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Effect of Rolling at Moderate Temperature on Mechanical and Physical Behavior of the Light Weighted Composite Materials

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Abstract:
An application of the light weight martials play the significant role in the modern industries. Such materials along with the high strength to weight ratio and significant mechanical attributes utilized to fabricate the new generation materials for automobile industries. Al and its alloy have been utilized widely in the current automotive industries, especially addition of silicon in aluminium alloy provide significant improvement in Mechanical and physical properties.
In the current study Al-Si alloy has been utilized as a base material to prepare the composite materials along with graphite powder. Fabricated materials have been characterized and evaluate the effect of rolling at moderate temperature on mechanical and physical properties. It has been found that the composite's material hardness have significant with respect to rising thickness reduction. The density of the materials continuously increases with increasing the percentage of thickness reduction and porosity reduced.

Keywords: *Aluminium Alloy, Density, Composite*

I. INTRODUCTION

Composite materials are employed in many different industries nowadays, such as electronics, sports, automobile, construction, marine, and aerospace. Their versatility, strength-to-weight ratio, and durability make them an integral part of modern manufacturing and engineering, which offering innovative solutions to various challenges in design and performance. Composite materials continue to advance, with ongoing research focused on improving their properties, reducing costs, and making them more environmentally friendly. Their versatility and ability to meet specific engineering requirements make them invaluable in various industries.[1]

Aluminium (Al) alloy-based composite materials combine aluminium alloys with other materials to enhance specific properties, making them suitable for various applications. These composites typically consist of an aluminium matrix reinforced with other materials like particles, fibres, or ceramics. These composites provide an equilibrium between the improved mechanical qualities of the reinforcing components and the lightweight nature of aluminium.[2] These materials are continually evolving, with ongoing research aimed at optimizing their properties, reducing costs, and expanding their range of applications.

Aluminium-silicon-graphite (Al-Si-Gr) composites are a type of composite material that combines aluminium (Al), silicon (Si), and graphite (Gr) to create a material with specific properties and characteristics. These composites are used in various applications where a combination of lightweight properties, thermal conductivity, and wear resistance is desirable. Aluminium is naturally lightweight, when combined with silicon and graphite, it retains its low density while gaining additional properties. Silicon and graphite are known for their excellent thermal conductivity. The inclusion of these materials in the composite enhances its ability to conduct heat, making it suitable for applications requiring efficient heat transfer. Addition of graphite to the composite increase its wear resistance, which enables it to be used in situations where friction and abrasion are concerns.[3] .

II. LITERTURE REVIEW

The low density (2.7 g/cm^3) of aluminium become the most significant qualities and commendable metal for engineering applications. Due to the softness of the pure aluminium metal, many aluminium alloys were created. Numerous alloys have been created as a result of the extraordinary physical and mechanical qualities of aluminium and its adaptability. The improvement of strength is often the major emphasis of element addition. The elements that play a significant part in the creation of aluminium alloys include copper, manganese, magnesium, nickel, silicon, and zinc.

Composites made of aluminium and its alloys offer high strength-to-weight ratios, strong malleability, good specific strength, good formability, and strong corrosion resistance and low density. [4]

The unique mix of qualities needed by many current technologies cannot be supplied by traditional materials. Materials used in the aircraft, automobile, and space industries are a prime example of this. Composite materials, which combine two or more metals, are a type of materials whose use is expanding quickly. Engineers may be able to create materials with custom qualities using composite materials, which is likely to be unachievable with traditional materials. Typically, a composite is described as "a multiphase material that is artificially made in which the constituent phases must be chemically dissimilar and separated by a distinct space". The bulk of composite materials have been formulated to improve a mixture of mechanical characteristics, such as hardness, stiffness, toughness, as well as strength at low and high temperatures.[5]

Cui et al.[6] has investigated high silicon content advanced aluminium alloys, as well as hypereutectic aluminium silicon alloys Al- Six (x = 18, 25, and 35 weight percent) that were spray produced under various heat settings obtained that the porosity of the spray- deposited Al-Si alloys which is significantly influenced by the heat conditions during the spray-forming process. It looks like gas entrapment, interstitial porosity under cold spray conditions and hot spray conditions, respectively, are the predominant processes of porosity generation.

