International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 6 (2015) pp. 15417-15428

http://www.ripublication.com

Influence of Specimen Temperature on Wear Characteristics of Al-Zn-Mg Castings

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Abstract

Al-6Zn-4Mg alloy blocks were prepared by stir casting process. The wear study was conducted by varying load, velocity and specimen temperature using pin-on-disc wear tester. It was observed that the wear rate (WR) increases with load at a constant velocity. The WR at constant load is less in the velocity range of 1.5 to 2 m/s. compared to the velocity range of 1 to 1.5 m/s. The specific wear rate (SWR) decreases rapidly between 10 to 20 N and marginally from 20 and 50 N. The SWR increases linearly with sliding velocity. The decrease in wear resistance is significant between 10 and 20 N and is marginal from 20 to 50 N. The wear resistance decreases linearly with increasing velocity. The WR decreases rapidly as the temperature of the specimen increases from 50 to 90 ºC and further increase of specimen temperature from 90 to 125 ºC, increases WR rapidly. The SWR also varied similar to WR versus temperature. The wear resistance of the specimen shows a reverse trend as compared with the WR and SWR. The variation of coefficient of friction (COF) with load, velocity and specimen temperature shows a marginal variation.

Keywords*:* Al-Zn-Mg alloys, WR, COF, wear resistance, dry sliding, pin-on-disc.

Introduction

Al and its alloys are used in automobiles, space & aircraft, defence applications and other engineering fields because of their superior performance of specific strength, stiffness, wear and seizure resistance [1] – [6]. The addition of magnesium to Al-Zn alloys offers good strength-to-weight ratio, machinability and corrosion resistance [7] – [9]. The low density of magnesium, which is approximately 2/3rd that of aluminium and 1/5th that of steel makes it attractive for applications where weight reduction is critical [7]. Recently, interest is shown to the use of Al–Zn–Mg alloys having high strength for aerospace structural applications and other common engineering areas. However, components made by Al–Zn–Mg alloys are joined by using rivets or bolts because of poor weldability. This leads to vibration at the joints and in dry conditions, causes sliding and fretting wear [10].

Number of investigators highlighted that there is a good relation between velocity and load to cause wear. According to their statement, depending on speed and load, four types of wear zones were observed in the alloy system such as: (a) mild (b) mixing and oxidative (c) de-lamination and (d) severe [1]. At low speeds and loads mild wear occurs. Further, at low speeds with the increase of load gradually, wear debris and mating surface material mix, due to higher temperature rise and gets oxidized. This in turn reduces the wear rate by covering the interface [1]. But at higher loads, increased wear rate was reported which is due to removal of oxide layer from the interface [1]. Hence, it is required to examine the wear characteristics of Al–Zn–Mg castings at elevated temperatures since only a few attempts have been made so far [11].

Therefore, in the present study, wear characteristics of Al–Zn–Mg castings using stir casting method at elevated temperatures are discussed in detail.

Experimental Procedure

The Al-6Zn-4Mg alloy blocks were prepared by stir casting process using metallic die. The stir casting equipment and the metallic die are shown in Figs. 1 and 2 respectively. The die was preheated to 200 ºC before the molten metal was poured in to the die. The melt was poured at 800 ºC. Before melting the various elements are also preheated. The as casted specimen is shown in Fig. 3. The cast specimen was tested for composition using spectrometer as shown in Table 1.

Table 1: Spectrometric result of alloy composition

Alloy	**Chemical composition**		
Al-6Zn-4Mg	**Al**	**Zn**	**Mg**
	89.92	5.95	4.06

Figure 1: Stir Casting Equipment

Figure 2: Mild Steel Permanent Mould

Figure 3: As Casted Specimen

The specimens for testing wear are prepared from these cast blocks as per ASTM G 99-04a standard. Ducom (India) make Pin-on-Disc wear tester was used to conduct test (Fig.4). The wear test was conducted by varying load, velocity and temperature of the specimen. An electronic balance was used to find the original and finishing weight of the specimens. The test parameters used for the wear test is reported in Table 2 for specimens tested for room temperature and test parameters for higher temperatures is reported in Table 3.

