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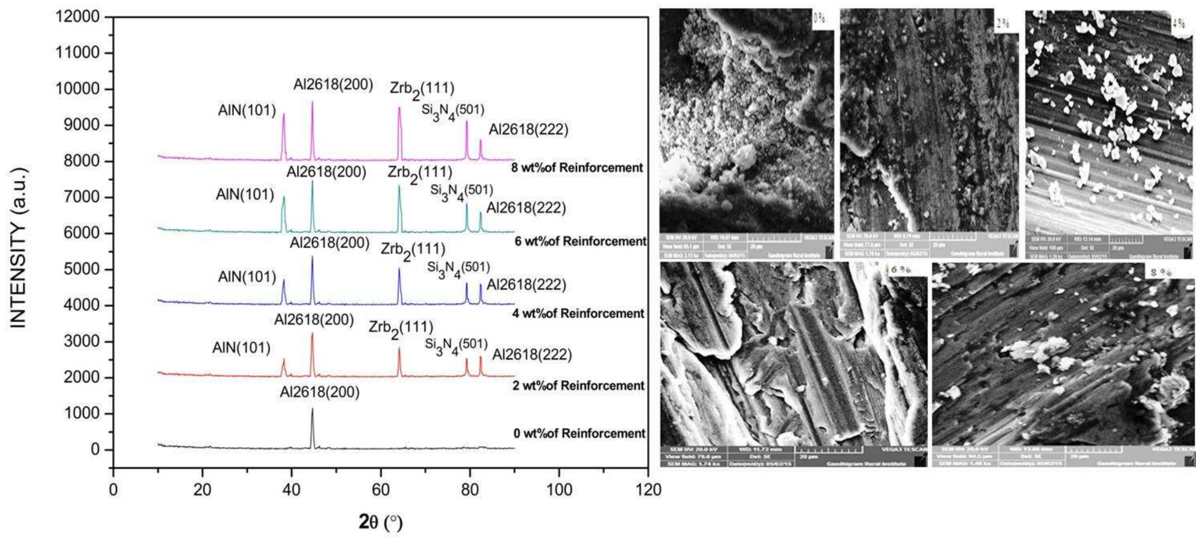

INTENSITY (a.u.)
2θ (°)
AlN(101)
Al2618(200)
Zrb2(111)
Si3N4(501)
Al2618(222)
8 wt%of Reinforcement
6 wt%of Reinforcement
4 wt%of Reinforcement
2 wt%of Reinforcement
0 wt%of Reinforcement
0%
2%
4%
6%
8%

Aerospace application on Al 2618 with reinforced - Si_3N_4, AlN and Zrb_2 in-situ composites

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ABSTRACT

In this study, the Al 2618 aluminium alloy is reinforced with Si_3N_4 (Silicon Nitride), AlN (Aluminium Nitride) & Zrb_2 (Zirconium Boride) in wt. % of (0,2,4,6,8) by stir casting process. The tribological and mechanical properties of these composites particles were investigated under dry sliding conditions. The mechanical properties of the composites is studied by conducting various test like hardness test, tensile test and compression test to understand the relationship between the wt. % of reinforcement and the matrix metal. This is followed by the micro structural study to examine the bond formation and effect of grain size reduction due to the addition of reinforcement. The Taguchi L_{25} orthogonal array is used to optimize the process parameters to obtain minimum wear rate and the analysis of variance (ANOVA) was used to investigate the influence of parameter affecting the wear rate. The Scanning Electron Microscope (SEM) analysis is carried out to understand the wear mechanism of worn out surfaces and the wear debris. The manipulate of the wt. % of reinforcements and applied load on the wear rate, wear resistance, specific wear rate, coefficient of wear rate and the mass loss were premeditated using the pin-on-disk method.

Keywords: Metal-matrix composites, wear testing, Micro structure, Taguchi Method, ANOVA.

1. INTRODUCTION

Aluminium alloys are used in many engineering applications to their light weight and high strength characteristics. However, low hardness and consequently low wear resistance limit their use in some applications [1]. At the present time, aluminium metal matrix composites have been well recognized and steadily improved because of their advanced engineering properties, such as their improved wear resistance, low density, specific strength and stiffness [2]. The improved wear resistance of AMMCs has attracted significant attentions in the field of tribology. However, the use of single reinforcement in an aluminium matrix may sometimes compromise the values of its physical properties. Both the mechanical strength and the wear resistance of composites increase with the addition of reinforcement particulates to the aluminium matrix alloy. However, the consequent increase in hardness makes machining difficult [3]. Compared with traditional ex situ composites, the in situ particles reinforced aluminium matrix composites possess more advantages in microstructure such as clean interface, strong interfacial bonding, fine particles and uniform distribution in matrix [4]. It has been stated that abrasive wear resistance of the composites increases with the amount of reinforcement. Also, the erosion wear behaviour of composite materials has been a subject of study for many investigators [5]. In this study, the metal matrix Al 2618 is reinforced with particles such as Si_3N_4, AlN, and Zrb_2 in various wt. % of (0,2,4,6,8) and Zrb_2 is developed by the composition of $K_2Z_rF_6$ and KBF_4 salts by insitu process to form the metal matrix composites. The mechanical properties such as tensile, compressive and hardness are measured by using universal testing machine and Vickers harness testing machine respectively. The composites are characterized by various processes such as X-ray diffraction (XRD) for analysis of different phased formed. The morphology of composite has been studied under optical microscope, scanning electron microscope and the wear effect mechanisms were conferred systematically. Taguchi L_{25} orthogonal array has been used to identify the most influential process parameter. Analysis of variance (ANOVA) is used to obtain the total percentage of contribution of each parameter.

2. EXPERIMENTAL PROCEDURE

2.1 MATERIAL SELECTION

In this study, the Aluminium 2618 is considered as the base metal. The matrix material is mixed with reinforced particles to examine the change of mechanical properties and its tribological behaviour in various weight percentages from its standard value. The Table. 1 shows the chemical composition of Al 2618 alloy in wt. %. The three reinforced particles mixed with base metal are Si_3N_4, AlN, and Zrb_2. These reinforced particles are added in wt. % of [0,2,4,6,8] with base metal to form a composite. The reinforcement particle Zrb_2 is formed owing to the blend of two types of salts namely $K_2Z_rF_6$ and KBF_4.

2.2 WORK PIECE DESIGN

The specimen is made with various weight percentages of reinforcement materials to carry out various experiments. Initially, the stir casting method is deployed to produce the specimen, the base metal Al 2618 was taken in a crucible made out of graphite and it is heated to a temperature of about 850 ^{0}C. The stirrer is used to stir the molten metal well to mix all the particles. The reinforcement particles such as Si_3N_4, AlN, and Zrb_2 are added with molten aluminium in weight ratio of (2,4,6,8). The stirrer is made up of mild steel which is coated with zirconium to avoid the possible contamination of the molten metal with iron. The chemical reaction between the inorganic salts and the molten Al took place to form in situ particulates [6]. The molten melt is well distinguished and it is poured in to a cylindrical mould of size possessing a specimen diameter of 10 mm diameter and length of 25 mm. When the mould reaches the room temperature, the specimen is taken out and the machining operations like facing and turning were done to obtain the required shape and size. The Fig. 1 shows the work piece with various wt. % of reinforcement particles with matrix metal aluminium.

2.3 PIN ON DISC WEAR TEST

The Pin on Disc apparatus is used to carry out the dry sliding wear test at room temperature according to the ATM G99 G95a Standard. The Schematic diagram of Pin on Disc apparatus is shown in Fig. 2. The specimen of size 100 mm diameters and length 25 mm is considered as test material with various percentage of reinforcement.

The electronic balance weight machine is used to measure the weight of the pin and disc before and after the test gets commenced. In total, about 25 specimens are taken for this test, a group of five pieces in each group with different weight percentage of reinforcement. The various input parameters are considered while conducting this wear test on Pin on Disc apparatus. The tribological test were carried out in room temperature in the ranges of applied normal load of 10N, 20N, 30N, 40N, 50N at a sliding speed range of 1 m/s, 2 m/s, 3 m/s, 4 m/s and 5 m/s in steps with a constant sliding distance of 3000 meters. The mass of the specimen is measured once the test is completed at room temperature. From the mass loss in the specimen, the wear rate, wear resistance, coefficient of friction and specific wear rate were calculated.

2.4 VICKER HARDNESS TEST

The hardness value of the Al 2618 alloy with the various wt% of reinforcement has been measured by using Vickers hardness testing machine. The hardness tests were conducted according to the ASTM E10-07 standards. The load of 0.5 kg have been provided to the loaded specimen for about 25 sec and carried out in room temperature. The Fig. 3 shows the Vickers hardness testing machine. The reinforcement materials such as Si_3N_4, AlN, and Zrb_2 were added to the matrix material in (0,2,4,6,8) wt. %. In total five specimens are carried out for hardness test. In each specimen, hardness test were conducted at five different locations to obtain an average value of hardness.

2.5 TENSILE TEST

The ultimate tensile strength for metal matrix with its reinforcement is calculated by using a universal testing machine. The tensile strength for the specimen is assessed as per the ASTM EO8-8 standard. Before the tensile test, the sample is polished with the help of 1200 grit grinding SiC Paper to diminish the machining scratches and also to reduce the effects of surface defects on the outer surface of the specimen. To carry out the tensile strength, loads of 10KN were applied to the specimen in the universal testing machine and it is evaluated at cross head speed of 2.5 m/min.

