EXPERIMENTAL INVESTIGATION OF IN-HOMOGENEITY IN PARTICLE DISTRIBUTION DURING THE PROCESSING OF METAL MATRIX COMPOSITES

M.Saravana Kumar[1,*], C.I.Pruncu[2, 3], P.Harikrishnan[4], S.Rashia Begum[5], M.Vasumathi[5]

[1*] Assistant Professor, Department of Mechanical Engineering ,Mount Zion College of Engineering and Technology, Pudukottai, Tamilnadu, India

[2] Design, Manufacturing & Engineering Management, University of Strathclyde, Glasgow, G1 1XJ, Scotland, UK.

[3] Department of Mechanical Engineering, Imperial College London, Exhibition Rd., SW7 2AZ, London, UK

[4] Research Scholar, Department of Materials and Production Engineering, King Mongkut's University of Technology North Bangkok (KMUTNB), Bangsue, Bankok, Thailand.

[5] Assistant Professor, Department of Mechanical Engineering, College Of Engineering, Anna University, Chennai, Tamilnadu, India

*Corresponding author e-mail:saravana312@gmail.com

Abstract

Particle reinforced metal matrix composites are skilled to fulfill the late needs of cutting edge designing applications, because of its tunable mechanical properties. Stir casting is one of the unmistakable and affordable strategies for preparing of particle reinforced metal matrix composites. However, complete investigation and evaluation of the vortex pressure and the homogenous distribution of particles are still an obstacle for the research community. In this method, vortex pressure and flow pattern are the important factors for the dispersion of particles in the liquid metal. Effectual flow pattern and vortex pressure can be attained by optimizing stir casting parameters such as volume concentration (5%, 10%), stirrer blade angle (45º, 90º), impeller position (20%, 40%) from the base, viscosity of Al melt (1.04 mPa-s, 1.24 mPa-s) and holding time (10 minutes, 15 minutes). In this research, computational fluid dynamics has been used to find the vortex pressure, which influences the particle distribution. A new photographic technique was implemented to find out the flow pattern of the reinforcement particles and the stir casting parameters are optimized using Taguchi method. Optimized parameters have been utilized for the production of PRMMCs. In addition, micro structural image and hardness test confirm the uniform particle distribution of the reinforcement particles. From the outcome of various experimentations, 10 minutes holding time of the stirrer blade with 45^{O} angle which was kept 40% from the base and the viscosity of the Al melt (1.04mPa-s) with 10% volume fraction of SiC particles shows effective flow pattern and optimum vortex pressure with homogenous distribution of SiC particles.

Keywords; Particles; vortex pressure; hardness; wear; tensile; flow pattern

1. Introduction

Metal matrix composites (MMCs) have three categories, one of the main categories is Particle

Reinforced Metal Matrix Composites (PRMMCs) in which Aluminium alloy plays a major role as the matrix material. "The PRMMCs possess good mechanical properties like low density, wear resistance, good co-efficient of thermal expansion, better stability at high temperature, and higher fatigue resistance. So, they are mainly used in defence, automobile and aerospace applications." [1, 2]. In this research, Al 8011 has been chosen as matrix material and Silicon carbide has been chosen as reinforcement particle due to its good chemical stability and high hardness. "The aluminium alloy possesses better strength, toughness and high temperature resistance and also the wear properties of the composites. When the SiC particle is reinforced with the aluminium 8011 alloy, the wear properties of the composites improve." [3]. The thermal conductivity of the SiC particles is 3.8 W/m.K [4]. Even though there are many applications of Al 8011/SiC composites, the application of Al 8011/SiC composites in the automobile engines is the most important one, because of its thermal resistance, light weight and better wear resistance.

There are many manufacturing processes for the processing of Al 8011/SiC composites. Choosing one of the manufacturing processes seems to be a difficult one. Even though there are many techniques for the manufacturing of PRMMC, stir casting is the most economical. "The composites obtained from the stir casting process has low porosity, uniform distribution of the reinforcement particles and better quality bonding and fine microstructure" [5]. In this method, accumulation of the reinforcement particles into aluminum melt is mainly due to the improper stir casting parameter. The clustering and accumulation may finally lead to the porosity and poor mechanical properties. Further, accumulation results in agglomeration of particles. However, "homogeneous dispersion of reinforcement particles can be obtained by optimized parameter" [6]. The flow behavior of the molten metal and the distribution of the particles are controlled by various stir casting parameters such as impeller position, stirring speed, viscosity of the molten metal, stirrer geometry and volume fraction. [6]. "In order to understand the flow behavior and the distribution of the particles, visualization experiments and the numerical simulations have been carried out" [2, 5–9]. It is impossible to study and analyze the fluid flow pattern, particle distribution and the clustering of the particles in the actual stir casting setup. As the process is carried out in the high working temperature, it is difficult to study the influence of all the stir casting parameters, since it is time overwhelming and costly [6]. "Finite element method (FEM) based computational fluid dynamics (CFD) will help us study the influence of fluid flow pattern in the molten metal" [11, 12]. Mostly, this method is used for parameter optimization of drilling, machining and upsetting [13, 14]. Even though, there are many researches on the influence of stir casting process parameters on the fluid flow pattern and the particle distribution [6, 10], optimal combination of parameters is still a challenging one.

In this research, to overcome these challenges, FEM based computational fluid dynamics (CFD) simulation software was used to study the vortex pressure of melt inside the crucible and flow pattern was captured using streak photography, while optimization of stir casting parameters was done by Taguchi method. Optimization of stir casting parameters was performed to achieve effective flow pattern without clustering. Moreover, PRMMCs were manufactured by stir casting process with optimized parameters. Furthermore, microstructure analysis and hardness test were done in order to verify validity of the CFD simulation, Streak photography and Taguchi method. The presented Computational fluid dynamic simulation is implemented to find the particle distribution and vortex pressure for any reinforcement particles, but the density and the thermal conductivity of the corresponding reinforcement particles must be given as the input to the CFD simulation. A systematic research to optimize the stir casting parameters were developed, in order to obtain the uniform distribution of the reinforcement particles, which improves the overall strength of the composites from which it can be used for gears, brake drums, bearings and drive shafts.

2. Materials and methods

Computational fluid dynamics simulation was used to simulate the fluid inside the crucible with respect to the stir casting parameters. The height of the crucible was 100mm, whereas the top and bottom diameter was 200 and 130mm respectively. Single impeller with four blade stirrer was used in this research and also 45^{O} and 90^{O} blade angles were selected. Theoretical model of stirrer blade with 45 and 90 degree blade angle as shown in Fig 1. Fig 2 shows the geometrical model of crucible with stirrer. The thickness and width of the blades were made constant for both the impellers. The stirrer position was kept less than 40% from the base, as it prevented the agglomeration of the particles.

