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STUDY OF MECHANICAL PROPERTIES OF ALUMINIUM-COPPER ALLOY

Dr. Bharath L[1*], Vidyadhar Pujar[2] and Dakshinamurthy M[3]
[1]Assistant Professor, Department of Mechanical Engineering, Government Engineering College, Ramanagara-562159
[2]Associate Professor, Department of Mechanical Engineering, The Oxford College of Engineering, Bangalore-560068
[3]Assistant Professor, Department of Civil Engineering, Government Engineering College, Chamarajanagar-571313
[1]bharathsmg@yahoo.co.in, [2]v8123340411@gmail.com and [3]dakshinamurthy66@gmail.com

ABSTRACT
The material known as duralumin is composed of 94.96% aluminium and 3-5% copper. For the purpose of this project, the composition of the duralumin alloy is being altered to consist of 80 percent aluminium and 15 percent copper. Following that, the sand casting procedure is utilised to incorporate these elements into a variety of models. Spreading copper particles throughout an aluminium matrix is the process that is known as casting. Products made of metal are produced as a consequence of this circumstance. An alloy with a composition that is quite similar to that of duralumin is used to analyse and compare their behaviour to that of the alloy. An investigation of the influence of the particle's composition is carried out by varying the percentage of copper, which can range anywhere from 5% to 15% during the experiment. When the amount of particle matter was increased, the material's hardness also increased. This was the case in both the cast and the homogenised settings. When contrasted with the alloy, the alloy exhibits a drop in strength of 13% and a fall in strain of 1.5 percent. There has been a reduction in the torsional strength of the new alloy, while there has been an increase in resistance to compression. Strength grows in a manner that is directly proportional to the quantity of reinforcing material that is utilised.

Keywords: Aluminium, Copper, Sand casting, Duralumin

INTRODUCTION
In this project, the composition of duralumin is altered to comprise 85% aluminum and 15% copper. The alloy is manufactured using sand casting. The process begins by melting the individual metals, with aluminum melting at a temperature of 600 degrees Celsius and copper melting at 1085 degrees Celsius. Copper boasts one of the highest melting points in the world, with molten lava in a volcano melting at 1200 degrees Celsius. The molten metal is then poured into a mold designed according to ASTM standards. The American Standard for Testing and Materials (ASTM) develops standardized testing methods, specifications, and guidelines for various subjects, including metals, construction materials, and consumer products. After the properties of the alloy are analyzed, it can be transformed into various shapes and products through rolling, forging, and extrusion. Although the tensile strength of duralumin is stronger than aluminum, its resistance to corrosion is weaker. Additionally, the electrical and heat conductivity of duralumin is lower than pure aluminum and higher than steel [1]. The Al-Cu alloys utilized for interconnections may encounter corrosion if not treated correctly with a passivating agent. Our investigation began with the examination of two instances of corrosion present on actual manufacturing wafers. Through observation, we have documented the progression of these defects and provided an explanation for their occurrence. Our findings indicate that the use of a fluoride-based product as a polymer remover can result in two distinct corrosion mechanisms, despite the solution having a pH that should maintain the stability of aluminum oxide [2, 3]. Because of the considerable impact it has on the industrial sector, the Al–Cu–Si ternary system has been the subject of a great deal of research over the past few years. Because of their low density and outstanding material characteristics, Al–Cu–Si alloys are becoming an increasingly essential component in the automotive and aerospace industries. These ternary alloys have a stronger strength than their binary counterparts, the Al–Si alloys, and a better resistance to corrosion than the Al–Cu alloys. In order to successfully create Al–Cu–Si alloys that are