2.6 COMPRESSION TEST

The computerized universal testing machine was used to calculate the ultimate compressive strength of the matrix material with its reinforcement. The test was carried out on the specimen as per the ASTM E9-09 standards. The ultimate compressive strength is measured by calculating the applied force adjacent to deformation in the universal testing machine. In total five specimen were carried out for compressive test possessing a reinforcement of (0,2,4,6,8) wt.% with the matrix material in room temperature.

2.7 MICROSTRUCTURAL STUDY

The electronic optical microscopic were deployed to observe the micro structural for the metal matrix with its reinforcement and the blend of both matrix material and reinforcement were analyzed through the micrographs of the formed specimen. The Fig. 4 shows the optical electron microscopic with specimen loaded to view its micro structural. The matrix material Al 2618 is mixed with the reinforcement material such as Si_3N_4, AlN, and Zrb_2 at a particular weight % of 0,2,4,6,8 by the process of stir casting method. Total of five specimens is formed based on the weight percentage of reinforcement and each specimen is cut in to five equal shapes by using the power hacksaw blade. The cold setting process is done for the equal shape specimen by using cold setting liquid and cold setting powder. Initially, the irregular scratches on the specimen is removed partially by using dry belt machines and the fine scratches on the specimen are reduced by using emery sheets with different sets of grade sheets. The chemical etchant called Kellers Etchant (Distilled water – 190 ml, HNO_3 – 5ml, HCl – 3 ml, HF – 2 ml) [7] is applied on the upper surface of the specimen and it is made to dry in hot air by using hot air gun for 30 sec to obtain the enhanced microstructure with various magnification.

3. OPTIMIZATION TECHNIQUE

3.1 TAGUCHI METHOD

Taguchi method which is a powerful tool in parameter design was used for conducting the experiments. It provided a simple, efficient and systematic approach to optimize the design for performance, quality and cost. The methodology is valuable when the design parameters are qualitative and discrete [8]. The greatest advantage of this method is to save the effort in performing experiments: to save the experimental time, to reduce the cost, and to find out significant factors fast [9]. Generally, there are three types of performance characteristics for the analysis of the S/N ratio, i.e., the lower the better, the nominal the better, and the higher the better [10]. In this method, Taguchi lower is better type is used to calculate the process parameters. The three process parameters which influence the wear rate of the composite alloy are wt. % of composites, Load and the velocity. L_{25} orthogonal array was used for this experiment. The Table. 2 show the L_{25} orthogonal array factors and its levels. The format of L_{25} orthogonal array is presented in Table. 3.

3.2 ANOVA METHOD

In order to optimize the machining parameters, the numerical optimization technique has been used. Using analysis of variance (ANOVA), the significance of input parameters is evaluated. MINI TAB statistical software is used to establish the design matrix, to analyze the experimental data and to fit the experiential data to a second-order polynomial. Sequential F test and other adequacy measures are used to check the model's performance [11]. To determine the optimal wear rate of the composite alloy parameters, the standard ANOVA procedure was performed using the mean values. The ANOVA table indicates the order of importance of the parameters influences the wear rate of the composite alloy.

4. RESULTS AND DISCUSSION

4.1 MECHANICAL PROPERTIES – Al 2618 MATRIX MATERIAL

In this study, the three mechanical property test such as hardness test, tensile test and compression test are carried out to determine the hardness value, ultimate tensile strength and ultimate compressive strength of the composite alloy Al 2618 with its reinforcement. The matrix material aluminium Al 2618 is reinforced with three particles such as Si_3N_4, AlN, and Zrb_2 with five stages of adding wt. % to the matrix material. It proves that mechanical properties posses higher value at adding more reinforcement than the base metal alloy. The mechanical tests were carried out as per the ASTM standards for each different test.

4.1.1 HARDNESS TEST

The micro hardness for the Al 2618 alloy along with the reinforcement is measured by using the Vickers hardness testing machine. The hardness values are calculated at different phases of composite to analysis about the effect of reinforced particles on the matrix materials. The Fig. 5 shows the hardness value for the composite Al 2618 with its five reinforcement composition. The reinforcement particles such as Si_3N_4, AlN, and Zrb_2 added with corresponding wt. % (0,2,4,6,8) to the matrix material Al 2618 reveals an increase of hardness value based on the composition added to it. Zrb_2 particles increase the hardness of the composite due to its fine particulate distribution [12]. One of the noticeable features is that composite has a fine participated diffusion which leads to increase the hardness value due to the presence of reinforced substances. It also may due to the acceleration in occurrence of hard Si_3N_4 particles in the aluminium matrix and high hardness of Si_3N_4 particles. It enhances their surface area and the size of aluminium matrix grains reduced. The occurrence of these hard surface areas of Si_3N_4 particles offer huge resistance to the plastic deformation which results into increase of the hardness of fabricated aluminium matrix composites [13]. In Addition of AlN reinforced particles, the improvement of hardness is due to the effect of hardening effect of the binder where more amount of alloy is dissolved and hardness of the aluminium reinforced composites is increased due to the decline of particles size. Hence the composite alloy attains higher hardness value due to the decrease of plastic deformation by the reinforced particles.

4.1.2 TENSILE STRENGTH

The effect of reinforcement particles such as Si_3N_4, AlN, and Zrb_2 on the tensile strength of the composite obtained from the tensile test are shown in Fig. 6. The tensile strength is one of the important characterization in mechanical properties. The tensile strength value of the composite materials increases along due to the addition of reinforcement materials such as Si_3N_4, AlN, and Zrb_2 with various wt.%. This is mainly due to the stress transmission from the Al 2618 matrix to the reinforcement particles. The interactions between the dislocations and reinforcement particles results in higher tensile strength. The presence of Zrb_2 particles enhances the tensile strength due to the addition of particles increases in volume fraction and also the elongation is significantly improves due to the value of particle volume fraction increases. The brittle behaviour of the Si_3N_4 particles plays a significant role in reducing the ductility as Si_3N_4 reinforcement is brittle and they enlarged the brittleness in the fabricated composites, which in-turns reduced the ductility content of the composites [14-15]. In the increase wt. % of AlN particles, the refinement of ceramic grains and homogenous microstructure is enhanced and exhibited the superior abrasive wear resistance. The scattering of reinforced particles are evenly distributed over the composite and possess continuous acquaintance leading to better tensile strength.

4.1.3 COMPRESSIVE STRENGTH

The ultimate compressive strength of the Al 2618 alloy is measured along with the reinforcement particles Si_3N_4, AlN, and Zrb_2 and the values of the compressive strength for the matrix alloy with five reinforcement materials are shown in the Fig. 7. The compressive strength of the matrix material is increased due to increment of wt. % of reinforcement material. At each stage of wt. % of (0,2,4,6,8) reinforcement material with matrix Al 2618 posses higher value compressive strength due to the hybrid composites are greater than that of base alloy [16]. The ultimate compressive strength is high due to the reinforcement particles act as a second phase in the phase and resist the movement of dislocation in the matrix composite [17].

4.2 EDX ANALYSIS

The EDX spectrometer is a powerful instrument for performing qualitative and quantitative elemental analyses of materials by measuring the characteristics of re-emitted X-rays [18]. The results obtained from the EDX spectrograph of the composite fillers consume a number of varying compositions of different types of particles. The Fig. 8 displays the EDX analysis of the worn surface after wear tested. The peaks of all aluminium alloy observed. One of the important features is that surface of the alloy contains the content of iron and also presence of oxygen indicates the oxidation reaction. The presence of O peak confirms the oxidation driven wear in all cases. Iron is transmitted from the wearing counter face by a mechanism of mechanically alloying which results in the formation of mechanically mixed layer (MML) in the wearing surface [19]. It indicates that the iron transfer layer inhibits contact between the surfaces, hence improving the wear resistance. This behaviour is in good agreement with the results of Rosenberger et al. [20]. The wear resistance is increased mainly due to the iron transmit layer restrain contact between the surfaces.

4.3 X-RAY DIFFRACTION ANALYSIS

The X-ray diffraction (XRD) results for the matrix metal Al 2618 with reinforcement particles Si_3N_4, AlN, and Zrb_2 are shown in Fig. 9. The diffraction peaks of Al, Si_3N_4, AlN, and Zrb_2 phases are observed. The obtained XRD result reveals that presence of aluminium is in form of largest peaks. The mixture of aluminium and nitride particles in the composite particles occurs at the level below to each other. The presence of silicon nitride particles and zirconium boride particles is indicated by minor peaks. The increase in the intensity of reinforcement particles with increase in the amount of reinforcement particles in the composite is evident. A measured shift of the Al particles to higher angles with increases in the weight % of the reinforcement Zrb_2 is also evident. In this analysis, samples are not subjected to oxygen reaction during the sintering process [21].

4.4 MICROSTRUCTURAL STUDIES

The five micrographs for the composite alloy of various wt. % have been shown in the Fig. 10. The micrograph of matrix Al 2618 without reinforcement materials such as Si_3N_4, AlN, and Zrb_2 in Fig. 10 (0%) reveals the grains of matrix phase with uniformly distributed its base metal particles. The microstructure of matrix metal reinforced with increasing percentage of reinforcement particles shown in Fig. 10. It implies that the grain size of matrix phase refines on in-situ formation of these particles. The enhancing the bond strength at the interface between the matrix and the reinforcement particles and the homogenous distribution of the reinforcement particles is achieved by stir casting method. Although reinforcement fracture might be severe, the improvement of the state of dispersion of the reinforcement had a good influence on the mechanical properties of the metal matrix composites [22].

