iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: VIII Month of publication: August 2021

DOI: https://doi.org/10.22214/ijraset.2021.37802

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com

Studies on Tribological and Statistical Modeling for Al/ZrO_2 MMC's

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Abstract: In recent era early growth and remarkable development with regards of composite materials has become a need of designing area on account of consideration to the drawbacks over conventional materials in improving material properties which includes viz, stiffness, density, toughness, and strength.This research focuses on utilizing the stir casting method of forming better metal matrix composite by using ZrO_2 as reinforcing material thereby developing a composite material.Current study investigates Al357 alloy is fortified with different percentage of ZrO_2 (3%, 5% and 7%) is concocted by the stir casting and studied for a microstructure, mechanical and the statistical modelling of wear analysis. Wear tracks of the as-cast alloy and its composites were examined using SEM. From the results it was concluded that compared to as-cast alloy A357/ 7 % ZrO_2 displayed better properties compared followed by 5% and 3% composites.
Keywords: MMC'S; ZrO_2; Aluminium 357 alloy; Hardness test; Statistical Analysis.

I. INTRODUCTION

In recent era early growth and remarkable development with regards of composite materials has become a need of designing area on account of consideration to the drawbacks over conventional materials in improving material properties which includes viz, stiffness, density, toughness, and strength, damping properties etc.[1-3].Likewise, some of the material portions which are commonly used have less measures of reinforcing materials, thus in any case they are not being considered as part of composite series since they attain the similar properties as that of initial base material matrix. Composites are known for their low density with high strength, stiffness, thermal stability, and improved fatigue properties and wear resistance. Many researchers have fortified SiC, Al_2O_3, Flyash, CNTs, to develop composites [4-7]. Kumar et al.[8]studied hardness and density variation of Al-MMC's bolstered with SiC and B_4C fabricated by PM route. Results reveals hardness value 32.27 VHN at 90%Al 3%Si 7% B_4C is greater than pure Al and also the tap density of B4C is more than SiC and Al. Purhoit et al.[9]worked on Fabrication of Al-MMC's bolstered with SiC fabricated by PM route and tested its mechanical assets like hardness, porosity, stretchy and compressive potency, resurface roughness as well as micro structural analysis. Compared to Al alloy, Al MMC,s showed improved properties. In the current examination Al357 compound was picked as grid material as a result of its more extensive aviation and automotive applications in ventures, similarly as the recreational things. At present little details is obtainable in the ZrO_2strengthened Al357 amalgam composites. As such, the current assessment attempts to incorporate the ZrO_2 reinforced Al357 combination composites by blend tossing methodology. Later these composites will be depicted similar to their Optical Microscope, SEM considers, hardness and statistical analysis of wear.

II. EXPERIMENTAL TECHNIQUE

In the current study, the Al357-ZrO_2 reinforced Al-MMC's is produced in the stirring mold method. While the fabrication of the Al357/ZrO_2 composite. ZrO_2 of particle size of 25 to 50 µm was selected after conducting sieve analysis for the present investigation. Three different composites of different reinforcement percentage (3%, 5% and7%) weight percent were fabricated by the stirring process. The study's goal is to investigate the impact of varying the percentage composition of A357/Zirconium Oxide (ZrO_2) composite on the mechanical attributes of MMCs and correlate the outcomes with As-cast and ZrO_2 composites.

S/No	Alloy/Composite	Designation
1	As-Cast (Al357 alloy)	A357
2	Al357 alloy + 3% Zirconium Oxide	A357-3ZO
3	Al357 alloy + 5% Zirconium Oxide	A357-5ZO
4	Al357 alloy + 7% Zirconium Oxide	A357-7ZO

Table 1.1: Designation of ZrO_2 Reinforced Alloy

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III. TESTING DETAILS

A. Microstructure Study

The microstructure of composites is taken from the OM We have used sandpapers of grid size 220µm, 400µm, 600µm, 800µm and 1000µm and grade 1.0, 2.0, 3.0, 4.0 & 5.0 are respectively used to polish to get mirror surface for microstructure analysis.

B. Wear Test

The Dry sliding wear tests were coordinated by ASTM-G99 norms. The wear rate relied upon the typical estimation of 3 tests. Statistical analysis was used to optimize wear results. A schematic flowchart of the tests conducted in the above studies have been represented in Figure 1.