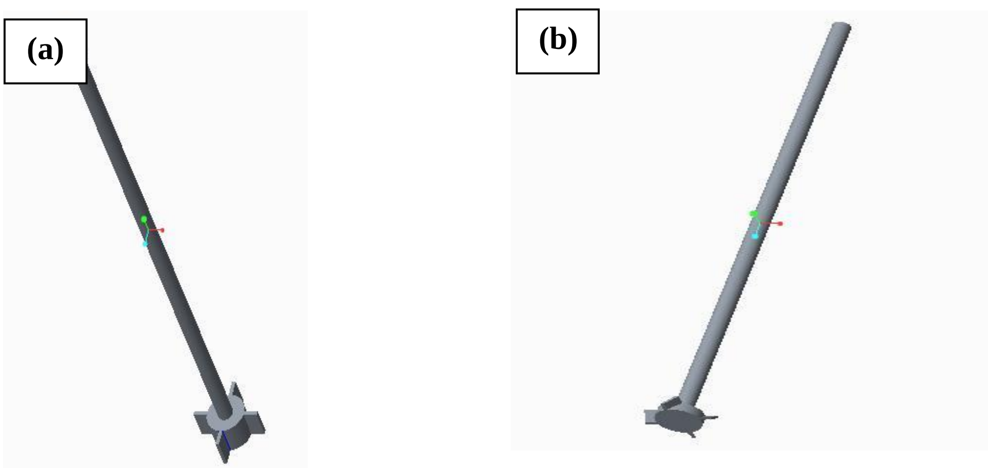


Fig.1 Geometrical model of Stirrer blades (a) Modelling of 90º stirrer blade (b) Modelling of 45º stirrer blade

Fig.2 Geometrical model of Crucible with stirrer **(a)** Crucible with 90º stirrer blade (b) Crucible with 45º stirrer blade

In this research, impeller position was kept 40% and 20% from the base of the crucible. Two different viscosities 1.04mPa-s and 1.24mPa-s were selected. Moreover, two different holding time 10 and 15 minutes were selected. The designed crucible with blade was carried out for simulation. For meshing, Tetrahedron pattern was used. L8 orthogonal array design matrix was used for the experimental investigation on five different parameters such as blade angle, impeller position, viscosity of Al melt, holding time and volume fraction of reinforced particles. The design table was shown in the Table.1.

Table 1.Design Table

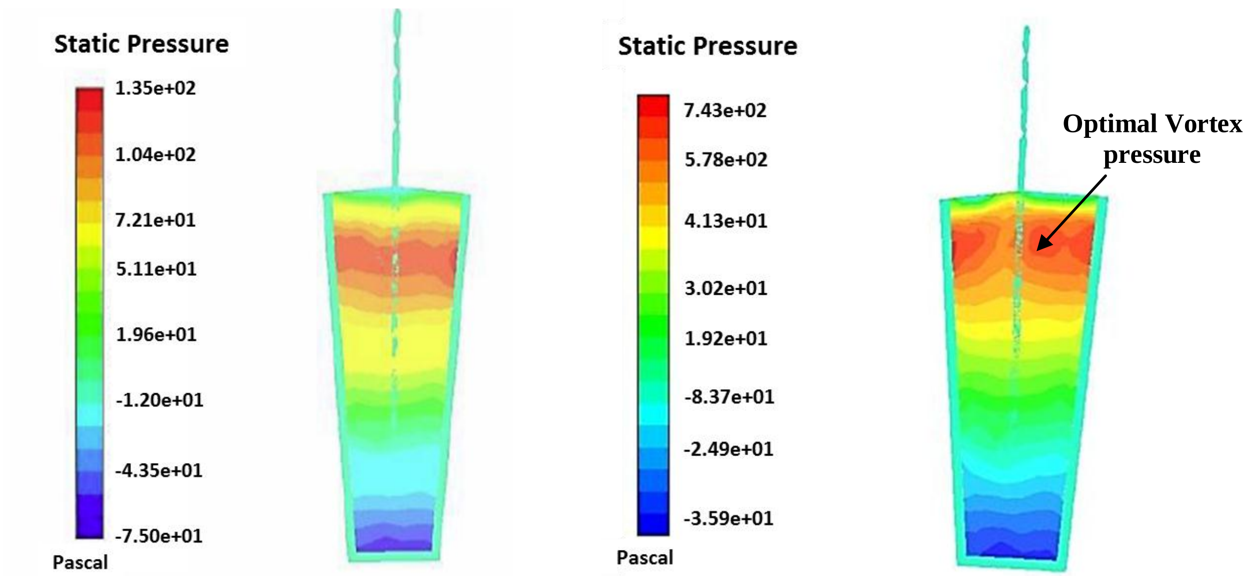
Input parameters	**level 1**	**level 2**
Volume concentration (%)	5	10
viscosity(mPa.s)	1.24	1.04
Blade angle(^{O})	45	90
Impeller position (%)	20	40
Holding time(min)	10	15

The effect of stir casting parameters on the vortex pressure is very essential. The present method of selection of parameters on desired vortex pressure was accomplished using Taguchi's parameter design approach. In this paper, our objective is to minimize the vortex pressure. The experimental results (or data) are further transformed into signal-to-noise ratio. There are a few S/N ratios accessible relying upon the kind of characteristic, lower is better (LB), nominal is better (NB) and higher is better (HB). The characteristics that lower value represents better vortex pressure is called lower is better(LB). Therefore "LB" for vortex pressure was selected for obtaining optimum stir casting parameter. Finding or detecting the flow pattern of the SiC particles was not feasible because of the elevated processing temperature in the stir casting process. [17]. Streak photography is the visualization experiment to trace a particle which helps to find out the flow pattern of the reinforced particles and the presence of clustering region of the fluid. In order to replace the aluminum and SiC particles, a glycerol water mixture with graphite particles were used [2]. Particle distributions were easily viewed inside the translucent glass container with 3.5 cm radius and 9 cm height. The size and shape of this container is the same as that of the graphite crucible. Graphite Particles were added to the glycerol water mixture and the mixing was carried out using a varic controlled dc motor. The stirrer speed was chosen in the range 200–250 rpm. The results of this visualization test were recorded as follows. The container was kept in the darkened background. The light beam was passed over a polar plane. Photographic images of the flow pattern of the graphite particles were captured using the suitable exposure time. This result from the visualization experiments helps to find the effective flow pattern based on the optimized parameters form the Taguchi design of experiments and the CFD simulation. The micro structural evaluation was carried out using the optical microscope and the scanning electron microscope. Optical Microscope (ZEISS AxioCam ERc 5s) was used to study the microstructure of casted specimen. Optical and illumination systems are its basic elements. Image can be magnified in the range of 0 to 100X. A more recent and extremely useful investigative tool is the Scanning Electron Microscope (JEOL JSM-6380LA). Magnifications ranging from 10X to in excess of 30,000X zoom diameters are possible. The mechanical testing was carried out using the tensile test and Vickers hardness test and wear test. The Tinius Olsen Computerized Universal Testing Machine, H50KL model was used to find the tensile properties for the cast specimens. Vickers micro-hardness tester was used to find the hardness value of the cast specimens and the wear testing were conducted by using the DUCOM pin-on-disc wear testing. The result from the microstructural evaluation and the mechanical testing proves the uniform distribution of the particles and the effective flow pattern with effective vortex pressure.

