ANALYZING EXPERIMENTALLY THE DYNAMIC CHARACTERISTICS OF JOURNAL BEARINGS UNDER VARIOUS LOAD CONDITIONS

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Abstract. This paper aims to experimentally assess the performance of plain bearings casted as self-lubricating composite materials. Metal stir casting is used to prepare plain bearings based on composite materials, which are made of AA 2218 Al alloy, 4% MoS_2, and 15% fly ash. Arrangement of shafts in the textile industry is reflected in the impression of the experimental setting, which was derived from earlier literature. To obtain vibration signals, the DAQ kit and accelerometer were connected using the Laboratory Virtual Instrument Engineering Workbench (LAB-view) as a graphical data collection and interpretation system. Different loads were applied to journal bearings with and without lubrication. The outcome demonstrates the amplitude fluctuation, temperature rise, and mass loss of journal bearings for Gun metal (Red brass), AA2218, and self-lubricating composite materials.

1. Introduction

An emerging trend in recent years has been the widespread usage of solid lubricants for several industrial applications [1-2]. The self-lubricating composites are appropriate for applications requiring reduced density, low coefficient of friction, enhanced hardness, and wear resistance [3]. In engineering applications, inadequate lubrication is the primary cause of most bearing failures. Excessive wear and elevated temperatures further shorten a bearing's life [4]. Maintaining the lubricating effect between the mating surfaces under high temperatures and high loads is extremely challenging. Plain bearing wear and temperature rise can be minimized by applying the newer material to these locations [5-6]. The creation of a substitute material for plain bearing applications is the objective of this exploration project. It is suggested that plain bearings can be used with self-lubricating composite material [8]. Experimentation can be used to assess the plain bearing's performance as per the ASTM C1812. The self-lubricating composite material's wear behaviour, temperature rise, and volume of material loss in comparison to traditional materials [9-10]. The test findings can be used to determine which material is most appropriate.

2 Materials and methods

2.1 Material

Similar to brass, aluminum is a silvery white metal with a high resistance to corrosion and a somewhat flexible nature. With a specific gravity of 2.7, it is comparatively lighter than metals including copper, brass, nickel, steel, and zinc. Aluminum can be machined simply and has a large range of surface finishes [2-3]. In addition, it is very reflective of light and heat and has good electrical and thermal conductivities. At room temperature (25°C), the elastic modulus of aluminum alloys typically ranges from 70 to 79 GPa. Aluminum alloys typically have a density of 2.6 to 2.8 g/cm^3. Tensile strength typically ranges from 230 to 570 MPa. Different heat treatment conditions are largely to responsibility for the wide range of ultimate tensile strength [4-5]. Composition of three bearing materials is listed in Table 2.1.

Table 2.1. Composition of Material

<table>
<tr><td colspan="10">MoS_2 Based Composite</td></tr>
<tr><td colspan="3">AA2218</td><td colspan="4">MoS_2</td><td colspan="3">Fly ash</td></tr>
<tr><td colspan="3">81%</td><td colspan="4">4%</td><td colspan="3">15%</td></tr>
<tr><td colspan="10">Gun metal (Red brass)</td></tr>
<tr><td colspan="3">Copper</td><td colspan="4">Tin</td><td colspan="3">Zinc</td></tr>
<tr><td colspan="3">88%</td><td colspan="4">8–10%</td><td colspan="3">2–4%</td></tr>
<tr><td colspan="10">AA2218 Al alloy</td></tr>
<tr><td>Aluminium</td><td>Copper</td><td>Magnesium</td><td>Nickel</td><td>Iron</td><td>Silicon</td><td>Zinc</td><td>Manganese</td><td>Tin</td><td>Chromium</td></tr>
<tr><td>91.35 to 92.95%</td><td>3.5 to 4.5%</td><td>1.2 to 1.8%</td><td>1.7 to 2.3%</td><td>1% max</td><td>0.9% max</td><td>0.25% max</td><td>0.5% max</td><td>0.25% max</td><td>0.1% max</td></tr>
</table>

3 Materials Preparation

3.1 Stir casting

Stir casting technique is used to create a self-lubricating composite plain bearing consisting of 15% fly ash, 4% molybdenum disulfide, and aluminum alloy 2218. Using mechanical stirring, a dispersed phase (ceramic particles) is combined with a molten matrix metal in the liquid state process known as stir casting [6-7]. Preheated reinforcement particles were continuously dispersed into liquid aluminum alloy using an electrical melting furnace equipped with a stirring assembly. To boost the surface reaction, MoS_2 and fly ash were preheated for an hour at 400°C.

