cum ar fi rezistența ridicată la coroziune și biocompatibilitatea. În ultimii ani, trei clase de BM au fost investigate pe larg, inclusiv BM pe bază de magneziu (Mg), BM pe bază de fier (Fe) și BM pe bază de zinc (Zn). Dintre aceste trei BM, materialele pe bază de Mg au fost supuse celor mai multe studii clinice. Cu toate acestea, BM pe bază de Mg prezintă, în general, rate de degradare mai rapide, care pot să nu corespundă perioadelor de vindecare a țesutului osos, în timp ce BM pe bază de Fe prezintă o

degradare in vivo mai lentă şi mai puţin completă. BM-urile pe bază de Zn sunt considerate în prezent o nouă clasă de BM-uri datorită ratelor lor intermediare de degradare, care se situează între cele ale BM-urilor pe bază de Mg și cele pe bază de Fe, necesitând astfel cercetări extinse pentru a valida adecvarea lor pentru aplicații biomedicale. Materialele pe bază de Zn-Mg-Ti au atras atenția comunității medicale datorită proprietăților lor unice, cum ar fi biodegradabilitatea și biocompatibilitatea. Acest articol explorează potențialul și aplicațiile materialelor biodegradabile pe bază de Zn-Mg-Ti în medicină, subliniind beneficiile și perspectivele acestora în dezvoltarea durabilă a tehnologiilor medicale.

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RESEARCH ON THE INFLUENCE OF INDIRECT ELECTRIC ARC WELDING ON THE MICROHARDNESS OF 10% MAGNESIUM ALUMINUM ALLOY

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Abstract. The paper presents some general aspects related to the indirect electric arc welding method, with direct applicability to the welding of an aluminum-magnesium alloy. The method used in the experiments is the modified one, in which profiled parts are used instead of additional plates. Parts from an aluminum alloy with 10% magnesium are used, after welding analyzing the microhardness profile on a section perpendicular to the weld bead. It was observed that the microhardness profile along the welded joint is not linear, showing minimums of approx. 54% (at the BM/HAZ limit), respectively approx. 68% in WM of the microhardness value of the base metal material.

Keywords: indirect electric arc welding method, aluminum-magnesium alloy, microhardness profile.

1. Introduction

The indirect electric arc welding method is based on electric arc welding in an inert gas environment, the melting of the base metal not taking place through direct contact with the electric arc but through thin metal plates

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(of the same chemical composition as the base metal) with role of feeding the joint, placed above the parts to be joined and aligned with the joint (Fig. 1a). Consequently, the metal bath will be composed of both metal from the filler wire, as well as from the additional plates and base material from the parts to be joined. It was found that the microstructure of the obtained assembly improves the corrosion resistance, as well as overall mechanical properties (García *et al*., 2002; Garcia *et al*., 2007).

Indirect electric arc welding allows for the joining of relatively thick plates in a single pass, without the occurrence of defects related to incomplete joint penetration and with a reduced heat input, resulting in a reduction of the thermal influence on the base metal (García *et al*., 2002; Guiterrez *et al*., 1996; Date *et al*., 1999).

A higher thermal efficiency compared to the conventional method of arc welding in a protective gas environment has been observed, explained by the fact that it is no longer in direct contact with the surrounding environment, which is instead confined within the volume between the additional plates. This characteristic of the method allows, in the case of welding aluminum alloys, the avoidance of the phenomenon of overaging in the heat-affected zone (HAZ), which leads to a decrease in the mechanical strength of the material in this area and, consequently, its fracture under low stress conditions (García *et al*., 2002; Garcia *et al*., 2007).

The main disadvantage of the method is that, after the welding operation is completed, the filler plates must be removed, which can lead to the deterioration of the assembly and an increase in the final price. However, this disadvantage can be overcome if these plates are replaced by a special design of the parts towards the joint area, which imitates the geometric shape of the filler plates (see Fig. 1b). In this way, the additional operation of cleaning/removing of the additional plates is eliminated and the results of mechanical tests are at least as good as in the case of conventional joining (Ambriz *et al*., 2006; Ambriz *et al*., 2011; Ambriz *et al*., 2009).

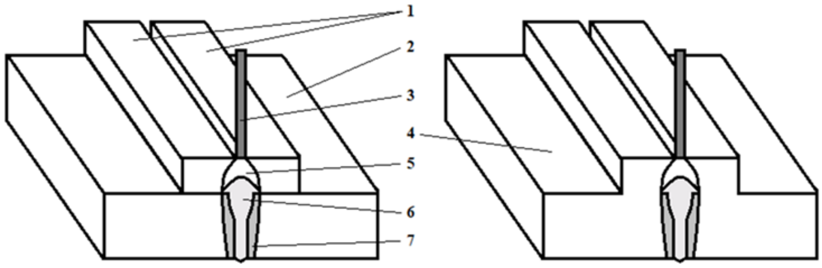

Fig. 1 – The principle of the indirect electric arc welding method; a-method with additional plates, b-method with profiled joint parts; 1-adder plates, 2-joints, 3-electrode, 4-profiled joints, 5-electric arc, 6-liquid metal bath, 7-molten base metal (after García *et al*., 2002).

In general, aluminum alloys are difficult to weld using electric arc welding methods, primarily due to their high thermal conductivity, rapid formation of an aluminum trioxide film on the weld pool, and tendency to form pores and solidification cracks (Date *et al*., 1999).

The heat required for fusion welding of aluminum alloys is approximately the same as that required for welding steels, even though the melting temperature of aluminum alloys is much lower. The phenomenon is due to the high thermal conductivity of these materials. The large amount of heat introduced into the welded area has negative effects, such as the appearance of unwanted structural changes, deformations and cracks, the reduction of mechanical properties in the areas of the welded joint compared to the base material (Pavel, 2022; Agudo *et al*., 2007).

From a structural standpoint, it can be considered that, generally, on both sides of the weld, there is a area of approximately 30 mm with significant structural changes (the heat-affected zone, HAZ) (Pavel, 2022; Agudo *et al*., 2007). The weld essentially has a cast structure.

Nonthermally hardenable aluminum alloys suffer in the thermally influenced zone a decrease in mechanical resistance to the level of a "soft" state of the base material, a phenomenon that can be eliminated by processing through cold plastic deformation of the material. In thermally hardenable alloys, the recovery of the mechanical strength characteristics of the welded joint can be achieved by applying after welding of a heat treatment involving solution quenching and aging (Pavel, 2022).

The elimination of the mentioned before disadvantages can be achieved by the method of indirect electric arc welding because, even if the parts to be welded are relatively thick 12.5 mm, (García *et al*., 2002) a single pass is sufficient, which makes the heat flux introduced into the process to be relatively small. Consequently, the thermal action on the base metal is reduced and, therefore, the decrease in the mechanical strength of aluminum alloys is minimal.

The use of the indirect method with profiled parts has the following advantages (Ambriz *et al*., 2006; Ambriz *et al*., 2009): high thermal efficiency, allowing welding in a single pass, thereby improving the mechanical properties of the material in the HAZ (heat-affected zone); enhanced dilution in the weld bath, leading to increased hardness after subsequent heat treatment; heterogeneous nucleation solidification reduces the formation of micro-porosities; the geometry of the welded parts improves the fatigue strength of the weld joint.

2. Microhardness study of the welded area

In order to analyze the influence of the indirect electric arc welding method on the mechanical properties of the welded zone, an aluminum alloy with 10% magnesium was chosen. Our choice is based on the fact that this alloy is commonly used in engineering due to its lightweight properties, and it can be successfully used to produce ultra-lightweight composite materials (Carcea and Roman, 2009).

The alloy was obtained by melting in an electric furnace with silite bars, with a maximum temperature of 900°C and a maximum capacity of 3 Kg. After introducing the raw material into the furnace crucible (nine parts pure technical aluminum and one part magnesium) and melting it, the metal bath was covered with a protective flux layer (a complex of salts based on CaF_2, NaCl, KCl and $MgCl_2$); a degassing agent was also used, the magnesium being introduced at the bottom of the crucible, with the help of a perforated tin bell (Rusu, 2017).

With the help of a QUANTA INSPECT F type scanning electron microscope, the EDX quantitative compositional microanalysis bulletin, shown in Fig. 2, and the electron diffraction analysis, Fig. 3, were obtained, which highlight the main chemical elements that enter the composition of the developed AlMg10 alloy.

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MgK  →  ··9.93→0.0302→0.9826→0.5693→1.0178¶
AlK  →  87.29→0.2933→0.9555→0.6301→1.0021¶
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Fig. 2 – EDX quantitative microanalysis bulletin of the developed AlMg10 alloy.

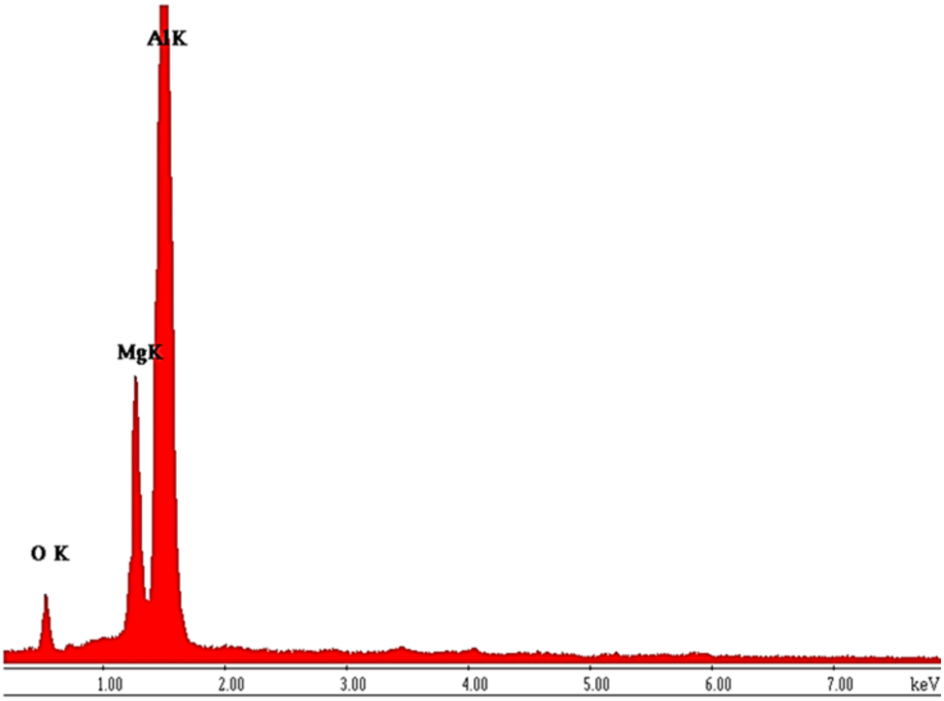

Fig. 3 – EDX Analysis of the elaborated AlMg10 alloy.

For the experiments, the indirect electric arc welding method with modified geometry of the parts to be joined was chosen, Fig. 4.

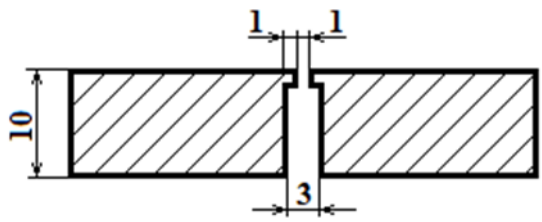

Fig. 4 – Sketch of the welded joint.

The welding was carried out in argon using a MIG welding gun - Spool Gun Stamos and Lincoln Electric AlMg5 wire with a thickness of 1 mm.

To determine the effect of the welding process on aluminum alloys, we create a microhardness profile along a direction perpendicular to the weld bead, as shown in Fig. 5 (with HVT 1000 microhardness tester).

Figure 5 shows a significant difference between the microhardness of the material in the welded zone (WM) and the heat affected zone (HAZ) compared to that of the material in the base zone (BM). The existence of a soft zone at the boundary of the BM with the HAZ can be observed, the microhardness in this zone being approximately half of the microhardness of the base metal material. It is possible that this area appeared as a result of the precipitation of some intermetallic compounds (Al_3Mg_2, AlMg), due to the special thermodynamic conditions determined by the high temperatures.

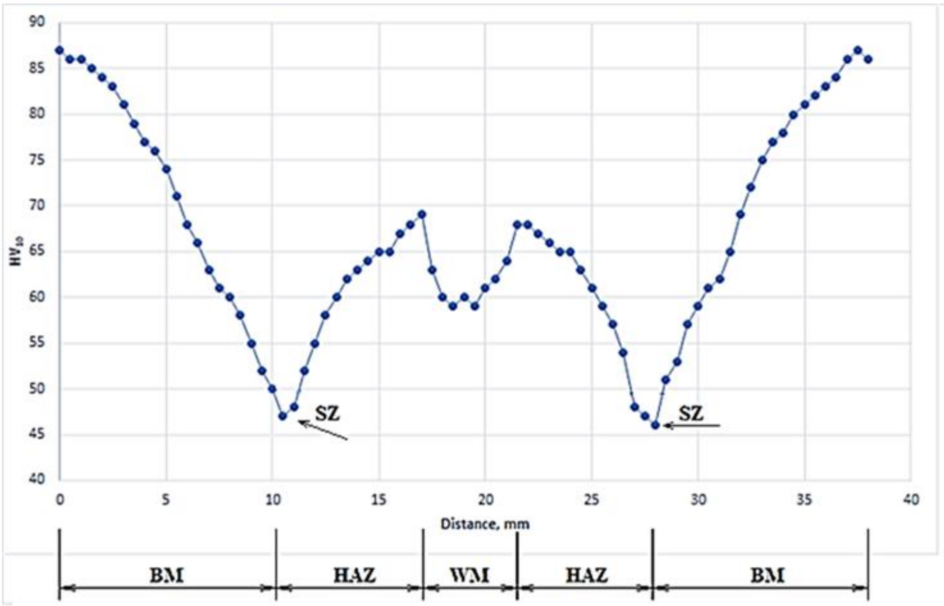

Fig. 5 – Variation of microhardness in a section perpendicular to the weld bead; BM - base material, HAZ - heat affected zone, WM - weld material, SZ - soft zone.

The decrease in microhardness HV10, at the BM/HAZ limit, is approx. 54%, namely from the value of 87 to 47 at a distance of approx. 10 mm compared to the considered origin, respectively from 86 to 46.

In the WM zone, a continuous decrease in microhardness is observed, up to the minimum value HV10 = 59 (decrease of approx. 68%), measured approximately in the middle of the zone, decrease due to the change in the general composition of the metal bath by mixing liquid alloys with different concentrations of magnesium (10% in the base material and 5% in the electrode wire material).

3. Conclusions

The indirect electric arc welding method allows the joining of relatively thick (10 mm) aluminum alloy parts with 10% magnesium in a single pass, without the appearance of defects related to the incomplete filled joint and with a reduced heat input. This results in a reduction of the thermal influence on the base metal.

The microhardness profile along the welded joint is not linear, showing a minimum hardness zone between the base material and the heat-affected zone (approximately 54% of that of the base alloy). Additionally, approximately in the middle of the WM zone, the microhardness decreases again to approximately 68% of that of the base material.

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CERCETĂRI PRIVIND INFLUENŢA SUDĂRII PRIN METODA CU ARC ELECTRIC INDIRECT ASUPRA MICRODURITĂŢII ALIAJULUI DE ALUMINIU CU 10% MAGNEZIU

(Rezumat)

Lucrarea prezintă câteva aspecte generale legate de metoda sudării cu arc electric indirect, cu aplicabilitate directă asupra sudării unui aliaj de aluminiu-magneziu. Metoda folosită în experimentări este cea modificată, în care în loc de plăcuţe de adaos se folosesc piese profilate. Se folosesc piese dintr-un aliaj de aluminiu cu 10% magneziu, după sudare analizându-se profilul microdurităţii pe o secţiune perpendiculară pe cordonul de sudură. S-a observat că profilul microdurităţii de-a lungul îmbinării sudate nu este liniar, acesta prezentând minime de cca. 54% (la limita ZMB/ZIT), respectiv cca. 68% în ZMS din valoarea microdurităţii materialului metalic de bază.

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MATERIALS USED IN THE MANUFACTURING OF SAFETY HELMETS: A SHORT REVIEW

BY

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Abstract. Safety helmets (SH) or hard hats are among the most important personal protective equipment (PPE), especially in the construction industry or any other industry that includes working at different heights or in areas where the risk of falling cannot be avoided. Currently, there are many types of SHs on the market; therefore, both the design and the type of materials used for their manufacturing are related to their areas of application. Among these, some of the most important are industrial SHs, due to the impossibility of eliminating the risks of head trauma in different working conditions. This category occupies a special place, especially when it comes to workplace safety. Nevertheless, usually the most serious and disruptive occupational injuries, i.e., work-related traumatic brain injuries, are due to the misuse or use of non-suitable helmets. However, in some cases, even if the type of helmet was chosen correctly, the failure of this PPE can be related to the material's durability since aging processes cannot be avoided. Therefore, before use, the SHs must be subjected to rigorous inspections to assure the safety of the operator. In practice, these tests are almost impossible since most of them can only be performed by specialized personnel or equipment and not by visual inspection of the operator. Consequently, to prevent any accidents, the users are forced to replace the SHs

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after short periods of use. To ensure sustainability in this sector, it is highly necessary to develop safety helmets that use green materials for their manufacturing while finding eco-friendly methods of recycling the old ones. This study presents a short overview of the literature regarding the materials used in the manufacturing of SHs, focusing on the shortcomings of each type of material. Therefore, it was observed that even though most of the SHs are made of plastics (thermoplastics, acrylonitrile-butadiene-styrene, polyethylene etc.), composite materials are also an excellent candidate.

Keywords: safety helmets, composite materials, personal protective equipment, hard hat, materials selection.

1. Introduction

Traumatic Brain Injury (TBI) stands for a disturbance of brain function that can result from a blow or shock to the head. TBI is a major cause of mortality, disability and a public health problem worldwide. Although TBIs can be minor, others can be fatal or lead to permanent impairment. TBI ranges from mild concussions to severe brain injuries. Concussions, as they are often called, are injuries suffered by construction workers and others, and in recent years they have gained increased attention in medical literature as well as in the field of occupational health and safety. TBI at the workplace is common and account for 20-25% of workplace injuries. They can make it difficult for an employee to return to their pre-injury job and can be costly to both businesses and employees in terms of long-term disability and recovery expenses (Trout, 2022). Personal Protective Equipment (PPE) acts as a barrier between workers and potential sources of hazards, such as physical, chemical, biological or other hazards. The main purpose of a safety helmet is to protect the worker's head against the following categories of hazards:

- Impact generated by objects falling from height;
- Impact generated by striking objects dangerously fixed to the worker;
- Impact with hard surfaces - where the worker falls from great heights;
- Lateral impact from moving objects;
- High temperatures - open flame, electric shock, molten metal splash;
- Direct contact with electrical sources.

Currently, there is a high risk of brain injury for workers in many industries such as mining, electricity, construction and forestry. Because of the nature of these workplaces, the hazards cannot always be eliminated, but they can be minimized by using PPE. The use of appropriate SHs is the only way to guarantee workers' safety. Statistical data on accidents at work show that the most common causes of TBI are impact with falling objects or sharp and hard objects. These are most common in the construction industry. Between 2014 and 2018, almost 50,000 accidents at work were reported in Germany, of which about 25% were TBI. In the year 2021, the Europe-wide statistics showed a huge number of accidents with a very high share of 19% occupied by workplace concussions. Considering the body part affected, statistics show that almost 7% of all accidents are due to non-use, improper use or ineffective use of safety helmets (Accidents at work: injuries & affected body parts in 2021, 2024).

2. Safety helmets characteristics

In 1919 Edward Bullard patented a "Hard-Boiled Hat" made with steam, cloth, glue and black paint (Lothrop, 2019). Not long after, he developed an internal suspension system to increase the safety of helmets. Later they were made of aluminum in 1938 and fiberglass in the 1940s. The first hard hat made of thermoplastic was manufactured in 1950, the first time SHs were produced from injection molded thermoplastics. In 1962, MSA (the largest EIP company in the USA) developed a polycarbonate hard hat which is still used in many fields today. According to the standards, these helmets must contain a shell and a harness system (suspension). A helmet shell is the overall external shape of the helmet, made of a hard material with a smooth surface. The head restraint (harness) is the complete assembly by which the hard hat is stably positioned and secured to the worker's head and through which the kinetic energy generated by an object is absorbed and dissipated.

The entire attachment-damping assembly can be attached to the cap at 4, 6, or more points on the cap. The suspension system, also known as the harness, consists of strips of polyethylene (LDPE) or textile material attached to the inside of the helmet that are in direct contact with the worker's head. The assembly is intended to take the energy from an impact on the helmet and redistribute it evenly over the entire helmet surface. This system thus minimizes the risk of penetration of the helmet and thus ensures the safety of the worker by reducing the severity of possible injury. Depending on the level of protection offered and the field of use of the safety helmets, they may have different components. Fig. 1 presents the schematic representation of industrial SH made in accordance with SR EN ISO 397 (equivalent to ANSI Type 1).

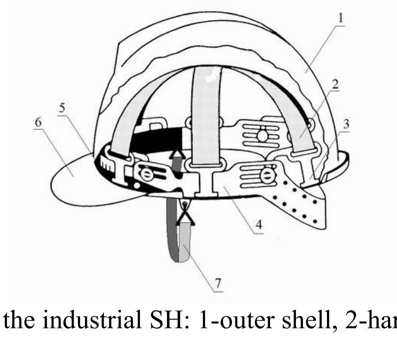

Fig. 1 – Components of the industrial SH: 1-outer shell, 2-harness, 3-harness fastening system, 4-contour/headband, 5-antiperspiration/comfort band, 6-tip, 7-headband that goes under the chin/jugular (Marcin Jachowicz, 2012).