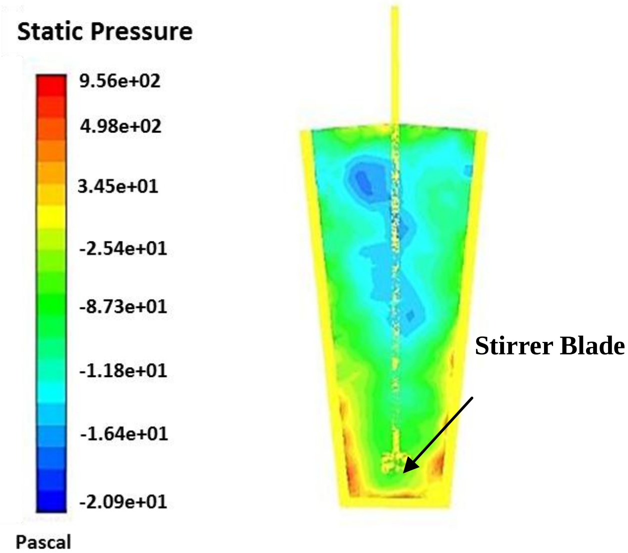
3. Results and discussion

3.1 CFD Simulation for Vortex pressure

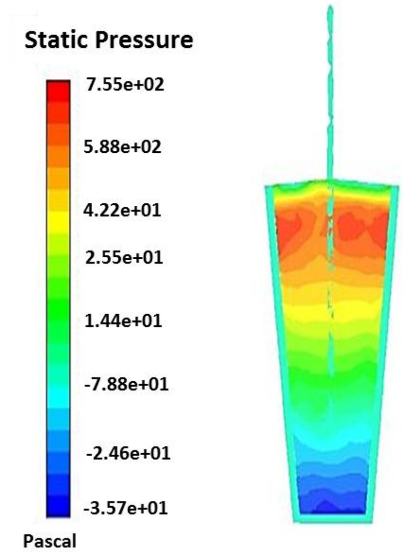
From the result of the computational fluid dynamics, it is observed that trial 1, 3, 5 shows higher vortex pressure in the range of 40 to 42 Pa and 2, 4, 8 shows better vortex pressure in the range of 15 to 26 Pa. The main condition for uniform distribution particle is that the pressure should be low and sufficient enough to distribute the particles all along the molten metal, whereas the higher vortex pressure may lead to the air entrapment and bubble formation [15]. From these data, it is unclear that which combination of parameters will minimize the vortex pressure to get uniform distribution of the particles, therefore optimization is required. Vortex pressure that creates inside the crucible is achieved from CFD simulations are shown in Fig.3. Vortex pressure for eight trials as per L8 design is shown in Fig.4



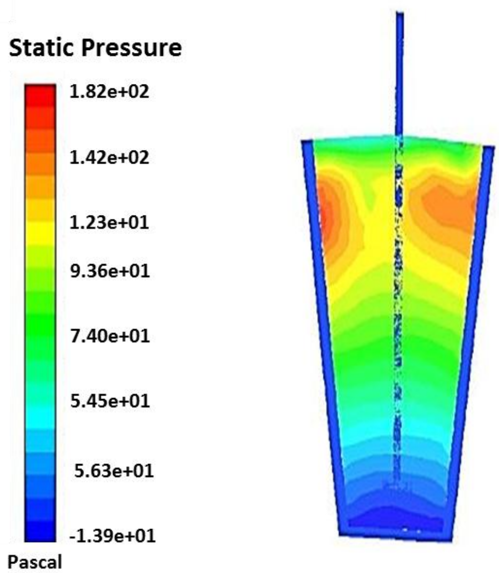
(a) Vortex Pressure for Trial 1 (b) Vortex Pressure for Trial 2



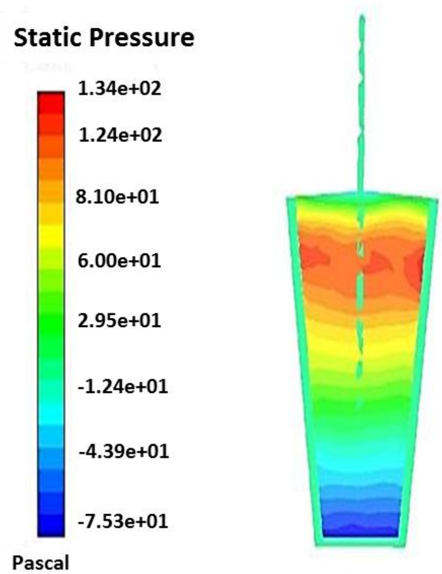
(c) Vortex Pressure for Trial 3



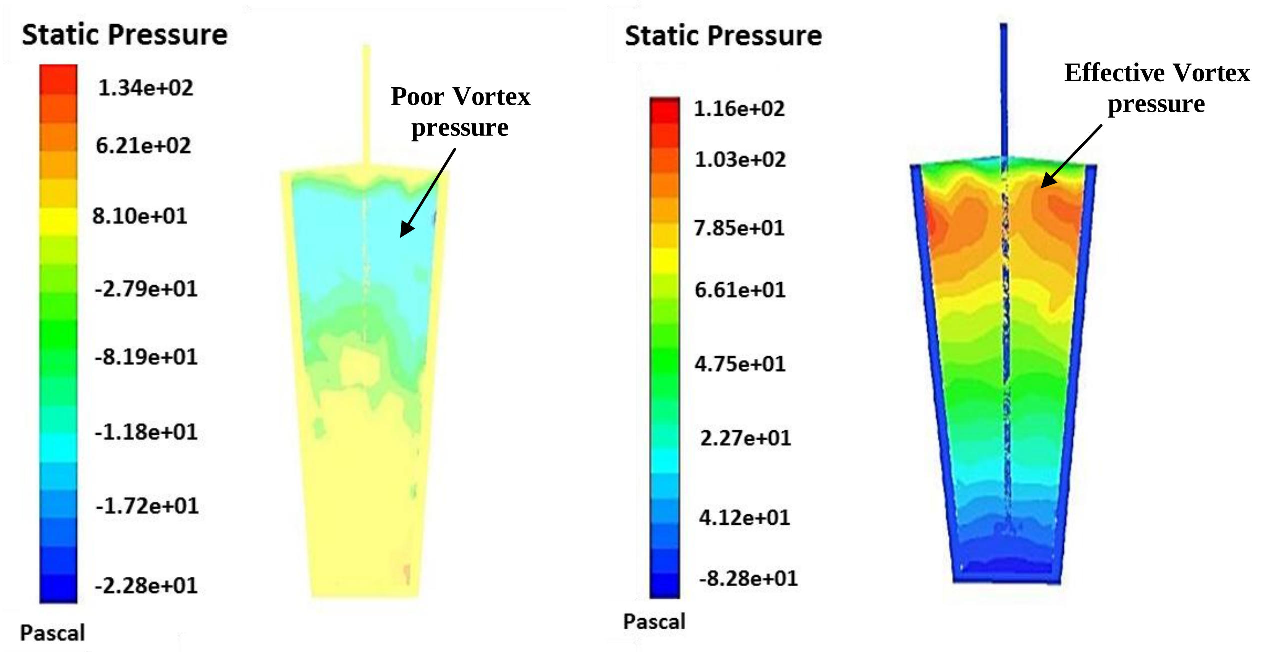
(d) Vortex Pressure for Trial 4



(e) Vortex Pressure for Trial 5



(f) Vortex Pressure for Trial 6



(g) Vortex Pressure for Trial 7 (h) Vortex Pressure for Trial 8

Fig 3.Vortex Pressure based on L8 Design.

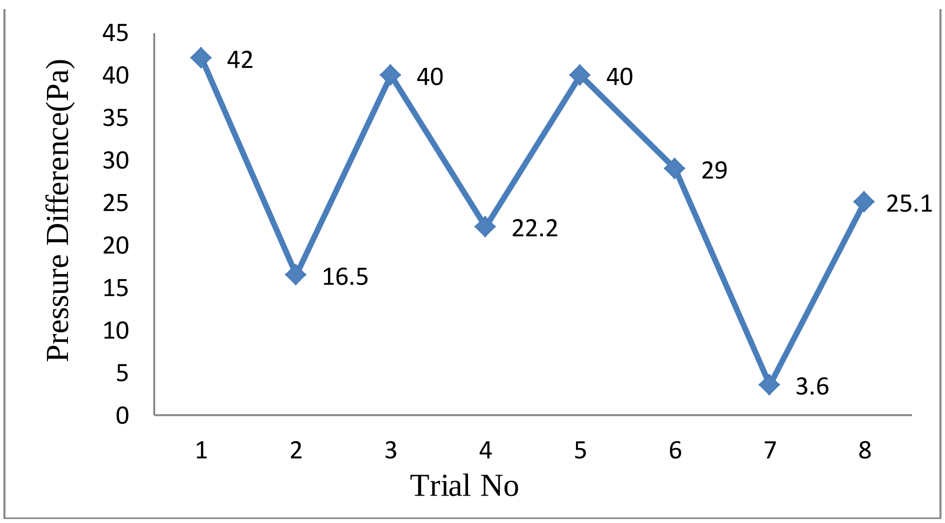


Fig.4 Pressure Difference (Pa) vs. Trial No

3.2 Optimization of stir casting parameters

In this research, two levels and five parameters were considered. In order to ensure an equal weight during the optimization procedure for all the factors (see details in Table 1) an L8 array was implemented. The main objective of the experiment is to optimize the vortex pressure that creates inside the crucible, because of the stir casting parameters. The results of the computational fluid simulation were used to analyze the distribution of the particles by Signal to Noise ratio and Analysis of Variance (ANOVA) method. The vortex pressure should be minimum and also it should be sufficient enough to distribute the particles all along the molten metal, so signal to noise ratio "smaller is better" was chosen. The vortex pressure values and the calculated signal to noise ratio are shown in Table.2.

