COMPARISON OF MICROSTRUCTURES AND PROPERTIES OF AZ91 AND AE42 MAGNESIUM ALLOYS

A THESIS SUBMITTED FOR THE DEGREE OF
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CERTIFICATE

This is to certify that the thesis entitled "**COMPARISON OF MICROSTRUCTURES AND PROPERTIES OF AZ91 AND AE42 MAGNESIUM ALLOYS**" being submitted by **AKHILESH KUMAR** (Roll no: **110MM0098**) for the partial fulfillment of the requirements of Bachelor of Technology degree in Metallurgical and Materials Engineering is a bona fide thesis done by him under my supervision during the academic year 2014-2015, in the Department of Metallurgical and Materials Engineering, National Institute of Technology Rourkela, India.

The results presented in this thesis have not been submitted elsewhere for the award of any other degree or diploma.

DATE: 25/11/2014

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ABSTRACT

Magnesium alloys have demonstrated superior specific strength and good machinability which have become essential requirement for automobile and aerospace industries. Other important properties include good surface finish, light weight and good corrosion resistance. In this project, an attempt has been made to compare the microstructures and properties of two magnesium alloy AZ91 and AE42. Microstructures were taken using optical microscopy after polishing them with belt grinding, paper polishing, cloth polishing, diamond polishing and etching. The XRD analysis plots and Vickers hardness of both these alloys were also compared

KEYWORDS: Magnesium alloys, AZ91, AE42, Microstructure, XRD plots, optical microscopy, Vickers hardness

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1. Introduction

Magnesium is the lightest structural metal. It has hexagonal closed packed lattice structure. Plastic deformation of the hexagonal lattice is more complicated than in cubic latticed metals like aluminium, copper and steel. Hence, magnesium alloys are typically used as cast alloys.

Improvements in mechanical properties and corrosion resistance have led to greater interest in magnesium alloys for aerospace and speciality applications, so they are now being used for specific programmes.

The strength-to-weight ratio of the precipitation-hardened magnesium alloys is comparable with that of the strong alloys of aluminium or alloy steels. Magnesium alloys, however, have a lower density and stand greater column loading per unit weight. They are also used when great strength is not necessary, but where a thick, light form is desired.

Magnesium (Mg) (density: 1.738 g/cm3 and 35% lesser in weight than Al) is the lightest structural metal and therefore, has the great potential for applications in the automobile and aerospace industries. In addition, it has high specific strength, good cast ability, good damping capacity, good machinability, good weld ability under controlled atmosphere and much improved corrosion resistance with high purity Mg. Due to these factors extensive use of Mg based alloys can be seen. The uses of Mg alloys are limited in the interior parts of automobile (like steering wheels, front control panels, clutch pedals, brake pedals etc.) where temperature is not an issue. The conventional Mg alloys (AZ and AM series) are having good cast ability, low cost and moderate strength at ambient temperature. However, they suffer from low creep resistance above 175°C due to the low thermal stability of the intermetallic $Mg_{17}Al_{12}$ phase (melting point: 437°C) which precipitates discontinuously during creep deformation lowering their creep resistance. Although alloying additions like Si, Ca, rare-earths (RE) etc. enhance creep resistance of Mg–Al based alloys.

2. Literature review

Casting magnesium alloys have been significantly used over the past few years initially to control rapid alloy oxidation, optimization and then develop to meets specific requirements.

THE ADVANTAGES OF MAGNESIUM ALLOY

1. Lowest density then other structural materials
2. High specific strength
3. It has good cast ability which suitable for good casting rate
4. Turning operation of these alloys can be carried out at high speed
5. By using high purity Mg alloy we get improved corrosion resistance
6. Comparable with polymeric materials
7. It is recyclable

THE DISADVANTAGES OF THE MAGNESIUM ALLOY

1. Low elastic modulus.
2. Limited toughness.
3. Its strength and creep resistance at elevated temperature is limited.
4. It has high chemical reactivity.
5. Limited corrosion resistance in some application

3. Materials and experimental procedure

3.1. Materials:

1. AZ91 Magnesium Alloy and
2. AE42 Magnesium Alloy

The compositions of the AZ91 and AE42 magnesium alloy are shown in the table below.