The average grain size of different composites is shown in the Table. 4. The average values of the grain size for composite alloy of 0%, 2%, 4%, 6%, 8% are 39.2 µm, 43.8 µm, 30.95 µm, 26.85 µm, 21.9 µm respectively. The main advantages in presence of reinforced and refinement of grains is achieved due to the restriction in the movement of solidification and also act as nucleation sites for matrix phase in increasing the number of grains. The particles have greater tendency to be pushed towards grain boundary by solidification front, thus the pinning effect of reinforced particles positioned at grain boundaries can suppress the grain growth. The grain refinement produced by the pushed particles is commonly observed in reinforced particles in dispersed composites [23].

4.5 WORN SURFACE ANALYSIS

The SEM micrographs of the matrix material Al 2618 with powder mixture of reinforcement particles such as Si_3N_4, AlN, and Zrb_2 is shown in Fig. 11. The matrix material Al 2618 is mixed with three reinforced particles such as Si_3N_4, AlN, and Zrb_2. The micrograph reveals that it possesses a uniform and homogenous microstructure of the composite alloy is successfully formed due to the stir casting process. In general, the wear resistance of metal matrix composites increases with increasing size and shape of the reinforcement particles [24]. The matrix metal Al 2618 is appeared in shape of round and cylindrical shapes. Size selection of the reinforcement particles was based on its potential applications and tribological features [25-26]. In Fig. 11 reveals the spotted image of dark and light regions confirms the presence of aluminium and Zrb_2 particles in their corresponding phases and it also reveals the presence of Si_3N_4 particles in the aluminium composite. The particles posses a cluster of space on the surface leads to deposition of these particles due to the high density of Si_3N_4 particles than the aluminium. The SEM Micrographs shows the metal matrix aluminium and Si_3N_4 particles posses a good interface between them.

The Fig. 12 shows the SEM micrographs of the worn surfaces of Al 2618 alloy sliding at room temperature. In Fig. 12 (0 %) The phases illustrate that proper interfacial bonding without any cracking on the surface between Al matrix and Zrb_2 reinforcements. The composite alloy is subjected to a load of 10 N to 50 N, the visibility of both wear mechanism of materials similar to abrasive and adhesive wear are occurred on the surface. The wear rate of the composite is increased extensively as the load is increased radically from 10 N to 50 N implies in more wear mechanism and hence transaction from mild to severe wear. In Fig. 12 (2% - 8 %) the presence of Si_3N_4 particles reflects the density of the aluminium composites. The density of the Si_3N_4 particles is increased mainly due to the wt. % of Si_3N_4 particles increases from 0% to 8%, which leads to the increase in the porosity in the composites. This rise in porosity may be because of existence of impurities in both the matrix material and reinforcement particles [27]. The sharp edges of abrasive particles shown in micrographs are the presence of AlN particles. The scratches, the grooves and the number of pits present in the composites are narrower and shallower are due to the effect of AlN particles. The coarse particles present in the composites cannot easily penetrate in to the interface but it revolves frequently between the worn surfaces and has an outcome of less material removal. Addition of AlN particles from 0 to 8 wt. % in matrix alloy leads to increase the hardness of the composites. The interface between the reinforcement particles and aluminium are very strong due to the absence of residual particles in the surface of the composite. The existence of small pores in the microstructure is due to the difference in thermal expansion of aluminium and Zrb_2 particles. The strength of the composites is high when compared to addition of reinforcement particles with aluminium posse's higher relative density, good interfacial bonding and free from micro crack in the microstructure. In this study, the particles present in the aluminium matrix are very slow in being detached due to the clear interface and the better bonding between the grains. Hence the stress is easily transferred from the matrix to the particles and increases the strength of the composites. When the addition of reinforcement particles increases in the matrix, the grain size of the composite alloy is decreases it leads to the increases the conflict for the dislocations movement across grain boundaries. It is believed that the grain boundaries act as micro-cracks nucleation sites due to residual stresses, which is induced by thermal elastic anisotropy of Zrb_2 particles during solidification process and the micro-crack develops locally at grain boundaries due to deformation subsequently [28].In the study of worn surfaces load was the dominant in lower loads passage of hard particles there was a abrasion wear found and higher load condition adhesive wear revealed.

4.6 INVESTIGATION OF WEAR PROPERTIES

4.6.1 VARIATION OF WEAR RATE AS A FUNCTION OF LOAD AND COMPOSITE (Wt. %)

The variation of the mass loss as a function of load at room temperature is shown in Fig. 13. The mass loss of the each composite wt. % is gradually increased when the load is increased from 10 N to 50 N during the experiment. The maximum loss of particles is seized at the maximum load applied to the composite. The variation of the wear rate as a function of wt. % of composite and load at room temperature is shown in the Fig. 14. In this study, the non-linearity is observed in the wear rates of the composites are implicit by knowing the factors of wear surfaces and wear debris. The wear rate of the alloy is very high when compared to the composites with 6% and 8 % at higher load of 50 N. It is evident that low load of 10 N, posses lesser wear rate of the composites with increases in wt. % of composites form 0 % to 8 %. The high peak hardness and good interracial bonding is achieved due to the lower wear rates in composites with higher amount of reinforcement particles. The variation of the wear rate as a function of load at room temperature is shown in the Fig. 15. The wear rate of the composites is increased as varying load of 10 N to 50 N is applied to the composites during the experiment. Wear rate is maximum due to the aluminium pin is showing the continuously increasing trend of wear with increasing normal load due to direct metal to metal contact. As a result large plastic deformation takes pace during dry sliding [29].

4.6.2 VARIATION OF SPECIFIC WEAR RATE AS A FUNCTION OF COMPOSITE (Wt. %) AND LOAD

The variation of the specific wear rate as a function of amount of reinforcement % with matrix metal and load is shown in Fig. 16 and Fig. 17. The figure shows that when a unit of normal load is applied to a particular unit which worn out the volume of material is knows as specific wear rate. The specific wear rate of the composite increases as the reinforcement particles increases in wt. % with aluminium matrix at room temperature. The specific wear rate at room temperature of composite and alloy is almost same. But it shows a foremost variation in the higher wt. % of reinforcement when compared with other wt. % of reinforcement at room temperature. It shows a slightly increases in specific wear rate when a load of 10 N to 50 N is applied gradually to the composite alloy. During the applied load of 50 N, there is a sudden increase in the specific wear rate at 8 % of reinforcement. It takes place possibly due to the loss of strength or softening of composite materials at various reinforcement wt. %.

4.6.3 VARIATION OF WEAR RESISTANCE AS A FUNCTION OF COMPOSITE (Wt. %) AND LOAD

The **Fig. 18** and **Fig. 19** show the wear resistance as a function of wt. % of reinforcement particle with matrix material and the load. It is the reciprocal of the wear rate of the alloy and the composite at various wt. % of reinforcement particles. The wear resistance at the room temperature is gradually increases along with the increase in wt. % of reinforcement particles. This improvement in inherent wear resistance of the composite is due to increased amount of reinforcement. The wt. % of Zrb_2 particles or reinforcement particles increase, the wear resistance also increased simultaneously **[30]**. But in case of applying load, the wear resistance of the composite posses a high value at applied of 10 N. but the wear resistance of composites gradually decreases when the load is applied from 20 N to 50 N.

4.6.4 VARIATION OF CO-EFFICIENT OF FRICTION AS A FUNCTION OF COMPOSITE (Wt. %) AND LOAD

The variation of co-efficient of friction as a function of wt. % of reinforcement particle with matrix material at room temperature is shown in Fig. 20. The values of the coefficient of friction of all loads (10 N to 50 N) are high at the matrix alloy with 0 % of reinforcement. As the wt. % of reinforcement particles increases, the coefficient of friction reduces at particular interval of wt. % of reinforcement. In this study, when sliding operation takes place. The particles are strongly bonded with matrix and the matrix material aluminium adjacent the particles will be wear away and basically all the contact will be afforded between the reinforcing particles and the steel counter face. The Fig. 21 shows that the movement of the coefficient of friction is same to that of wear rate. When the experiment is carried of out in dry sliding conditions with varying velocity speed, the coefficient of friction of composites is decreased as the applied load is increased from 10 N to 50 N simultaneously with increasing in sliding velocity.

4.7 OPTIMIZATION TECHNIQUE

In this study, the Matrix material Al 2618 and the three reinforcement particles such as Si_3N_4, AlN, and Zrb_2 in the percentage weight of 0,2,4,6,8 and around twenty five pieces with three different set of parameters has been considered in this method. The each matrix materials Al 2618 is mixed with reinforcement materials to form the group of five pieces. The experimental is conducted by the Taguchi L_{25} orthogonal array factors and with three sets of levels. The three factors are wt. % of composites, Load and velocity are subjected to be input parameters for the materials and the wear rate of the composites is calculated by means of arithmetical formula for all the twenty five pieces and the minimum wear rate is found to be 0.00030 mm^3/m which is obtained at the composites of 8 %, load of 10 N and the velocity at rate of 5 m/s. the output parameter wear rate is used for calculating the mean and S/N ratio. Table. 5 shows input and output parameters of In-situ process according to L_{25} orthogonal array.

4.7.1 SIGNAL-TO-NOISE RATIO

The significant characteristic is the wear rate of the composites for investigating the quality of composite alloys. The mean and Signal-to-Noise (S/N) ratio for the each factor has been calculated to assess the influence of factor on response. The condition smaller is better is considered for selecting the S/N ratio to make the majority of response. Table. 6 provide the response table for means, and Table. 7 provide the response table for S/N ratio. The MINITAB software was used for determining the influence of process parameters (factors) on the composition of the composite alloy. It is clear that a larger S/N ratio corresponds to better quality features. The mean effect and S/N ratio for wear rate were calculated by statistical software are shown in the Fig. 22 and Fig. 23 respectively, indicating that the wear rate was at its minimum, with parameter of composites of 8 %, load of 10 N and the velocity at rate of 5 m/s.

