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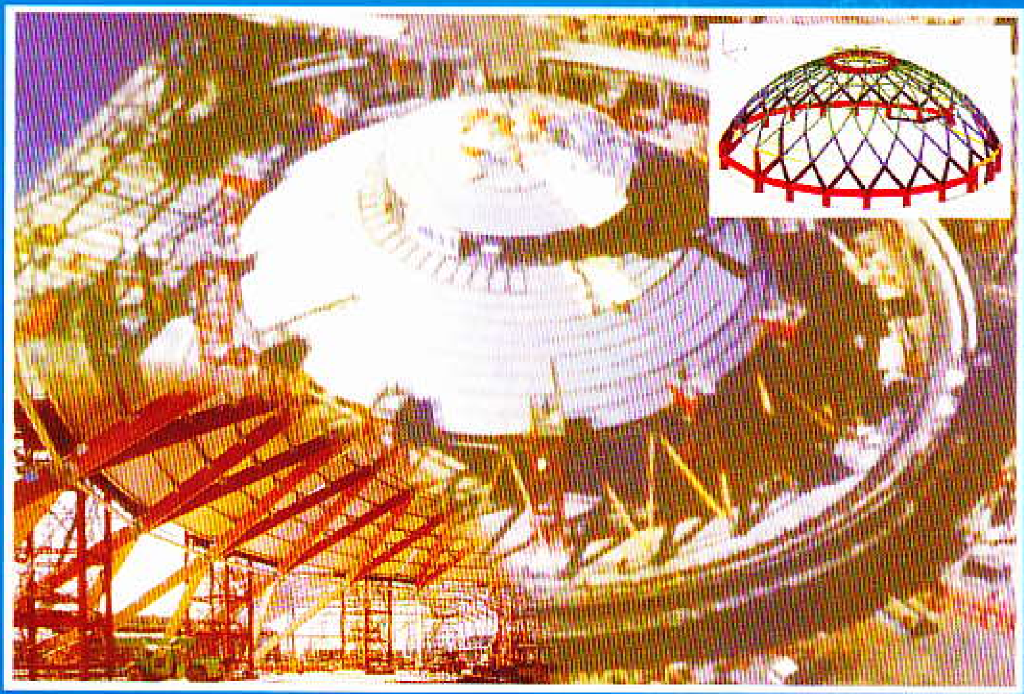

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LEMBAR PENGESAHAN

Judul : Potentiality And Drawback On The Application Of Magnesium And Its Alloy In Automobile Industry

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Jurnal Kajian Teknologi Fakultas Teknik Universitas Tarumanagara terbit pertama kali pada Nopember 1999. Redaksi mengundang para profesional (dari dunia usaha, pendidikan & peneliti) untuk berpartisipasi mengembangkan profesi dan menyebarluaskan perkembangan ilmu melalui penelitian maupun kajian dan studi tertentu di Jurnal Kajian Teknologi yang diterbitkan 2 (dua) kali setahun pada bulan Mei dan Nopember.

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EDITORIAL

Penerbitan Jurnal Kajian Teknologi (JKT) Fakultas Teknik Universitas Tarumanagara kali ini memuat 7 (tujuh) makalah yang mewakili bidang-bidang ilmu yang ada di Fakultas Teknik Universitas Tarumanagara. Hal ini sungguh sangat menggembirakan sekaligus mudah-mudahan dapat memberikan kontribusi kepada perkembangan lembaga.

Para penulis kali ini bukan hanya diwakili oleh civitas Universitas Tarumanagara, tetapi juga ada beberapa rekan-rekan dari beberapa institusi di luar UNTAR, yaitu : Jurusan Teknik Sipil FT Universitas Lampung, Jurusan Teknik Mesin FT Universitas Lampung dan dari Jurusan Teknik Mesin Universitas Bengkulu.

