Effect of heat treatment on Mechanical properties of Al-Cu-Mg-Zr alloy

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in partial fulfillment of the requirement for the award of the degree of

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ABSTRACT

The goal of the current study was to find out what impact adding Zr to Al-Cu-Mg alloys had on their mechanical characteristics. The examined alloys are non-heated Al-Cu-Mg alloy, heated Al-Cu-Mg alloy, non-heated Al-Cu-MgZr alloy, and heated Al-Cu-MgZr alloy were created by stir casting to create plates and then underwent cold rolling treatment. The findings demonstrated that alloying with Zr had a considerable impact on the mechanical characteristics, significantly strengthening the heat-treated Al-Cu-Mg alloys.

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NOMENCLATURE

Zr - Zirconium

Al - Aluminium

Cu – Copper

Mg – Magnesium

YS – Yield strength

UTS – Ultimate tensile strength

UTM – Universal testing machine

CHAPTER-I

INTRODUCTION

In recent years, aluminium alloys form a very important class of engineering materials and are invariably used in mechanical components such as gears, cams, bearings, bushes, bearing cages, where strength is a key parameter for the material selection, However, aluminium alloys is rarely used as bearing materials in its pure form, because neat aluminium alloys could not satisfy the demands arising from the situations where a good mechanical properties is required. aluminium alloys with minor additions of transition elements are the most rapidly growing class of materials, due to their good combination of high specific strength and specific modulus, are widely used for variety of engineering applications. This chapter presents an overall view of aluminium alloys. Aluminium alloys are among the most rapidly growing classes of materials and are finding more applications in various fields. The use of aluminium alloys are on the increase for improved performance in many areas of applications including tribological purposes. This chapter covers the motivation, objectives and scope of the present investigation.

1.1 Introduction to aluminium alloys

1.1.1 Classification of wrought aluminium alloys

Wrought Aluminium alloys are generally classified as strain-hardening alloys and age-hardening alloys and the detailed classification is shown in Figure 1.1. In wrought aluminium alloy designation system, the first digit refers to the main alloying elements, the second digit gives the modification in that alloy, the third and fourth digits give the individual alloy variations and identification of the alloy in that group. The strain-hardening alloys (1xxx, 3xxx, 4xxx and 5xxx alloy series are non-heat treatable). The strength of these alloys may be improved by strain hardening technique. The age-hardening alloys (2xxx, 6xxx and 7xxx alloy series). These alloys improved their properties by heat treatment and quenching followed by natural or artificial aging.

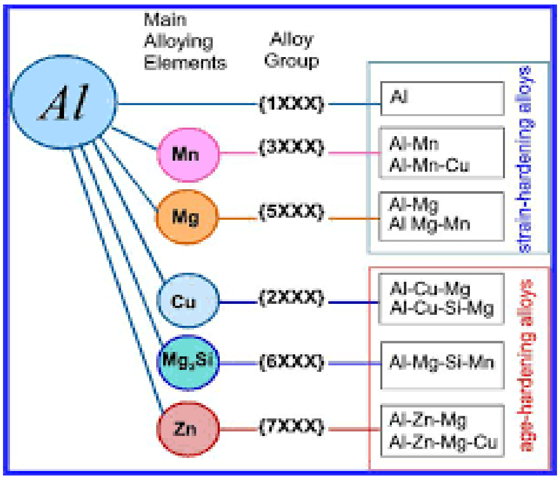


Figure 1.1 Classification of Aluminium alloys

1.1.2 Aluminium alloy chosen for the present study

In this project work, a 2xxx series alloy is chosen for the investigation and it is shown in figure 1.2. This alloy usually contains aluminium (Al), copper (Cu), magnesium (Mg) as principal alloying constituents and traces of other metals. Al-Cu-Mg alloy is an aluminium alloy, with copper as the primary alloying element.

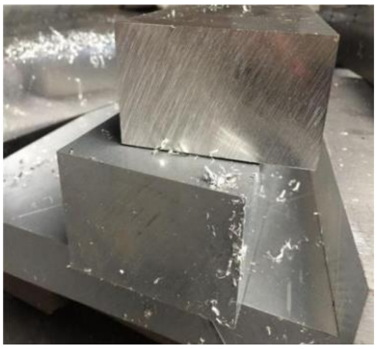


Figure 1.2 Al-Cu-Mg Alloy

It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weldable only through friction welding, and has average machinability. Due to its high strength and fatigue resistance, Al-Cu-Mg alloy is widely used in aircraft, especially wing and fuselage structures under tension. Additionally, since the material is susceptible to thermal shock, Al-Cu-Mg alloy is used in qualification of liquid. Al-Cu-Mg alloy is commonly extruded, and also available in sheet and plate forms. It is not commonly forged.

