Magnesium and It's Applications in the Field of Engineering – A Review

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Abstract. Magnesium is emerging as a most suitable biomaterial thanks to its unique ability to blend naturally with the human body. Magnesium is not only biocompatible but also safely biodegradable, in contrast to conventional materials, meaning it can gradually dissolve in the body without releasing harmful by-products. This makes it an exciting option for medical applications. When the proper alloying elements and process settings are used, magnesium alloys have appropriate mechanical qualities and a moderate rate of corrosion, which makes them interesting. It was additionally noted that the synthesis methods and component choices have an impact on the characteristics and performance of the magnesium-based biomaterials. Numerous magnesium based materials have been created by researchers using a variety of methods, and they have examined their mechanical characteristics, biocompatibility, and degrading behavior using in silico, in vitro, and in vivo testing. This paper is focused on different applications of magnesium based alloys and composites in the realm of biomedical as well as engineering applications.

Keywords: Magnesium, Alloys, Composites, Biomaterials, Biomedical, Corrosion, Mechanical Testing, Durability, Orthopedic Implants, Biodegradabili.

1 Introduction

It is generally accepted that biomaterials fall into four groups. These include composites, metals, ceramics, and polymers. Among these, ceramics are regarded as the best option for coating because of their osteo conductivity, high biocompatibility, and non-toxicity. They are not appropriate for load-bearing circumstances, nevertheless, because to their mechanical characteristics and high rates of corrosion in acidic environments.

Polymeric biomaterials are easily molded into complicated shapes and have easily adjustable surface characteristics. Furthermore, polymers can have their mechanical and chemical characteristics somewhat altered. However, the use of polymers is limited. This is due to the inadequate mechanical qualities. Furthermore, the living tissue may be harmed by certain dangerous substances such plasticizers, stabilizers, and antioxidants that are used in the production of polymers.

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Metallic biomaterials are therefore typically chosen for applications requiring great load bearing capacities and long term durability due to their exceptional ductility and high strength, which result in strong fracture resistance.

Coming to its history, it was until Joseph Black in the year 1754 who recognized it as an element, magnesium was considered as a compound. It was Antonie Alexander Bussy who developed the first pure magnesium, despite the fact that Humphry Davy made the initial discovery of it in 1808. Early on, battles and military uses spurred its development. Magnesium, for instance, was used as a weapon to make explosives, flash bangs, flares, and rounds. Magnesium interacts exothermically with oxygen, nitrogen, and water, making it nearly impossible to put out once it begins to burn. But since magnesium metal in mass is difficult to ignite, a thermite reaction was the central component of every bomb. More than enough heat is released by the thermite reaction between iron oxide and aluminium powder to ignite the magnesium case of the bomb. Because the metal burns brightly, it was also utilized in photographic flash bulbs.

As the lightest engineering metal, magnesium also possesses a low density (around 1.74 g/cm^3), a good strength to weight ratio, and better ductility and castability than steel and aluminum when it is pure. It has good thermal and electrical conductivity as well, along with vibration damping, shock absorption capabilities. It may be fashioned using any known technique and has good machinability. However, it is susceptible to corrosion under two scenarios. When magnesium-based alloys are subjected to strong electrolytes or contain metallic impurities. Nevertheless, to overcome this coating techniques have come into picture. For structural and technical purposes, pure magnesium is not the best option. To customize its qualities, it needs to be alloyedso that its primary characteristics are unaffected while its weaker qualities are strengthened and meet the requirements as per the specific application as well.

2 Mg based Alloys in different Engineering Fields

2.1 As a Bio Material

Magnesium is often alloyed to unlock its potential, making it an exciting material for various applications. Selecting the appropriate alloying elements is crucial since they have a big impact on magnesium alloys' strength, corrosion resistance, and biosafety [1]. These components can be carefully chosen to improve the alloy's mechanical characteristics and degradation rate [2,3,4]. Common additions like zinc, calcium, zirconium, manganese, silicon, and rare earth elements play a cucial role in increasing not only magnesium alloys' mechanical properties and resistance to corrosion, but also their biocompatibility, which makes them extremely adaptable to the needs of[5,6]

Orthopedic implants. Current practice of autografting is actually used in the repair of bone because it stimulates actual new bone formation. The downside, however is the possibility of a definite lack of donors and the process calls for two surgeries when the implant needs to be removed after the bone is completely healed and recovered[7]. Ideally, the synthetic bone substitute should possess five essential qualities: proper mechanical strength and desirable bioactivity, interconnected porosity, biocompatibility, and biodegradability[8]. As traditional bioinert metallic implants often require multiple surgeries and pose risks such as stress shielding, the medical community has come to seek implant materials that are both biocompatible and biodegradable but as close to nature as human bone[9].