The wear rate of the composite alloy is minimum, with parameter of composites of 8 %, load of 10 N and the velocity at rate of 5 m/s. the optimal tribological behaviour is identified only in the condition smaller the better. The wear of the friction composite materials shows that the composition of the alloy posses low wear rate due to the presence of more weight percentage of reinforcement materials. The wear rate of the composite will be decreases when the composition of reinforcement increases in the matrix material. The material has lower wear rate would increase the life of the composite material and the higher co-efficient would present an enhanced performance.

4.7.2 ANOVA (ANALYSIS OF VARIANCE)

Analysis of variance (ANOVA) method is used to identify the process parameters that are statically significant which influence importance the wear rate of the composite material. The percentage of contribution for each process parameter is estimated by using the statically software MINITAB [31]. The Table. 8 show the obtained result of ANOVA**.** The calculated percentage illuminates the most important process parameter is load of about 79 % is followed by wt. % of composites of 14 % and velocity of 6 %. Fig. 24 represents the interaction plot of means for compressive strength and Fig. 25 reveals the respective percentage of contributions represented graphically and Table. 9 show the percentage of contribution for the each process parameter.

5. CONCLUSION

1. Matrix material(Al2618) and Reinforcements(Si_3N_4,ALN,ZrB_2) are mixed in various wt% (0,2,4,6,8) and uniform distribution has achieved by stir casting method.
2. Mechanical properties are increased with the increasing of wt% of reinforcements by decreasing of plastic deformation.
3. The grain size of the composite is decreased and posses value of 21.9 µm at 8 wt. % of particles which restricts the movement of solidification for matrix phase.
4. Abrasive wear was found in lower load conditions and in higher load conditions Adhesive wear was found in SEM analysis.
5. EDX experiment is carried out to identify the presence of particles in the Al2618 alloy. It proves the matrix element chemical composition.
6. Load is identified in most significant parameter of the composites. The minimum wear rate is calculated with composites of wt. 8%, load of 10 N and the velocity at rate of 5 m/s is to be 0.00030 mm^3/m.
7. The results from ANOVA shows that the most significant variables affecting the wear rate of the composites in terms of their individual percentage of contribution are load (79.00 %), wt. % of composites (14.00 %) and velocity (6 %).

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TABLE CAPTION

Table 1

Element	**Cu**	**Mg**	**Fe**	**Ni**	**Si**	**Ti**	**Al**
Wt. %	2.30	1.60	1.1	1.0	0.18	0.07	Bal

Table 2

FACTOR	**LEVELS**				
	1	**2**	**3**	**4**	**5**
COMPOSITES (Wt. %)	0	2	4	6	8
LOAD (N)	10	20	30	40	50
VELOCITY (m/s)	1	2	3	4	5

Table 3

EXPERIMENT NUMBER	INPUT PARAMETERS		
	COMPOSITES (Wt. %)	LOAD (N)	VELOCITY (m/s)
1	0	10	1
2	0	20	2
3	0	30	3
4	0	40	4
5	0	50	5
6	2	10	2
7	2	20	3
8	2	30	4
9	2	40	5
10	2	50	1
11	4	10	3
12	4	20	4
13	4	30	5
14	4	40	1
15	4	50	2
16	6	10	4
17	6	20	5
18	6	30	1
19	6	40	2
20	6	50	3
21	8	10	5
22	8	20	1
23	8	30	2
24	8	40	3
25	8	50	4

Table 4

S.No.	Weight percentage (%)	Grain Size of Matrix Phase (μm)
1	0	39.2
2	2	43.8
3	4	30.95
4	6	26.85
5	8	21.9

Table 5

EXPERIMENT NUMBER	INPUT PARAMETERS			OUTPUT PARAMETERS
	COMPOSITES (Wt. %)	LOAD (N)	VELOCITY (m/s)	WEAR RATE (mm3/m)
1	0	10	1	0.00036
2	0	20	2	0.0016
3	0	30	3	0.0027
4	0	40	4	0.0026
5	0	50	5	0.0057
6	2	10	2	0.00043
7	2	20	3	0.0016
8	2	30	4	0.0024
9	2	40	5	0.0022
10	2	50	1	0.0051
11	4	10	3	0.00045
12	4	20	4	0.0014
13	4	30	5	0.0014
14	4	40	1	0.0017
15	4	50	2	0.0053
16	6	10	4	0.00033
17	6	20	5	0.00048
18	6	30	1	0.0011
19	6	40	2	0.0011
20	6	50	3	0.0035
21	8	10	5	0.00030
22	8	20	1	0.00043
23	8	30	2	0.00055
24	8	40	3	0.00079
25	8	50	4	0.0026

Table 6

LEVEL	COMPOSITES (Wt. %)	LOAD (N)	VELOCITY (m/s)
1	0.002432	0.000390	0.001902
2	0.002306	0.001026	0.001816
3	0.002046	0.001470	0.001604
4	0.001282	0.001658	0.001666
5	0.000938	0.004460	0.002016
DELTA	0.001494	0.004070	0.000412
RANK	2	1	3

Table 7

LEVEL	COMPOSITES (Wt. %)	LOAD (N)	VELOCITY (m/s)
1	54.77	68.30	58.34
2	55.35	60.94	58.47
3	56.55	57.56	57.90
4	60.55	56.24	57.38
5	63.27	47.44	58.39
DELTA	8.50	20.86	1.10
RANK	2	1	3

Table 8

SOURCE	DF	Adj.SS	Adj.MS	F	P	PERCENTAGE OF CONTRIBUTION
COMPOSITES (Wt. %)	4	0.000009	0.000002	7.07	0.004	14.00
LOAD (N)	4	0.000049	0.000012	40.09	0.000	79.00
VELOCITY(m/s)	4	0.000004	0.000000	0.47	0.760	6.00
Error	12	0.000001	0.000000			1.00
Total	24	0.000062				100

Adj. SS, adjusted sum of squares; Adj. MS, adjusted mean squares; F. statistical test; P. statistical value

Table 9

FACTORS	PERCENTAGE OF CONTRIBUTION (%)
COMPOSITES (Wt. %)	14.00
LOAD (N)	79.00
VELOCITY (m/s)	6.00

FIGURE CAPTION

Fig. 1 work piece sample with various wt. % of reinforcement
Fig. 2 Schematic diagram of pin on disc apparatus
Fig. 3 Vickers hardness testing machine
Fig. 4 Electron microscope with loaded specimen
Fig. 5 Hardness value for the composite alloy with amount of reinforcement (wt. %)
Fig. 6 Tensile strength value for the composite alloy with amount of reinforcement (wt. %)
Fig. 7 Compressive strength value for the composite alloy with amount of reinforcement (wt. %)
Fig. 8 EDX spectrum of Al 2618 alloy
Fig. 9 XRD results for the prepared composites
Fig. 10 Micrographs of the in-situ composite in varied wt. (0,2,4,6,8)%
Fig. 11 SEM micrographs of specimens of Al 2618 matrix with wt. % of reinforcement particles (0,2,4,6,8)
Fig. 12 SEM micrographs of the worn surfaces of Al 2618 – (Si_3N_4, AlN, and Zrb_2) with wt. % of 0, 2, 4, 6, 8
Fig. 13 variation of mass loss as a function of load (N)
Fig. 14 variation of wear rate with amount of reinforcement (%)
Fig. 15 variation of wear rate as a function of load (N)
Fig. 16 variation of specific wear rate with amount of reinforcement (%)
Fig. 17 variation of specific wear rate as a function of load (N)
Fig. 18 variation of wear resistance with amount of reinforcement (%)
Fig. 19 variation of wear resistance as a function of load (N)
Fig. 20 variation of co-efficient of friction with amount of reinforcement (%)
Fig. 21 variation of co-efficient of friction as a function of load (N)
Fig. 22 Main effect plots for means
Fig. 23 Main effect plot for S/N ratio
Fig. 24 Interaction plot – data means for wear rate
Fig. 25 percentage contribution of process parameters