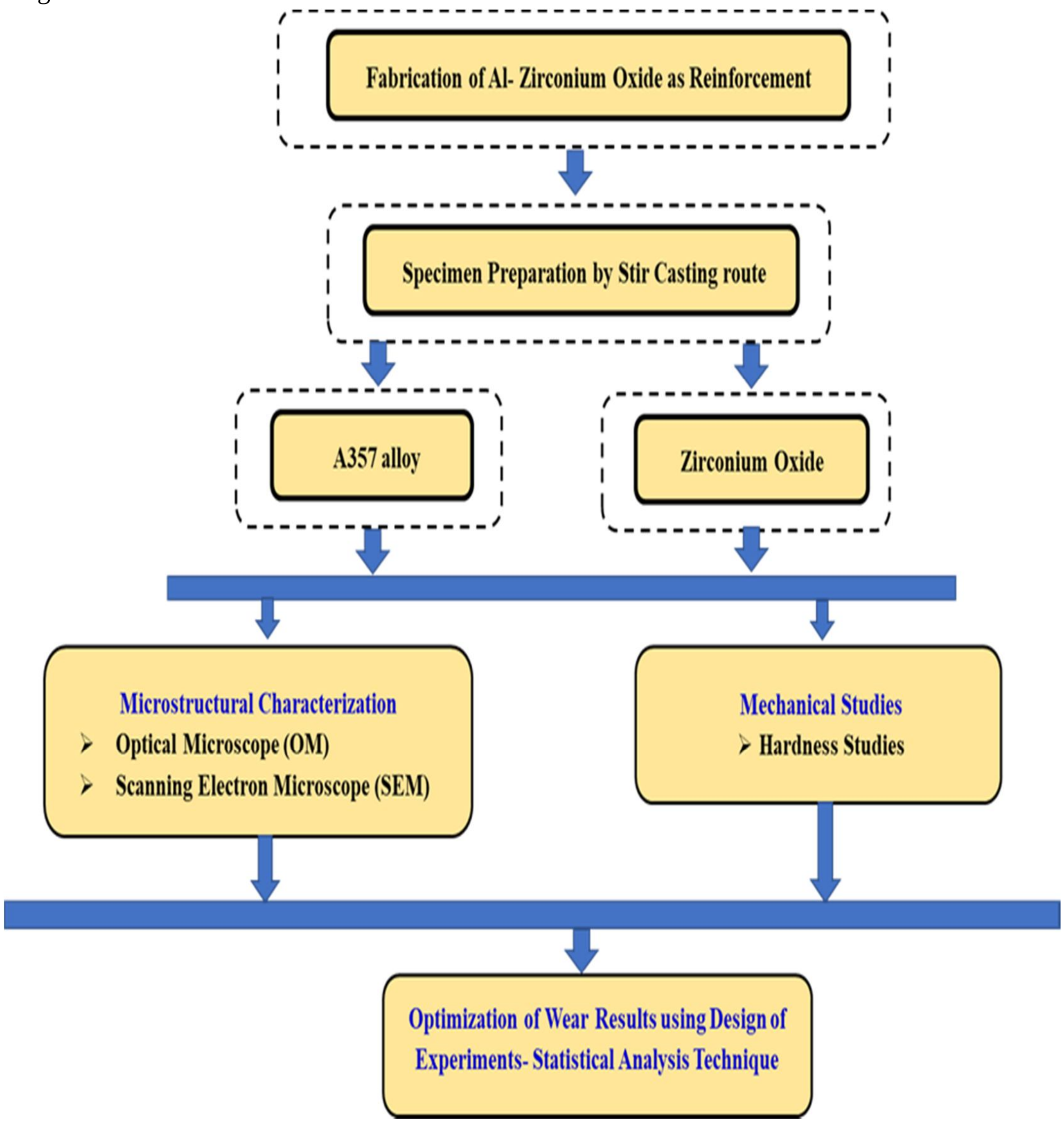

Figure 1 :Flow Chart of Experimental Work

IV. RESULTS AND DISCUSSIONS

A. Microstructural Analysis

The optical micrographs of matrices alloy Al357 before heat treatment are shown in Figure 2 (a). The optical micrographs of the matrix alloy Al7005 and its composites system are shown in Figures 2(b), 2(c), and 2(d). In all of the cast composite systems evaluated the microstructure evidently illustrates a pretty consistent allocation of reaffirmation (Zirconium Oxide (ZrO_2)) with negligible porosity in the matrix alloy. Fine precipitates in a matrix of dendrimer Aluminium solid solution form the microstructure. There is no stratification or porosity in the section [10-11].Similar results were observed by Parthasarathy and Sajjan [12-13].

