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Study on Mechanical Properties and Microstructure of Aluminium Alloy 63401 Reinforced with Alumina Powder

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Abstract

Objectives: This paper includes the study of mechanical properties and microstructure characterization of aluminium alloy 63401 reinforced with alumina powder of different mesh size and different weight percentage. **Methods**: Fabrication of composite material is done by stir casting process because it is the cheapest way to fabricate mass samples. Different grain size of (149µm, 74µm, 37µm) and different weight percentage of (3%, 6%, 9%) have been used in this experiment. **Findings**: The tensile strength, impact strength and hardness of the composite material produced by reinforcing alumina powder increases with increase in the percentage of alumina powder and also vary with particle size of alumina powder. **Applications**: This type of composite material can be used in aerospace and automobile sectors.

Keywords: AL 63401, Alumina Powder, Stir Casting

1. Introduction

The purpose of fabricating metal matrix composites is to enhance the mechanical properties like hardness, tensile strength, ductility etc. and also to reduce their wear rate. MMCs produced by adding reinforcement material in the metal. The choice of reinforcement material is very important according to its field of application. Ceramic materials, organic compounds and industrial waste like red mud, fly ash are commonly used as reinforcement materials. Hybrid metal matrix composites are fabricated by adding two or more reinforcement materials in the metal matrix. Aluminium metal matrix composites having wide applications in automobile field and in aerospace field due to its high strength with low density. Diesel engine pistons made of MMC which offers less wear rate and high temperature strength. Metals like Zn, Mg, and Cu are also used as a base metal to produce composites. Alumina powder, graphite in particle or whisker forms and silicon carbide are mainly used as reinforced material [1-5]. To fabricate composite material there are various type of techniques like stir casting, spray casting, squeeze casting, liquid metal infiltration.

In[6] fabricate AA6063- Al_2O_3composite with various weight percentage (3%, 6%,9%15%,) of alumina power by using two step stir casting process and found increment in the hardness, tensile strength by increasing the weight percentage of reinforcement material. Fracture toughness

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of the composite decreases with increase in the alumina percentage.

In[7] studied mechanical properties, tribological properties and microstructure of Al6061-SiC and Al7075-Al_2O_3. Weight percentage of reinforcement material vary from 2%-6% and research shown that tensile strength and hardness of the composite material increases with increase in the weight percentage. Wear rate of Al6061-SiC is better than Al7075-Al_2O_3 composite.

In[8] investigates the mechanical properties of aluminium alloy LM25 with silicon carbide, red mud, E glass. Author found increment in the tensile strength and impact strength with increase in the weight percentage of reinforcement material. Minimum facture toughness found when E glass is used as reinforcement material.

In[9] studied mechanical properties, microstructure and wear properties of Al 6061 reinforced with 10% SiC and 2.5%, 5% and 10% TiB_2. Author found that SiC and TiB_2 are uniformly distributed in the metal matrix. Hardness also increases with the addition of SiC and TiB_2. In case of Al/10% SiC composite hardness increases by 38% and in case of Al/10%SiC/5%TiB_2 hardness increases by 35.7%. On the addition of SiC and TiB_2 wear rate and coefficient of friction also decreases.

In[10] studied the mechanical properties and microstructure of aluminium metal matrix reinforced with untreated fly ash (14.3%) and treated fly ash (13.2%). Energy dispersive X-ray analysis shows that there was complete conversion of SiO_2 in to SiC. Aluminium metal matrix composite reinforced with treated fly ash shows better mechanical properties like hardness, compressive strength and tensile strength than the AMC reinforced with untreated fly ash.

In[11] fabricate Al (LM6) composite reinforced with boron carbide of different weight percentage (2.5, 5, 7.5 and 10) % to study the microstructure, mechanical properties and wear properties. Author investigate that with increase in the weight percentage density of composite material decreases which results in high micro hardness and high ultimate compressive strength. Microstructure of the composite material also studied which shows uniform distribution of boron carbide particles in metal matrix composite. Wear resistance also increases with the increase in the boron carbide particles.