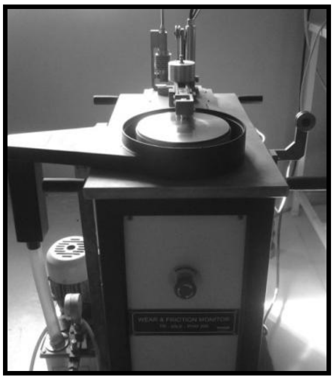

Figure 4: Pin–on–Disc wear tester

Table 2: Wear test parameters (Room Temperature)

Parameters	Values
Speed, rpm	212, 320, 425
Velocity, m/s	1, 1.5, 2
Track radius, mm	45
Time, s	600
Sliding distance, m	600, 900, 1200
Load applied, N	10, 20, 50

Table 3: Wear test parameters (Higher Temperature)

Parameters	Values
Speed, rpm	425
Velocity, m/s	2
Track radius, mm	45
Time, s	600
Sliding distance, m	1200
Load applied, N	40
Specimen Temperature, °C	50, 75, 100, 125, 150

Results and Discussion

As seen from Figure 5, WR increases continuously with load of 10 to 50 N at constant velocity of 2 m/s. It is due to increasing frictional force with increasing normal load. The relationship between frictional force and normal load is as given below.

$F = \mu N$ (where, F = Force of friction, N; μ = COF; N = Normal applied load, N)

The increased frictional force tends to increase the interface temperature (specimen and disc) and soften the material. Initially, there are less number of aspirates between the specimen and disc. Because of softening of the contact surface, these aspirates are plastically deformed and subjected to increased stress concentration. As the load increases, the deformed aspirates are detached from the specimen as fine particles and increase the WR.

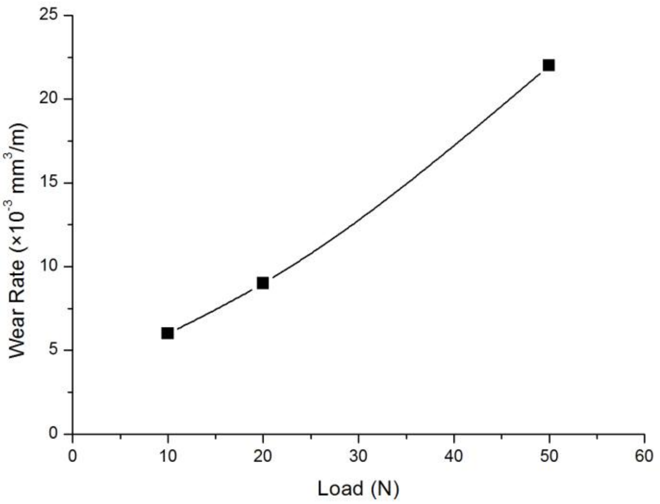

Figure 5: Normal load versus WR

Figure 6 represent the variation of WR as the velocity changes from 1 to 2 m/s, at a constant load of 50 N. It is seen that the WR is considerably less between 1.5 to 2 m/s as compared to velocity range of 1 to 1.5 m/s. This is due to high temperature at the interface and oxidation of the specimen / counter face. These oxidized layers coat the surface and reduce the WR.

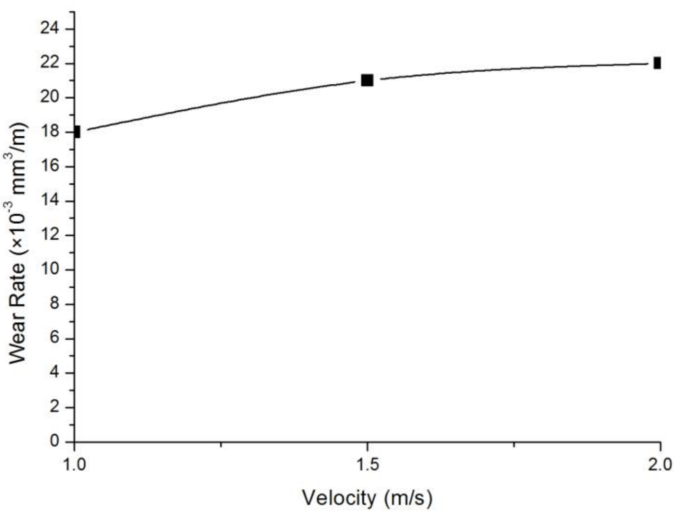

Figure 6: Sliding velocity versus WR

Figure 7 shows the deviation of SWR as the load increases from 10 to 50 N, maintaining velocity at constant value of 2 m/s. It is seen that the SWR rapidly decreases from 10 to 20 N and is marginal between 20 and 50 N. It is due to the work hardening effect of the specimen when the load increases.