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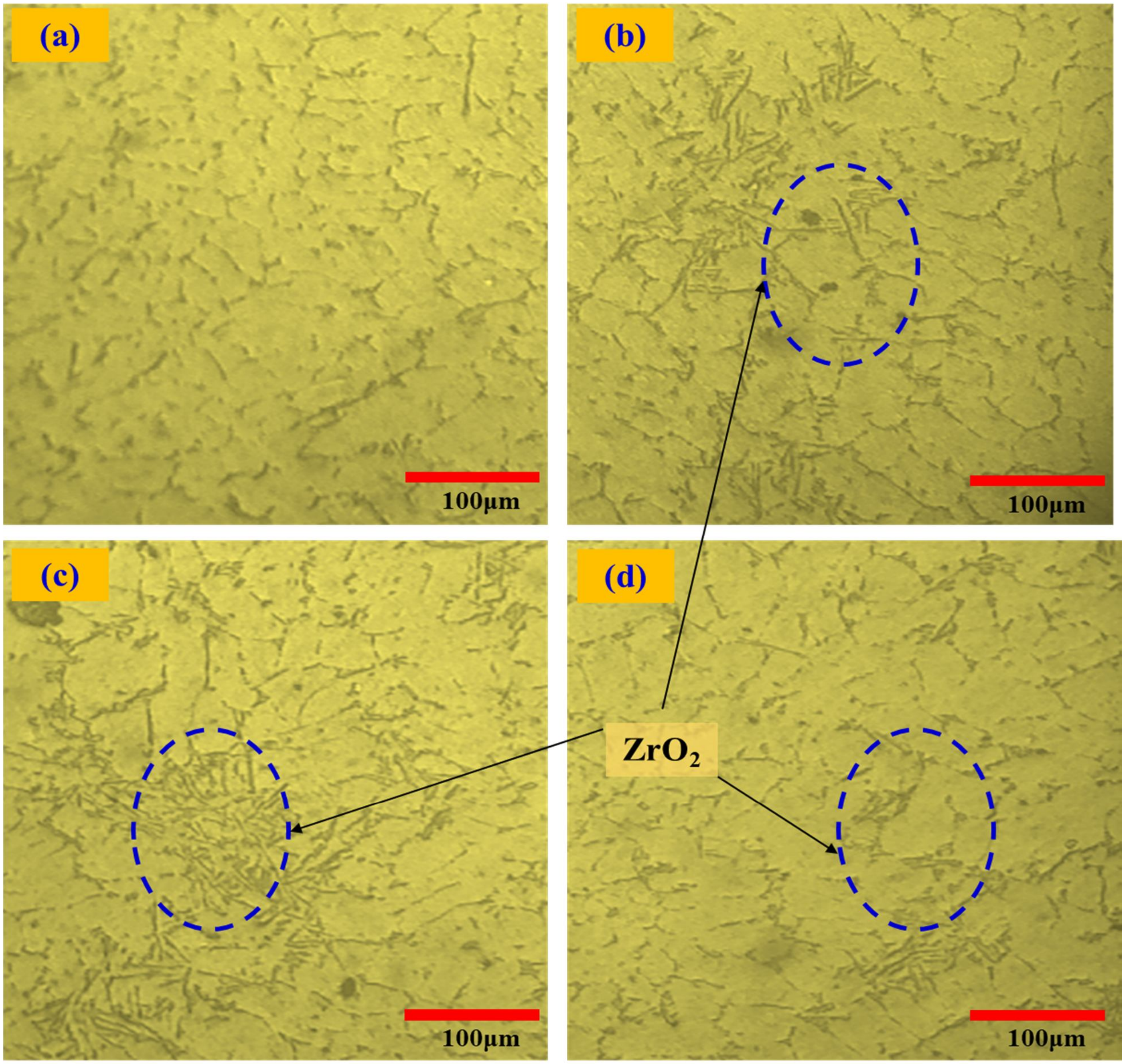

Figure 2: Figure shows optical micrographs of A357 alloy and its composites. Where (a) A357 alloy,(b) A357 alloy + 3 % Zirconium Oxide (3ZO) (c)A357 alloy + 5 % Zirconium Oxide (5ZO) (d)A357 alloy + 7 % Zirconium Oxide (7ZO).

B. Wear Test results

The goal of the exploratory strategy is to outline the significant aspects and combos of factors affecting the wear processes to achieve the lowest wear rate and COF. The studies were made on the basis of an OA, with the goal of determining the effect of sliding speed applied load and sliding distance. Such design criteria are unique and inherent attributes of the phase that impact and evaluate the composite effectiveness Taguchi implies evaluating the S/N ratio abstractly, which entails graphing the effects and visibly defining the major factors[18]. The outcomes for various parameter pairings were acquired by starting the study according to the OA and are shown in Table 1 and Table 2. The observed data were calculated using the software MINITAB 15, which is created especially for DOE apps.

Level	Load (N)	Sliding Speed (rpm)	Time (min)
1	10	200	5
2	20	300	10
3	30	400	15

Table 1: Method factors and levels of Al357 alloy and it’s composites.

S/No	Load (N)	Sliding speed (rpm)	Time
1	10	200	5 Min
2	10	300	10 Min
3	10	400	15 Min
4	20	200	5 Min
5	20	300	10 Min
6	20	400	15 Min
7	30	200	5 Min
8	30	300	10 Min
9	30	400	15 Min

Table 2: Method factors and levels of Al357 alloy and it's composites.

C. Case 1: A357 alloy

From the Figure 4 its observed that the value of Load (N) is less than, 0.5 (0.019) as observed which is significant, followed by Sliding Speed (mm/s) (0.559)which is greater than 0.5 which is not significant.From the Figure 5 its observed that Root mean square value is 63.8% which is approximately 58.6 % of the predicted values compared to that of Experimental values and the Predicted values are passing thru 45 degree line.