Biodegradable polymers are the candidates among the new emerging material that are studied for compatibility with the body[9]. Their applications are limited due to reduced mechanical strength and brittleness against metal implants; they can produce a longstanding inflammatory response in tissues around, which can retard bone regeneration[10]. On the other hand, magnesium based bio-materials have gained a great interest owing to its superior mechanical properties toward bone fracture repair[11].

Magnesium based implants not only provide strength but also resorb naturally within a biological system, without the necessity of further surgery once the bone has fully hardened[2]. Although magnesium alloys do present many challenges. In this application, corrosion is extreme and their potential is very high. For example, magnesium alloyed with aluminium and rare earths has proved promising for temporary implants in providing both strength and corrosion protection. However, more and more elements, including aluminium and rare earth elements, are cytotoxic, which makes them unsuitable for long-term use. Yet, newer smart biodegradable materials based on magnesium-zinc alloys are in the offing and considered as better alternatives in terms of being more biocompatible[12,13].

While zinc and manganese incorporation to these alloys improved their corrosion resistance, mechanical properties, and reduced toxicity, some of these alloys have been surface modified to improve blood compatibility. Several magnesium alloy coatings, including an $Al + xAl_2O_3$ composite coating, have been proved to increase wear and corrosion resistance[14]. It may further enhance the conditions to increase the material's fatigue limit and yield strength, therefore giving magnesium alloys a good shot at orthopedic implants. Although it deteriorates extremely quickly, magnesium has, due to new metallurgy developments, become an area of interest for the medical community. These developments greatly enhanced magnesium alloys' mechanical performance and resistance to corrosion[15].They have been gaining continuously growing suitability for orthopedic applications. It could well be that, due to its degradability and biocompatibility, magnesium based implants might become increasingly acceptable as a substitute for traditional metallic implants, especially in musculoskeletal and orthopedic surgical procedures such as bone fixation, ligament and tendon repair, and joint replacement surgery[11].

Magnesium based biomaterials were compared with the traditional metals like stainless steel, cobalt-chromium and titanium alloys in terms of density and mechanical properties. They had a closer match with human bone, providing reduced stress shielding and promotion of healthier regeneration of bone tissue. Magnesium based implants hold a greater promise for future advancement compared to polymeric biomaterials as it possesses a higher strength-to-weight ratio and greater fracture toughness[8].

Composites manufactured from magnesium alloys are widely used in biomedical applications due to their exceptional biocompatibility and mild strength. Pure magnesium and magnesium alloys may corrode too quickly and lose its desired qualities before bone heals under physiological conditions. Orthopedic applications can be met by magnesium composites in the new era. As materials with biological aspects, magnesium-based composites can service mechanical properties that can be adjusted under physiological conditions, such as corrosion resistance, ductility, ultimate tensile strength and elastic modulus. The matrix materials in magnesium-based composites are biomedical magnesium alloys, including magnesium-calcium, magnesium-aluminum, magnesium-zinc, and magnesium-rare earth elements alloys. Calcium polyphosphate (CPP), hydroxyapatite (HAP), and β-tricalcium phosphate (β-TCP) particles serve as the foundation for the reinforcements.

Not only does it possess a high strength-to-weight ratio, magnesium has a density of 1.738 g/cm^3, which is quite comparable to that of bone. Due to magnesium's biomedical advantage, it's composites and alloys have been used as the go to implant material and a possible substitute. Due to their non-toxic nature, magnesium alloys are mostly utilized in biomedical applications. Composites have noticeable corrosion resistance and mechanical strength in addition to this magnesium matrix[52].

When used as bone fixings, magnesium based orthopedic implants have been demonstrated to aid the formation of new bone in the physiological conitions. One of the best options for temporary fixation devices is a magnesium-based alloy due to its exceptional mechanical properties, outstanding biocompatibility, and unique combination of biodegradability. Mg-aluminium and rare earth elements based alloys, including AZ91, AZ31, AZ61, WE54, WE43 , ZM21, LAE442 and JDBM to determine their potential as biomedical implants. These alloys have been shown to provide the sufficient mechanical strength and resistance to corrosion needed for applications involving temporary orthopedic implants.

