



A REVIEW ON THE CHARACTERISTICS AND DIVERSE APPLICATIONS OF MAGNESIUM AND ITS ALLOYS

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ABSTRACT

Magnesium and its alloys have attracted significant attention across various industries due to their unique combination of properties, including low density, high strength, and excellent corrosion resistance. This comprehensive review explores the characteristics of magnesium and its alloys, shedding light on their diverse and innovative uses in industries such as automotive, aerospace, electronics, medical, and more. Additionally, it delves into the challenges associated with magnesium applications and outlines future prospects for this versatile material.

Index Terms- Magnesium, Mg components, Mg applications. Automotive industry, Transportation, Fuel economy.

INTRODUCTION

The main objective of reviewing and evaluating the applications of magnesium in various applications conservation is commendable, as magnesium alloys have the potential to make a significant impact in these areas. Here's a breakdown of the key points and findings mentioned in your study:

Objective: The primary goal of your study is to assess how magnesium and its alloys can be utilized in the automotive sector to achieve two main objectives: improving fuel economy and promoting environmental conservation.

Current Advantages: The study highlights the existing advantages of using magnesium alloys in automotive applications. These advantages likely include magnesium's low density, which can lead to weight reduction in vehicles, thus improving fuel efficiency.

Limitations: It's important to discuss any limitations associated with using magnesium alloys in the automotive industry. These might include cost considerations, availability, or specific technical challenges.

Technological Barriers: The study acknowledges technological barriers that might hinder the widespread adoption of magnesium alloys in the automotive sector. These barriers may include manufacturing processes, material properties, and safety concerns.

Future Prospects: Discussing the future prospects of magnesium alloys in the automotive industry is essential. This could include advancements in materials science, innovative manufacturing techniques, and potential

breakthroughs that may overcome current limitations.

Impact on Environmental Conservation: Emphasize how the use of magnesium alloys can contribute to environmental conservation. This might include discussing reduced greenhouse gas emissions due to lighter vehicles and improved fuel efficiency.

Recent Developments: Highlight recent developments in the field of magnesium alloys, particularly in terms of coating and alloying. Discuss how these developments have improved properties such as creep resistance and corrosion resistance, making magnesium alloys suitable for a wider range of automotive applications.

Weight Reduction: Mention the substantial weight reduction achieved by using magnesium alloys compared to alternative materials. This reduction can lead to improved fuel economy and lower environmental impact.

Increasing Use: Highlight the trend of increasing usage of magnesium in automotive components as knowledge of forming processes and material properties improves. This suggests a positive trajectory for the adoption of magnesium alloys in the industry.

Ensure that your study includes relevant data, case studies, and references to support the claims and findings you've mentioned. Additionally, consider discussing safety considerations and potential challenges related to recycling and disposal of magnesium materials in automotive applications, as these are important factors for environmental conservation.