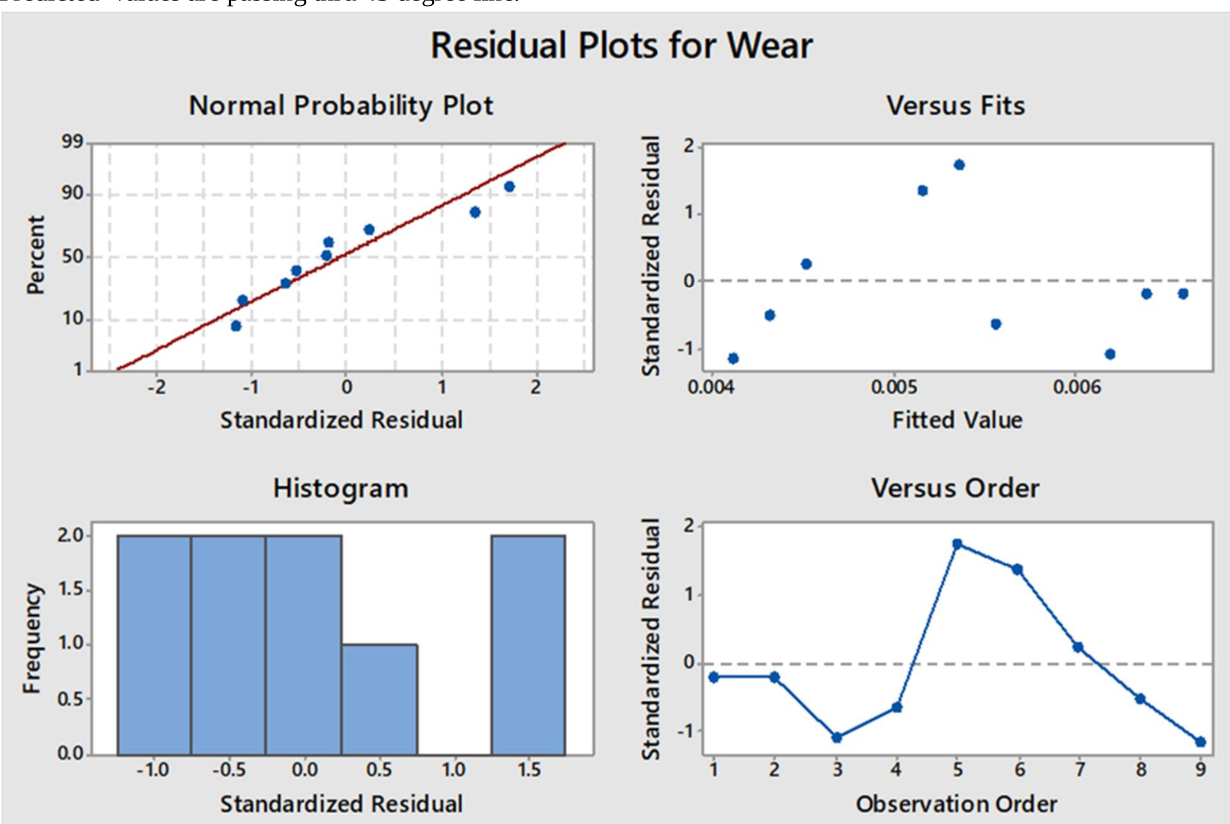

Figure 4: Residual Plots for Wear (mm^3/min) V/s Load (N), Sliding speed (mm/s) of A357 alloy.

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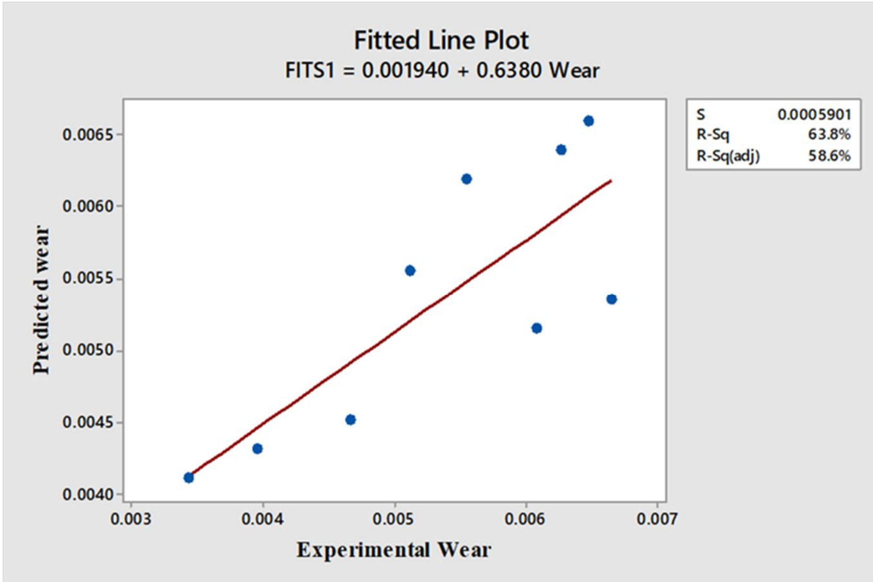

Figure 5: Fitted Line Plot for Wear (mm^3/min) V/s Load (N), Sliding speed (mm/s) of A357 alloy.