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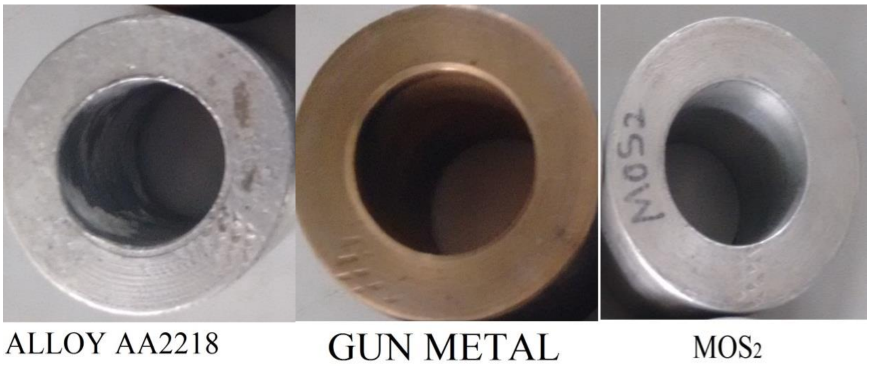

Figure 3.1 Composite based plain bearing

After that, the heat-treated particles were introduced to the melt via the vortex that was created by constant stirring. For around ten minutes, the stirrer's speed was kept between 300 and 400 rpm in order to achieve low porosity and enough mixing. Plain bearings made of pure alloy and gunmetal are machined to the specified size. Three test specimens were ready for applications involving plain bearings. Fig. 3.1 shows the plain bearings for experimentation.

3.1.1 MoS_2 Based Aluminum Composites

Even with lubrication, MoS_2 based aluminum composites offer exceptional low-friction properties due to the intrinsic lubricating nature of MoS_2 particles. These composites exhibit high wear resistance, which is further enhanced by the presence of lubrication, reducing metal-to-metal contact and prolonging the lifespan of the bearing [7-8]. Under variable loads, these materials provide stable performance by maintaining a consistent lubricating layer, reducing the risk of abrasive wear and surface fatigue. The combination of MoS_2 and external lubricants effectively manages friction and wear, even under fluctuating load conditions.

3.1.2 Gunmetal (Red Brass)

Red brass (Gun metal) bearings benefit significantly from lubrication, which helps mitigate their higher inherent friction coefficients compared to MoS_2 composites. Lubrication reduces wear and improves the lifespan of Red brass bearings, especially under variable loads where the risk of metal contact and wear is heightened. Red brass also exhibits good corrosion resistance, which, when combined with appropriate lubricants, can provide robust protection in harsh environments. However, the wear resistance of Red brass, while improved with lubrication, typically does not match that of MoS_2 composites, particularly under high-load conditions.

3.1.3 Aluminum Alloys

Lubricated aluminum alloy bearings can achieve lower friction and enhanced wear resistance, making them suitable for a range of applications. The lubrication layer reduces direct metal contact, which is crucial for managing wear under variable loads. Aluminum alloys' lightweight nature and good thermal conductivity help dissipate heat generated from friction, further protecting the bearing surfaces. However, despite these advantages, aluminum alloys generally do not match the wear resistance and low friction performance of MoS_2 composites, particularly in demanding load conditions. They may also require more frequent lubrication maintenance to ensure optimal performance [8-9].

