Tribological characteristics of EN8 and EN24 steel against aluminium alloy 6061 under lubricated condition

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Abstract

Abrasive wear of steel-aluminium tribo-pair is one of the major problems in engineering applications. In this research study, our main objective is to find out the tribological behaviour of shaft material, usually made of hardened EN8 and EN24 steel under lubricated condition against Aluminium alloy 6061. A conventional lubricant SAE 20W50 has been used, as it is the most common lubricating oil used in IC engines. Tribological tests were conducted on reciprocating friction test rig using pin-on-disc configuration under various operating parameters such as speed, load and temperature. The effect of these parameters on friction and wear was studied. It was observed in this study that with increase in load and speed, the coefficient of friction decreased while it increased with increase in temperature. However, comparison of results revealed that with the increase in load, EN24 alloy is suitable than the EN8 steel with coefficient of friction as deciding factor. The specific wear coefficient and wear volume increased with increase in all of these parameters and it was observed that under varying speed the tribo-pair consisting of EN24 steel is more suitable in comparison to EN8 steel from the wear point of view. Copyright © 2017 VBRI Press.

Keywords: Friction, wear, EN8, EN24, lubrication.

Introduction

Metals and its alloys are widely used in the field of automobile and manufacturing industries and wear is the main criteria for failure of such components. In an IC engine, most of the frictional losses come from the three main components, viz. piston-cylinder assembly, bearings and valve trains, and all these component use steel and Aluminium as a tribo-pair. Crankshaft of an Internal Combustion Engine being the main part responsible for power production has important influence on engine performance. In terms of wear and the consequent reliability and durability, crankshaft-bearing has proven to be the most difficult to design and lubricate effectively [**1**].

Nowadays, a critical need exists to develop new harder, tougher, lighter, more wear resistant, oxidation resistant and heat resistant components which can operate effectively under high temperature and hostile environments. Studies on crankshaft of IC engine mainly focus on tribological analysis, which include friction and wear for maximizing power output by reducing the frictional losses.

The other most important industrial application involves the use of die-casting tools because abrasive wear of die-casting tools is some of the biggest problem faced by the Aluminium die casting industry [**2**]. The Aluminium and different steel grade tools under various surface conditions were investigated. The tests were performed to find the suitable grade of steel, in the temperature range of 250 °C to 450 °C. It was found that the temperature plays an important role in tribological behaviour of Aluminium/steel tool pair. Material adhesion was observed at 450 °C whereas, abrasive wear mechanism was observed at 250 °C. However, fretting wear is the prominent mode of failure in components used in engineering applications comprising of materials such as, EN8 and EN24.

Fretting wear needs to be studied in tribo-pairs such as, hardened-tempered and nitriding structural steel, EN8 and bearings steel, EN24, used in most of the engineering applications. The fretting wear loss depends on the contact condition, stick-slip or gross slip, which depends upon the normal load at particular constant slip amplitude [**3**]. Hardness plays only a marginal role. The fretting behaviour of liquid nitride material was superior compared to the as-received material at different normal loads. The load at which the transition occurs to stick-slip nature depends on the surface composition and not on the hardness.

Aluminium based bearing alloys and EN24 shafts used in high speed engines, which are produced by metal mould casting, need to be studied for tribological properties. The result showed that the friction and wear behaviours of the alloys changed according to the sliding condition and normal load [**4, 5**].

The friction and wear behaviour of carbon steel EN8 was investigated under dry, lubricated, and contaminated sliding conditions. It was observed that the coefficient of friction and wear volume increased when the shaft material was slid ing contaminated test conditions. The effect of sliding speed and normal load on friction and wear property of an Aluminium disc sliding against stainless steel pin was studied [**6, 7**]. Experiments were carried out under normal load 10-20 N, speed 500-2500 rpm and relative humidity 70%. Results showed that the friction coefficient decreases with the increase of sliding speed and normal load for Aluminium. It was also found that the wear rates increase with the increase of sliding speed and normal load.