D. Wear surface Morphology results of Wear rate (mm^3/min) V/s Load (N), Sliding speed (mm/s) for A357 alloy.

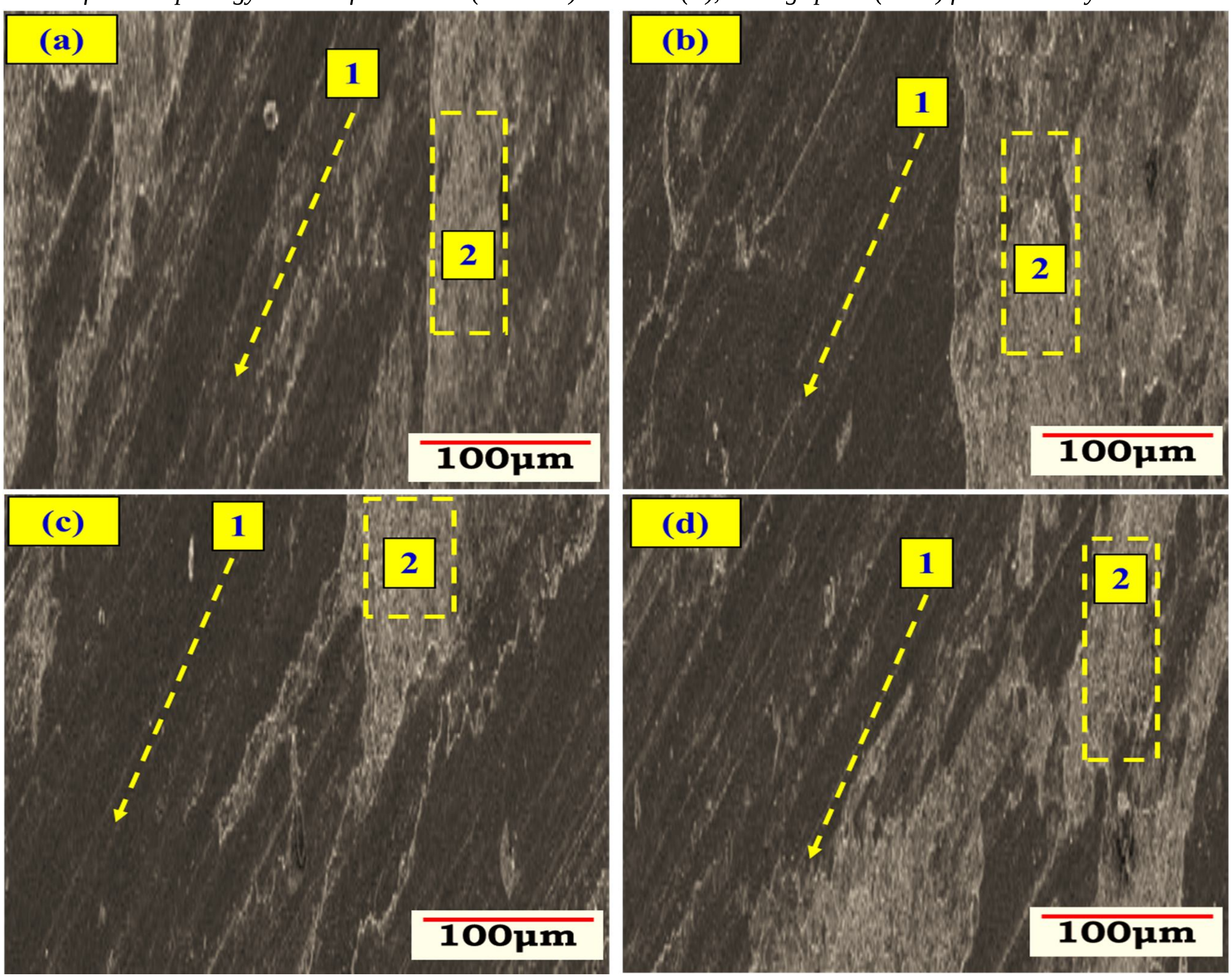

Figure 6: Wear surface morphology results of A357 alloy.