up to par with particular standards, one absolutely needs to have a profound comprehension of the full ternary phase diagram. The Al–Cu system and the Cu-rich region of the Al–Cu–Si phase diagram, as well as the binary subsystems, are particularly difficult to understand. In spite of the many investigations that have been conducted on phase equilibria, the ternary phase diagram is still only partially explained. This study aims to contribute to a better knowledge of those parts of the phase diagram that have not been fully resolved in earlier literature or that have generated inconsistent results from different authors. In other words, the purpose of this study is to contribute to a better understanding of those sections of the phase diagram. A comprehensive analysis of the published research on the Al–Cu–Si ternary system and its binary subsystems is offered in the following paragraphs. [4, 5] When exposed to air or water-based media, pure aluminum produces a protective oxide film that acts as a barrier against corrosion. This allows aluminum to maintain an outstanding level of corrosion resistance. However, due to its lack of hardness, it is not an ideal candidate for use as a high-strength material in the construction of huge buildings. Aluminum-based alloys have been produced in order to improve specific qualities in order to circumvent this limitation. Copper is a common metal that is used as an alloying component since even trace amounts can considerably boost the material's level of hardness. Due to their low density, strong electrical and thermal conductivity, and good corrosion resistance in specified settings, aluminum copper alloys are currently utilized extensively in industry. This is because these characteristics make these alloys extremely advantageous from a technological point of view [6]. Aluminum-copper alloys, including copper-based duralumins and aluminum bronzes, are extremely valuable due to the one-of-a-kind physical and chemical qualities that they possess. As a result of their low weight in comparison to their great strength, as well as their high flexibility and resistance to corrosion, they find widespread application in the fields of mechanical engineering and aviation manufacturing. The number of aluminum atoms relative to the number of copper atoms in an alloy is the primary factor that determines its viscosity, thermal conductivity, electrical resistivity, and magnetic susceptibility [7, 8]. Many product designs are based on previous designs, with modifications made to optimize performance. In high-volume transportation industries such as the automotive sector, designs are often tailored based on durability and warranty experiences. Casting is a process that poses risks of failure during production, so it's essential to take measures to ensure that the final product is free of defects. Clay-bonded sand mixes, also known as green molding sands due to their high moisture content, are utilized in the vertically separated automatic flaskless casting process. This process makes use of a molding machine and a mold transportation conveyor in order to complete the casting procedure [9, 10]. Sand made of silica, clay made of bentonite, and various other components make up these combinations. Metal casting is a versatile primary manufacturing method that has the capability of producing products weighing from a few grams to several tons in any meltable material. Sand castings are manufactured in specialized facilities called foundries, with over 70% produced through the green sand casting process [11]. The purpose of this research is to investigate the effects that a variety of parameters have on the quality of castings made of aluminum alloys that are manufactured using the sand mold casting process. Castings with the same shape and dimensions were produced, however there were some differences in the sand particle size, clay content, moisture content, and number of ramming cycles used. The resulting castings were then evaluated for their mechanical properties to identify the ideal conditions that result in high-quality castings. The purpose of the study is to find ways to improve casting processes so as to minimize the occurrence of defects in the finished product. These flaws are frequently brought on by inadequate casting conditions [12]. The findings of this research will give a scientific foundation upon which the design and optimization of a bimetallic composite structure may be carried out. In addition, the findings of this research will be helpful in the creation of novel composite materials, which will have improved electrical conductivity as well as strength. Furthermore, the findings of this research can be applied to the design of power transmission systems that require high electrical conductivity and strength, such as electric vehicles and wind turbines. It is anticipated that the 1060Al-T2Cu FSW joint will find widespread use in a variety of industries, including the aerospace industry, the automobile industry, and the renewable energy industry. Thus, this study will contribute to the development of a more efficient, reliable, and environmentally friendly power transmission system [13, 14]. However, as the copper content exceeds this limit, the corrosion resistance of the alloy decreases. Therefore, a proper balance between strength and corrosion resistance must be maintained when using high copper content aluminum alloys. In order to strike this delicate balance, the alloy may have additional elements, such as magnesium or zinc, added to it in calculated proportions in order to improve its resistance to corrosion. Because of the exceptional combination of high strength, resistance to corrosion, and excellent conductivity that these alloys possess, they find widespread use in a variety of applications, including those involving aerospace, transportation, construction, and electrical engineering. The microstructure and mechanical properties of these alloys can be further improved by proper heat treatment and processing, making them highly desirable for various applications [15]. Aluminum is non-magnetic and has important applications in the electrical and electronics industries. It is also non-flammable, making it a safe choice for handling and exposure to combustible materials. The metal is non-toxic and is often used in food and beverage containers. In addition to this, aluminum has an appealing physical look since it may be finished with a coating that is velvety and lustrous, brilliant and shining, or any other color or texture. The simplicity with which it can be fabricated into any form is one of its most valued features since it enables it to compete with materials that are less workable and more affordable. Aluminum can be cast using any foundry method, rolled to various thicknesses, stamped, drawn, spun, roll-formed, hammered, forged, or extruded into various profiles. It can even be stranded into cable of any desired size and type [16, 17]. An increase in the amount of copper in aluminum-copper alloys results in a greater rise in the material's elasticity. When heated to temperatures that are somewhat close to the point at which the alloy will melt, the modulus of elasticity drops to about half of what it is at ambient temperature. Copper additions to the alloy raise its strength at high temperatures, but also lower the alloy's capability for dampening vibrations. When it is in solid solution, copper's ability to resist fatigue in aluminum-copper alloys improves along with the alloy's copper concentration. In alloys composed of aluminum, silicon, and copper, the addition of copper improves the material's hardness, strength, fatigue resistance, creep resistance, and machinability. Within specified composition limits, the incorporation of copper into aluminum-magnesium alloys has a negligible effect on the materials' resulting mechanical properties [18].