From the above literature review it is clear that shaft materials such as EN8 and EN24 with counter body as Aluminium alloy (Al 6061) need to be studied for various tribological conditions such as load, speed and temperature along with the preference for most suitable tribo-pair from friction and wear point of view.

Experimental

Materials

All the materials used were purchased from M/s Bushan alloys new Delhi. The authenticity and purity of the material was confirmed by the XRD provided by the supplier. The composition of the materials used is shown in **Table 1** and **Table 2**.

Table 1. Chemical composition of EN8 steel and EN24 steel.

Element	EN8 Min. (%)	EN8 Max. (%)	EN24 Min. (%)	EN24 Max. (%)
Carbon (C)	0.36	0.44	0.35	0.45
Manganese (Mn)	0.60	1.0	0.45	0.70
Silicon (Si)	0.1	0.4	0.1	0.35
Sulphur (S)	-	0.05	-	0.04
Phosphorus (P)	-	0.05	-	0.04
Chromium (Cr)	-	-	0.9	1.4
Molybdenum (Mo)	-	-	0.2	0.4
Nickel (Ni)	-	-	1.3	1.8

Table2. Chemical composition of Aluminium Alloy 6061.

Element	Min. (%)	Max. (%)
Iron (Fe)	0.36	0.44
Manganese (Mn)	0.60	1.0
Silicon (Si)	0.1	0.4
Chromium (Cr)	0.04	0.35
Zinc (Zn)	-	0.25
Titanium (Ti)	-	0.15
Magnesium (Mg)	-	0.8

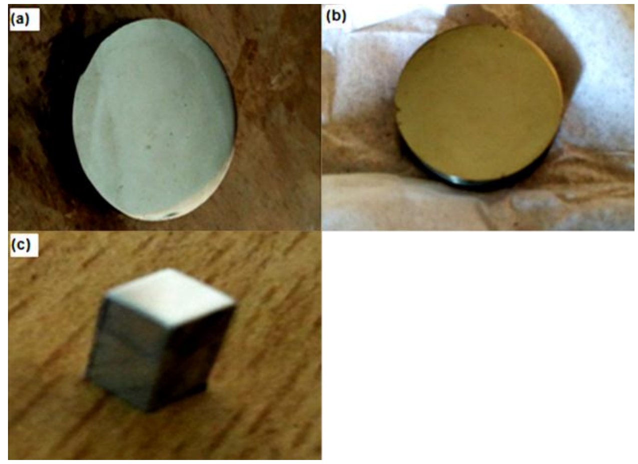

Fig. 1. Prepared samples of (a) EN8 disc (b) EN24 disc (c) AL6061 pin.

Sample preparation

Reciprocating friction and wear test on EN8 steel and EN24 steel disc of diameter 30 mm and 7 mm thick, against Aluminium alloy 6061 pin of dimension 3X4 mm^2 cross-section with 7 mm height, were conducted on a tribometer using a pin-on-disc specimen configuration.

Both pin and discs as shown in **Fig. 1** were mirror polished by using the different grit size of emery papers made of SiC (silicon carbide) i.e. 80, 220, 400, 600, 1000, 1200, 1500 and 2000 with a unidirectional surface texture followed by polishing on velvet cloth using diamond paste of 3, 1 and 0.25 microns to produce a mirror polished surface.

Reciprocating friction monitor

Reciprocating friction monitor (TE-300E, Magnum) shown in **Fig. 2** is versatile digitally controlled test rig for measuring friction and wear properties of materials under dry and lubricated conditions. A specimen is loaded and then reciprocally slides against a fixed counter body.