In addition to such alloy systems, it has lately gained popularity to incorporate certain bodily nutrients, such as zinc, calcium, magnesium, sulfur, and so on, into magnesium in order to create temporary implants that are biocompatible. This is due to the fact that these alloying elements are considered non toxic in moderation because they are thought to be essential trace elements for the body.

Using computer tomography and fluorescence imaging, numerous animal experiments have demonstrated the osseous development of magnesium implants. According to reports, using magnesium implants can greatly improve the mice's ability to grow new bone surrounding the implanted bone. Many studies have been conducted on the cast state of magnesium based alloys. Depending on the alloying addition, the majority of the alloys in cast form consist of an alpha magnesium matrix with precipitates constituting the secondary phase. The second phase precipitates in as-cast alloys are preferentially dispersed at the grain boundaries, which degrades the alloys' ductility and corrosion resistance instead of helping to strengthen them[54].

Magnesium and its alloys, with or without surface treatment, are gaining significant interest as a new class of metallic biomedical materials because of their biodegradability and potential to prevent removal once the implant has served its purpose of surgically fixing injured musculoskeletal tissues. Clinical trials of Mg-based orthopaedic implants with enhanced physicochemical qualities for bone fracture repair were conducted in Germany, China, and Korea just lately, despite the fact that a few clinical instances involving these implants were documented over a century ago.

Apart from its metabolic characteristics and functions, magnesium has a suitable mechanical strength near cortical bone, which may alleviate worries about refracture or an inadequate healing result at the fracture site by lowering stress shielding[62].

Heart implants. Coronary heart disease is the most common health burden seen around the world and stents have become a key tool in addressing it. Initially, it is designed to prevent emergency surgery following failed angioplasty, stents quickly became the best solution to treat coronary stenosis. Then they proved unusually effective in the treatment of venous obstruction and pulmonary artery stenosis[16]. As for stent materials, they should fulfill some criteria, including biocompatibility to avoid inflammatory and restenosis(a condition where a blood vessel narrows again after a procedure to open it) response, elongation rate greater than 15% and yield strength above 200 MPa. Stents are required for long periods of 6 to 12 months to be absorbed or degraded in order to reduce risks at long term[2].

This fact made people be interested in biodegradable magnesium based stents. The magnesium based stent can also degrade over time, which frees the risk and cost of risky removal surgeries[2,11]. This is particularly necessary in the cardiovascular interventions where complications like thrombosis and restenosis are dangerous. Magnesium based stents, although mainly still in experimental stages, have received attention in using them as stent grafts, artificial valves, and pacemakers. These stents have the same mechanical properties as those of stainless steel, high collapse pressure, and minimal recoil after expansion, thus making them highly competitive with current technological developments[17,18].

Magnesium based stents have been noted to be promising for both applications in preclinical and clinical stages[19]. For instance, stents that were fabricated from the AE21 alloy(magnesium alloy with 1% rare earth elements and 2% aluminum) implanted in pig coronary arteries(The primary blood arteries that provide the cardiac muscle with oxygen-rich blood) resulted in no major complications and easily degraded with time without causing obstructions[20]. In human trials, the magnesium based stents showed success in treating below knee lesions with no allergic reactions or toxicity. On the other hand, the DREAMS(Drug-Eluting Resorbable Magnesium Scaffold) stents have shown encouraging results in a 12 month trial period with no incidence of cardiac deaths, thus promising a potential in cardiovascular applications[16,21].

Not only do magnesium based stents show remarkable degradability, but these stents also exhibit marked anti microbial effects that are important factors in minimizing infection and restenosis. It may self engage with the vascular smooth muscle cells and platelets to provide antibacterial effects. However, issues like elevated pH levels and hemolysis are a matter of concern because of the rapid degradation of magnesium[22]. Fortunately, the advancements regarding coatings and heat treatment have improved the corrosion resistance and reduced the inflammation process, which makes the magnesium based stent a better candidate for long-term use[19,23].

Biodegradable Surgical Wires and Staplers for Wound Closure. An ideal wound closure device should meet some of the following needs. It would be nontoxic and sterile, easy to use, efficient, painless as much as possible, and inexpensive. For instance, surgical wires and staplers need to have a high tensile strength and strength-to-diameter ratio. For these components to fit into and enter the wound, they should be elastic and plastic.Furthermore, for them to be utilized safely in surgery, they need to be stable at body pH, biocompatible, non ferromagnetic and bio degradable[2,24]. With the rising number of gastrointestinal cancers, the scientific community has specifically undertaken R&D work related to enhancing biodegradable and biocompatible materials for surgical application, especially for gastric bypassing[25].