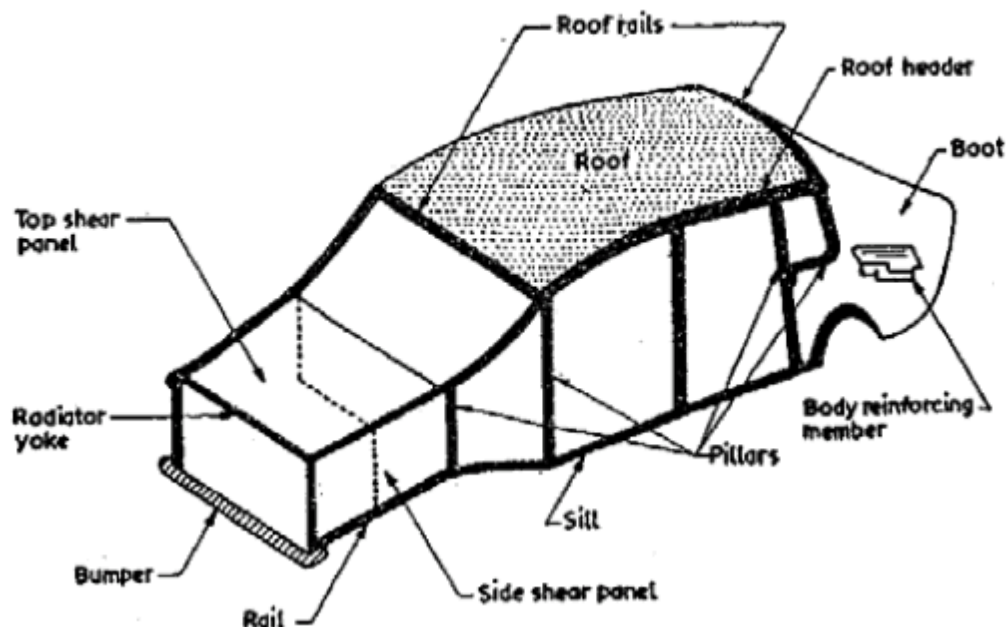


Figure 1: Constructional details of automotive components

The bodywork has to be structurally strong, easily accessible, and of a good finish.

Some of the important considerations for a good bodywork include the following :

1. Attractive body styling.
2. Upholstery work should be well-trimmed and comfortable.
3. Body structure should be rust preventing.

4. Paintwork and other finishing should be appealing.
5. The body should be structurally strong and light. Therefore, construction material should be of lightweight, strong, and cheap.
6. Doors and windows should be conveniently located, and easier to operate.
7. Controls should be located at convenient positions and should be easily approachable.
8. The arrangement of hand controls and foot pedals should be foolproof and untiring.
9. Provision of sufficient space for accommodating accessories, instruments, and controls.
10. Driver's and passengers' seats should be comfortable and adjustable and should be conveniently located.
11. Interior cabin should be dustproof and soundproof.
12. The body should be equipped with sufficient safety provisions.

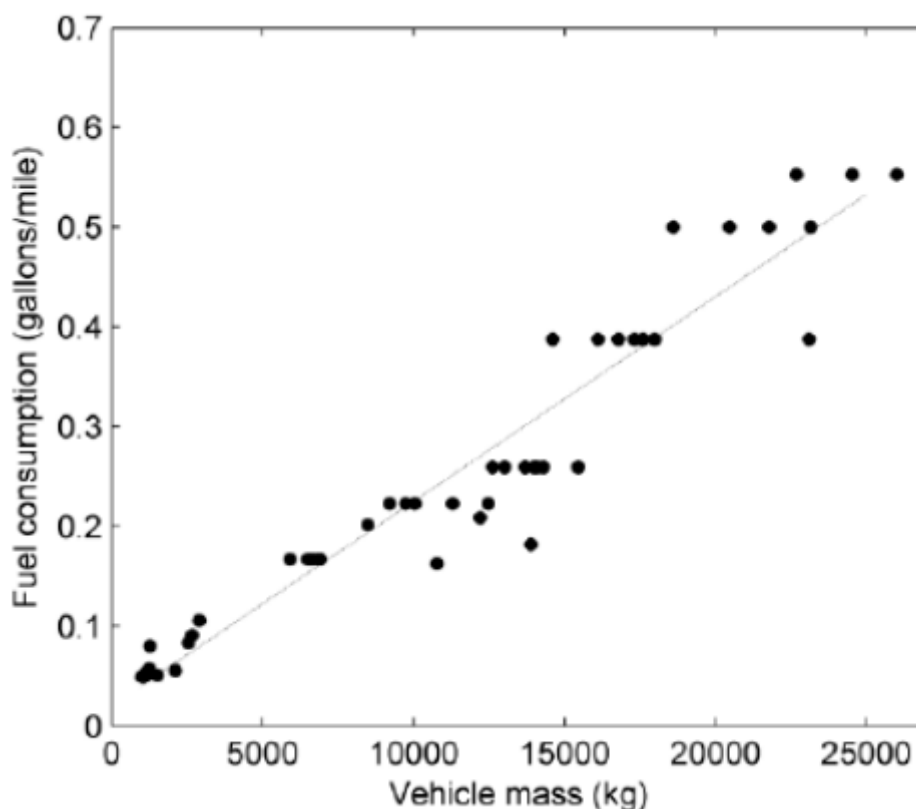


Figure 2: The Relation between Vehicle Mass and Fuel Consumption

MG & ALLOYS

Elemental Magnesium (Mg):

Magnesium is a chemical element with the symbol Mg and atomic number 12.