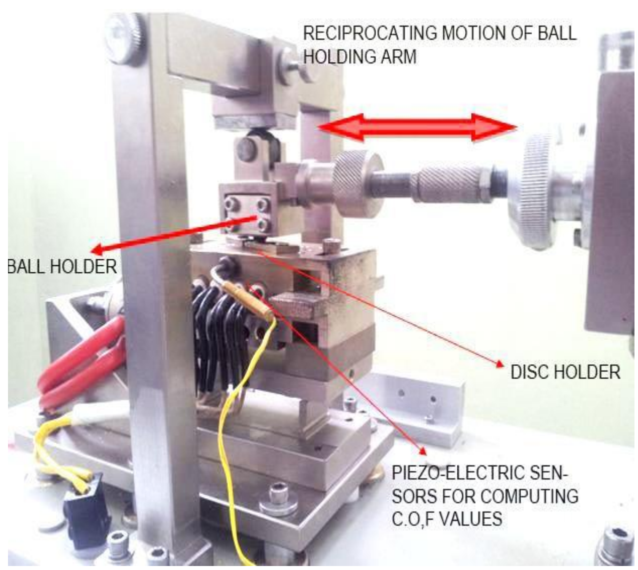

Fig. 2. Attachment details of Reciprocating Friction Monitor.

The oscillating motion is provided by a variable speed AC servo motor which is controlled through PC, by an eccentrically scotch yoke mechanism for the adjustment of the stroke. The horizontal force is measured through flexure mechanism which is connected to piezoelectric transducer. Piezoelectric transducer gives voltage output calibrated for frictional force and directly acquires data through acquisition software. The normal load is applied through motorized loading system on a load cell which measures normal load displayed on monitor through acquisition software MAGVIEW. The heater block is heated by five electrical 150 watts cartridge heaters and the temperature is monitored by a k-type thermocouple.

Friction and wear tests on EN8 & EN24 steel with Aluminium alloy 6061 were conducted in lubricated condition with varying one parameter at a time keeping other two parameters constant and variation of coefficient of friction and specific wear coefficient was observed under the defined operating parameters.

The test operating parameters were as follows:

- Temperature: 50 °C, 75 °C, 125 °C and 150 °C.
- Load: 40 N, 60 N, 80 N and 100 N.
- Speed: 1000 rpm, 1250 rpm, 1500 rpm and 1750 rpm.

Coefficient of friction (COF)

The behaviour of coefficient of friction on the tribo-pair on Aluminium alloy 6061 against EN8 & EN24 steel observed under lubricated conditions at various operating parameters is shown in **Fig. 3-5**. It was observed from **Fig. 3** that with the increase in speed from 1000 rpm to 1750 rpm while keeping load and temperature constant at 60 N and 50 °C respectively, coefficient of friction decreased linearly. The decrease in friction coefficient with the increase in speed may be due to the change in the shear rate which can influence the mechanical properties of the mating materials. The strength of these materials is greater at higher shear rates which results in a lower real area of contact and a lower coefficient of friction under lubricated condition.

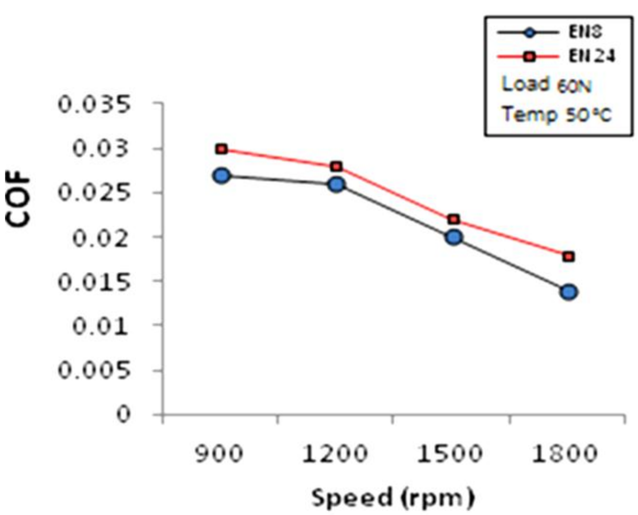

Fig. 3. Coefficient of friction vs. speed at constant load & temperature for EN8 & EN24 steels.