3.1.4 Application Suitability and Considerations

In summary, MoS_2 based aluminum composites, when used with lubrication, offer superior wear resistance and low friction, making them ideal for high-load, variable-load conditions. Red brass bearings, while less wear-resistant than MoS_2 composites, perform adequately with lubrication, offering good corrosion resistance and moderate mechanical properties. They are suitable for applications where environmental resistance and cost-effectiveness are priorities. Aluminum alloys, benefiting from lubrication, provide good thermal management and are suitable for applications where weight savings are crucial, though they may require more maintenance to maintain performance levels [10]. The selection of bearing material should consider the specific operational demands, including load variability, environmental conditions, and maintenance capabilities, to ensure optimal performance and longevity.

3.2 Test Rig:

Test rig consist of mild steel with 1Horse power AC induction motor used to drive the EN8 steel shaft. Also, it has spring loaded weight balance to apply load on the bearing. The shaft is supported in the rolling contact bearings. Among the rolling contact bearings, the plain bearing (Test specimen, refer Fig. 3.1) was placed. The test rig shows in the Fig. 3.2.

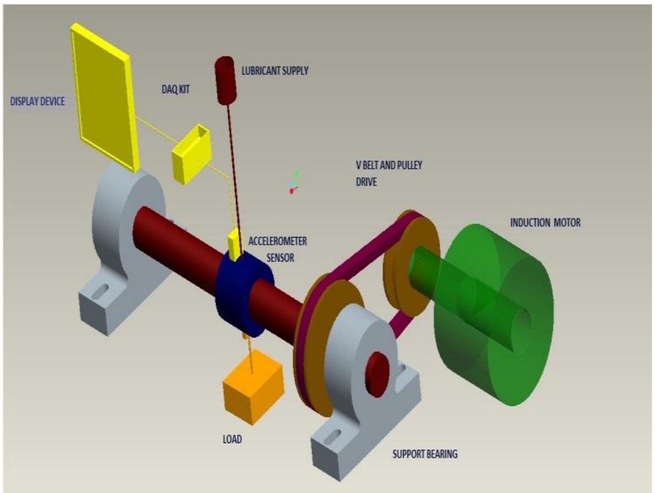

Figure 3.2 Experimental setup

3.3 Data Acquisition

Data acquisition (DAQ) in the context of a journal bearing test setup involves the systematic collection of data from various sensors that monitor different parameters during the test. Sampling signals to measure physical conditions in the actual world and turning the resulting testers into arithmetical numeric data that a computer can manipulate is the process of data acquisition [11-12]. Analog waveforms are usually converted obsessed by digital data for treating during data capture. The parts of data acquisition systems are Sensors that translate electrical signals from physical properties, Signal conditioning circuitry to transform sensor data into a format suitable for digital value conversion, and Analog-to-digital converters these devices change sensor signals that have been conditioned into digital values. Fig. 3.3 displays the DAQ kit

Figure 3.3 DAQ kit

3.4 Lab View

The product called Lab VIEW, which stands for Laboratory Virtual Instrumentation Enable Work bench, is created by National Instruments. With the graphical programming language Lab VIEW, applications can be created with icons rather than text lines. Lab VIEW employs dataflow programming, which decides program execution by the flow of data, as opposed to text-based programming languages, which depend on instructions. In LabVIEW, a user interface can be made with a range of components and tools. The front panel is the name given to the user interface. To add code to manipulate the objects on the front panel, one can use graphical representations of functions. This code is present in the block diagram. The block diagram is similar to a flowchart in certain aspects. The block diagram and Lab VIEW software are used to store all of this vibration data on a computer [13-14]. A block diagram is displayed in Fig. 3.4.

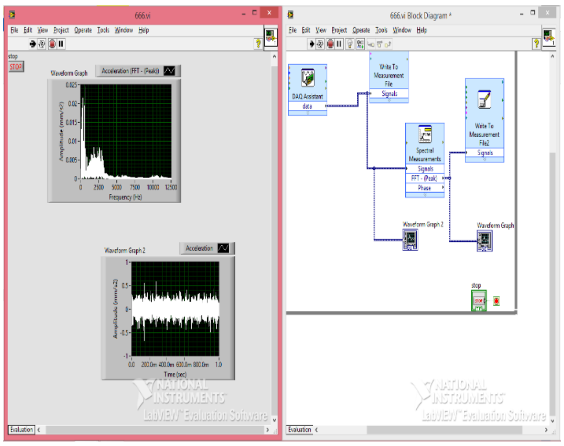

Figure 3.4 Black diagram

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3.5 Thermocouple

A thermocouple is a device that measures temperature by connecting two dissimilar conductors at one or more locations where the separate conductors experience temperature differences. We use the "J" type thermocouple, though there are other varieties as well [15-16]. Given that it is composed of iron and constantan and has a temperature range of - 210 to 760°C.