From the Figure 6 we can observe the wear surface morphology of A357 alloy at a low and high load of 10N and 30 N. Figure 6(a) depicts the wear surface morphology of A357 alloy at a low load of 10 N, 200 rpm and 5 minutes. Figure 6(b) depicts the wear surface morphology of A357 alloy at a low load of 10 N, 400 rpm and 15 minutes. 6(c) depicts the wear surface morphology of A357 alloy at a low load of 30 N, 200 rpm and 5 minutes. Figure 6(d) depicts the wear surface morphology of A357 alloy at a low load of 30 N, 400 rpm and 15 minutes. Figure 6(a) and (c) reveals the formation of profound permeant ridges and oxide stack fracture, that might have led to the increase in wear loss. The worn surfaces in Figure 6(b) and (d) depict coarser ridges and subtle plastic deformation at the groove edges because of high load. From the Figures 6(a), (b), (c) and (d) numbering 1 represents sliding direction and 1 represents abrasive and coarse ridges. Similar observations were made by several researchers [19-20].

E. 4.3.3 Case 2: A357 alloy + 7% Zirconium Oxide

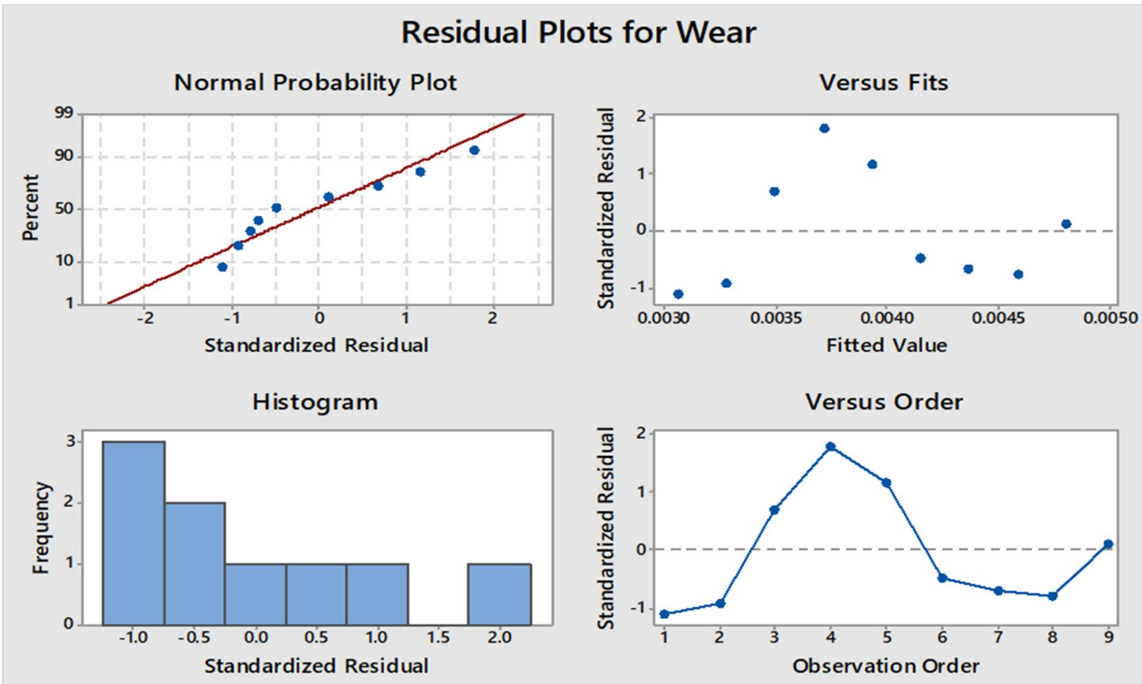

Figure 7: Residual Plots for Wear (mm^3/min) V/s Load (N), Sliding speed (mm/s) of A357 alloy + 7% Zirconium Oxide.

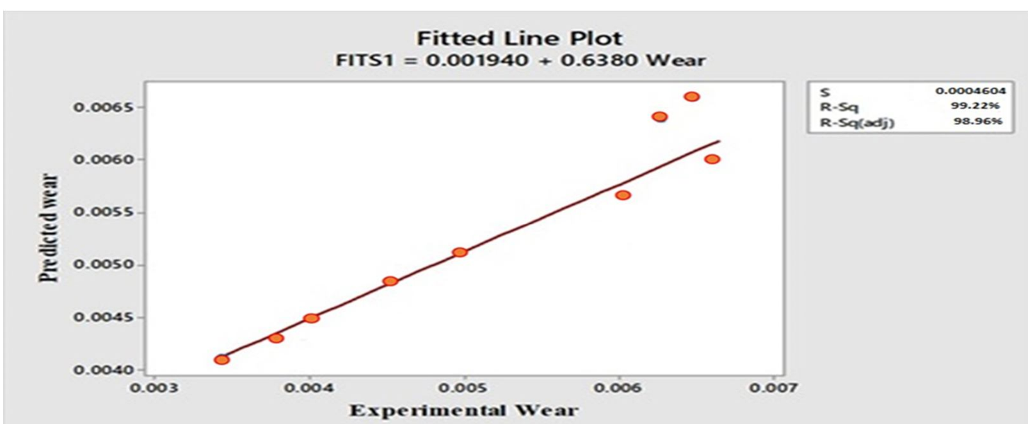

Figure 8: Fitted Line Plot for Wear (mm^3/min) V/s Load (N), Sliding speed (mm/s) of A357 alloy + 7% Zirconium Oxide.