Table no. 1: Composition of the AZ91 alloy

Magnesium	Balance
Aluminium	8.25%
Manganese	0.22%
Zinc	0.63%
Other Metals	

1. Copper	0.003%
2. Iron	0.014%
3. Be	0.002%

Table no. 2: Composition of the AE42 alloy

Magnesium	Balance
Aluminium	4%
Rare earth metals	2.5%
1. Lanthanum	0.6%
2. Cerium	1.2%
3. Neodymium	0.4%
4. Praseodymium	0.1%

3.2. Specimen preparation for metallographic observation

Metallography is the microscopic study to characterize the phases present in a metal or an alloy. The success in microscopic study depends mostly upon the care taken in the preparation of the specimen. So, objective is to produce a flat, scratch-free, mirror like surface.

Steps involved in sample preparation:

The steps adopted in specimen preparation are as follows.

1. Cutting the specimen to desired size & shape.
2. Rough grinding
3. Intermediate polishing
4. Fine polishing
5. Etching

3.2.1. **Rough grinding:** Belt sander was used to rough-ground the sample. The specimen cooled by continuous dipping it in water during the grinding operation. The specimen was made to move perpendicular to the direction of existing scratches. The rough grinding was continued until the surface was made flat and

free of nicks, burrs, etc. Scratches due to the hacksaw were also not visible after rough grinding.

3.2.2. Intermediate polishing: After rough grinding, the specimens were polished by brushing the specimen surface against the emery papers 1/0, 2/0, 3/0, 4/0 (arranged in decreasing order of roughness). Each polishing stage removes the scratches from the previous coarser paper. This was more easily obtained by orienting the specimen perpendicular to the previous scratches, and watching the previously oriented scratches. After polishing, the specimen were thoroughly washed with soapy water and then allowed to dry.

3.2.3. Fine polishing: The final approximation to a flat scratch-free surface was obtained by use of a wet rotating wheel covered with a cloth. The abrasive used during polishing was diamond paste. The selection of a polishing cloth depends upon the specific material being polished and the purpose of the metallographic study. The cloth used in our case was velvet cloth.

Figure 1: Rotating disc for polishing

3.2.4. Etching: The purpose of etching is to make visible the many structural characteristics of the metal or alloy. The process must be such that the various parts of the microstructure should be clearly differentiated. This was accomplished by use of etchant having chemical compositions of 20 ml distilled, 10 ml acetic acid, 5 ml picric, ethanol.

3.3. Microstructural characteristics

3.3.1. Optical Microscope

Figure 2: Optical Microscope

Under computerized optical microscope microstructures of the samples were observed in etched conditions and characterization was done.

3.3.2. X-Ray Diffraction Technique

Figure 3: X-Ray Diffraction Machine

XRD analyses of the samples was carried at 30 kV and 20 mA using Cu Kα radiation

Other the parameters used are as follows:

Scanning angle is 10 to 100 degree of 2θ

2 degree step size for scanning

1 minute is the time per step

3.4. Hardness Testing

Vickers Hardness Test:

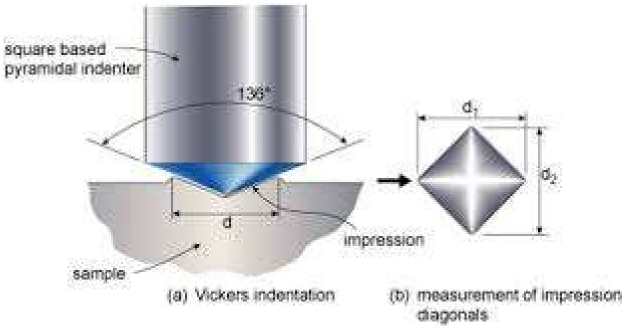

Figure 4.1: (a) Vickers Indentation (Vickers Hardness Test) (b) Measurement of impression diagonals(Vickers Hardness Test)

The two sample were polished using different size of emery paper and cloth polished also the Vickers hardness of the final polished samples were measured by indentation test, with square base diamond base indenter which under the application of 5kg load with a dwell time of 10sec. Then the diagonals of the indent formed on the material surface (both alloy and composite) were measured then the hardness was calculated based on the following relation

Vickers hardness **(HV) = p/A = 2psin (136°/2)/d²**

Which can be approximated by evaluating the sine term to give

$$(HV) = 1.854p/d^2$$

Where

$A = d^2/2\sin(136°/2)$ is the surface area of the resulting indentation in square millimetres.

HV is the Vickers hardness

p is the load applied

d = (d1+d2)/2 "d1 is diameter of diagonal 1 and d2 is diameter of diagonal 2"

4. Results and discussion

4.1. Microstructure

The following are the microstructures of AZ91 and AE42 alloy as obtained from optical microscopy.

AZ91

Figures 5.1, 5.2 and 5.3 show the microstructure of AZ91 Mg alloy. In the microstructures, two phases are visible namely α-Mg (primary phase) and β-$Mg_{17}Al_{12}$ (intermetallic phase).