Dasgupta et al.[7] has investigated Al-base alloy compositions benefit from improving experimental conditions and alloy composition as they relate to particle size, shape, and dispersion in the matrix. It was also discovered that notable advancements had been made, such as the composites withstanding far tougher conditions whereas the basic alloy seized at considerably gentler conditions.

Karthikeyan et al.[8] has used SEM and EDAX to study the mechanical characteristics and wear behaviour of the Al-Si-SiC- Graphite composite. Tests on various mechanical qualities have shown them to be superior than the basic alloy. The composite material's impact on graphite is established by the lubricating film production under load, as demonstrated by the experimental findings.

Dagale et al.[9] investigated heat-treated extruded aluminium 6063 alloy that is utilized in many structural and technical parts, including drive shafts, valves, window frames, railings, and aircraft wings and fuselages. Al-6063, one of the aluminium alloys in the 6000 family, is extensively utilized because to its exceptional qualities, which include moderately to extremely strong, strong resistance to environmental modifications, high elongation at break, low density, and excellent machinability. This work presents a summary of the mechanical, tribological, and microstructural properties of stir-cast Al-6063 metal/matrix composites (MMCs).

Shakya K et al.[10] has investigated the microstructural analysis as well as the hardness and wear study of Al-Si alloy. decent ratios of strength to weight, good wear resistance, low densities, and low coefficients of expansion due to heat have all been demonstrated by compositional analysis, hardness, and wear analysis carried out for several samples of the same composition also Si is distributed uniformly throughout the produced alloys by microstructural analysis.

Shrivastava V et al.[11] has investigated mechanical properties and microstructural characteristic of Al-6.5Si and Al-18Si.These alloys wear Hot-extruded using a 6:1 area reduction ratio and sprayed at 480°C. The spray deposited material's microstructure Al- 6.5Si The alloy exhibited a spherical main α-phase morphology, whereas the eutectic Si phase at the interparticle boundaries had a globular form.

Shanmughasundaram P. et al.[12] has investigated Al-7.5 weight percent Gr composite's microstructure, which was created via a two-phase casting method technique followed by a squeeze casting technique. It is evident that the graphite particles are evenly spaced and have a strong connection with the aluminium matrix. Strong interfacial bonding is ensured by a clean contact between the graphite the Al matrix and its constituent particles. The composite showed no signs of porosity or graphite particle aggregation. indicates that an increase in graphite content causes a progressive drop in the hardness of Al-Gr composites.

III. MATERIAL AND METHODOLOGY

A. Materials and Composition

Chemical composition of Al-6Si alloy is shown in table 1, 1% Graphite and 1% Mg has been introduced in the alloy externallyduring the fabrication of composite material**.**

Table 1 Chemical composition of Al-6 wt.% Si alloy

Si	Fe	Cu	Mn	Mg	Zn	Sn	Al
6.0130	0.298	0.0101	0.3963	1.3985	0.1998	0.0112	balance

B. Reinforcing Material

Graphite was employed as a material for reinforcement. The graphite particle size that was obtained ranged from 63 to 200µm insize. The reinforcement particles were sieved after being received and the desired particle size 20-50 µm was chosen.

C. Rolling

Rolling at multiple passes on the fabricated composite sample has been done at temperature 250°C.

IV. TESTING AND CHARACTERIZATION

A. Porosity

Porosity has been measured both before and after each thickness decrease using the Archimedes principle (ASTM B962-08) in anexperimental setting.

B. Hardness Measurement

Using a force of 10 N and a dwell duration of 15 seconds, a Vickers hardness test was conducted on the mirror-polished surface.The reported values for hardness are the average of 12 measurements captured at various points across the sample.

V. RESULT AND DISCUSSION:

A. Microstructure and Porosity Analysis

Equi-axed grains of the α-Al, porosity, and graphite particle along with magnesium dispersion have been examined. Figure. 1 demonstrates the spray-casting's optical microstructure. Al-6Si-1Gr-1Mg composites. From Figure 1, it is clear that the graphite is present in-between the equi-axed grains of aluminium whereas silicon is present as well as the grains of aluminium. Porosity is present near the graphite interphase.