Alumina powder (aluminium oxide) also named as corundum in its crystalline form is used as reinforcement material due to its cost effectiveness and easily availability. Due to readily availability and reasonable price of raw material from which this ceramic is fabricated the cost of alumina is very reasonable. Cost effectiveness with excellent properties fine grain alumina has wide applications. Due to hardness of this ceramic it is used as an abrasive material. Alumina used as reinforcement in metal matrix and results in low wear rate of the composite.

2. Experimental Methodology

Aluminium alloy 63401 is used as a base metal for this research. Chemical composition of aluminium alloy 63401 shown in Table 1.

Table 1. Chemical composition of Al 63401

Cu	0.05
Mg	0.4-0.9
SiC	0.3-0.7
Fe	0.50
Mn	0.03
Zn	0.10
Ti	0.10
Cr	0.03
Al	Remainder

Casting of composite material is done by stir casting technique. Aluminium alloy 63401 reinforced with different weight percentage (3%, 6%,9%) and different mess size (149µm,74µm,37µm) of alumina powder. Alumina powder separated in different mesh size by subjected to sieve analysis. AL63401 placed in the crucible and then crucible placed in the furnace having temperature 750°C. Alumina powder is placed in the muffle furnace at 350°C to remove moisture content from the powder. Reinforcement material added in the molten metal and stir with the alumina rod for 5 min. Mg metal with 1% weight percentage is added in the molten metal to improve the wett ability. Alumina with MgO coating improves wett ability. MgO produced at high temperature when alumina melts with AL63401.

The melt poured in the die and allow to cool. After machining the samples, samples for tensile strength, impact strength and hardness are produced to find the result of these properties.

3. Result and Discussion

3.1 Microstructure

Microstructure of the composite material formed is investigated by using optical microscope. Results show that alumina is nearly uniformly distributed in the metal matrix composites. Figure 1 to 3 given shows the microscopic images of metal matrix composite.

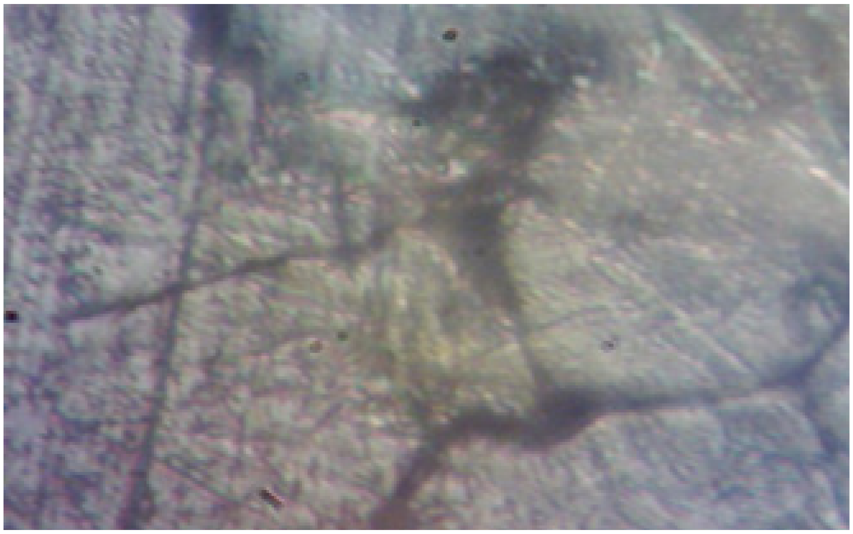

Figure 1. AL 63401 reinforced with 3% alumina powder having particle size 37 micron, its surface is studied on the optical microscope and found that alumina is uniformly distributed.