1.1.3 Base material properties

Aluminium alloy Al-Cu-Mg alloy has a density of 2.78 g/cm^3, young's modulus of 73 GPa across all tempers, and begins to melt at 500°C. The chemical and mechanical properties of Al-Cu-Mg alloy are shown in the table 1.1 and table 1.2.

Table 1.1 Al-Cu-Mg Alloy Chemical composition

S. No.	**Elements**	**%**
1	Cu	4.5
2	Mg	1.5
3	Si	0.5
4	Mn	0.5
5	Zn	0.25
6	Fe	0.4
7	Cr	0.1
8	Ti	0.15
9	Al	Balance

Table 1.2 Al-Cu-Mg Alloy Mechanical Properties

Base Material	**Al Al-Cu-Mg alloy**
Density value	2.78 g/cc
Young‘s modulus value	73.1 GPa
Ultimate Tensile strength value	483MPa
Elongation at break value	18%
Poisson‘s ratio value	0.33
Melting temperature value	502 - 638°C
Thermal conductivity value	121 W/(m-k)
Vickers Hardness number	137

1.2 Aluminium Zirconium Alloy

Zirconium is a specified minor addition to a number of high strength wrought aluminum.. the Figure 1.3 shows the Al 10%Zr master alloys selected for the present study.

Figure 1.3 Al 10%Zr alloy

Zirconium is commonly used as an alloying element in aluminum alloys, including Al-Cu-Mg alloy, to improve their mechanical properties. The effect of zirconium on the tensile strength of Al-Cu-Mg alloy depends on the concentration of zirconium in the alloy.Studies have shown that the addition of zirconium to Al-Cu-Mg alloy can increase its tensile strength by up to 20%. This is because zirconium forms small, coherent particles with aluminum, which strengthen the material by impeding dislocation motion and increasing the resistance to deformation.However, the effect of zirconium on the tensile strength of Al-Cu-Mg alloy is also influenced by other factors, such as the presence of other alloying elements and the processing conditions used during the manufacturing process. Therefore, the exact impact of zirconium on the tensile strength of Al-Cu-Mg alloy will depend on the specific composition and processing conditions of the alloy.Overall, zirconium can be an effective alloying element for improving the tensile strength of Al-Cu-Mg alloy, but the optimal concentration and processing conditions will depend on the specific application and requirements of the material.

The presence of zirconium in aluminum alloys

- inhibits recrystallization and grain growth at elevated temperatures,
- enhances weldability by resisting grain coarsening in the heat,
- sensitive zones close to welded joints
- reduces susceptibility to stress corrosion

- reduces sensitivity to quenching rate from solution temperatures

CHAPTER-II

LITERATURE REVIEW

Sagar [1] investigated the mechanical property of Aluminum alloy Al-Cu-Mg alloy with beryl as the reinforcement. Study reveals that there is an up gradation of ultimate tensile strength by 107%, hardness by approx 11% and the toughness increases almost 300%. Hence it is clearly visible that Al Al-Cu-Mg alloy- beryl composites have improved significant property than AlAl-Cu-Mg alloy As-cast material.

Venkatesh [2] investigated synthesis Aluminium - silicon agro wasted based hybrid metal matrix composites. In this investigation Al Al-Cu-Mg alloy reinforced with SiC and anacardium occidentale ash to enhance the mechanical properties. The result shows that thehardness of the hybrid composites decreases slightly with increase in cashew nut shells ash content with maximum reduction.

Preetam Kulkarni [3] developed the Aluminum-E- glass fly ash composites. In this investigation Aluminum alloy Al-Cu-Mg alloy is used as a metal matrix and E-glass fly ash as reinforcement. The specimen was tested for tensile and compression strength using UTM and it was found that the aluminum matrix composites has obtained better tensile and compression strength when compared to metal alloy itself

Albiter [4] fabricated an aluminum metal matrix composite reinforced with Tic via pressureless melt infilteration and investigated the microstructure study and heat treatment response of composite. The study reveals that after heat treatment there is an enhancement in Mechanical properties of the composites Such as increased in hardness from 28.5 to 38.5 HRC; whereas UTS increased from 379 to 480 MPa.

Huabing Yang [5] developed an aluminum(Al-Cu-Mg alloy) metal matrix composites with the reinforcement of TiC via casting method. The result shows that the increment in mechanical properties like ultimate tensile strength increased from 105 MPa to 151 MPa and the value of yield strength increased 84% of its previous value whereas the elongation of material decreased.