Depending on the specifics of the activity carried out, they may be fitted with different equipment (goggles, walkie-talkies, pagers, etc.), as well as additional elements for special functions (neck protection, adjustable laces, hearing and face protectors, etc.). These may differ according to the chosen design, may have a different shaped top, brim/rim, water guide channel, or ventilation holes, and may be of different colors. Fig. 2 presents the schematic representation of high-performance industrial SH made in accordance with SR EN ISO 14052 (equivalent to ANSI Type 2).

Compared to industrial SHs, high performance SHs are used in work environments where the risk of traumatic brain injuries (TBI) is very high, and the degree of protection offered by industrial SHs is not sufficient. From a constructional point of view, they must offer a high level of protection both for vertical shock absorption on the helmet and for frontal, back and side impacts. For protection against side impacts, high performance safety helmets also have a protective liner.

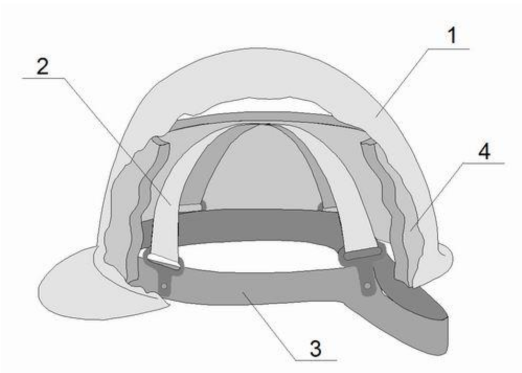

Fig. 2 – The components of high-performance industrial SH: 1- outer shell, 2- headgear, 3- headband (including sweatband), 4- protective liner (Marcin Jachowicz, 2012).

Workplaces present different risks, so those responsible for the safety and security of workers must make the right choice of PPE for the activities they perform. As far as the protection of the worker's head is concerned, one of the 2 variants presented above can be chosen.

When choosing the appropriate type of SH, the environmental conditions in which they will be used should also be considered, such as: enclosed enclosure, season, average temperatures, bad weather, special conditions (electrical risk). There shall be markings on the protective helmet, specifying the temperature at which they can be used, the category of protection offered, the dielectric strength, as well as the year and month of manufacture. Safety helmets must retain their properties in the temperature range possible in the workplace (-30 ÷ +150), so they can be divided into four categories according to the temperature at which they are used. Labeling of safety helmets is beneficial in order to easily recognize the environmental recommendations to which the helmet may be exposed. Labeling and marks found on the shell provide information on: date of manufacture, dielectric strength, anti-electrostatic properties, resistance to impact with hot metals, temperature at which they can be used, resistance to side impacts, conformity marking, material of which it is made, size range of the head fit.

2.1. Materials used in the manufacture of safety helmets

The standards require durable materials to be used for the manufacture of the elements of safety helmets. Their characteristics shouldn't be affected by ordinary environmental conditions (exposure to sun radiation, rain, dust, heat, cold, vibration, contact with the skin, exposure to different types of substances etc.). Also, after aging, the materials used for the SH manufacturing should not cause skin irritation while providing increased comfort and most importantly, be lightweight.

2.1.1. Materials used for the manufacturing of the shell (cap) of SHs

Conventionally, helmet shells are made of materials that are primarily shock-absorbing, stiff and lightweight. Usually, plastics and natural polymers or man-made polymers derived from synthetic raw materials (fossil fuels or natural gas) are the predominant materials used in a wide range of fields and applications. Polymers are ideal materials to be used due to the superior properties they possess, such as high strength-to-weight ratio, durability, impact resistance, accessibility and easy processability (Głogowska *et al*., 2020). Polymeric matrices are divided into thermoplastic matrices, thermoset matrices and elastomers, which exhibit different reactions, bonds and characteristics.

Elastomers possess very good elastic properties, these materials can return to their original shape when deformed, when the yield strength is not exceeded. Thermosetting polymers have strong chemical cross-links and a rigid structure/network. After the curing or polymerization reaction, thermoset polymers can no longer be heat-processed and are hardly recyclable materials. In contrast to thermoset polymers, thermoplastic polymers have weaker characteristics, but several advantages/properties such as reusability, stability and density make them ideal candidates for use. Thermoplastic polymers such as acrylonitrile-butadiene-styrene (ABS), polyamide/nylon (PA), polycarbonate (PC), polyethylene (PE), polypropylene (PP), high density polyethylene (HDPE) can be re-molded and reused many times (Rajeshkumar *et al*., 2021).

The most common and often used materials for creating the shell of helmets remain thermoplastic materials, namely ABS, PA, HDPE or PC (Dhinakaran *et al*., 2020). Safety helmets can have different strength and shock absorption performance by combining the following 3 variables: the material used to make the shell, the material used to make the harness and the number of harness attachments on the shell. The performance standards impose their strength limits including the distance between the suspension system and outer shell of SH. (Baszczyński, 2014) studied the performance of lightweight industrial SHs to absorb impact energy at different temperatures. He tested and compared 7 types of lightweight industrial SH helmets from several manufacturers with various designs and different materials of component parts. All helmets were manufactured according to EN 397 and CE certified.

Safety helmets made of ABS, PC or PA thermoplastics offer good impact resistance with high hardness (Maiyuran *et al*., 2018; Surendran *et al*., 2021) compared the properties of ABS and PA thermoplastics used for the manufacture of safety helmets. They concluded that the strength of SH made of polyamide 4-6 (PA) is better than those made of ABS. Other studies, conducted by (Obele and Ishidi, 2017) compared the impact resistance of ABS and PC plastics and concluded that the impact resistance of polycarbonate is superior to other plastics. They also used coconut fibers, up to 30 wt.%, in an epoxy resin-based polymer matrix, and obtained a composite material with good adhesion between the reinforcing elements and the matrix. Tensile tests obtained a tensile strength of up to 23.68 N/mm^2 and 26.43 N/mm^2 impact strength. However, for SH made of composite reinforced with more than 30% coconut fiber, the tensile strength decreases.

Nowadays, the increase in environmental issues has led to the accelerated development of new advanced materials, namely the creation of composite materials that can be used in the manufacture of helmets. The use of composite materials is of interest because post-industrial wastes can be incorporated into it and exhibit better properties compared to conventional materials (Arif *et al*., 2022; Meira Castro *et al*., 2013; Todor *et al*., 2020). Composite materials consist of the matrix and the reinforcing material. The matrix can be polymer, metallic or ceramic, and the reinforcing material, can be in the form of fibers (long, short, natural, synthetic) or particles (Giyahudeen, 2017). The use of natural fibers in advanced composites gives them biodegradability and easy decomposition properties (Bajpai *et al*., 2014). Moreover, by blending natural fibers with synthetic fibers in a polymer matrix, hybrid composites can be obtained (Ashik and Sharma, 2015).

Hybrid composites with thermoplastic polymer matrix have proven to be ideal to produce lightweight and strong components in many fields: aeronautics, wind energy industry, civil construction and also for safety helmets (Gururaja and Rao, 2012). The work published by (Ali *et al*., 2013) demonstrated that the fiber glass-based composite materials used in the manufacture of SHs provide reliability and higher impact resistance compared to the performance of conventional SHs made of ABS. Thus, they concluded that fiberglass composite materials are a good alternative to ABS. (Yuhazri and Dan, 2007) compared the performances of an epoxy composite material reinforced with natural coconut fibers with those of helmets made of ABS and

PC. Accordingly, they observed that changing the weight percentage, as well as the length of the coconut fiber in the composite material, can result in significant differences in impact, bending, twisting and tensile strength of the material.

The use of sisal, jute and banana fibers in hybrid composites results in up to 50% reduction in the mass of the safety helmets while ensuring high durability (Murali *et al*., 2014) and economic advantages (Johnson *et al*., 2016).

Studies conducted by (Campbell and Cramer, 2008; Walsh *et al*., 2005) have combined the properties of two thermoplastic polymer matrix composites to produce helmets for military applications. The hybrid composite material consisted of two layers, the first of a thermoplastic polymer matrix hybrid composite material reinforced with carbon fibers, and the second of the same matrix reinforced with aramid. Composite materials reinforced with para-aramid synthetic fibers (such as Kevlar or Twaron) or reinforced with crystallized ultra-high molecular weight polyethylene UHMWPE crystallized fibers (such as Dyneema or Spectra) are predominantly used in the manufacture of safety helmets used by soldiers. The currently used hybrid composites combine at least two types of materials (Fig. 3) to achieve excellent impact resistance properties (Liang *et al*., 2022).

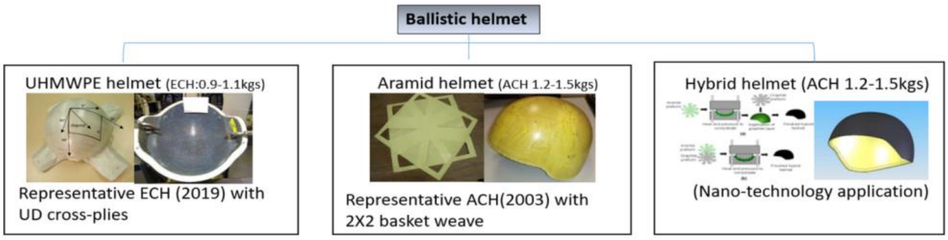

Fig. 3 – Subcategories of ballistic helmet on material base (Liang *et al*., 2022).

Kostopoulos *et al*. (2002) carried out a finite element analysis of a composite safety helmet used by motorcyclists. The aim was to analyze the dynamic response of the helmet and the parameters influencing its behavior when subjected to mechanical shock. They used 3 types of composite materials for the helmet shell (mainly made of woven carbon, Kevlar and glass fibers, embedded in a polymer matrix). Also, they used Expanded Polystyrene (EPS) foam for the helmet liner. Tests have shown that damage development and crack propagation in the material is directly influenced by the stiffness of the shell. During analyzing the mechanical behavior of carbon fiber and Kevlar reinforced composites they observed that fibers stiffness can play a negative role in the behavior of SH. This behavior is due to the fact that shock reduction is mainly related to deformation and breaking of the bonds between the reinforcing fibers and the matrix. Composites reinforced with glass fibers and carbon fibers had similar results but when Kevlar fibers were used, matrix cracking and delamination led to more extensive damage due to the higher shear strength of Kevlar fibers. Also, they highlighted the disadvantages of using the composite material in low velocity shocks, which can lead to higher accelerations because the minimum force for breaking the link between matrix and fibers, i.e., debonding and delamination, is not reached.

In terms of energy absorption capacity at very high velocity impacts, the composite material shows a significant improvement in performance over helmets conventionally made of ABS. Moreover, it was observed that the energy transferred to the foam was higher for the Kevlar woven fiber reinforced composite material. At higher velocity impacts, the composite material absorbs a greater amount of energy until it breaks completely, providing greater safety to the human head by transferring less energy to the EPS foam (Kostopoulos *et al.*, 2002).

Thanikachalam *et al.* (2018) studied the effect of natural fibers treated in sodium hydroxide. They found that treating the fibers prior to their integration into the matrix benefits the composite material. Natural reinforcing fibers can be treated in NaOH solution to improve the bond between them and the polymer matrix. The epoxy resin matrix was reinforced with up to 40% natural fibers of luffa bamboo and palm tree. Choosing these three fiber types was primarily based on their similar mechanical characteristics. Further, they evaluated the mechanical performances of the composite materials and analyzed the results to establish whether the new composite material could be used to manufacture the shell of a helmet. Accordingly, they concluded that the composite materials reinforced with these natural fibers have good mechanical performances, while those reinforced with palm and luffa fiber also exhibit good tensile strength (1.8 ÷2.1 kN) and flexural strength (136 ÷132 N).

Therefore, combining the properties of the composite materials into a single hybrid composite material resulted in promising mechanical results with values indicating that these new hybrid composites could be used in helmet shell applications. The obtained hybrid composites had the following two mixtures; one hybrid composite made of 17% palm fiber, 17% luffa fiber, 6% bamboo fiber and 60% matrix, and one hybrid composite made of 15% palm fiber, 15% luffa fiber 10% bamboo fiber and 60% matrix. Both hybrid composites had better mechanical properties than conventional composite materials.

The treatment of fibers with sodium hydroxide is an essential step in the obtaining of composite materials, because it is mainly responsible of the adhesion between the fiber and the matrix. Also, the presence of impurities on the surface of natural fibers, such as waxes, can weaken the adhesion between fibers and matrix. The use of acids in fiber surface treatment leads to a modification of the surface structure of natural fibers and an increase in the microroughness of the fiber. As a higher fiber surface roughness is achieved, the mechanical adhesion increases, leading to an increase in mechanical properties.

The degree of wetting is also reduced as the treatment of the fibers can contribute to their dimensional stabilization by decreasing their tendency to absorb moisture and decreasing shrinkage in humid conditions.

2.1.2. Materials used in the manufacture of harness - shock absorption system and protective padding

The influence of the harness design and the number of attachment points is also a very important characteristic related to the performances of SH. Shock absorption systems in industrial SHs are essential for protecting workers against head injuries. These systems are developed using a variety of materials and structural designs to maximize impact resistance and energy dissipation. The lining of hard helmets is usually made of polypropylene, polyethylene, polystyrene or LDPE, but attempts are being made to incorporate other materials (Yaswanth *et al*., 2024). Recent studies are using polymer nanocomposites and anisotropic materials to manufacture the inner cuff of safety helmets to achieve better shock absorption and reduce the overall weight of the helmet (Zhang *et al*., 2024). In addition, innovative materials such as carbon nanotube foams and liquid crystal elastomers are being studied and used in the fabrication of the protective layer inside the helmet inner shell for their superior shock absorbing properties (Blanco *et al*., 2014; Bottlang *et al*., 2020; Migue, 2020).

3. Performance and properties of SHs

Performance standards for SHs are fundamental to ensuring adequate protection for workers. Compliance with these standards is essential to ensure that SHs provide the optimum level of protection and comfort. Globally there are different standardizations on performance requirements for industrial SHs, but the European ones are the most complex. Under the requirements of EN 397 and EN 14052, SHs complying with these standards stand out as the best performing and are subject to the most rigorous testing. These standards set strict requirements for safety and durability. Therefore, safety helmets must withstand higher impact forces and offer a high level of protection. Also, they must protect the front, back, top and side of the head against falls, falling objects or collisions with stationary objects. Consequently, these SHs provide safety in work environments with a high risk of traumatic brain injury (TBI), since SH, that meet these standards, guarantee a high level of safety and durability, making them preferred in high-risk workplaces.

The performance requirements and standard tests for shock absorption require that the force transmitted to the headform impactor after testing shall not exceed 5 kN for a headform impact to the helmet bumper. The deceleration of the impacting mass shall not exceed 300 g for impacts outside the crown of the head. The test of the penetration resistance of safety helmets requires that the tip of the impactor isn't allowed to touch the headform. The force transmitted to the headform of the impactor isn't allowed to exceed 5 kN for impacts on the crown of safety helment and 15 kN for lateral impacts. The helmet restraint system shall retain the helmet on the head moulding following penetration and shock absorption tests. The chinstrap restraint system shall yield to a force higher than 250 N but shall withstand a minimum of 150 N on the test artificial chin. Flame resistance testing of the SH shall require that the helmet shall not burn with flame emission for more than 5 seconds after the flame source has been removed.

The penetration resistance test requires two shocks to the helmet at a minimum distance of 75 mm apart and at an inclination of 60°. The impact shall take place from a height of 2,5 m and involve striking the safety helmet with a pointed body of mass of 1 kg (Fig. 4-1a, 1b). The shock absorption test shall be performed using a spherical impactor of mass 5 kg. It must be struck in a controlled manner from a height of 5 m, twice, at a distance of at least 75 mm apart and at an inclination of 60° (Fig. 4-2a, 2b). The impact energy at the helmet clip shall be 100 J (Romanian Standards Association, 2013).

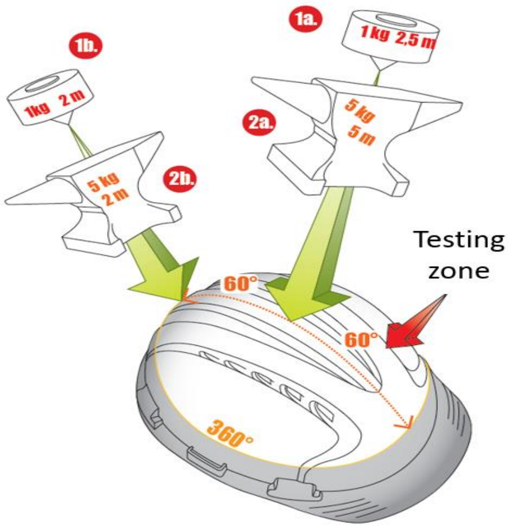

Fig. 4 – Testing of high-performance safety helmets according to EN 14052 1a- penetration test on the pincer, 1b- penetration test on the side, 2a- shock absorption test on the crown, 2b- shock absorption test on the side (EN14052 Testing, n.d.).

The hard hat test stand is equipped with a head mold on which the hard hat is placed. Above this is the percussion table which can be changed according to the type of test. After striking the impactor, the striking trolley is electromagnetically locked so that the helmet is struck only once. The trolley moves along vertical slides. The velocity of the impactor at the helmet contact is measured by acceleration sensors and a recording and analysis system connected to a computer that processes this data.

The optional requirements refer to the resistance to shock absorption and penetration resistance at very low or very high temperatures, depending on the category of performance requirements to be met. The test temperatures are as follows; -20°C, -30°C, -40°C, and for testing at very high temperatures, the test chamber enclosure shall be 150 ± 5°C and the temperature of the test head on which the helmet is placed shall be heated to 50 ± 2.5°C. In addition, resistance to UV ageing, immersion in water, dielectric strength, resistance to radiant flame, splash protection with molten metal on the helmet surface, shall all be checked and tested if certification of resistance under such conditions is sought.

Following impact with a flat surface with a 0° inclination, the shock absorption system can reduce the force of the shock and block it from being transmitted to the brain. However, in the case of impact with inclined surfaces or bodies striking the safety helmet at an inclined angle, brain trauma may occur due to rotational acceleration transmitted to the head and further to the brain (Kleiven, 2013). Fig. 5 present biomechanic of an oblique impact compared with perpendicular impact.

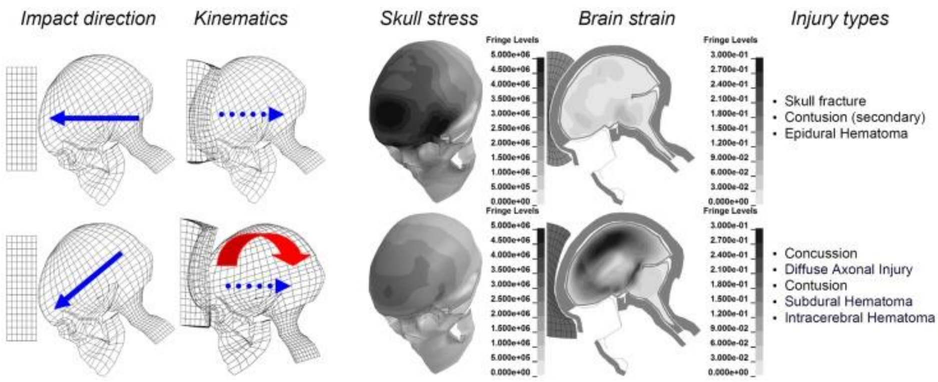

Fig. 5 – Illustration of the biomechanics of an oblique impact (lower), compared to a corresponding perpendicular one (upper), when impacted against the same (Kleiven, 2013).

As the standards do not mention impact testing with inclined surfaces, researchers are testing the performance of safety helmets in these cases as well, usually recording the forces transmitted to the neck (Bottlang *et al*., 2022). Fig. 6 presents the test stand for oblique impact.

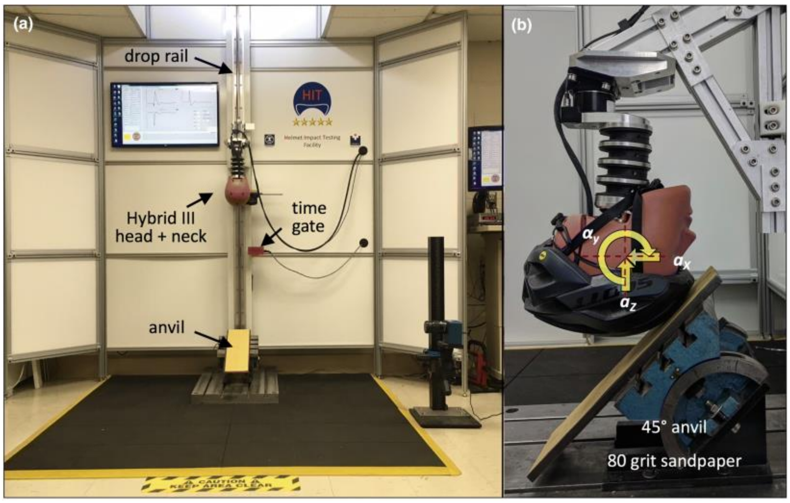

Fig. 6 – Impact Testing facility for vertical drop with linear and rotational headform accelerometers to capture headform kinematics in terms of linear acceleration (a) and rotational acceleration (α) (Bottlang *et al*., 2022).

4. Conclusions

The current development of the industry led to significant improvements in safety helmets, both in terms of the materials used in their manufacture and their mechanical, physical and chemical performance. This evolution has been driven by the need to withstand extreme working and environmental conditions. From high or low temperatures, to contact with chemical agents, electrical currents, splashes of molten materials, SHs have had to be constantly improved to suit the specifics of each field of activity. Safety helmets conventionally made of thermoplastics meet the minimum requirements of the standards, but they have low durability. The use of composite materials is beneficial because they can incorporate post-industrial waste, renewable raw materials and have better properties compared to conventional materials.

