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Synthesis and Characterisation of Al-Si Alloy

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Abstract - Within the last few years there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application make the study of their wear and tensile behaviour of utmost importance. In this present investigation, Aluminium based alloys containing 12% weight of Silicon were synthesized using Centrifugal casting method. In case of this centrifugal process the molten metal is poured in to the mould rotating at different rotational speeds. The centrifugal force helps in feeding and positioning metal in the mould. The product produced by centrifugal casting has a good quality, dimensional accuracy as Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centrifugal action removes unwanted inclusions, dross, cleaner casting, and material that contains shrinkage, which can be machined away. Study of microstructure has showed the presence of primary silicon. Hardness is compared with the different casting speeds. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength are studied for different rotational speeds. Wear behavior was studied and resistance to wear is analyzed. The worn surfaces were analyzed.

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SYNTHESIS AND CHARACTERISATION OF AL-SI ALLOY

Strictly as per the compliance and regulations of :

Synthesis and Characterisation of Al-Si Alloy

Prashantha Kumar H.G [α], Asst. Prof. Mohan Kumar.S [σ] & Prof. Keerthiprasad K.S[ρ]

Abstract - Within the last few years there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application make the study of their wear and tensile behaviour of utmost importance. In this present investigation, Aluminium based alloys containing 12% weight of Silicon were synthesized using Centrifugal casting method. In case of this centrifugal process the molten metal is poured in to the mould rotating at different rotational speeds. The centrifugal force helps in feeding and positioning metal in the mould. The product produced by centrifugal casting has a good quality, dimensional accuracy as Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centrifugal action removes unwanted inclusions, dross, cleaner casting, and material that contains shrinkage, which can be machined away. Study of microstructure has showed the presence of primary silicon. Hardness is compared with the different casting speeds. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength are studied for different rotational speeds. Wear behavior was studied and resistance to wear is analyzed. The worn surfaces were analyzed.

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I. Introduction

Centrifugal casting is a casting technique that is typically used to cast thin walled cylinders. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use.

Centrifugal casting consists of producing castings by causing molten metal to solidify in rotating moulds. The speed of the rotation and metal pouring rate vary with the alloy and size and shape being cast. The following operations include in centrifugal casting - rotation of mold at a known speed, pouring the molten metal, proper solidification rate, and extraction of the casting from the mold. Centrifugal are relatively free from gas and shrinkage porosity. In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (200 to 2000 rpm) as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away. Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centre of rotation and the lighter impurities like slag, oxides and inclusion are squeezed out to the centre. The castings produced have a close grain structure, good detail, high density and superior mechanical properties.

In recent years aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of aluminium alloys have a brilliant lustre in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloy of 4xxx series, containing major elemental additives of Si, are now being used to replace steel panels if various automobile industries. Due to such reasons, these alloys were subject of several scientific studies in the past few years.

Silicon also has a low density (2.34 g cm^{-3}), which may be an advantage in reducing the total weight of the cast component. Silicon has a very low solubility in aluminium; it therefore precipitates as virtually pure silicon, which is hard and hence improves the abrasion resistance. Aluminium-silicon alloys form a eutectic at 12.6 wt% silicon, the eutectic temperature being 577°C. This denotes a typical composition for a casting alloy because it has the lowest possible melting temperature [6]. Al-Si alloys containing more than about 12% Si exhibit a hypereutectic microstructure normally containing primary silicon phase in a eutectic matrix [10].Wislei R. Osório et. al [13] studied the effect of microstructure on mechanical properties for Al–9wt% Si.

Mechanical properties of Al–Si casting alloys depend not only on their chemical composition but are also significantly dependent rotational speed of the mould. The effects of silicon on the mechanical properties of Al-Si alloys are well studied.

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II. Experimental Set Up

Actual centrifugal casting set up as shown in fig.1 Here a mild steel mould of dimensions 81mm in inner diameter and 88mm in length with wall thickness on 10mm is connected to a motor of 2HP through a shaft. The mould is rotated precisely 20 to 2000 without vibrations. The material was prepared to study the influence of rotational speed on cast. Aluminium is melted in a pit furnace heated to a 720 degree Celsius temperature with 200 degree Celsius super heat. After skimming dross, it was poured into the rotating mould quickly. After a few seconds the motor is turned off and casting pulled out, casting thickness of the cast was controlled by taking calculated amount of metal .these casting were made for different speeds.