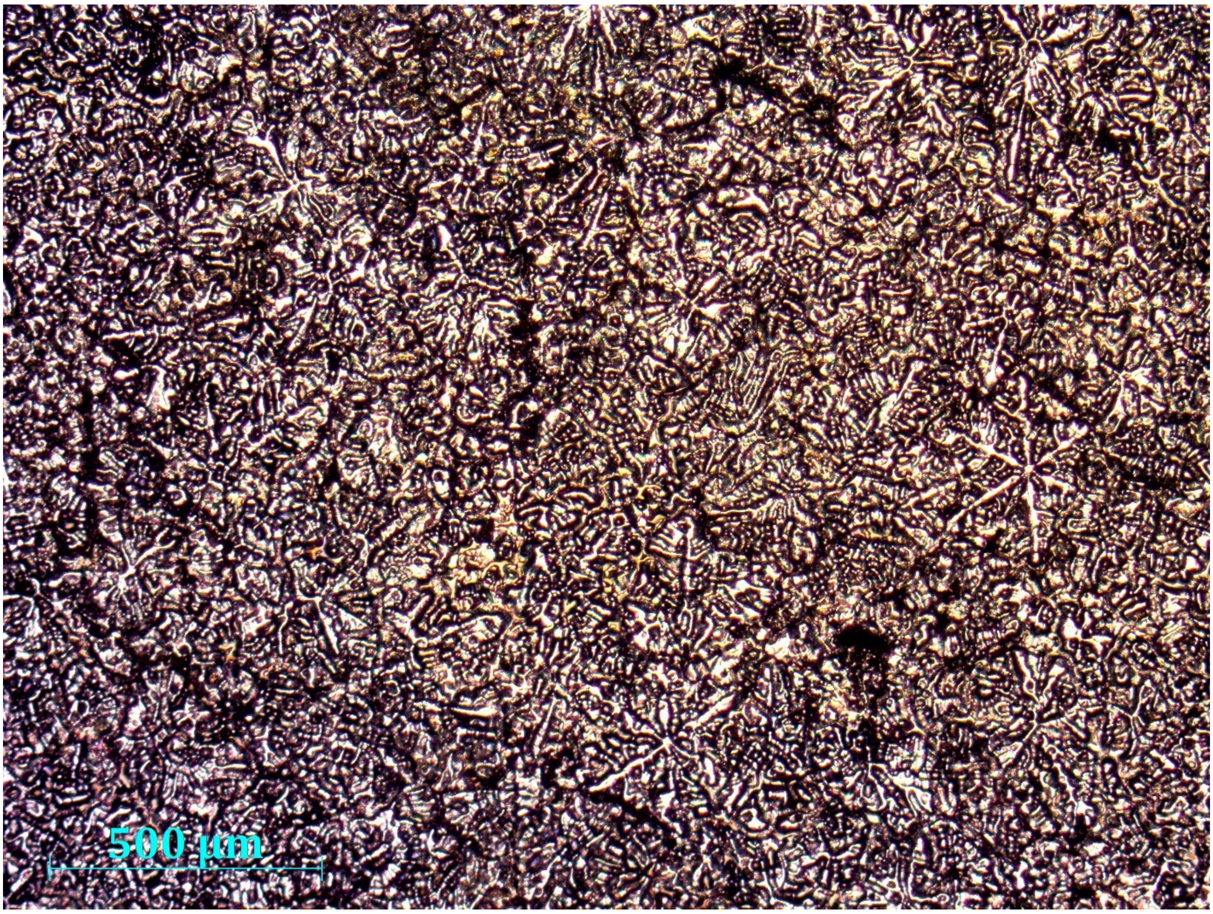

Figure 5.1: Optical micrograph of the AZ91 alloy (Magnification: 50x)