Composite materials reinforced with natural fibers, coconut fiber, palm fiber, luffa, bamboo, jute offer better mechanical properties compared to conventionally used thermoplastics. The use of natural fibers also reduces the mass of the composite material by up to 50%. Reducing the mass of the safety helmets makes them easier and more comfortable to wear.

Hybrid composites, which combine two or more composite materials, remain the most widely used for special, military or aerospace applications. The thermoforming manufacturing process allows for strong and durable bonding of material layers.

Performance standards for hard hats are fundamental to ensuring adequate protection for workers. Compliance with EN 397 and EN 14052 is essential to provide a high level of protection and comfort. The requirements imposed by European standards are the most stringent, therefore compliance with them guarantees wearer safety.

The design and external shape of the helmet shell can influence its mechanical performance. The material used to create the shock-absorbing fastening system is also very important as it ensures energy dispersion. It is very important to choose a material with good elastic properties, such as LDPE. The number of grips and the gripping technology of this suspension system is also important, better mechanical results have been achieved by helmets with a higher number of grips. Cellular dome technologies, and EPS foams remain the most widely used linings for safety helmets, but further improvements are being investigated.

Hard hats can be recycled. However, it depends on the material they are made of. Most are made of high-density polyethylene (HDPE), PC or ABS, which are recyclable plastics. The composite materials concept itself involves recycling and reintegration of other post-consumer materials. Superior mechanical properties can only be achieved through complex structures such as coatings and composites, and this will conflict greatly with the requirements to separate materials from their composition for recycling.

The issues need to be addressed at two different levels for society as a whole: the recycling of existing composites and the development of new and better recyclable composites. For existing composites, how to find an efficient, low-cost recycling technology to separate and recycle the composites currently in use. In order to achieve this goal industrially and commercially, there are a number of boundary conditions and constraints:

- available technologies for recycling fibers and fillers and/or matrix materials.
- the availability of composite waste versus the economy of scale the recycling operation.
- compatibility of recycled material quality with existing markets.
- environmental regulations on the storage and incineration of composite materials.

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MATERIALELE UTILIZATE ÎN FABRICAREA CĂȘTILOR DE PROTECȚIE: SCURT REZUMAT

(Rezumat)

Căștile de protecție, sunt printre cele mai importante echipamente de protecție individuală (PPE), în special în industria construcțiilor sau în orice altă industrie care include lucrul la diferite înălțimi sau în zone în care riscul de cădere nu poate fi evitat. În prezent, există multe tipuri de căști de protecție pe piață; prin urmare, atât designul, cât și tipul de materiale utilizate pentru fabricarea acestora sunt legate de domeniile lor de aplicare. Dintre acestea, unele dintre cele mai importante sunt căștile de protecție industriale, datorită imposibilității de a elimina riscurile de traumatism cranian în diferite condiții de lucru. Această categorie ocupă un loc special, în special atunci când vine vorba de siguranța la locul de muncă. Cu toate acestea, de obicei, cele mai grave și perturbatoare leziuni profesionale, și anume traumatismele cranio-cerebrale legate de muncă, se datorează utilizării greșite sau utilizării unor căști neadecvate. Cu toate acestea, în unele cazuri, chiar dacă tipul de cască a fost ales corect, eșecul acestui EPI poate fi legat de durabilitatea materialului, deoarece procesele de îmbătrânire nu pot fi evitate. Prin urmare, înainte de utilizare, căștile de protecție trebuie să fie supuse unor inspecții riguroase pentru a garanta siguranța operatorului. În practică, aceste teste sunt aproape imposibile, deoarece cele mai multe dintre ele pot fi efectuate numai de către personal sau echipamente specializate și nu prin inspecția vizuală a operatorului. În consecință, pentru a preveni orice accident, utilizatorii sunt obligați să înlocuiască căștile de protecție după perioade scurte de utilizare. Pentru a asigura durabilitatea în acest sector, este extrem de necesar să se dezvolte căști de protecție care să utilizeze materiale ecologice pentru fabricarea lor, găsind în același timp metode ecologice de reciclare a celor vechi. Acest studiu prezintă o analiză scurtă a literaturii de specialitate cu privire la materialele utilizate în fabricarea căștilor de protecție, concentrându-se pe deficiențele fiecărui tip de material. Astfel, s-a observat că, deși majoritatea căștilor de protecție sunt fabricate din materiale plastice (termoplastice, acrilonitril-butadien-styren, polietilenă etc.), materialele compozite sunt, de asemenea, un candidat excelent.

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A DOCUMENTARY SYNTHESIS OF THE RESEARCH-DEVELOPMENT STAGE OF SOLID-STATE ORDER-DISORDER TRANSITION IN Cu-BASED SHAPE MEMORY ALLOYS

BY

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Abstract. Shape memory alloys (SMAs) are characterized by a reversible martensitic transformation which represents the microscopic mechanism of the Shape Memory Effect (SME). During this reverse martensitic transformation, the martensite retransforms to the parent phase (austenite), during heating or isothermal unloading, if the martensite phase was stress-induced. β-type SMAs are characterized by an austenitic phase with a body-centered cubic (bcc) crystalline structure and an electronic valence (number of valence electrons/number of atoms of the unit cell) of approx. 1.5. According to the solid sphere model, a bcc unit cell comprises a central atom surrounded by eight atoms that form the eight corners of a cube. When a second or third atomic species is involved, more ordered structures can be obtained. Most of the β-type SMAs experience a thermoelastic martensitic transformation, which is characterized by a continuous balance between the thermal and elastic effects. The most representative β-type SMAs are NiTi and Cu-based, the latter being represented by Cu-Zn-Al and Cu-Al-Ni(Mn) systems. In Cu-based SMAs, the crystalline structure of austenite is ordered. The first atomic ordering, when considering at least two atom species, involves an atom of the first species, for example A, to

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be surrounded by eight atoms of the second species, B. By simply imagining such a unit cell, one can easily observe that each atom of the B species is surrounded by eight atoms of A species. Since these eight atoms simultaneously belong to eight unit cells, the stoichiometric formula would be the equiatomic AB. This is the case of the intermetallic compound CuZn, from Cu-Zn-Al SMAs. On the other hand, at Cu-Al-based SMAs, the stoichiometric formula of austenite is Cu3Al. When adding the third alloying element, such as Ni or Mn, the unit cell becomes even more ordered since the first atomic species would be in the center of the unit cell, the second would occupy two unparallel diagonals of two parallel faces and the third atomic species would occupy the rest of the four remaining positions.

Keywords: Order-disorder solid state transition; shape memory alloys; crystallography; differential scanning calorimetry; cycling effects.

1. Introduction

Shape memory alloys (SMAs) are characterized by a reversible martensitic transformation which represents the microscopic mechanism of the Shape Memory Effect (SME). During the reverse martensitic transformation, the martensite retransforms to the parent phase (austenite), during heating or isothermal unloading, if the martensite phase was stress-induced. Figure 1 exemplifies the two types of reversible heating-induced or stress-induced martensitic transformations.

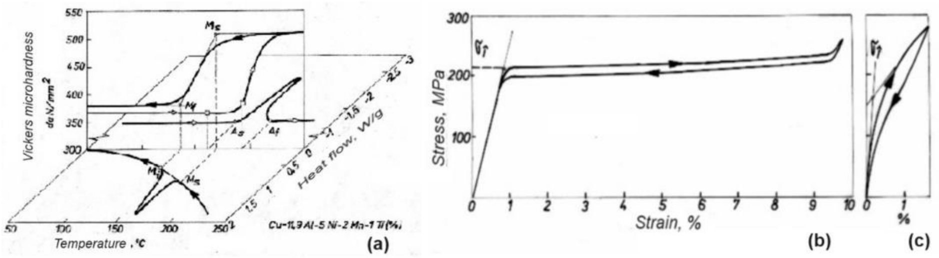

Fig. 1 – Typical examples of reversible martensitic transformations, illustrated by the variations of: (a) microhardness and heat flow with the temperature at a Cu-Al-Ni-Mn-Ti SMA; (b) stress with strain at a Cu-16Zn-15Al SMA monocrystal and (c) stress with strain at a Cu-25Zn-9Al SMA polycrystalline specimen (% at.) (Eucken *et al*., 1992; Patoor *et al*., 1987).

A particular type of martensitic transformation is the thermoelastic one during which the martensite plates are continuously growing during isothermal loading and continuously shrinking back during isothermal unloading. The thermoelastic martensitic transformation requires a reinforced parent phase (austenite), either as an effect of high crystallographic ordering or by coherent precipitation (Wayman, 1975).

Among the SMAs that experience thermoelastic martensitic transformations, there are β-type SMAs, such as NiTi, CuZnAl or CuAlNi(Mn)-based, which are characterized by an austenitic phase with a body-centred cubic (bcc) crystalline structure and an electronic valence (number of valence electrons/ number of atoms of the unit cell) of approx. 1.5. According to the solid sphere model, a bcc unit cell comprises a central atom surrounded by eight atoms that form the eight corners of a cube, as schematized in Fig. 2.

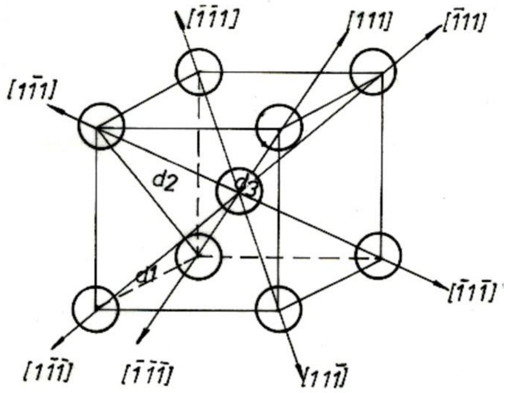

Fig. 2 – Schematized bcc unit cell, illustrating eight close-packed crystallographic directions (Bujoreanu and Baciu, 2003).

In Cu-based SMAs, the crystalline structure of austenite is bcc ordered, as illustrated in Fig. 3.

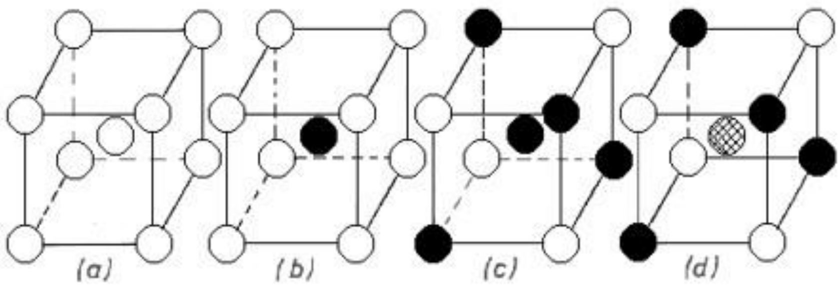

Fig. 3 – Bcc unit cell ordering by the substitution of the atoms from different species: (a) A2 disordered bcc with all the atoms of the same species; (b) B2 (CsCl type) with the central atom of a different species; (c) D0$_3$(Fe_3Al type) with central atom and the atoms from parallel faces and unparallel diagonals of a different species; (d) L2$_1$ (Cu_2AlMn or Heusler type) with the central atom belonging to the third atomic species (Wayman and Duerig, 1990).

The first atomic ordering (B2), when considering at least two atom species, involves an atom of the first species, for example A, to be surrounded by eight atoms of the second species, B. Since these eight atoms simultaneously belong to eight unit cells, the stoichiometric formula would be the equiatomic AB. More ordered bi-atomic unit cells are called $D0_3$ where in addition to B2, the atoms of the second species of two parallel faces are on antiparallel diagonals. Finally, if in $D0_3$ ordering, the central atom belongs to a third species, the unit cell is called $L2_1$.

In the following sections, the occurrence of order-disorder transitions in three Cu-based SMA systems will be reviewed.

2. The Order-Disorder Transition of Austenite in CuZnAl-based SMAs

2.1. Heat treatment effect on order-disorder transition

Figure 4 shows the differential scanning calorimetry (DSC) charts recorded during the heating up to 873 K of Cu–21.57 Zn–7 Al (mass. %) SMA specimen fragments in two heat treatment states: (i) A_0, hot worked (pressed at 1023 K and cooled in air) and (ii) B_0, homogenized (maintained 30 min at 1073 K and water quenched).

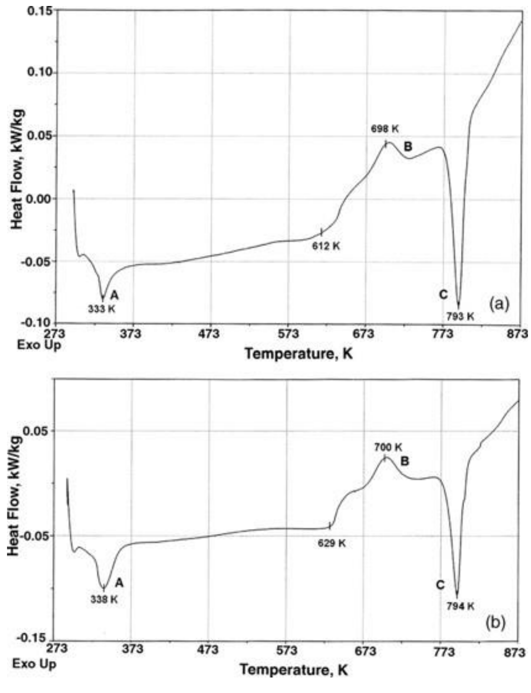

Fig. 4 – DSC charts recorded during heating up to 873 K, associating order-disorder transition with the peak C: (a) hot-worked; (b) homogenized (Bujoreanu, 2008).

In both charts three transformations occurred which in this case, according to literature, have been ascribed to: A–endothermic reverse martensitic transformation; B–exothermic precipitation of α-phase and C–endothermic order-disorder transition of austenite (Spielfield, 1999). In this case, the B2 structure, based on the CuZn intermetallic compound, transforms to A2 disordered bcc structure.

In spite of the different treatments applied to hot-worked A_0 and homogenized B_0 which have different structures, the three transformations occurred at approximately the same temperatures. In addition to the three transitions, a fourth flat endothermic peak located above 600 K has been illustrated in the figure. This peak, also observed on the DTA thermograms, corresponds to bainite formation (Bujoreanu, 2008).

2.2. The effect of work-generating SME training, in air, on the order-disorder transition

Specimens of Cu-14.86 Zn-5.81 Al (mass%) SMA were homogenized (1073K/ 30 min/ water), hot rolled (at 1020 K) and trained in bending. The specimens were 0.8 g soft martensitic lamellas and were bent at room temperature (RT) under a 40 g load, fastened at their free end. During training, the specimens were subjected to 100, 200, 300, 400, and 500 heating–cooling cycles, during which they lifted the load by work generating (WG) SME and lowered it due to the softening induced by direct martensitic transformation (Vitel *et al*., 2012). Figure 5 illustrates the DSC charts recorded during the heating of these specimens.

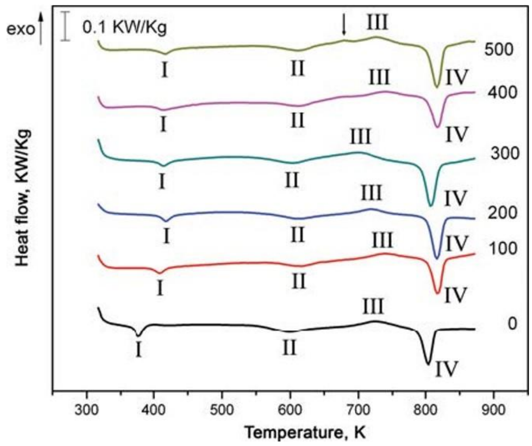

Fig. 5 – WG-SME training cycle effects on the DSC response on heating, comprising: (I) martensite reversion to austenite; (II) transitory formation of bainite; (III) precipitation of α-phase and (IV) order-disorder transition of austenite (Vitel *et al*., 2012).

The four solid-state transitions, previously noticed in Fig. 4 also occur during the heating of the thermomechanically trained martensitic Cu-Zn-Al SMA: I) martensite reversion to parent phase, accompanied by an endothermic peak; II) transitory formation of bainite, revealed by a flat endothermic peak; III) precipitation of a α-phase, emphasized by an exothermic peak; and IV) order-disorder transition of parent phase associated with a sharp endothermic peak. It has been pointed out that, as an effect of training cycles, all four phase transitions tend to shift to higher temperatures.

In the particular case of order-disorder transition, the corresponding peak was located at 793 K at the hot worked specimen and at 794 K at the homogenized one. As an effect of thermomechanical training cycles, the order-disorder transition peak increased from 807 K, in hot rolled state up to 821 K, after 100 training cycles (Vitel *et al*., 2012).

2.3. The effect of free-recovery SME training, in hydraulic oil, on the order-disorder transition

The specimens of Cu-14.86 Zn-5.81 Al (mass%) SMA which were thermomechanically trained by WG-SME, in air (as described above), were further subjected to heating-cooling cycles, performed by free-recovery (FR) SME in a continuous stream of hydraulic oil, which was heated and cooled, successively. Each specimen, which was trained in bending for 100, 200, to 500 cycles, was initially in a martensitic state and had a bent "cold shape", being submerged into continuously pumped hydraulic oil. During oil heating (performed by an electric resistance), its temperature exceeded the critical temperature A_s, of the beginning of martensite reversion to austenite, which triggered FR-SME. The specimen (actuator) deflected until touching an electric contact that turned off the electric resistance that heated the oil.

To control the pushing force of the actuator, it was positioned against the electric contact at a smaller distance than its maximum stroke. For this reason, corroborated with the thermal inertia of the oil heating system, the actuator was overheated.

While fresh oil was continuously pumped, it finally cooled down the actuator until its temperature dropped below M_s, the beginning of the forward martensitic transformation. This caused the occurrence of a two-way shape memory effect (TW-SME) and the specimen bent back during cooling (Vitel *et al*., 2016).

Oil temperature is kept above 363K by means of an electric resistance, which is turned on by a Shimaden controller each time oil temperature drops below this value.

Figure 6 displays the DSC charts of fragments cut from the specimens trained by WG-SME in bending for 100, 200, …, 500 cycles, performed in air, and subsequently cycled, by FR-SME performed in pumped oil.

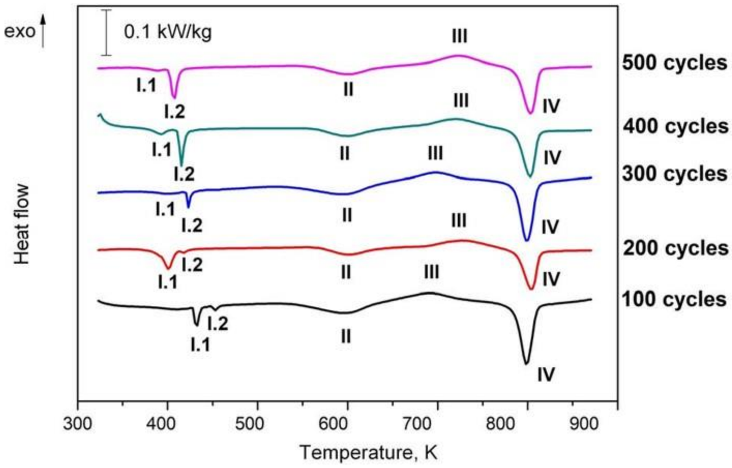

Fig. 6 – FR-SME cycling effects on the DSC response on heating of the fragments cut from air-trained specimens, comprising: I) martensite reversion to austenite; II) transitory formation of bainite; III) precipitation of α-phase; and IV) order-disorder transition of parent phase (Vitel, 2016).

It is noticeable that transition I, associated with martensite's reversion to austenite, was split into two parts, due to temperature memory effect caused by the occurrence of two groups of martensite plates, biased by different amounts of stored elastic energy. On the other hand, after FR-SME oil-cycling the peak associated with order-disorder transition varied between 798 and 804 K (Vitel *et al*., 2016).

Table 1 summarizes the temperature values of the peak associated with order-disorder transition, in the specimens trained by WG-SME and cycled by FR-SME.

Table 1
Temperature values of the endothermic peak associated with order-disorder transition

No of cycles	WG-SME training, in air	FR-SME cycling, in oil
0 (hot rolled)	*807*	-
100	*821*	*798*
200	*817*	*804*
300	*811*	*799*
400	*819*	*803*
500	*818*	*803*

These results show that, in Cu-Zn-Al based SMAs, there is a B2 austenite, with bcc unit cell, comprising 1 Zn atom surrounded by 8 Cu atoms (end vice-versa) which becomes disordered, when heated above approximatively 793 and 821 K.

3. The Order-Disorder Transition of Austenite in CuAlNi-based SMAs

Five CuAlNi-based SMAs were obtained by induction melting, homogenized (1173 K/ 8·hrs/ water), hot forged at 973-1023 K and quenched (973, 1023, 1073 K/ 5 min/ water) to obtain γ'_1 thermally induced martensite. The five chemical compositions are listed in Table 2 and their DSC charts in Fig. 7.

Table 2
Chemical compositions of five CuAlNi-based SMAs (mass. %)

No.	*Cu*	*Al*	*Ni*	*Mn*	*Fe*	*Zn+Sn+Pb+Si+Mg+Ti+Co+Cd+P+S*
3	*Bal.*	*13.67*	*4.28*	*0.54*	*0.14*	*0.402*
4	*Bal.*	*13.95*	*3.62*	*0.002*	*0.2*	*0.08*
6	*Bal.*	*14.95*	*4.63*	*0.006*	*2.95*	*0.112*
7	*Bal.*	*13*	*3.73*	*0.002*	*0.61*	*0.127*
12	*Bal.*	*12.25*	*3.22*	*0.000*	*0.09*	*0.105*

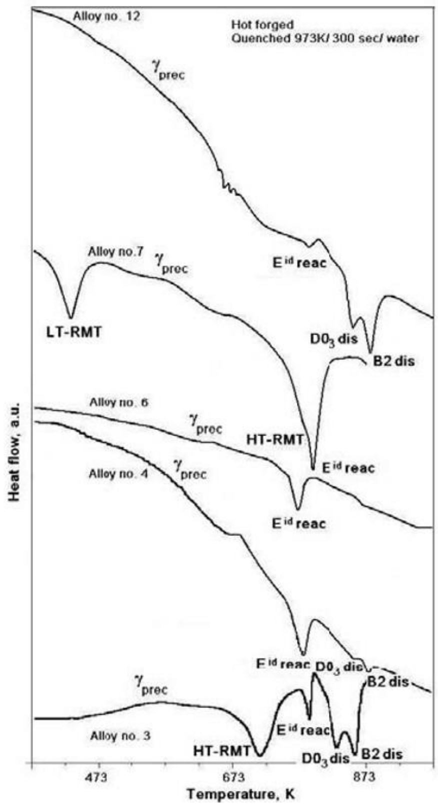

Fig. 7 – DSC charts recorded during the heating of the five CuAlNi based SMAs listed in Table 2 (Stanciu *et al.*, 2008).