III. Experiments

Charging calculated amount of Al &Si into Graphite crucible pit furnace and temperature of about 720˚C is maintained for few seconds till it turns to molten boiling temperature 200̊C maintained for few seconds. This process is to remove absorbed gasses. Hexachloroethane (C2Cl6) in tablets form are used a mild steel mould is used. It is Connected to a 2HP motor can rotate at 0 to 2000 rpm till it get steady then setting the RPM of the mould ie 400, 600, 800, 1000, 1400,1600,1800. Then pouring the Al-Si 12% molten into mould, It will get solidify within 8 to 10 sec. Solidified cast is taken out from the mould and used for further analysis.

Figure 1 : Centrifugal casting set up

Figure 2 : Castings of 8 mm-thick cylinders

IV. Results and Discussion

Experiments are carried out to study the influence of rotational speed on formation of full hollow cylinder and their effects on mechanical properties. Al-Si alloys (12%) are used as study materials. These melts are centrifugally cast at different rotational speeds to get 8 mm thick hollow cylinders. During casting of 8 mm thick hollow cylinder at lower speeds ie, at 200 RPM and 400 RPM the speed not enough to lift the melt. Very poor cylinder with non uniform distribution of molten metal and irregular shape is formed. At 600 RPM uniform hollow cylinder is formed it has poor inner surface with non uniform thickness. At 800 RPM a cylinder formed with poor inner surface. At 1000 RPM a good cast is formed with good inner surface and mechanical properties compare to than at 800 RPM. At 1200 RPM & 1400 RPM higher centrifugal force tends to lift the melt poured and also impression of raining are observed due to high fluidity.

a) Microstructure of Al-12%Si alloy

Metallographic preparation, sequential steps have to be performed to prepare Al- 12%Si for micro structural investigation are involved careful selection of sectioning, mounting, grinding, polishing, and etching procedures is required, and each step must be optimized for each.

Figure 3 : Machined specimen for microstructure

The microstructures shown in the figure.3 at across the section of the casting, under various rotational speeds, it may be seen that more-or-less rounded particles of aluminium (light areas, α-solid solution) are crystallized, which are surrounded by fine eutectic silicon (dark areas). Here, silicon has networked structure. The silicon has long rod like structure. Here the primary silicon appears as coarse polyhedral particles. In addition, presence of primary silicon is also observed in the Al-12% Si, although the size and volume fraction of the primary silicon is more at the outer diameter, as compared to inner diameter of the different speed alloys. It was observed that the rotational speed of the mould has profound influence on the microstructure of Al-12%Si alloys.

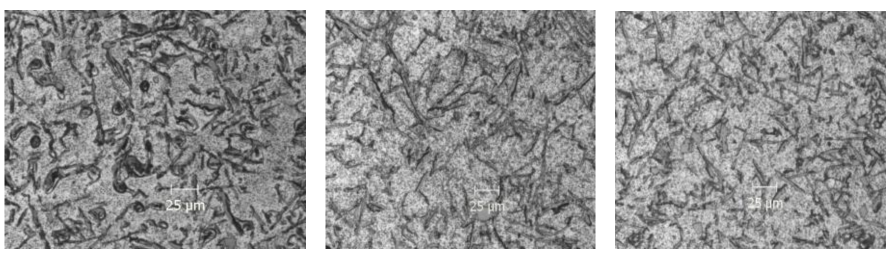
b) Wear Test

i. The tests were carried out by varying one of the following three parameters and keeping other two constants: Applied load (is 0.5,1.0, 1.5, 2.0 N is varied).
ii. Sliding speed (is 600 rpm, when constant).
iii. Sliding distance (is 2266 m, when constant).