From the Figure 7 its observed that the value of Load (N) is less than, 0.5 (0.009) which is significant, followed by Sliding Speed (mm/s) (0.421)which is greater than 0.5 which is not significant.From the Figure 8 its observed that Root mean square value is 99.22 % which is approximately 98.96 % of the predicted values compared to that of Experimental values and the Predicted values are passing thru 45 degree line.

F. Wear surface morphology results of Wear rate (mm^3/min) V/s Load (N), Sliding speed (mm/s) for A357 alloy + 7% Zirconium Oxide.

From the Figure 9 we can observe the wear surface morphology of A357 alloy + 7% Zirconium Oxideat a low and high load of 10N and 30 N. Figure 9(a) depicts the wear surface morphology of A357 alloy + 7% Zirconium Oxide at a low load of 10 N, 200 rpm and 5 minutes. Figure 9(b) depicts the wear surface morphology of A357 alloy + 7% Zirconium Oxide at a low load of 10 N, 400 rpm and 15 minutes. 9(c) depicts the wear surface morphology of A357 alloy + 7% Zirconium Oxide at a low load of 30 N, 200 rpm and 5 minutes. Figure 9(d) depicts the wear surface morphology of A357 alloy+ 7% Zirconium Oxide at a low load of 30 N, 400 rpm and 15 minutes. Figure 9(a) and (c) reveals the formation of profound permeant ridges and oxide stack fracture, that might have led to the increase in wear loss. The worn surfaces in Figure 9 (b) and (d) depict coarser ridges and subtle plastic deformation at the groove edges because of high load. From the Figures 9 (a), (b), (c) and (d) numbering 1 represents sliding direction and 1 represents abrasive and coarse ridges. Similar observations were made by several researchers [21-22].

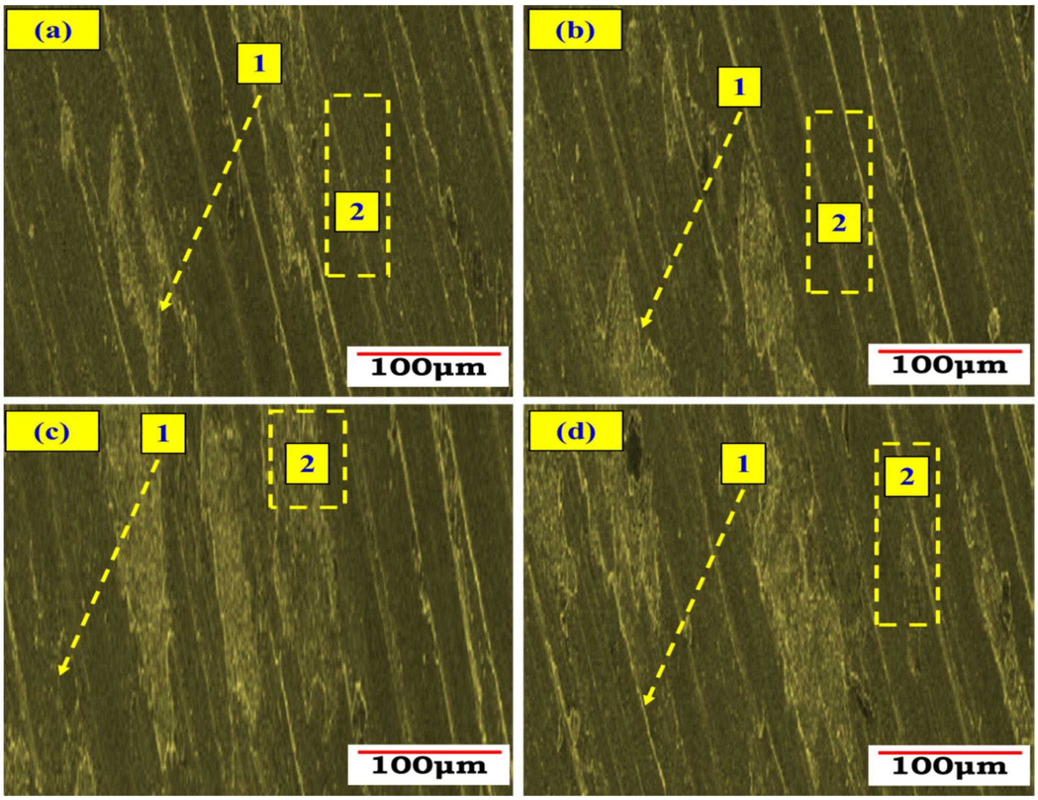

Figure 9: Wear surface morphology results of A357 alloy + 7% Zirconium Oxide.