4. Testing Parameters

Table 4.1 Test condition

Materials	**With Lubrication**			**Without Lubrication**		
	Load 1	**Load 2**	**Load 3**	**Load 1**	**Load 2**	**Load 3**
AA2218	**0**	**5**	**10**	**0**	**5**	**10**
MoS_2	**0**	**5**	**10**	**0**	**5**	**10**
Gun Metal	**0**	**5**	**10**	**0**	**5**	**10**

Three types of plain bearing tested 1 hour at constant speed. Test the bearing at no load, 5 N and 10 N loading conditions under with and without lubrication. To measure the vibration signals at time domain and frequency domain. Also, the temperature intensification and volume of material removed to be measured. The test conditions are listed in table 4.1.

5. Results and Discussions

The graph shows the vibration signals on variation of vibration signals for MoS_2 compared with gun metal and pure alloy under the No load condition, 5 N and 10 N loads by varying lubrication condition [17-18].

5.1 Vibration Measurement

The accelerometer and DAQ kit are configured via the LAB-view program. sensors for accelerometers that translate physical characteristics into electrical impulses, can be obtained as digital values in curve form by signal conditioning circuitry, which transforms sensor inputs into a format that can be converted to digital values [19-20].

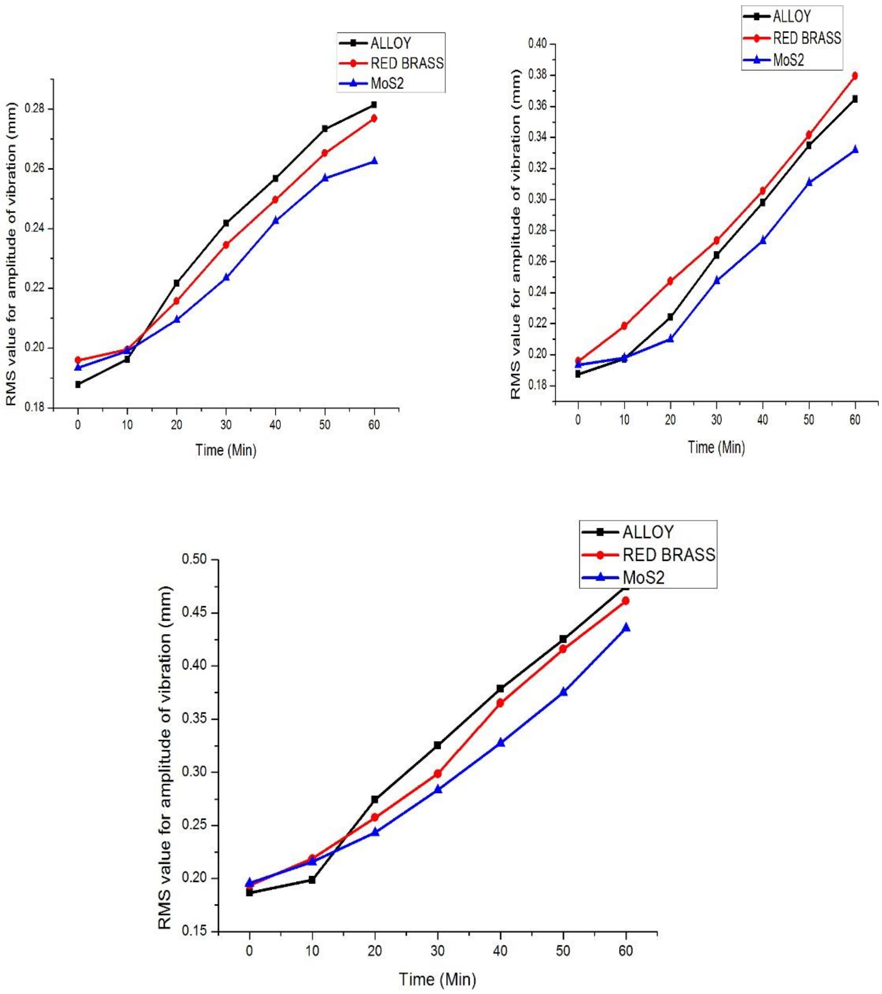


Figure 5.1 RMS value without lubrication No load, 5 N & 10 N load

The structure and composition of MoS_2 based composites can influence their mechanical and physical properties [21-22]. These materials often exhibit higher strength-to-weight ratios and better wear resistance, contributing to more stable and consistent performance under dynamic conditions, thus reducing 10-12% of RMS value for amplitude of vibrations at no lubrication condition as reported in Fig. 5.1.

MoS_2 based composites may have different thermal conductivity properties compared to Red brass and aluminum alloys. This can affect the heat distribution and thermal expansion behaviour, which in turn influences vibration characteristics. More uniform thermal properties can lead to less thermal-induced distortion and vibration. The manufacturing processes for MoS_2 based composites might result in a smoother and more consistent surface finish compared to Red brass and aluminum alloys. A smoother surface can reduce mechanical interferences and irregularities that contribute to vibration [23]. MoS_2 based composites typically exhibit properties like higher hardness and wear resistance, which can contribute to reduced operational vibrations, thus reducing 6.8-0.02% of RMS value for amplitude of vibrations at lubricated condition as reported in Fig. 5.2. These materials can maintain their shape and structure better under load, leading to more stable operation.