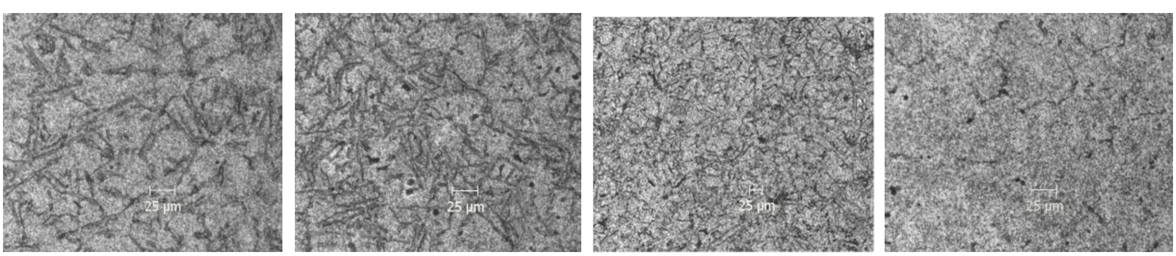
The wear tests of Al-Si alloys were carried out with varying applied load, constant sliding speed and constant sliding distance. The results are obtained from the series of tests which is done by keeping two parameters out of the constant against wear. The effects of these parameters have been studied. Relationship between Cumulative Mass Loss (CML) with time, wear rate dependence of sliding distance etc. have been co-related. The results from the above tests are noted and corresponding curves are drawn.

Table 1 : Wear test parameters

PARAMETER	UNITS	USED
Wear disc		
Diameter	mm	100
Thickness	mm	8
Counterpart Material	Carbon steel	
Square pin	mm*mm	4*4
Length	mm	10
Wear track dia	mm	30
Disc speed	RPM	600
Normal load	N	0.5,1.0,1.5,2.0
Test duration	s	1200
Track distance	Km	2.262
Samples duration	s	60



a. Al Si 400RP b. Al Si 600 RPM c. Al Si 800 RPM



d. Al-Si1000 RPM e. Al-Si 1400 RPM f. Al-Si 1600 RPM g. Al-Si 1800 RPM

White background – Aluminium (Al), Light black portion- Silicon (Si),

Figure 3 : Effect of Rotational speed on microstructure of Aluminium Silicon alloy