The alloys under study were in a stabilized martensitic state, so they experienced a two-stage reverse martensite transformation, produced at: (i) low temperature (LT-RMT), due to the reverse motion of martensite/ austenite interfaces and (ii) high temperature (HT-RMT) caused by the re-nucleation of fine austenite lamellae, as a direct effect of martensite stabilization.

At each of the alloys under study, a eutectoid reaction (E^{id} reac) should be normally at about 770 K.

The austenite obtained during heating above the E^{id} reac has a $D0_3$ unit cell. During heating, the $D0_3$ unit cell became less ordered and transformed to B2 ($D0_3$ disordering) and further to A2 (B2 disordering) after complete disordering of the bcc structure. Austenite disordering is more prominent at alloys 3 and 12 and less visible at alloy 4 (Stanciu *et al*., 2008).

Further DSC analyses were performed on fragments cut from specimens of alloy no 12, quenched after being held for 5 minutes at three different temperatures: 973, 1023 and 1073 K. The representative thermograms are illustrated in Fig. 8

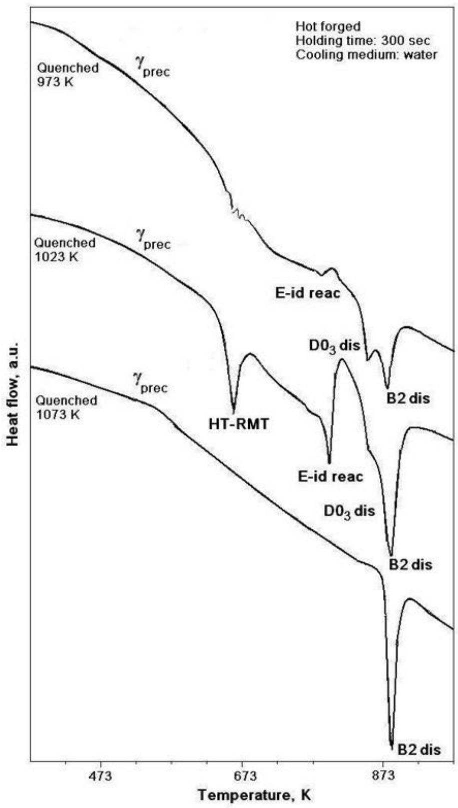

Fig. 8 – DSC charts recorded during the heating of alloy no. 12, illustrating the effects of quenching temperature (Stanciu *et al*., 2008).

With increasing quenching temperature from 973 to 1073 K the two disordering reactions tend to become less distinctive, in such a way that only B2 disordering became noticeable at the specimen quenched from 1073 K (Stanciu *et al.*, 2008).

4. The Order-Disorder Transition of Austenite in CuAlMn-based SMAs

$Cu_{63}Al_{26}Mn_{11}$ SMA was obtained by induction melting, cast, hot forged (at 973 K) and homogenized (1173 K/ 8·hrs/ air). Fig. 9 presents a typical DSC thermogram recorded during the heating of $Cu_{63}Al_{26}Mn_{11}$ SMA specimens, emphasizing three solid-state transitions.

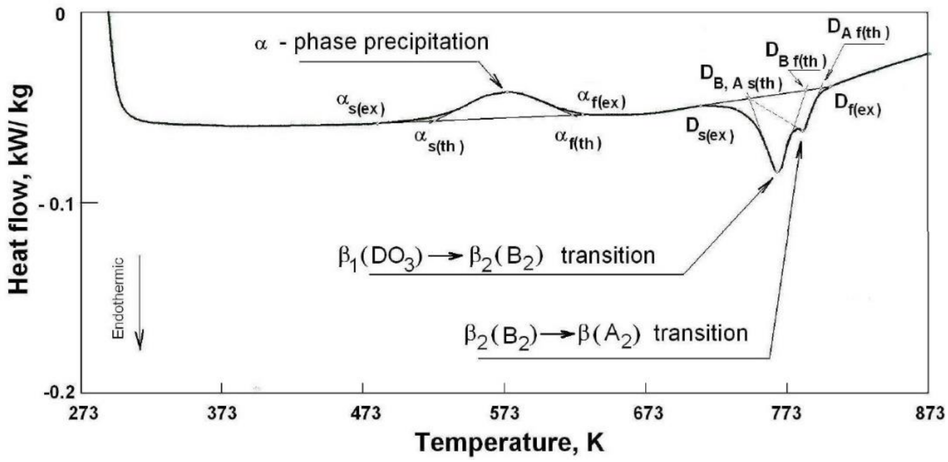

Fig. 9 – Typical DSC thermogram recorded during the heating of hot forged (60% thickness reduction at 973 K) and homogenized (1173 K/ 8·3.6 ksec/ water) $Cu_{63}Al_{26}Mn_{11}$ SMA revealing three solid state transitions (Stanciu *et al.*, 2009a).

Considering that Al content is rather low, α-phase precipitation occurred around 575 K. Between 712 K and 804 K two disordering transitions occurred: (i) β_1 (DO3) → β_2(B2), between 747 K and 787 K and (ii) β_2 (B2) → β (A2), between 747 K and 797 K (Stanciu, 2009a).

These results are in good agreement with those presented for CuAlNi-based SMAs, in the previous section, and confirm the two-step order-disorder transition of austenite DO_3 → B2 → A2.

Another line of experiments refers to A Cu-9.23 Al-5.3 Mn-0.6 Fe (mass, %) SMA, which was obtained by casting, hot rolling (973 K) and homogenization annealing (1173 K/ 8·hrs/ air). The typical DSC thermogram of a fragment cut from a hot rolled solution annealed specimen, during a heating-cooling-heating cycle, is illustrated in Fig. 10.

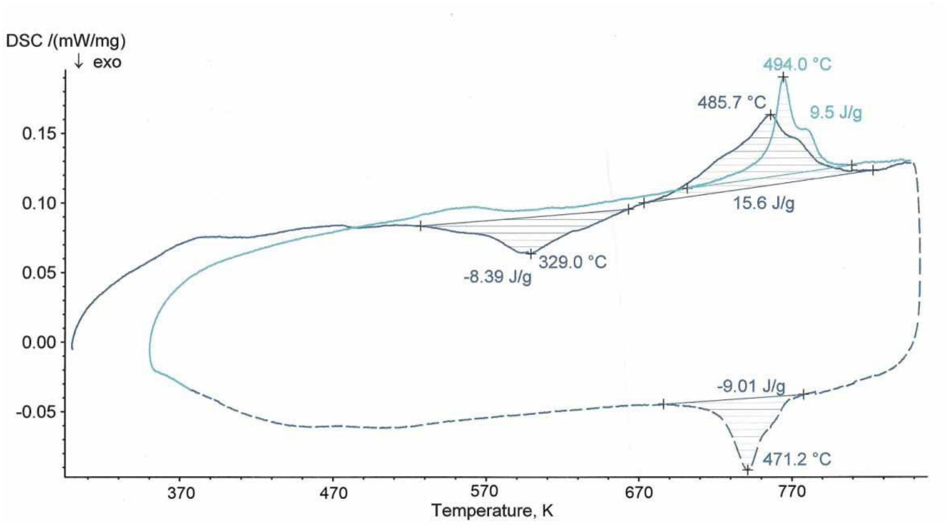

Fig. 10 – Typical DSC thermogram of a fragment cut from a hot rolled solution annealed Cu-9.23 Al-5.3 Mn-0.6 Fe (mass, %) SMA recorded during a heating-cooling-heating (Stanciu *et al*., 2009b).

During the first heating, the exothermic precipitation of α-phase occurred at 600 K, followed by the two-step order-disorder transition of austenite, DO_3 → B2 → A2. It is noticeable the first disordering transition is more prominent, being located around 756 K. During cooling, a two-step ordering exothermic transition occurred, in the sense A2 → B2 → DO_3. B2 → DO_3 was located at about 741 K.

Disorder-order transition becomes noticeable, being located at. Because cooling was interrupted at room temperature (RT), the direct martensitic transformation did not occur. During the second heating, only the two-step order-disorder transition occurred at 764 K, at slightly higher temperatures, as compared to the first heating. The α-phase precipitation did not occur because the matrix was already depleted in Cu during the first heating (Stanciu *et al*., 2009b).

5. Conclusions

Based on the documentary synthesis reviewed in the above sections, the following conclusions can be drawn:

- in Cu-based SMAs, the parent phase, commonly called austenite, has a highly ordered bcc crystalline structure based on CuZn of Cu_3Al intermetallic compounds;
- CuZn-based austenite has a B2 unit cell while Cu_3Al unit cell has a $D0_3$ one;

▪ with increasing temperature, the amplitude of atomic vibrations also increases and the bcc unit cells become disordered;

▪ during heating, the disordering reactions gradually occurred in the succession $DO_3 \rightarrow B2 \rightarrow A2$;

▪ during cooling, austenite became more and more ordered, in the reverse sense $A2 \rightarrow B2 \rightarrow DO_3$.

Subsequent studies have to be performed to meticulously emphasize the influence of thermomechanical treatment parameters on order-disorder transition during both heating and cooling. In addition, other experimental techniques, besides DSC, have to be used (such as scanning electron microscopy of X-ray diffraction, both of them performed during heating in a thermal chamber) to report the influence of this transition on other structural properties.

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O SINTEZĂ DOCUMENTARĂ ASUPRA STADIULUI CERCETĂRII –DEZVOLTĂRII TRANZIŢIEI ORDINE-DEZORDINE ÎN STARE SOLIDĂ ÎN ALIAJELE PE BAZĂ DE CUPRU CU MEMORIA FORMEI

(Rezumat)

Materialele cu memoria formei (SMAs) sunt caracterizate de o transformare martensitică reversibilă care reprezintă mecanismul microscopic al efectului de memoria formei (SME). În timpul acestei transformări martensitice inverse martensita se retransformă în faza inițilă (austenită), în timpul încălzirii sau relaxării izoterme, dacă faza martensitică a fost indusă prin tensiune. Materialele cu memoria formei de tip β sunt caracterizate de o fază austenitică cu o structură cristalină de tip cubic cu volum centrat (cvc) și o valență electronică (număr de electroni de valență/număr de atomi pe celulă unitară) de aproximativ 1,5. Conform modelului sferei solide, o celulă elementară cvc conține un atom central înconjurat de opt atomi plasați în colțurile cubului. Când este implicată o a doua sau a treia specie de atomi pot fi obținute mai multe structuri ordonate. Cele mai multe aliaje cu memoria formei de tip β suferă o transformare martensitică termoelastică, caracterizată de un echilibru continuu între efectele termic și elastic. Cele mai reprezentative aliaje cu memoria formei de tip β sunt NiTi și pe bază de Cu, ultimele fiind din sistemele Cu-Zn-Al and Cu-Al-Ni(Mn). În aliajele cu memoria formei pe bază de Cu, structura cristalină a austenitei este ordonată. Prima ordonare atomică, când se consideră cel puțin două specii atomice, implică un atom din prima specie, de exemplu A, să fie înconjurat de opt atomi din a doua specie, B. Prin simpla imaginare a unei astfel de celule elementare se poate observa cu ușurință că fiecare atom din specia B este înconjurat de opt atomi din specia A. Deoarece acești opt atomi aparțin simultan la opt celule elementare formula stoechiometrică ar fi cea echiatomică AB. Acesta este cazul compusului intermetalic CuZn, din aliajul cu memoria formei Cu-Zn-Al. Pe de altă parte la aliajele cu memoria formei pe bază de Cu-Al, formula stoechiometrică a austenitei este Cu3Al. Când se adaugă al treilea element de aliere, cum ar fi Ni sau Mn celula unitară devine mai ordonată deparece prima specie atomică ar fi în centrul celulei elementare, a doua ar ocupa două diagonale neparalele a două fețe paralele, iar a treia specie atomică ar ocupa cele patru poziții rămase.

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DESIGNING, MANUFACTURING AND TESTING OF AN EXPERIMENTAL SETUP FOR THE STUDY OF SHAPE MEMORY EFFECT IN R-PET THERMOFORMED CUPS

BY

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Abstract. Recycling polymeric waste, and especially polyethylene represents one of mankind's major concerns, due to the huge trash amounts accumulated in the oceans. Following our previous study on recycled polyethylene terephthalate (R-PET) and recycled polyethylene terephthalate glycol (R-PETG), the present work has been focused on the design, manufacturing, and testing of an experimental setup for the study of the shape memory effect (SME) in the case of thermoformed cups from 80% recycled PET (80R-PET). The thermoforming process involves (i) heating of the extruded R-PET foil; (ii) hot deep drawing, with symmetrical geometry, according to a depth-to-width ratio exceeding 1:1 (the process being plug-assisted, to enable the most uniform material distribution for constant wall thickness obtainment) and (iii) instant cooling. After deep drawing, it is the instant cooling that "freezes" the deformed state of 80R-PET and blocks the deformation state of the polymer, which becomes amorphous and attains a temporary (deformed) state. During subsequent heating, glass transition occurs and the amorphous polymer becomes softer, thus releasing the internal stresses that enable the recovery of a part of the permanent shape. This process can be monitored using a special experimental

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setup, meant to sustain the thermoformed cups and to enable their heating to recover (a part) of their permanent (flat) shape.

Keywords: Shape Memory Polymer, Shape Memory Effect, Glass Transition, Tensile Testing, Work Generation.

1. Introduction

The main characteristic of shape memory polymers (SMP) is their ability to recover a permanent (undeformed) shape after the application of an external stimulus (under the form of heat, radiation, pH changing, or mechanical unloading) while being in a temporary (deformed) shape. This shape recovery is termed shape memory effect (SME) (Behl *et al*., 2010).

Within previous reports, the occurrence of SME was emphasized in recycled polyethylene terephthalate (R-PET) (Pricop *et al*., 2022) and recycled polyethylene terephthalate glycol (R-PETG) (Sava *et al*., 2023). More recently, a series of particularities were reported in the behavior of R-PETG during cooling (Sava *et al*., 2024). All these papers reported the presence of SME both in filaments and 3D printed specimens, which were bent at room temperature (RT) and partially or totally recovered their permanent undeformed shape, by heating.

The present paper aims to introduce the design and manufacturing of a special experimental setup used to explore the capacity of thermoformed R-PET cups to develop both free-recovery (FR) and work-generating (WG) SME by partially recovering their permanent flat shape or by lifting various loads, during heating.

2. Experimental

The raw material was an extruded rigid film of 80% R-PET. The film had a 0.85 mm thickness, a 650 mm width and a 361 m length. The process has been schematized in Fig. 1.

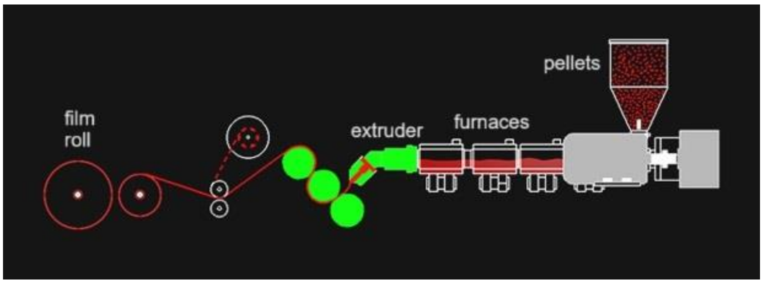

Fig. 1 – Schematic illustration of the extrusion process of rigid film of 80% R-PET.

From a mixture of 20% pristine and 80% recycled PET pellets, the rigid film was extruded at 270ºC, successively rolled and stored in the form of roll. This hot working process gave anisotropic mechanical properties due to the difference between longitudinal (rolling) and transversal directions.

The cups were experimentally produced by hot deep drawing, with symmetrical geometry and a depth-to-width ratio exceeding 1:1, the process being plug-assisted, to enable the most uniform material distribution for constant wall thickness obtainment. The thermoforming process is schematically illustrated in Fig. 2.

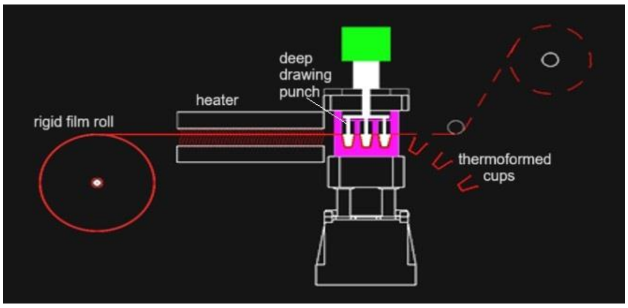

Fig. 2 – Schematic illustration of the thermoforming process.

Up to 27 cups were simultaneously produced by hot deep drawing from a roll of extruded rigid film. The thermoforming process was performed through plug-assisted deep drawing of preheated film at 120ºC during a total cycle time of 3.5 seconds.

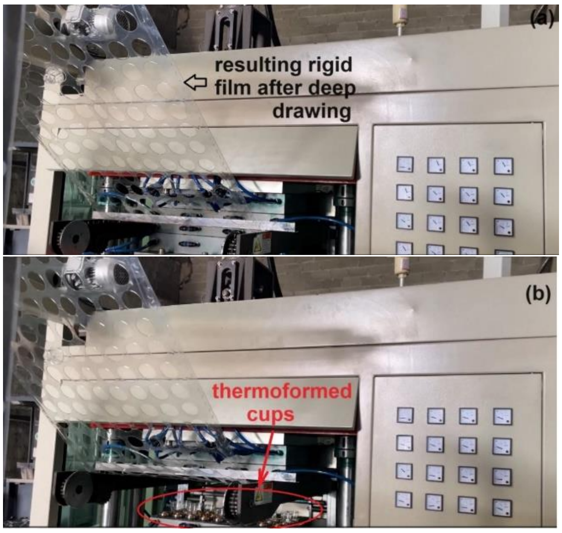

Fig. 3 – Images of two technological steps of the thermoforming process (a) deep drawing punching; (b) punch lifting to eject the thermoformed cups.

Figure 3 offers images of the thermoforming process, by illustrating two moments when the punch is down, Fig. 3(a) and lifted, Fig. 3(b) allowing the resulting cups to become visible. Between these two technological steps, the resulting drilled film is removed from the machine.

The film was plastically deformed, by deep drawing, at hight temperature and instantly frozen through cold air, so internal stresses were stored in the material that became amorphous. During heating, glass transition occurred and the hard low-temperature amorphous phase transformed into a soft high-temperature (semi)crystalline one (Dong *et al*., 2002), that was deformed back by stored internal stresses. Figure 4 offers images and geometric dimensions of the two types of thermoformed cups, for long-dink, 350 ml, Fig. 4(a) and for shots, 50 ml, Fig. 4(b).

Fig. 4 – Technical drawings and schematic views of the two types of thermoformed cups: (a) 50 ml, for shots and (b) 350 ml, for long drinks.

Figure 5 shows images of each type of cup, placed on an analytical balance, which enables seeing their weights: 8.3135 and 2.4714 g, respectively. It is noticeable that both cups are transparent.

Fig. 5 – Images of the two types of thermoformed cups, placed on an analytical balance: (a) 350 ml, for long drinks and (b) 50 ml, for shots.

Since studying SME on this cup geometry is not as simple as with filament, a special experimental setup was designed, manufactured and tested, as described in the following.

3. Experimental results and discussion

3.1. Designing and manufacturing an experimental setup for SME testing in thermoformed cups

The setup had to fulfill the following requirements:

- firm fixture of the cups through their upper brims;
- stable fastening of the hot air gun and temperature measuring multimeter;
- providing a uniform distribution of heat on the cup's surface;
- clear visualization of both cup bottom lifting and temperature variation, during heating.

Based on the above requirements, the experimental setup has been designed as an assembly comprising a 3D-printed skeleton and 3 supports for the two types of cups and the heat gun. All of them were designed and 3D printed from polylactic acid (PLA) using a Prusa printer. The structural sustainment elements were not designed as solid (massive) bars but as round pipes to enable easy sliding of the cup supports. When designing the support for the cup, one had to consider the constant need to adjust the position of the heating gun (because of the necessity to modify the nozzle and the heating angle (because the air stream did not exhaust straightly from the nozzle). The scheme of the design of the experimental setup is shown in Fig. 6.

Fig. 6 – Images of the design of the experimental setup: (a) assembly view; (b) finite element modeling of the components. 1-shot cups holder; 2-long-dink cup holder; 3-heat gun holder.

In case a shot cup would be tested, the hot air gun must be fastened in the long drink cup holder (2) and the heat gun holder (3) would be removed. Conversely, when long drink cups would be studied, the shot cups holder (1) would be removed. Based on the above considerations, the experimental setup was 3D-printed and assembled, as illustrated in Fig. 7.

