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Research Article

Application of Acoustic Emission Technique (AET) to the Study of Adhesive Wear of two Aluminium Alloys 2024 and 2024-T_4

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ABSTRACT

The adhesive wear resistance of (2024&2024-T_4) aluminium alloy under dry and lubricated conditions has been investigated by using the weighing method and the Acoustic Emission Technique (AET). Pin–on-plate reciprocating wear apparatus was used. The AET has capability of predicting an impending failure much ahead of time of its occurrence. The AE measurements are made with the help of a tape recorder system into isolated chamber from external noises. The results show that 2024-T_4 alloy has higher wear resistance with three distinct stages of wear rate in comparison with 2024 alloy under the working conditions. The AE data analysis showed a clear evident that the Events Rate and Peak Amplitude value display a clear-cut distinction between the wear rate stages in dry and lubricated conditions of both alloys giving a good agreement with the weighing method results.

Keywords: Aluminium; Alloys; Emission

INTRODUCTION

Wear is one of the most commonly encountered industrial problems leading to the replacement of components and assemblies in engineering. Since the friction loss is proportional to the normal load, one of the most effective ways to save energy through tribology is to reduce the normal load between rubbing surfaces. This is one of the reasons for increasing use of lightweight materials such as aluminium alloys in machine parts.

Aluminium alloys have excellent resistance to corrosion superior fatigue resistance, good thermal conductivity and moderate cost. However, they have a major drawback: the tendency to weld or seize in dry conditions or in boundary lubrications [1]. Therefore, when a machine part is to be replaced by aluminium one without any reduction in the performance, a good lubricating property must be required [2]. Several condition monitoring techniques such as vibration Monitoring, Shock pulse measurements, Thermal Monitoring, oil analysis etc., are available to predict the impending failure, the capability of predicting an impending failure much a head of time of its occurrence, commonly known as "lead Time" is one of the important factors for the choice of the type of technique to be used in any situation. Acoustic Emission testing, one of the latest and non-destructive testing tools has the capability to be used as "Condition Monitoring Technique". This technique displays a high sensitivity so as to provide sufficient "Lead Time".

The cylinder liner of the machine engines is one of the most critical component prone to failures due to improper fitting misalignment, lubrication starvation etc. And need proper maintenance and careful inspection to insure safe operation of the machinery. Application of the AE technique to monitor surface failures is relatively new area of work and hence there are not many publications available in open literature [3].

Bloch and Finley [4] made use of AE monitoring as an on-line system in rotating equipment bearings. Armos and Frank [5] used the AE technique to detect cracks in shafts, bearings and blade rubbing in steam turbine. Baur [6] and Sato [7] have detected some of the defects in a slider bearing like metal wipe-out, tilting of shafts in journal etc. Using wireless AE monitor, Yoshioka and Fujiwara [8,9] showed that the technique give useful results in the detection of the fatigue failures in rolling element bearing.

The present paper deals with the use of Acoustic Emission Technique in conjunction with the commonly destructive weighing method to study the adhesive wear resistance of aluminium alloys. The available information indicates a strong

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support for introducing the AET to study the failures of engineering surfaces.

MATERIALS AND METHODS

The materials used were 2024 (H=50 HRB) and 2024-T_4 (H=65 HRB) aluminium alloys of density 2.7 gm/cm3 and 100 Cr [6]. Tool steel of density 7.87 gm/cm^3 (H=94 HRB). The chemical analysis and mechanical properties of aluminium alloys and tool steel are given in Tables 1-4.

Table 1: Chemical composition of 2024 aluminium alloy.

Component	Si%	Fe%	Mn%	Mg%	Cr%	Zn%	Ni%	Al%
Standard [0]	0.5	0.5	0.3-0.9	1.2-1.8	0.1	0.25	_	Balance
Measured	0.375	0.42	0.516	1.38	0.006	0.026	0.017	Balance

Table 2: Chemical composition of 100 cr 6 tool steel.

Component	Si%	P%	Mn%	S%	Cr%	Zn%	C%
Standard [9]	0.15-0.35	0.03-0.01	0.3-0.9	0.03-0.01	1.35-1.65	0.3-0.2	0.95-1.1
Measured	0.23	0.021	0.5	0.024	1.6	0.25	1.02

Table 3: Mechanical properties of 2024 aluminium alloy.