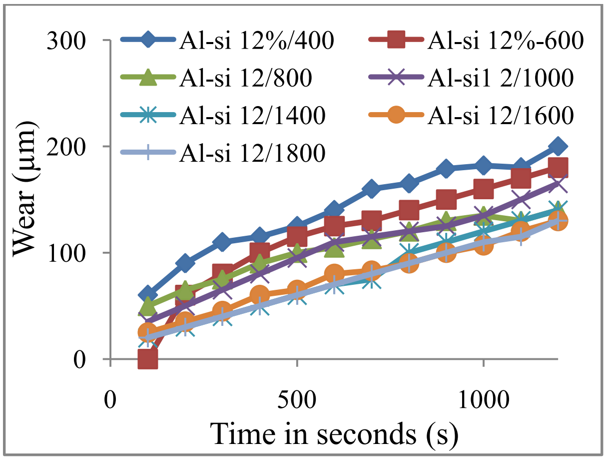


Figure 4 a : Wear rate for 0.5N load

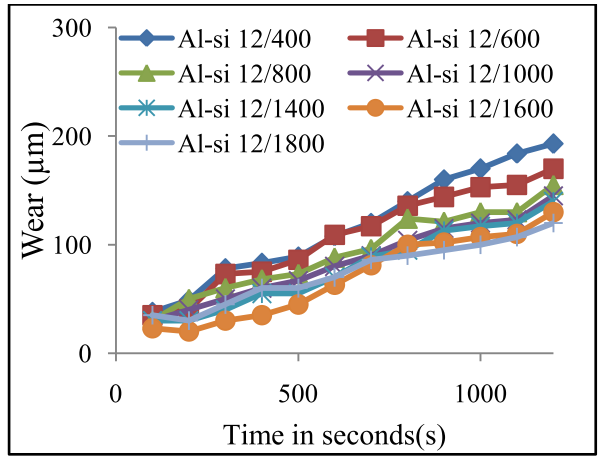


Figure 4 b : Wear rate for 1.5N load

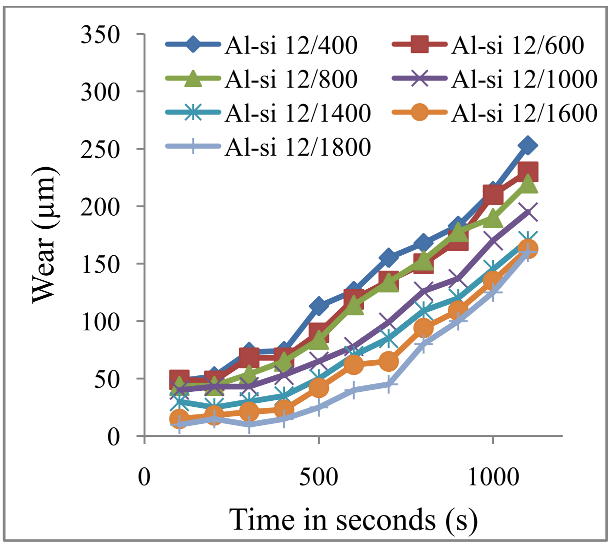


Figure 4 c : Wear rate for 1.0N load

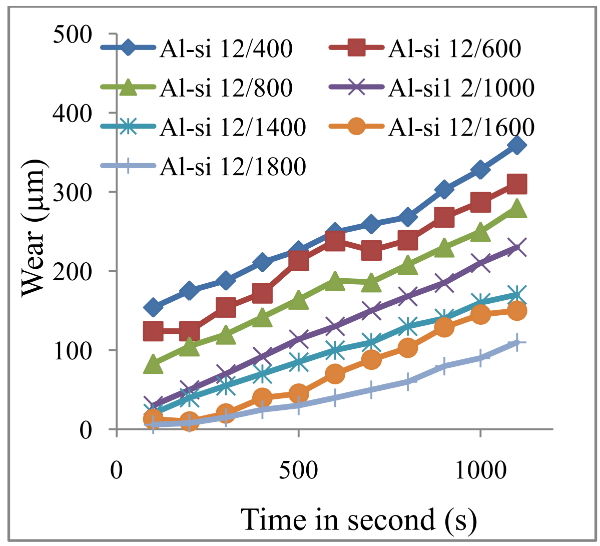


Figure 4 d : Wear rate for 2.0N load

i. *Load v/s coefficient of friction*

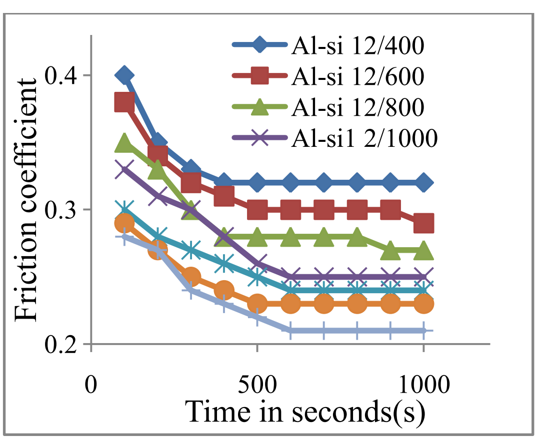


Figure 5 a : Friction behaviour for 0.5N load

For Al-12% Si alloy, the maximum height loss is for lower casting speeds specimen for all loads,