Egizabal [6] developed metal matrix composites Al alloy Al-Cu-Mg alloy and reinforced TiC by stir casting process. The results obtained in the metallurgical analysis and mechanical tests confirmed that the presence of TiC particulates has a positive effect on mechanical properties through different mechanisms such as grain refining and reduction of porosity. Small agglomerations as well as individual particulates are mainly located in the intergranular region. Most of the particulates present a size ranging from 1 to 5 microns.

Shashi Prakash Dwivedi [7] developed a composite of Al Al-Cu-Mg alloy alloy by utilizing ground nut shell ash as reinforcement material to enhanced the mechanical property. It was observed that waste groundnut shell (agricultural residues) is inexpensive which can be used as reinforcement for the development of the metal matrix composite as well as its enhanced the mechanical properties of the composites.

Sairam Varma [8] fabricated a metal matrix composites AA Al-Cu-Mg alloy reinforced with TiC by using stir casting method. The main purpose of this study was to evaluate the microstructure and mechanical properties of the material. It was found that an incremental value of mechanical properties such as UTS, YS and hardness.

Suresh Kumar [9] developed an aluminum(Al-Cu-Mg alloy) metal matrix composites reinforcement of B4c-Tic via casting procedure and investigated mechanical properties of the composites and further investigate its machinability. In this investigation it was found that the fabricated hybrid composite, ALAl-Cu-Mg alloy-TiC-B4C is having the improved mechanical properties such as hardness, tensile strength, ultimate strength and yield strength and decreases the impact strength due to the increased ceramic fillers

Murali Dharan [10] prepared Aluminum matrix composites with the reinforcement of ZrB2. In this experimental investigation it was found that there was a refinement of grains in the composite due to ZrB2 particles. The mechanical properties such as UTS, YS were improved remarkably by the reinforcement of ZrB2 particles.

CHAPTER-III

OBJECTIVE AND METHODOLOGY

3.1 OBJECTIVE

The research contributions available from the reputed international journals are reviewed on the Al-Cu-Mg alloy and mechanical properties and the contributions are discussed in the Chapter-2. After the observation of numerous review paper and articles, the mechanical properties of various Aluminum alloys have been studied and it was perceived that Zr offers a combination of features inhibits recrystallization and grain growth at elevated temperatures, suspectibilty of stress corrosion and excellent weldability which is used as a alloying element for the preparation of the aluminium alloy. Therefore, the present research is taken-up on four Al-Cu-Mg alloys and the objectives are outlined below:

1. To study the effect of heat treatment on mechanical properties of Al-Cu-Mg alloy .
2. To study the influence of Zirconium on mechanical properties of Al-Cu-Mg alloy
3. To analyze the results obtained for Al-Cu-Mg and Al-Cu-Mg-Zr alloys after tested for different mechanical properties

3.2 METHODOLOGY

3.2.1 Stir Casting

Alloys are made via a process called stir casting, often known as the stir casting process or the stir casting technique (MMCs). In this procedure, mechanical stirring is used to incorporate alloying elements into a molten metal alloy.

The metal alloy is typically melted at a high temperature in a boiler or crucible before being stir cast. The alloying elements are added to the molten alloy after which the mixture is agitated with a revolving impeller or a magnetic stirrer. A uniform mixture is created and the elements are distributed more evenly thanks to the stirring ball diameter, D is the disk diameter, R is the wear track radius, and w is the rotation velocity of the disk.

Compared to the basic metal alloy, the resulting alloy has better mechanical and physical qualities. Strength, stiffness, wear resistance, and thermal conductivity are just a few of the attributes that the additional particles might enhance. In sectors requiring high-performance materials, such as aerospace, automotive, and electronics, stir casting is frequently employed.

Figure 3.1 Stir Casting equipment

3.2.2 Heat treatment

Heat treatment is the process of heating and cooling metals, using specific predetermined methods to obtain desired properties. Both ferrous as well as non-ferrous metals undergo heat treatment before putting them to use.Over time, a lot of different methods have been developed. Even today, metallurgists are constantly working to improve the outcomes and cost-efficiency of these processes.For that they develop new schedules or cycles to produce a variety of grades. Each schedule refers to a different rate of heating, holding and cooling the metal.These methods, when followed meticulously, can produce metals of different standards with remarkably specific physical and chemical properties.

Figure 3.2 Heat Treating Process

3.2.3 Age Hardening

Age hardening is a heat treatment process used to increase the strength and hardness of certain metals, particularly those that contain alloys such as aluminum, copper, magnesium, and nickel. The process involves heating the metal to a specific temperature, holding it at that temperature for a certain amount of time, and then cooling it rapidly.

During the heating stage, the alloying elements in the metal are dissolved into the metal's crystal lattice structure. The metal is then quenched rapidly in water or oil, causing the atoms to become trapped in their positions. This creates a supersaturated solid solution in which the alloying elements are evenly distributed throughout the metal.