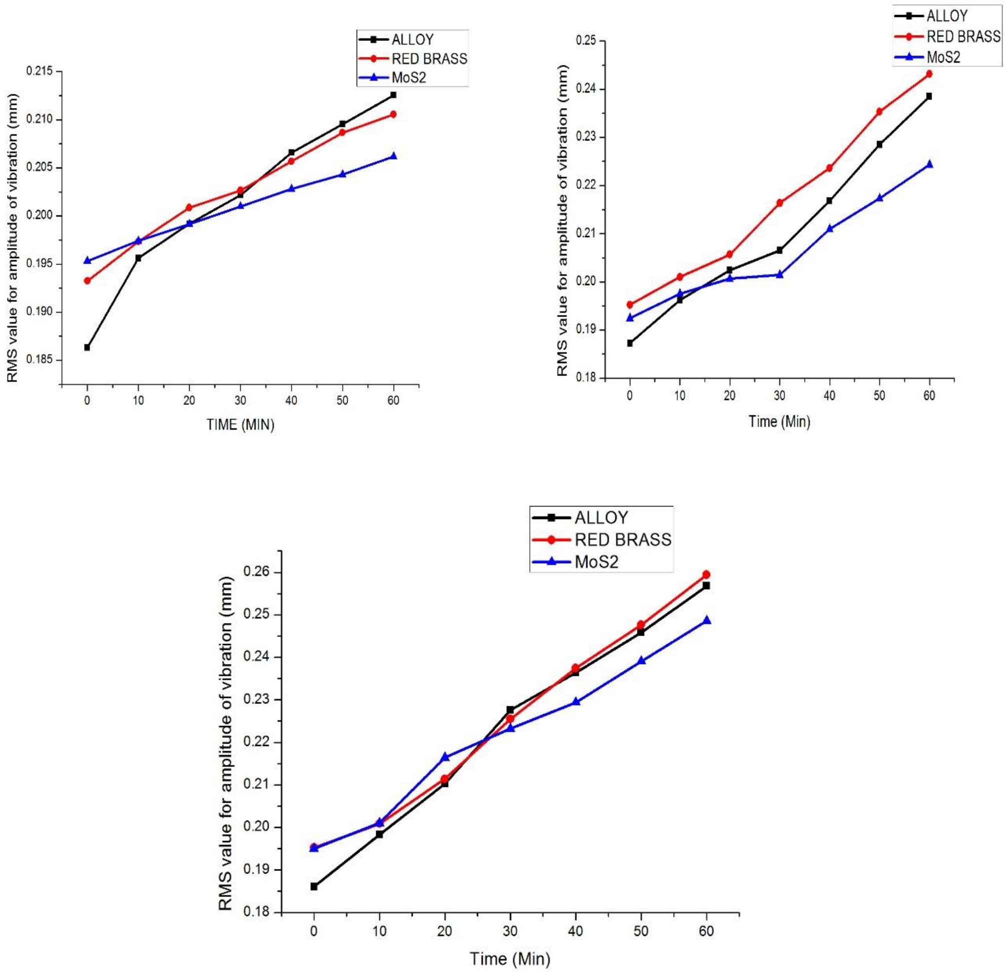


Figure 5.2 RMS value with lubrication No load, 5 N & 10 N load

MoS_2 based aluminum composites offer superior wear resistance, low friction, and excellent damping properties compared to Red brass and standard aluminum alloys, making them ideal for high-precision and low-vibration applications. Red brass provides good corrosion resistance and machinability, while aluminum alloys are favoured for their lightweight and good thermal properties [24]. The choice of material depends on the specific requirements of the application, including load, environment, and desired longevity. MoS_2 based aluminum composites stand out for their superior wear resistance and low friction characteristics, making them highly suitable for applications involving variable loads and where lubrication cannot be guaranteed. Red brass, while less effective in terms of wear resistance and friction, offers good corrosion resistance and can be a cost-effective option for less demanding applications.

5.2 Temperature Measurement

Temperature rise is measured by using a J type thermocouple. In this test MoS_2 specimen plain bearing, gun metal and pure alloy plain bearing under without lubrication and with lubrication condition of varying loading condition. Get temperature value in digital format at specified intervals.