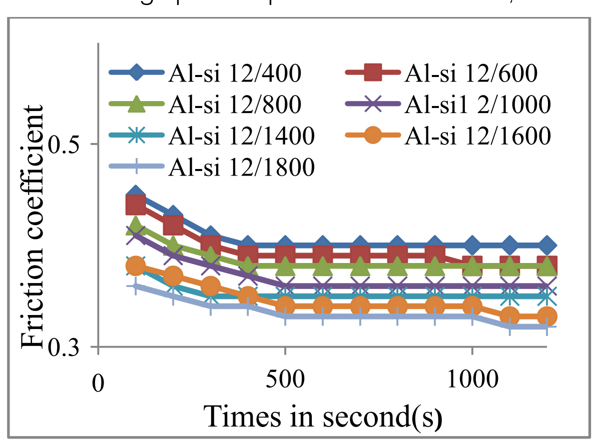


Figure 5 a : Friction behaviour for 1.5N load

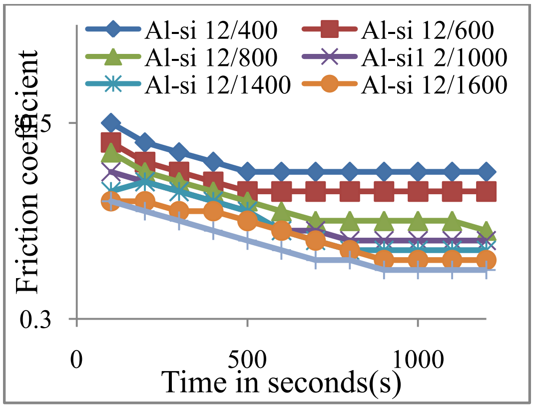


Figure 5 a : Friction behaviour for 1.0N load

ii. *Mass loss comparison*

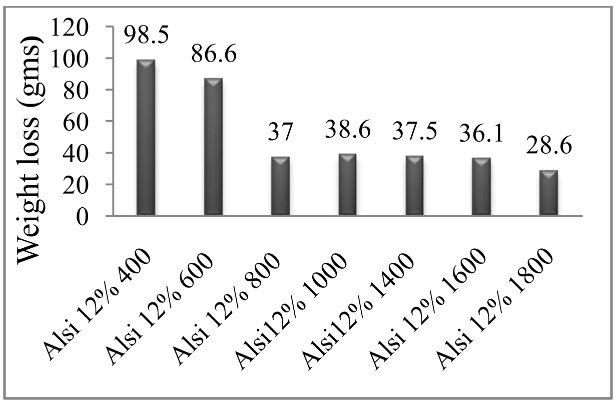


Figure 6 : Mass loss comparison

The results of wear tests on all samples with varying loads (0.5, 1.0, 1.5, 2.0 N) behaviour is illustrated in Fig 4.a to Fig 4.d. It is noticed that the height loss (wear loss) due to wear decreases when the casting speed increases.

Whereas for Al-12% Si alloy, the height loss was increasing when the load increasing, and also height loss is decreasing with the increasing the casting speeds. Similar trends in height loss for all other loads are observed.

The values of co-efficient of friction obtained from the experiment and friction behaviour is illustrated in Fig 5.a to Fig 5.d. From the graphs it is observed that as the load increases friction also increases and increasing in the coefficient of friction, for lower speeds castings the friction is low and it is range from 0.1 to 0.3 and for higher speeds castings it is range from 0.3 to 0.5.

The Optical micrographs for the worn surfaces in un lubricated conditions are obtained at equal magnify -cations. The micrographs of the samples are shown in Fig 4.2.4.a to Fig 4.2.4.g. The worn surface after dry sliding of Al- 12% above all micrographs shows deep well separated grooves. Cracks are also observed which are spread perpendicular to the sliding direction.

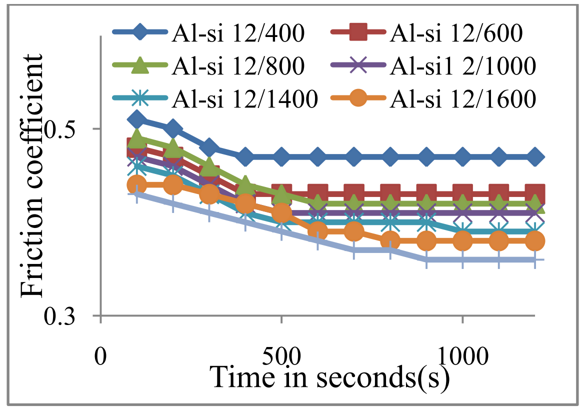


Figure 5 a : Friction behaviour for 2.0N load

It is found that the grooves are along the sliding direction, but not many cracks are seen. However, crack propagation is seen along the same direction as sliding. With presence of Si content hardness of the material has increased. Deeper grooves in dry sliding condition may be assigned to the abrasion of Si particles that have forced the Silicon in platelet form, for which deeper grooves are produced.