The metal is then aged at a lower temperature for a specific amount of time. During this stage, the alloying elements begin to cluster together, forming small particles. These particles obstruct the movement of dislocations in the metal, which makes it more difficult for the metal to deform under stress. This results in an increase in the metal's strength and hardness.

The age hardening process is commonly used in the aerospace, automotive, and construction industries to produce strong, lightweight metals that can withstand high stress and temperature conditions.

3.2.4 Cold rolling

Rolling process is a common method used after casting to transform the material into a desired shape or thickness. The rolling process is particularly useful for metals and metal alloys that have high ductility and can be easily deformed without losing their structural integrity.

The rolling process involves passing the cast material between a series of rotating rollers, which apply pressure to the material and cause it to elongate and reduce in thickness. The rollers may be arranged in a variety of configurations, including a simple two-roller arrangement or a more complex cluster of rollers, depending on the desired shape and thickness of the final product.

Rolling can be done either hot or cold, depending on the material being rolled and the desired properties of the final product. Hot rolling involves heating the material to a high temperature, typically above its recrystallization temperature, and then rolling it to achieve the desired shape and thickness. Cold rolling, on the other hand, is done at or near room temperature and is used to achieve a more precise thickness or to improve the surface finish of the material.

Overall, the rolling process can significantly improve the mechanical properties and surface finish of cast materials, making it a valuable technique in the manufacturing of a wide range of products.

Figure 3.3 Cold Rolling Process

CHAPTER-IV

EXPERIMENTATION

4.1 Materials

In the present study, the four aluminium alloys Al-Cu–Mg alloy (hereafter named as specimen-1), Al–Cgu–Mg heat treated alloy (hereafter named as specimen-2), Al–Cu–Mg–Zr alloy (hereafter named as specimen-3), and Al–Cu–Mg–Zr heat treated alloy(hereafter named as specimen-4) were produced by melting in an electrical resistance furnace. These alloys were prepared by stir casting, using Al–Cu–Mg alloy and master alloy (Al–10Zr) that were melted alumina crucible and then poured into a metal mould.

The final temperature of the melt was always maintained at 510 ± 15 C with the help of the electronic controller.Then, the melt was homogenised under stirring at 490^{o}C. Casting was done in mild steel metal mould with graphite paste (die coat) as mould releasing agent preheated to 200^{o}C. After casting, the plates were machined into 150 *150 * 6 mm^{3} using wire-cut electric discharge machine,and sheets are heat treated and then cold-rolled to 5-mm-thick sheets.

4.2 Mechanical Properties:

4.2.1 Vickers Microhardness Measurement:

Vickers microhardness was measured from the specimens by microhardness tester on the surface of the specimens by applying a load of 200gf for 15s dwell time. Vickers hardness equipment and the specimens before testing are shown in Fig. 4.1 and 4.2 respectively. After testing the specimens are shown in Fig. 4.3. The hardness values of each specimen were calculated by averaging five data points

Figure 4.1 Vickers Hardness Equipment

Figure 4.2 Hardness Specimen Before Testing

Figure 4.3 Hardness Specimen After Testing

4.2.2 Tensile Test

Uniaxial tensile tests and three-point bend tests at room temperature were conducted using computerised universal testing machine. Tensile tests were done according to the standards of ASTM E8 with constant cross head speed by using TUE-C-600 model universal testing machine to achieve material’s parameters such as ultimate strength, yield strength, and % elongation. Tensile specimens were machined to standard sub-specimens of 50-mm gauge length and 12.5 9 5 mm2 cross-sectional area. Ultimate strength, yield strength, and % elongation were recorded after averaging of three data points. Fig. 4.4 shows the universal testing machine and Fig. 4.5 and 4.6 shows the specimens before testing and after testing. After tensile test it was observed that the failure occurred within the gauge length.

Figure 4.4 Universal Testing Machine

Figure 4.5 Tensile Specimen Before Testing

Figure 4.6 Tensile Specimen After Testing

4.2.3 Bend Test

The three-point bend tests were performed to evaluate the bending strength of the test specimens with mandrel size 4t (t is thickness of the specimen). Bend test equipment is used for bending test for the prepared specimens as shown in Fig. 4.7 The size of the specimen was 100 * 10 * 5 mm3 as shown in Fig . 4.8. Four specimens for each alloy were tested and averaged.Fig. 4.8 and 4.9 shows the bending test specimen before and after testing.