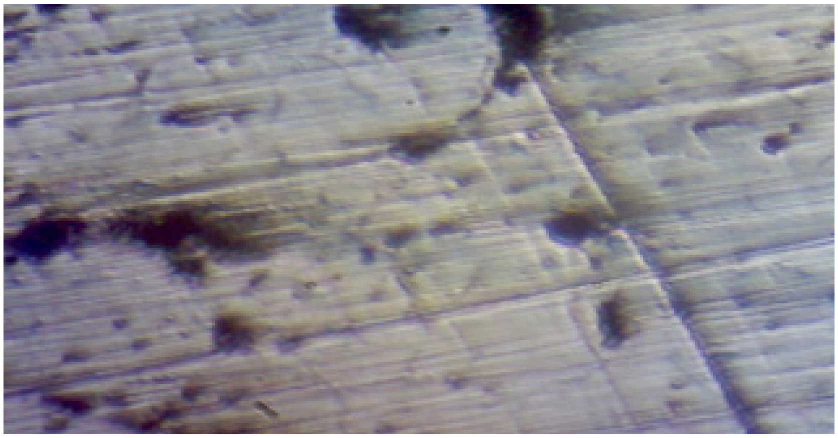

Figure 2. AL 63401 reinforced with 6% alumina powder of 37 micron having moderate uniformity.

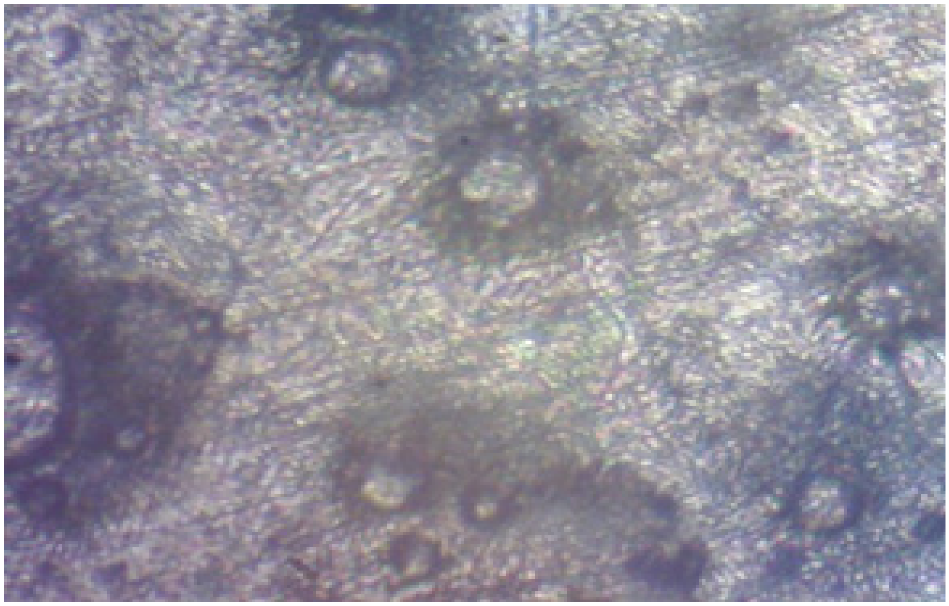

Figure 3. Microstructure of AL63401 reinforced with 9% of alumina powder of 74 micron shows the least uniformity and shows the formation of cluster.

3.2 Tensile Strength

Tensile strength of the composite material is determined on universal testing machine by making dumble shape samples having diameter of 14.01 mm. The tensile strength of composite according to different alumina particle size (149, 74, 37 micron) with weight percentage of 3% alumina powder is shown below Table 2. Tensile strength with different weight percentage (3, 6, 9) % with same grain size (149 micron) has shown in Table 3 given below.

Figure 4 shows the variation of tensile strength with different grain size of Al_2O_3 (149μm, 74μm, 37μm) with constant weight percentage 3%. From the graph plotted it is concluded that with small particle size the tensile

Table 2. Tensile strength with different particle size

Particle size in micron	Weight percentage of alumina powder	Tensile strength (KN/mm^2)	Elongation (%)
149	3	0.123	5.64
74	3	0.141	8.7
37	3	0.151	10.5

Table 3. Tensile strength with different weight percentage

Weight percentage of alumina powder	Particle size (μm)	Tensile strength (KN/mm2)	Elongation (%)
3	149	0.123	5.64
6	149	0.147	13.7
9	149	0.154	30.1