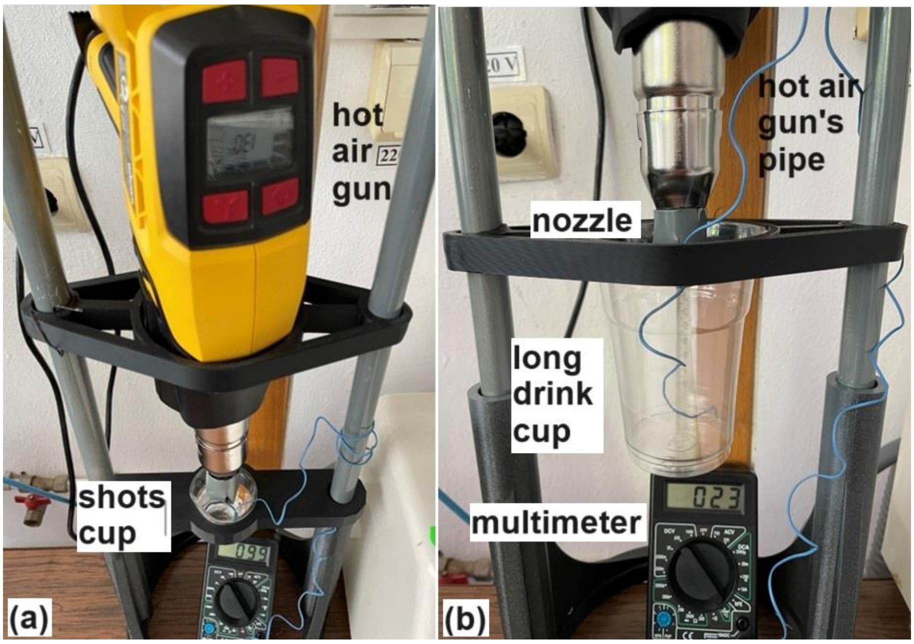

Fig. 7 – Assembly views of the experimental setup during: (a) the heating of a thermoformed shot cup; (b) the heating of a thermoformed long-drink cup.

In each case, a multimeter was used which was equipped with a thermocouple meant to measure the temperature inside the tested cup.

To emphasize the occurrence of both FR and WG SME, the influence of numerous parameters was investigated, namely:

- distance between cup bottom and hot air gun nozzle;
- heating time and intensity;
- visualization of cup bottom displacement;
- magnitude of lifted loads;
- nozzle design.

Nozzle design proved to be extremely important from the point of view of heat distribution. Fig. 8 illustrates the results of several experimental attempts, performed on different types of thermoformed cups with different types of nozzles.

Fig. 8 – Assembly views of the results obtained after the testing of the experimental setup: (a) nozzle variants for more uniform heat dispersion inside the tested cup; (b) shrunk shot cups after the tests; (b) shrunk long-drink cups after the tests.

It is obvious that the SME-caused shrinkage of the thermoformed cups occurred neither smoothly nor uniformly. Initially, it was planned to monitor the variation of cup bottom's lifting with the increase in temperature, either without (FR-SME) or with an applied load (WG-SME).

Because of the irregular deformation of the cup, the variations of cup's bottom vertical position cannot be accurately determined. So, it was decided to monitor cup's volume variation, from room temperature (initial state) to the end of heating (final state).

The functionality of the experimental setup was tested by heating both types of thermoformed cups, either in a free state or with a load put into them.

3.2. Testing the functionality of the experimental setup

Figure 9 displays the changes observed at thermoformed shot cups before and after FR-SME occurrence.

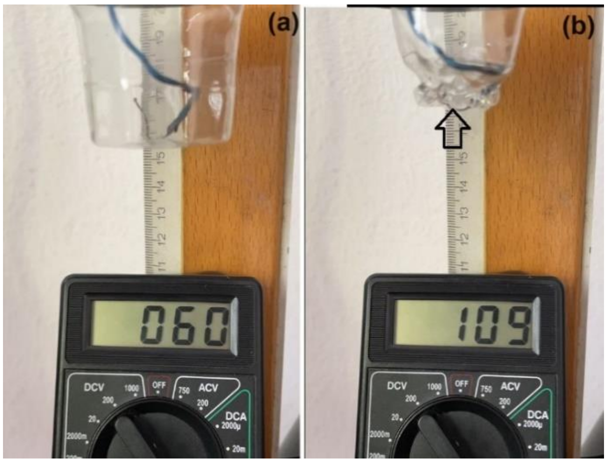

Fig. 9 – FR-SME-induced changes at a thermoformed shot cup: (a) before glass transition and (b) after SME occurrence (black arrow showing cup's bottom lifting).

One can easily notice that the bottom of the shot cup was lifted about 14 mm. Figure 10 displays FR-SME-associated changes at long drink cups.

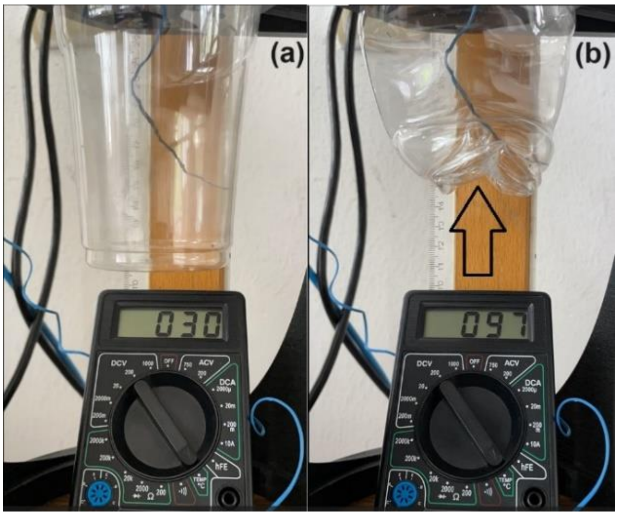

Fig. 10 – FR-SME-induced changes at a thermoformed long drink cup: (a) initial shape at RT and (b) after SME occurrence(black arrow showing cup's bottom lifting).

At long drink cups, the thermoformed surface was larger than at shot cups so the shape change should be more prominent (McClung *et al*., 2017). For this reason, the cup bottom's lifting exceeded 40 mm, which represents about 36% of the cup's height.

Figures 11 and 12 illustrate the changes observed at thermoformed shot and long drink cups, respectively, before and after WG-SME occurrence.

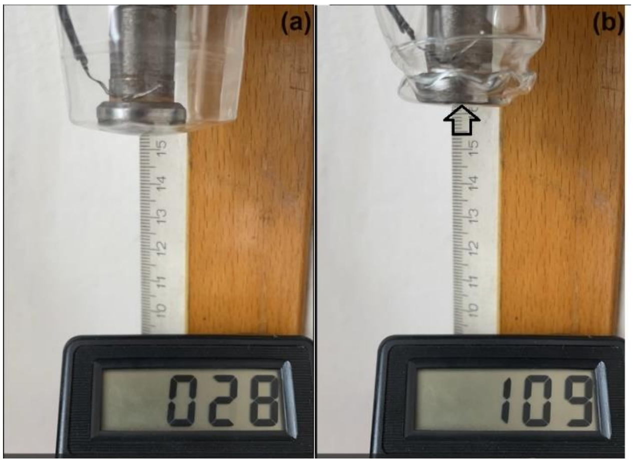

Fig. 11 – WG-SME-induced changes at a thermoformed shot cup that lifted a 30 g-load (12.1 times heavier): (a) at RT and (b) at 109ºC (black arrow shows cup's bottom lifting).

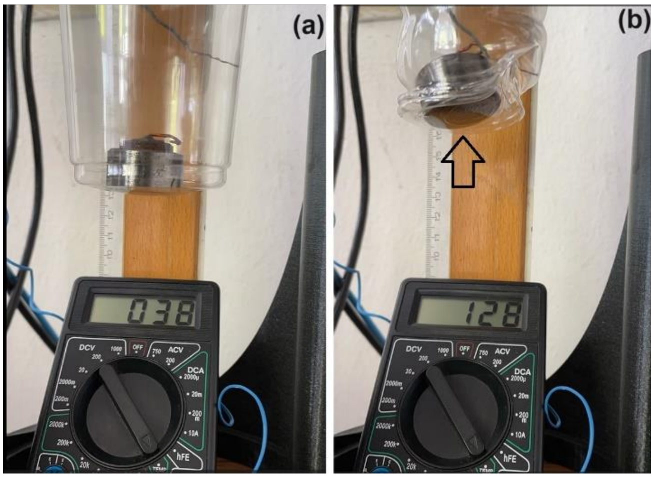

Fig. 12 – WG-SME-induced changes at a thermoformed long drink cup that lifted a 70 g-load (8.5 times heavier): (a) at RT and (b) at 128ºC (black arrow shows cup's bottom lifting).

The detailed results and discussion on the SM behavior of thermoformed cups, from 80m% R-PET, when heated to different maximum temperatures, for different periods, while lifting various loads, will be reported in a subsequent paper.

4. Conclusions

The extrusion process of rigid films from 80% R-PET was generally described and the thermoforming technology of deep-drawn cups was detailed. Two types of transparent thermoformed cups were introduced and their tendency to recover their permanent flat shape, present before deep drawing, was emphasized. In order to highlight their shape recovery during heating, by FR-SME or WG-SME, a special experimental setup was designed and manufactured.

The experimental setup was preliminarily tested and the occurrence of both FR and WG SME was emphasized in both types of thermoformed cups.

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PROIECTAREA, PRODUCEREA ŞI TESTAREA UNUI STAND EXPERIMENTAL PENTRU STUDIUL EFECTULUI DE MEMORIA FORMEI PE PAHARE TERMOFORMATE DIN PET RECICLAT

(Rezumat)

Recilarea deșeurilor polimerice și în special a polietilenei reprezintă una dintre preocupările majore ale umanității din cauza uriașelor cantități de deșeuri acumulate în oceane. Urmând studiul nostru anterior despre reciclarea polietilen tereftalatului (R-PET) și a polietilen tereftalat glicolului (R-PETG), prezenta lucrare s-a concentrat pe proiectarea, producerea și testarea unui stand experimental pentru studiul efectului de memoria formei (SME) în cazul unor căni termoformate din 80% PET reciclat (80R-PET). Procesul de termoformare implică (i) încălzirea foliei extrudate de pet recilat (R-PET); (ii) ambutisare la cald, cu geometrie simetrică cu un raport adâncime – lărgime mai mare de 1:1 (procesul fiind controlat continuu pentru a permite obținerea celei mai uniforme distribuții pentru obținerea unor pereți de grosime constantă) și (iii) răcire instantanee. După ambutisare, răcirea instantanee "îngheață" starea deformată a 80R-PET și blochează starea deformată a polimerului, care devine amorf și atinge o stare (deformată) temporar. În timpul încălzirii ulterioare, tranziția vitroasă apare și polimerul amorf devine mai moale, eliberând astfel tensiunile interne care permit recuperarea parțială a formei permanente. Acest proces poate fi monitorizat folosind un stand experimetal special, menit să susțină paharele termoformate și să permită încălzirea lor pentru recuperarea (parțială) a formei lor permanente (plate).

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POLYMER COMPOSITES THERMISTORS USED AS HEAT FIRE DETECTORS: A SHORT REVIEW

BY

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Abstract. Fast fire detection is crucial in assuring fire safety for the occupants in buildings, so they have enough time for egress, assure a fast fire response and limit casualties and the gravity / damages caused by the fire. The most commonly used fire detection systems rely on point detectors. In these systems, the detection time depends on how long it takes for fire byproducts (such as smoke, gas, and heat) to reach the detectors. This timing is influenced by factors such as the height of the room, air movement, the number of detectors, and their placement. One way to reduce detection time is to use a fire detector (FD) placed directly on equipment that poses the highest fire risk, such as electrical batteries. This allows the detector to identify the early signs of a fire, potentially even before combustible materials ignite. This study presents a short overview of the literature regarding polymer composites thermistors that can be used as heat FD. The most important characteristic of these materials is the change in electrical resistivity that occurs with the increase of temperature. A better performer material can be considered the one that has a higher electrical resistivity gradient in a specified temperature range (that can be the ingnition temperature of the protected material).

Keywords: fire detector, thermistor, composite materials, fire safety, electrical resistivity, temperature.

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1. Introduction

Heat detectors (HDs) are meant to offer early detection of fires in environments where other detection methods may be ineffective due to specific environmental. The main component of the HD is the thermistor.

Thermistors are resistive components that vary with temperature, typically made from metal oxides. They exhibit a significant change in resistance with temperature, which is generally negative; that is, resistance decreases as temperature rises. Their temperature response is highly nonlinear. Thermistors with a negative temperature coefficient are referred to as NTC thermistors, while those with a positive temperature coefficient (PTC) are less commonly used for temperature measurement.

The resistance measurement of a thermistor is conducted similarly to that of metallic probes. One of the key benefits of thermistors is their typically high resistance, which reduces the need for precise compensation for the resistance of measurement wires. The measurement range for thermistors varies based on the type of probe, generally spanning from −100 to +300°C. However, their stability is not as reliable as that of metallic resistances, and thermistors lack the standardization seen in some metallic probes. Nonetheless, thermistors offer a significant change in resistance with temperature, and their wide variety of sizes and shapes, along with their low cost, enhances their appeal in terms of metrological performance.

Incorporating HDs into household appliances or directly attaching them to electrical batteries can reduce detection time for one of the most common causes of fire - electrical malfunctions.

This method allows for much faster detection compared to traditional punctual FD, where the detection time is influenced by how long it takes for fire byproducts (such as smoke, gas, and heat) to reach the detectors. This timing can be affected by factors like the height of the room, air circulation, the number of detectors and their positioning, while attaching the thermistor on the circuits with fire risk, the detection of a fire will be made before the ignition of the combustible materials. The majority of combustible materials have higher ignition temperatures than the response temperature interval of most thermistors (e.g. combustible polymers from power equipments have a flammability temperature exceeding 300°C).

2. Materials used for thermistors

The materials used for NTC thermistors are created through the reaction of various oxides. Commonly utilized materials for temperature ranges between 30°C and 300°C, particularly in domestic and industrial applications, consist of ceramics made from transition metal oxides, such as manganese, cobalt, copper, and nickel, which can form a new crystal structure known as spinel. For high-temperature applications, especially in the automotive sector, materials like ZrO_2, Y_2O_3, and ThO_2 are employed, suitable for temperatures ranging from 300°C to 1000°C. The formation of nickel manganite ($NiMn_2O_4$), a widely used material for NTC thermistors, has been extensively studied. In binary compositions of Ni and Mn oxides, the complete formation of spinels necessitates a specific atomic ratio of Mn to Ni, which corresponds to weight ratios of 1.873 and 1.864 for the metal contents. Approximately 65 atomic percent of manganese should be included in the composition; otherwise, excess nickel oxide will exist as a secondary phase (Kamat and Naik, 2002).

Other NTC thermistors have been made from manganite ceramics, and it has been shown that the resistance drift is not due to the use of metallic electrodes or the interfaces between metal and ceramic (Metz, 2000; Feteira, 2009).

The thermoresistive behavior of multiwall carbon nanotube (MWCNT)/polymer composites were olso examined, with an emphasis on the influence of the polymer matrix. Investigations involved the experimental analysis of the cyclic thermoresistive response of MWCNT composites featuring three types of thermo-mechanically distinct matrices: a thermosetting resin (vinyl ester), an engineering thermoplastic (polysulfone), and a commodity thermoplastic (polypropylene) (Balam *et al*., 2019). The thermoresistive characterization included cyclic heating and cooling within the ranges of 25°C to −30°C and 25°C to 100°C. The results revealed a significant impact of the polymer matrix, highlighting variations in response linearity, thermoresistive sensitivity, and hysteresis, which are dependent on the thermo-mechanical properties of the polymer. Among the composites, polypropylene nanocomposites exhibited the highest sensitivity and lower hysteretic parameters, attributed to their high coefficient of thermal expansion, low elastic modulus, and low glass transition temperature. Both polypropylene and polysulfone nanocomposites demonstrated high fidelity in their performance as thermistors, yielding readings comparable to those of commercial thermistors (Verma *et al*., 2020).

Copolymer nanocomposites made from polyethylene glycol (PEG) / polyurethane (PU) were synthesized to create low-cost, flexible sensors for heat detection (Kumar *et al*., 2022). A thermosensitive phase change PEG polymer was incorporated in a PU flexible material, incorporated through a chemical crosslinking and mechanical mixing. Nanocomposite with thermoresistive properties were obtained by incorporating multi-walled carbon nanotubes (MWCNT) as conductive filler to the PEG-PU.

The optimal conductivity of the nanocomposite was determined by evaluating different concentrations of MWCNT (2 wt.% to 10 wt.%). The study was made in the temperature range of 25°C to 50°C in order to determine the impact of MWCNT concentration on the thermal sensitivity of the nanocomposite (Mojtaba *et al*., 2022). The thermal sensitivity of crosslinked and physically mixed polymeric nanocomposites were compared by spin coating on screen-printed interdigitated (IDT) electrodes (Mojtaba *et al*., 2022).

Polymeric PTC thermistors featuring various gradient distributions of TiC and CB fillers were fabricated using a solution mixing and subsiding method. The gradient distribution of fillers within the PVDF matrix could be flexibly controlled by adjusting the subsidence time and the mass ratio of the different fillers, resulting in enhanced conductivity of the thermistor (Qize Tang *et al*., 2023).

3. Conclusions

There are many types of polymer composites used as thermistors, most of them nanocomposites. In order to fabric accessible heat fire detectors further studies on polymer composites with carbon microfillings are needed. This way, will be possible a change in paradigm regarding the way the fire detection is made, not on the room's ceiling, when the fire has already developed, but on the source, before the ignition of the combustibile material.

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MATERIALE COMPOZITE POLIMERICE UTILIZATE CA DETECTOARE DE INCENDIU: SCURT REZUMAT

(Rezumat)

Detectarea rapidă a incendiului este crucială în asigurarea siguranței la incendiu pentru ocupanții din clădiri, astfel încât aceștia să aibă suficient timp pentru ieșire, să asigure un răspuns rapid la incendiu și să limiteze victimele și gravitatea/daunele cauzate de incendiu. Cel mai utilizat sistem de detectare a incendiilor utilizează detectoare punctuale, dar la acestea, timpul de detectare este determinat de timpul necesar pentru ca efluenții de incendiu (de exemplu, fum, gaz, căldură) să ajungă la detectoare (fiind influențați de înălțimea încăperii, mișcarea aerului, numărul de detectoare și locația acestora).

O metodă de reducere a timpului de detectare este utilizarea unui detector de incendiu care poate fi pus direct pe echipamentele care prezintă cel mai mare pericol de incendiu (ex.: bateriile electrice), putând astfel detecta declanșarea unui incendiu chiar înainte de aprinderea materialelor combustibile. Acest studiu prezintă o scurtă prezentare a literaturii de specialitate referitoare la termistorii din compozite polimerice care pot fi utilizați ca detectoare de incendiu. Cea mai importantă caracteristică a acestor materiale este modificarea rezistivității electrice care are loc odată cu creșterea temperaturii. Un material mai performant poate fi considerat cel care are un gradient de rezistivitate electrică mai mare într-un interval de temperatură specificat (care poate fi temperatura de aprindere a materialului protejat).

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MODERN METHODS OF SEVERE PLASTIC DEFORMATION: A SHORT REVIEW

BY

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Abstract. The study provides an overview of modern methods used in severe plastic deformation processes. Many plastic deformation techniques have gained significant attention for their ability to refine the grain structure and a property of the analyzed mechanical materials. Various contemporary methods, such as high-pressure twisting, equal-channel angular pressing, and accumulative role bonding, are analyzed in terms of their principles, advantages, and applications at the scientific level. The integration of severe plastic deformation techniques used in the field of implantology is a promising way improve the mechanical property and performance of dental work devices. Biocompatible materials processed by severe plastic deformation represents a revolution in regenerative medicine. These materials, particularly metal alloys and tough polymers, are designed to be compatible with the human body, minimising the risk of rejection or adverse reactions. Metal, such as titanium or its alloys, is preferred because of its high mechanical strength and biocompatibility, making it suitable for supporting biting and chewing forces. Polymers, on the other hand, are mainly used for aesthetic restorations as they can be shaped and stained to match the natural appearance of teeth. These materials also offer an optimal combination of strength, durability and aesthetics, which are essential in modern

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implant dentistry. Through advanced severe plastic deformation techniques, these materials are precisely shaped to produce complex and detailed structures suitable for custom implants. An important advantage of these materials include the ability to stimulate tissue regeneration around the implant. By combining materials engineering with advanced manufacturing technologies, new perspectives are opening up in the treatment of patients with biocompatible implants, which promise more durable and effective results in modern implantology. Analysing biocompatible materials processed by severe plastic deformation, it is possible to obtain refined microstructures, good strength and tailored mechanical properties suitable for implantology applications. The purpose of this study is to highlight recent advances and key findings in the field of severe plastic deformation, providing insights into the evolving landscape of materials processing and development in implantology field.

Keywords: severe plastic deformation, mechanical property, biocompatible materials, implantology, performance.

1. Introduction

In order to improve the deformability and mechanical properties of metals, one of the best methods used for obtaining ultrafine grain (submicron or nanocrystalline) structure is severe plastic deformation (Cazac, 2016). This processing technique has the ability to produce consolidated materials with ultrafine or even nanometric grain structures. In these processes, it is important to understand the distribution of strains, stresses, or strain rates in order to determine the optimal process conditions for a given material (Comăneci *et al*., 2006).

Severe plastic deformation method describes a group of metal and alloy processing techniques that involve very high stresses, without causing significant changes in the overall dimensions of the model or the workpiece (Valiev *et al*., 2000; Rosochowski *et al*., 2004; Estrin and Vinogradov, 2013; Bejinariu *et al*., 2017; Cazac *et al*., 2017).