Type of alloy	0.2 Offset yield Stress MPa	Tensile Stress MPa	Elongation%	Hardness HRB
2024	372.78	376	13	50
2024-T_4	370.41	386	11	65

Table 4: Physical properties of the oil SAE-40.

Specific weight at 15ºC	Flash (ºC) Minimum	Flash (ºC) Minimum	Pour Point Pour Point
0.895	236	13-16.5	-12

Specimens preparation

Aluminium specimen: Cylindrical test pins were machined from the received bars to dimensions 40 mm long and 9 mm diameter. Some of the specimens were heat treated to within a temperature range (495ºC to 505ºC) for 90 minute in an electric furnace with forced air circulation, then quenched in water for 15 minutes (water at 22ºC), after that aged naturally at room temperature for several days (4 to 5 days). The ends of the pins were all ground on a high-speed grinding wheel to produce a smooth, uniform surface finish of about 0.2 to 0.3 μ m.

Tool steel specimen: The specimens of dimensions 15 × 17 × 100 mm, were heated to 850ºC for 1.5 hour, and then tempered in air at temperature about 180ºC for about 2 hours. Also, the specimens grounded in the same way of the aluminium specimens.

Acoustic emission instrumentation

It was planned to carry out this investigation with the help of a microprocessor based AET system and the AE sensor is a piezo-electric type transducer with amplifier to amplify the signal. In addition a cathode Ray Oscilloscope (CRO) to be connected with the AET system for visual observation of the AE output signal. But due to the difficulty of obtaining this instrumentation, therefore, it was replaced by a tape recorder (type QT 77 double microphones) in isolated chamber. Although, the efficiency of this instrument is not as the AE system, but it proved it can give reliable results. The AE signal was analyzed by using oscillography recorder.

Laboratory tests

Adhesive tests were carried out utilizing the pin-on-plate reciprocating machine on which the aluminium alloys pin rubbed against fixed rectangular tool steel specimen supported by a reciprocating steel plate of 6 cm stroke.

Three types of tests were carried out in dry and lubricated conditions.

- Wear rate versus load for 20-minute duration with constant sliding speed and surface roughness.
- Wear rate pin surface roughness for 20-minute duration with constant sliding speed and applied normal load.
- Wear rate versus sliding speed for 20-minute duration with constant applied load and surface roughness.

Each pin was weighed before and after testing after it was washed with acetone and dried by air before weighing. The wear rate was obtained by measuring the loss in weigh of the pin using a micro-balance.

An engine oil SAE-40, its physical properties in Table 4, was used as a lubricant between the sliding surfaces.

At each stage of the above tests the Acoustic Emission was recorded after preventing the external noises to interfere with that come from the rubbing surface of the aluminium pin and tool steel.

Analysis of the AE signal is helped by various parameters like ring down count, peak amplitude, event duration, rise time and others. The practice is to select the most informative parameters, which will differ from situation to situation and carry out signal analysis to distinguish between different stages of the surface wearing. In this work peak amplitude and event duration variations were investigated.

RESULTS AND DISCUSSION

All the results have been plotted in a way to show the effect of different parameters on wear rate both alloys in dry and lubricated conditions.

Weighing method

Effect of applied load: Figure 1 shows the effect of normal load on wear rate for heated (2024-T_4) and unheated (2024) alloys for both lubricated and dry conditions. It can be seen that for both alloys the wear rate increases with increasing the applied load in three distinct stages which are nomenclature as [10]:

- "Mild Wear" in which wear rate increases gradually with increasing the applied load.
- "Transient Wear" in which wear rate increases rapidly with load.
- "Sever Wear" in which the increasing rate is more rapidly.

The difference in wear rate between the above stages perhaps due to the increasing of the real area of contact with increasing the normal load which resulting in rising the wear rate, while the difference in the value of the wear rate between the heated and unheated alloys may due to the difference in their hardness. Also, the same figure shows the effect of boundary lubrication in reducing the wear rate to about 66% for unheated alloy and about 32% for heated alloy.

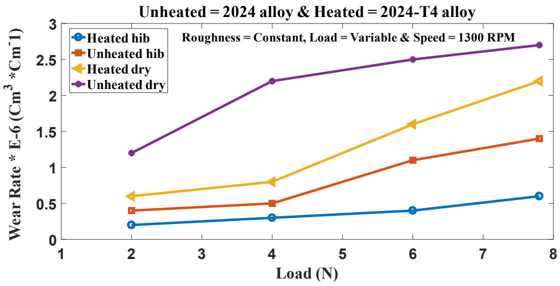

Figure 1: Relationship between the applied load and wear rate.