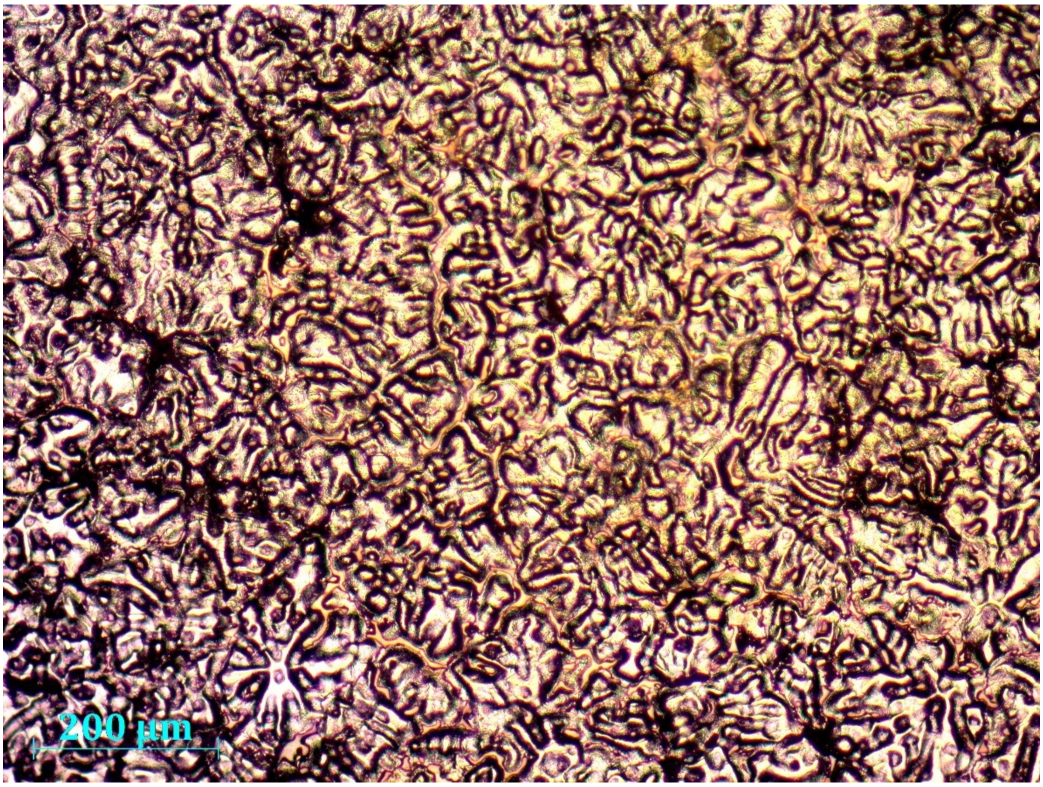

Figure 5.2: Optical micrograph of the AZ91 alloy (Magnification: 100x)

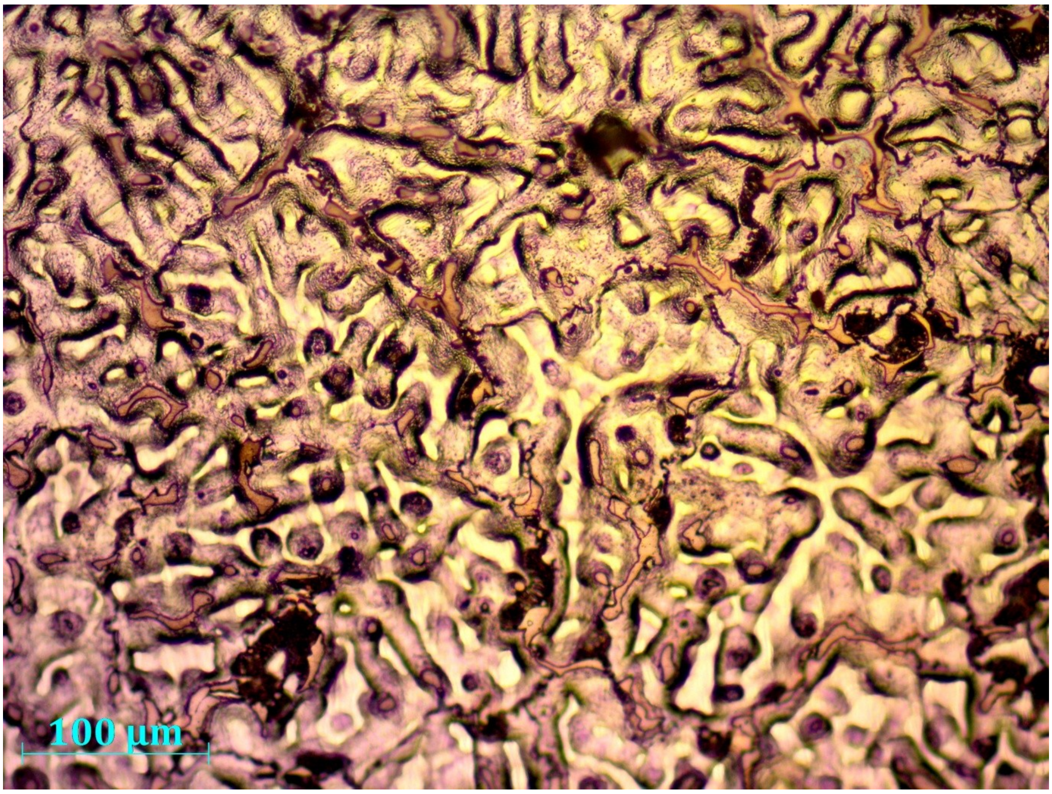

Figure 5.3: Optical micrograph of the AZ91 alloy (Magnification: 200x)