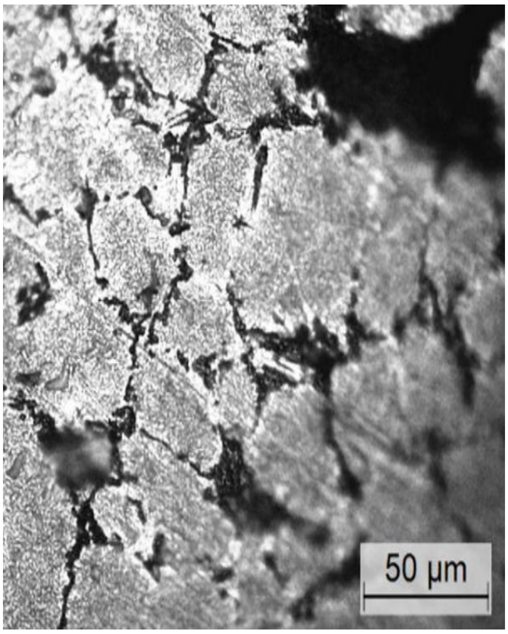

Fig. 1 Optical microscope image of Al-Alloy composite materials

Due to solidification shrinkages, and gas entrapment, porosity in spray produced alloys and composites is an unavoidable condition. The degree of porosity is influenced by the spray casting process operating parameters as well as variations in the melt percentage in the preform that is being deposited. To a considerable extent, the nature of the pores strongly influences mechanical qualities including wear, strength, and corrosion due to a wettability issue with the main phase α-Al of the graphite in this instance, porosity develops at the point where the graphite particles and matrix meet.

Figure 2 depicts the porosity changes as a function of thickness % decrease underneath the rolling of the spray-casted Al-6Si-1Gr- 1Mg composite. Under rolling, it has been shown that porosity value falls as thickness reduction increases.

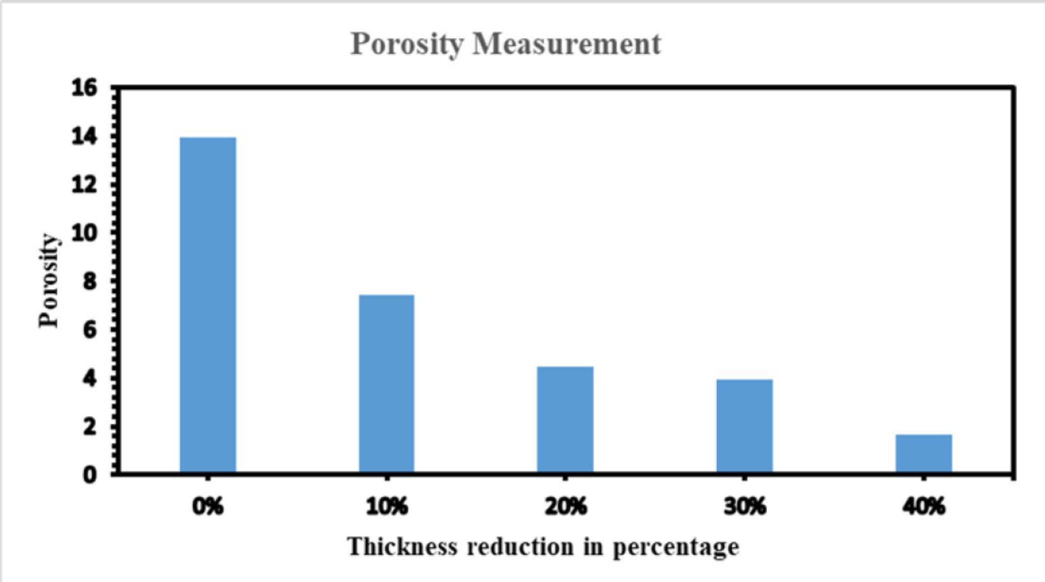

Fig. 2 Variation in porosity with % of thickness reduction

B. Density Analysis

Density of the composite materials at initial level was low and increase with continuous increment on thickness reduction. Thickness reduction collapse the pores and increase the tendency of particle to fracture into the matrix. Which further leads to reduce the porosity, hence density is higher at 40% i.e., 2.6116 gm/cm^3 thickness reduction.