V. CONCLUSION

The following results were obtained from tests to comprehend the mechanical behaviour of ZrO_2 reinforced A357 composites with different reinforcement weight fractions:

1) The Optical Micrographs of polished specimens, the following was observed:
a) The spreading of Zirconium Oxide (ZrO_2) is found to be even in A357 alloy matrix.
b) The Zirconium Oxide (ZrO_2) Particles acted as virtuous moistening with the A357matrix which added to the enhancements of the mechanical and wear properties.
2) Wear rate of the A357alloy at 10N is less than that of A357alloy at 30N. The worn surfaces is deeper for A357alloy at 30N compared to that of A357alloy at 10N. Coarser ridges and subtle plastic deformation at the groove edges because of high load of 30N.
3) Wear rate of the A357alloy + 7% Zirconium Oxideat 10N is less than that of A357alloy + 7% Zirconium Oxideat 30N. The worn surfaces is deeper for A357alloy + 7% Zirconium Oxideat 30N compared to that of A357alloy + 7% Zirconium Oxide at 10N. Coarser ridges and subtle plastic deformation at the groove edges because of high load of 30N.

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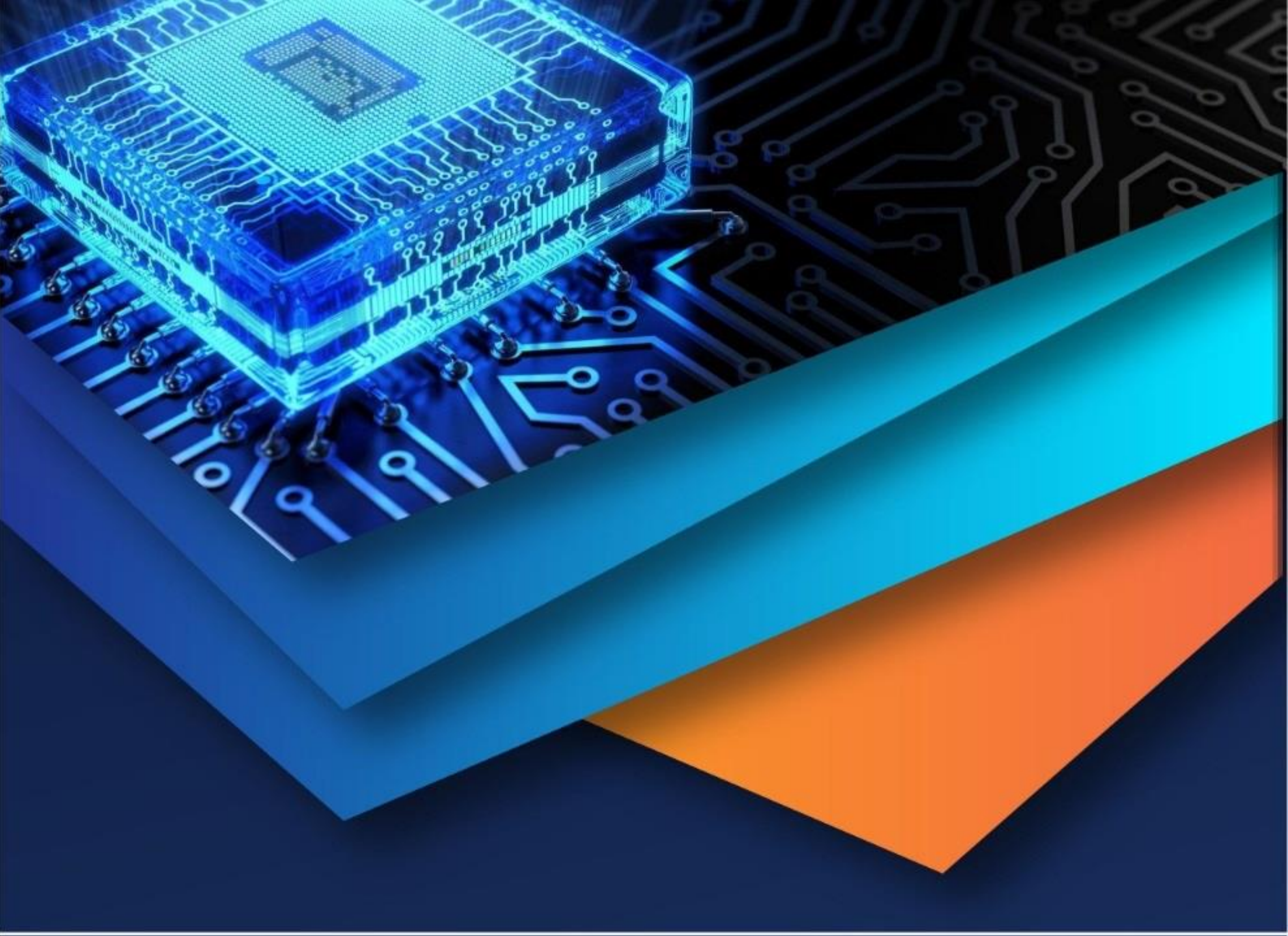

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