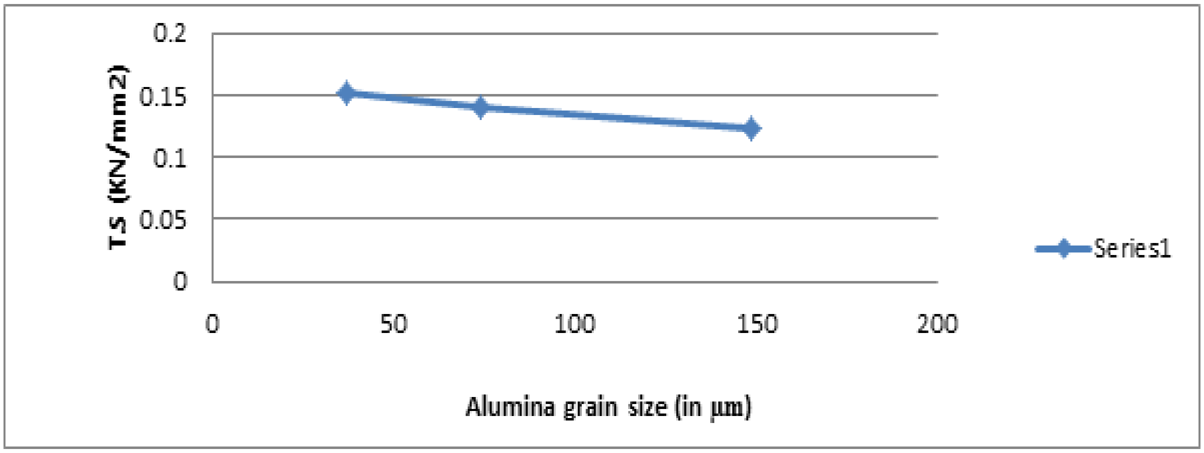

Figure 4. Represents the variation of tensile strength with different reinforcement grain size.

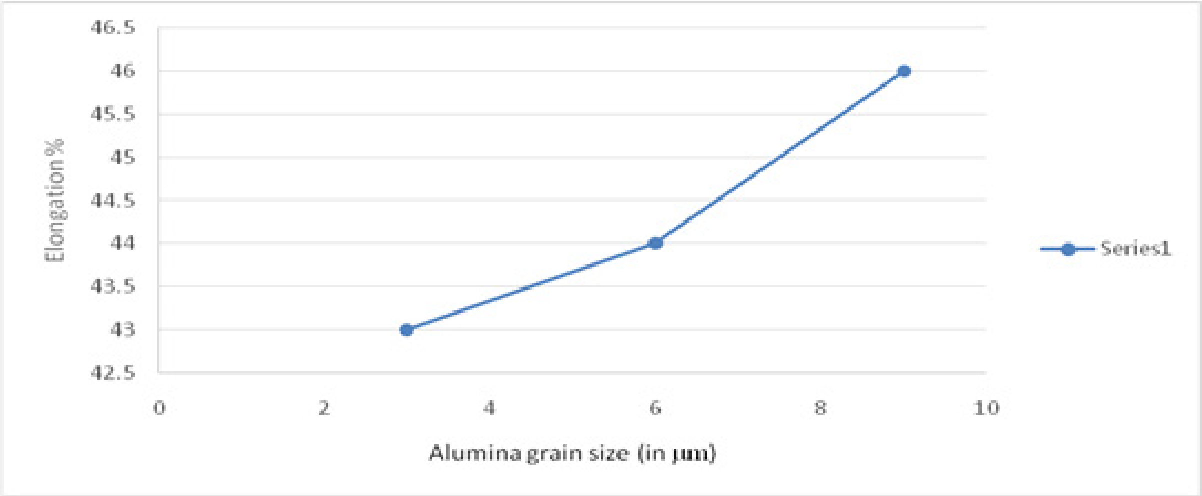

Figure 5. Effect of alumina powder grain size on elongation of composite.