In the past two decades, surgical wires and staplers have emerged as a popular tool for anastomosis. An advantage of using the anastomotic staples instead of the manual sutures includes lower operative time, complications, and pain experienced by the patients post operation[26]. Although suture materials consisting of polymeric materials, such as polylactic acids and polyglycolic acids are commercially available, the most common material to be used in metallic staples is titanium due to its superior mechanical properties, biocompatibility, and high radiopacity[25]. However, besides their increased use, problems like inflammation, foreign body reactions, and interference with imaging techniques limit their wider applicability[27].

Magnesium based materials have appeared as promising alternatives, in which biodegradability is combined with mechanical stability and a high level of biocompatibility superior to the standard existing titanium materials[9,11,18]. The usage of wires, clips, rings, and staples made of magnesium began to spread in the fields of hemostasis and gastrointestinal reconstruction because they reduce the post operation complications such as bleeding and inflammation. Their biodegradable nature puts an end to the possibility of removal surgeries thereby minimizing the discomfort of the patients. In addition to gastrointestinal procedures, Additionally, materials based on magnesium are being researched for use in dental implants or staples for bones where the mechanical characteristics support the fast healing process[27].

Though promising, there are major issues with magnesium based materials. Rapid corrosion and hydrogen gas evolution in physiological conditions limits their applications[28]. The materials now offer improved corrosion resistance and biocompatibility due to recent developments in alloy composition and surface treatments. For example, magnesuim-zinc-calcium alloys demonstrated excellent sealing properties while significantly reducing inflammatory response in animal studies, whereas high purity magnesium staples used in gastric anastomosis displayed excellent controlled degradation and reduced inflammation as well[2,5].

Magnesium based materials are also inherently antibacterial, making them very effective in surgery. Magnesium ions released in alkaline environment acts as a natural resistance to infections[29]. Furthermore, the introduction of other alloying elements like copper, silver and zinc in magnesium matrix causes strong enhancement of these antibacterial effects, which are yet another strength to be harnessed in clinical applications[30,31].

Magnesium based Materials with Anti-Tumor Properties. For materials to be used in tumor treatments, they must meet several demands. First, a material that is biocompatible in order not to provoke unwanted immune responses, mainly affecting the tumor cells alone, and capable of loading and controlled drug release so as to provide the right concentration of antitumor agents in the desired location during the required amount of time[2]. Biodegradability is also required, so that once the material has delivered its therapeutic effect, it is safely absorbed by the body[32]. It is also crucial to ensure compatibility with imaging techniques for tumor treatment when monitoring in real time. Although bioinert metals like titanium alloys do not stop tumors from growing. But biodegradable magnesium based materials are showing promise as a treatment for tumors[2].

According to studies, magnesium can trigger programmed cell death, or apoptosis, in cancer cells, and more importantly, results in significantly smaller sizes of tumors[33]. Magnesium, being biodegradable, is released in controlled amounts in the body. Consequently, its potential for toxicity is greatly minimized compared with most other drugs applied in chemotherapy[32]. Moreover, magnesium plays a vital role as a modulator that increases the natural host resistance to cancer through regulation of the immune system.

Further research is necessary to throw more light on the role played by magnesium in antitumor therapy and its overall clinical application in studies involving humans. Magnesium has been demonstrated to be toxic to several cancer cells, including osteosarcoma as well as human oral cancer cells[34]. Additionally, it has been shown to prevent tumor cells from adhering with simultaneous alteration in shape. It has been further able to increase the pH of the environment, which further supports the idea that magnesium may alter the cytoskeleton of bone cancer cells, making it an antitumor agent[13].

Amongst the magnesium alloys, Mg–1Ag–1Y was specifically effective in animal studies against tumor growth, which may be attributed to their alkaline environment. They inhibit the levels of chemokine receptors and increase the synthesis of prostacyclin for mediating tumor inhibition[35]. Another significant factor related to their effectiveness is the degradation rate of magnesium alloys, because their relatively faster breakdown as compared to those of iron and zinc alloys implies that they are more suitable for drug-loaded implants[4,5,9]. Alloying magnesium with elements such as silver, gadolinium, and strontium has improved the antitumor properties[5,6].

Deposition of a coating onto magnesium based materials is one common practice in ensuring uniform degradation rates, a necessary condition for the antitumor effectiveness of such materials[36]. Composition, microstructure, and surface treatment have been cited as the factors that influence the extent of antitumor activity in several studies[37]. Besides their antitumor property, magnesium based compounds also possess antimicrobial properties, which can be used to prevent infections secondary to cancer[22]. These compounds have the ability to paralyze the growth of microbes and cancerous cells by blunting their cell membranes. Magnesium further improves how well antibiotics and chemotherapy drugs work by increasing the permeability of cells. Thereby, more entry of drugs will take place into the cell. Its antioxidant activity, in addition to its immunostimulating activity, helps confer added safety against infections and tumor impacts.