It is a lightweight, silvery-white metal and is the eighth-most abundant element in the Earth's crust.



Properties of Magnesium:

Low Density: Magnesium has a low density, about 1.74 g/cm³, making it one of the lightest structural metals.

High Strength-to-Weight Ratio: Despite its low density, magnesium exhibits good strength, particularly when alloyed with other metals.

Good Heat and Electrical Conductivity: Magnesium is a good conductor of heat and electricity.

Corrosion Resistance: Magnesium is prone to corrosion, but this can be mitigated through alloying and coatings.

Magnesium Alloys:

Magnesium is often alloyed with other elements to enhance its properties and overcome some of its limitations.

Common alloying elements include aluminum (to form aluminum-magnesium alloys, known as "mag-alloys"), zinc, manganese, and rare earth elements.

The choice of alloying elements and their proportions can be tailored to achieve specific properties like strength, corrosion resistance, and creep resistance.

Applications in the Automotive Industry:

Magnesium alloys are used in various automotive applications due to their lightweight properties, which contribute to improved fuel efficiency and reduced emissions. Common automotive applications include transmission cases, engine components, steering wheels, and structural components. Magnesium's high strength-to-weight ratio makes it a suitable choice for reducing the weight of vehicles.

Advantages:

Weight Reduction: Replacing heavier materials with magnesium alloys can result in significant weight savings, leading to improved fuel economy.

Environmental Benefits: Lightweight vehicles produce fewer emissions, contributing to environmental conservation and reduced carbon footprint.

Recyclability: Magnesium alloys are recyclable, making them more environmentally friendly.

Limitations:

Corrosion: Unalloyed magnesium is prone to corrosion, especially in harsh environments. Proper coatings or alloying elements are needed to address this issue.

Flammability: Magnesium is flammable and can ignite at relatively low temperatures, requiring safety precautions in manufacturing and usage.

Technological Barriers and Challenges:

Challenges forming magnesium alloys due to their low ductility at room temperature. Limited availability of magnesium resources compared to other metals like aluminum and steel.

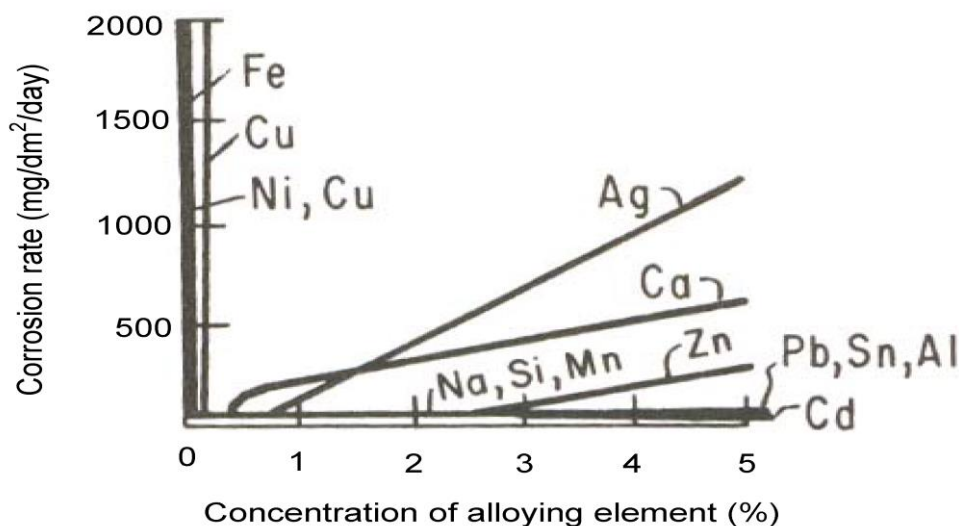
Future Prospects: In processing and Ongoing research and development are focused on improving the properties of magnesium alloys, such as corrosion resistance, creep resistance, and formability.