Bidang Arsitektur diwakili oleh 1 (satu) makalah yang membahas tentang struktur dasar sebuah bangunan yang ada dalam bidang arsitektur. Bidang Teknik Sipil yang diwakili 1 (satu) makalah yang membahas tentang pengaruh *filler* terhadap deformasi permanen campuran beraspal. Bidang Teknik Mesin diwakili oleh 4 (empat) makalah yang berasal dari institusi luar 2 (dua) makalah dengan bahasan tentang teknik *forecasting* untuk penentuan kehandalan mesin *roller mill* dan *potentiality and drawback on the application of magnesium and its alloy in automobile industry*. Sedang 2 (dua) makalah dari Jurusan Teknik Mesin FT Untar, membahas tentang identifikasi kekerasan permukaan material pada proses bubut dengan kecepatan potong tinggi dan pembahasan mengenai peta kendali proses tebal *bracket* tipe STD di PT. A. Makalah ilmiah dengan pembahasan mengenai pengkodean Huffman dalam perancangan dan implementasi enkripsi data merupakan perwakilan dari Jurusan Teknik Elektro. Pembahasan yang dapat memberikan sumbangan pada usaha pengembangan bidang ilmu teknik dan sumber daya manusia ini, akan memberikan kontribusi dalam usaha meningkatan mutu jurnal. Atas dasar tersebut, redaksi ingin mengucapkan banyak terima kasih kepada seluruh penulis yang telah dan akan turut serta dalam penulisan di JKT selama ini. Mudah-mudahan *trend* seperti ini dapat terus menjadi ciri dari JKT pada penerbitan-penerbitan yang akan datang.

Akhir kata, Redaksi berharap dan mengundang kepada seluruh rekan-rekan penulis serta calon penulis ilmiah bidang ilmu teknik (Arsitektur, Teknik Sipil, Planologi, Teknik Mesin dan Teknik Elektro) dapat turut serta berpartisipasi dalam usaha penyebaran dan pengembangan ilmu dengan menyumbangkan karyanya pada penerbitan-penerbitan yang akan datang. Selamat membaca.

BAS

POTENTIALITY AND DRAWBACK ON THE APPLICATION OF MAGNESIUM AND ITS ALLOY IN AUTOMOBILE INDUSTRY

By:

Irza Sukmana[*)]

Abstrak

Penemuan material baru memegang peran kunci di dalam pengembangan teknologi di masa yang akan datang. Saat ini, paduan magnesium merupakan material baru yang telah digunakan pada berbagai aplikasi, dimana setiap paduan memiliki keunikan sifat fisik dan mekanik tersendiri, bergantung pada unsur paduan utamanya. Perkembangan terbaru dalam pengembangan Magnesium menunjukkan potensialitas yang tinggi di dalam aplikasinya di dunia industri otomotif, namun sifat ketahanan korosi yang rendah dan tingginya biaya produksi merupakan hambatan utama. Artikel ini mereview berbagai informasi mengenai magnesium dan paduannya, seperti: sifat mekanik, aplikasinya di bidang otomotif, sifat korosi dan ketahanan creep, serta biaya produksinya.

Keywords: magnesium, aplikasi di bidang otomotif, sifat creep, dan ketahanan korosi.

INTRODUCTION

The demands made of new materials are increasing rapidly. Consequently there is a new kind of inter-metallic alloy based on titanium with a property profile that combines the advantages of metallic and ceramic materials. It can be used at a high temperature and is also light and extremely rigid yet pliable and tough. There are also magnesium-based materials, developed for more extensive use in automotive technology to advance the potential for the use of metallic materials in lightweight construction compared to that of polymeric materials.

The automotive industry is striving to produce lighter vehicles. At present this is achieved through the use of ultra-light steels, aluminum alloys and magnesium alloys for some body parts. Magnesium has the highest strength-to-weight ratio of any structural metal so engineers are keen to use as much magnesium as possible in their vehicles. However, magnesium alloys creep, even at room temperature, restricting their use.

Typical uses of magnesium alloys are not only in automobile industry but also for aircraft and missile components, material-handling equipment, portable power tools, ladders, luggage, bicycles, sporting goods, casing computer and electronic products, and general lightweight component. The use of magnesium is also being increased, there has been significant growth of magnesium in averaging almost 20% per annum worldwide [1,6,15].

Magnesium is the one of lightest metal available and also has good vibration-damping characteristics. Its alloys are used in structural and nonstructural applications where weight is of primary importance. Magnesium and its alloys have a fairly good corrosion resistance under normal ambient condition, but it tends to corrode strongly in chloride, sulfate, carbonate and nitrate containing solutions [2,4,5,6].

MAGNESIUM ELEMENT

Magnesium (Mg) is the third most abundant metallic element (about 2.5%) in the earth's crust, after iron and aluminum. Most magnesium common from seawater, which contain about 0.14% magnesium in the form of magnesium chloride [2,4,14].