Table 2.Experimental results for Vortex Pressure.

Volume Concentration (%)	Viscosity(mPa.s)	Blade Angle(degree)	Impeller position (%) from the base	Holding Time(min)	Pressure Difference (Pa)	S/N for PD
5	1.24	90	20	15	42	-32.465
5	1.24	45	40	10	16.5	-24.3497
5	1.04	90	20	15	40	-32.0412
5	1.04	45	40	10	22.2	-26.9271
10	1.24	90	20	15	40	-32.0412
10	1.24	45	40	10	29	-29.248
10	1.04	90	20	15	3.6	-11.1261
10	1.04	45	40	10	25.1	-27.9935

Taguchi prescribes examining information utilizing the S/N ratio that will offer two favorable circumstances. It gives direction to choosing the ideal level dependent on least variety around the normal value, which is nearest to target, and furthermore, it offers target correlation of two arrangements of test information concerning deviation of the normal from the objective.

3.2.1 Optimal combination of parameters

Table.3 Response Table for Signal to Noise Ratio Smaller is Better.

Level	Volume Concentration	Viscosity	Blade Angle	Impeller position	Holding Time
1	-28.95	-24.52	-23.98	-26.92	-30.44
2	-25.1	-29.53	-30.06	-27.13	-23.61
Delta	3.84	5	6.08	0.21	6.83
Rank	4	3	2	5	1

It shows that the holding time and blade angle contribute more towards the creation of the vortex pressure inside the crucible. Response table for signal to noise ratio is shown in Table.3. Plot for S/N ratio shown in Fig.5, explains there is less variation in the impeller position and high variation in the blade angle and holding time.

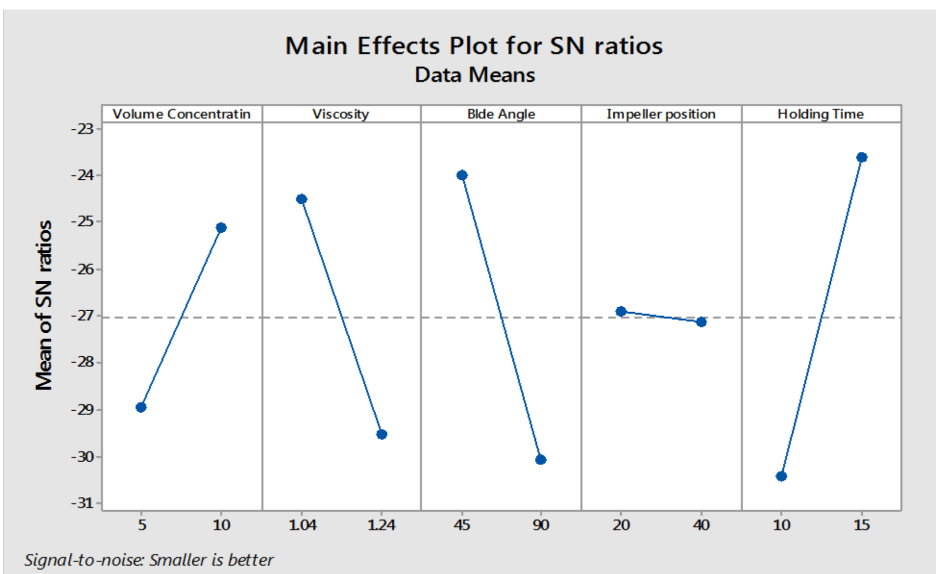


Fig 5.Mains effect plots for Vortex pressure.

Holding time of the stirring played a major role in the uniform distribution of the particles. When the holding time went beyond 10mins, the reinforcement particles were thrown away due to the centrifugal force and longtime stirring, which led to the clustering of the particles. When the stirring was stopped before 10mins, distribution was affected due to the adequate pressure distribution all along the liquid melt. So, the stirring time of 10min would have a significant impact in obtaining uniform distribution of the particles and enhanced mechanical properties.

Stirrer blade angle also had the major effect in distribution of the reinforced particles.

When the blade angle was kept below 45^o, the required shear force for creating the vortex pressure was very low which led to non-uniform distribution of the particles. When the blade angle was kept above 45^o, it created higher vortex pressure which led to bubble formation and air entrapment. Hence, 45^o stirrer blade angle would be the optimal parameter for better flow pattern and uniform distribution of the particles.

Processing temperature of the Al melt also possessed significant effect over the distribution of the particles. When the temperature was kept below 730^oC (1.04mPa-s viscosity), viscosity of the Al melt increased, which was difficult to distribute the particles throughout the crucible. When the temperature was maintained above 730^oC, the viscosity decreased which led to the settling of reinforced particles before pouring into the die, because of the density difference between the matrix and the reinforcement. Hence, the processing temperature at 730^oC (1.04mPas viscosity) of Al melt would be the optimal parameter for elimination of pores and for reducing the clustering of particles.

The volume fraction possessed an important role in the uniform distribution of the particles. When the volume fraction was less than 10 %, the mechanical properties of the composites were dropped because of the lower contribution and non-uniform distribution of the reinforced particles. When the volume fraction was more than 10 %, the clustering of reinforced particles took place due to the higher concentration, which led to poor mechanical properties. So, 10% volume fraction of the SiC particles would be the optimal parameter for improving mechanical properties

The stirring position of the impeller also had some influence over the distribution of the particles. If the impeller was kept above 40 % from the base, the clustering of the particles will takes place at the bottom region of the crucible because of the lack of vortex pressure at the bottom of the crucible. If the impeller was kept below the 40 % from the base, then there will be a lack of vortex pressure at the top of the crucible and also due to higher stirring at the bottom will through away all the reinforced particles from the bottom which leads to the un uniform distribution of the particles. The impeller position at 40% from the base of the crucible would be the optimal parameter for eliminating the clustering and settling of reinforcement particles.

3.2.2 Analysis of Variance

Taguchi strategies could not pass judgment and decide impact of individual parameters on the whole procedure. Contribution of individual parameters of process could be determined using ANOVA. Minitab 17 software of ANOVA module was used to investigate the effect of stir casting parameters on the vortex pressure which influenced the uniform distribution of the particles. The vortex pressure analysis determined with ANOVA and inserted in Table. 4 indicated an F value of 2.59 for the holding time which has a contribution of about 28.93%; F value of 1.74 for the blade angle which has a contribution 19.35%. They are associated with the most contribution in order to minimize the vortex pressure. Apart, an F value of 0.47 endorses a lower contribution of about 5.29% for the minimum vortex pressure. Trial no 1, 3, 5 showed high vortex pressure which should be avoided. From the optimization results, it was concluded that the trial no 2, 4, 8 possessed better vortex pressure towards the uniform distribution of the particles.

