Handbook of Characterization of Metals and Alloys

Principles and Properties

Avery Logan
Editor

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Preface

Metals and alloys are critical building blocks of many products in modern society. From nanomaterials to architectural structures, these materials have a huge range of uses and applications. High-purity metals and alloys find uses in automobiles, semiconductor devices, aircraft, sputter targets, evaporation sources, magnetic media, and many other products. Accurate and precise determination of their chemical composition ensures that end users have the right materials for their specific applications.For many applications the surface finish of the material can determine its lifetime and stability. This is particularly important in the biomedical field. Surface passivation can extend the lifetime of a biomedical implant, improve biocompatibility and reduce toxicity.

Characterization of Metals and Alloys provides an introduction to surface and interface analysis techniques for specialists and educated professional metallurgists or scientists. This book illustrates with case histories how characterization techniques can be used to determine important properties of metals and provides a systematic approach to the task of correlating structure and composition with properties. This is a useful reference book for practical engineers and scientists who want to learn what can be accomplished with modern analytical techniques, or who want troubleshooting advice on problems involving the structure/property relationships in metals and alloys. In the first chapter magnesium alloys have always been attractive to designers due to their low density, only two thirds that of aluminum alloys in the aerospace industry and therefore can be an innovation technology if used for low weight airframe structures. This has been a major factor in the widespread use of magnesium alloy castings and wrought products. In the chapter second and third chapter we discussed the quality of Mg alloys with high specific modulus and specific strength is the lightest in the structural materials. Their density is about 2/3 of aluminium alloys and 1/4 of steels. The weight of whole structural materials is decreased drastically owing to some components or parts produced by Mg alloys. Thus, Mg alloys are widely used in aerospace, weapons, automobile and other fields. In the forth chapter we discussed use of earth metals in medicine. In the fifth chapter we discussed about lightweight Mg alloys with excellent shock-absorption properties are being actively adopted for use in electronic information devices and automotive parts. In the sixth chapter we discussed about the use of Mg alloys in welding. In the seventh, eight and nine chapters we discussed the use of different alloys in different fileds and research on them.

Editor

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Chapter 1

APPLICATION OF MAGNESIUM ALLOYS IN TRANSPORT

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INTRODUCTION

Magnesium alloys have always been attractive to designers due to their low density, only two thirds that of aluminum alloys in the aerospace industry and therefore can be an innovation technology if used for low weight airframe structures. This has been a major factor in the widespread use of magnesium alloy castings and wrought products.

New light materials are currently inserted in world strategies of transport vehicle industry since the environment necessities for pollution and reduction of fuel consumption. Therefore the industry takes part of the risk of development of such alloys but, in fact, some of this has been made at academic level. Some aspects of the necessities and characteristics concerning those alloys are: low costs, insulation (sound and thermal), impact safety, deformation strength, recyclability and guarantee (to aging as example). All those aspects are linked with the increasing of new vehicle models and reflect in production programs that are more and more complexes (Raynor, 1959; Roberts, 1960; Eliezer et al, 1998).

However to use this low weight material several mechanical properties have to be increased and the technological behavior improved. A further requirement in recent years has been for superior corrosion performance and dramatic improvements have been demonstrated for new magnesium alloys. Improvements in mechanical properties and corrosion resistance have led to greater interest in magnesium alloys for aerospace and specialty applications.

Magnesium alloys are also used in many other engineering applications where having light weight is a significant advantage. Magnesium-zirconium-aluminum alloys tend to be used in relatively low volume applications where they are processed by sand or investment casting, or wrought products by extrusion or forging.

Actually it´s well known that there are a growth in primary production of magnesium due to a supplementary application of your products in market. A total 2010 production of primary magnesium in the world was approximately 809,000 tons. The main producer are China 654,000 tons, USA 45,000 tons, Russia 40,000 tons, Israel 30,000 tons, Kazakhstan 20,000 tons and Brazil 16,000 tons (China Magnesium Association; U. S. Geological Survey).

MAGNESIUM ALLOYS FOR TRANSPORT APPLICATIONS

The automobile have more than a hundred years since its invention and the light alloys have been utilized since 1915. In the 30's the aluminum did substitute almost completely the casting iron as main component of pistons. In th ne decade, in Germany, magnesium alloys were utilized i uction of camshaft and in the gear box, which le total decrease of weight at least 7% of the total

Magnesiun have traditionally been driven by aerospace in 's for lightweight materials to operate under incre g conditions. In the last decade several heavy magnes been assembled in passenger cars, such as gear box ho nk cases (Aghion, 2003).

Considerable research is magnesium processing, alloy development, joining, su , corrosion resistance, and mechanical properties improvement. Surface coatings produced for magnesium die-casting by hexavalent chromium baths have been used to provide stand-alone protection and as a pretreatment for painting. Teflon resin coating has been developed for Mg alloys; initially the coating is obtained with an aluminum vapor deposition and finish treatment with a Teflon resin coating. The Teflon resin coating is a low cost, chromium-free corrosion resistant coating for magnesium alloys. The coating not only has corrosion resistant properties, but also good lubricity, high frictional-resistance and non-wetting properties (Kulekci, 2008).