Under biological conditions, magnesium alloys are prone to corrosion. In addition, two difficult issues with magnesium implants are their high rate of corrosion and limited bioactivity, both of which must be fixed before using them in clinical settings. Because of their outstanding mechanical compatibility with human bone and their excellent biodegradability and biocompatibility, magnesium and its alloys are very interesting prospects for the creation of temporary, biodegradable implants in load-bearing applications[4].

In the emerging fields of technology such as 3D printing, magnesium based materials may be used to induce treatments to cancer. Custom implants with dimensions equal to that of a tumor can be prepared to maximize the anticancer effects by maintaining a high concentration of magnesium ions at the location of the desired effect. It is cost-effective and saves time, thereby making it an accessible treatment. Research indicated that a 3D printed magnesium scaffold may also be utilized for delivering customized therapies for other types of cancers, not only osteosarcomas[38].

As Biodegradable Implant Materials. Pure magnesium quickly deteriorates in the body, impairing its mechanical integrity before enough bone has had time to mend. In this study, 0.5 weight percent zirconium and 0.1 weight percent of graphene nanoplatelets were dispersed in magnesium powders using a high energy ball mill. The powder mixture underwent cold pressing into green compacts under 760 MPa and sintered in argon atmosphere for a couple of hours above 600°C. The results demonstrated that the addition of zirconium and graphene nanoplatelets to the magnesium matrix reduced the rate of corrosion by 48% in the hydrogen evolution test and by 68% in the potentiodynamic polarization test, and significantly raised the compressive yield strength by 91% when compared to pure magnesium.

It is cytocompatible with L929 and MG63 and human mesenchymal stem cells (HMSC), and recent studies have examined the formation of new bone using silicon nitride and magnesium matrix.By adding hydroxyapatite (HAP) and fluorapatite (FAP) particles, the porosity of magnesium-based composites was reduced, improving the viability of MG63 cell lines and corrosion resistance in artificial seawater. Similarly, it was discovered that graphene nanoplatelets enhanced the mechanical characteristics of metal matrices via a number of strengthening techniques and showed biocompatibility when in contact with blood[53].

Fine Mg2 Si eutectic dense structure is observed after verifying results of surface and mechanical characterization after alloying it with silicon. This increases the composite's hardness and also lowers its ductility. The biomechanical integrity and corrosion performance of the composite are thought to have been improved by the formation of biocompatible phases inside the composite. The degradation rate of the Mg-3 Si composite was reduced from 2.05 mm/year to 1.19 mm/year by alloying HAP. Furthermore, the produced composites showed exceptional bioactivity and gave MG-63 cells an interface or conduit for adhesion, proliferation, and differentiation[55].

Bioactive Composites. Pure magnesium and magnesium alloy were combined with hydroxyapatite and bioactive glass particles, and the mixture was subsequently solidified into disc shaped specimens using high pressure torsion at room temperature.

After several HPT spins, the bioactive particles seemed evenly distributed within the metal matrix. To achieve full consolidation, pure magnesium had been used although after 50 revolutions, the core of the AZ91 disc was incapable of doing so. After immersing the magnesium-hydroxyapatite composite in Hank's solution, it showed a declining rate of corrosion and high cellviability

Magnesium has a fracture toughness of around 15–40 MPa/m2, which is higher than the ~3-6 MPa/m2 of bone. Because magnesium and bone have similar densities and elastic moduli, it is a good material option for bone grafting applications because these characteristics will reduce stresses at the implant-bone interfaces. To increase strength without changing the composition, grain reinforcement is vital. To determine grain sizes and refine the grain structure of metallic materials, extreme plastic deformation techniques such as Equal-Channel Angular Pressing (ECAP) and High-Pressure Torsion (HPT) have been used. smaller than those produced using conventional techniques, falling into the submicrometer or nanoscale range of thermomechanical processing techniques.

The CP-Mg-based composites show a uniform distribution of microhardness within the range of 75–80 Hv, but the AZ91-based composite is harder with values in the range of 115–125 Hv [56].