AE42

Figure 6.1 and 6.2 show the microstructure of AE42 sample. In the microstructures, two phases are visible namely α-Mg (primary phase) and Al_4RE (intermetallic phase, which is sometimes also called $Al_{11}RE_3$)

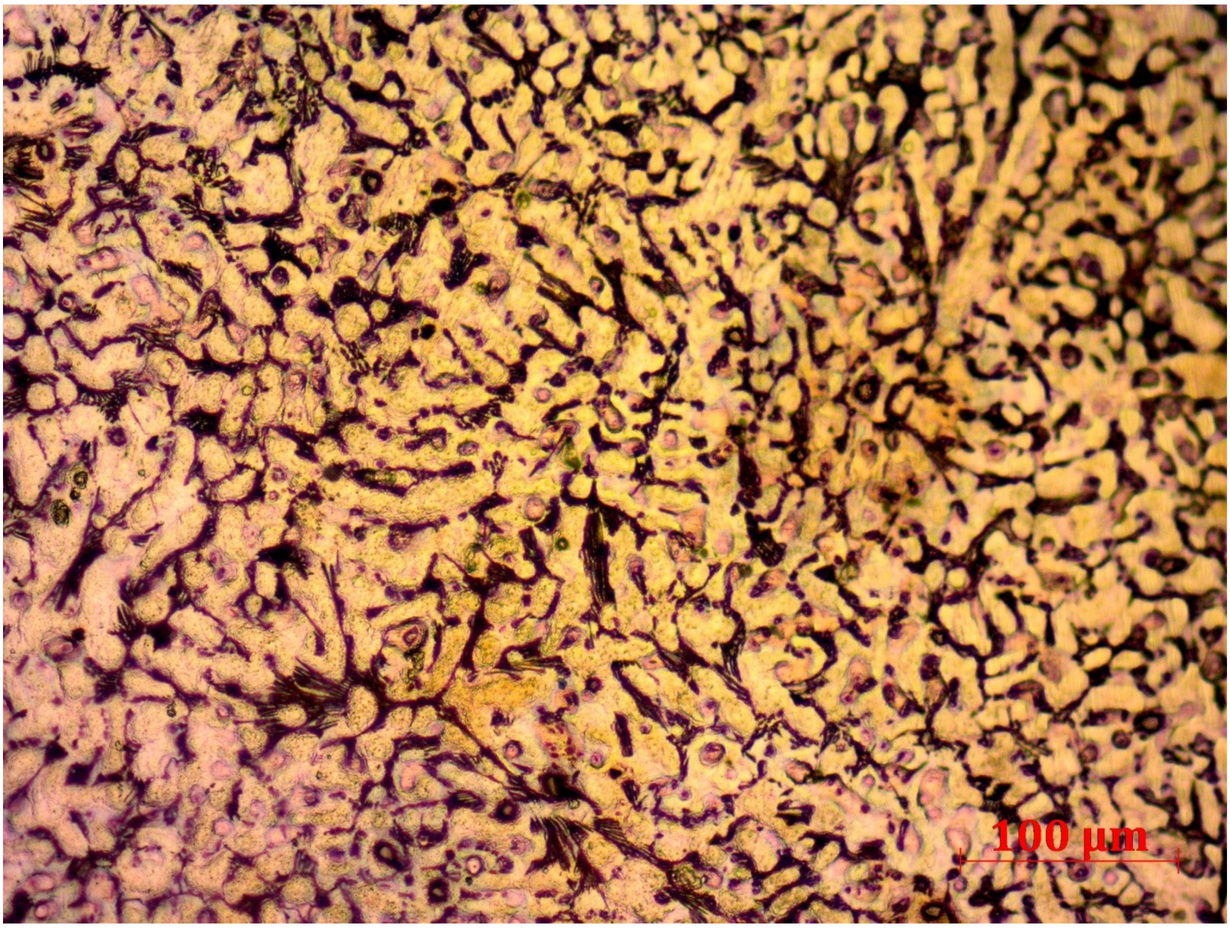

Figure 6.1: Optical micrograph of the AE42 alloy (Magnification: 200x)