These new projects are concerned on the modification of existing and the development of new magnesium wrought products (sheets and extrusions), that provide significantly improved static and fatigue strength properties for lightweight fuselage applications (Development of material models and failure criteria for the prediction of forming processes, plastic deformation and failure behavior of components; material adapted design and the evaluation of structural behavior to close the process and development chain for aeronautic components).

The specific strength properties of these innovative materials are required to be higher than AA2024 for structural applications (secondary structure) and higher than AA5083 for non- structural applications. At the beginning of the project new alloys will be developed and experimental alloys will be tested. Appropriate manufacturing (rolling, extrusion), forming and joining technologies require development, simulation and validation for the innovative material and application (Hombergsmeier, 2011). The technological objective is a weight reduction of the fuselage structure, system and interior components up to 30 %. The strategic objectives are an increase in the operational capacity of 10 %, a reduction in the direct operating cost of 10 % and finally a reduction in the fuel consumption of 10 % and therefore a reduced environmental impact with regard to emissions and noise (Hombergsmeier, 2009).

Regarding corrosion is also a problem to be solved with newly adapted surface protection systems according to aerospace requirements and advanced design concepts. The addition of chemical elements and special surface treatments in magnesium to avoid flammability (auto-ignition temperature); Mg alloys with eutectic phases, low melting temperature, ignite first with comparative investigations to aluminum alloys (Hombergsmeier, 2011).

For those purposes there are nowadays some new techniques for the production of this kind of light alloys, notably: powder metallurgy (PM), which is essentially the process that leads small particles (from sizes in a range from nanometers to tens of micrometers) to a consolidation process that results in a uniform and fine grained structure material; spray forming techniques that relies in production processes which allows the production of parts and components by deposition of sprayed particles in semi-molten state that will consolidate in an injection mold with a substrate and metal foam. In addition the nanostructured materials have been the utmost in materials development due mainly to their particular relationship between microstructure of grains or hyperfine particles and mechanical properties, differentiated from those produced by conventional processes.

The development of solid state powder metallurgy makes it possible to increase the values of solute above the limits of conventional metallurgy arising a new era for the magnesium and aluminum alloys. Increasing the amount of "thirds" alloying elements gives to these alloys new characteristics such as high deformation rates at room temperature, refinement of microstructure (hyperfine grains or nanostructured materials), new conditions for cold and hot work processing, welding, wear resistance, increase of hardness as examples.

Also, recyclability of magnesium and aluminum alloys is a growing factor in choice for utilization in automotive industry, since nowadays it's possible to recycle up to 99% of parts and pieces made of magnesium and aluminum which reduces the costs with transportation and this is also good for the environment.

News production technologies search for minimize the quantities of energy employed in its processes and the recyclability shows an economy of 95% of energy comparing to that produce primary magnesium and aluminum generating an "ecological compensation".

Another influence in research for new technologies of materials and light alloys relies on the shortening of life of models. New materials and alloys are usually more expensive than commercial materials, so there is direct needs of investment in reduce the costs of production and development of such alloys allowing the utilization in large scale in the automobile production processes.

Despite the fact that the introduction of light alloys and new technology light alloys is a tendency not changeable, the utilization effective today still is more applicable to competition or sportive cars and motorcycles, due to the high costs previously mentioned. However if compared along the existence of automobile the employment of light alloys rise exponentially from the earliest up to the latest commercial model. The influence of 1970's in the development of such technologies is notable comparing with the few kilograms used in the first automobiles. All those factors contribute to new researches and development of this class of materials for structural and mechanical applications in automotive industry (transport).

Global effort in magnesium materials development has diversified in recent years, targeting new automotive, aerospace, and also in biomedical applications. The 1990s saw a strenuous effort in the tissue to regenerate without the use of a second surgery to remove the repair implant. Research in this field is focusing on the development of new magnesium alloys with low rates of biodegradation. Emerging areas of application for magnesium are the input for global effort in magnesium materials development. Interdisciplinary and international collaborations will be the key in developing magnesium to its full potential as an environmentally friendly structural material with wide-ranging applications (Beals et al., 2007).

A very interesting program to benefit the magnesium utilization is MagForming, an international project (12 different partners) with the aim to advance the state of the art in forming methods for a range magnesium alloys in extruded, sheet and plate forms using aerospace prototypes. This includes forging, superplastic forming, roll bending, pad forming, deep drawing and creep forming. The project aims to develop best practices for all of these methods via production of aerospace prototype parts. The data results in production of useful parts for testing, potentially leading to the use of magnesium in the system and structure areas from which the parts have been taken (Davis et al., 2009).

