"EFECT OF HOT FORGING ON MECHANICAL PROPERTIESE OF MAGNESIUM ALLOY (AZ31) FOR THE 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*

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.

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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).

1.4Flammability of Magnesium Alloy:

Some tests to determine the auto-ignition temperature of magnesium alloys have been carried out by the Technion. 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)

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**.**

Experimental Procedure

3.1 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.

3.2 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.-3.1: Chemical Composition

Components	% Al	% Zn	% Fe	% Mn	% Mg
Mass fraction	3.07	0.98	0.0001	0.16	95.7899

3.3 Forging of AZ31

` (a) (b)

Figure 3.1: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.T he 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.

Literature Survey

2.1 Introduction

The objective of literature review is providing the background information regarding on the issue to be considered in this thesis and to emphasize the relevance of present study. This treatise embraces various aspects of magnesium alloy for auto mobile and aircraft with special reference to effect of forging on mechanical properties of magnesium alloy strength and hardness of connecting rod applications.

2.2Need of Research

Casting is the most economical manufacturing route for such materials. Magnesium alloy components are usually produced by various casting processes. Mechanical properties of cast Mg alloy components are often inadequate for most applications. Die-casting is one of the most effective fabrication methods to produce magnesium components in automotive industry. However, the number of available Mg-based alloys for die-casting is very limited.

In order to extend the applications of magnesium, secondary processing has to be welldeveloped. Forging these components will produce the desired mechanical properties.
Near-net shape forming technologies are preferred for industrial applications. The main problems for these processes are:-

- Low ductility of magnesium alloy due to hexagonal closed pack structure.
- Low slip plane available at room temperature.

2.3Literature Survey

L. Wang et al. (2013)in this paper author try to find formability of AZ31 alloy. For obtain formability, conduct stretching test of AZ31 at different temperature. The formability of AZ31 sheets at high temperature was evaluated by forming limit diagrams (FLD). The formability increases with the increasing of the forming temperature. That may be because the non-basal slip system starts to move by thermal activation at high forming temperature he higher the forming temperature is, the more obvious the effect of the forming speed is. The forming temperature is the main dominating factor on the formability of AZ31 Mg alloy. [2]

Michal et al. (2015) in this paper investigate the effect of process variables and material condition on the forgeability of magnesium wrought alloys of the Mg-Al-Zn group. The forging capabilities test at hot and warm forging temperature. Hardness of material are affected by aluminium amount, heat treatment and forming. [4]

ADziubinska et al. (2015)the object of this study on the microstructure and mechanical properties of AZ31 alloy aircraft brackets produced by a new technology of semi-open die forging.In this paper authors is advised to conduct additional heat treatment after forging, which type and parameters will be determined at the further stage of research works. [9]

B. PLONKA et al. (2015) the objective of this study was to develop parameters of plastic deformation process of magnesium alloy ZK60A. The tests have showed that for this alloy it is possible to use the temperature of the plastic deformation process ranging from 350^0C to $450^{\mathbf{0}}$C. Samples were characterized by mechanical properties and

structure in different heat treatment tempers. This magnesium alloy obtained in the T5 temper higher mechanical properties then T6 temper. [10]

P Agarwal et al. (2015),the main objective of this paper is to proposed different properties of different material used for the production of connecting rod. This has entailed performing a detailed load, deformation, fatigue, stress and strain analysis. Connecting rod is subjected to more stress than other engine components. Failure and damage are also more in connecting rod, so identification and comparison of different materials for connecting rod is very important. [11]

X. Yang et al. (2013),the microstructural development in an AZ31 magnesium alloy during cold multi-directional forging followed by annealing is investigated in a wide range of cumulative strains up to 5.Theannealing process and the mechanisms occurring after cold multi-directional forging are discussed comparing with those after hot multi-directional forging. [13]