Advances in manufacturing techniques, including 3D printing, are expanding the potential

applications of magnesium in various industries, including aerospace and automotive.

S. No.	Alloy	Name	Composition
1	Mg alloy	AZ61	Mg-Al-Zn-Mn-Si-Cu-Ni-Fe
2	Al alloy	Aluminum 6061-T6	Al-Mn-Mg-Si- -Cu-Cr
3	Cast iron	ASTM Grade 40	Fe-C-Si-Mn-P-S

Alloy	grain size, μm	σ_{YS} , MPa	σ_{UTS} , MPa	δ , %
Mg-0.8Ca (this work)	2.1	193.2	308.2	7.2
AZ31 [12]	1.2	~280	~350	~17
Mg-3Al-0.4Mn [17]	~2.2	~160	~230	55
Mg-5.25 wt.% Zn-0.6 wt.% Ca [18]	~3.9	178	276	25.9
AZ31 [19]	2.2	144	254	60
AZ31 [20]	2.2	-	~175	3
AM60 [21]	~2	~180	~290	~18





CORROSION CHARACTERISTICS OF MG ALLOYS

Magnesium alloys in general can be divided into two main groups: (1) those containing aluminium as the primary alloying element; and (2) those free of aluminium and containing small additions of zirconium for the purpose of grain refinement. The most widely used magnesium alloys are those with aluminum (to 10%), zinc (to 3%), and manganese (to 2.5%). It is desirable that other metals, particularly Fe, Cu, Ni and Si be present in very small amounts not exceeding a total of 0.4% to 0.6% [13]. Mg alloys corrosion is governed by the characteristics of its surface film. The properties of film on Mg alloys depend on Mg alloys' metallurgy and environmental factors. Magnesium metallurgy includes alloying and impurity elements, phase components and microstructure. Metallurgical manipulation can provide an effective means to improve the corrosion resistance of magnesium alloys.

Corrosion characteristics of pure magnesium:

Magnesium, like most metals and alloys, relies on a natural surface film to control its corrosion. However, the nature of this film is not thoroughly understood. Good passive films are those that restrict the outward flow of cations, resist the inward flow of damaging anions or oxidants, and rapidly repair themselves in the event of localized breakdown. The structure and composition of the surface films, which depends strongly on environmental and metallurgical factors, such as electrolyte species and impurities in the metal, determine the protective ability of a passive film.

Environmental effects

No material shows high corrosion resistance in all kinds of environments. The high corrosion resistance of materials always refers to some specific environments. Magnesium has its own preferred service environments. However, there are fewer media that are suitable for the magnesium and magnesium alloys compared with other materials, such as steels and aluminum alloys. For example, magnesium and magnesium alloys are usually stable in basic solutions, but in neutral and acidic media they dissolve at high rates. This is quite different from aluminum alloys that are normally stable in neutral media but are unstable in both basic and acidic solutions.

General corrosion in aqueous solutions

With few exceptions, there is no appreciable corrosion of pure magnesium near room temperature unless water is present. Magnesium dissolution in water or aqueous environments generally proceeds by an electrochemical reaction with water to produce magnesium hydroxide and hydrogen gas. Such a mechanism is relatively insensitive to the oxygen concentration, although the presence of oxygen is an important factor in atmospheric corrosion.

PROCESSING METHODS OF MAGNESIUM AND ITS ALLOYS

Significant research is still needed on magnesium processing, alloy development, joining, surface treatment, corrosion resistance, and mechanical properties improvement.