*) Jurusan Teknik Mesin Universitas Lampung

Magnesium is a light silvery-white metallic element of the alkaline earth series, occurring principally is in Carnallite ($MgCl.KCl.6H_2O$), Dolomite ($MgCO_3.CaCO_3$), and Magnesite ($MgCO_3$): used in light structural alloys, with symbol of Mg. Magnesium has an atomic number 12 and atomic weight 24.312 and valency number 2. The relative density of Magnesium is 1.738 and melting point on 651°C. Pure Magnesium have a crystal structure close packed hexagonal (hcp) (a=3.2030 c= 5.2002) [2,14].

Magnesium element was first isolated in 1808 by the English scientist Davy, but it was not until 1852 that Bunsen demonstrated that magnesium metal could be isolated by electrolysis of fused anhydrous magnesium chloride, magnesium being released at the cathode and chlorine at the anode of the cell.

A German company, Chemische Fabrik Griesheim Elektron (now known as **Magnesium Elektron Co.**), first exploited the commercial possibilities of the electrolytic method of production in 1909. By the 1920's, the electrolytic process had been worked out on an industrial scale and the metal became available in commercial quantities to justify its use as a structural material.

Today, magnesium is used in a diverse range of markets and applications, each one exploiting the unique physical and mechanical properties of the element and its alloys. World production of magnesium totals 415,000 tonnes per annum and the figure is increasing annually as the lightweight properties of magnesium alloys are used increasingly in the automotive industry as a means of reducing weight, increasing fuel efficiency and reducing greenhouse gas emissions. [15]

MAGNESIUM ALLOYS

The principal mechanism which magnesium may strengthen alloys is precipitation strengthening, which usually involves aluminum compounds. Magnesium alloys have been developed for a variety of applications where low density is more important than strength. Table 1 explains about lists alloy compositions of casting magnesium alloys.

Table 1: Alloying elements used in die casting magnesium alloys.
The elemental compositions are all given as percentage weight (ASTM B-93) [2,14]

Alloy	Al	Zn	Si	Mn	RE	Cu	Fe	Ni	Others
AM20	1.7-2.2	<0.1	<0.1	>0.5		<0.008	<0.004	<0.001	<0.01
AM50	4.5-6.3	<0.1	<0.1	>0.27		<0.008	<0.004	<0.001	<0.01
AM60B	5.7-6.3	<0.20	<0.05	>0.27		<0.008	<0.004	<0.001	<0.01
AS41A	3.7-4.8	<0.10	0.60-1.4	0.22-0.48		<0.04		<0.01	<0.30
AZ91D	8.5-9.5	0.45-0.90	<0.05	>0.17		<0.015	<0.004	<0.001	<0.01
AE42	3.6-4.4	<0.20		>0.27	2.0-3.0	<0.04	<0.004	<0.004	<0.01
ZC63		5.5-6.5		0.25-0.75	1.8-3.0	2.4-3.0			

Magnesium alloys are designated as follows [1,14]:

a. One or two prefix letters, indicating the principal alloying elements,
b. Two or three numerals, indicating the percentage of the principal alloying elements, rounded off to the nearest decimal.
c. A letter of the alphabet, except the letters I and O, indicating the standardized alloys, with minor variations in composition.
d. The temper of the material, indicated by the same symbols used for Al alloys.

For example, the alloys AZ91C-T6 indicated that:

- The principal alloying elements are aluminum (A, 9 percent, rounded off) and zinc (Zn, 1 percent)
- The letter C, the third letter of the alphabet, indicates that is the third alloy standardized, after A and B, which were the first and second alloys, respectively, that were standardized
- T6 indicated that this alloy has been solution treated and artificially aged.
- The alloying element and its impurities of Magnesium alloys can be divided into several terms as follow:
  - Major Elements: Al, Zn, Mn, where AM series mean Al and Mn as major elements, and AZ series mean Al and Zn elements as major elements
  - Minor Elements: Sn, Zr, Ce, Th, and Be
  - Impurities: Cu, Fe, Ni