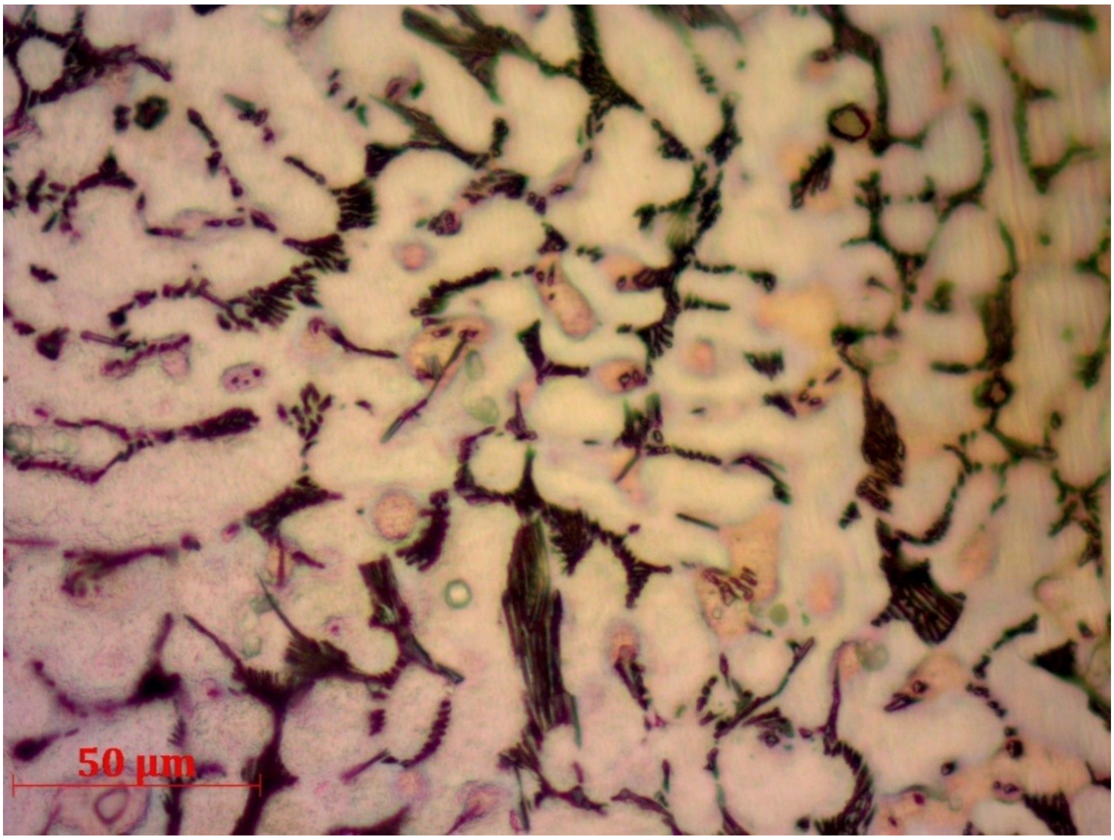

Figure 6.2. Optical micrograph of the AE42 alloy (Magnification: 500x)

4.2. X-Ray Diffraction analysis

Following are the plots of the XRD analysis of AZ91 and AE42 Mg alloys.

The AZ91 plot shows α-Mg and β-$Mg_{17}Al_{12}$ peaks whereas AE42 plot shows α-Mg and $Al_{11}RE_3$ peaks.