2.2 As an engineering material

Aerospace industry. Magnesium based materials provide an attractive reduction in structural weight in the transportation sector because of their light weight[39]. However, despite huge savings in aerospace, applications have been less due to general fears of flammability. Despite this, magnesium did see much usage in military aircraft, such as the B-36 bomber, Eurofighter Typhoon, Tornado, and F16. However, now, with more relaxed Federal Aviation Administration(FAA) regulations regarding selected magnesium alloys, Elektron 21 and WE43 are being accepted for installation within the cabins of commercial aircraft. The space industry is also looking into the use of magnesium in satellite components making further push for its applications in the aerospace sector[40,41].

Early uses of magnesium date back to World War I and World War II with its use in the incendiary bomb, as well as pyrotechnics. Magnesium also played an important role in the building of WWII military aircraft that opened pathways into civil aerospace. High castability, good machinability, excellent ductility, and low weight make magnesium an attractive alternative to traditional metals, such as aluminium[15]. Substituting aluminium alloys with magnesium in aircraft building will achieve impressive savings in weight. For example, as evidenced by a Boeing 747 model, where about 28% savings in operating empty weight could be achieved, which is about 60.4 tonnes[40].

In spite of these plus points, inherent disadvantages of magnesium, namely flammability, poor corrosion resistance, and low surface durability, led to restriction in its application[43]. Exquisite rules set by the FAA and other regulatory bodies also kept it away as such for a long time from common utilization in contemporary aeronautics.

At present, magnesium alloys are used primarily for parts such as the engine and transmission,and the landing gear, but it is not applied to structural or outer structures. However, recent advancements in magnesium alloy research suggest that this metal is attracting greater attention and wider uses in aircraft engineering[43,44].

When efforts were made to address magnesium's flammability concerns, it became possible to design less-flammable magnesium alloys, which are now possible for use in aircraft interior areas[15,43]. Apart from flammability, other developments have been in the mechanical properties of magnesium, which primarily revolve around strength. With fields like aerospace, weight is a major concern, this is the most important area of magnesium applications. In that regard, it is the high performance alloys such as Elektron 21 and Elektron 675 that possess a higher strength to weight ratio than any other metal, while the latter has half the weight of titanium and twice the strength of aluminum[45]. All these advances would unlock new doors for magnesium opportunities in the aerospace sector.

Automobile Industry. Although the promise of weight reduction for the automotive industry has long been held by magnesium based materials, high strength to weight materials such as magnesium are being used to help reduce vehicle weights and subsequently improve fuel efficiency. Presently, it is widely used in sheet form or in engine blocks, in addition to components such as instrument panels, dashboards, steering wheels, powertrains, and transfer cases[46]. However, its wider use for critical engineering parts is still restricted, mainly by its poor resistance to corrosion. Separation of magnesium components can effectively minimize galvanic corrosion. Nevertheless, their full potential in automotive applications can be realized only through more cost-effective coatings and protection methods[47]. Such development is very important to make the material more resistant to degradation and corrosion, thus making it possible for magnesium to play a much bigger role in the automobile industry without losing performance and increasing costs.

Coming to its history, magnesium entered the automotive industry as early as 1918, where the Indycar 500 used engine pistons made of magnesium. It was Volkswagen's use of a magnesium engine block in the Beetle in the 1930s that really brought widespread applications into the industry[48,49]. It is being used in powertrains, framework, and support structures and now represents the third most-used metal in the industry, following steel and aluminium[50].

While magnesium is still finding its way into the industry, its relative use compared to other metals is still small. Its use depends almost entirely on advantages. For instance, better fuel efficiency and more environmental benefits. But so far, it hasn't fully replaced materials like steel and aluminium because of performance and cost concerns[50]. As the automobile industry is under pressure regarding reduced emission and sustainability, magnesium gains an interest at the point that one can reduce vehicle weight without losing strength or functionality to eventually get an outcome on the environment[46]. This renewed interest has made many persons look into the research in regard to magnesium and manufacturing methods, specifically casting processes.

Cast magnesium alloys are the major application to date because of the attractive properties in this field. They are used in most structural parts where weight has to be reduced significantly, thus instrument panels, seat frames, cross car beams and roof frames. These parts run along the front and upper parts of a car and should weigh as low as possible in order to ensure that the vehicle performs well[50]. Most magnesium based alloys used in the automotive industry are aluminium based alloys or magnesium based. These are divided into two major categories, the AZ and AM series[51].