Table.4 ANOVA for vortex Pressure.

Source	DF	Adj SS	Adj MS	F-Value	Contribution %
Volume concentration	1	66.13	66.13	0.47	5.29
Viscosity	1	167.45	167.45	1.2	13.39
Blade angle	1	242	242	1.74	19.35
Impeller position	1	134.48	134.48	0.96	10.75
Holding time	1	361.81	361.81	2.59	28.93
Error	2	278.89	139.44		
Total	7	1250.74			

3.3. Visualization experiment

Due to the elevated working temperature of Al melt, it was not feasible to experimentally validate the simulation. So, visualization investigation using the glycerol water mixture and graphite particles was used to discover the flow pattern of the reinforced particles. The captured flow pattern of the graphite particles was shown in Fig.6, in which that image was compared with the computational fluid dynamics simulation image and also confirmed the best flow pattern by confirmation experiments.

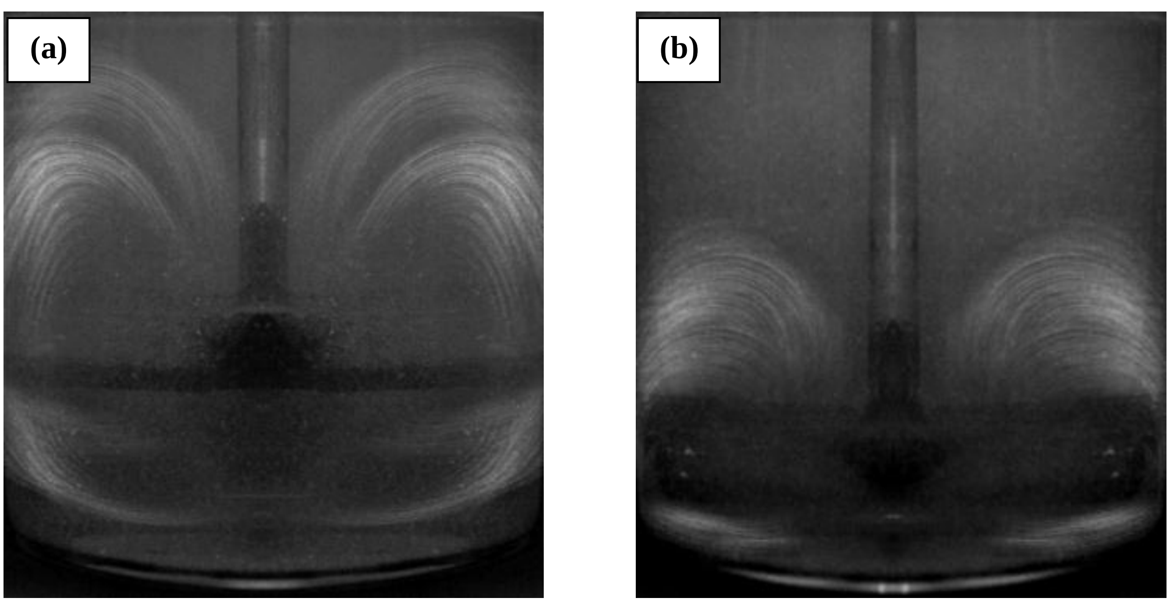


Fig.6 Visualization experiment (a) Impeller position of 40% from the base (b) Impeller position of 20% from the base

The white lines in the photograph were the paths followed by the graphite particles through the glycerol water mixture, which reflected the general fluid flow pattern [16]. The optimum vortex pressure obtained from the simulation showed concurrent result with the visually investigated one. The visualization experiments confirmed that the impeller position of 40% from the base provided better flow pattern when compared to the impeller position of 20% from the base. So, based on the results of CFD simulation, optimization and visualization experiment, the confirmation experiments were done using the stir casting parameters such as 45 degree blade angle, impeller position 40% from the base, viscosity of Al melt 1.04 mPa.s, 10% volume concentration of SiC particles and 10 minutes holding time which was based on the trial 2, 4 and 8.

4. Confirmation experiments

Confirmation experiments include microstructural analysis using the optical microscope and scanning electron microscope. Mechanical testing was carried out using tensile test, hardness test and wear test. Aluminium alloys and SiC particles (mesh size 300) were selected as the matrix and the reinforcement particles. Table.5 shows the chemical composition of Aluminium 8011. Using stir casting process with optimized process parameters in the L8 design table (2, 4, 8), Al 8011/SiC composites were fabricated. So, sample 2 (45 degree stirrer blade, 40% impeller position, 10 min holding time, 1.24mPa.s viscosity of Al melt and 5% of SiC), sample 4 (45 degree stirrer blade, 40% impeller position, 10 min holding time, 1.04mPa.s viscosity of Al melt and 5% of SiC) and sample 8 (45 degree stirrer blade, 40% impeller position, 10 min holding time, 1.04mPa.s viscosity of Al melt and 10% of SiC) were fabricated. In order to prove the optimized parameters from the results of CFD, microstructure examination and mechanical testing were carried out.

Table.5 Chemical Composition of Aluminium 8011

Elements	% Composition
Silicon	0.213
Iron	0.40
Copper	0.10
Manganese	0.018
Magnesium	0.10
Titanium	0.009
Zinc	0.210
Lead	0.009

Tin	0.030
Bismuth	0.002
Zirconium	0.002
Chromium	0.002
Aluminium	Remainder (98.905)

4.1Microstructural

From the microstructural analysis, it was observed that the sample 2, 4 and 8 possessed better uniform distribution of the particles, low porosity and no clustering of particles [3,18]. Even though the probability of clustering was high for the higher volume fraction of the SiC particles (10 % of SiC), due to the optimized parameters, uniform distribution of SiC particles were obtained for both the 5 % and 10 % of SiC particles (sample 2 and 8). It was evident that due to the higher viscosity 1.24 mPa-s, there occurred some agglomeration of the particles in the sample 2, which was mainly due to the fact that the particles were unable to disperse in the higher viscous medium and also due to the resistance force offered by the one layer of the liquid over the other. It was evident that the stirrer blade with 45º angle showed homogenous distribution of particles when compared to the stirrer blade with 90º angle. This was mainly due to the role of high vortex pressure 40 Pa, which was created by the 90º blade angle that resulted in clustering of SiC particles and void formation. But, the 45º blade angle created vortex pressure (15 – 26 Pa) which was sufficient enough to distribute the particles all along the liquid. The flow pattern obtained from the visualization experiments proved that the impeller position 40% from the base helped to distribute the SiC particles uniformly. The vortex pressure created by the impeller of 40 % from the base possessed sufficient shear force to transfer the particles throughout the molten liquid. But, the vortex pressure created by the impeller of 20 % from the base did not give appropriate shear force throughout the liquid. It produced higher vortex pressure at the bottom and lower pressure at the top which tended to produce non homogenous distribution of the particles. It was observed that the prolonged stirring of 15 minutes might lead to the erosion of stainless steel stirrer blades and also through the particles towards the outer surface of the molten metal which formed clustering of particles at the inner surface of the crucible. So 10 minutes of stirring produce efficient vortex pressure and uniform distribution of the particles. Fig.7 shows the OM images at various cross sections of the casted samples at 100µm magnification, Fig.8 shows SEM images at various cross sections of the casted samples at 100µm magnification. Hence, the stir casting process parameters such as 45 degree stirrer blade angle, impeller position of 40% from the base of the crucible and stirring time of 10 minutes were considered for the mechanical characterization. Therefore, these three samples were carried to mechanical testing such as tensile, hardness and wear tests.

