ASSESSMENT OF MAGNESIUM VISION 2020

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Abstract - The goal of this study is to review and asses the use of magnesium alloys as successful substitute to the iron and steel in automobile industry to lower the impact of automotive industry on environment and achieve a greater fuel economy. Magnesium vision 2020 estimates that 15% of vehicle weight can be reduced by replacing iron and steel components with magnesium alloys. Advantages, technological barriers, future prospects, and limitations of magnesium alloys in automotive were discussed in this study. The recent development of new magnesium alloys to overcome the limitations of using ain applications at elevated temperatures such as corrosion and creep is also evaluated. The result of this study concludes that the limited magnesium infrastructure makes the replacement of heavy materials components in automobile is highly expensive in near future. More cooperation and collaboration among organisations on global level will lead to overcome the limitations over increasing use of magnesium in automotive industry. The accessibility of existing use of high steel strength infrastructure make high strength steel the main candidate to replace iron and steel component in vehicles.

Index terms - Magnesium Alloys, Magnesium Vision 2020, Limitations, Advantages, Competitors.

I. INTRODUCTION

One of the most important issues in this century is the negative human impact on the environment. Knowing that CO_2 is the largest polluting gas to the environment, many legislations in the industrialized countries- such as EU 2006 regulations have been taken to decrease the amount of CO_2 emission. One of the areas which has been looking at to decrease CO_2 emission is the automotive industry which is considered as the largest contributor of CO_2 emission .The global trend of automobile industry , especially in Euro region , is to do it in harmony with human and environmental (Shibata, 2008). Safety and environmental issues should be taken into account for new designs of automobile according to the European legislation and the amount of CO_2 emission should not exceed 90g/km. by 2020. These new legislations called for the need to improve the automobile technology to achieve the target. These improvements include better fuel consumption, lighter weight, less CO_2emission, and should be done with crash worthiness and cost competitiveness. One of the means to decrease CO_2 and improve fuel consumption is by decreasing the weight of the car. Using light weight materials such as Magnesium instead of steel in many parts of car components will decrease the weight, reduces Co_2 emissions and give better fuel consumption and cost. Furthermore, improved mechanical properties, cost competiveness, technical issues, and environmental performance should be taking into account prior to deployment of new material. Collaboration/cooperation among material suppliers, carmakers is becoming more important than ever. (Anup Bandivadekar 2008)

II. ENVIRONMENTAL ISSUES

As shown in the figure (1). The number of cars in the road is increasing every year and it is estimated to reach 1.4 billion cars by 2025. This increase in vehicles number has increased the fuel consumption and polluting emissions. The increase in oil consumption is expected to continue and reach the peak in 2015 and after that will decline. (Shibata 2008) Many countries have adopted rules that regulate the amount of polluting emissions such as (CO, CO_2 HC), in vehicle exhaust emissions. Kyoto protocol put plan for reducing CO_2 emissions in USA, Japan, and Europe. According to protocol the emission level need to be reduced by 6%. Figure (2) shows the relationship between fuel consumption and vehicle mass.

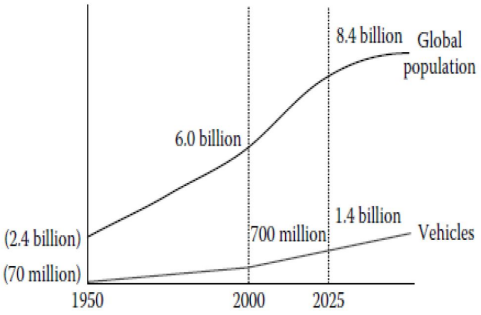


Figure 1 the number of the cars in period from 1950 and estimated in 2025 (Shibata 2008)

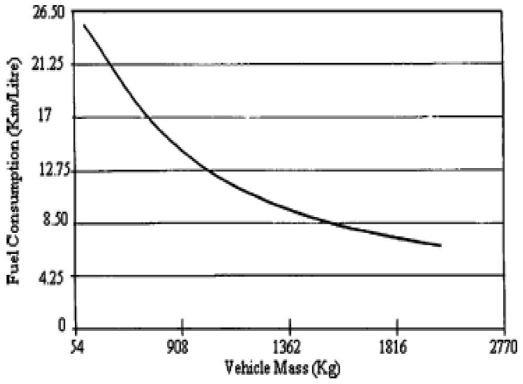


Figure 2 the relation between vehicles mass and fuel consumption. (kulekci 2008)

III. MARKET TREND

Global market of automobile industry is under high pressure of issues related to environment and government legislation. The automobile companies have to manufacture friendlier to environment, safer, lighter, and cheaper cars. To achieve that, companies are concentrating on reducing the weight of the car by using light materials and considering the other requirements that are shown in figure (3).