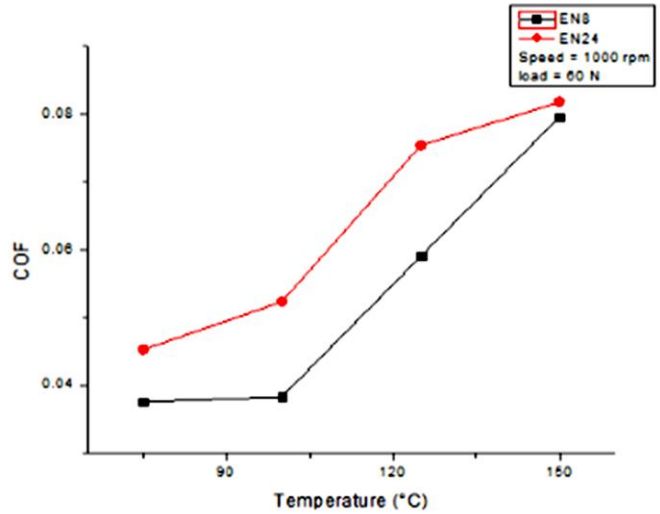

Fig. 4. Coefficient of friction vs. temperature at constant load & temperature for EN8 & EN24 steels.

Fig. 4 shows the variation of COF with temperature keeping other two parameters i.e. speed and load constant at 1000 rpm and 50 N respectively. It was observed that for the range of 75-100 °C there was not much change in the coefficient of friction and with the increase in temperature from 100 °C to 150 °C the coefficient of friction increases suddenly. The reason for variation in the coefficient of friction is due to the decrease in the viscosity of lubricant at higher temperature and also the strength of the material decreases by increasing the temperature.

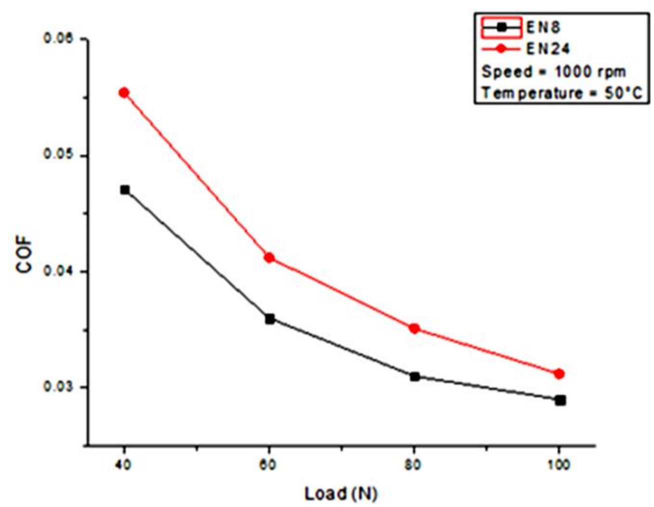

Fig. 5. Coefficient of friction vs. load at constant load & temperature for EN8 & EN24 steels.

Fig. 5 shows the variation of COF with load, keeping the other two parameters i.e. speed and temperature constant at 1000 rpm and 50 °C respectively. It was observed that with increasing the load the coefficient of friction decreased continuously. This is due to the fact that with increased load, large quantity of wear debris accumulated in the contact zone and got mixed with lubricant which acted as third body. Hence three body abrasive wear mechanism was responsible for the decrease in friction coefficient. From the comparison, it was concluded that with the variation in load, the coefficient of friction of the EN24 alloy is always greater than the coefficient of friction of EN8 steel. When Friction is the main criteria of the energy loss the tribo-pair of EN8 and Al 6061 is preferred over tribo-pair of EN24 and Al6061.