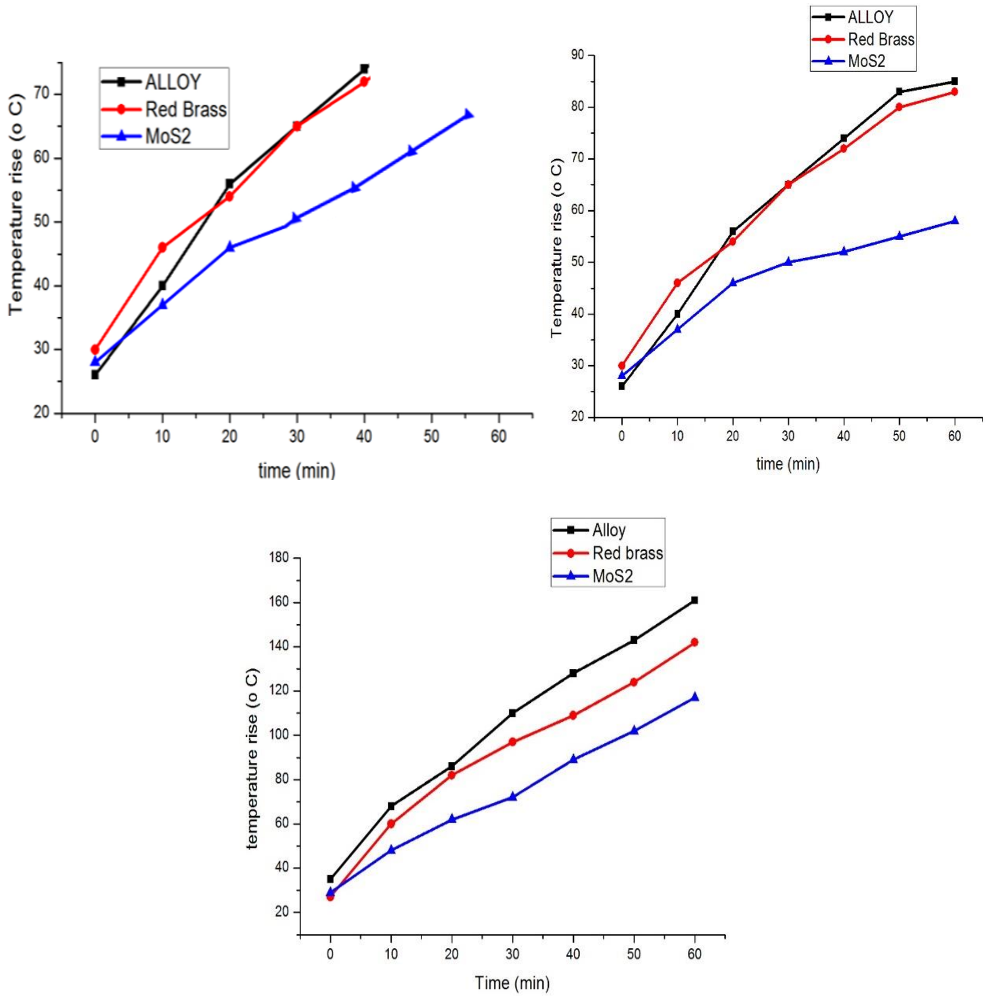


Figure 5.3 Temperature rise without lubrication No load, 5 N & 10 N load

Graphs 5.3 and 5.4 represents, the AA2218 alloy reinforced with fly ash and MoS_2 composite has a substantially lower temperature