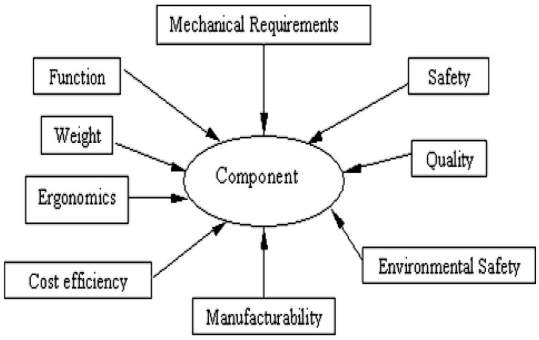


Figure 3 Basic requirements for vehicle components (kulekci 2008).

IV. MAGNESIUM VISION 2020 STRATEGY

The main purpose of using magnesium is to achieve weight reduction which leads to less emission and fuel economy with keeping reasonable production cost. Magnesium vision 2020 is to achieve average mass reduction 290 lbs. by replacing 630 lbs. of steel, iron, and aluminium with 340lbs. of magnesium. The driving force for materials realignment is technically, socially and politically. (USAMP 2006)

- The economic driver: magnesium must have equal function at reduced cost, or better function with equal cost. Any increased cost must be justified per weight unit saved.
- Technical driver: less component parts assembly due to alternating cast methods to high powder die casting (HPDC). The barriers of increase use of magnesium such as corrosion issues, alternate casting to HPDC method, low cost alloys coupled with low cost stamping, forging, and extrusion.
- Infrastructure requirement for supporting technological changes. The lack of magnesium infrastructure is the main barrier to increase the use of magnesium in vehicles, raising the cost so high of replacing the heavy materials. This can be overcome by collaborating and cooperation among global organisations to share the researches and developing new products.
- Social and Political driver: decrease emissions, less foreign oil imports, and fuel economy.

The current distribution of components materials in vehicle as following is shown in table (1)

Table (1) distribution of component materials in vehicles (USAMP 2006)

MATERIAL	WEIGHT (lb.)	VEHICLE %
Steel + Cast Iron	2,145	63.8%
Aluminum	278	8.3
Polymer/composites	255	7.6
Others	423	12.6
Rubber and Glass	249	7.4
Magnesium	*10-12*	*0.3*

Magnesium vision 2020 proposes reducing weight by 290 lbs. This weight saving can be obtained as following: Magnesium can replace Cast iron and steel at 50% weight reduction. Also 130lbs. Aluminium can be replaced by 90lb. of Magnesium at 31% weight reduction. A secondary weight savings about 210 lbs can be achieved by reducing the weight of chassis, power train, and suspension components. The total reduction of the weight of the vehicle will be about 500lbs making 15% of average vehicle weight. (USAMP 2006) Figure 4 shows the challenges of replacing iron and steel by new materials vs. time as a god example of transforming to the reduction of vehicle weight this philosophy depends mainly on various production processes in manufacturing different components.The total share of china grew from 48% in 2001 to 78% in 2006. The production of magnesium in USA is as secondary production. The major demand is covered by imports. Many countries announced to build new magnesium production capacity such as Australia, Canada and Egypt. Yet no one started because of financing expenses, and unaffordable market conditions. For that reason the current Supply of magnesium production, from Russia and china, will last for near future. In USA the availability of large amount of magnesium as secondary production and less demand of magnesium made the investors cautious about investing new projects. However the trends to produce light weight vehicles with better fuel consumption could increase tendency to increase use of magnesium in automotive applications. USA is the largest consumer of Magnesium, followed by Europe and Japan and used mainly as additive to Aluminium and only 34% is directly used for magnesium parts. The cost of car parts made of magnesium may be higher than aluminium. But the save in fuel consumption by using magnesium parts may compensate that difference in cost. The high cost of finished magnesium product is the main barrier for increase the use of magnesium in automobile industry. European and U.S. automakers have different criteria for utilizing magnesium. In the EU, weight reduction is used both to increase fuel efficiency (Consumers have to cope with gasoline prices that are two to three times those in NA.) and to reduce emissions (Impending EU 2006 regulations significantly reduce CO_2 tailpipe emissions). Mg in North America has been used at times to address Corporate Average Fuel