ADziubinskaet al.(2016),in thispaper presented the most important forging processes for magnesium alloy parts for aircraft and automotive applications developed in recent years.Theoretical and technological aspect of forming of magnesium alloy part for application in aircraft and automotive industry is discussed. Forging technologyis discussed mainly for wrought magnesium alloy.Research is conducted on new, innovative techniques for forging magnesium alloys using various forging tools (hydraulic presses, screw presses, hammer presses). [15]

2.4 Research Gap

a) The literature review presented above reveals the following knowledge gap that helped to set the objective of this research work:

b) There was no significant co- relation between the different types of mechanical properties.

c) Still research work needed in standardization of theories that can justify the manufacture connecting rod through forging of magnesium alloy.

d) Significantly very less work had done on enhancement of mechanical properties.

e) It is needed to it brought out in contrast for further investigation for various field of application.

f) Studies carried out worldwide on surface behavior of magnesium alloy have largely been experimental and use of statistical techniques in analyzing fatigue application characteristics is rare.

2.5 Objectives of Research Work

The objectives of this research work are outlined as follows:

a) To improvement of microstructure of Mg alloy through hot forging.
b) To improve of mechanical properties such as tensile strength and hardness.

All these objective set for application in automotive application (usually for connecting rod)

Result and discussion

4.1 Introduction

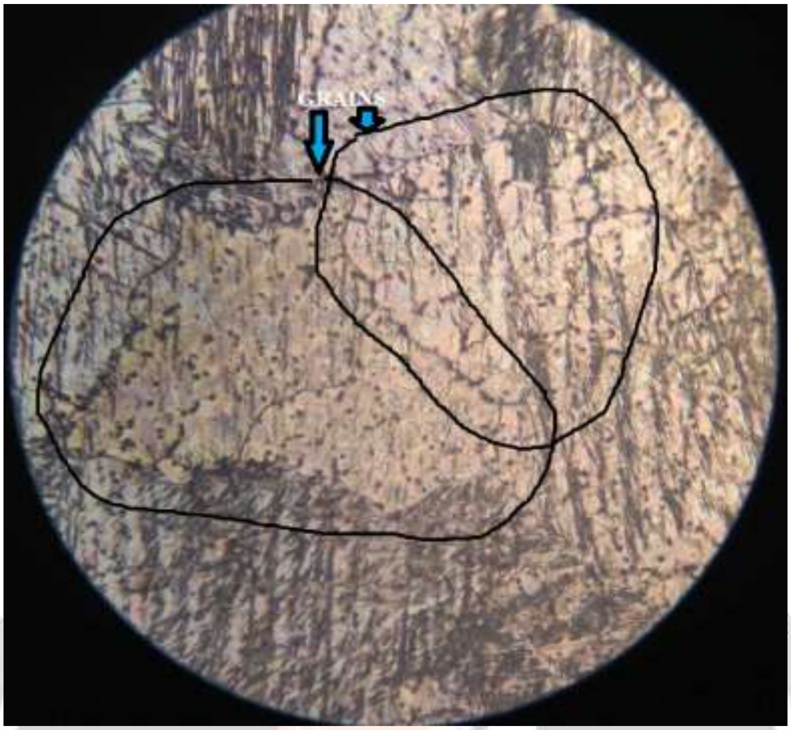
This chapter describes the result of experimental work, its effect, and cause on the properties of magnesium alloy (AZ31). After and before the forging the samples were characterized.