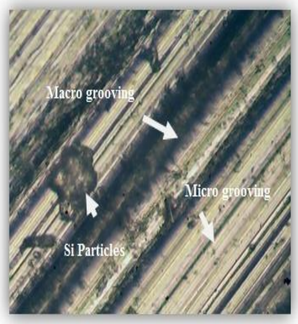


Figure 7 a : 400RPM

Figure 7 b : 600RPM

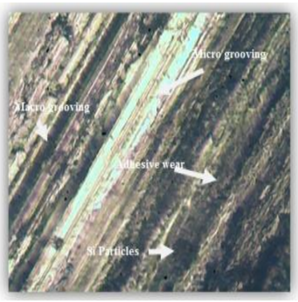


Figure 7 c : 800 RPM

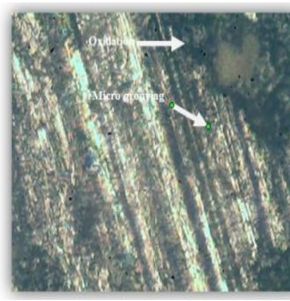


Figure 7 d : 1200 RPM

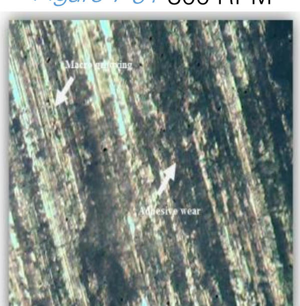


Figure 7 e : 1400RPM

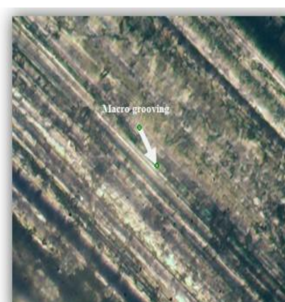


Figure 7 f : 1600RPM

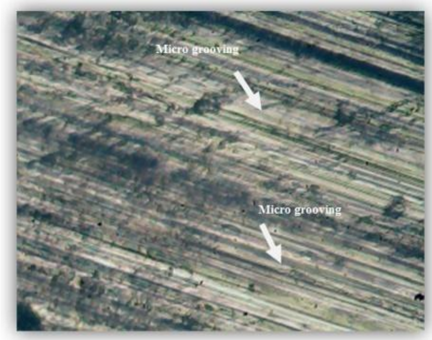


Figure 7 g : 1800RPM

c) Hardness Test

The micro hardness tests of all the samples were conducted using a Vicker's hardness testing machine with a dwell time of 10 s and applied load of 0.1kgf (P) during the tests. For each specimen indentations were taken at inner and outer and value is reported. The following table shows the calculated Vickers hardness number (VHN).The Vickers hardness numbers (VHN) for Al-12% Si for different speeds are found to be range from 55to75. Fig 8.a shows the hardness at outer and inner surface, and it is found that hardness at outer is slightly more compare to that of inner surface at the cast, this is due to concentration of Si particles is more at outer surface.