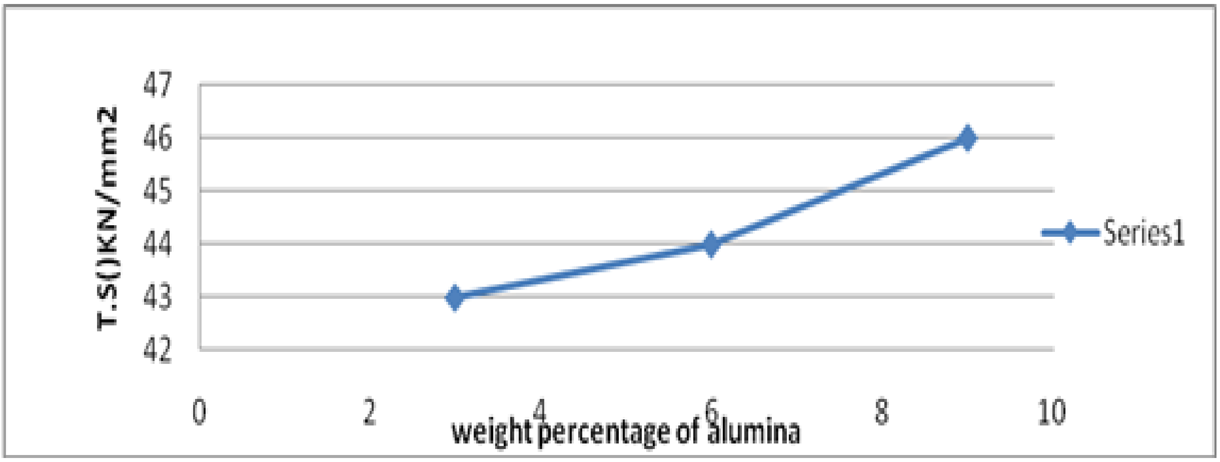

Figure 6. Effect of weight percentage on the tensile strength of composite.

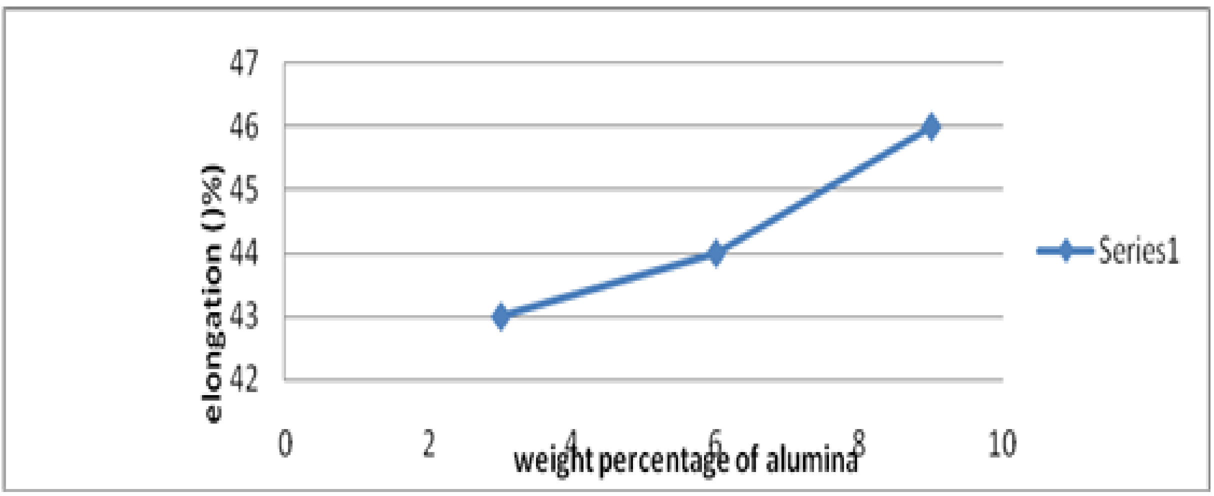

Figure 7. Effect of weight percentage on the %age elongation.