4.2Metallographic

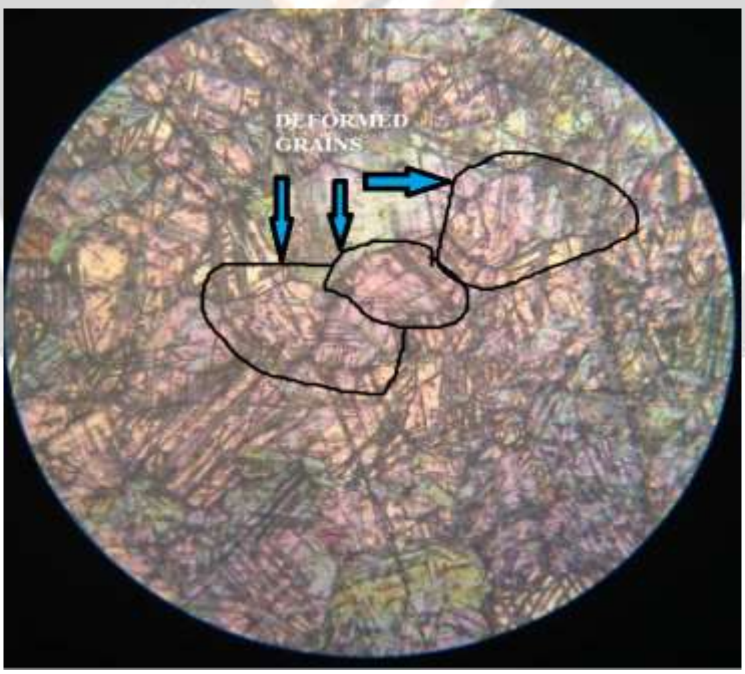
Microstructure of AZ31 alloy in initial stateand after forging was analyzed using optical microscopy (OM) and scanning electron microscopy (SEM).The metallographic investigation of the samples was performed in the initial state and after the forging. The analysis of the microstructure was focused on the formation of the cracks that were highlighted during the technological production of the forgings and the individual phenomena associated with the forming of magnesium alloys (dynamic recrystallisation, twinning, growth and shape of grains).

4.2.1 Optical Microscopic

Optical images of the as received material and forging AZ31 alloy in the cross sections perpendicular to forging direction shown in figure 4.1



(a)



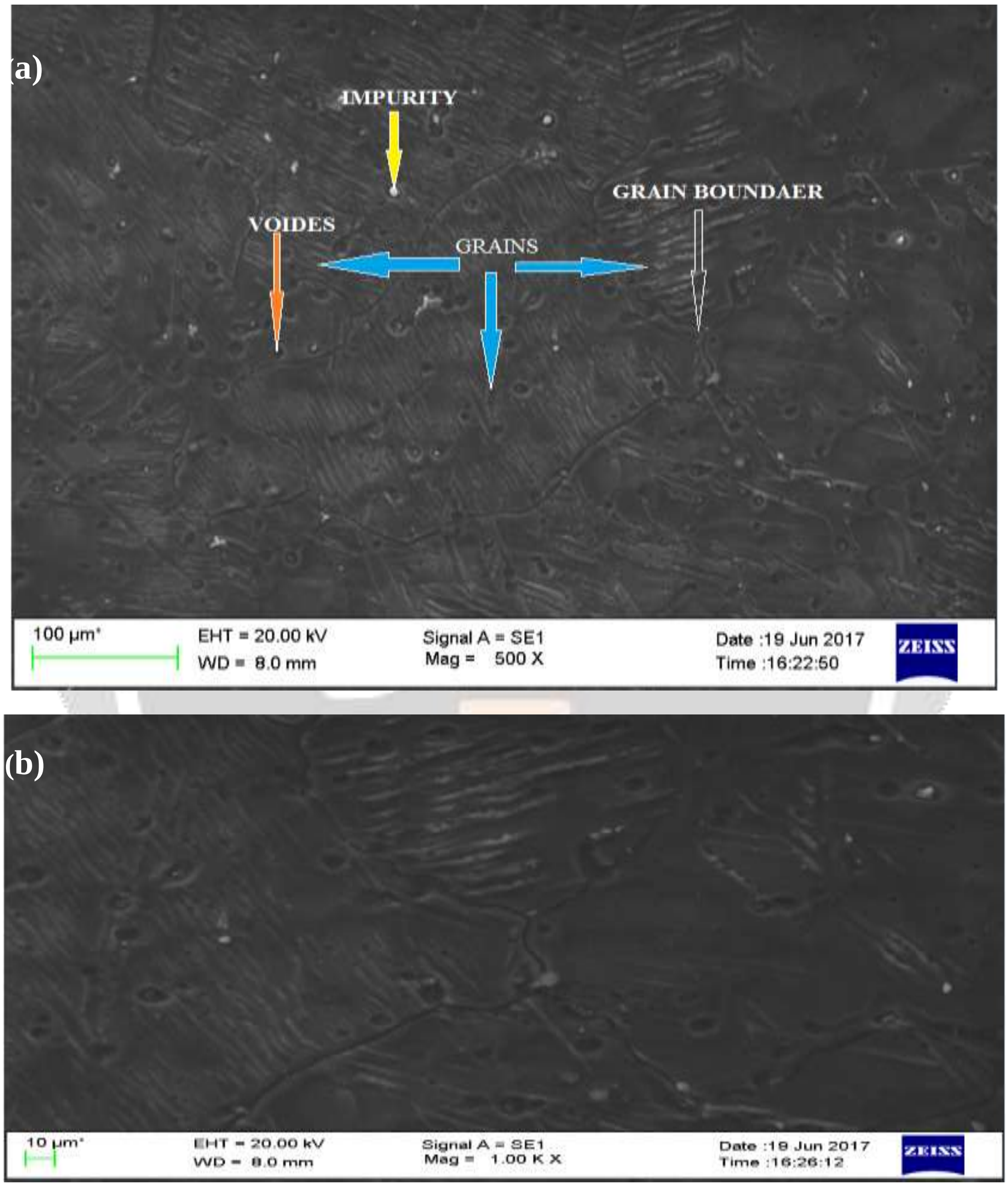
(b)