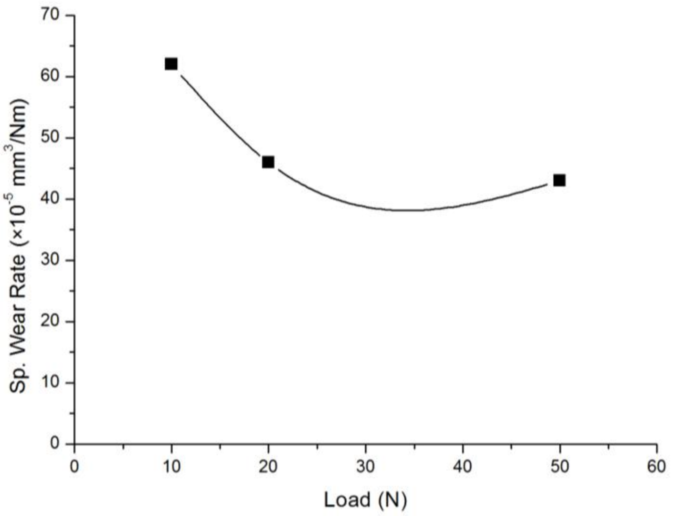

Figure 7: Normal load versus SWR

Figure 8 characterize the variation of SWR as the velocity changes from 1 to 2 m/s, at constant load of 50 N. It is found that the SWR changes linearly with velocity. This is because, heat is conducted through the specimen and the disc resulting in reduction in temperature at the contact surface. This leads to less oxide layer formation and more direct metal to metal contact. Hence, the result shows an increasing trend.

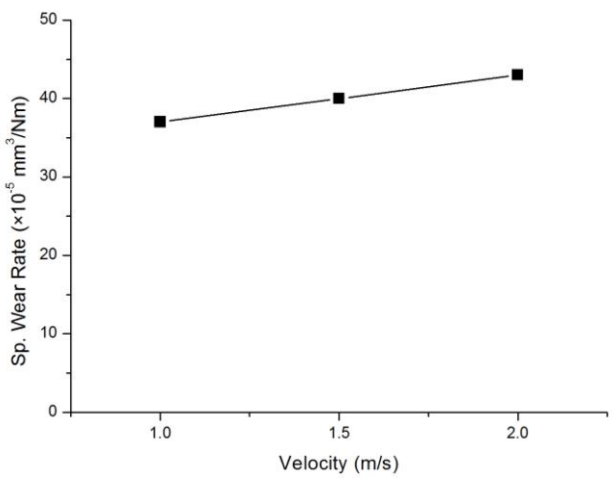

Figure 8: Sliding velocity versus SWR

Figure 9 shows the deviation of wear resistance as the load increases from 10 to 50 N, at fixed velocity of 2 m/s. The decrease in wear resistance is significant between 10 and 20 N due to small contact area between the specimen and disc. When the load is increased, the contact area also correspondingly increases. This leads to increase in material removal and decrease in wear resistance.

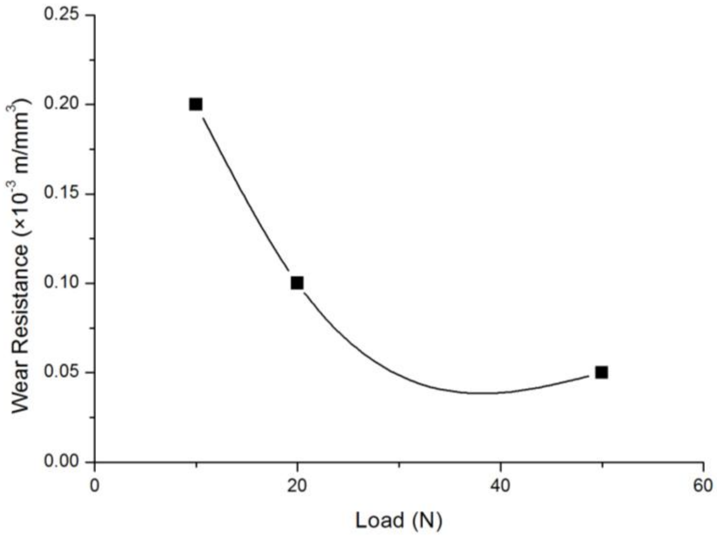

Figure 9: Applied Normal Load Versus Wear Resistance

It is observed from Figure 10, the wear resistance decreases linearly with increase in velocity. This is due to increasing contact distance as the velocity increases, which removes more volume of material from the specimen surface.