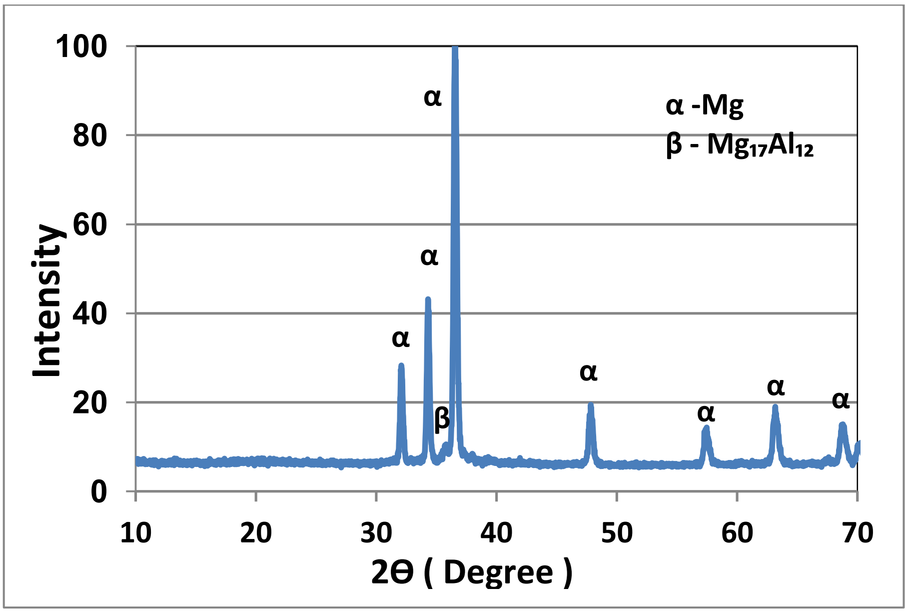

Figure 7: XRD plot of AZ91 alloy

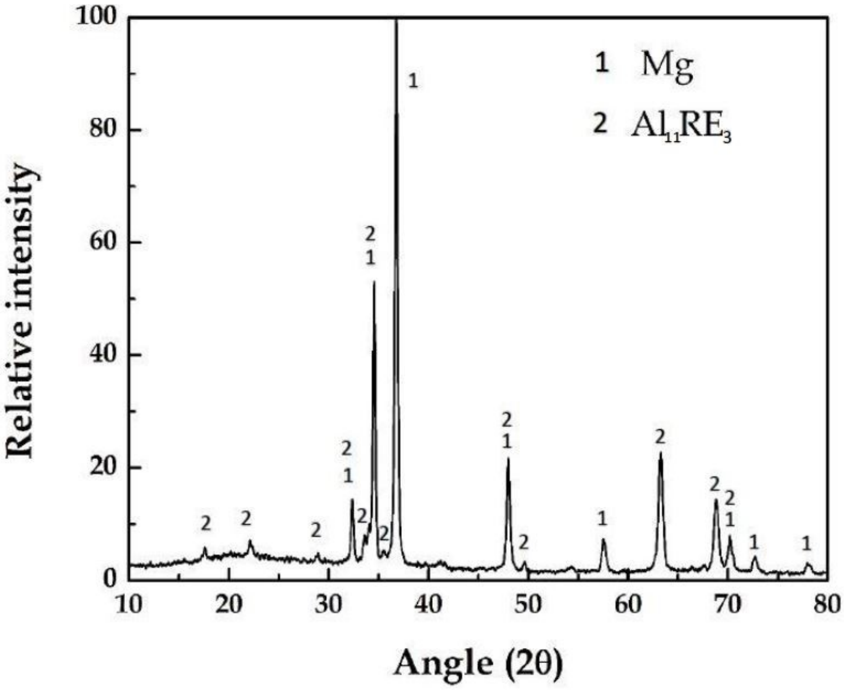

Figure 8: XRD plot of AE42 alloy

4.3. Hardness

4.3.1. Vickers Hardness:

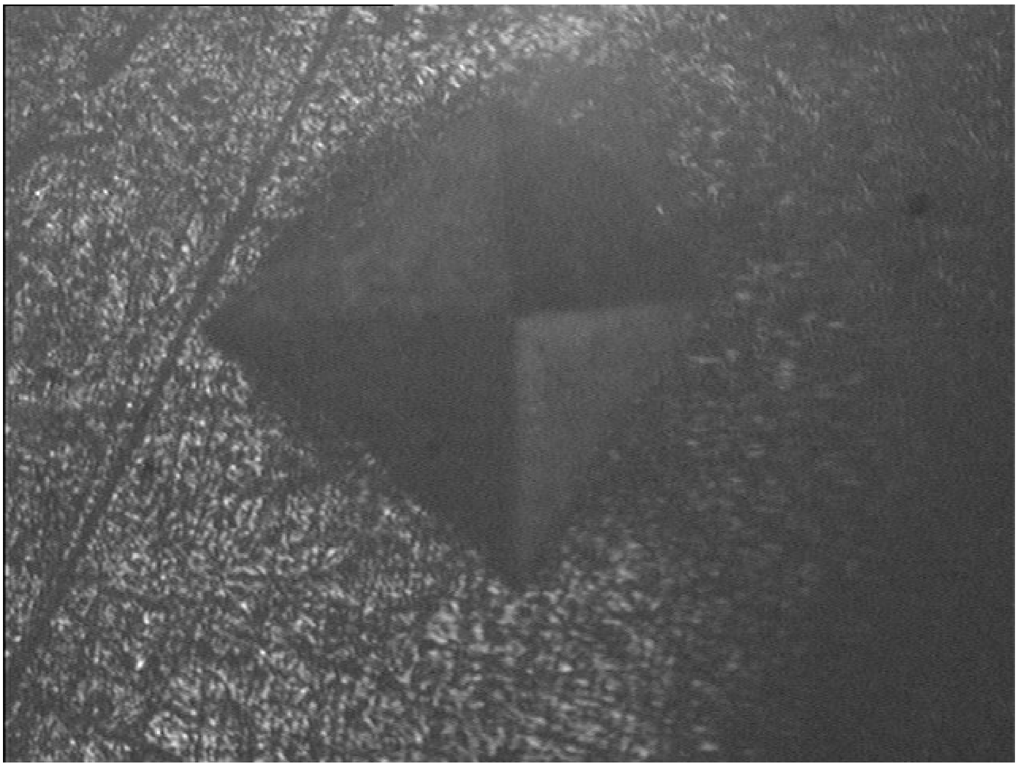

Figure 9: Indentation on AZ91 alloy

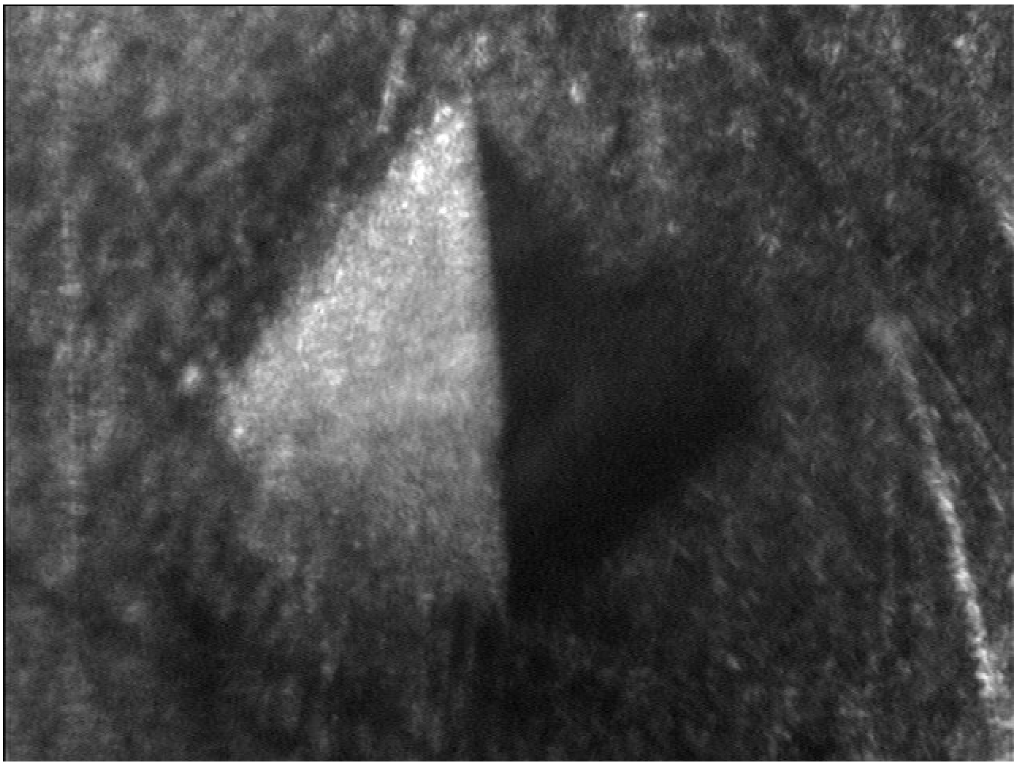

Figure 10: Indentation on AE42 alloy

Table no. 3

Hardness data for AZ91 and AE42 alloys

Sl. No.	AZ91 (HV)	AE42 (HV)	Load (kg)	Dual Time (s)
1.	63.7	44.6	5	10
2.	62.1	42.0	5	10
3.	52.1	41.7	5	10
4.	59.0	53.6	5	10
5.	55.2	44.1	5	10

Average Vickers hardness for

AZ91 = (63.7+62.1+52.1+59.0+55.2)HV/5 = 58.42 HV

AE42 = (44.6+42.0+41.7+53.6+44.1)HV/5 = 45.2 HV

5. Conclusions

After observing and the present study and the result and their pertinent analyses lead to infer the following conclusions:

1. In case of AE42 alloy, Primary α-Mg and $Al_{11}RE_3$ were observed whereas in case of AZ91 α-Mg and β-$Mg_{17}Al_{12}$ were observed.
2. The hardness of the AZ91 alloy was observed to be higher than that of AE42 alloy.

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