POTENTIALITY AND APPLICATION IN AUTOMOBILE INDUSTRY

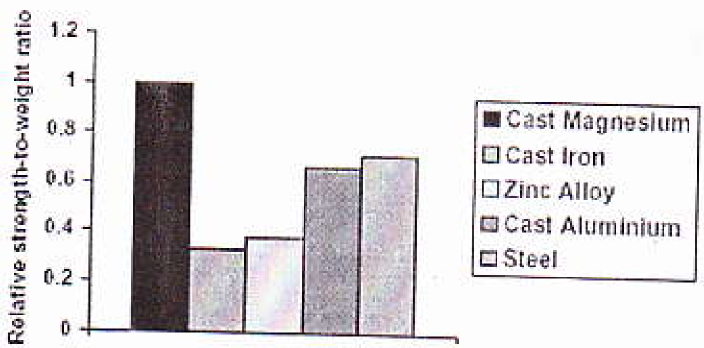

Figure 1. Strength–to–Weight Ratio of Common Steel Relative to Magnesium

The potential of magnesium alloy in the application in general are the very high strength–to–weight ratio, good castability and good machinability, as explain on Figure 1 and Figure 2 as follows [7, 10].

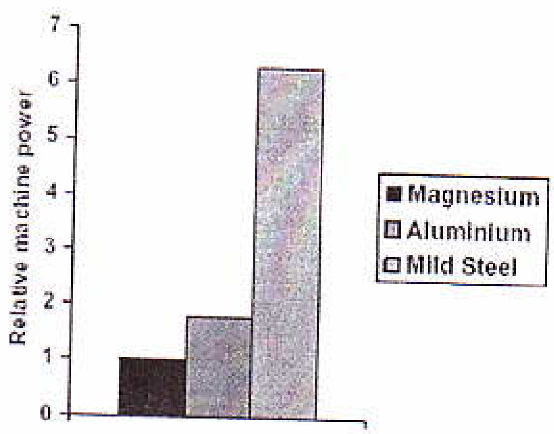

Figure 2. Machine Power Needed to Perform Another Alloy Relative to Magnesium

Application in Automobile Industry

Magnesium is increasingly becoming an attractive alternative to steel, aluminum, and polymer composites for vehicle weight reduction due to its ability to meet vehicle performance requirements. The weight reductions have been made possible by the replacement of steel by light metal alloys, usually aluminum or magnesium. In production vehicles, the weight is saved through the use of lightweight steels, which have reduced the weight of cars by 10% since 1978, without compromising safety [7,13].

Beside that, Customers' awareness of fuel efficiency has been made more acute by increasing fuel prices and the popularity of environmental issues. Car manufacturers are also affected by legislation to control air quality, such as the European Union directive that cars should produce less than 120 g of CO2 per kilometers by 2005, and are approaching this problem by attempting to reduce the weight of their cars. "Concept cars" produced in recent years have been lightweight, for example, the Ford P2000 which weighs only 544.3 kg [7]. The potential for weight saving by using magnesium is about 6%: 77kg for a medium sized car, as on Figure 3 [7].

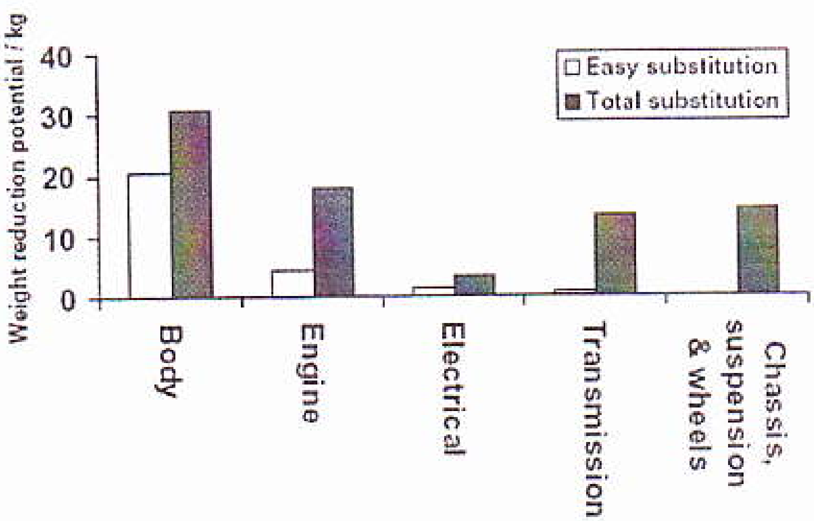

Figure 3. Potential weight reduction by using magnesium alloy

There are some common applications of magnesium alloy in automobile industry as on Table 2.