Figure 4.1:Image of Optical Microscopic (a) before, (b) after forging.

Grain deformation shown in above figure 4.1, the grain size is decreased after forging.

4.2.2 Scanning Electron Microscopic (SEM)

Observations conducted on scanning electron microscope of sample revealed twin strains figure 4.5(a) and presence in grains of elongated twin limits (marked in Figure 4.6 (b), which are characterized at magnesium alloys deformation. Visible white places (spots) on the placed microstructures(Fig. 4.2) can mean appearance of micro hollows or impurity in initial material.



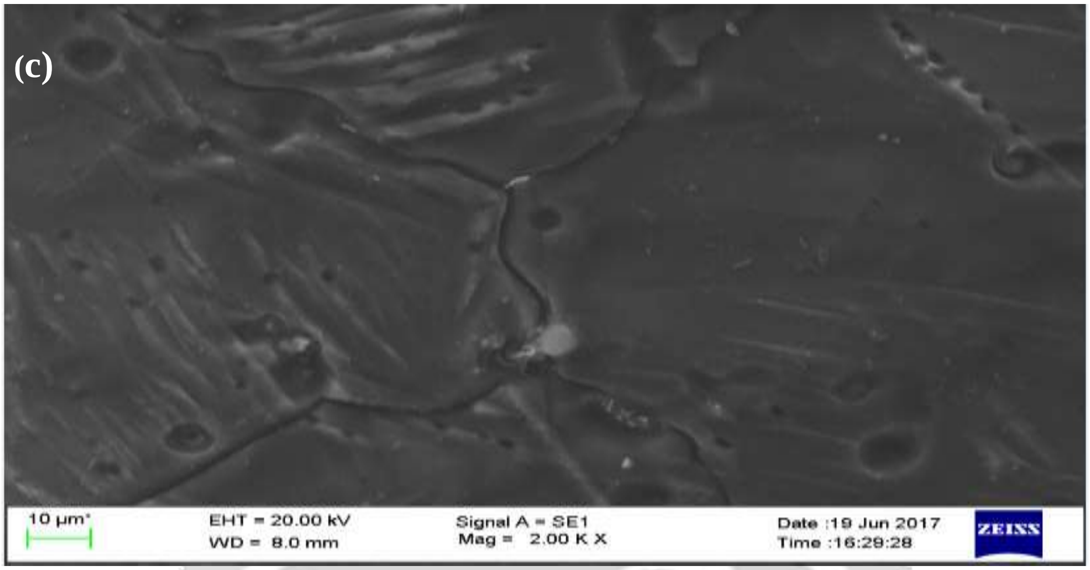
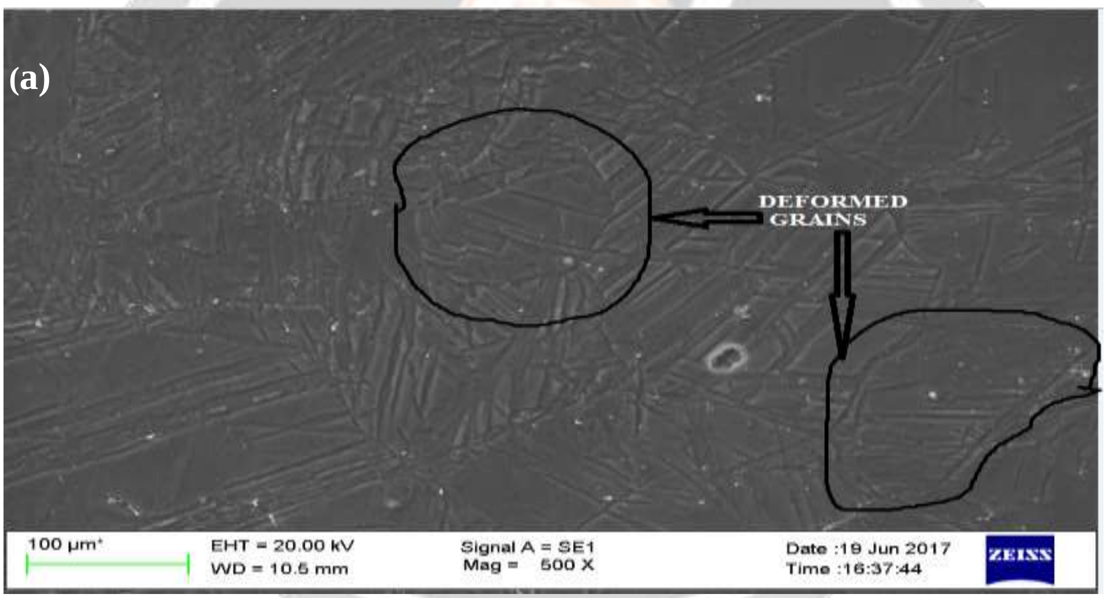
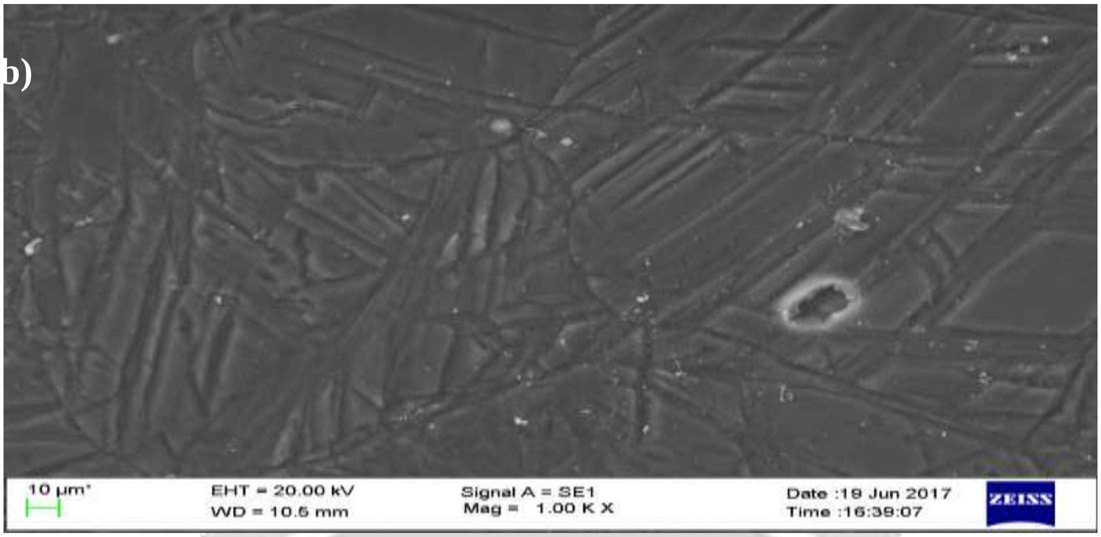