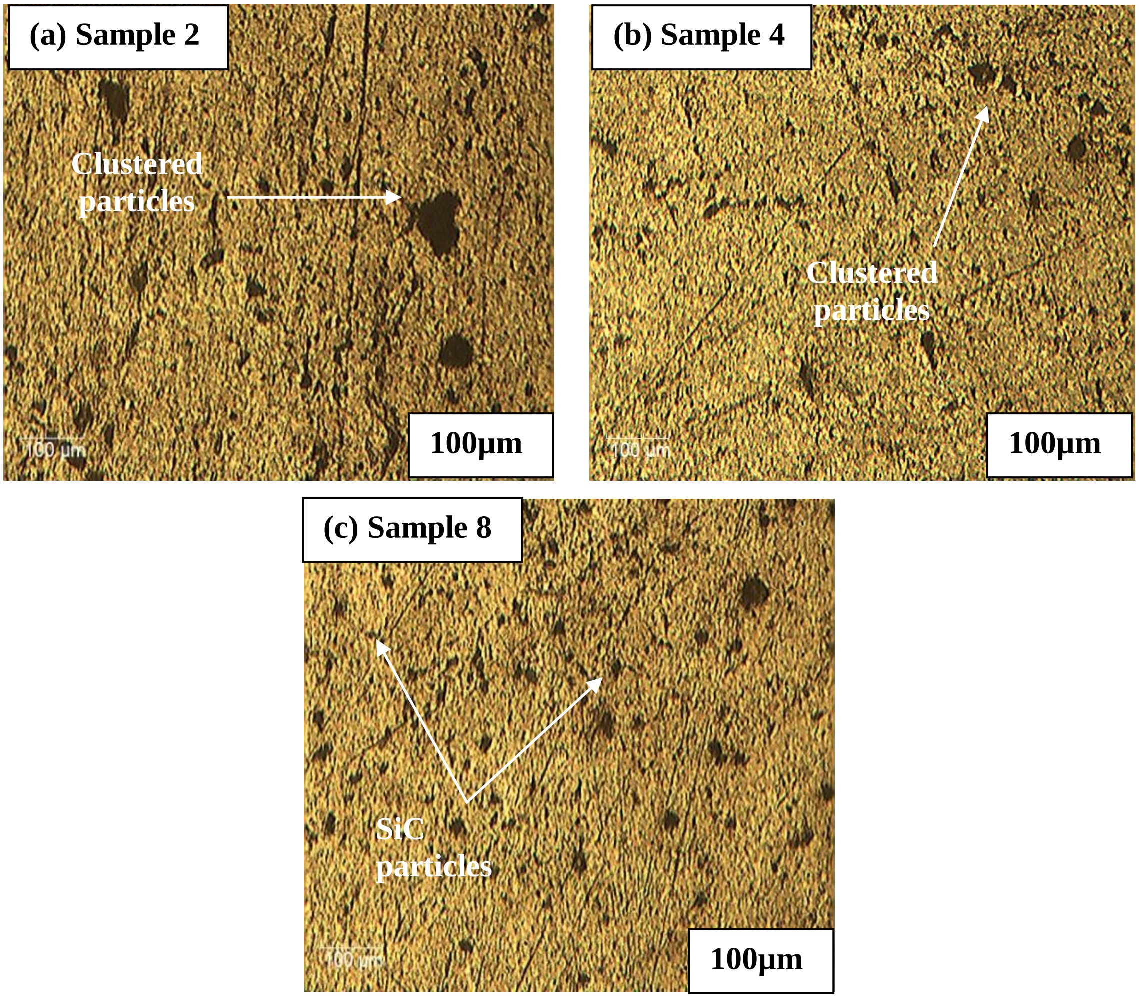
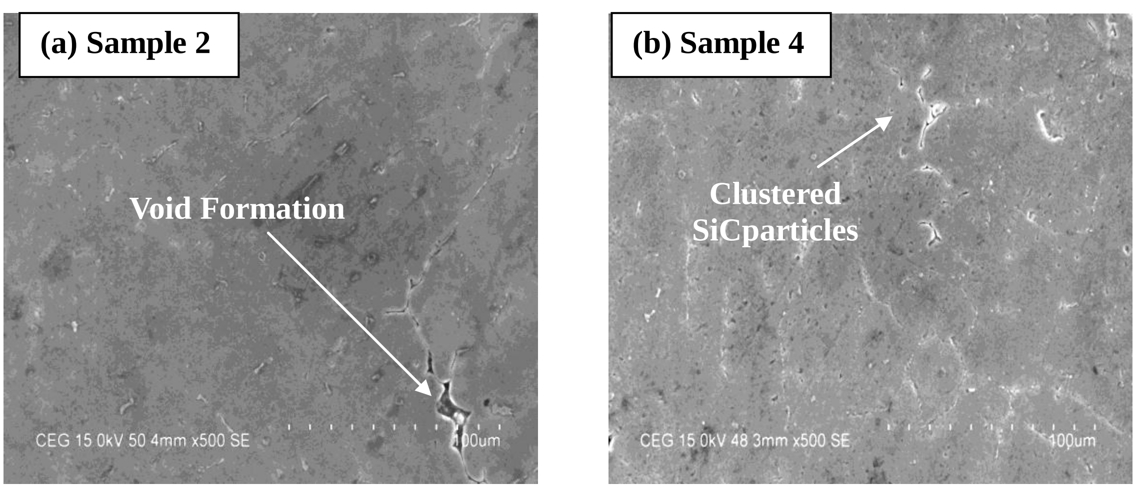


Fig.7.Optical Micrograph Image at Various cross sections



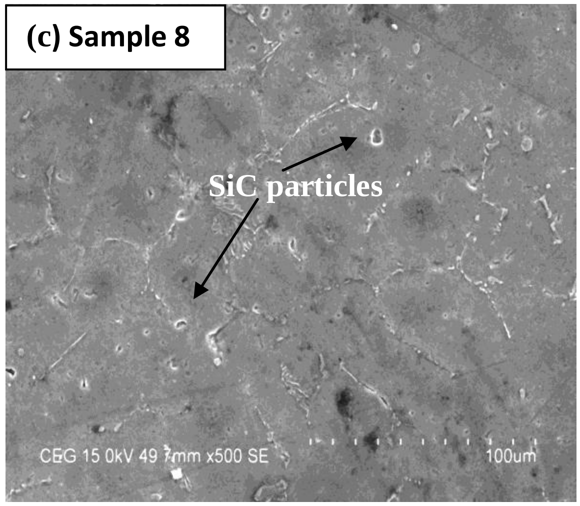


Fig.8.SEM Image at Various cross sections

4.2. Mechanical Testing

4.2.1 Tensile test

The specimens for tensile testing were cut as per ASTM E-8 standard by Wire cut Electric Discharge Machining (WEDM) and the tensile test was carried out using universal testing machine. Five specimens were tested for each sample. From the result of the tensile test it was observed that the sample 8 possessed higher tensile strength than the other two samples (Fig.9). The increase in the tensile strength of the sample 8 was mainly due to the higher concentration of the SiC particles [19], whereas, the other two samples had only 5 % of SiC particles. This was also the main reason for the ductile behavior of sample 2 and 4. It was also detected that the sample 2 possessed lower tensile strength of 61MPa which was lesser than the sample 4 having the tensile strength of 67MPa. This controversy was due to the viscosity of the molten metal. The higher viscosity of molten metal (1.24mPa-s) would lead to particle clustering and void formation which consequently decreased the tensile strength of the composite. The vortex pressure decreased with high viscous fluid which was also the major fact in decreasing the tensile strength of the sample 2. The SEM image of the fractured samples (Fig.10) shows that the ductile fracture was evident in the sample 2 and 4 (5% of SiC) and the brittle fracture was found in the sample 8 (10% SiC). This was mainly due to the presence SiC particles which restricted the deformation moments.