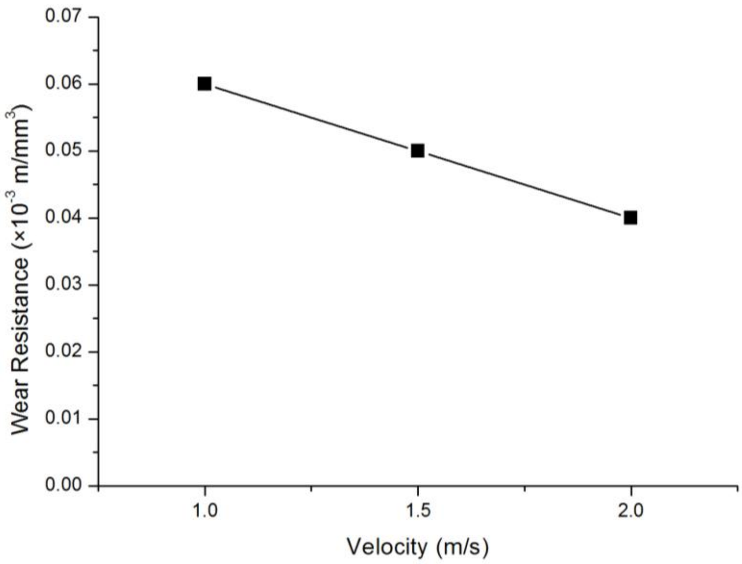

Figure 10: Sliding Velocity Versus Wear Resistance

The wear profile of the specimen at constant load of 40 N and velocity of 2 m/s, when the temperature increased from 50 to 150 ºC is shown in Fig. 11. It is observed from Figure 11 that WR decreases rapidly as the temperature increases from 50 to 90 ºC (approximately) and further increase of specimen temperature from 90 to 125 ºC, increases wear rate rapidly. But beyond 125 ºC it is marginal. The decrease in wear rate between temperature 50 and 90 ºC is due to formation of oxide layer. At higher temperature, the oxide layer is broken and detached from the specimen surface and thus resulting higher WR.

Similarly, the SWR also varied and is shown in Figure 12. The wear resistance of the specimen found to be reverse of the WR versus temperature as shown in Fig. 13.