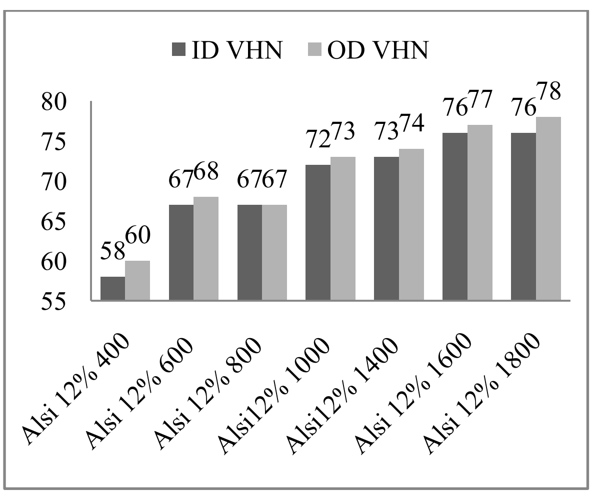


Figure 8 a : Comparison of ID and OD VHN

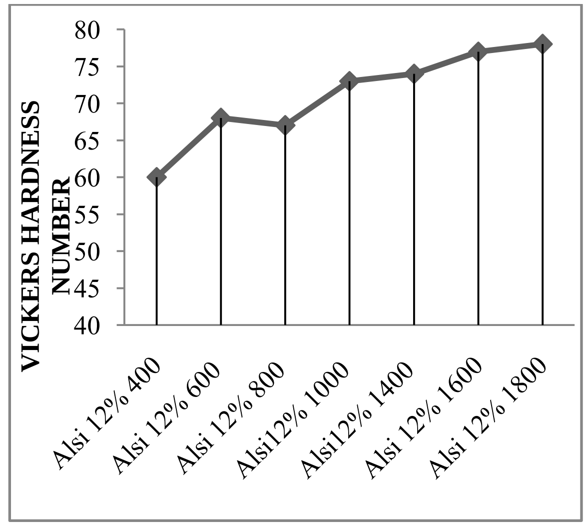


Figure 8 b : Variation of VHN at ID

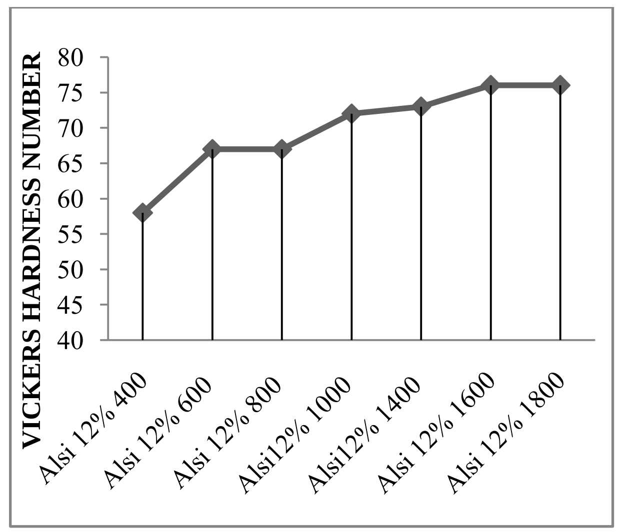


Figure 8 c : Variation of VHN at OD

Fig 8.b&Fig 8.c shows that Variation of VHN with respect to increase in the casting speed, It is such that the hardness increases with increase in rotational speed.

d) Tensile Test Results

From the load and elongation values, obtained from the universal testing machine, corresponding engineering stress and engineering strain were calculated and plotted to get stress vs. strain curves for different samples of Al-12%Si alloys.

