# EFFECT OF HOT FORGING FOR AUTOMOTIVE APPLICATION

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## ABSTRACT

*The present work is investigated to desire properties for connecting rod which is use in automobile industry. AZ31 alloy was processed by hot forging at different 300 $^0$C temperatures. Then the relationship between tensile properties and microstructural parameters including grain size were investigated by using tensile test along perpendiculars to forging direction. After hot forging, the grain structure of the AZ31 alloy ring is significantly refined. Microstructure evolution of the specimen during the Forging process was investigated and correlated with the mechanical properties. Upon Forging, the material undergoes pronounced grain refinement but an inhomogeneous grain structure is formed due to the inhomogeneous strain distribution between the center and edge regions. Tensile tests show a significant improvement of mechanical properties after forging.. Among the experimental forging temperatures, 350 °C is favored to get more uniform mechanical properties across the specimen. Significant mechanical anisotropy is found for the sample and attributed to varied deformation mechanisms along different directions. Effects of grain size and texture on mechanical behavior are discussed.*

**KEYWORD:-** *EFFECT OF HOT FORGING, MECHANICAL PROPERTY, MAGNISIUM ALLOY, AUTOMOTIVE APPLICATION*

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### 1.1 Introduction

Now day's interest is focusing on the increasing demand for more fuel-efficient vehicles to reduce energy consumption and air pollution that are a challenge for the current automotive industry. Powered by needed, the researchers did many research so that they could get the appropriate content that meets the requirement Parts of the vehicle[2,3,6]. Castings of most metals are traditionally ironed, however, with greater emphasis on increased engine efficiency through weight loss, manufacturers are looking for alternatives alloys which are lighter than cast iron, which inspire the industry to move in aluminium alloys and other non-phases mixed, such as magnesium, which they believe can maintain the strength needed to withstand the same force Cast iron as. The weight of the car affects the fuel consumption and performance, overweight fuel consumption and performance decreased [2,5,17 ]. According for the research done by Julian allowed of the University of Cambridge, global energy use can be overwhelming Lighter cars were reduced by using, and the weight of 500 kilograms is being received well[17,18].

Automotive industry, due to being specialty the biggest potential for development is getting one important users of magnesium content. Use of Magnesium was limited to vehicles in decades casting of complex shapes for engines and wheels [8]. Traditional die-casting for traditional reasons the possibility of using components from magnesium Content with chassis and drive is going now is believed[4].
Magnesium alloys are taking a great research interest in light metal structure materials, automobiles, aerospace, weapons, electronic and other fields for engineering applications, because of their low density, high specific strength and hardness, good damping characteristics, as well as With excellent buyer[8]. Especially in the field of automobile industry, magnesium alloys have replaced steel, cast iron and aluminium alloys because they can reduce the weight of vehicles, which contributes to fuel economy and reduces CO2 emissions. **[**2].

**1.2 Background and Motivation**

Over the past decades leading automobile makers have used magnesium-based materials in their automotive parts such as gearbox housing, steering wheel, fuel tank cover, air bag housing and suspension systems however its role as a major material for auto-body manufacturing is still challenged.

Following advantage use of magnesium alloy motivate me to work on magnesium alloys:

**1.2.1 Recent research**

Auto manufacturing companies have made the most of research and development on Mg and its alloys. Recent research and development studies of magnesium and magnesium alloys have focused on weight reduction, energy saving and limiting environmental impact.

**1.2.2 Fuel Saving**

Weight reduction of 100 kilograms represents a fuel saving of about 0.5litres per 100 kilometres for a vehicle

**1.2.3Environmental Conservation**

Environmental conservation is one of the principal reasons for the focus of attention on Mg and its alloys. A lightweight part made of magnesium on a car may cost more than that of aluminium, but Mg cost compensates for Al cost due to reduction in fuel and CO2 emission.

Therefore, it is essential to examine the mechanical performance of magnesium alloy component manufactured by forging method.