METHODOLOGY

The methodology of the project starts from procurement of materials which basically means to select the materials on which the process is to be performed. Hence aluminium and copper were selected because of their light weight and abundance availability in the environment [19, 20]. Then the 3D and 2D designs were made using Solid Edge software according to ASTM standards. Then similar patterns were created in the sand mould for sand casting. Then these metals were used in their respective ratio and melted using a furnace, later the liquefied metal was poured into the sand mould and let to solidify. Later the parts were machined to specific shapes and sizes to get them ready for testing. Then these parts were tested for torsion and compression test and the results were obtained and the graphs were plotted using python. Figure 1. Flow chart of the process of this study [20, 21].

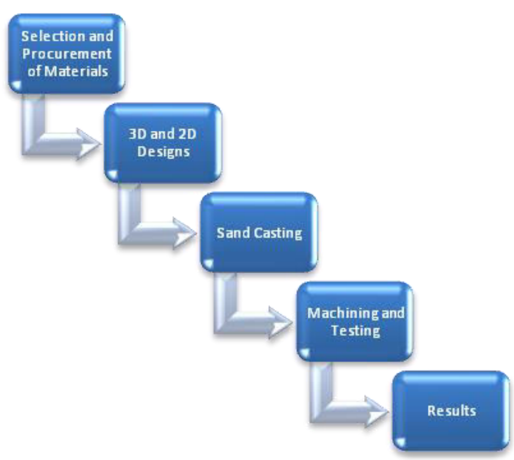


Fig. 1. Flow chart of the process of this project

Figure 2. Shows the 2D and 3D model of compression test specimen.

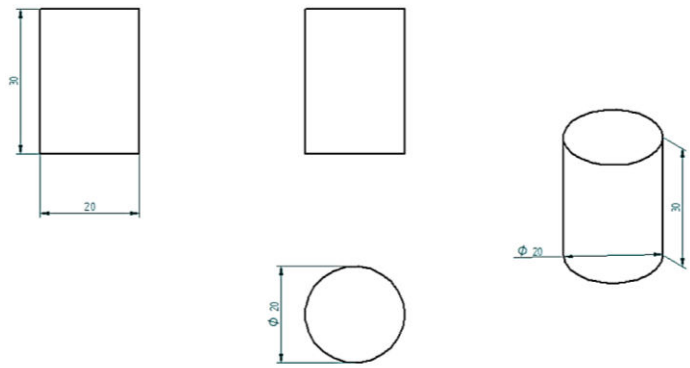


Fig. 2. 2D and 3D model of compression test specimen

Figue 3 shows the 2D and 3D model of torsion test specimen.