i. *Comparison of total elongation*

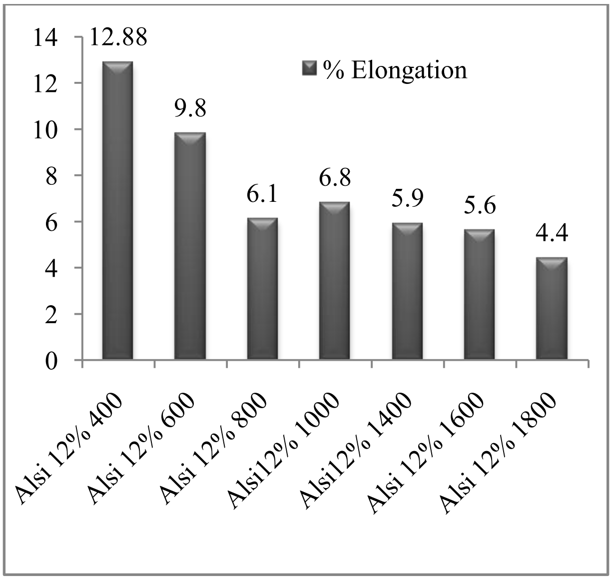


Figure 9 a : Comparison of total elongation

ii. *Comparison of Yield Stress*

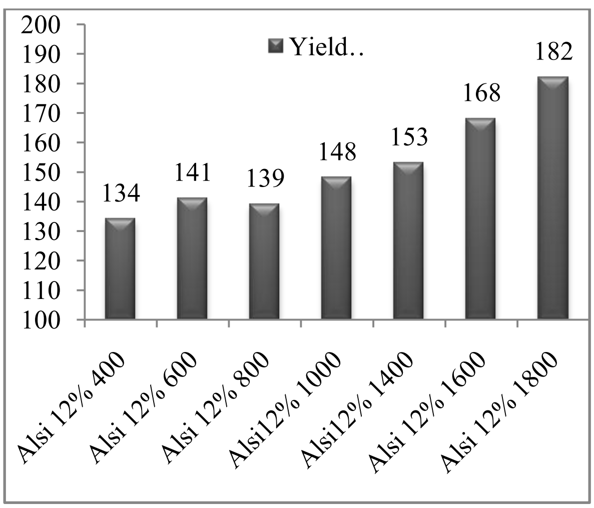


Figure 9 b : Comparison of yield stress

iii. *Comparison of ultimate tensile strength*

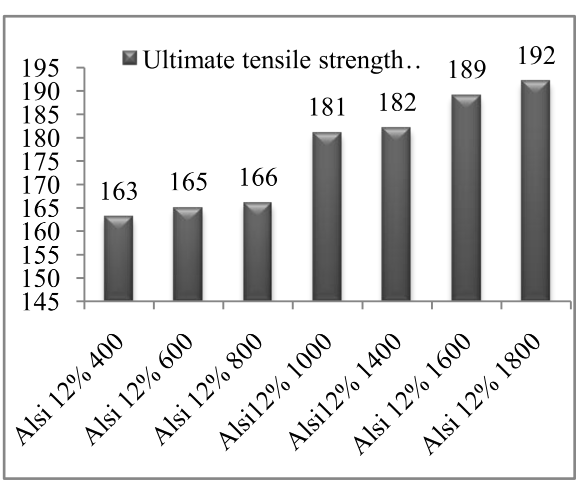


Figure 9 c : Comparison of ultimate tensile strength

From Fig. 4.4.2 and Fig. 4.4.3, it can be observed that, there is continuous increase in the rotational speed of the casting, yield strength and the tensile strength increases with transition from elastic to plastic region takes place. Therefore, the yield strengths of the alloys are computed by 0.2% offset method, according to ASTM standard E8M [20]. From Fig. 4.4.1 it is observed that, it is reverse for the total elongation. This may be due to the presence of hard silicon precipitates which increases the hardness with increase in the rotational speed of the casting of Al-Si alloys.

iv. *Comparison of young's modulus*

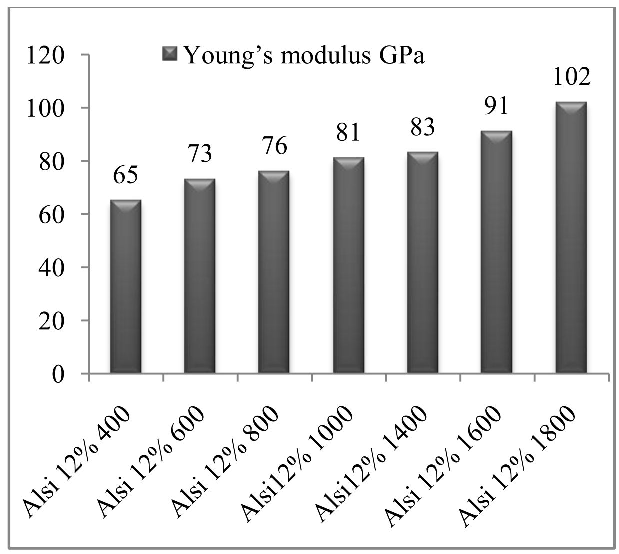


Figure 9.d : Comparison of young's modulus

The modulus of elasticity is calculated from the stress strain curve for all rotational speeds alloy and the values are compared, it shows decreasing with the increasing in the rotational speed of the casting.

V. Conclusions

1. The present study rotational speed is one of the significant parameters in controlling the size and distribution of aluminium and silicon particles.
2. With the increase of rotational speed to the optimum value, there was a remarkable improvement in the microstructure, where a fine equiaxed structure was formed. The microstructure for the specimens rotated at below and above this optimum speed.
3. Wear behaviour is dependent on applied load, sliding speed mainly. However, the wear rate increases with increase in the load.
4. Hardness of the Al-Si alloy increases with the increase in rotational speed of the cast.
5. The height loss due to wear decreases when the increase in rotational speed of the cast.
6. The hardness increase marginally with increase in rotational speed of the cast.

7. Hardness is more at the outer surface compared to the inner surface of the cylinder.
8. Tensile strength also increases marginally with increase in rotational speed.
9. Yield strength and ultimate tensile strength increases with the increase in the rotational speed of the cast.
10. Total elongation decreases with the increase of rotational speed of the cast.

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