rise as 52.7-0.07% without lubrication and 10-0.05% with lubrication than the plain AA2218 aluminum alloy and conventional plain bearings made of gunmetal.

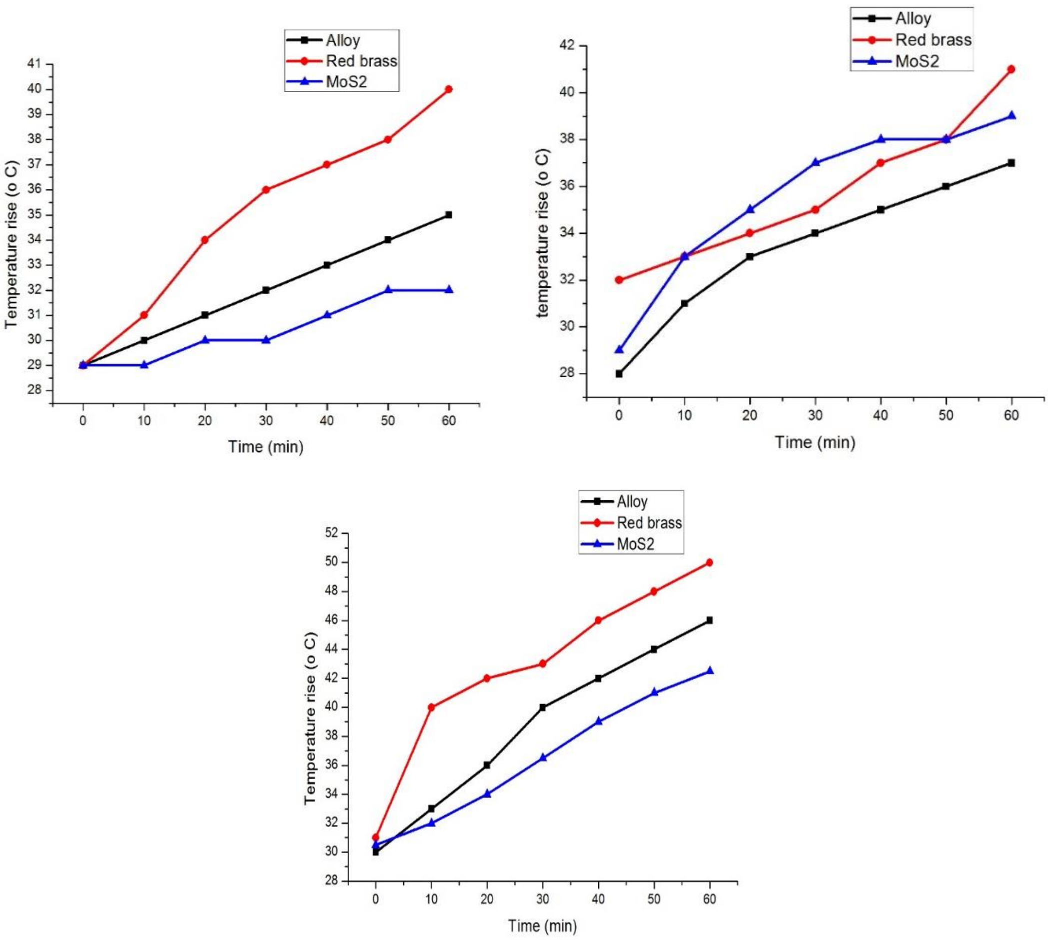
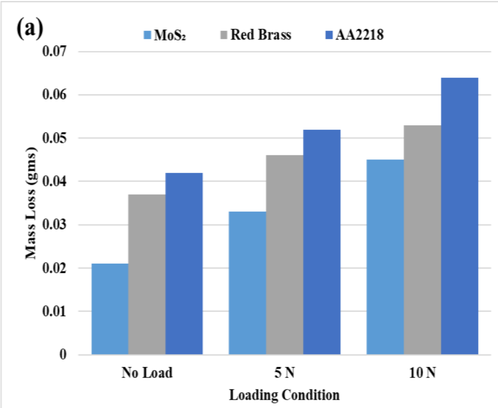