Figure 4.7 Bend Test Equipment

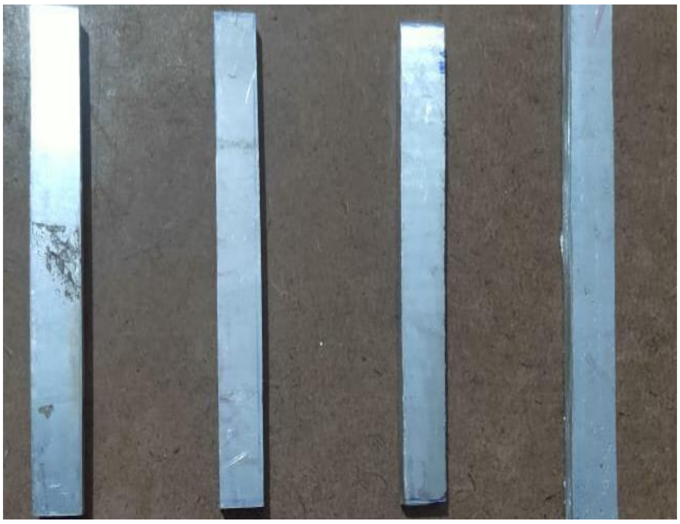


Figure 4.8 Bending Specimen Before Testing

Figure 4.9 Bending Specimen After Testing

4.2.4 Impact Test

The Charpy V-notch impact tests were performed using Krystal Elmec, model KI 300, range-168 J to know the actual energy observed by the specimens. The standard specimen size for Charpy impact testing was 10 * 5 * 55 mm^3 containing 45 V-notch, 2 mm deep with a 0.2 mm root radius. Two specimens for each composition were tested and averaged. Fig 4.10 shows the impact test equipment ,Fig. 4.11 and 4.12 shows the specimens before and after impact test, respectively.

Figure 4.10 Impact test Equipment

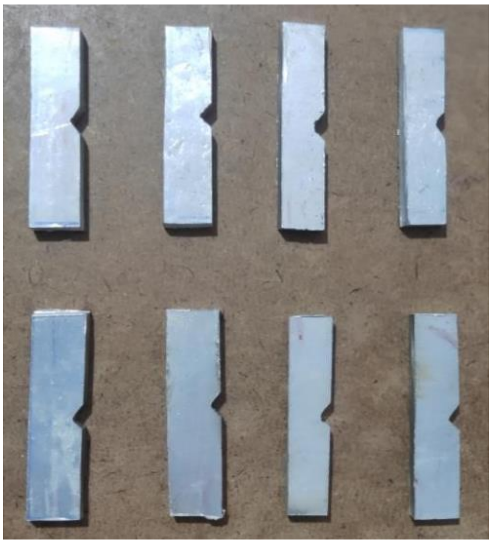


Figure 4.11 Impact Specimen Before Testing

Figure 4.12 Impact Specimen After Testing

CHAPTER-V

RESULTS AND DISCUSSION

The heat treatment promotes the hardening of the alloy Al-Cu-Mg alloy and the degree of aging is a function of time and temperature used for treatment. In this study, cold rolling of plates done followed by heat treatment at constant temperature (190ºC) for three hours were responsible for the change in mechanical properties.