A principal characteristic of severe plastic deformation techniques is that shape retention is achieved due to the special geometries of the die, which involve the free flow of the material, thus producing significant hydrostatic pressure. The presence of high hydrostatic pressure, combined with large shear stresses, is essential for generating a high density of crystal lattice defects, particularly dislocations, which can lead to significant grain refinement (Shi *et al*., 2010; Guo *et al*., 2012). Since the dimensions of the workpiece do not change during SPD processing, the process can be applied repeatedly to impose very high stresses. The optimization of SPD paths and regimes can ultimately induce an extremely fine microstructure in the processed material, which extends homogeneously throughout the semi-finished product.

2. Severe plastic deformation methods presentation

At the scientific level, the following modern processing methods have been used in the processing of metals and alloys: equal chanel angular pressing - ECAP, high pressure torsion – HPT, accumulative roll bonding - ARB, ciclic closed die forging - CCDF, cyclic extrusion compresion – CEC, repetitive corrugated and straightening – RCS, severe torsion straining – STS, repetitive extrusion and upsetting – REU and repetitive extrusion – RE.

The ECAP was defined as plastic deformation performed by extruding the semi-finished product through angular channels with a constant cross-section. The cross-sectional area of the semi-finished product remains constant, and the imposed degree of deformation is achieved by repeating a calculated number of extrusions. In his studies, Segal (Segal, 1995, 2002) proposed in 1977 the creation of a material with ultrafine grain structure using this technique.

The HPT process was investigated by Valiev (Valiev, 1997a, b) and represents a continuous severe plastic deformation method that involves shearing the material by torsion between two anvils - one fixed and the other rotating (Gurau *et al*., 2015). The required torque is determined by the friction forces on the contact areas between the semi-finished product and the tool.

The ARB process was developed by Saito (Saito *et al*., 1998; Lee *et al*., 2002; Saito *et al*., 1999) and this technique consists of successive rolling by transversely cutting the product laminated in a previous pass, overlapping the resulting parts, and re-rolling them with deformation degrees more than 50%, without changing the distance between the rolls.

The CCDF process was studied by Amit K. Ghosh (Ghosh *et al*., 2000) and involves producing fine grains in certain aluminum alloys by using three-axis deformation. The semi-finished product is first heat-treated, allowed to precipitate for a period of time, and then hot-deformed along the three main axes (x, y, z) until a cumulative deformation degree. In this case, the semi-finished product is rotated again and pressed along the z-axis. After these three operations that complete the first deformation cycle, is resulting a semi-finished product that has been deformed along three axes that retains the same dimensions as the initial semi-finished product (Ghosh *et al*., 2000).

The CEC process was developed by Korbel (Korbel *et al*., 1981) and highlights a sample that is placed into a die and then repeatedly extruded back and forth. This process was invented to allow arbitrarily large deformation of a sample while maintaining the original shape of the sample even after n passes (Rosochowski *et al*., 2000).

The RCS process was analized by Huang (Huang *et al*., 2001) and involves bending a straight bar using corrugating tools and then restoring the shape of the bar with flat deformation tools.

The STS process was studied by Nakamura (Nakamura *et al*., 2004) and requires creating a locally heated zone and applying a torsion force in that area by rotating one end of the rod while the other end is fixed. The rod is moved along its longitudinal axis while generating localized stress, so this method is used along the rod.

The REU process was patented by Zaharia (Zaharia *et al*., 2014) and begins by extruding a semi-finished product to elongate the grains. Since an undeformed end remains in the deformation zone, a new semi-finished product is introduced to fully deform the first one. After the complete extrusion, the first semi-finished product is upset until the initial diameter is restored, allowing the extrusion process to be repeated.

The RE process was developed by Zaharia and uses an extrusion die with a square cross-sectional container, where the initial semi-finished product is inserted and pushed by punch towards the calibration area, which has a rectangular cross-section. This results in the extruded semi-finished product, which is then transversely cut into two equal parts using knife. These parts are then reassembled to obtain a square cross-section of the semi-finished product, after which it is reintroduced into the container. The process is repeated until an ultrafine grain structure is achieved (Zaharia *et al*., 2014).

The various severe plastic deformation methods presented, such as ECAP, HPT, ARB, CCDF, CEC, STS, REU and RE, highlight the significant advancements in material processing. These techniques are crucial for refining grain structures and enhancing the mechanical properties of metals and alloys without altering the overall dimensions of the workpiece. As research continues, the optimization and combination of these techniques will further expand the potential for producing high-performance materials with superior strength, durability, and functionality.

3. Advantages and disadvantages of the severe plastic deformation methods

The processing through the application of severe plastic deformation offers opportunities to achieve exceptional grain refinement, down to submicron or nanometric sizes. The advantages that arise from developing various materials this method are vast, which is why this technological branch is an industrial field experiencing rapid technological growth. After studying all the severe plastic deformation methods we can highlight that the most important advantages include:

- improved mechanical properties - due to the new, denser, and more homogeneous structure obtained;
- the ability to produce parts with different and improved functional properties - across the section, depending on how the material volumes were displaced during plastic deformation;

- high productivity - the processing is executed with broad possibilities for mechanization and automation, and the ability to produce products with simple or complex configurations, maintaining the same section over long lengths;
- high dimensional accuracy - the resulting parts often being interchangeable and, in many cases, reaching final dimensions even for use in industries that require very high precision;
- significant labor savings - since in most cases, fully mechanized and automated equipment is used, with increasing trends toward digitalization and even robotization.

The analysis of grain size is conducted on very small areas, with the clear advantage that detailed investigations of grain boundaries at the atomic level can be carried out. This type of investigation has been recently performed in a series of studies, which revealed a number of important characteristics of these boundaries (Belyakov *et al*., 2001).

Although the advantages of processing through severe plastic deformation are significant, there are also some disadvantages: high initial investment for expensive equipment capable of developing very large forces and variate tools used for each category of parts produced through plastic deformation.

4. Conclusions

The following conclusions can be drawn after searching about the severe plastic deformation method:

- significant potential for material refinement - severe plastic deformation offers an unique ability to achieve exceptionally refined grain structures, down to submicron or even nanometric scales, resulting in materials with vastly improved mechanical properties.
- enhanced functional properties – the ability to produce parts with tailored functional properties. The displacement of material volumes during the process allows for varying properties across different sections of a part, making it highly versatile and leading to better performance in demanding operational conditions compared to parts made by other processing methods.
- high precision and repeatability – these techniques can yield extremely precise parts, often reaching final dimensions with minimal need for further processing.
- increased automation and efficiency - these processes benefit from a high degree of mechanization and automation, leading to significant improvements in production efficiency.

- cost savings through automation - despite high initial investments in specialized equipment, severe plastic deformation offers long-term cost savings through reduced labor and increased efficiency.
- high initial investment - the high upfront cost associated with purchasing the complex machinery required for the process. These machines must be capable of generating extremely high forces, which drives up the initial capital investment. This barrier may limit accessibility for smaller manufacturers or industries with limited budgets.
- specialized tooling requirements – this method often requires specialized tools that are custom-made for specific parts or applications.
- limited versatility of equipment - the specialized nature of the equipment means that it is often not versatile enough to be used for a wide range of parts.
- advanced research opportunities – the modern method of severe plastic deformation highlight the investigation of grain boundaries at the atomic level. This allows for detailed analysis of material behavior, which can lead to the discovery of new material properties and the development of advanced materials with enhanced performance characteristics.
- balancing costs and benefits – all the analyzed methods offers numerous benefits, including superior material properties and potential for automation, it also comes with challenges related to cost and tooling. Manufacturers must weigh the long-term gains in material performance and productivity against the high initial investments in equipment and tools. In industries where material strength and precision are critical, the severe plastic deformation remains a valuable and promising technology used in academic and industry area.

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METODE MODERNE DE DEFORMARE PLASTICĂ SEVERĂ: SCURT REZUMAT

(Rezumat)

Lucrarea oferă o perspectivă de ansamblu asupra metodelor moderne utilizate în procesele de deformare plastică severă. Numeroase tehnici de deformare plastică au fost evidențiate datorită capacității lor de rafinare a structurii granulare și a proprietăților materialelor mecanice analizate. Variate metode contemporane, precum torsiunea la presiune înaltă, presarea unghiulară în canal egal și laminarea prin acumulare, sunt analizate la nivel științific ținând cont de principiile, avantajele și aplicațiile lor. Integrarea tehnicilor de deformare plastică severă folosite în domeniul implantologiei reprezintă o metodă promițătoare de îmbunătățire a proprietăților mecanice și performanțelor dispozitivelor dentare. Materialele biocompatibile procesate prin deformare plastică severă produc o revoluție în medicina regenerativă. Prezentele materiale, în special aliajele metalice și polimerii rezistenți, sunt concepute pentru a fi compatibile cu corpul uman, minimizând riscul de respingere la nivelul organismului. Metalele, precum titanul sau aliajele sale, sunt utilizate preponderent datorită rezistenței mecanice ridicate și biocompatibilității, fiind adecvate pentru susținerea forțelor de mușcare și masticație. Polimerii, sunt de asemenea utilizați, în principal, la nivelul restaurărilor estetice, întrucât acestea pot fi modelate și pigmentate (colorate) pentru a se potrivi cu aspectul natural al dinților. Materialele prezintă un cumul optim de rezistență, durabilitate și estetică, prezentele elemente fiind esențiale în implantologia modernă. Prin tehnici avansate de deformare plastică severă, materialele sunt modelate cu o deosebită precizie cu scopul de a obține structuri complexe și detaliate, adecvate implanturilor personalizate. Un avantaj important al acestor materiale include capacitatea de a stimula regenerarea țesuturilor în jurul implantului. Prin combinarea ingineriei materialelor cu tehnologiile avansate de fabricație, se deschid noi perspective în tratarea pacienților cu implanturi realizate din materiale biocompatibile, ce promit rezultate mai durabile și eficiente. Analizând materialele biocompatibile prelucrate prin deformare plastică severă, se obțin o serie de microstructuri rafinate, caracterizare prin rezistență și proprietăți mecanice adaptate aplicațiilor din stomatologie. Scopul acestui studiu este de a evidenția progresele recente și principalele descoperiri în domeniul deformării plastice severe, printr-o serie de perspective ale evoluției de prelucrare și dezvoltare a materialelor în domeniul medicinii dentare.

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THE ROLE OF AEROBIC EXERCISE ON THE HEALTH OF THE HUMAN BODY

BY

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Abstract: Occupational health refers to the maintenance of the physical, mental and social well-being of employees at work. It is an area that aims to promote physical and mental health by providing conditions that support employees' well-being, including ergonomic workspaces, regular breaks and mental health support. Aerobic exercise has multiple benefits on human body systems, both short and long term. They increase the efficiency of the heart by strengthening the cardiac muscle, can reduce blood pressure, preventing hypertension, improve blood flow by dilating the arteries, increase the efficiency of the respiratory and digestive systems have numerous benefits on the locomotor system, and metabolic adaptations following aerobic exercise lead to a state of well-being of the exercisers.

Keywords: health, benefits, exercises.

1. Introduction

Aerobic exercise is exercise that is obtained in long-duration, medium- and low-intensity training. Aerobic exercise has far-reaching health benefits for

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the whole body, supporting optimal organ function as well as mental and emotional health. Regular exercise can contribute to a longer, healthier and more active life. Following aerobic exercise, the human body responds with a number of standard physiological adaptations. These responses are essential to cope with increased energy demands and to ensure optimal functioning of the body during physical activity (Bejinariu *et al*., 2017).

There is also anaerobic-type exercise, this is exercise that involves maximal intensity, of short duration, with workouts involving force and speed. Anaerobic effort is achieved during intense exercise such as: jumping, sprinting, HIIT (high intensity interval training) or even weight lifting. In contrast to aerobic exercise, anaerobic exercise involves faster breathing, and the amount of oxygen in the blood reaches a maximum. During anaerobic exercise, the body begins to tap into energy stores and uses less oxygen to cope with the intense exertion (artrosport.ro).

2. Cardio-vascular system

During aerobic exercise, the heart rate increases to send more blood (and therefore oxygen) to the muscles. The mechanism by which this process occurs is regulated by the sympathetic nervous system, which releases adrenaline and noradrenaline, stimulating the heart to increase its rate.

With light and moderate exertion, the adaptation time of the cardio vascular system is 1 to 2 minutes, whereas with intense exertion it is longer. Trained people adapt more quickly to exercise than those untrained.

After cessation of exercise, cardiac output gradually decreases to resting level, with an exponential recovery curve. The exponential recovery curve refers to a process in which the recovery (or improvement) of a particular variable, such as physical performance, occurs at an accelerated rate, but with a rate of increase that progressively decreases over time. In this type of curve, progress or recovery is very rapid and as time passes, progress becomes slower but continuous.

This is characteristic of phenomena in which an initial rapid gain is obtained, but as recovery nears completion, the changes become smaller and slower (Hefco, 1997).

Cardiac output (the volume of blood pumped by the heart in one minute) increases substantially during exercise. This is due to both the increase in heart rate and the volume of blood pumped with each beat.

The benefits materialize in that, it delivers more oxygen and nutrients to active muscles and removes carbon dioxide and metabolic waste faster.

Redistribution of blood flow occurs at the same time; blood is being redistributed to the active muscles and blood flow to organs not directly involved in exertion (e.g. digestive tract) is temporarily reduced. Vasodilatation (dilation of blood vessels) occurs in the active muscles, while vasoconstriction (narrowing of blood vessels) occurs in other areas (Sbenghe, 2008).

3. Respiratory system

Immediately with the onset of exercise, ventilatory changes occur, in which there is a rapid increase in ventilation and its adaptation to the amount of exertion. It is difficult to specify which stimulus triggers the increase in respiratory ventilation because there are several, including at the time we prepare to start physical exercise, the stimulus being the psychological one.

Following aerobic exercise there is an increase in respiratory rate; breathing becomes faster and deeper to meet the increased oxygen demand and to remove carbon dioxide produced by muscle metabolism.

Another consequence is increased oxygen consumption, which becomes significant for fueling active muscles. Maximal oxygen uptake capacity (VO2 max) is an important indicator of aerobic performance.

The mechanism is triggered by the fact that oxygen in the blood is transported more efficiently to the muscles, and the mitochondria in the muscle cells use it to produce energy through cellular respiration.

4. Locomotor system

Improving joint flexibility and mobility is the most important benefit, aerobic exercise such as running or cycling helps to maintain good joint mobility, preventing stiffness and loss of mobility, especially as we get older.

Aerobic exercise involves repetitive movements that can tone and strengthen muscles. Although strength exercises have a greater impact on muscle growth, aerobic activities help maintain muscle tone and reduce muscle loss (Sbenghe, 2008).

Aerobic activity promotes better oxygenation of tissues and accelerates the elimination of toxins from the muscles, which contributes to muscle recovery and reduces fatigue.

Maintaining bone density a considerable benefit that combats bone fragility. Moderate-impact exercise, such as walking or light jogging, stimulates the bone to maintain proper bone density, preventing conditions such as osteoporosis.

Aerobic training often involves movements that help develop coordination and balance, which reduces the risk of falls and injuries (Bernevig-Sava *et al.*, 2019).

By strengthening the muscles and improving joint mobility and flexibility, aerobic exercise can help prevent injuries related to overtraining or undertraining.

5. Physiological adaptations

Aerobic exercise performed seriously, with well-established workouts and techniques, leads to increased fitness levels and increased resistance to physical activity. These effects are achieved through multiple physiological adaptation processes both at rest and during exercise.

Physical exercise requires increased energy consumption, which locally adapts through an enhanced ATP-generating capacity achieved by an increase in the number and size of muscle cell mitochondria.

The metabolic adaptation to aerobic exercise is achieved by decreasing the consumption of muscle glycogen as an energy source. This glycogen-sparing process is possible after submaximal training by increasing the ability to mobilize and oxidize fat as an energy source.

Thus, glycogen is not only not consumed but also stored in the muscle. The muscle will quickly consume it during times of intense exertion.

Although the mechanism of production is not well determined, there is a decrease in blood lactate levels during exercise, a waste product of muscle activity under hypoxic conditions.

6. Digestive system

Aerobic exercise plays an extremely important role in improving intestinal motility. Aerobic exercise stimulates peristaltic movements of the intestines, leading to digestion that is more efficient. The gut microbiome can also be affected by blood sugar levels. One specialized study found that the diversity of the gut microbiome declines sharply before the onset of type 1 diabetes. Therefore, by exercising in aerobic effort, it controls and consumes glucose in the blood (Bilic, 2011).

Another study observed that even when people consume the same foods, blood sugar levels could vary greatly. This may be due to the types of bacteria in the gut. Aerobic exercise can help reduce inflammation in the digestive tract. Moderate aerobic exercise can reduce chronic inflammation in the body, including in the digestive tract. This can be beneficial for people with inflammatory digestive conditions such as Crohn's disease or irritable bowel syndrome.

Improved blood flow to the organs that produce digestion is another benefit of aerobic exercise. Exercise increases blood flow throughout the body, including the digestive organs. This can contribute to better functioning of organs involved in digestion, such as the stomach, liver and intestines (McGregor, 2017).

Regular aerobic exercise can help prevent digestive conditions such as gastro-esophageal reflux disease, chronic constipation and irritable bowel syndrome, as it helps regulate digestive tract functions.

Weight management and prevention of metabolic diseases as well as blood glucose control are aspects commonly considered when practicing aerobic exercise. Aerobic exercise helps to maintain a healthy body weight, which reduces the risk of developing digestive-related conditions such as hepatic steatosis (fatty liver) and type 2 diabetes.

The beneficial effects of aerobic exercise on the digestive system are optimized when exercise is performed regularly and in balance with a healthy diet.

7. Neuronal system

Aerobic exercise stimulates the formation of new connections between neurons and supports the brain's adaptation to new information and experiences. This is known as neuroplasticity, and plays a key role in learning, memory and recovery from brain injury.

Studies show that aerobic exercise can help to increase the volume of certain regions of the brain, particularly the hippocampus, which is essential for memory and learning. This may help prevent cognitive decline associated with ageing. Aerobic exercise supports the release of neurotrophic factors, which promote the survival and growth of neurons, thereby improving cognitive function and memory (Dănăilă, 2023).

Regular physical activity reduces cortisol (the stress hormone) levels and increases levels of endorphins and serotonin, neurotransmitters that induce a feeling of well-being and reduce stress and anxiety. This can improve mental health and prevent depression.

Aerobic exercise increases blood and oxygen flow to the brain, which contributes to cerebral vascular health. This can help prevent strokes and vascular dementia.

Improved sleep quality is significant following aerobic exercise. Regular aerobic physical activity is associated with deeper and more restful sleep, which is essential for neuronal regeneration processes and maintenance of good cognitive functioning.

Aerobic exercise has been linked to a reduced risk of neurodegenerative diseases such as Alzheimer and Parkinson's. These exercises help protect and maintain neuronal health by stimulating the release of neuroprotective substances.

8. Conclusions

After analyzing the benefits that aerobic exercise has on the whole body, we can only conclude that the practitioner of aerobic exercise, following a well-documented strong workout, possibly in consultation with a physiotherapist in special cases, will have the best responses for his body.

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ROLUL EXERCIȚIILOR FIZICE AEROBICE ASUPRA SĂNĂTĂȚII ORGANISMULUI UMAN

(Rezumat)

Sănătatea în muncă se referă la menținerea bunăstării fizice, mentale și sociale a angajaților în cadrul activităților profesionale. Este un domeniu care urmărește promovarea sănătății fizice și mentale prin asigurarea de condiții care sprijină bunăstarea angajaților, inclusiv spații de lucru ergonomice, pauze regulate și suport pentru sănătatea mentală. Exercițiile fizice aerobice au multiple beneficii asupra sistemelor organismului uman, atât pe termen scurt, cât și pe termen lung. Ele cresc eficiența inimii prin întărirea mușchiului cardiac, poate reduce tensiunea arterială, prevenind hipertensiunea, îmbunătățește fluxul sanguin prin dilatarea arterelor, crește eficiența aparatului respirator şi digestiv, are numeroase beneficii asupra sistemului locomotor, iar adaptările metabolice în urma efortului aerob conduc spre o stare de bine a practicanților de mișcare.

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STUDY OF WATER ABSORBTION AND WATER SENSITIVITY FOR BA16 ASPHALT CONCRETE OBTAINED USING MODIFIED BITUMEN WITH MR8 PLASTIC WASTE

BY

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Abstract. The use of non-recyclable plastic, considered waste, in the technology of obtaining asphalt concrete is an approach aimed at solving the general problem of long-term waste storage. The amount of plastic waste that can be used in the composition of asphalt is a very important issue if we consider that the desire to add as much of this waste as possible is limited by the need not to adversely affect the use properties of the new product obtained. The paper presents the results of the study of water absorption and water sensitivity of an asphalt concrete type BA16 produced by replacing in the recipe a quantity of bitumen with plastic waste type MR8.

Keywords: plastic recycling; bitumen replacement; water sensitivity, water absorbtion.

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1. Introduction

The motivations for using recycled plastic in asphalt concrete recipes are known to be as pragmatic as can be. For example in India some plastic waste can be used in road constructions (//rdso.indianrailways.gov.in/works/ uploads/ File/WKS-G-16.pdf) because there is a need to get rid of it.

Another example of approach is the reduction of the equivalent of CO_2 contained in a certain product. For asphalt concrete industry this can be done by replacing a quantity of bitumen in the recipe of the asphalt. This conduct can be considered by someone as a step forward for sustainability (Sustainable Asphalt Pavements, USA, 2019), even if the step size is tiny.

Some data offered by the producer, referring to a certain material obtained form plastic waste, namely MR8, show an economy of 4.65 kg of CO_2 equivalent per tonne of asphalt concret obtained using it in the recipe, in a fraction 3kg/tonne.

Following an observation of Brasileiro, who concluded "there are still uncertainties and gaps in the current knowledge about the use of the reclaimed polymer for asphalt modification" (Brasileiro *et al.*, 2019), we started a study about the asphalt concrete properties obtained using MR8 as a bitumen modifier (Filimon *et al.*, 2023).