Melting

Molten magnesium does not attack iron in the same way as molten aluminum which has high affinity to iron; thus, magnesium alloys can be melted and held in crucibles fabricated from ferrous materials. It is common practice to melt and process molten magnesium in steel crucibles and deliver it to casting operations in steel tools and devices. Fig. 4 shows the cross-sectional design of a typical fuel-fired stationary crucible furnace, from which metal for small castings can be hand, poured using ladles. This use of metallic crucibles allows the crucible to be supported from the top by means of a flange, leaving a space below the crucible. The furnace chamber has a base that slopes toward a cleanout door. Modern casting operations generally use electrical furnaces with steel covers and melt transfer devices.

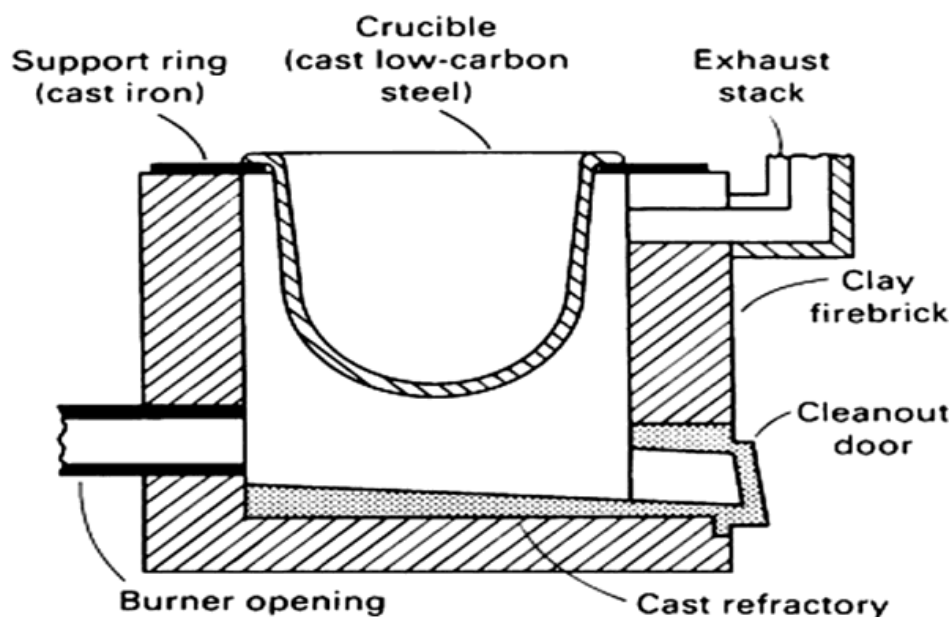


Figure 4: Crucible Furnace

Melt Protection

Molten magnesium tends to oxidize and burn, unless care is taken to protect its surface against oxidation. Unlike aluminum alloys which tend to form a continuous, impervious oxide skin on the molten bath limiting further oxidation, magnesium alloys form a loose, permeable oxide coating on the molten metal surface. This allows oxygen to pass through and support burning below the oxide at the surface. Protection of the molten alloy using either a flux or a protective gas cover to exclude oxygen is therefore necessary. There are basically two main systems, flux and flux less, for the melt protection of magnesium alloys.

Flux Process

Protecting molten magnesium using flux was developed before proper gaseous protection was developed. A typical flux-melting procedure would be for the crucible with a small quantity of flux (about 1% of charge weight) placed in the bottom, to be preheated to dull red heat. Additional flux is lightly sprinkled onto the melt surface during melt holding and casting operations. Since the discovery of sulfur



hexafluoride (SF₆) as effective protective gas for magnesium melting and casting, flux melting is limited to casting of special gravity casting alloys with very high melting points.

Flux less Process

Flux less melting using air/SF₆, air/CO₂/SF₆ or CO₂/SF₆ as protective gas mixtures developed in the 1970's was a significant breakthrough in melting, holding, and casting of magnesium alloys. SF₆ has been shown to be an extremely effective oxidation inhibitor for magnesium alloys

High Pressure Die Casting

High pressure die casting (HPDC) offers attractive flexibility in design and manufacturing of light metals components. The excellent die filling characteristics of magnesium alloys allow large, thin-walled and complex castings to be economically produced by this process, replacing steel structures made of numerous stampings and elements.