Effect of pin surface roughness: Figure 2 shows the effect of pin surface roughness on wear rate of both alloys. Approximately the same stages of wear rate can be observed with little difference in slope except the unheated alloy under lubrication condition, the increasing is very smooth with surface roughness.

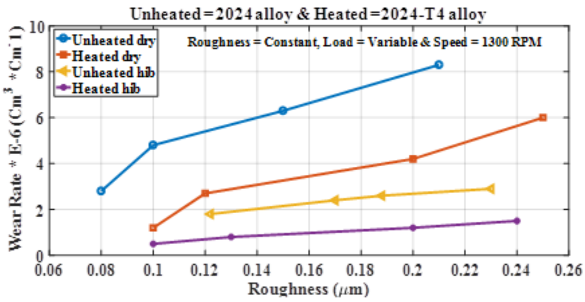

Figure 2: Relationship between the surface roughness and wear rate.

Effect of sliding speed: Figure 3 shows, in general, approximately the same wear rate stages of changing the slope with increasing the speed of sliding with more rapid in severe stage.

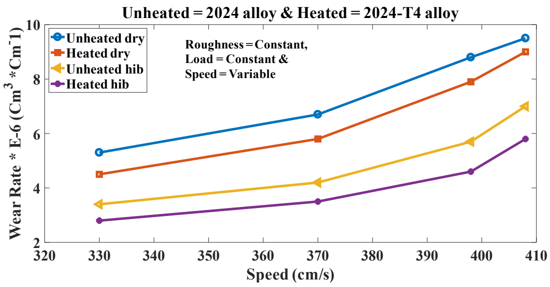

Figure 3: Relationship between the sliding speed and wear rate.

AE method

Figures 4 and 5 show the relation between the average number of events (number of peaks per a certain sample length and reference line) and the average peak amplitude with the applied load, for both alloys in dry and lubricated conditions. Clearly can observe three regions of events activity, characterized by the change of slops (which are lower in values when compared with weighing method). The first region is characterized by high initial activity referred to "Mild Wear" region, while the second and third regions are referred to transient and sever wear regions, respectively. Figure 5 shows approximately a linear increment in peak amplitude with increasing the applied load in lubricated and dry conditions.

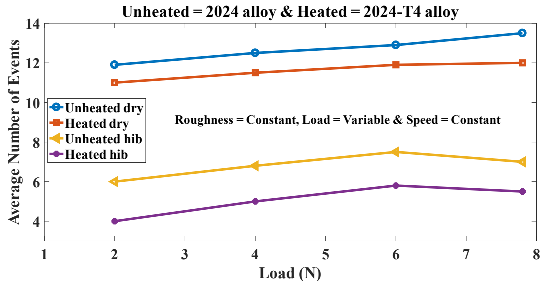

Figure 4: Relationship between the average number of events and the applied load.

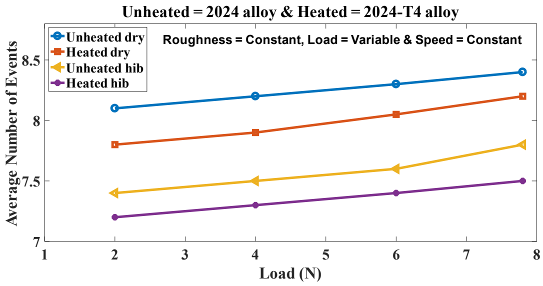

Figure 5: Relationship between the average amplitude of events and the applied load.

Also, the same trend of wear stages can be seen in Figures 6 and 7 when the average number of events and peak amplitude of these events are plotted with pin surface roughness.

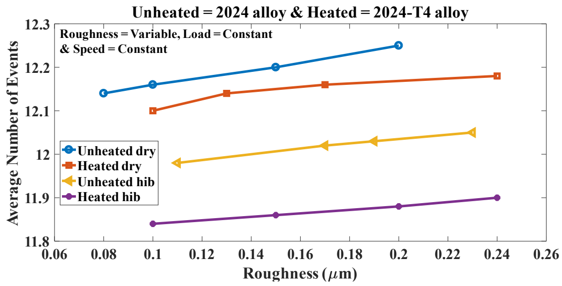

Figure 6: Relationship between the average number of the events and the surface roughness.