Economy (CAFÉ) requirements. European Original Equipment Manufacturers (OEMs) also use magnesium in their more expensive vehicles to improve drivability and performance by reducing weight in the front. (USAMP 2006)

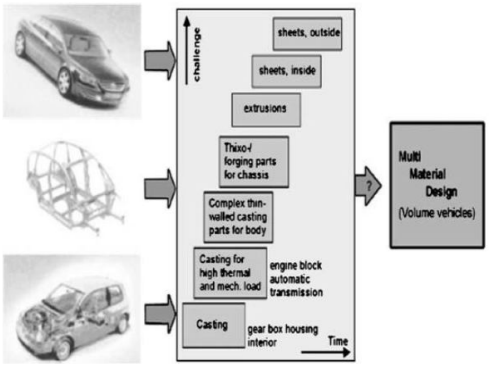


Figure 4 Illustration of vehicle weight reductionphilosophy (Kulekci 2008)

V. MAGNESIUM MARKET

The worldwide primary production of magnesium in 2006 was 689, 00 tones. The main production mainly Come from China, Russia, and Canada.

VI. MAGNESIUM ALLOYS

Mg-Al alloys series are the most important alloys of magnesium alloys group. Aluminium increases the strength of magnesium by solid solution mechanism where 11.5 % Al are soluble in mg at 437c. The microstructure of this group of alloys is characterised by (Mg17 Al12). However Mg-Al alloys are not stable at elevated temperature over 150c for long term. The super saturated solution transform to matrix of Mg with dispersed coarsely Al(Mg) precipitates causes grain boundary migration and creep deformation. Al(Mg) precipitates are also unstable and easy to be aged making Mg-Al alloys undesired at high temperature. However adding some other alloying elements can improve some of magnesium properties such as strength and hardness.

VII. MECHANICAL PROPERTIES OF MAGNESIUM ALLOYS

In the Design of automobile materials and structure where the energy consumption is the main concern, the specific strength, specific stiffness and light weight properties are highly required. Magnesium alloys have these properties but they suffer of low creep resistance even at low temperature. It is one of the challenges that magnesium face to increase its use in automobile industry. Magnesium alloys have to meet the requirements of automobile components especially strength and creep at elevated temperature. Magnesium has slightly lower specific stiffness in comparison with aluminium, and iron, on the other hand, specific strength of magnesium is significantly higher than aluminium and iron. The grain boundary sliding is the main mechanism of creep in magnesium alloys in the stress-temperature range of automobile applications. While at low temperature magnesium creeps by stress-recovery mechanism where the slip takes place in the grain and sub grains. At high temperature the creep takes place by diffusion – dependant mechanism. Magnesium components in automobile should have high strength, castability, creep resistance, good corrosion resistance and have stable phases at high temperature. To achieve that, new alloys have been produced such as AE42 alloys which have good creep resistance. The recent developed magnesium alloy is Mg-Al-Sr. This alloy has very good mechanical properties, corrosion resistance, better creep resistance, and excellent castability. The experimental investigations showed magnesium alloys such as AM20, AM50, and AZ91 have significantly better buckling properties than mild steel and aluminium alloy 6061 T6 of same weight, but less than that of same thickness. This gives the magnesium superior characteristics where good energy absorbing with less mass. Magnesium is also better than plastic in terms of both stiffness and strength ratio. To achieve the same stiffness of steel, the thickness and mass of plastic should be 4.5 times of that of steel and 0.65 of steel weight. This represents 2.7 and 1.66 times of magnesium thickness and mass respectively. And also to achieve the same strength of steel, the thickness and mass are 1.73 and 1.07 times that of magnesium.