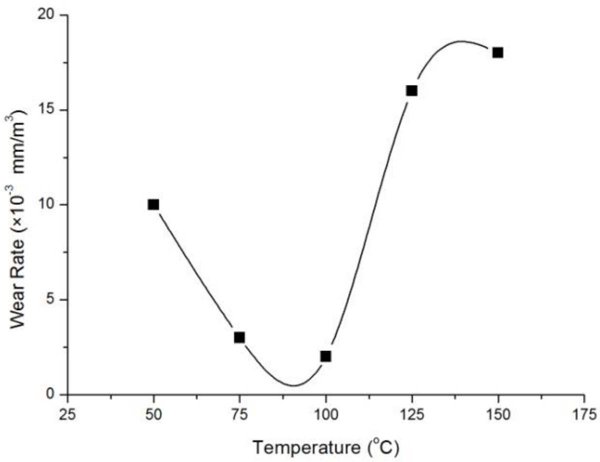

Figure 11: Specimen temperature versus WR

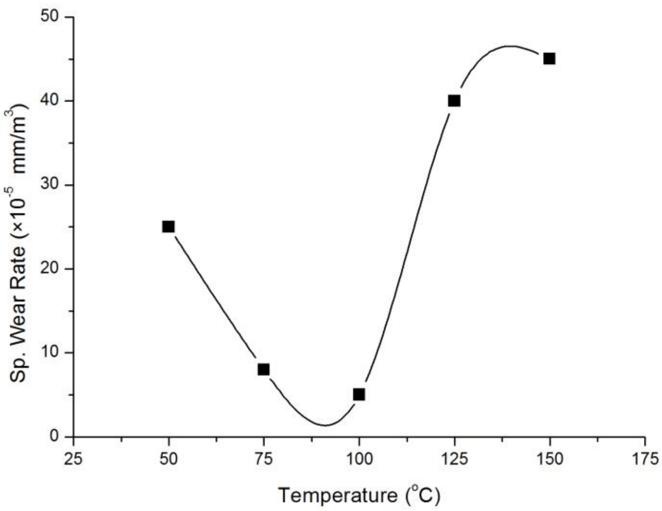

Figure 12: Specimen temperature versus SWR

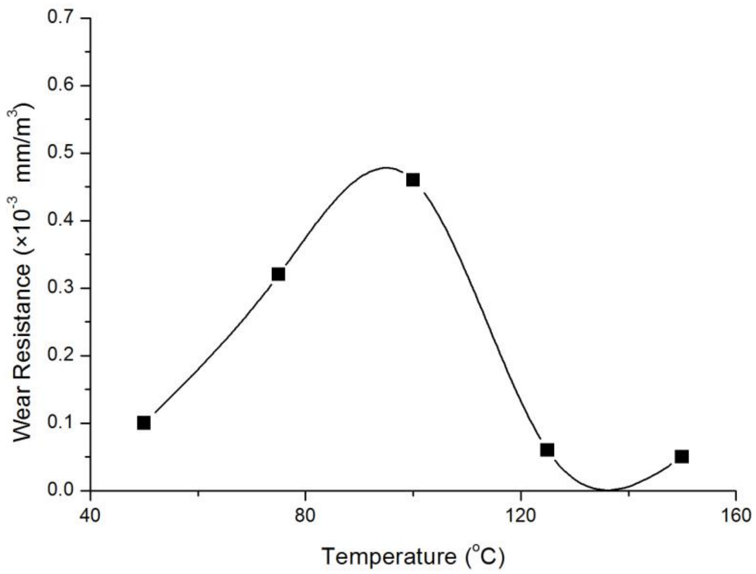

Figure 13: Specimen temperature versus Wear resistance

Figures 14 to 16 show the deviation of COF with load, velocity and specimen temperature respectively. It is found that in all three cases the COF value marginally varies. It is inferred that the average value of COF is around 0.45. The marginal increase in COF is due to increase in specimen temperature, which changes the properties of the material.