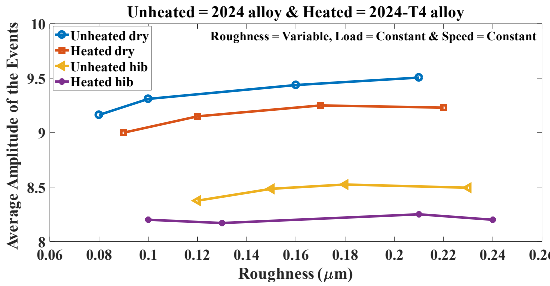

Figure 7: Relationship between the average amplitude of the events and the surface roughness.

Speed variation with events number and peak amplitude in Figures 8 and 9 shows a weak distinction between the wear rate stages. Perhaps, because at higher speeds the noises of the apparatus which is fairly high, many interfere with that generated by wearing process. This problem can be avoided if the AE system is used, i.e., these results could be more satisfactorily if the transducer is used to sensor the AE instead of the tape recorder which is liable to many external interferences'. Figure 10 shows some examples of AE signals at different loads analysed by the oscillography recorder.

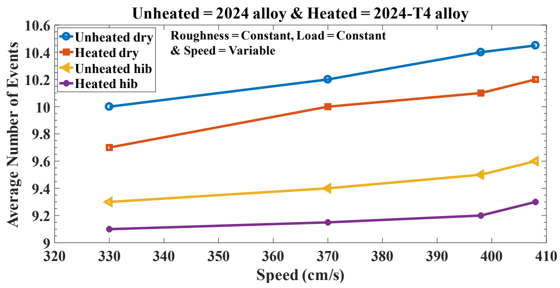

Figure 8: Relationship between the average number of the events and the sliding speed.

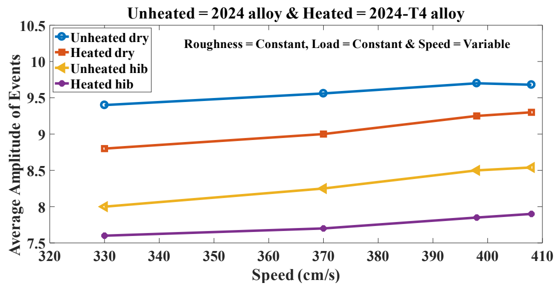

Figure 9: Relationship between the average amplitude of the events and the sliding speed.

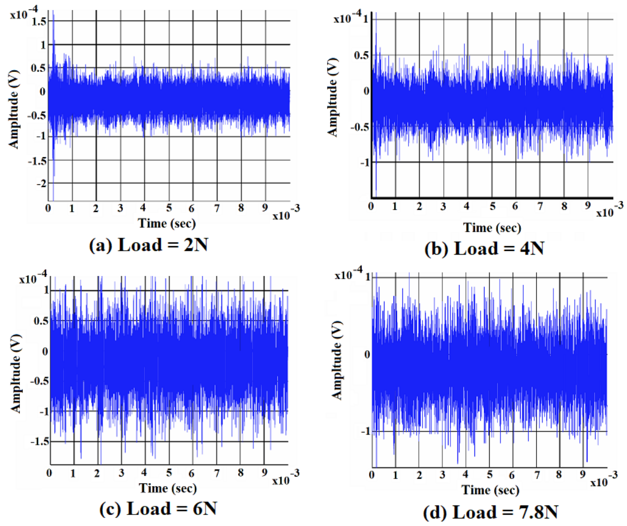

Figure 10: AE Signals at different loads for 2024 alloy, dry conditions.

CONCLUSION

From the above discussions, there is a strong evident that in all the studied cases, the AE method can give a clear-cut distinction between wear Stages of the rubbing surfaces using events rate and peak amplitude when compared with the commonly destructive weighing method. Therefore, AE method can be used to study the wear of engineering surfaces giving satisfactory results. The results show that 2024-T_4 alloy has higher wear resistance with three distinct stages of wear rate in comparison with 2024 alloy under the working conditions. The AE data analysis showed a clear evident that the Events Rate and Peak Amplitude value display a clear-cut distinction between the wear rate stages in dry and lubricated conditions of both alloys giving a good agreement with the weighing method results.

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