Figure 1

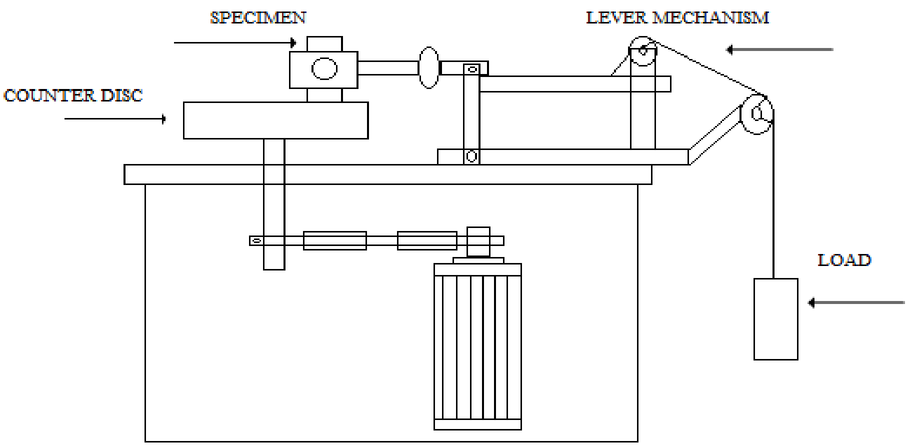


Figure 2

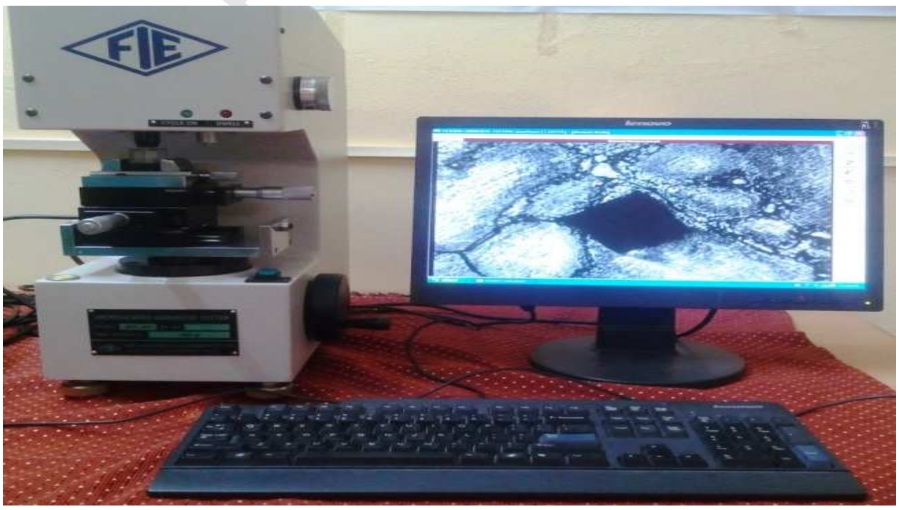


Figure 3

Figure 4

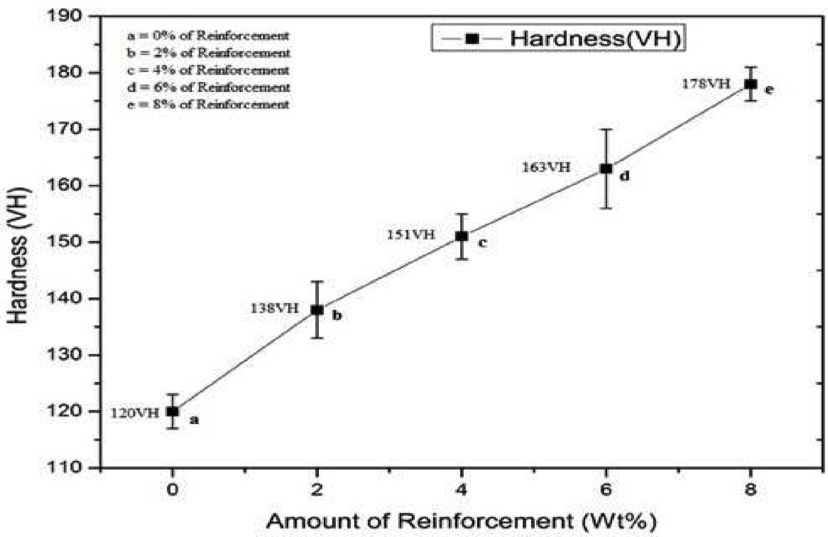


Figure 5

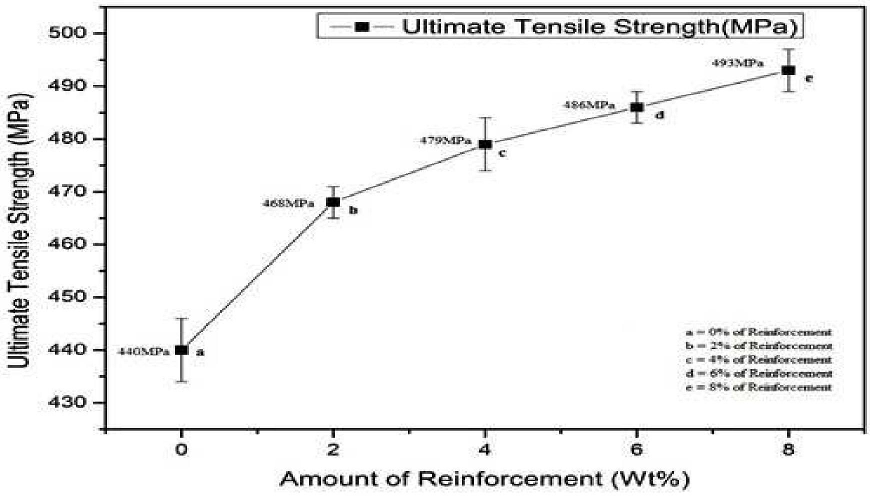


Figure 6

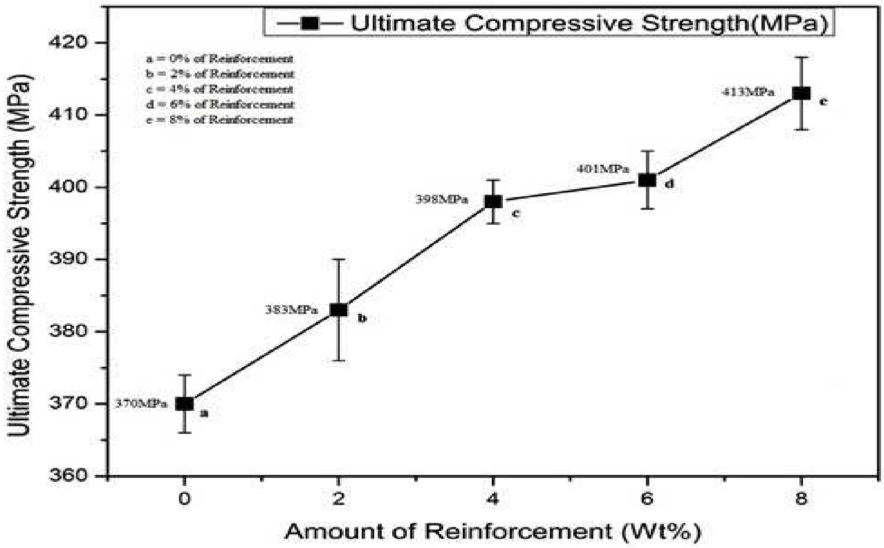


Figure 7