**1.3Magnesium Alloy**

This is the eighth most lavish element. Elemental magnesium is a gray-white lightweight metal, two-thirds the density of aluminium. It tarnishes slightly when exposed to air. Its atomic number (*Z*) 12, group 2,s-block, and elemental category alkaline earth metal. Its physical properties are Phase-solid, Melting point - 923 K (650 °C, 1202 °F), Boiling point - 1363 K (1091 °C, 1994 °F), Density - 1.738 g/cm$^3$, when liquid, at m. p. - 1.584 g/cm$^3$.Low density and ready availability are not the only ones benefits of magnesium alloys [1]. Other benefits include:

a) High specific strength (related to low density);
b) Good castability (particularly for high pressure die casting);
c) Can be turned / milled at high speed;
d) Good weldability;
e) Improved corrosion resistance (using high purity magnesium).

Also emphasize a number of advantages of magnesium alloys over polymeric materials, a major competitor to magnesium alloy in light weighting applications. These advantages are:
a) Better mechanical properties;
b) Resistant to aging;
c) Better electrical and thermal conductivity;
d) Recyclable.

Of course, magnesium and its alloys are not without their disadvantage and, again for a succinct summary of these including disadvantage:
a) Low elastic modulus;
b) Limited cold workability and toughness;
c) Limited strength and creep resistance at elevated temperature;
d) High shrinkage on solidification;
e) High chemical reactivity with associated poor corrosion resistance. [5]

**1.4Flammability of Magnesium Alloy:**

Some tests to determine the auto-ignition temperature of magnesium alloys have been carried out by the Technic. First the mechanism of auto-ignition was studied to understand the problem of flammability and to conclude on the influence of different alloy compositions.

• Eutectic phases ignite first (low melting temperature)
• Homogeneity of bulk increases auto-ignition temperature (no low-temperature melting phases)
• Highly dependent on geometry (powder, bulk)

• No standard for solid materials available (the closest standard is ASTM standard E659-78)
• Dependent on atmosphere and reactions[12].

### 1.4.1 Ignition temperature of magnesium alloy:

WE43 had the highest ignition temperature of 644 $^{0}$Cfor AZ91, AZ91 had an ignition temperature lower than that of AZ31. This correlated with the fact that AZ91 has a melting temperature lower than that of AZ31, attributed to a higher Al content. This result indicates that alloying of Al into Mg reduces the ignition temperature. The high ignition temperature of the WE43 is attributed to its high Y content**. [11]**

## 1.5Forming of Magnesium Alloy:

### 1.5.1 Cold forming:

Cold forming is done at temperatures, typically 0.3Tm, where Tm is melting temperature. Cold forging has advantages such as good surface finish, high strength and greater accuracy Because of their hexagonal crystal structure, the cold forming of magnesium alloys is restricted to mild deformation and generous bend radius [8,]

### 1.5.2 Warm Working

Warm forming is a metal forming process carried out above the temperature range of cold working, but below the recrystallization temperature of the metal. Warm forming is done in the temperature range: 0.3 Tm to 0.5 Tm. Warm working may be preferred over cold forming because it will reduce the force required to perform the operation. Also, the amount of annealing of the material that may have been necessary for the cold formed part may be less for warm working.[8,9]

### 1.5.3 Hot forming:

Hot forming is done at temperatures above recrystallization temperatures, typically 0.6 Tm, or above, where Tm is melting temperature.Magnesium alloys, like other alloys with hexagonal crystal structures, are much more workable at elevated temperatures than at room temperature. This is because at elevated temperatures, additional slip planes become available, and plastic deformation becomes easier. Consequently, magnesium alloys are usually formed at elevated temperatures. The methods and equipment used in forming magnesium alloys are the same as those commonly employed in forming other metals, except for differences in tooling and technique that are required when forming is done at elevated temperatures.

Working of metals at elevated temperatures has several advantages over cold working. Magnesium alloy parts are strained at elevated temperatures in one operation without repeated annealing and redrawing, thus reducing the time involved for making the part and also eliminating the need for additional die equipment for extra stages. Hardening dies are unnecessary for most types of forming. Hot-formed parts can be made closer to dimensional tolerances than cold-formed parts, because of less spring back. [8,15]

## 1.6Application of Magnesium Alloys

Today, magnesium alloys are recognized alternatives structural material to steel and aluminium to reduce the weight of product. The earliest usage of magnesium alloy parts is racing vehicles in the 1920's. In the recent years, Mg alloys have been Progressively used in industrial field, such as automobile parts, aerospace parts, portable Electronic devices, Magnesium application in defence industries etc. because magnesium alloys offer much advantages such as light weight, high strength ratio, higher vibration absorption, environment friendly, etc.[15]In addition, the alloys improved heat resistance and strength have extended their possible range of application. Magnesium is particularly desirable in applications where a reduction in component weight is a key objective. In recent years, magnesium has garnered interest in the automotive industry as more stringent emissions standards are being implemented [6]. Automotive manufacturers have begun investigating methods to reduce fuel consumption, and subsequent exhaust emissions. In addition to performance benefits, the reduction in overall vehicle weight has been identified as one of the most effective approaches to reducing fuel consumption. Figure 1-1 compares the relative changes in fuel consumption for various physical parameters [3].