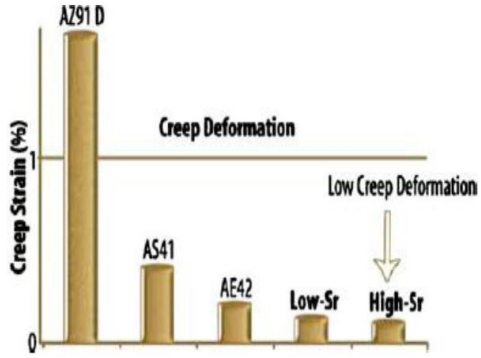


Figure 5 creep deformation of Mg alloys. (Kulekci 2008))

VIII. MG ALLOYS APPLICATIONS IN UTOMOTIVE INDUSTRY

BMW Company manufactured Mg-Al alloy engine (R6), which is the lightest engine of 3.0 litres in line six-cylinder gasoline series in the world (161 kg). BMW managed to reduce the fuel consumption during the period of 1990-2007 by 30%. The light weight of magnesium enabled the engine R6 the lowest specific fuel consumption and best power to weight ratio with less parts and engine assembly work. Mercedes-Benz manufactured 7G-tronic seven speed automatic transmission without any in increase in weight by using magnesium. Audi also reduced the

weight of Audi V8 Quattro model engine 5kg by using Mg components. Steering wheel is made of magnesium alloy. Instrument panel of GMH van vehicle is made of Mg alloy giving better crashworthiness and less weight than that made of steel. Ford also changed the tubular steel, extruded aluminium and melded plastic composites materials with AM-60 MG alloy. AM20 and AM50 Mg alloys used in cars seats structure. Fig(6) Some of automotive components made of Mg. (Kulekci 2008). Developing new magnesium alloys such as high-ductility AM20 and AM50, and corrosion resistance AZ91E increased the use of Mg. 90% of magnesium alloys is consumed by automotive industry. Examples of standard parts made of Mg alloys are: core parts, transmission cases, intake manifolds, are shown in figure 7.

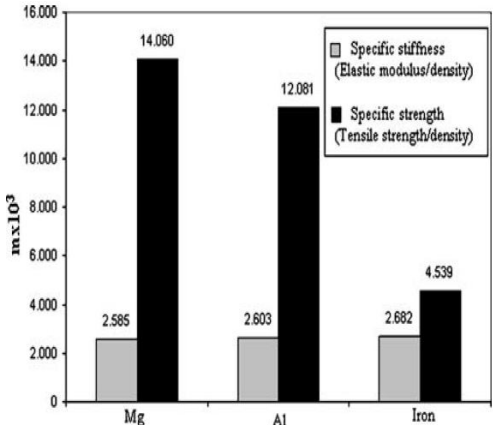


Figure 6 comparision of basic structural properties of Mg with Al and Iron. (Kulekci 2008)

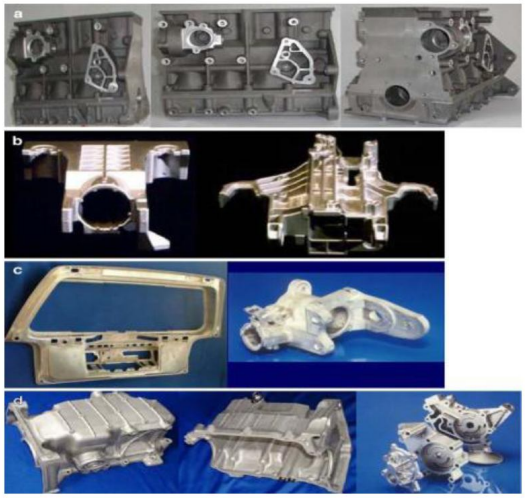


Figure 7 Magnesium components in automobile (Kulekci 2008)

IX. TECHNOLOGICAL BARRIERS AND SOLUTIONS

The disadvantages of magnesium alloys are poor galvanic, fatigue, and creep corrosion resistance, and the high reactivity in molten salt. The major problem of magnesium alloys is the fire hazard during fabrication and usage. This hazard can be overcome by avoiding dull tools and, fine cuts and high speed. The use of proper coolant system and tool design is very necessary to avoid accumulation of chips and dust on machines. The other problem of magnesium is the reactivity as magnesium exists in the nature as compound, therefore, the process of production requires huge amount of power adding extra cost and making magnesium relatively expensive. Two mechanisms of magnesium reactivity can take place, either, by reacting with oxygen or water and form oxides, or by activating galvanic action as magnesium is at the bottom of galvanic series. To overcome reactivity problem mg alloys can be painted by anodic coating. Welding of magnesium alloys can cause the risk of fire if the molten metal exposed to the air. To prevent this problem, the welding needs to be shielded by inert gas or flux. All magnesium alloys must be used in the region of temperature well below the melting point; otherwise the possibility of fire exists. Magnesium alloys can contain inclusions if precautions are not taken in the refining process. These inclusions don't float to the surface. To overcome this problem the method of refining should include sparking the molten with argon, which brings dross to the surface which can be skimmed off.