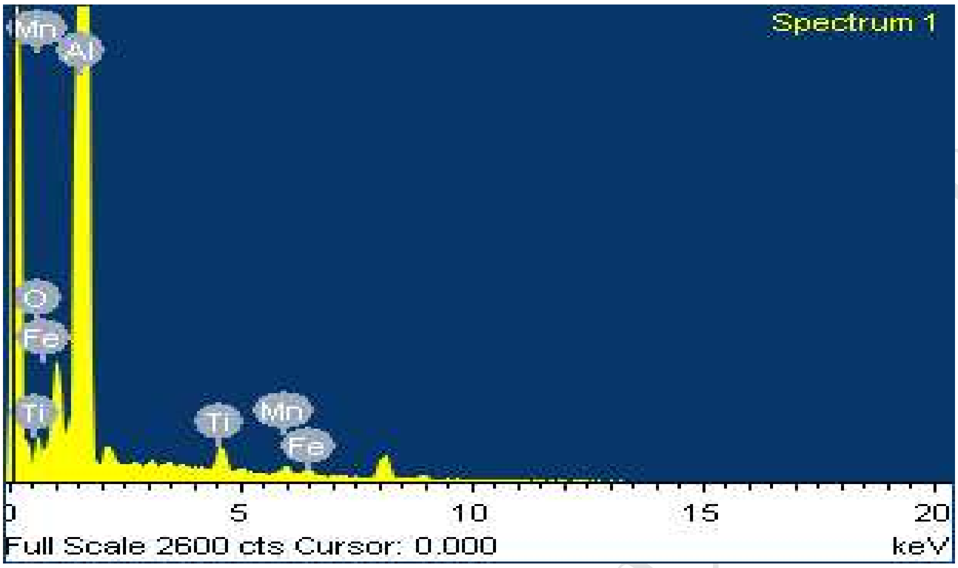


Figure 8

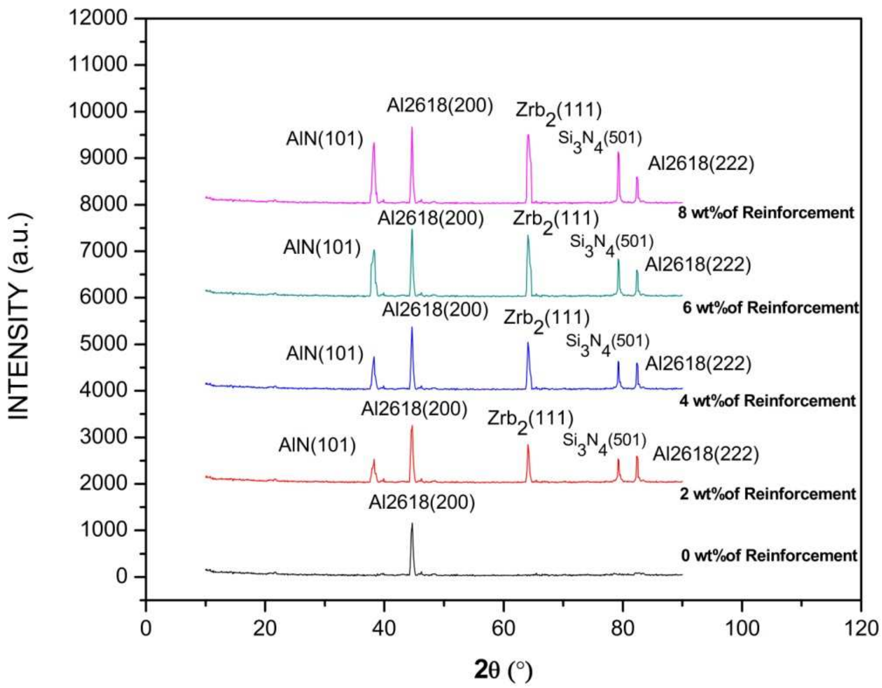


Figure 9

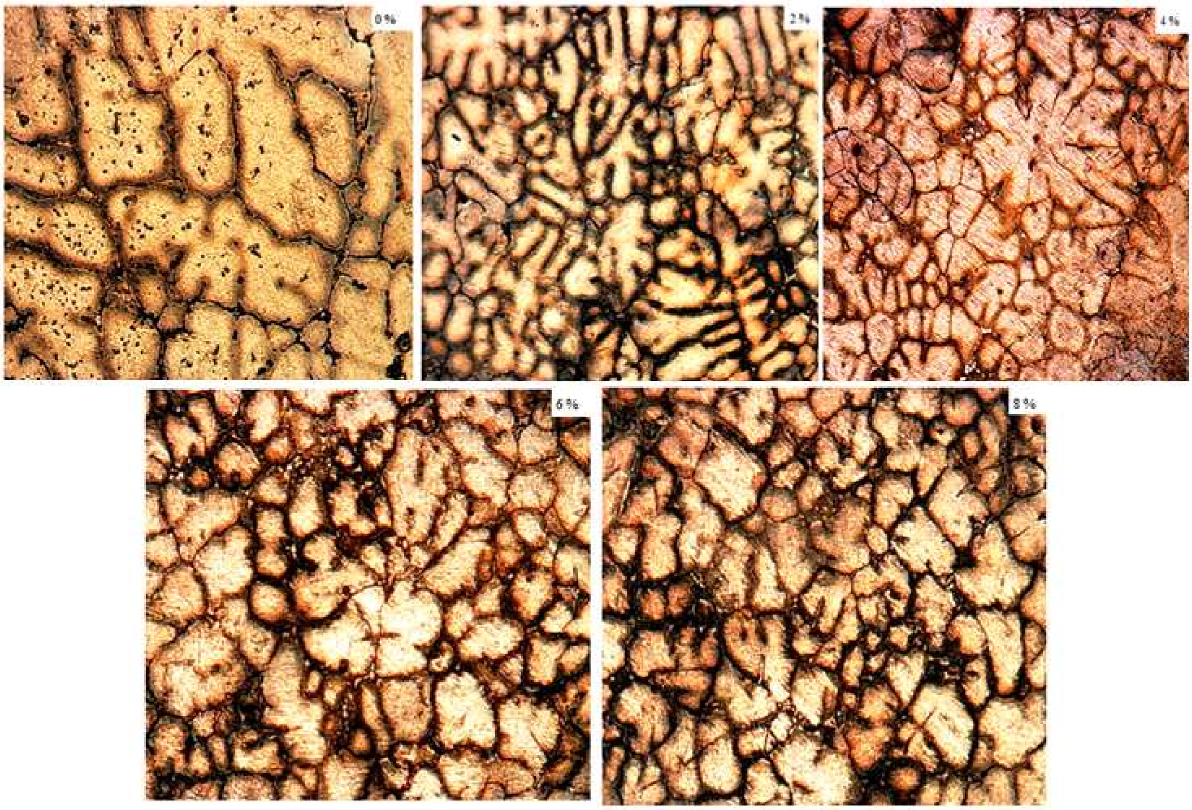
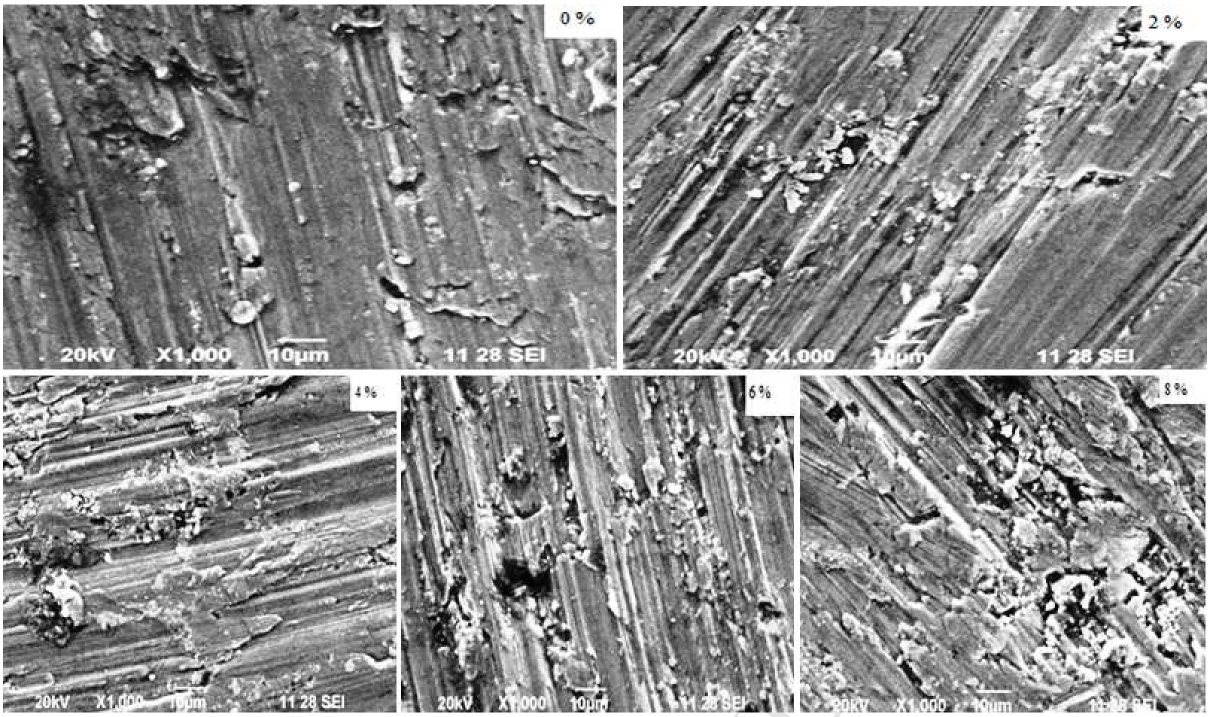


Figure 10



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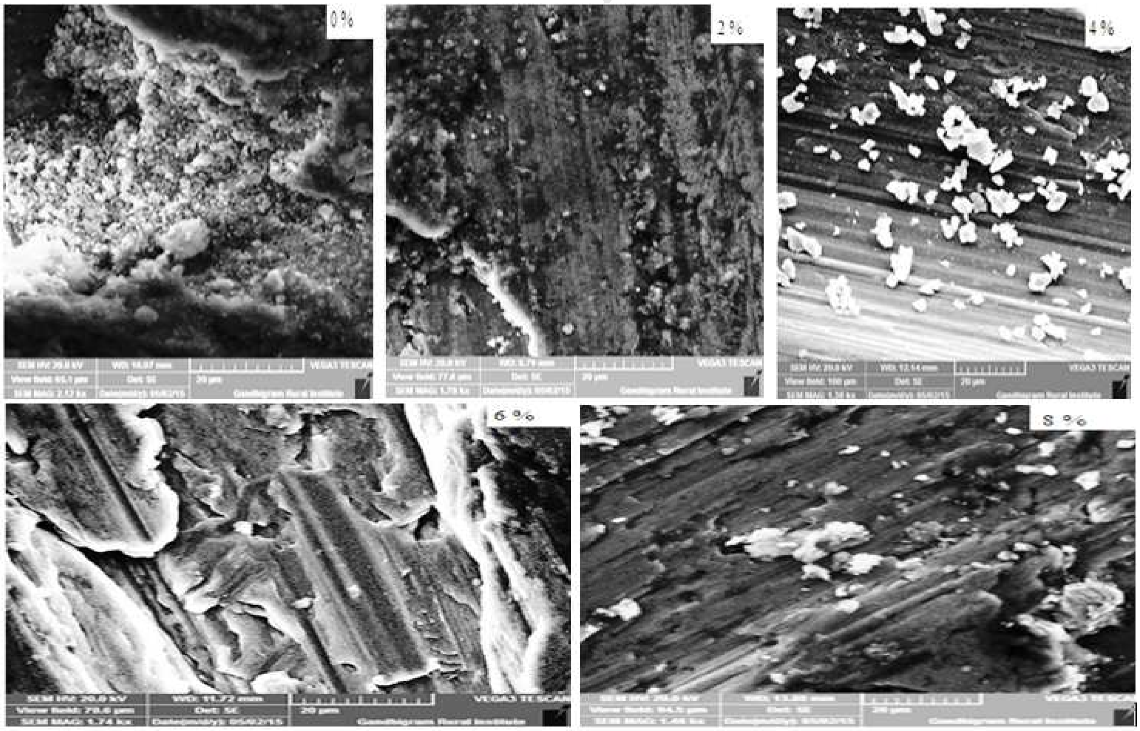