strength increases. Maximum tensile strength is found at grain size 37µm that is 0.151 KN/mm^2 and minimum tensile strength is found at grain size 149µm that is 0.123 KN/mm^2. Average enhancement 22.7% has been observed when particle size decreases from 149µm to 37µm. Figure 5 shows the elongation percentage variation with decrease in the mesh size. It is concluded that with decrease in the grain size of alumina powder the elongation percentage increases. Variation in tensile strength with various weight percentage of reinforcement material has been shown in Figure 6. From Figure 6 it has been concluded that with increase in the weight percentage of alumina powder tensile strength increases significantly. Figure 7 represents the effect of weight percentage on the %age elongation of the composite material. From the Figure 7 it is concluded that with increasing the weight percentage of alumina powder of same grain size of 149μm, there is gradual increase in the elongation percentage has been observed.

3.3 Impact Test

Izod v-notch test method is used to determine the impact strength of the composite material. Impact strength variation is presented according to the decrease in grain size in Table 4 and increase in the weight percentage of the alumina powder in Table 5. Figure 8 shows the effect of grain size on impact strength and it has been concluded that impact strength increases with decrease in the grain size. Figure 9 addresses the effect of weight percentage on impact strength. From the graph plotted it has been observed that impact strength increases with increase in the weight percentage of alumina powder.

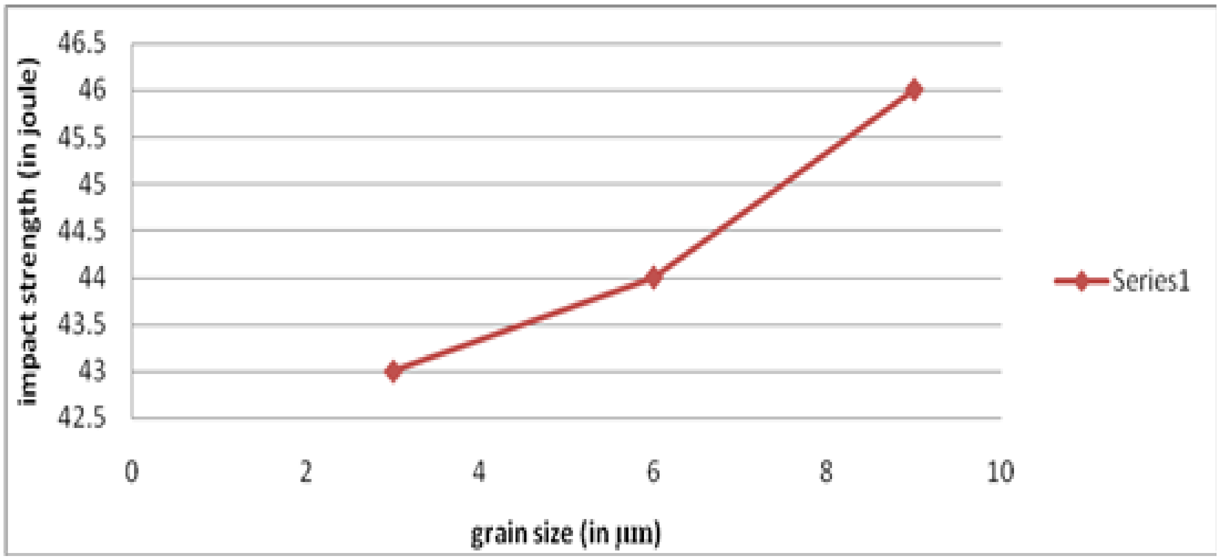

Figure 8. Effect of grain size on the impact strength.