The mentioned paper presented the results obtained for stability (S) and flowing index (F), using 8 different concentrations of MR8, product made by MacRebur.ltd, (https://macrebur.com/the-product - consulted 26th March 2023; https://macrebur.com/pdfs/product/MacReburProductSheet_v3.pdf) added in the asphalt concrete recipe.

This paper presents new results obtained using MR8 in the asphalt concrete recipe.

2. Materials

The asphalt obtaining methods were presented in short in a previous paper (Filimon *et al.*, 2023).

The goal of this new study is to determine two more properties of the asphalt concrete BA16 obtained using MR8 as bitumen modifier.

Taking into account its properties and also its limitations this asphalt is recommended by MacRebur for use for parkings and driveways (https://macrebur.com/pdfs/product/MacReburProductSheet_v3.pdf).

Samples for the control specimen were prepared according the specifications of a Moldavian standard for obtaining asphalt concrete, SM SR EN 12697-27 and the samples made using different quantities of MR8 for each test were prepared according SM SR EN 932-2 using a smaller mixer (Filimon *et al.*, 2023).

Because it can be modified using polymers bitumen type BR 50/70 was used. The modification using MR8 was achieved by inserting it in hot bitumen. The reclaimed polymer quantities used in this experiment were from 10% and 25%. The properties of asphalt mixtures obtained using modified bitumen were compared with those of an usual concrete asphalt BA16 made by the classic recipe using 5.7% bitumen BR 50/70 (Filimon *et al*., 2023).

The parameters controlled during the obtaining of the asphalt concrete using bitumen modified with MR8 were: the amount of polymer added into the bitumen, temperature of aggregates, mixing time, and rotation speed of the mixer shaft.

3. Experimental method

Water sensitivity determination

Because of the microstructure of asphalt concrete where the aggregates are partially covered and there are significant voids, water sensitivity is an important issue to consider in mix design and structural design. The experimental data in such conditions are very important and cylindrical specimens as in Fig. 1 are used for obtaining them.

Fig. 1 – Asphalt concrete samples using MR8 as bitumen modifier.

The cylindrical specimens are divided into two equal sets and each set is kept in a prescribed environment. The first set is kept in a dry environment. The second set is allowed to absorb water. Then, the relative tensile strength of both sets of specimens is determined in accordance with STN EN 12 697-23 at the stipulated test temperature. The ration of the indirect tensile strength (ITSR) of the set of specimens kept in water to the set of specimens kept dry is expressed in %.

Test and auxiliary equipment

The list of equipment used comprises:

- A vacuum pump (pump, vacuum indicator, etc.) that can be used to create a residual pressure in a desiccator of (6.7 ± 0.3) kPa in (10 ± 1) min and maintain vacuum for (30 ± 5) min.
- A weighing equipment, precision 0.001 kg.
- A thermostatically controlled water bath that can be used to maintain the ambient temperature of the specimens at (25 ± 2)°C. The bath must have a perforated bed at the top of the flanges at the bottom of the bath. The bath must be large enough for the top of the specimens to be 20 mm below the surface of the water.
- Equipment for tensile strength measuring according to STN EN 12697-23.
- A testing machine capable of exerting at least 28 kN of pressure and at the same time applying a load to the specimen at a constant speed of (50 ± 2) mm/min
- A test head with hard steel press jaws with a radius of curvature corresponding to specimens having a diameter of (100 ± 3) mm, jaw width of (12.7 ± 0.2) mm, jaw length of at least 75 mm.
- An indicator for measuring force with an accuracy of ± 0.2 KN.

Calculations and results

The tensile strength of wet and dry specimens can be calculated as follows:

$ITS = (2xP)/(\pi xDxL)$

where:

P - the maximum load force rounded to three decimal places in [kN],
D - diameter of the specimen, rounded to one decimal place, in [mm],
L - the height of the specimen, rounded to one decimal place, in [mm].

The tensile strength ratio ITSR is calculated as follows:

$ITSR = 100x(ITS_w/ITS_D)$

where:

- ITSR is the ration of tensile strengths in [%];
- ITS_W - the average tensile strength of wet specimens in [kPa];
- ITS_D - the average tensile strength of dry specimens in [kPa].

4. Results

Tests were performed on three types of samples O, I and II of asphalt concrete, using 0%, 10% and 25% MR8 as bitumen replacement.

Table 1 shows the tensile strength and tensile strength ratios.

Table 1

Tensile strength ITS, and ration of tensile strengths ITSR, values for water sensitivity according to SR SM EN 12697-12

Mixture	BA-16	BA-16
Used binder	Asphalt concrete 65/105-65, without polymer	Asphalt concrete 70/100, with polymer - sample I 10% and sample II 25%
ITS_D [kPa]	Sample – O - 840	*Sample I* – 938.8
ITS_W [kPa]	Sample – O - 664.3	*Sample I* – 810.2
ITS_D [kPa]	Sample – O - 407.5	*Sample II* – 485.4
ITS_W [kPa]	Sample – O - 330.3	*Sample II* – 402.9
ITSR [%]	Sample – O - 80	*Sample I* – 86
ITSR [%]	Sample – O - 81	*Sample II* – 83

Table 2 shows the results for water sensitivity in parallel with those obtained for water absorption for samples O, I and II.

Table 2

Asphalt concrete properties obtained using 0%, 10 % and 25 % content of MR8 in the bitumen as replacement

Characteristics on the Marshall cylinder	**MU**	**Obtained values**			**Admissible values CP D.02.25**
		O	**I**	**II**	
MR content in butimen quantity (5.7% bitumen)	%	0	10	25	
Water absorbtion in volume	%	1.5	1.61	1.9	1.5...5.0
Water sensitivity	mm	80	86	83	min. 80

5. Conclusions

For both sample 10% and 25% MR8 in the composition of the bitumen, the water sensitivity was acceptable exceeding the minimum value 80 obtained on the control sample.

Tests about freezing and de-freezing resistance must also be performed.

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STUDIUL ABSORBȚIEI DE APĂ ȘI A SENSIBILITĂȚII LA APĂ A BETONULUI ASFALTIC BA16 OBȚINUT FOLOSIND BITUM MODIFICAT CU DEȘEURI DE PLASTIC MR8

(Rezumat)

Utilizarea plasticului nerecliclabil, considerat deșeu, în tehnologia de obținere a betoanelor asfaltice este o abordare menită să rezolve problema generală a depozitării deșeurilor pe termen lung. Cantitatea de deșeuri de plastic care poate fi utilizată în compoziția asfaltului este o problemă foarte importantă dacă luăm în considerare faptul că dorința de a adăuga o cantitate cât mai mare din aceste deșeuri este limitată de necesitatea de a nu afecta negativ proprietățile de utilizare ale produsului nou obținut. Lucrarea prezintă rezultatele studiului absorbției apei și a sensibilității la apă a unui beton asfaltic tip BA16 produs prin înlocuirea în rețetă a unei cantități de bitum cu deșeu de plastic tip MR8.

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Secţia
ŞTIINŢA ŞI INGINERIA MATERIALELOR

MODEL DEVELOPMENT FOR MEASURING THE INFORMATION SYSTEM SUCCESS AND IMPLICITLY THE ORGANIZATIONAL SUSTAINABILITY WITH THE HELP OF ARTIFICIAL INTELLIGENCE

BY

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Abstract. Developing a model to measure the success of an information system (IS) and implicitly its impact on organizational sustainability using artificial intelligence (AI) requires a holistic approach. The model should combine technical, organizational, and environmental metrics, emphasizing how AI can enhance information systems' effectiveness and contribute to sustainability goals. By integrating AI into both the IS success model and sustainability frameworks, organizations can achieve real-time, data-driven insights into how well their information systems are performing and contributing to sustainability. This model would ensure that IS contributes positively to the organization's long-term sustainability goals, enhancing both operational efficiency and overall corporate responsibility.

Keywords: information system, organizational sustainability, artificial intelligence.

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1. Introduction

Creating a model to measure the success of an information system (IS) with an emphasis on organizational sustainability and leveraging artificial intelligence (AI) requires a structured approach that considers both performance metrics for the IS and sustainability indicators.

The research methodology corresponding to this article is rendered by excellence mainly by the qualitative method. Thus, the following work strategy was resorted to: using search engines, recent specialized works on the subject of this article were searched; after finding them, they were filtered according to the key terms included; the articles were analyzed, compared and filtered again in order to obtain the necessary data.

Artificial Intelligence (AI) can significantly enhance the development and implementation of models for measuring the success of Information Systems (IS) and, by extension, contribute to organizational sustainability. By leveraging AI technologies such as machine learning (ML), natural language processing (NLP), and data analytics, organizations can create more dynamic, adaptive, and accurate models that measure various dimensions of IS success, while also supporting long-term sustainability goals (Kohli and Devaraj, 2018; Müller and Sweeney, 2019; Kuo and Lee, 2020; Pantano and Priporas, 2020; Zhao and Zhang, 2021). Here's how AI can help.

Real-Time Monitoring and Predictive Analytics. AI can enable continuous monitoring of key performance indicators (KPIs) related to IS success. Machine learning algorithms can analyze large volumes of real-time data from IS usage, performance, and outcomes to predict potential issues and identify trends. AI can analyze system logs and user interactions to detect performance bottlenecks or user dissatisfaction before they escalate. By predicting when system failures or downtimes may occur, businesses can proactively address these issues, thus maintaining uninterrupted operations and enhancing organizational sustainability. AI can help organizations sustain their operations by ensuring that IS systems remain efficient and aligned with business goals, reducing downtime and enhancing productivity, which contributes to long-term operational sustainability (Pantano and Priporas, 2020).

Personalized User Experience and Optimization. AI can analyze user interactions and behavior to optimize the system's performance and tailor it to individual user needs. By understanding user preferences, AI can improve user satisfaction, one of the key components of IS success, by customizing the interface and functionality based on their actions and feedback (Müller and Sweeney, 2019). AI-driven recommender systems can personalize content delivery and workflows, ensuring that users can interact with the IS in a way that maximizes their productivity and satisfaction. A system that is personalized and efficient reduces wasted resources, increases user engagement, and encourages long-term adoption of the IS, which in turn helps ensure the IS's long-term success and supports sustainable business practices (Ives and Olson, 1984).

Sentiment Analysis and Feedback Processing. Using natural language processing (NLP), AI can analyze user feedback, support tickets, and social media comments to gauge user sentiment and identify areas for improvement. This sentiment analysis can be incorporated into the IS success model to provide a more accurate measure of user satisfaction. AI tools can analyze qualitative user feedback to detect patterns of dissatisfaction with system features or interfaces, offering insights that help organizations improve the system's quality and usability. By continuously improving the system based on user feedback, AI supports the long-term relevance and success of the IS, ensuring it meets the evolving needs of users and contributes to organizational sustainability (Müller and Sweeney, 2019).

Dynamic Key Performance Indicators (KPIs). AI can help in the dynamic creation and adjustment of KPIs that reflect not only the operational success of the IS but also the broader sustainability goals of the organization. AI models can correlate IS performance with financial, social, and environmental factors, allowing for the creation of sustainability-oriented KPIs. AI can correlate system use with energy consumption patterns or the impact of IS on supply chain efficiency, helping organizations track how well their information systems contribute to sustainability metrics, *exempli gratia* carbon footprint, resource efficiency). AI-driven KPI systems can measure and align the IS success with environmental, social, and economic sustainability goals, such as minimizing energy consumption, reducing waste, or enhancing ethical decision-making within the system (Zhao and Zhang, 2021).

Automated Decision Support. AI can enhance decision-making processes by providing organizations with automated, data-driven insights on how to improve both IS performance and organizational sustainability. This can include recommending system improvements, changes in user training programs, or adjustments in business processes that contribute to greater overall success. AI algorithms can analyze IS usage data, financial performance data, and sustainability-related metrics to provide actionable recommendations on optimizing the IS. For example, an AI system can recommend adjustments to reduce energy usage in cloud-based IS systems, based on the system's energy consumption patterns. AI supports sustainability by offering insights into how technology can be better aligned with sustainability goals, *exempli gratia* reducing environmental impact, optimizing resource allocation), contributing to the organization's long-term viability (Zhao and Zhang, 2021).

Improved Resource Allocation and Efficiency. AI can optimize resource allocation within an IS, such as balancing server loads or allocating computational resources based on usage patterns. These optimizations not only enhance the IS's performance but also contribute to more efficient use of organizational resources, which is key to sustainability. Machine learning algorithms can predict and adjust server resource demands, ensuring that systems use resources efficiently and without waste. Optimizing resource use reduces operational costs, minimizes environmental impact like energy consumption, and supports long-term organizational sustainability (Zhao and Zhang, 2021).

Automation of System Maintenance and Updates. AI can help automate system maintenance, such as bug detection, patch management, and system updates, which are critical for the long-term success of IS. Automation helps reduce the manual effort required to maintain the system, improving reliability and ensuring the system is continuously up to date. AI-based systems can automatically apply updates to software systems, fix security vulnerabilities, and deploy patches without human intervention, ensuring continuous operation with minimal downtime. AI-driven automation of system updates and maintenance ensures that the IS is always aligned with the latest standards, enhancing its longevity and reducing the cost and resource consumption of manual interventions (Zhao and Zhang, 2021).

Advanced Analytics for Strategic Decision Making. AI can perform complex analytics to understand the strategic impact of IS on organizational goals, sustainability efforts, and overall business performance. By analyzing historical and real-time data, AI can help organizations make better-informed decisions about IS investments and improvements. AI models can predict the ROI (Return on Investment) of an IS upgrade by analyzing past performance data, user behavior, and financial outcomes. This helps organizations allocate resources more effectively. AI's ability to predict outcomes and optimize investments helps organizations achieve their sustainability goals by prioritizing initiatives with the most significant long-term impact, such as energy-efficient systems or sustainable software development practices (Pantano and Priporas, 2020).

Continuous Learning and Adaptation. AI can support the development of a continuously improving IS. As the system interacts with users and gathers data, machine learning models can adapt to new user needs and business environments, making the system more effective over time. An AI system can learn from user behavior and continuously optimize processes, interfaces, and functionalities, ensuring the system evolves in alignment with user needs and business goals. By ensuring that the IS evolves and adapts, AI promotes the sustainability of the IS by ensuring its relevance and efficiency in the long run, which, in turn, supports the organization's broader sustainability objectives.

AI would be a Key Enabler for IS Success and Organizational Sustainability. By incorporating AI into models for measuring IS success, organizations can achieve more accurate, real-time, and comprehensive insights into the performance of their systems. These AI-enhanced models can dynamically adjust to changes in both system usage and broader organizational goals, ensuring that IS continuously contributes to both operational efficiency and sustainability. Through optimization, predictive analytics, automated decision-making, and resource efficiency, AI not only drives IS success but also plays a critical role in advancing organizational sustainability (Pantano and Priporas, 2020).

2. Proposed Model

Several key authors and researchers have made significant contributions to the development of models for measuring the success of Information Systems (IS). These models are often rooted in various perspectives, from technical and operational measures to user satisfaction and organizational impacts. Below are the most influential authors and their contributions.

Davis' Technology Acceptance Model focuses on the factors that influence user adoption and acceptance of technology. The key constructs are: Perceived Ease of Use - the degree to which a person believes that using a particular system would be free of effort; Perceived Usefulness - the degree to which a person believes that using a particular system would enhance job performance. TAM helped bridge the gap between user acceptance and IS success, stressing that user perceptions of ease of use and usefulness directly affect the adoption and continued use of the IS. By improving user adoption and minimizing resistance, TAM emphasizes long-term system viability and organizational sustainability (Davis, 1989).

DeLone and McLean are perhaps the most prominent researchers in the field of IS success measurement. Their original model (1992) and its subsequent revision (2003) have been widely adopted. The model identifies six interrelated dimensions of IS success: System Quality - refers to the technical performance and reliability of the IS; Information Quality - the quality of the information generated by the system, including accuracy, timeliness, and relevance; Service Quality - the support provided to users and the quality of IT service; Use - the degree to which users interact with the system; User Satisfaction - the satisfaction of users with the system; Net Benefits - the outcomes or benefits realized by individuals, groups, or organizations from using the IS (DeLone and McLean, 2003). They introduced the concept of "net benefits" as an overarching measure of success and stressed the interdependence of the dimensions, with user satisfaction being a critical link between system usage and net benefits. DeLone and McLean's model remains one of the most cited frameworks for measuring IS success, offering a comprehensive and widely accepted view that links various dimensions to tangible benefits (DeLone and McLean, 1992).

Kaplan and Norton’s Balanced Scorecard is a strategic management framework that includes four perspectives for measuring organizational performance: Financial - how well the IS contributes to financial outcomes; Customer - how well the IS meets the needs of customers or users; Internal Processes - how well the IS supports internal operations and efficiency; Learning and Growth - how well the IS supports organizational learning, employee skills, and innovation. The BSC integrates performance measures across different dimensions and shows how IS success can be linked to broader organizational goals, making it a holistic way to assess the impact of IS on organizational sustainability (Kaplan and Norton, 1992).

Seddon built upon the DeLone and McLean model and proposed a more comprehensive view that includes individual and organizational impacts as direct outcomes of IS usage: System Quality - technical reliability, Information Quality - usefulness and accuracy, Individual Impact - effects on individual performance, Organizational Impact - effects on organizational performance, User Satisfaction - a direct measure of user contentment with the system. Seddon emphasized user satisfaction and organizational impact as crucial metrics for determining IS success (Seddon, 1997).

Lederer and Sethi focused on identifying the Critical Success Factors (CSFs) that drive IS success like Top management support, User involvement, Clear objectives, Adequate resources as funding, skills. The CSF model emphasizes that effective leadership and resource allocation are critical to ensuring the long-term sustainability and success of IS (Lederer and Sethi, 1998).

DeLone's work in 1999 emphasized the multi-dimensional nature of IS success. In addition to expanding on his work with McLean, he introduced the "user satisfaction" dimension more clearly and described it as one of the key indicators of IS success. His approach linked user satisfaction with the realization of long-term benefits, directly contributing to sustained IS success.

Bhattacherjee proposed an extension to the Technology Acceptance Model (TAM) by adding post-acceptance behaviors such as system continuance as continued usage over time and satisfaction. His research emphasized how users' initial acceptance of IS is linked to continued usage, which is a critical measure of long-term IS success. Bhattacherjee's work further stressed that long-term IS success is not only about initial adoption but also sustained usage, a critical aspect for organizational sustainability (Bhattacherjee, 2001).

The UTAUT model consolidates eight models of technology acceptance into a unified framework that identifies four key determinants of IS success: Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions. This model expands on TAM by considering social influence and facilitating conditions, helping organizations understand the broader social and environmental factors that influence system success and user acceptance (Venkatesh *et al.*, 2003).

Chin and Torkzadeh's model builds on the DeLone and McLean framework by integrating multiple constructs and perspectives on IS success, offering a more detailed analysis (Torkzadeh and Doll, 1999). Their work refined IS success measurement, offering a more dynamic, iterative framework for assessing success and the relationship between user satisfaction, system use, and net benefits (Chin and Torkzadeh, 2007).

These authors have shaped the field of IS success measurement by proposing models that encompass technical, user-centered, organizational, and strategic dimensions. Collectively, their work provides a comprehensive framework for understanding IS success, helping organizations align their technology with business objectives, user needs, and long-term sustainability goals. The models from DeLone and McLean, Davis (TAM), Seddon, and Kaplan and Norton (BSC) are especially influential in integrating user satisfaction, system performance, and organizational impact into comprehensive success assessments.

These references cover a wide range of perspectives on measuring IS success, from technical performance to user satisfaction and organizational impact. The works of DeLone and McLean (1992, 2003), Davis (1989), Seddon (1997), and Kaplan and Norton (1992) are foundational in defining and refining the dimensions of IS success. Other authors like Venkatesh et al. (2003), Chin and Torkzadeh (2007), and Bhattacherjee (2001) have further developed models that incorporate user acceptance, continuance behavior, and critical success factors, which are all important for understanding the long-term sustainability of IS in organizations.

The integration of Artificial Intelligence (AI) in developing models to measure the success of Information Systems (IS) is a relatively newer area of research, but it is growing in importance as organizations seek to leverage AI for real-time analytics, predictive insights, and dynamic system performance evaluations (Kohli and Devaraj, 2018; Müller and Sweeney, 2019; Kuo and Lee, 2020; Pantano and Priporas, 2020; Zhao and Zhang, 2021). Below are key references on this emerging intersection, combining traditional models of IS success with AI methodologies for improving success measurement.

While not specifically about AI, this foundational work provides the basis for much of the research on IS success. The model can be adapted using AI techniques such as machine learning to dynamically assess system quality, user satisfaction, and net benefits in real time (DeLone and McLean, 2003).

This research compares traditional IS success evaluation frameworks with AI-driven models, proposing that AI can enhance the assessment of user engagement, transaction success, and service quality in e-commerce settings (Jiang and Klein, 2012).

Agarwal and Dhar explore the role of AI in augmenting traditional IS success measures by incorporating intelligent, context-aware components. The paper presents a model where AI helps in both predicting and enhancing the outcomes of IS through adaptive learning algorithms (Agarwal and Dhar, 2014).

Kohli and Devaraj explore the integration of AI into IS performance evaluation. Their work discusses how AI technologies such as machine learning and natural language processing (NLP) can analyze complex user feedback and operational data to improve IS success models (Kohli and Devaraj, 2018).

This paper discusses how AI-based sentiment analysis and NLP techniques can be applied to measure user satisfaction and feedback in real-time, which is a key component of IS success, especially for systems that involve large user bases (Müller and Sweeney, 2019).

This study proposes using machine learning (ML) algorithms to evaluate IS success by integrating real-time system performance data and user feedback to dynamically assess system quality and user satisfaction. It highlights how AI can make the evaluation of IS success more adaptive and immediate (Jabbar and Nguyen, 2020).