Mg alloys easy to corrode in chloride environment which limited the practice of these alloys in many applications. However, these disadvantages can be alleviated by using a good design and applying the safety concepts.

X. COMPETITORS OF MAGNESIUM

There are five main materials that can be used to substitute heavier iron and steel in the vehicle. High strength steel, aluminium, plastic, polymers and composits. The properties of these materials are summarized in the table 2

Table 2 Mg competitors in automobile industry

Material	Density, g/cm³ (relative)	Yield strength, MPa	Tensile strength, MPa	Elastic modulus, GPa	Relative cost per part [Powers 2000]
Mild steel	7.86 (1.00)	200	300	200	1.0
High strength steel (A606)	7.87 (1.00)	345	483	205	1.0-1.5
Iron (D4018)	7.10 (0.90)	276	414	166	-
Aluminum (AA6111)	2.71 (0.34)	275	295	70	1.3-2.0
Magnesium (AM50)	1.77 (0.23)	124	228	45	1.5-2.5
Composites - Carbon fiber - Glass fiber	1.57 (0.20)	Flexural: 200	810	190	2.0-10.0

HIGH STRENGTH STEEL (HSS): HSS is much desired alternative automotive material because it makes use of existing vehicle manufacturing infrastructure, and there is Original Equipment Manufacturers (OEM) back for short-term use. The challenge for this material is to develop technologies to make the use and production of these new materials economically viable on large volume scale. Currently one-fifth of steel in automobile is high strength steel. The existing knowledge and infrastructure of high strength steel and low production cost make HSS is the highest candidate to increase use in vehicle and replace the structural steel parts. (Luo 2002)

ALUMINIUM: most of aluminium used in automobile is cast and mainly used in the engine, drive line, transmission, and wheels and this consists about 9% of materials used in the automobile. It is projected by many researchers such as Ducker that the use of Aluminium in automobile applications will reach 144kg in near future. Aluminium is more difficult to form than steel and harder to spot welding. The higher cost of aluminium is considered the main barrier to overtake steel in the near –term use. . Aluminium will show also increase in use in vehicle due to more cost-effective at large production volume scale in comparison with magnesium and polymers due to the existing manufactures familiarity, and infrastructure. Cast aluminium use is likely to increase and substitute cast iron components such as stamped aluminium for stamped steel panel body. (Wallentowit 2003)

PLASTIC, POLYMERS AND COMPOSITES: plastic and polymer make up 8% of vehicle weight and about 50% of volume and these percentages are expected to increase slowly. Glass fibre reinforced thermoplastic polypropylene is the most common type of automotive composites which is applied to roofs, rear hatches, door surrounds, door inner structures, and brackets for the instrument panel. Other types include sheet moulding compounds made of glass fibre reinforced thermoset polyester, and glass fibre reinforced thermoset vinyl ester. Carbon fibre reinforced polymer (CFRP) is less popular because of its cost, although it offers good strength and weight saving benefit. The main factors that restrict the growth of polymer composites are the long production cycle times, the cost of fibres and the infrastructure to deliver large quantities and the recycling system of composites at the end of the vehicle life and the high impact on environment during the process of both production and recycling. (Luo 2002)

CONCLUSION

Better fuel consumption and emission reduction can be achieved by reducing the weight of the vehicles. This weight saving can be done by replacing the conventional heavy material with lightweight materials. One of the candidates to achieve the goal is magnesium. Magnesium vision 2020 propose that 5oo lbs. weight saving equivalent 15% (primary and secondary savings) can be feasible by replacing many vehicle component made of steel and aluminium. There are many barriers restrict the increase use of magnesium in auto vehicle industry. The main barrier is the limited magnesium infrastructure either that related to R&D centres or the production plants that produce raw material. These barriers cause in highly cost of increasing use of magnesium in a large scale. High strength steel is major candidate to continue increase of the near-term use due to the existing infrastructure that makes it much cheaper than magnesium. Aluminium is also likely to continue due to manufacturer`s familiarity with this material. The enhancing the researches and development activities simultaneously with global collaboration and cooperation among organisations will lead to overcome the limitations of magnesium use.

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