As mention earlier, magnesium alloys had been widely used in aircrafts up to the 1950s. Due to some major drawbacks such as high corrosion sensitivity and, under extreme conditions, flammability other materials, both metals and plastics, have increasingly replaced magnesium. Airbus is now reappraising the introduction of magnesium alloys in aircraft based on the results of recent research projects that suggest some promising applications for different alloys and product forms. Additionally Airbus is developing and investigating approaches for a lab scale fire testing procedure with the scope to ensure compliance with FAA-regulations on aircraft fire safety (Knüwer at al. 2009).

THE FUTURE OF LIGHT ALLOYS APPLICATION INCLUDING ENVIRONMENT ASPECTS

New energies that will substitute the mineral energy font (petroleum) and also nowadays the increasing emission of CO_2 in the entire world in the last decades lead to a special condition. So new regulations attempt to control or reduce emission and consumption has been created all over the world. In Europe the requirements also faced the reduction of production and maintenance costs and enhance the lifetime and reliability of automobile. All these conditions bring a wide field of possibilities for light alloys and new processes of production (Ditze, 1999; Kimura, 2002; Scharf, 2004).

Utilization of light alloys has as main advantages their lightness, this characteristic applied to the transport industry is related directly to the decrease of the pollution by gas emission. Some studies appointed that the reduction of 100 kg in net load lead to a mean reduction of combustible of 0.5 liter/100 km and 2000 kg less of CO_2 production during the mean life of the automobile. The increases in uses of light alloys in parts of automobiles make it much more efficient today if compared with those of the decade of 1970.

Production and application technologies must be cost effective for magnesium alloys to make magnesium alloys an economically viable alternative for the automotive industry. At moment, the energy consumption in light alloys processes production is equivalent to steel or iron alloys.

Close to eighty percent of total energy amount used in processing production of metals were dedicated only for aluminum, iron, copper, zinc and titanium since the mining to the final alloys. A good comparison is when including light alloys recycling process where a necessity of only fifth percent of necessary energy is applied (preservation of mineral).

The environmental benefits provided by lightweight, unlimited, and recyclable Mg alloy have the potential to grow significantly in the future if the global Mg industry is working together to demonstrate its stewardship by eliminating global warming SF6 or other protective gases as well as Be addition not only for environment and toxicity issues but also for the synergy of cast shop infrastructure with Al industry and by ensuring safety during manufacturing and application, especially without sacrificing process abilities and mechanical properties or increasing the cost of Mg alloy (Kim et al., 2009).

A matrix of potential recycling alloys has been set up to find a potential system for the recycling of heat resistant magnesium alloys. The matrix was processed via permanent mould casting. With the development of new heat resistant magnesium alloys, the automotive industry has introduced several parts to the drive train. The rising number of large magnesium components will result in a higher quantity of automotive post consumer scrap. A matrix of potential recycling alloys based on the Mg-4.97Al-0.3Mn alloy was prepared via permanent mould casting (Fechner, 2009).

The magnesium die casting is a production process which is used for many years for the serial production of different products. The technology used for that has been developed considerably further in the last years. Today the die casting process is a production process with a high grade of automation. Following the state of the art is explained, to describe with it the room for improvement with regard to environment, energy consumption and safety in the process guidance. The described technology allows new procedures so that efficiency and productivity of the die casting process increase. Results are shown by means of some examples, especially in the application of high-grade and thin-walled magnesium die casting (Erhard and Schlotterbeck, 2009).

Therefore the amount of weight of light alloys in transport vehicles which that will need more primary resources could be reduced and all the parts of the environment that would be preserved to the future is huge. At moment only 30% of recycled materials can be used in automotive industry. Notwithstanding of this, the industry announces that more than ninety percent of the vehicle can be recycled today. An environmental problem in automotive industry is the actual life cycle of a vehicle, today is near 3 years.

As mentioned before environmental conservation is one of the principal reasons for the focus of attention on magnesium to provide vehicle weight reduction, CO_2 emission and fuel economy. Weight reduction through Mg applications in the automotive industry is the effective option for decreasing fuel consumption and CO_2 emissions. Improvements in Mg alloying and processing techniques will make it possible for the automotive industry to manufacture lighter, more environmentally friendly, safer and cheaper cars.

Significant research is still desirable on magnesium processing, alloy development, joining, surface treatment, corrosion resistance and mechanical properties improvement to realize future targets to reduce the vehicle mass and the amount of greenhouse gases.

COMPARATIVE AND EFFECTIVE USE OF NEW MG ALLOYS

New light materials are effectively nowadays inserted in world strategies of automotive industry since the environment necessities for pollution and reduction of fuel consumption. Therefore the industry takes part of the risk of development of such alloys but, in fact, some of this has been made at academic level. It is possible to enumerate some aspects of the necessities and characteristics concerning those alloys: low costs, insulation (sound and thermal), impact safety, deformation strength, recyclability and guaranty (to aging as example). All those aspects are linked with the increasing of new automobile models and reflect in production programs more and more complexes.

Different joining techniques were applied to magnesium wrought semi-finished products, in order to promote their introduction on aeronautical structures. Airbus has performed some first tests to