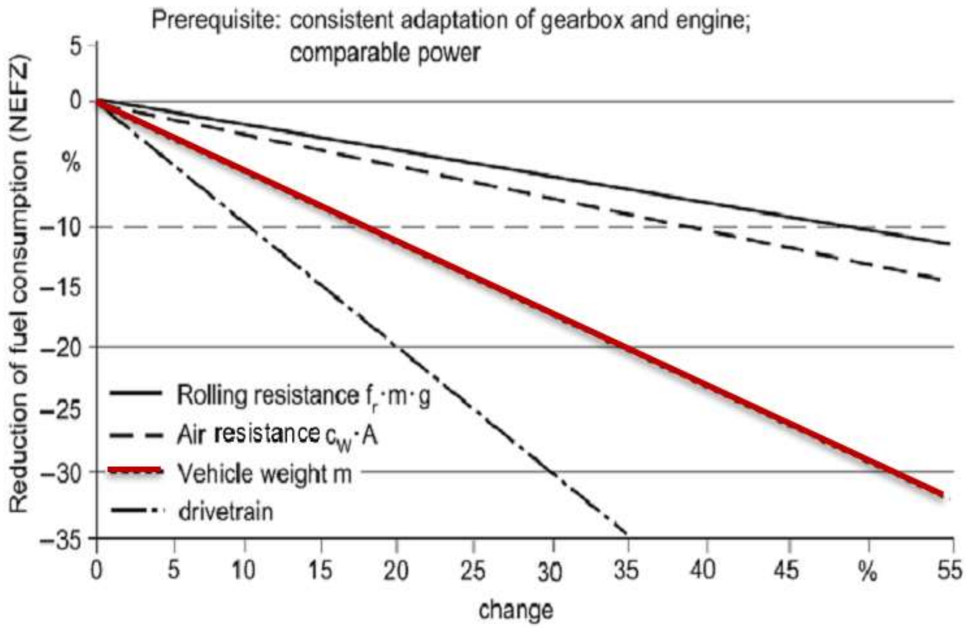


**Figure 1.1:** Influence of various parameters in fuel consumption of automobiles [2]

The physical properties of magnesium make it an ideal material choice for the light-weighting of automobiles. In Europe, manufacturers such as Volkswagen, Audi, and BMW have developed 2 prototypes to showcase how magnesium can be integrated into automobiles for various applications. Some examples include gearbox housings, intake manifolds, crankcases, seat structures, and aluminum-magnesium hybrid body panels [3, 6]. Although the components were only produced as showcases of technology, it is evident that the applications of magnesium have mostly been limited to die-cast and sheet-formed components. The relatively poor mechanical properties obtained from casting have prevented the use of magnesium in structural components such as suspension control arms and sub frames [6]. However, it has been observed that more favourable mechanical properties can be obtained with wrought alloys, particularly in applications involving cyclic loading [2]. Of the commercially available magnesium alloys, the aluminum-zinc (AZ) family is of high industrial importance, as they are relatively inexpensive and easy to produce.

## Experimental Procedure

### 2.1 Introduction

This chapter describes the materials and methods used for the processing of the entire thesis under this investigation. It presents the details characterization which the samples are subjected to. The methodology related experiment method and analysis.

### 2.2 Materials

The material used in the present study was a commercial Mg–Al–Zn alloy (AZ31) and was received as a commercially cast sheet form. For the research work magnesium AZ31 was supplied by VenukaEngineering pvt. Ltd. Hyderabad India.