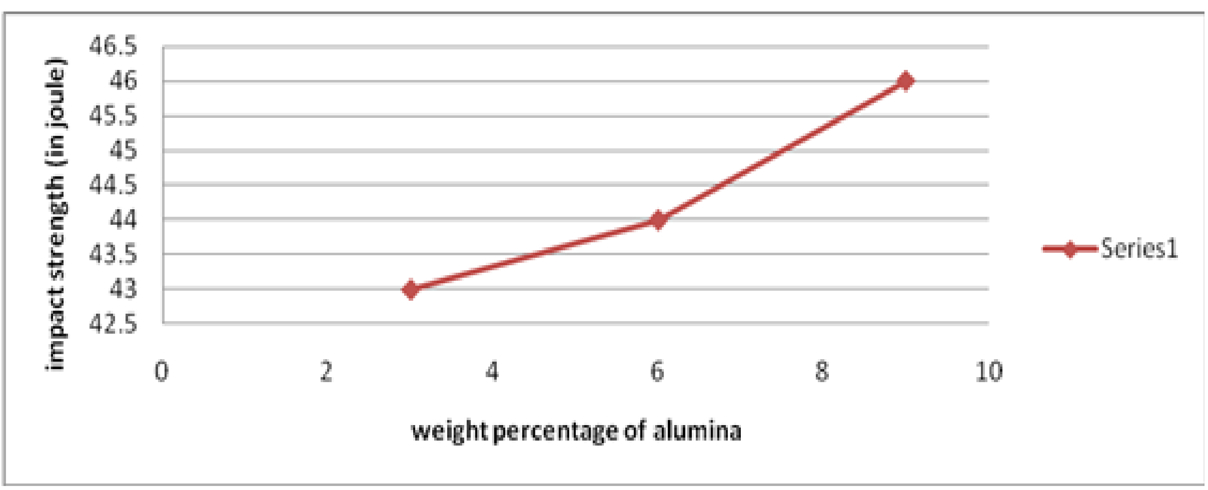

Figure 9. Effect of weight percentage of alumina on impact strength.

Table 4. Impact strength with different grain size

Grain size(in µm)	Weight percentage of alumina	Impact strength (J)
149	3	16
74	3	17
37	3	19

Table 5. Impact strength with the different weight percentage of alumina

Weight percentage of alumina	Grain size (in µm)	Impact strength (J)
3	149	16
6	149	21.5
9	149	22.5

3.4 Hardness

Vickers hardness test is used to investigate the hardness of the composite material. Hardness is shown in table of composite materials having same weight percentage (3%) and different grain sixe (149µm, 74µm, 37µm). Variation in hardness of composite material with different grain size and with different weight percentage of alumina powder is shown in Table 6 and Table 7 respectively. Figure 10 represents that with decrease in the grain size alumina powder hardness increases. As we know hardness depends on grain size, so less the grain size more closely the particles get packed which improves the hardness. Effect of weight percentage on hardness has been shown by Figure 11. Results show that with increase in weight percentage hardness of the composite material increases.

Table 6. Hardness with different grain size

Weight percentage of Al_2O_3	Grain size (in µm)	Hardness (HV)
3	149	43
3	74	54
3	37	56