Figure 4.2 microstructure of AZ31 as received at different magnificationsin a, b, c..





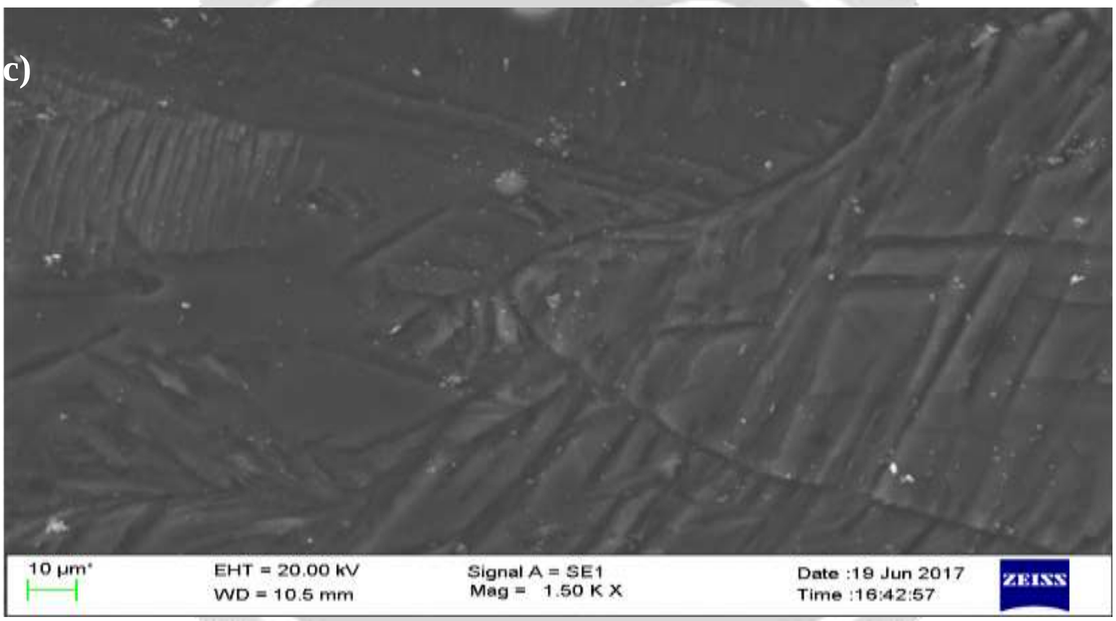


Figure 4.3 microstructure of AZ31 after forging at different magnifications, in a, b, c.

The structures of the forged Mgalloys (AZ31) did not show any defects thatc ould cause a subsequent failure of the components. The grains of both alloys were stretched in the direction ofthe intensive flow of the material, i.e., in the longitudinal direction of the forging. Over-etching microstructure revealed twins that are shown at a higher magnificationin. Twins, which are symmetrical intergrowths of adjacent crystals, appear as elongated microstructural features of differing lengths and widths with sizes that depend upon the grain size as well as other features (since a number of grains displayed no twins). They are typically intragranular and parallelto one-another. However, as noted in, some of the twin spread beyond grain boundaries. Some grains also appear more heavily twinned than others. Note that twinning was absent in both the microstructures and. Although twins can result from polishing and/or strain accumulation (i.e. prior cold work), microstructure was the only one of the three microstructuresthat exhibited twins both before and after tensile deformation.