5.1 Effect of Zr additions on Hardness of Al-Cu-Mg alloy

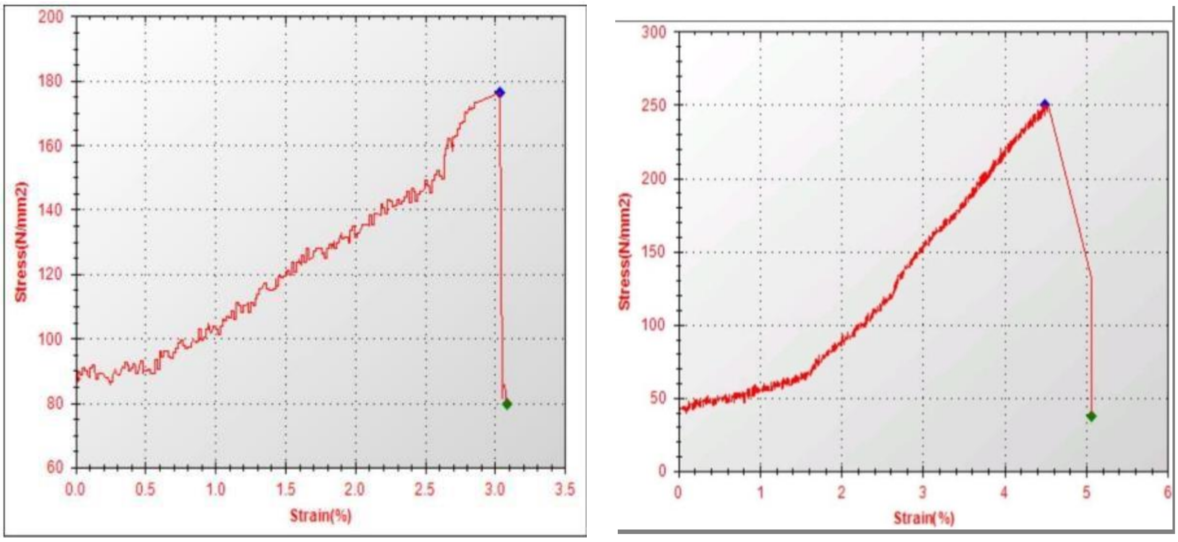
Zirconium is commonly added to aluminum alloys to improve their mechanical properties, including hardness. Al-Cu-Mg alloy is an aluminum alloy that contains copper as its primary alloying element, with magnesium as a secondary element. When zirconium is added to Al-Cu-Mg alloy, it forms a fine-grained precipitate known as ZrCu. Studies have shown that adding zirconium to Al-Cu-Mg alloy can increase its hardness by up to 20%. The specific increase in hardness will depend on the amount of zirconium added, the processing conditions, and the heat treatment used. In conclusion, the addition of zirconium to Al-Cu-Mg alloy can significantly increase its hardness, which can improve its mechanical properties and make it suitable for applications that require high strength and durability.Table No. 5.1 shows the variation of Vickers hardness of the specimen-1 to specimen-4, which reveals significant effect of Zr additions upon the hardness of the alloy. The hardness of alloy increases by adding zirconium and decreased when heat treating it. The effect of heat treatment on the hardness of Al-Cu-Mg alloy depends on the specific heat treatment process used. The most common heat treatment processes for Al-Cu-Mg alloy are solution heat treatment and precipitation hardening. To increase the hardness of Al-Cu-Mg alloy, it is subjected to precipitation hardening. This involves heating the alloy at a lower temperature (around 120-190°C) for a specific period of time, which causes precipitation of hardening phases within the microstructure. The hardness of the alloy increases with an increase in the amount of precipitated phases. Heat treatment can significantly affect the hardness of zirconium-added Al-Cu-Mg alloy. The alloy can be heat-treated using either a solution treatment or precipitation hardening process. On the other hand, during the precipitation hardening process, the alloy is heated to a lower temperature to allow the zirconium particles to precipitate out of the supersaturated solid solution and form strengthening precipitates. This process results in an increase in hardness due to the formation of these precipitates.

Table No. 5.1 Effect of Zr additions on Hardness of Al-Cu-Mg alloy

Alloy	VHN
Al-Cu-Mg alloy	215.4
Heat treated Al-Cu-Mg alloy	348.7
Al-Cu-Mg-Zr alloy	373.3
Heat treated Al-Cu-Mg-Zr alloy	236.7

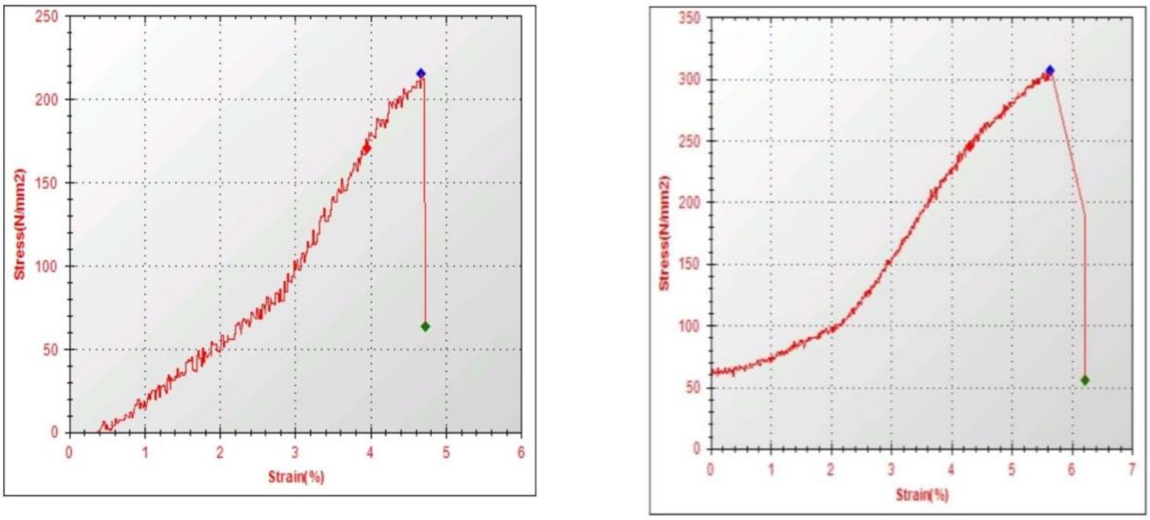
5.2 Effect of Zr additions on Tensile strength of Al-Cu-Mg alloy