Powder Metallurgy

Magnesium and other reinforcement elements are powdered, mixed, pressed and sintered at a temperature under controlled atmosphere. It has potential of high volume fraction of reinforcement but this is a costly process. This technique is not ideal for mass production. A variety of magnesium matrix composites like Al₂O₃/AZ91, SiC/AZ91, TiO₂/AZ91, ZrO₂/AZ91, SiC/QE22, and B₄C/AZ80 have been fabricated through powder metallurgy.

Vapor Processing

CVD (Chemical Vapor Deposition), PVD (Physical Vapor Deposition) vapor processing involves the deposition of thin films by condensation of vaporized desired material on work piece surface. Vapor deposition is a primary process where the matrix is deposited from the vapor phase on to individual reinforcement of ingredients. This process is very slow but there is no mechanical disturbance at the interface region as it is purely a chemical process. This method has been widely adapted to Mg-Al-Zn alloys for surface coatings to improve corrosion resistance.

Squeeze Casting

There are two types of squeeze casting processes: direct and indirect squeeze casting. In both types of the processes, molten metal is introduced to casting cavities with minimum turbulence and solidifies under very high pressure (typically above 100 MPa) within closed dies.

Direct Squeeze Casting

Direct squeeze casting (DSC) is also termed liquid metal forging. As shown in Fig. 11, the direct squeeze casting process consists of metering liquid metal into a preheated, lubricated die and forging the metal while it solidifies. The pressure is applied shortly after the metal begins to freeze and is maintained until the entire casting has solidified. Casting ejection and handling are done in much the same way as in closed die forging.

Indirect Squeeze Casting

While direct squeeze casting is generally performed on a vertical machine (similar to a forging press), indirect squeeze casting (ISC) is more akin to conventional high pressure die casting, using both vertical or horizontal machines. During an indirect squeeze casting such as the "Horizontal Vertical Squeeze Cast"



(HVSC) process, molten magnesium is transferred (preferably in an enclosed tube) to the shot sleeve, and then injected into the die cavity through relatively large gates and at relatively low velocity (usually under 0.5 m/s). Melt in the die cavity is then solidified under high pressure “indirectly” applied by the plunger through the large gating system.

CONCLUSION

In conclusion, magnesium and its alloys offer a compelling array of properties and applications across diverse industries. These lightweight metals have captured the attention of engineers, scientists, and manufacturers due to their unique combination of strength, low density, and corrosion resistance. Here are some key takeaways from the applications of magnesium and its alloys:

Automotive Industry: The automotive sector has witnessed significant advancements in the use of magnesium alloys. Substituting heavier materials with magnesium has led to substantial weight reduction in vehicles, contributing to improved fuel economy and reduced environmental impact. The ongoing research and development in magnesium alloys, particularly in terms of corrosion resistance and formability, are likely to expand their use further in this industry.

Aerospace and Aviation: Magnesium alloys find applications in aircraft components due to their lightweight properties, contributing to reduced fuel consumption and enhanced performance. These alloys are prized for their strength-to-weight ratio and their ability to withstand high-temperature and corrosive environments.

Electronics: In the electronics industry, magnesium alloys are used in laptops, cameras, and other consumer electronics due to their lightweight and efficient heat-dissipating properties. These alloys help reduce the weight of electronic devices while maintaining structural integrity.

Medical Implants: Biodegradable magnesium alloys have gained attention in the medical field. These implants gradually dissolve in the body, eliminating the need for additional surgeries for removal. This innovation reduces the long-term impact of medical procedures on patients.

Challenges: While magnesium and its alloys offer numerous advantages, they are not without challenges. Corrosion remains a significant concern, necessitating protective coatings and alloy modifications. Safety precautions are essential, as magnesium is flammable and requires careful handling during processing and usage.

Future Prospects: The future of magnesium alloys appears promising. Ongoing research efforts are focused on improving their properties, particularly corrosion resistance and creep resistance, to address some of the limitations. Advances in manufacturing techniques, including additive manufacturing, open up new possibilities for the use of magnesium alloys across industries.

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