Figure 5.4 Temperature rise with lubrication No load, 5 N & 10 N load

The AA2218 alloy composite bearing performs significantly because of the addition of fly ash, which increases wear resistance and hardness, and MoS_2, which functions as a solid lubricant to lower friction. Because of this combination, there is a much less rise in temperature while the device is operating. Because the reinforcing components work together to limit surface degradation, the composite has better tribological qualities. This suggests that the composite material has improved heat dissipation and thermal stability [25]. The incorporation of fly ash and MoS_2 results in enhanced thermal conductivity and decreased friction, hence suppressing the production of heat during operation.

5.3 Volume of Metal Loss

Calibrate the weight of plain bearing before and after completion of test. By using weight gauge, the volume loss of bearing measured at end of the experimentation as shown in the given Fig. 5.5.



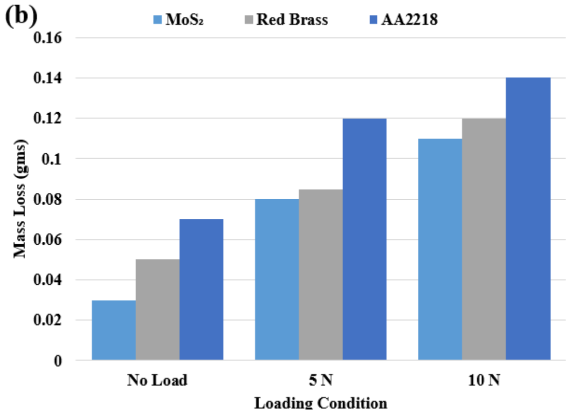


Figure 5.5 Mass loss with lubrication (a) and without lubrication (b)

The composite's ability to withstand wear, even under high loads, is substantially improved due to the reinforcement of fly ash and the solid lubrication provided by MoS_2. MoS_2 acts as an effective solid lubricant, especially in non-lubricated conditions, leading to reduced material wear and lower mass loss. The inclusion of fly ash increases the hardness of the AA2218 matrix, providing enhanced resistance to material degradation under load [26,27]. The composite outperforms both plain AA2218 alloy and gunmetal, particularly at higher loads, demonstrating its suitability for high-load applications. The reduced mass loss suggests that AA2218 + fly ash + MoS_2 composites are more durable and efficient, extending the service life of bearings under various load conditions.

Conclusions

The SLMMC based on AA2218 aluminum alloy + fly ash + MoS2 was cast using the liquid metal stir casting approach. Tribological performance evaluation was performed both with and without lubrication condition. The tribological properties and vibration characteristics were examined. The following observations were made:

- SLMMC exhibits lesser vibration (RMS value) compared to Red Brass and AA2218 alloy.
- While increasing the load proportionately the vibration level also increased gradually.
- SLMMC generates comparatively less temperature rise than Red Brass and AA2218 alloy.
- Volume losses of SLMMC lower than Red Brass and AA2218 alloy.

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