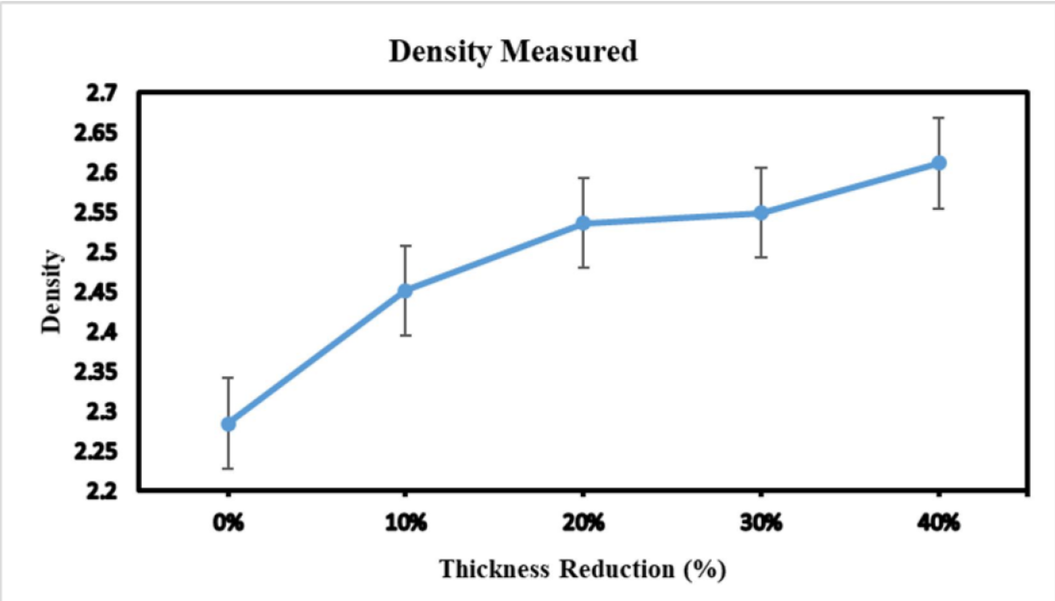

Fig. 3 Variation in density with increasing the % of thickness reduction

C. Hardness Analysis

Experimental findings for spray-casted Al-6Si-1Gr-1Mg composite with rolling along with various percentages of thickness decrease are displayed in Fig.4 using a Vickers hardness testing machine. It is evident that rolling enhances the composite's hardness. In addition, as the thickness decreases, the hardness rises. under rolling. The type of the second phase particles, their engagement, and the hardness is influenced by the size and form of the dispersed particles, or their morphology.

Porosity drops between the graphite particles and the aluminium matrix, along with a rise in the dispersion of shattered silicon particles following every decrease in thickness during rolling, may reduce the speed of the displacement and raise the hardness of the composite. As a result of the rolling, dislocations may also develop and grow

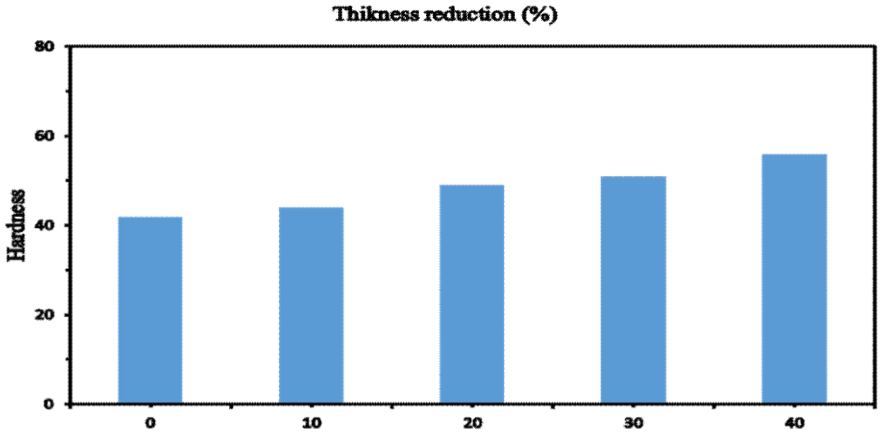

Fig. 4 Variation in hardness with increasing the % of thickness reduction

VI. CONCLUSIONS

In the current study, Graphite reinforced and Magnesium introduced aluminium alloy composites processed through rolling has been investigated. This chapter includes significant conclusions from the results obtained and findings from the current investigation. There are further findings which can be drawn:

1. As casted composite materials show the distribution of graphite reinforced particles along with the presence of magnesium into the aluminium matrix.
2. Rolling is the effecting process to reduce the porosity presence in the as received composite materials
3. Density of the composite materials consciously increases with increasing the percentage of thickness reduction.
4. The composite's enhanced hardness with increased the percentage of thickness reduction.

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