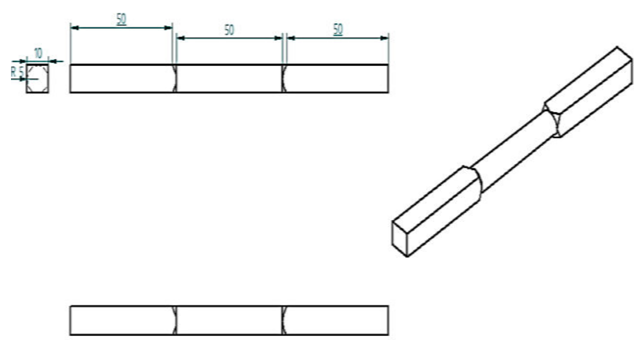


Fig. 3. 2D and 3D model of torsion test specimen

EXPERIMENT

To conduct the experiment first the 2D and 3D designs were considered to make the patterns in the sand mould. Then green sand was used to make the sand mould where the patterns were made according to the designs [22]. Then the liquefied metal was poured in the cavity of the mould and it was removed after solidification. Then the alloy was brushed to remove the sand particles on it. Later the alloy was bought to its required size and shape by removing excess material on it by using a lathe machine. Then the alloy was tested for torsion and compression strength. Later the values were tabulated and the unknowns were calculated which led to the results [23]. Figure 4 shows the Liquefying the metals in a graphite crucible in their respective ratios.

Fig. 4. Liquefying the metals in a graphite crucible in their respective ratios

Figure 5 shows the Graphite Crucible, Aluminium, Copper.

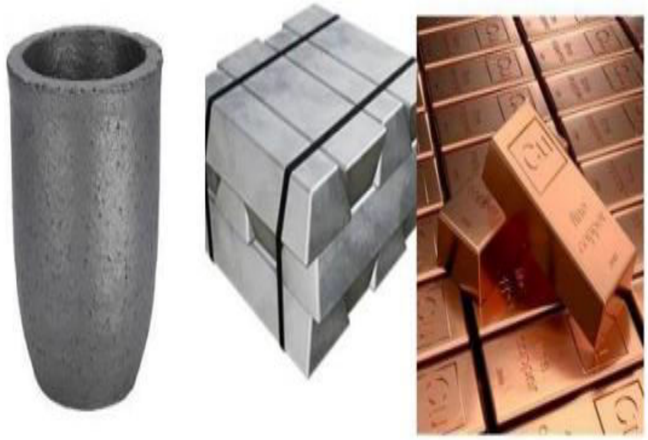


Fig. 5. Graphite Crucible, Aluminium, Copper

Fig. 6. Shows the Microstructure of the alloy.

Fig. 6. Microstructure of the alloy

Fig. 7. Shows the Specimen after compression test.

Fig. 7. Specimen after compression test

RESULTS AND DISCUSSION

The torsion test results are shown in the Table 1.

Table 1. Torsion Test Results

Sl. No.	*Angle (In Degrees)*	*Angle (In Radians)*	*Torque (In KN-m)*	*Shear Stress (N/m^2)*	*Shear Strain*	*Modulous of Rigidity (N/mm^2)*
11	5	0.0872	0.026	145.086	$8.99*10^{-3}$	16123.71
22	10	0.1745	0.059	325.23	0.018	18283.53
33	15	0.2618	0.129	719.85	0.02701	26645.78

The compression test results are shown in the Table 2.