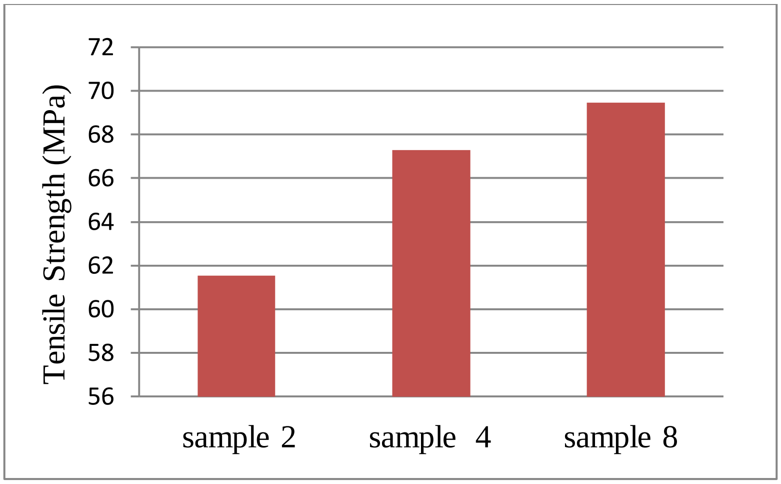
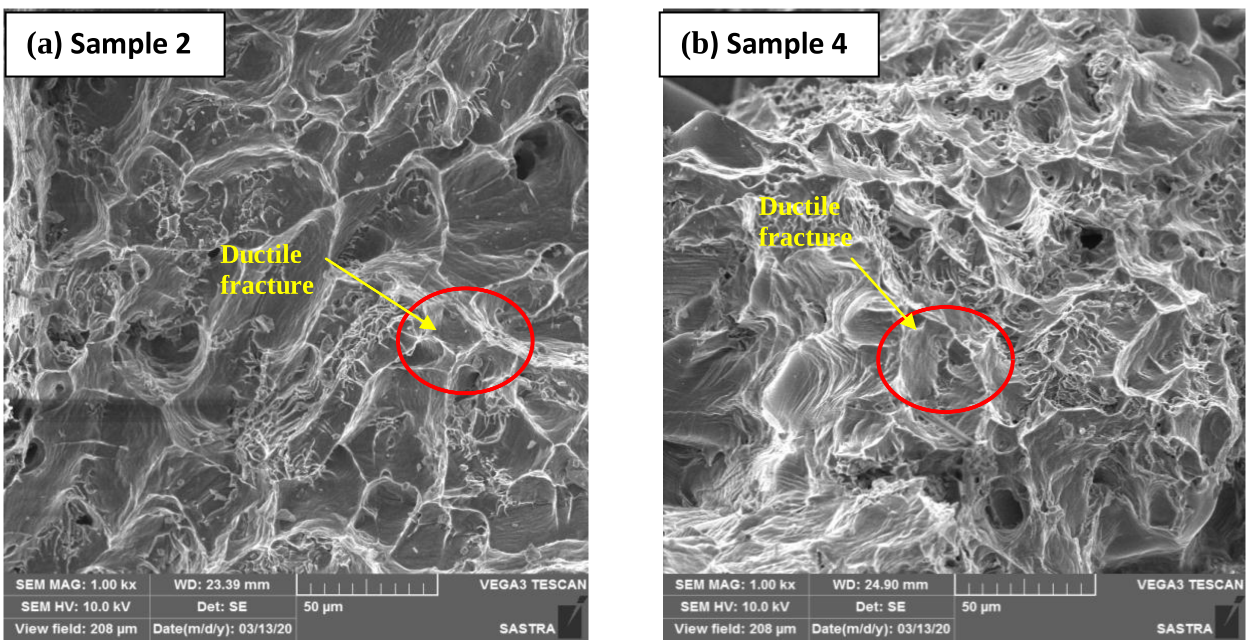


Fig.9.Tensile test



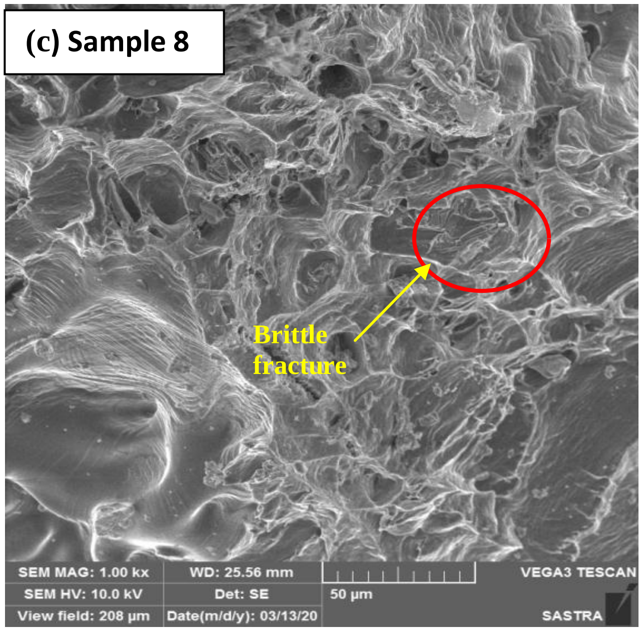


Figure.10.SEM image of the fractured samples

4.2.2 Hardness test

The specimens for Vickers hardness test were cut as per ASTM E-92 standard. Five observations were taken for the each sample. From the result of the hardness test, it was observed that the sample 8 had higher hardness when compared with the other two samples (Fig.11). Even though the sample 2 and sample 4 had the sample volume fraction of the SiC particles (5 % SiC), the hardness result showed 42 HV for sample 4 sand 37 HV for sample 2, which was due to the influence of viscosity factor in the molten metal. The higher viscosity (1.24 mPa-s) which meant the lower working temperature of 700ºC, would give rise to the improper distribution of the SiC particles which considerably decreased the hardness of the composites. This shows that the 10% volume fraction of the SiC particle would increase the hardness of the composite [20] and also proves that the uniform distribution of the SiC particles would give better hardness.

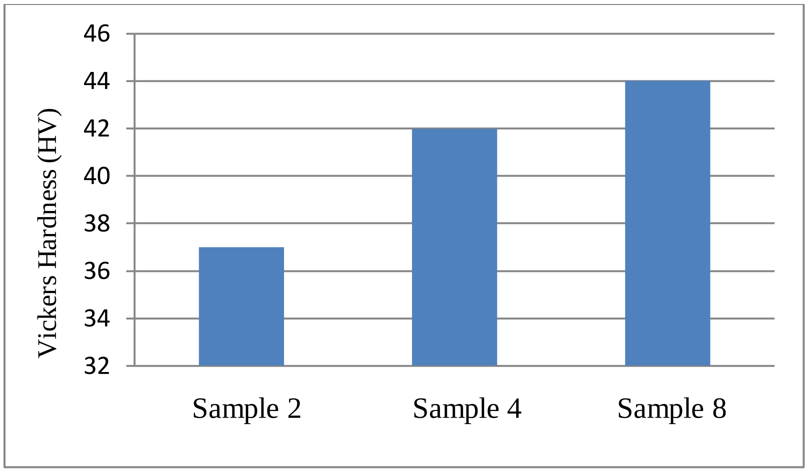


Fig.11.Hardness test

4.2.3 Wear test

Wear testing was conducted using the pin-on-disc wear testing apparatus (TR-20LE, DUCOM). The test specimens of 6mm diameter and 25mm length were prepared by machining. ASTM G-99 standard was used in the testing under dry sliding condition. As the load was applied over the pin, the composite pin began to slide over the counter face disc and wear debris were formed. These wear debris acted as a third body abrasion and grooves were formed by ploughing action. Wear rate was noted for 1000m and 1500m sliding distance. The result shows that the sample 8 had lower wear rate when compared to the other two samples (Fig.12), because of 45 degree blade angle, impeller position 40% from the base, viscosity of Al melt 1.04 mPa.s, 10% volume concentration of SiC particle and 10 minutes holding time. The Wear test shows that the Wear rate of the composite decreased as the percentage of SiC particles increased [21]. The SEM images of the worn-out surface of the samples (Fig.13) also proved that the uniform distribution of the particles would reduce the wear rate of the composites (sample 8). Sample 2 possessed lower wear resistance that was due to the higher viscosity (1.24mPa-s) of the Al melt which resulted in clustering of SiC particles.