**Physical properties:** Density- 1.77 gm/cc, Melting point – 650 $^{0}$C.

**Chemical composition:** there chemical composition shown in Table no. 3.1

**Table No.-2.1:** Chemical CompositioN

| | % Al | % Zn | % Fe | % Mn | % Mg |
|---|---|---|---|---|---|
| **Mass fraction** | 3.07 | 0.98 | 0.0001 | 0.16 | 95.7899 |

**2.3 Forging of AZ31**

` (a) (b)

**Figure 2.1**:Sample(a) before forging, (b) After forging

For forging, cut the sample from received material. The blank for the forging had the following dimensions: 30 mm × 30 mm × 10 mm. The forged materials were made of magnesium alloys of types AZ31.

The forging was performed in an open die on a hydraulic press MW PA200 of capacity of 100 ton load. The samples were forged with a single strike at a temperature of 300°C. The temperature of the die tool was approximately150–170 °C. The ESPON-GLF3 lubricant diluted with water at a ratio of 1:20 was used as a lubricating medium. The power of the stamping machine was set to60 % and its stroke to 220 mm. pressing speed is 0.5m/s.

As per investigation it is found that the connecting rod requires one of the mechanical properties tensile and strength**.** For test of tensile strength the sample (before and after forging of AZ31 alloy) made indog bone shapeas per ASTM-E8 standard, shown in figure-3.2.

(a)

(b)


(c)

**Figure 2.2**:a) Tensile Test Machine (BISS) b)Tensile strength test specimen before forging, c)Tensile strength test specimen after forging

The tensile test is generally performed on flat specimensshown in figure 3.1.During the test a uni-axial load is applied through both the ends of thespecimen. The ASTM standard test method for tensile properties of magnesium alloy has the designation AZ31. The length of the test section should be 50 mm. The tensile test is performed in the universal testing machine(UTM) Instron 1195 (Figure 3.8) and results are analyzed to calculate the tensilestrength of magnesium alloy samples. The loading arrangement is shown in figure 3.2.

**2.5 Hardness test**

For hardness test the sample prepare as per ASTM E10-17 standard.The hardness of the heat treated samples was measured using a LeitzWetzlar Germant-088303, Brinell micro hardness measuring machine with a load of 0.4903 N. The load was applied for 30 seconds. In order to eliminate possible segregation effect a minimum of three Figure 3.3 Microhardness tester **hardness readings were taken for each specimen at different locations of the test samples.**

**2.6Metallographic Procedure**

Evaluation of the grain mean size was made according to norm ASTM E112-10. The sample preparation also included their grinding, polishing and subsequentetching. The polishing was performed in two phases. The metallographic procedure utilized in sample preparation for Scanning electron microscopy is outlined below. Grinding of each forge sample to a depth close to the mid plane, and parallel to the compression axis, was performed on 220, 400, 600, 800, 1000, 1200, 1500, and 2000 grit grinding (emery) paper. After polished with emery paper 2000 grit sample are polished with velvet cloth with alumina pest. The polishing was performed in two phases. In the first phase the samples were polished on a cloth with a soft nap using a polishing suspension based on $Al_2O_3$.However, after the completion of the first phase of the polishing, the sample surfaces still contained a large amount of scratches and it was, therefore, necessary to start the second phase of polishing on a very fine velvet\ cloth with short hair. Thus polished samples were cleaned with water, rinsed in alcohol and dried by warmair.

## Conclusion

On the basis of qualitative research results analysis of the forgings by means of open die forging the following conclusions were made:

a) Forgings formed by means of the proposed method are characterized by large heterogeneity of structure. This is connected mainly with complex schema of material flow during such a process.

b) This work has demonstrated the desirable mechanical properties can be obtained in magnesium alloys by forging.

c) Strength properties of the forgings show large heterogeneity in particular areas of the analyzed forged sample.

## References


1. Michal Madaj, Miroslav Greger, VlastimilKaras, *“Magnesium-alloy die forgings for automotive applications,”* Materials and technology 49 (2), 267–273 (2015).

2. Lei Wang, Qi Qiao, Yang Liu, Xiu Song, *“Formability of AZ31 Mg alloy sheets within medium temperatures,”* Journal of Magnesium and Alloys, 1 312-317 (2013).

3. A.H Musfirah, A.G Jaharah,*” Magnesium and Aluminum Alloys in Automotive Industry,”* Journal of Applied Sciences Research, 8(9), 4865-4875 (2012).

4. Adrien Chapuis, Julian H. Driver, “*Temperature dependency of slip and twinning in plane strain compressed magnesium single crystals,”* ActaMaterialia 59, 1986–1994 (2011).