Table 2. Magnesium components currently used by car manufacturers [7,10,15]

Component	Car manufacturer
Hand brake lever	Porsche
Instrument panel	General Motors, Smart, Buick, Cadillac
Intake manifold	Diamler Chrysler
Oil pan	Honda
Steering wheel	Ford, Lupo, Volkwagen
Cylinder head cover door	Lupo
Pedal bracket	General Motors, Ford
Seat cushion	Smart, Fiat, Jaguar
Radiator support	General Motors
Cam cover	Ford
Grill sections	Pontiac

DRAWBACK OF APPLICATION IN AUTOMOBILE INDUSTRY

Even though there are some potentiality in the application of magnesium alloy, but there are some restrictively applications of Magnesium alloy in Automobile Industry such as poor corrosion performance, creep resistance and relatively high of production cost of magnesium alloys.

Corrosion Behaviour of Magnesium Alloys

The relatively poor corrosion performance of magnesium alloys is a major issue, which limits their application. Currently, the use of magnesium alloys in the automotive industry is mainly limited to components in mild service environments. For those parts exposed to outside environments, corrosion is still a serious issue [2,6,7,10,14]

Unalloyed magnesium is not extensively used for structural purpose, consequently the corrosion resistance of magnesium alloys is primary concern. The corrosion resistance of magnesium alloys depend on two critical factors, there are [5,6,8,13]:

- The effect of alloying elements and
- The effect of Microstructure

The of elements on the saltwater corrosion performance of magnesium in binary alloys are:

- Aluminum, manganese, sodium, silicon, tin and lead have little effect on pure magnesium when their solid solubility of max. 5%
- Cadmium, zinc, calcium, and silver have mild to moderate accelerating effects on corrosion rate of magnesium alloys
- Increasing of iron, nickel and copper contamination of magnesium alloys will increase the corrosion rate. For the AM and AZ series that contain manganese, the iron tolerance would be maximum 0.032 w%.

The effect of Microstructure on corrosion behavior of different type of Mg alloys (AZ, AM series) can investigate with standard electrochemical techniques. The determination of corrosion rates and corrosion potentials can be investigated with potentio-dynamic experimental technique to have the polarization curve at the surface of Mg alloy.

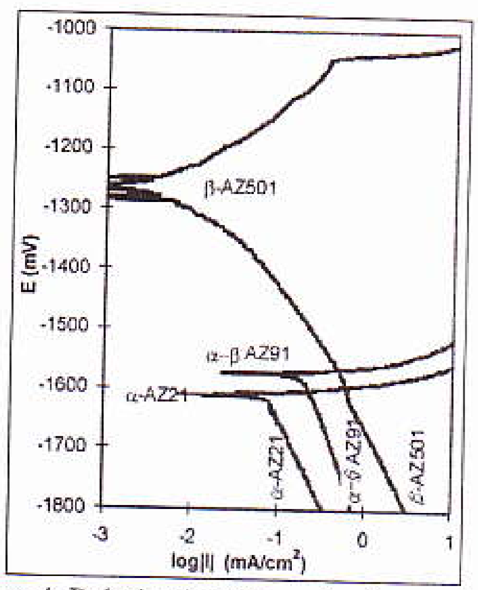

Figure 4. Polarization Curve for β, α and α-β eutectic phase of Mg alloy

There are three types of Magnesium microstructure phase: Mg-αphase, Mg-βphase, and eutectic phase. The polarization curves clearly indicate that the Mg-αphase is the more active phase with a corrosion potential approximately 200 mV lower than the eutectic phase [3,6,9,12]

The βphase ($Mg_{17}Al_{12}$) has a dual effect on the corrosion reaction, where it can be an initiator of corrosion and it also acts as a barrier to corrosion growth in the matrix. In general, β-phase has a good corrosion resistant and normally not corroded if exposed to a sodium chloride.

The best corrosion resistance is obtained when there is a fine grain of alloys microstructure. The β phase forms a network around the α matrix with many corrosion barriers; there is a typical microstructure for a good quality of magnesium die-casting alloys.

The Polarization curves of β phase, α phase and α–β binary phase are presented by G. SONG et. al., as shown on Figure 4 [6,9].