$$wear\ rate = \frac{(\text{Before weight} - \text{After weight})}{\text{Sliding distance}} (\mu mm3/m)$$

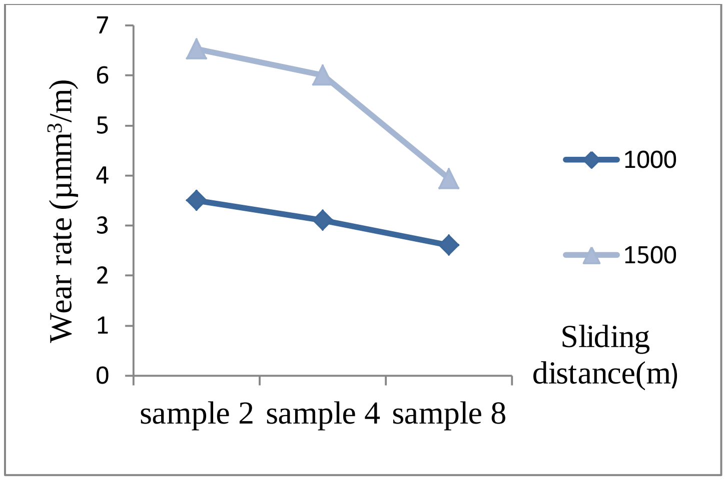
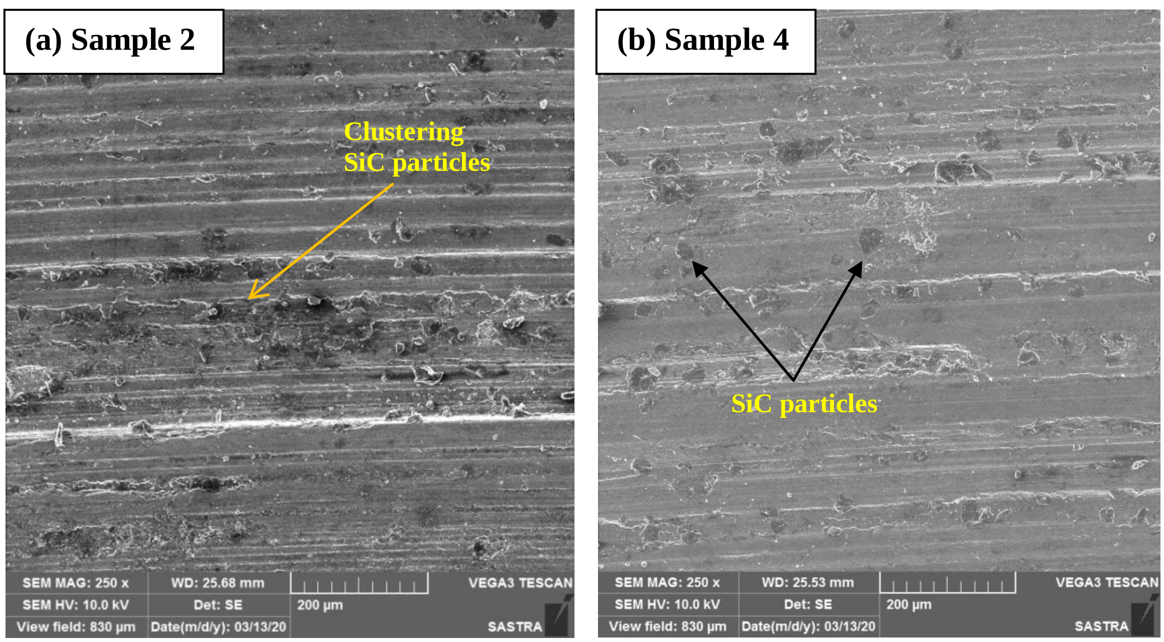


Fig.12.Wear test of the casted sample



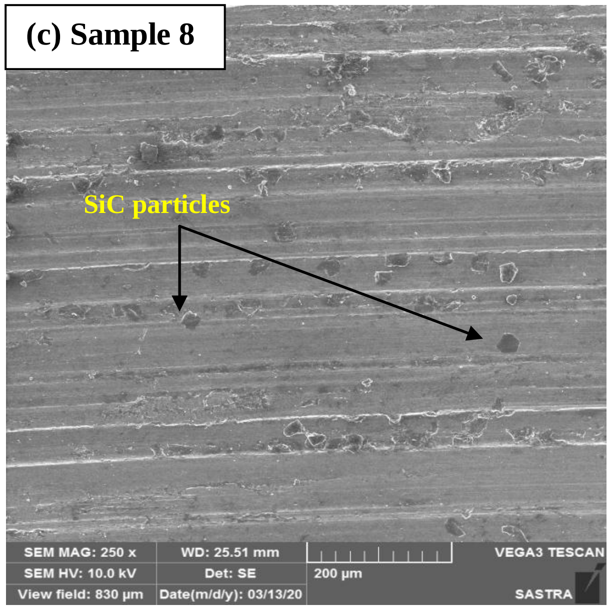


Figure.13.Worn-out surface

5. Conclusion

Experimental investigation of influence of the various stir casting parameters was evaluated to obtain the optimum vortex pressure and the uniform distribution of the reinforcement of the particles. The main objective of the research is to optimize the stir casting parameters in order to obtain the uniform distribution of the reinforcement particles which improves the overall strength of the composites from which it can be used for gears, brake drums, bearings and drive shafts. The conclusions from the investigations are listed below.

- Homogenous distribution of the reinforcement particles depends on optimum vortex pressure. The optimal vortex pressure of 15 to 26 Pa is required for the uniform distribution of the reinforced particles and effectual flow pattern, which is obtained with the help of Computational fluid dynamics simulation.
- The presented Computational fluid dynamic simulation is implemented to find the particle distribution and vortex pressure for any reinforcement particles but the density and the thermal conductivity of the corresponding reinforcement particles must be given as the input to the CFD simulation.
- The volume fraction plays an important role in the uniform distribution of the particles. 10% volume fraction of the SiC particles gives more wear resistance and also shows improved mechanical properties.
- The stirring position of the impeller also has some influence over the distribution of the particles. The mechanical properties of the fabricated composites are improved by eliminating the clustering of SiC particles and obtaining the homogenous distribution of the SiC particles by holding the stirrer 40% from the base of the crucible.

- Holding time of the stirring plays a major role in the uniform distribution of the particles. The stirring time of 10 minutes helps in obtaining uniform distribution of the particles and enhanced mechanical properties.
- Stirrer blade angle also shows important contribution towards the homogenous distribution of the SiC particles. Better flow pattern and the homogenous distribution are obtained from the Stirrer blade with 45^o angle.
- Processing temperature of the Al melt also possesses significant effect over the distribution of the particles. 730^oC processing temperature (1.04mPas viscosity) of Al melt results in elimination of pores and reduces the clustering of particles.

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The authors have no conflicts of interest to declare that are relevant to the content of this article.

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