This paper proposes a conceptual framework that combines AI and big data analytics for evaluating IS success. The authors argue that AI can provide deeper insights into user behavior and system performance, thereby offering more accurate success metrics (Pantano and Priporas, 2020).

This research compares traditional methods of IS success measurement with AI-enhanced models, focusing on how predictive analytics can anticipate system failures or user dissatisfaction and thereby provide earlier intervention strategies to improve IS performance (Kuo and Lee, 2020).

This paper highlights how predictive modeling and machine learning can improve the accuracy of IS success metrics by analyzing real-time data. It shows how AI can optimize the use of system logs, user interactions, and feedback loops to dynamically measure and improve IS outcomes (Li and Yang, 2020).

This paper integrates AI-based techniques, particularly data mining and predictive analytics, into IS success measurement. It discusses how AI tools can analyze massive amounts of operational and user interaction data to measure the success of systems in real time (Zhao and Zhang, 2021).

These references reflect the growing interest in using AI to improve the measurement of IS success. Many of the studies focus on integrating machine learning, predictive analytics, natural language processing (NLP), and real-time data analytics into existing IS success frameworks like the DeLone and McLean Model and TAM. These AI-enhanced models aim to provide more dynamic, adaptive, and accurate assessments of IS performance, improving the understanding of user satisfaction, system quality, and net benefits in organizations (Müller and Sweeney, 2019).

Creating a model to measure information system (IS) success and indirectly assess organizational sustainability with AI involves a multi-dimensional approach. Below is an outline of how this can be structured.

Conceptual Framework. The foundation of the model will include two key elements: Information System Success (IS Success) - how well the IS performs in terms of functionality, usability, and alignment with business goals and Organizational Sustainability - how the IS contributes to the environmental, economic, and social sustainability goals of the organization.

Theoretical Models to Draw From. A hybrid model combining elements of two well-established frameworks can serve as a starting point: firstly, Delone and McLean IS Success Model - it evaluates IS success based on system quality, information quality, service quality, user satisfaction, and net benefits (DeLone and McLean, 1992) and secondly, Triple Bottom Line (TBL) Framework - it assesses organizational sustainability based on three pillars: economic (profit), environmental (planet), and social (people).

Proposed Model for AI-Enhanced IS Success and Organizational Sustainability. The model, as seen in Fig. 1 bellow, integrates AI-driven indicators with traditional IS success and sustainability metrics. For the Success of the Information System we would have the following: System Quality - measured by AI-driven performance monitoring (uptime, error rate, response time); Information Quality - improved through AI for data validation, accuracy, and real-time updates; Service Quality - enhanced through AI-driven customer support and service automation; Usage Metrics - tracked using AI analytics to understand user behavior and engagement; User Satisfaction - analyzed using AI for sentiment analysis, feedback collection (Müller and Sweeney, 2019); Net Benefits - improved business outcomes, productivity gains, and cost savings driven by AI. For the Organizational Sustainability: Economic Impact - measured by AI-driven cost reductions, revenue generation, and profitability; Environmental Impact - tracked through AI for resource optimization and carbon footprint analysis; Social Impact - assessed using AI for employee engagement, social initiatives, and inclusivity metrics.

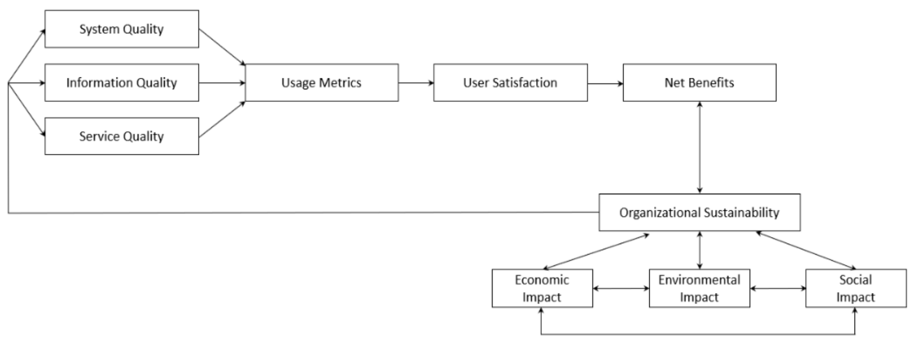

Fig. 1 – Proposed Model for AI-Enhanced IS Success and Organizational Sustainability.

AI-Enhanced Success Metrics. To measure IS success and organizational sustainability, AI can enhance both measurement and analysis in the following areas: IS Success Metrics and Organizational Sustainability Metrics. As for IS Success Metrics we have the following. For System Quality an AI Application would do: predictive maintenance, error detection, and automatic performance tuning. The Metrics obtained would be: AI-based fault prediction accuracy, downtime reduction, user interface (UI) enhancements. For Information Quality an AI Application would do: Natural Language Processing (NLP) for better data mining, AI-based recommendations, and semantic analysis for data accuracy. The Metrics obtained would be: data accuracy, completeness, timeliness *exempli* *gratia* reduced data latency through AI, and AI-assisted data insights. For Service Quality an AI Application would do: chatbots for IT support, AI-driven helpdesks, predictive service issue resolution. The Metrics obtained would be: user satisfaction with AI support systems, ticket resolution time improvement through AI tools. For Use an AI Application would do: user behavior analytics, AI-driven personalization, recommendation systems. The Metrics obtained would be: user engagement, system utilization, feature adoption rates. For User Satisfaction an AI Application would do: AI-based feedback collection, sentiment analysis. The Metrics obtained would be: AI-analyzed user satisfaction scores, improvement in NPS (Net Promoter Score) due to AI-driven features. For Net Benefits an AI Application would do: predictive analytics for decision-making, process automation, and efficiency improvements. The Metrics obtained would be: productivity increase, cost savings due to AI automation, improved decision-making quality using AI insights (Müller and Sweeney, 2019; Pantano and Priporas, 2020; Zhao and Zhang, 2021). As for Organizational Sustainability Metrics we have the following. For Economic Sustainability (Profit) an AI Application would do: predictive models for financial forecasting, cost optimization, and demand forecasting. The Metrics obtained would be: cost savings, increased revenue, ROI on AI investments. For Environmental Sustainability (Planet) an AI Application would do: AI-driven energy management, carbon footprint analysis, and resource optimization. The Metrics obtained would be: reduced energy consumption through AI, reduction in waste, lower carbon emissions. For Social Sustainability (People), an AI Application would do: AI-powered employee engagement tools, diversity and inclusion analysis, and AI-driven social responsibility initiatives. The Metrics obtained would be: employee engagement levels, diversity improvement, AI-driven community or social project impact (Müller and Sweeney, 2019; Pantano and Priporas, 2020; Zhao and Zhang, 2021).

AI-Driven Data Collection and Analysis. AI tools can be used to gather and analyze data in real-time, providing deeper insights into system performance and sustainability impacts. AI-driven sensors, IoT, and big data analytics can track system performance, energy usage, user interactions, and other sustainability-related factors. AI Techniques as Machine Learning (ML) - it can predict future system performance and sustainability trends based on historical data; Deep Learning - it can be used for more complex analyses, like image recognition in environmental monitoring or customer sentiment analysis. Natural Language Processing (NLP) - it can analyze user feedback, support tickets, and social media data for assessing satisfaction and social impacts (Pantano and Priporas, 2020).

AI-Powered Continuous Improvement. AI systems can not only provide real-time measurements but also suggest improvements for both IS success and sustainability as AI Feedback Loop - continual system learning from user interactions and operational data to suggest improvements for performance and sustainability.

Potential AI Tools and Techniques could be considered, such as: Predictive Analytics - to foresee future trends and impacts on organizational sustainability; Reinforcement Learning - to optimize system operations and decision-making over time; Natural Language Processing (NLP) - to analyze qualitative feedback and assess social sustainability metrics.

3. Conclusion

Measuring the success of an information system (IS) and its contribution to organizational sustainability, especially when leveraging artificial intelligence (AI), involves a multi-dimensional approach. The goal is to assess how well the IS supports the organization's objectives, enhances sustainability, and creates long-term value.

Measuring the success of an information system (IS) is a complex process, as it encompasses various dimensions such as performance, user satisfaction, and business impact. Several models have been developed to evaluate the effectiveness of IS. Below is an integrated approach combining the key models for measuring IS success (Prasad and Ramamurthy, 2001).

DeLone and McLean IS Success Model (2003). The DeLone and McLean model identifies six interrelated dimensions of IS success: System Quality - the technical performance and reliability of the system; Information Quality - the relevance, accuracy, and timeliness of the information provided by the system; Service Quality - the support provided by the IT team and the service aspects associated with the system; Use - the extent to which the system is used by its intended audience; User Satisfaction - the users' overall satisfaction with the system; Net Benefits - the positive outcomes resulting from the use of the system, such as increased productivity or improved decision-making (DeLone, and McLean, 2003).

Technology Acceptance Model (TAM). The Technology Acceptance Model, developed by Davis (1989), focuses on user acceptance and adoption of technology. It suggests two key factors: Perceived Ease of Use - the degree to which a user believes that using the system will be free from effort and Perceived Usefulness - the degree to which a user believes the system will enhance job performance. These factors influence the user's intention to use the system and, ultimately, the system's success (Davis, 1989).

Balanced Scorecard (BSC). The Balanced Scorecard (Kaplan and Norton, 1992) emphasizes a broader view of organizational performance, incorporating four perspectives: Financial Perspective - assessing how the IS contributes to the organization's bottom line *exempli gratia* cost savings, revenue generation; Customer Perspective - evaluating the value the IS brings to customers *exempli gratia* customer satisfaction, retention; Internal Processes - analyzing the system's efficiency in supporting business operations *exempli gratia* process improvements, operational efficiencies; Learning and Growth - evaluating the system's impact on the organization's ability to innovate and improve over time *exempli gratia* employee skills, knowledge development (Kaplan and Norton, 1992).

Information System Success Model (ISS). Seddon proposed a revised IS success model with a focus on the following dimensions: System Quality - technical aspects of the system; Information Quality - the usefulness and correctness of the information generated; Individual Impact - the effect the system has on the individual user's performance; Organizational Impact - the broader organizational effects, including productivity and profitability. This model highlights the dual focus on both individual and organizational impacts of IS use (Seddon, 1997).

End-User Computing Satisfaction (EUCS) Model. The EUCS model focuses specifically on the satisfaction of end-users with the system. Key components include: Content - the quality of the system's output and data; Accuracy - the correctness of the information; Format - the usability of the interface and presentation of data; Ease of Use - how user-friendly the system is; Timeliness - the speed at which the system delivers information. The overall user satisfaction is considered a strong indicator of IS success (Müller and Sweeney, 2019).

Critical Success Factors (CSF) Model. This model identifies the key areas where successful performance is essential for achieving the desired outcomes with an IS. Factors may include: Executive Support - strong leadership and strategic alignment with organizational goals; User Involvement - active participation from end-users in the development and implementation of the system (Ives and Olson, 1984); Quality Assurance - ensuring high standards in system development and performance; Training and Support - adequate resources for training users and providing ongoing support. The CSF model helps to ensure that the right factors are in place for IS success.

Combining elements from the above models, a comprehensive framework for measuring IS success could look as follows: System Quality from DeLone and McLean, Seddon to assess technical performance, reliability, and ease of use; Information Quality from DeLone and McLean, EUCS to evaluate accuracy, relevance, and timeliness of data; User Satisfaction and Acceptance from DeLone and McLean, TAM, EUCS to measure perceived ease of use, perceived usefulness, and overall user satisfaction; Service Quality from DeLone and McLean to assess the quality of technical support, training, and maintenance services (DeLone and McLean, 1992); Organizational Impact from Seddon, BSC to evaluate the effects on productivity, decision-making, and business performance; Individual Impact from Seddon to assess the effects on individual user performance, satisfaction, and productivity (Seddon, 1997); Net Benefits from DeLone and McLean to measure the overall value generated by the system for both individuals and organizations *exempli gratia* cost savings, revenue, efficiency gains (DeLone and McLean, 2003); Critical Success Factors from CSF to identify key success factors, such as executive support, user involvement, and quality assurance; Financial Impact from BSC to evaluate how the IS contributes to financial outcomes, like profitability or cost reduction. The main key outcomes would be the following: User-Centric Success - high user satisfaction, acceptance, and ease of use; Performance Impact - increased efficiency, productivity, and decision-making quality; Strategic Alignment - successful contribution to organizational goals and growth; Sustained Value - tangible and intangible benefits, including financial, customer, and process improvements.

This integrated model allows for a multi-faceted approach to evaluating IS success, combining technical, organizational, and user-centered dimensions for a comprehensive assessment.

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DEZVOLTAREA UNUI MODEL DE MĂSURARE A SUCCESULUI SISTEMULUI INFORMAȚIONAL ȘI IMPLICIT A SUSTENABILITĂȚII ORGANIZAȚIONALE CU AJUTORUL INTELIGENȚEI ARTIFICIALE

(Rezumat)

Dezvoltarea unui model care să măsoare succesul unui sistem informațional (SI) şi implicit impactul acestuia asupra sustenabilității organizaționale folosind inteligența artificială (IA) necesită o abordare holistică. Modelul ar trebui să combine valorile tehnice, organizaționale și de mediu, subliniind modul în care IA poate spori eficiența sistemelor informaționale și poate contribui la obiectivele de durabilitate. Prin integrarea inteligenței artificiale atât în modelul de succes, cât și în cadrele de sustenabilitate, organizațiile pot obține informații în timp real, bazate pe date, asupra cât de bine funcționează sistemele lor de informații și contribuie la sustenabilitate. Acest model ar asigura că SI contribuie pozitiv la obiectivele de sustenabilitate pe termen lung ale organizației, sporind atât eficiența operațională, cât și responsabilitatea corporativă generală.

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THE IMPORTANCE OF EXERCISE IN THE PREVENTION OF OCCUPATIONAL DISEASES

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Abstract. Prevention through movement and exercise of work-related disorders is essential, especially in the context of a sedentary lifestyle that characterizes many modern workplaces. Physical activity helps to reduce the risks associated with various conditions such as back pain, cardiovascular diseases or musculoskeletal disorders.

Keywords: work, security, prevention, health.

1. Introduction

Occupational safety and health is a set of institutionalized activities aimed at ensuring the best possible conditions in the work process, protecting the life, physical and mental integrity and health of workers and other persons involved in the work process (Bernevig-Sava *et al.*, 2019).

There is a wide range of work-related illnesses that occur depending on the working environment, namely: environments with pollutants, environments with physical overload, environments in which those involved work from a sitting

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position for long periods of time, jobs requiring repetitive movements, environments with influences on the auditory, ocular, neuronal apparatus, etc.

As far as musculoskeletal diseases are concerned, these occupational diseases can occur as a result of weight handling, repetitive movements, microtrauma, extreme positions, overstraining, vibration (https://www.inspectiamuncii.ro/documents/).

Among the most common occupational diseases are: bursitis, epicondylitis, synovitis, tendinitis, tendonitis, tenosynovitis, meniscus lesions, arthrosis, spinal deformities, disc herniations, herniated discs and even bone fractures.

2. Spinal disorders

Kyphosis, as an occupational disease, can occur mainly due to prolonged incorrect positioning of the spine during work activities. This condition is characterized by excessive curvature of the spine in the thoracic area, resulting in a rounded back.

Common work-related causes can be incorrect posture, working at a desk in fixed and incorrect positions, activities involving constant bending, such as in construction, sewing, or assembly. Lifting weights without following spinal protection rules, repetitive motions that overload the back muscles.

Solutions for prevention would be to adopt a correct posture during work. Using ergonomic furniture and adjusting it to each person's needs. Regular breaks for movement and stretching exercises. Exercise to tone back muscles and improve posture.

Scoliosis, as an occupational disease, can occur due to factors related to work activities that cause the spine to deform into an abnormal curve (S- or C-shaped). Although scoliosis is frequently associated with genetic or developmental causes, certain working conditions may promote or aggravate the condition, particularly in people with long-term exposure to specific risk factors. Occupational causes that may contribute to the onset or aggravation of scoliosis may be asymmetrical working positions, work involving an incorrect or stooped trunk position for long periods (e.g. construction, carpentry, tailoring). Work performed on one side of the body (such as frequent lifting of heavy objects on one shoulder or excessive use of one arm). Uneven physical exertion by lifting and handling weights that are not evenly distributed.

Prevention of occupational scoliosis can be achieved by adjusting the working position and furniture to support a symmetrical and correct posture (Paraschiv and Paraschiv, 2021).

Using equipment that reduces physical strain. Alternating work tasks and even distribution of the weight handled. Implementation of aids for lifting heavy objects:

– Promote an exercise program that supports back and trunk muscles;

- Encourage active breaks to reduce muscle tension;
- Programs by physical therapists on correct posture,
- Awareness exercises on correct lifting and positioning techniques.

3. Herniated disk

Disc herniation can be recognized as an occupational disease in certain circumstances, especially when there is a direct link between working conditions and the development or worsening of the condition. It occurs when one of the intervertebral discs (which act as a shock absorber between the vertebrae) deteriorates and its gelatinous nucleus protrudes, compressing the spinal nerves (Sbenghe, 1987).

Herniated disc as an occupational disease is associated with activities involving: strenuous or repetitive physical exertion; frequent lifting and carrying of heavy weights, especially if the techniques used are incorrect; repetitive handling of objects that put strain on the back, without sufficient breaks.

Static or incorrect postures also working in prolonged bending or twisting positions of the trunk. Prolonged sitting in uncomfortable chairs without adequate lumbar support (such as bus, truck or taxi drivers).

4. Bursitis

Bursitis is an inflammatory condition of the bursae, small fluid-filled sacs that reduce friction between tissues (bones, muscles, tendons). In the context of occupational diseases, bursitis is common in people who overuse their joints repetitively or maintain awkward positions for long periods of time (https://mcmedexpert.ro/boli-profesionale-prin-suprasolicitarea-aparatului-locomotor).

Common causes of bursitis are repetitive motions such as repetitive motions by twisting or pushing heavy objects, typing intensively or using manual equipment. Prolonged pressure on joints such as construction workers sitting on their knees or agricultural workers constantly resting their elbows on hard surfaces. Repeated minor trauma through repeated jarring, vibration or repeated small bumps.

The most commonly affected areas are the shoulder (subacromial bursitis), elbow (olecranon bursitis), knees and hip.

One measure to prevent bursitis in the work environment is the effectiveness of adjusting work equipment to reduce stress on the joints (e.g. adjustable desks, ergonomic chairs). Periodically changing working position to avoid constant pressure on certain areas. Knee supports for those who work a lot on their knees (e.g. plumbers, gardeners).

Taking regular breaks to relax joints and avoid prolonged repetitive movements, breaking up activities that overload the same joints to alternate movements.

Preventive exercises include muscle strengthening exercises, stretching exercises and strengthening the muscles around the joints, as well as exercises that improve flexibility and reduce the risk of overuse.

Preventing bursitis as an occupational disease relies on adopting healthy practices in the work environment, adjusting equipment and promoting active breaks. Through a combination of ergonomic and educational measures, the risk of this condition can be considerably reduced (Bejinariu *et al.*, 2017).

5. Arthrosis

Arthrosis is a chronic degenerative joint disease characterized by wear and tear of the articular cartilage, changes in the subchondral bones and local inflammation. In an occupational context, arthrosis may occur more frequently in people exposed to occupational risk factors such as repetitive movements, incorrect posture or excessive strain on joints (Manu, 1983).

Occupational causes of arthrosis:

- Strenuous physical work with activities involving heavy lifting, jumping or repetitive movements;
- Standing for long periods, also frequent use of certain joints: For example, drivers who drive long hours may develop knee or hip arthrosis;
- Constant use of vibrating tools (e.g. chainsaws, pneumatic hammers) affects hand joints;
- Repeated trauma in activities that increase the risk of joint injuries (e.g. athletes, construction workers).

Joints frequently affected in a professional context are:

- knee (gonarthrosis);
- hip (coxarthrosis);
- spine (spondyloarthrosis);
- hands (particularly in jobs involving repetitive manual work).

Arthrosis prevention in the work environment:

- Adjust work equipment to reduce strain on joints (ergonomic chairs, adjustable desks);
- Introduce active breaks to relax joints and prevent stiffness;
- Avoid continuous stress on the same joints by diversifying tasks;
- Learning proper lifting and carrying techniques;
- Reducing sudden movements or overuse of joints;
- Regular physical activity as well as performing exercises to strengthen the muscles that support the joints;
- Stretching exercises to maintain flexibility and mobility;

– Managing body weight.

Obesity increases pressure on joints, especially the knees and hips. Maintaining an optimal weight reduces the risk of arthrosis. Use anti-vibration equipment and take regular breaks to prevent damage to hand joints (Sbenghe, 2008).

Wearing protective equipment, such as kneepads or elbow pads, for workers who work in awkward or repetitive positions.

Informing workers about the benefits of an active lifestyle and preventive measures.

Preventing arthrosis as an occupational disease requires a multidisciplinary approach, including ergonomic improvements, employee education and adoption of a healthy lifestyle. By reducing risk factors and promoting joint health, the progression of this condition can be prevented or slowed down.

6. Conclusions

There are many more disorders that occur in professional environments, in this paper we describe a small part of them. In the case of work environments, where the diseases that occur in particular in the locomotor system, collaboration with specialists in the field of medicine and physiotherapy, the development of special programs that include physical exercises, the use of protective equipment, and last but not least the awareness of employees that over time certain diseases can develop.

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IMPORTANȚA EXERCIȚIILOR FIZICE ÎN PREVENIREA BOLILOR PROFESIONALE

(Rezumat)

Prevenirea prin mişcare și exerciții fizice a afecțiunilor asociate locului de muncă este esențială, în special în contextul unui stil de viață sedentar care caracterizează multe locuri de muncă moderne. Activitatea fizică contribuie la reducerea riscurilor asociate cu diverse afecțiuni, cum ar fi durerile de spate, bolile cardiovasculare sau tulburările musculo-scheletice.