Creep Resistant Behavior of Magnesium Alloys

The most economic use of magnesium in the automotive industry presently is in diecast applications because of the high productivity of the diecasting process that upsets the cost of the Mg metal. The current commercial magnesium alloys developed for diecasting applications fall into two classes. The first group is based on the Mg-Al system and Mg-Al-Zn systems (AM and AZ alloys). These alloys have been developed for good room temperature strength and/or ductility but do not exhibit good creep resistance. They make up the bulk of the Mg alloys used in automotive applications [7,16]

The second group of alloys has been developed for improved elevated-temperature performance. These alloys are based, for the most part, on the Mg-Al-RE and Mg-Al-Si systems (AS alloys) developed by VW in the 70's. The AS alloys (AS21, AS41) offer only borderline improvement in creep resistance. The AE alloys (AE42, AE22, AE51 etc), despite their good creep resistance, have cost disadvantages due to the expensive rare earth additions. The AE alloys also have other shortcomings such as poor diecastability, high oxidation rate, low fatigue resistance.

The Noranda alloys (Noranda is a Canadian Magnesium Producer) have been produced as a new magnesium alloy with better creep resistant, as shown in Table 2. [7,16]

Table 2. Some Magnesium product with better creep resistant

ALLOY	TENSILE STRENGTH* (MPa)			YIELD STRENGTH* (MPa)			ELONGATION* %			CREEP (%)** (35MPa, 200 hr)		CORROSION RATE***
	R.T	150°C	175°C	R.T	150°C	175°C	R.T	150°C	175°C	150°C	175°C	(mg/cm²/day)
AZ91	239	170	138	157	105	89	4.7	18.0	20.5	1.21	1.84	0.10
AE42	226	142	121	135	87	81	9.2	22.5	23.1	0.07	0.14	0.21
Noranda A1	202	164	148	145	108	103	4.0	13.6	14.8	0.03	0.09	0.09
Noranda A2	233	149	133	138	102	97	8.8	16.4	21.4	0.07	0.05	0.14
Noranda N	236	152	137	133	101	98	10.3	16.4	20.1	0.12	0.06	0.13
AS41	249	153	127	132	94	85	8.9	16.8	18.0	0.13	0.5	0.16
A380	290	255	248	155	149	154	3.2	6.4	7.1	0.18	0.15	0.34

Production Cost of Magnesium Alloys

Despite magnesium being abundant, it has been nearly twice as expensive as aluminum in recent years (Fig. 5). One of the reasons for the high cost is the relatively low demand for magnesium metal. Magnesium is extracted either from ores such as dolomite, magnesite and carnalite or from seawater. The extraction process involves processing the ore or brine to make MgCl2, which is then split by electrolysis to give pure magnesium [7].

The cost of AE42 makes it too expensive to use in automobiles and alternatives with lower costs are currently being developed. Several alloys based on the Mg-Al-Ca system (ACX alloys) have been investigated for creep-resistance. Norada alloys have been also developed to meet the need for a creep resistant magnesium alloy.

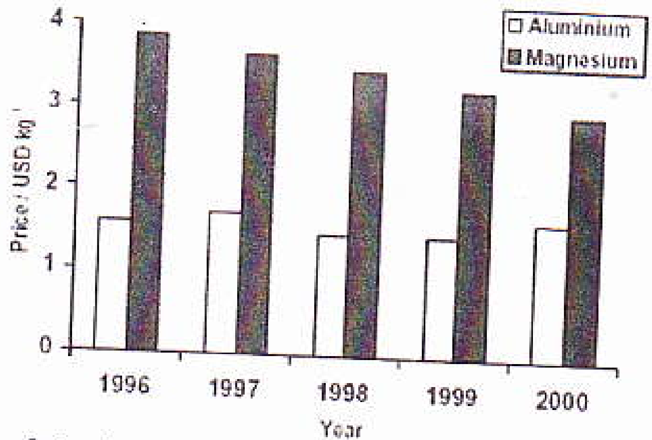

Figure 5. The price of aluminum and magnesium ingots over the five years 1996-2000

SUMMARY

Magnesium Alloys is a new solution material in engineering fields, especially in automobile industry application. Magnesium alloys solves the problem where weight is the most constrain in engineering application. There are some potential and drawbacks on the application of magnesium alloy in automobile industry. A new magnesium alloy show good result due to tensile strength, elongation, creep properties and corrosion resistance explaining a good solution of its application in automobile industry.

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