High strength magnesium alloys and nanocomposites with exceptional thermal and dimensional durability appear to be interesting options for high temperature applications.[51]. Other than cast magnesium alloys, which can be seen in the automotive sectors, magnesium remains underutilized in other forms such as sheet magnesium and extruded magnesium[50]. Material performance, processing techniques, and cost-effectiveness issues are major challenges that still stand before magnesium when it can unlock its truest potential and revolutionize the automotive industry.

3 Analysis of Properties of Magnesium-based composites

3.1 Corrosive and Mechanical Behavior

Mg-5%ZrO2, Mg-1%Sn, and Mg-1%Sn/5 % ZrO2 were produced using an ultrasonic assisted squeeze casting process. The morphology of the composites was determined by characterization tests that are SEM with EDAX and XRD. Micro-hardness and compression tests were used to assess mechanical properties. Also, to know the level of corrosion, Tafel and electrochemical impedance spectroscopy were adopted as testing methods. The magnesium alloy bio-composite (Mg-1%Sn/5 % ZrO2) outperforms the base magnesium and non-reinforced magnesium bio-composite (Mg-1% Sn) in terms of compression (291.2 MPa) and yield (215.3 MPa), strength, elastic modulus (55.7 GPa), hardness (941.4 MPa), and decreased corrosion rate (0.475 mm/yr), according to the results.The ZrO2-reinforced magnesium bio-composite can be used as an implantation supporting material for bone fractures.

As ultrasonic squeeze casting is a method which can bring aboutparticle dispersion in a uniform manner, porosity reduction, and highly refined microstructure, it is better conventional stir casting. This makes the finished composite material more consistent and has better mechanical qualities, which makes it a more efficient fabrication method [3]. As magnesium is a metal that helps create biodegradable components for biomedical implantation material, it's corrosion resistance ascertians the need of alloying in order to attain a more complete biomaterial. To know it's biomedical capacity, the authors plan to create novel Mg-Sn-ZrO2 biodegradable composites and carefully assess their bio-corrosion and mechanical properties. As it could heavily upgrade magnesium alloys' mechanical properties without compromising their biocompatibility, tin (Sn) was chosen as the alloying element for this investigation[57].

To create a new magnesium alloy with enhanced qualities needed for medical use. Aluminiun , Bismuth , Copper, Cd, RE, Iron, Thorium, Zr, Lithium, Manganese, Nickel, Pb, Ag, Cr, Si, Y, Sb, and Zinc were among the elements that were alloyed with magnesium. To lower the rate of magnesium corrosion, various magnesiumbased alloys have been created using the given elements. The main processes affecting magnesium alloy corrosion include fatigue corrosion, stress corrosion cracking, pitting corrosion, as well as galvanic corrosive effect. The concurrent activity of such corrosion occurances in implant materials based on magnesium has led to a number of problems and complex concerns. In order to create implants with the best strength and resistance to corrosion in a physiological setting, it is crucial to design innovative composite materials.

The purpose of magnesium-enriched Al2O3 was to increase bone cell adherence to the magnesium-enriched substrate. There was an increase in bioactivity because magnesium plays a positive effect in the process of cell adhesion. In the newly created Mg-Cu alloys, Cu has been demonstrated to support osteogenesis, cell survival, new bone formation, and the avoidance of bacterial infections. Therefore, MC3T3_E1 cells and HUVECs were not harmed by the Mg-0.03wt% Cu alloy. Cell proliferation and the formation of new bone in Mg-Sr alloys were enhanced when 0.5wt% Sr was substituted with HA layer in SBF solution. Likewise, Mg-Ag alloys with 2 and 4 weight percent Ag showed good antibacterial properties and biocompatibility following heat treatment [58].

3.2 Design, Synthesis and Testing

Biodegradable magnesium is now known to be one of the most best choices for biodegradable sports medicine implants and degradable biliary stents due to its remarkable biocompatibility and physicochemical properties.Ureteral stents are made from magnesium alloys because to their antibacterial and biodegradable qualities. The density of magnesium and magnesium alloys is 1.74–2.0 g/cm3, and its elastic modulus is 40–45 GPa, making it very similar to the human bone. Additionally, compared to titanium alloy implant materials, it has a lesser yield strength. In a clinical experiment, Lambotte treated an A child aged 8 who had been diagnosed with a transdiaphyseal humerus fracture with a magnesium plate. About three weeks after, the magnesium metal plate had almost entirely degraded and the fracture line of the bone was not visible in the test reports.