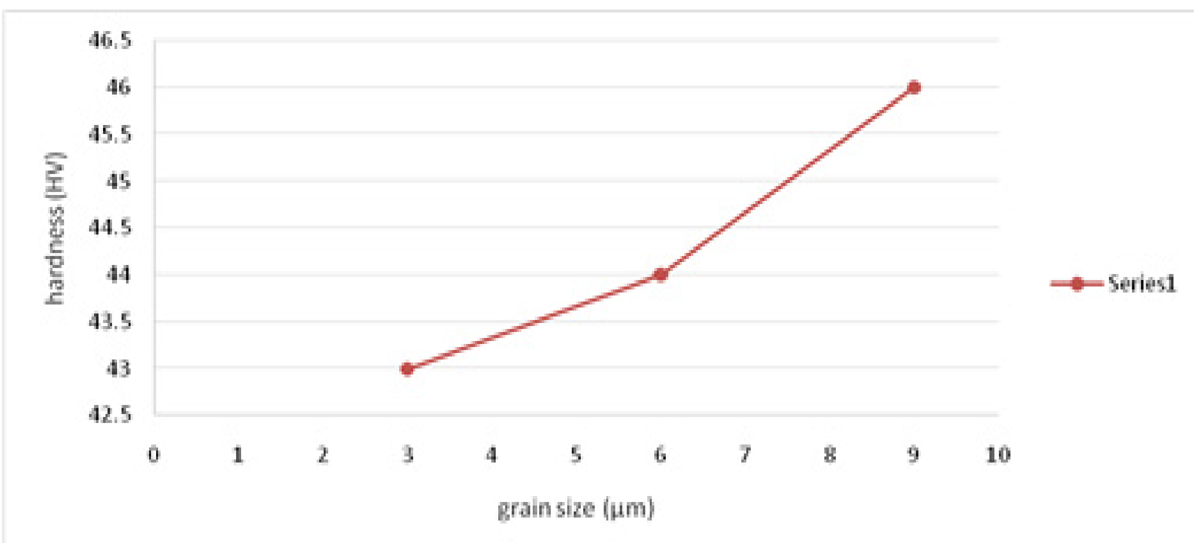

Figure 10. Effect of grain size on the hardness.

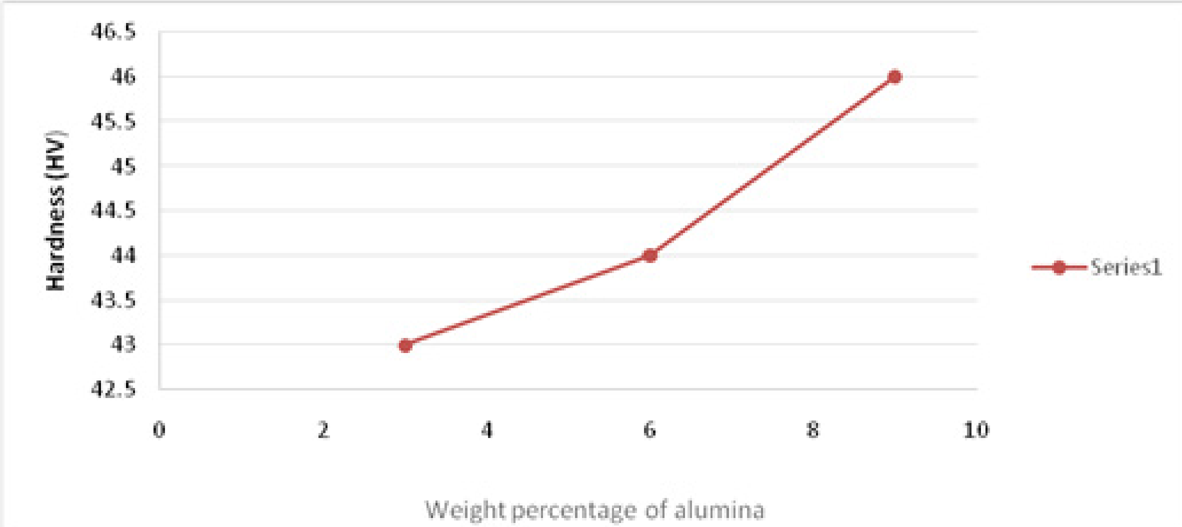

Figure 11. Effect of weight percentage on hardness.

Table 7. Hardness with weight percentage

Weight percentage of Al_2O_3	Grain size (in µm)	Hardness (HV)
3	149	43
6	149	44
9	149	46

4. Conclusion

Al 63401 reinforced with alumina powder with different grain size and weight percentage to fabricate composite material by using stir casting process. Stir casting used due to its cost effectiveness for mass production. Different mechanical properties like impact strength, tensile strength, hardness are studied. Microstructure of the composite material is also studied and shows that there is uniform distribution of reinforcement material with less weight percentage. With increase in the percentage of the alumina powder there is least uniformity and forms cluster. From the impact strength test and tensile strength test it is concluded that with increase in the weight percentage of the alumina powder and with decrease in the grain size of the alumina, tensile strength and impact strength increases significantly. Hardness of the composite material shows the same variation and increases with the increase in the weight percentage of alumina powder and decrease in the grain size, this is due to closely packing of reinforcement material particles.

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