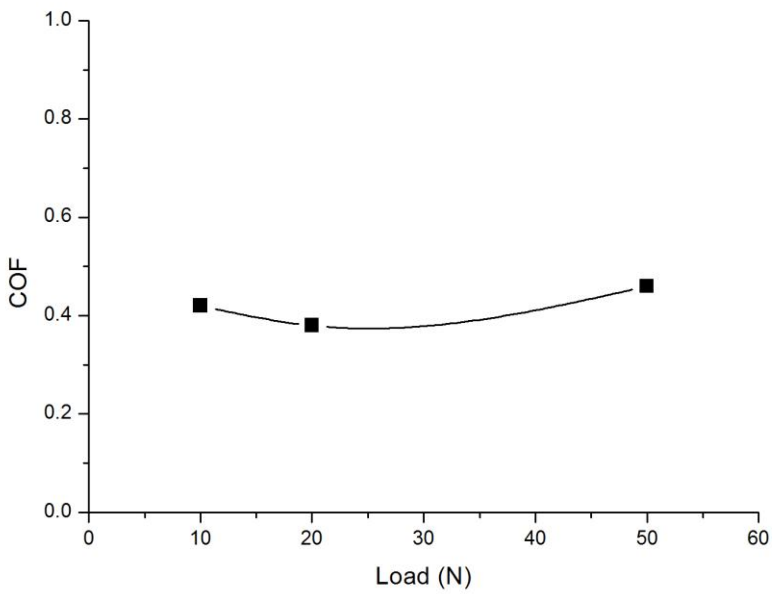

Figure 14: Normal load versus COF

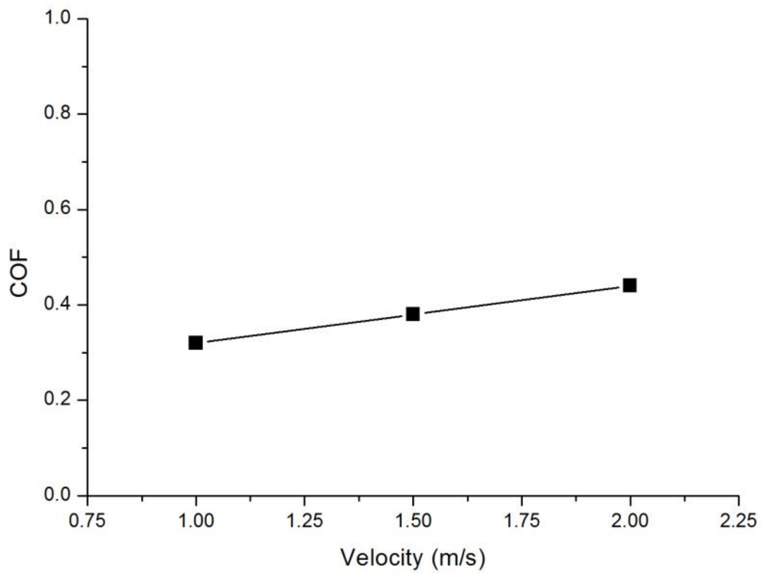

Figure 15: Sliding velocity versus COF

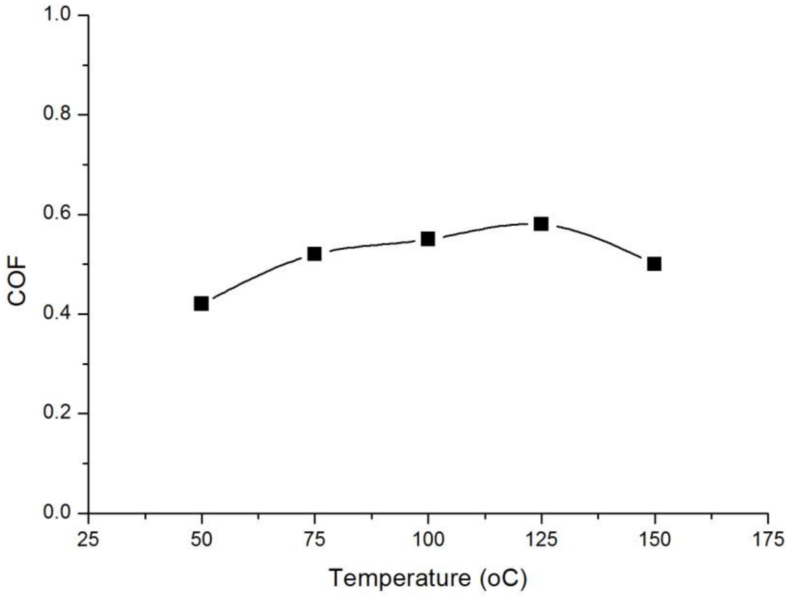

Figure 16: Specimen temperatures versus COF

Conclusions

- The increase in WR with load is due to detachment of aspirates from the specimen as fine particles.

- As compared to velocity range of 1 to 1.5 m/s, the wear rate is considerably less between 1.5 to 2 m/s. This is due to elevated temperature rise at the interface and oxidizing the specimen / counter face materials. These oxidized layers coat the surface and decrease the WR.
- The SWR rapidly decreases from 10 to 20 N and is marginal between 20 and 50 N. It is due to the work hardening effect of the specimen when the load increases.
- The SWR increases linearly with velocity.
- The decrease in wear resistance is significant between 10 and 20 N and not significant from 20 to 50 N. Initially, there is a small contact area between the specimen and disc. But by increasing load, the contact area also correspondingly increases. This leads to comparatively more amount of material removal and reduces the wear resistance.
- The wear resistance decreases linearly with increasing velocity. This is due to increasing sliding distance as the velocity increases which removes more volume of material from the specimen surface.
- The WR decreases rapidly as the temperature of the specimen increases from 50 to 90 ºC and further increase of specimen temperature from 90 to 125 ºC, increases WR rate rapidly. The decrease in WR between temperature 50 and 90 ºC is due to formation of oxide layer. At elevated temperature, this layer is broken and detached from the interface surface and thus resulting higher WR.
- The SWR also varied similar to WR versus temperature. The wear resistance of the specimen found to be reverse of wear rate.
- The deviation of COF with load, velocity and specimen temperature shows a marginal variation. The average COF value obtained is around 0.45. The variation in COF is due to increase in specimen temperature, which changes the properties of the material.

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