Table 2. Compression Test Results

Sl. No.	*Angle (In Degrees)*	*Angle (In Radians)*	*Torque (In KN-m)*	*Shear Stress (N/m^2)*	*Shear Strain*
1	5	0.1	0.013	0.0031	4.19
2	10	0.95	0.026	0.02	1.3
3	15	1.4	0.039	0.043	0.9
4	20	2.4	0.052	0.075	0.69
5	25	2.72	0.065	0.085	0.76
6	30	2.9	0.078	0.096	0.81
7	35	3.15	0.092	0.098	0.96
8	40	3.18	0.105	0.099	1.06
9	45	3.35	0.118	0.104	1.13
10	50	3.42	0.13	0.106	1.22
11	55	3.5	0.144	0.109	1.32
12	60	3.56	0.157	0.111	1.41
13	65	3.65	0.17	0.114	1.49
14	70	3.71	0.18	0.155	1.56
15	75	3.78	0.19	0.118	1.6
16	80	3.83	0.21	0.119	1.68
17	85	3.9	0.22	0.121	1.81
18	90	4	0.23	0.128	1.79
19	95	4.1	0.24	0.129	1.86
20	100	4.13	0.26	0.13	2
21	105	4.15	0.27	0.1301	2.07
22	110	4.18	0.28	0.1306	2.14
23	115	4.2	0.3	0.132	2.72
24	120	4.28	0.31	0.133	2.33
25	125	4.38	0.32	0.136	2.35

Fig. 8. Shows the Torsion test graph

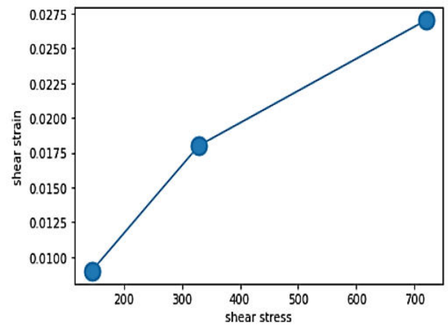
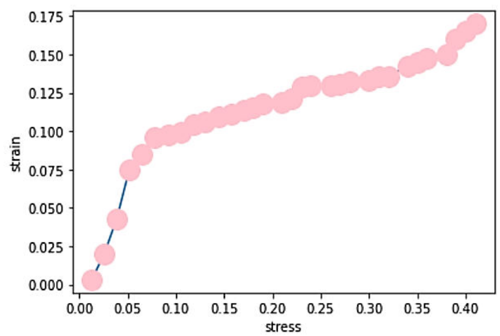
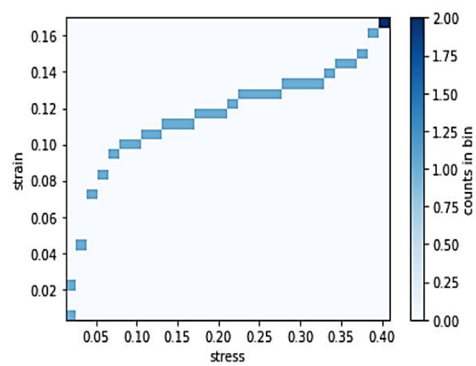


Fig. 8. Torsion test graph



(a)

Figure 7 is an illustration that shows how the variation in shear strain in reaction to shear stress can be easily observed and studied within the context of the torsion test. There is evidence that the shear strain is growing at a pace that is proportional to the shear stress [24, 25]. A connection between these two things has been found. As a result of the alloy's unusually high level of hardness, it did not possess really wonderful torsional properties. Figure 8, is an illustration that shows how the shear strain varies in relation to the shear stress. This is something that may be observed during the compression test. In this particular instance, the shear strain increases at an exponential rate up until a particular point, and then it begins to increase at a more gradual rate after reaching the yield point that was discussed before [26, 27]. This is as a result of the alloy having a high compression strength, which implies that it is able to sustain heavy loads. This is the reason why this is the case. These results are therefore brought about as a result of the modification that was made to the composition of the duralumin alloy. Figure 9 shows the compression test graphs.



(b) **Fig. 9.** Compression test graphs

CONCLUSIONS

The variation of shear strain with regard to the shear stress could be easily identified and analyzed in the torsion test. It has been discovered that the shear strain is growing at a rate that is proportional to the shear stress. Since the alloy is hard it didn't possess very good torsional properties. But in compression test we can see the variation of shear strain with respect to the shear stress. Here the shear strain increases exponentially till a certain point an then increases steadily ie., after reaching yield point. This is because the alloy consists of good compression strength which expresses that it can with stand heavy loads. Therefore the change in composition of duralumin alloy gives these results.

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