The tensile and compressive yield strengths of the Mg-15 HAP and ZM61-15 HAP were 129.6 MPa, 147.1 MPa, and 225.5 MPa, 245.3 MPa, respectively, per a study. Additionally, the strength of these composites was increased by the inclusion of HAP. The tensile strength of the composites has increased to 5% HAP. Because of the hard space of the HAP particle, the HAP in Mg and ZM61 reduces ductility and enhances brittleness in Mg-HAP and ZM61-HAP composites.Tensile and compressive (bracketed) yield strengths for the Mg-15 HAP and ZM61-15 HAP are 129.6 MPa, 147.1 MPa, and 225.5 MPa, 245.3 MPa, respectively. Additionally, these composites' strength increased with the addition of HAP [59].

Actually, temporary implant components such as stents, screws, and plates were in significant demand in 2004, for instance, more than two million drug eluting coronary stents were implanted. Because of their exceptional mechanical characteristics and biodegradability, material researchers and engineers have been investigating new biomaterials to replace traditional biometals. In the realm of biomaterials, magnesium and magnesium-based alloys are receiving a lot of attention. It is imperative that possessing a number of specific qualities such as adequate durability, uniform degradation, full bone regeneration and biocompatibility is necessary for biocompatible implants. Magnesium-based metals are believed to satisfy specific criteria.

In view of the bone implants, magnesium alloys are preferred because to their reduced Young's modulus value of around 37.5–65GPa which is closer to a human bone and can help reduce osteolysis and stress-shielding. Furthermore, magnesium alloys outperform ceramic and polymeric biomaterials in terms of tensile strength, fracture toughness, and strength/weight ratios. Furthermore, The synthesis of proteins, thermoregulation, the control of neuromuscular and central nervous system activity to maintain appropriate cardiac contraction, and the activation of many enzymes are all processes that depend on magnesium, an essential element for human health[60].

In 1878, magnesium was first used in medicine as ligatures. In 1878, the doctor Edward C. Huse stopped three patients' bleeding vessels with magnesium wires (Huse, 1878). He discovered that magnesium corroded more slowly in vivo and that The size of the magnesium wire affected the deteriorating period (Huse, 1878). Because pure magnesium was too brittle to knot easily, the wire was alloyed with specific elements to make it more ductile. In order to maintain or restore joint motion in animal joints, physician Erwin Payr was the first to suggest employing magnesium plates and sheets in 1900. When magnesium sheets were put into dog and rabbit knee joints, they rusted completely after 18 days.

Since the end of the previous century, there has been a tremendous advancement in the field of magnesium research; as well as related alloys as biodegradable material components. The German company Biotronic lead the development of biodegradable metal coronary stents and received the 2013 CE mark for a biodegradable magnesium alloy coronary stent. In 2013, the German business Syntellix Co. obtained the CE mark for a biodegradable magnesium alloy screw after a clinical trial to treat hallux valgus surgery[61].

3.3 Recent Progress

Magnesium alloys are sought-after materials in the automobile sector due to their exceptional qualities, particularly their high strength/weight ratio. Their significant vulnerability to corrosion, however, has severely restricted or perhaps eliminated their wider use in a number of applications. One of the best ways to stop magnesium alloys from corroding is to apply an organic coating[63].

4 Conclusion

Due to their advantageous mechanical qualities, biodegradability, and low weight, magnesium and its alloys are currently used most effectively in the biomedical and engineering domains.
Due to biocompatibility, degradability, magnesium-based materials are ideally suited for orthopedic implants, cardiovascular stents, and surgical staples, as they will do away with the need for their removal surgeries. Alloying and surface modifications have improved corrosion resistance and mechanical strength significantly.

Magnesium alloys appear to show some promise in cancer therapy with studies demonstrating support for tumor inhibition, along with applicability to targeted drug delivery using 3D-printed implants.

New developments in magnesium provide light weight and a high strength-to-weight ratio to the automotive and aerospace industries; resulting in reduced weight and an increased range of fuel economy. Innovations in alloying have addressed concerns of flammability and corrosion.
Research in alloy development, surface modification, and composite technology continue to improve the possibilities with magnesium and thus ensure further development across medical and industrial applications.proposed technique, along with the methodology which is similar to the basic coverless image steganography, it uses a modified hashing algorithm. The refined hashing algorithm for preparing the index structure takes the less time comparatively with the basic hashing algorithm. This method is also be as good as existing to defend against many image security attacks. And using modified algorithm, effectively it improves the performance of entire system. It can perform efficiently when the size of the secret information considerably small. When the size of the secret information is a large enough, it would not be a good choice, because it requires more number of images need to be sent which can be more burden to the network and creates blockage. As part of future scope, it can be improved further to support large informations by combining known steganography methods into it.

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