Figure 12

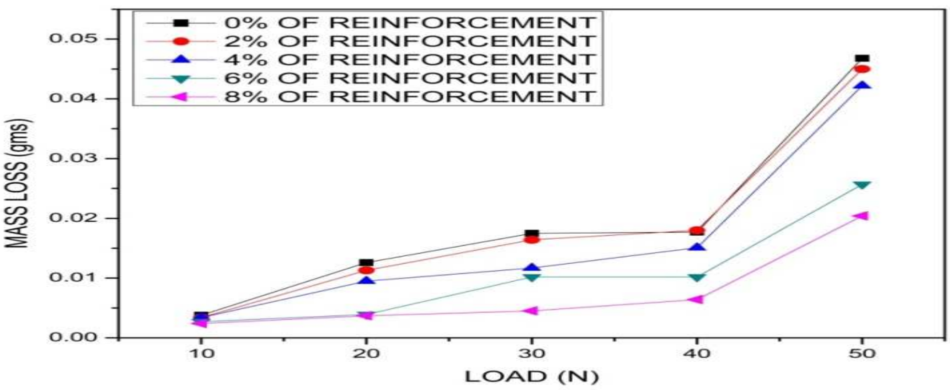

Figure 13

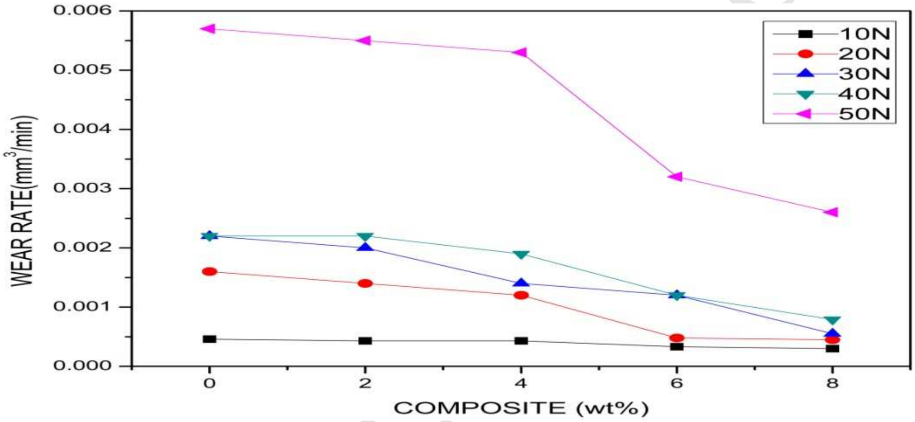

Figure 14

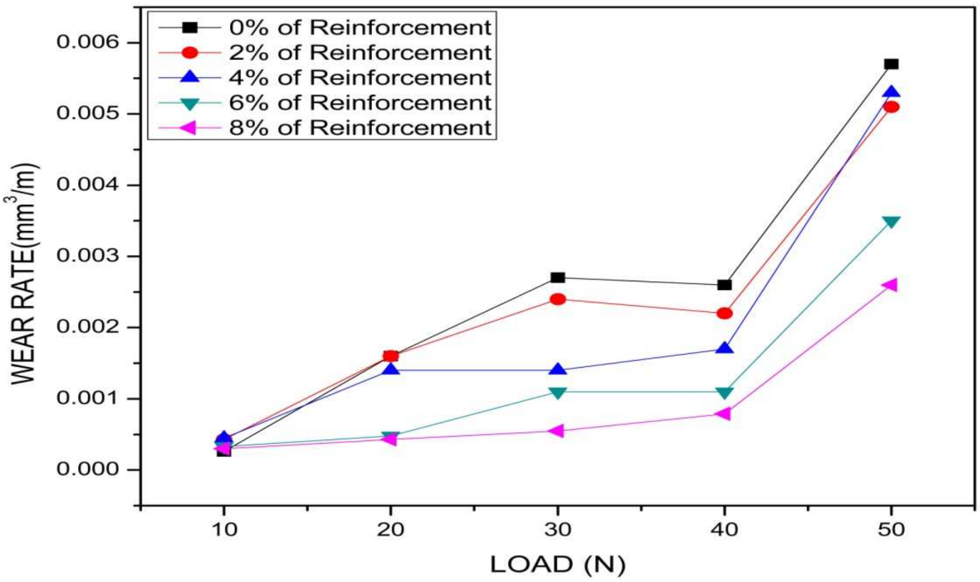

Figure 15

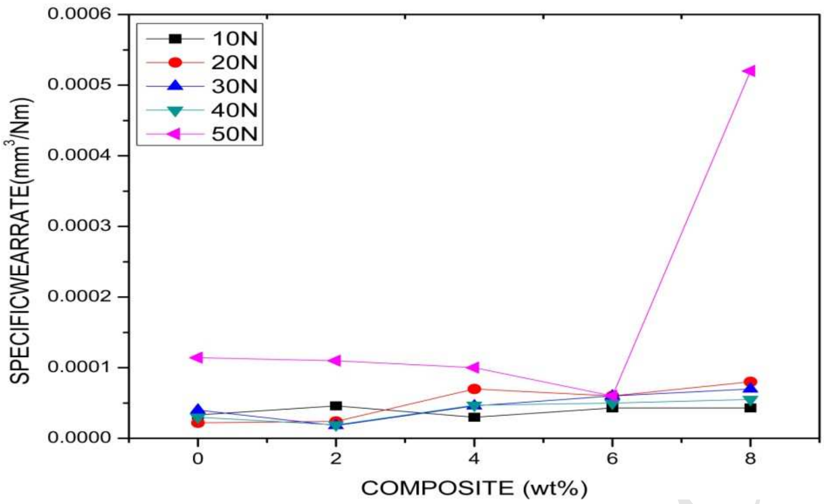

Figure 16

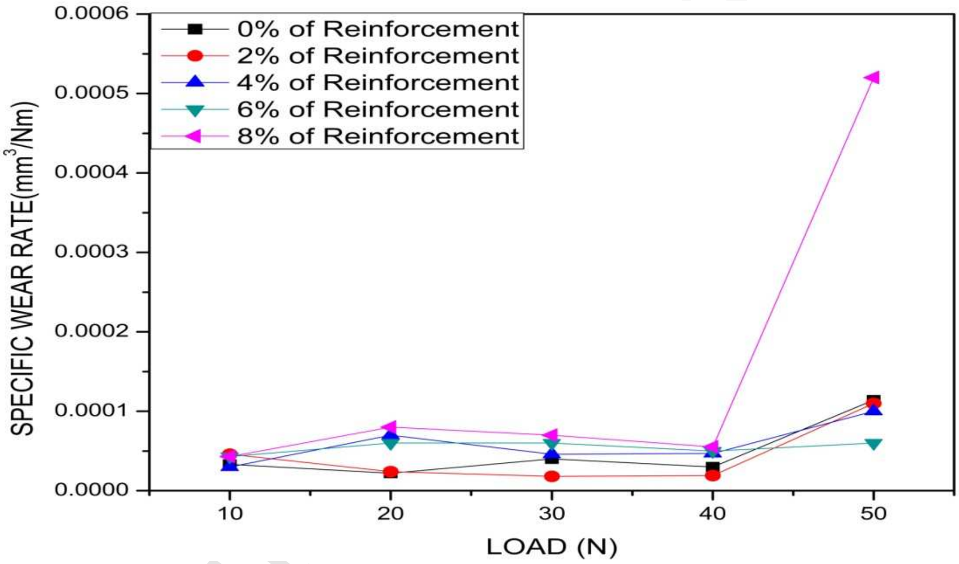

Figure 17

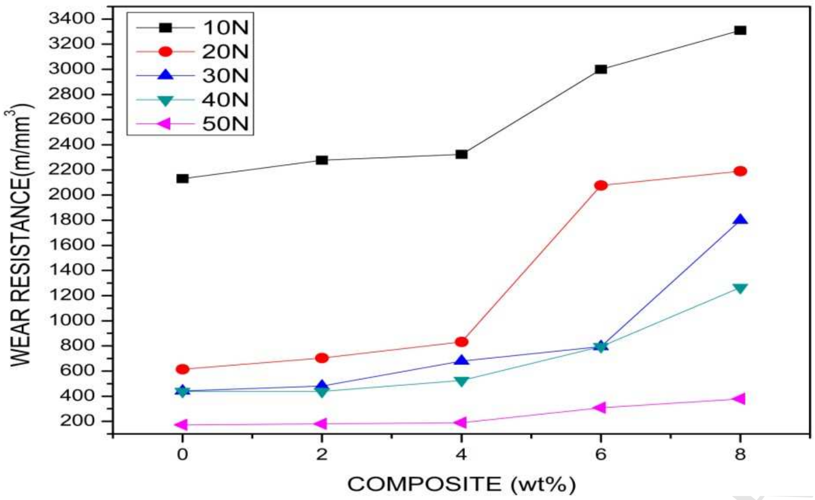

Figure 18

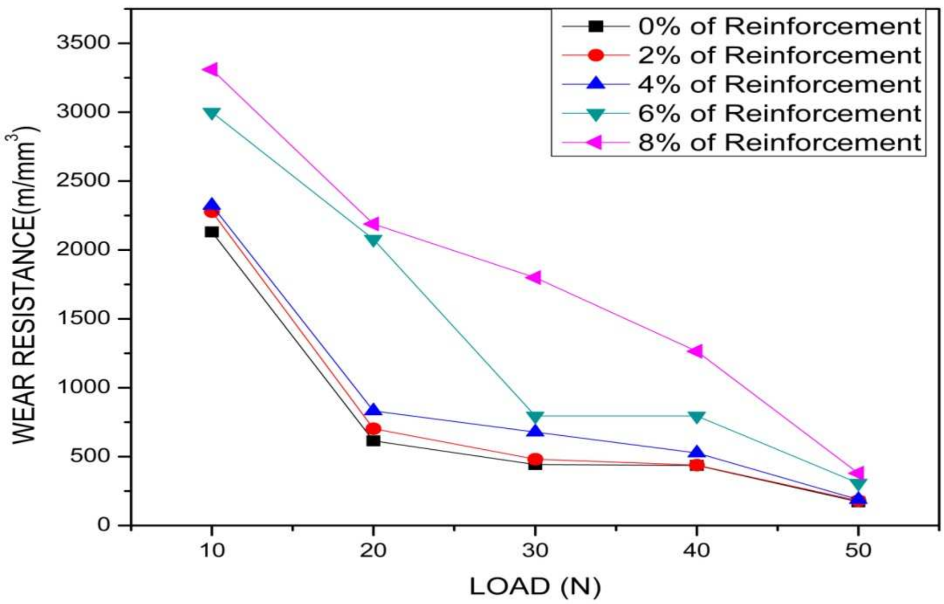

Figure 19

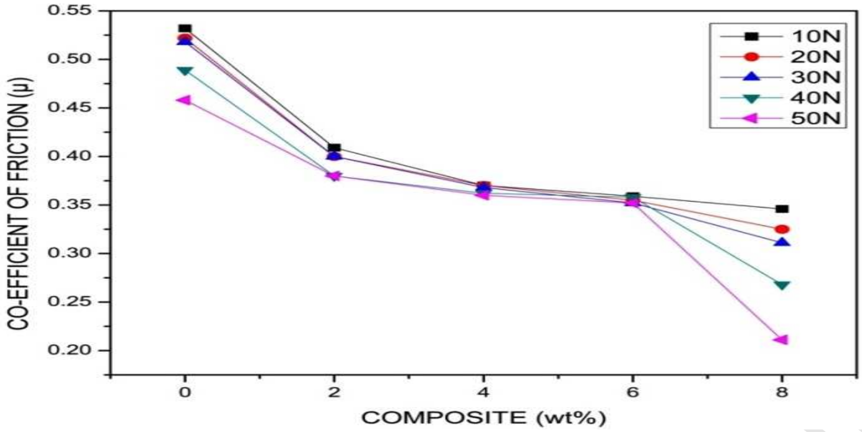

Figure 20

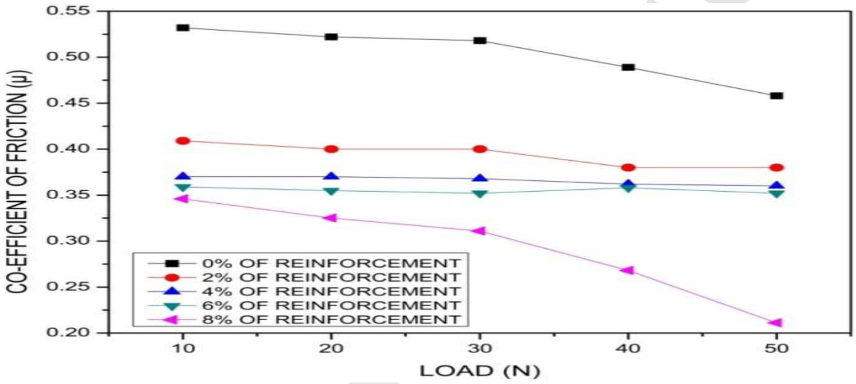

Figure 21

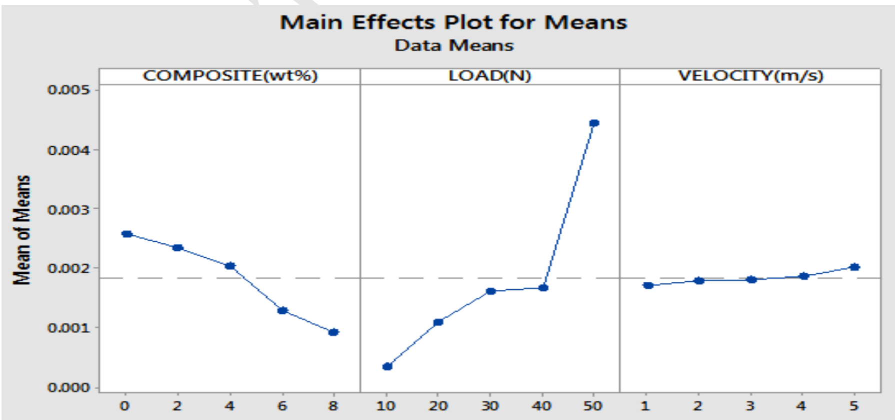

Figure 22

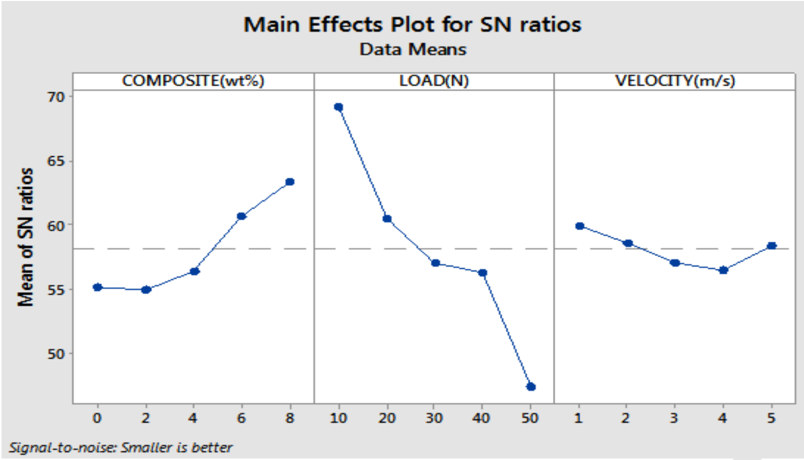

Figure 23