The effect of heat treatment on the tensile strength of Al-Cu-Mg alloy can vary depending on the specific heat treatment process used. Generally, the strength of Al-Cu-Mg alloy can be increased through heat treatment processes such as solution heat treatment and age hardening. Age hardening, also known as precipitation hardening, is a secondary heat treatment process that involves reheating the alloy to a lower temperature to encourage the formation of precipitates within the alloy. These precipitates can increase the strength and hardness of the alloy. The exact temperature and duration of the age hardening process can be tailored to achieve specific strength and hardness properties.The effect of zirconium on the tensile strength of Al-Cu-Mg alloy is also influenced by other factors, such as the presence of other alloying elements and the processing conditions used during the manufacturing process. Therefore, the exact impact of zirconium on the tensile strength of Al-Cu-Mg alloy will depend on the specific composition and processing conditions of the alloy.Overall, zirconium can be an effective alloying element for improving the tensile strength of Al-Cu-Mg alloy, but the optimal concentration and processing conditions will depend on the specific application and requirements of the material.The tensile properties of Al-Cu-Mg alloy such as yield strength, tensile strength, percentage of elongation, were evaluated. In each condition, four specimens were tested, and the average of these results were obtained and it is observed a gradual increase in yield strength. Figure 5.1 shows the stress vs. strain curves of the investigated alloys. The effect of heat treatment on the tensile strength of zirconium-added Al-Cu-Mg alloy depends on the specific heat treatment process used. The two main types of heat treatment processes used for aluminum alloys are precipitation hardening and annealing.In precipitation hardening, the alloy is heated to a specific temperature range to allow the alloying elements to form precipitates. These precipitates create barriers that impede dislocation movement, resulting in an increase in strength. The process is followed by a rapid quenching step to "freeze" the precipitates in place. The alloy is then aged at a lower temperature to allow for further precipitation hardening.



(a) Al-Cu-Mg alloy

(b) Heat treated Al-Cu-Mg alloy



(c) Al-Cu-Mg-Zr alloy

(d) Heat treated Al-Cu-Mg-Zr alloy

Figure 5.1 (a-d)Stress vs. Strain curves

Table No. 5.2 Effect of Zr additions on Tensile strength of Al-Cu-Mg alloy

Alloy	Tensilestrength (N/mm^2)	Yield strength (N/mm^2)	%elongation (mm)
Al-Cu-Mg alloy	196.53	130.18	1.92
Heat treated Al-Cu-Mg alloy	230.57	184.03	3.14
Al-Cu-Mg-Zr alloy	173.26	137.88	2.65
Heat treated Al-Cu-Mg-Zr alloy	306.538	245	3.73

Table No. 5.2 The tensile strength (UTS) of specimen-1 to specimen-4 are 196.53 N/mm^2, 230.57 N/mm^2, 173.26 N/mm^2, 306.538 N/mm^2, respectively, the yield strengths (YS) are 130.18 N/mm^2, 184.03 N/mm^2, 137.88 N/mm^2, 245 N/mm^2, respectively. In summary, adding zirconium to Al-Cu-Mg alloy and subjecting it to a carefully controlled heat treatment process can increase its tensile strength. The specific heat treatment process and parameters must be carefully chosen to achieve the desired mechanical properties.it is observed that there is increase in tensile strength and yield strength on adding zirconium and heat treating the Al-Cu-Mg alloy.

5.3 Effect of Zr additions on bending strength of Al-Cu-Mg alloy

Al-Cu-Mg alloy can be heat treated using two main processes, solution heat treatment and precipitation hardening. In the solution heat treatment process, the alloy is heated to a high temperature (around 500-550°C) and then quenched in water or other cooling media. This process increases the alloy's ductility and toughness but reduces its strength. precipitation hardening involves a series of heat treatments to promote the formation of fine precipitates in the alloy. This process improves the strength and hardness of the alloy, making it more resistant to deformation.Therefore, the bending strength of Al-Cu-Mg alloy can be improved by precipitation hardening. The strength and hardness of the alloy increase with increasing aging time and temperature. However, excessive heat treatment can lead to over-aging and a decrease in the alloy's strength.In summary, the effect of heat treatment on the bending strength of Al-Cu-Mg alloy depends on the specific heat treatment process used. Precipitation hardening can improve the alloy's strength and bending strength, while solution heat treatment can reduce the strength but increase the ductility and toughness. The addition of zirconium to Al-Cu-Mg alloy can refine the grain size of the alloy, which can lead to an increase in its bending strength. This is because smaller grains result in more grain boundaries, which act as barriers to dislocation motion, making it more difficult for deformation to occur. This leads to an increase in the strength of the material.Studies have shown that the bending strength of Al-Cu-Mg alloy can be increased by up to 60% with the addition of zirconium. However, the exact effect of zirconium on the bending strength of Al-Cu-Mg alloy can depend on various factors such as the amount of zirconium added, the processing conditions, and the specific application of the material. Heat treatment can have a significant effect on the microstructure and mechanical properties of zirconium-added Al-Cu-Mg alloy. The specific heat treatment process used will depend on the desired properties of the final product. Zirconium has a beneficial effect on the aging response of Al-Cu-Mg alloy, improving the distribution and density of the precipitates that form during aging. The addition of zirconium also enhances the recrystallization resistance of Al-Cu-Mg alloy during heat treatment.