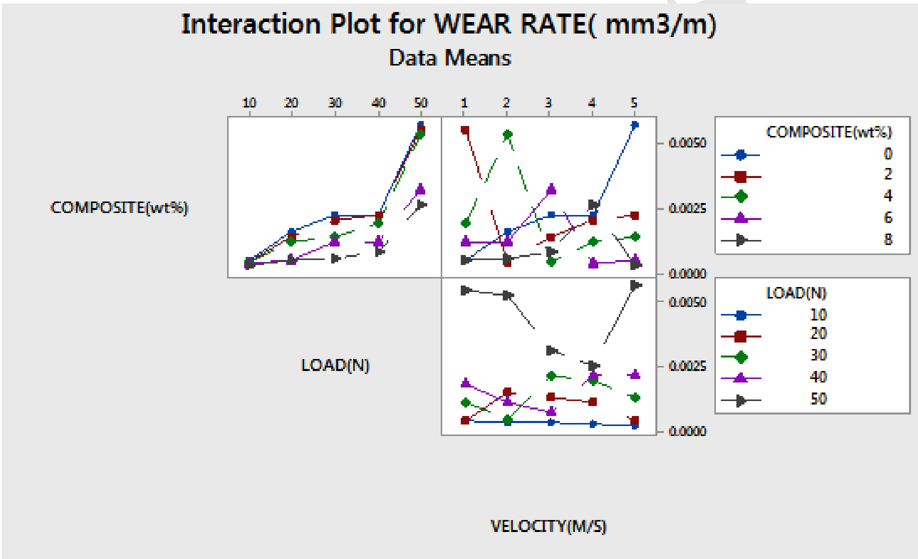

Figure 24

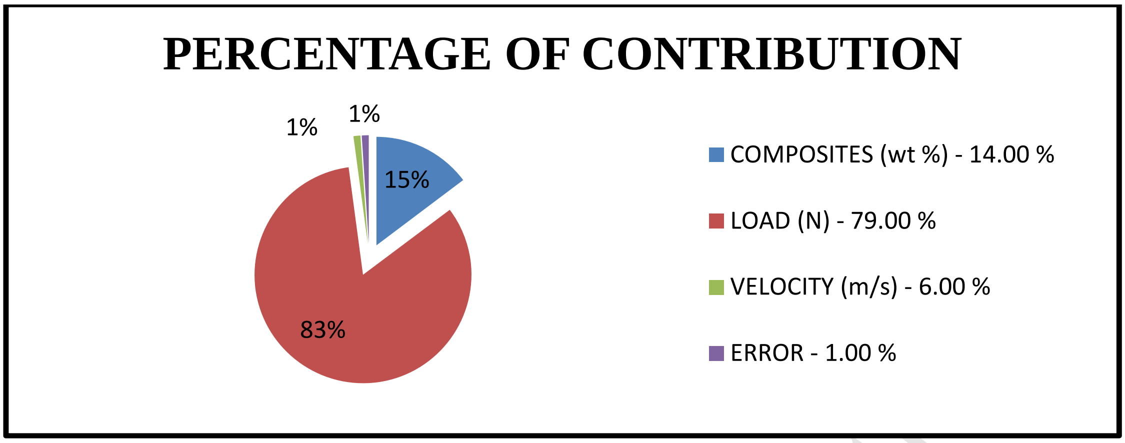
PERCENTAGE OF CONTRIBUTION
1%
1%
15%
83%
COMPOSITES (wt %) - 14.00 %
LOAD (N) - 79.00 %
VELOCITY (m/s) - 6.00 %
ERROR - 1.00 %

Figure 25

RESEARCH HIGHLIGHTS

- The mechanical properties of the composite are improved with addition of reinforcement.
- In microstructure the uniformly distributed reinforcement particles are improved the bond strength.
- X-ray diffraction (XRD) analysis confirms that presence of aluminum and its reinforcements.
- The most significant process parameter affecting the wear rate of composite is identified.