Table No. 5.3 Effect of Zr additions on bending strength of Al-Cu-Mg alloy

Alloy	**bend strength (N/mm^2)**
Al-Cu-Mg alloy	694.7
Heat treated Al-Cu-Mg alloy	749.03
Al-Cu-Mg-Zr alloy	130.76
Heat treated Al-Cu-Mg-Zr alloy	1258.65

Overall, the addition of zirconium and the proper heat treatment can significantly improve the mechanical properties of Al-Cu-Mg alloy, including its strength, hardness, and resistance to fatigue and corrosion.It is observed that there is a increase in bending strength when the material is heat treated comparing to non heat treated material.

5.4 Effect of Zr addition on Impact strength of Al-Cu-Mg alloy

The impact strength of Al-Cu-Mg alloy can be improved by heat treatment. The heat treatment process involves heating the material to a specific temperature and holding it at that temperature for a certain amount of time, followed by quenching and aging. The impact strength of Al-Cu-Mg alloy is influenced by several factors, including the composition of the alloy, the heat treatment process, and the testing conditions. In general, a higher degree of aging results in a higher impact strength, as the aging process increases the density of precipitates, which act as barriers to crack propagation.It is important to note that excessive heat treatment can lead to a reduction in impact strength, as the material may become too brittle. Therefore, it is essential to carefully control the heat treatment process to ensure that the desired properties are achieved.In conclusion, heat treatment can improve the impact strength of Al-Cu-Mg alloy, but the process must be carefully controlled to avoid over-treatment and brittleness. Studies have shown that the addition of zirconium to Al-Cu-Mg alloy can improve its impact strength. The improvement in impact strength is mainly attributed to the refinement of the grain structure and the prevention of grain growth during processing and heat treatment. However, the effect of zirconium on the impact strength of Al-Cu-Mg alloy can depend on several factors, such as the amount of zirconium added, the processing conditions, and the specific composition of the alloy. Therefore, it is important to carefully control these factors when using zirconium as an alloying element in Al-Cu-Mg alloy to achieve the desired improvement in impact strength. In the case of Zirconium-added Al-Cu-Mg alloy, the effect of heat treatment on impact strength depends on the specific heat treatment process used. Al-Cu-Mg alloy is a commonly used aluminum alloy that contains copper and magnesium, which can form strengthening precipitates during heat treatment.

Table No. 5.4 Effect of Zr addition on Impact strength of Al-Cu-Mg alloy

Alloy	Energy(J)
Al-Cu-Mg alloy	4
Heat treated Al-Cu-Mg alloy	4
Al-Cu-Mg-Zr alloy	6
Heat treated Al-Cu-Mg-Zr alloy	8

In summary, the effect of heat treatment on the impact strength of Zirconium-added Al-Cu-Mg alloy depends on the specific heat treatment process used. Table no 5.4 shows the impact strength of the prepared specimens, which shows that there is a increase in adding zirconium and heat treating the ASl-Cu-Mg alloy.

CHAPTER VI

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

1. Al-Cu-Mg-Zr alloys were successfully fabricated by stir casting technique.
2. Vickers hardness measurement showed a gradual increase in hardness with its peak at specimen-3, when zirconium is added to it and decreased after heat treating the plate.
3. Addition of Zr introduced a relatively high level of strength in Al-Cu-Mg as shown by improvement in hardness and tensile strength.
4. Tensile test showed a gradual increase in tensile strength observed with its peak at specimen-4, when zirconium is added to Al-Cu-Mg alloy and heat treating the plates.
5. Unnoticable values were observed with the effect of addition of Zr on elongation% ,impact strength and bending strength.

6.2 FUTURE SCOPE

Further this material is used for studying about corrosion properties,wear properties and fatigue properties.How the present material is behaving when studying about above mentioned properties.

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