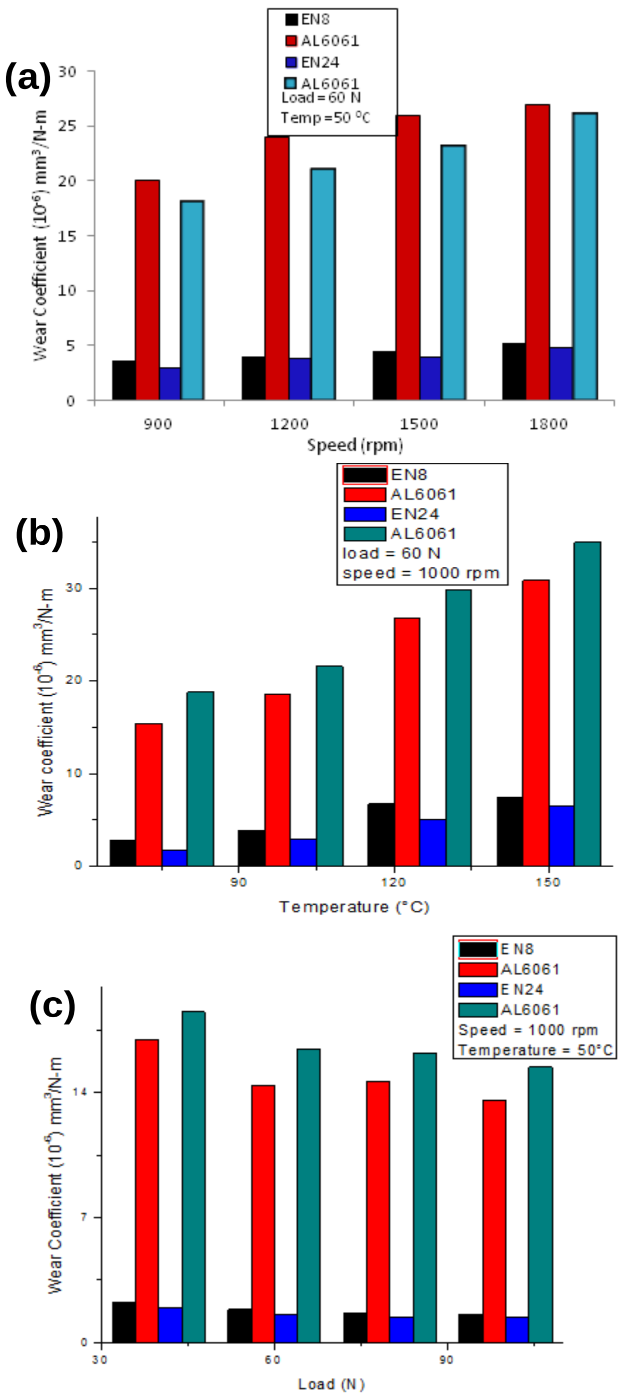

Fig. 6(a). Specific wear coefficient vs. speed for Al 6061/ EN8 and EN24 tribo-pair, (b) Specific wear coefficient vs. temperature for Al 6061/ EN8 and EN24 tribo-pair. (c) Specific wear coefficient vs. load for Al 6061/ EN8 and EN24 tribo-pair

Wear measurement

Wear Coefficient was measured by using Archard's Wear Model. Wear coefficients was acquired by a wear mass loss, which was measured by weighing the samples before and after each of the wear tests with high precision digital balance. Density of the material was used to calculate the wear volume in mm^3. Wear of disc and pin was calculated, in terms of specific wear coefficient (K_w), which is obtained by Archard's wear model Eq. (1) given below [**8**].

$$K_W = \frac{V_W}{D_S \times P} mm^3/Nm \qquad (1)$$

where, V_w is the wear volume (mm^3), D_s is the sliding distance (m) and P is the normal load (N).

It was found from the bar chart that the wear coefficient increased with increase in the speed from 900 to 1800 rpm keeping the load and temperature constant. It is evident from the **Fig. 6**(**a**) that wear coefficient of EN24 is less than the wear coefficient of EN8 steel under these conditions of varying speed. Under varying speed the life of tribo-pair consisting of EN24 steel is more suitable in comparison to EN8 steel from wear point of view. Also, the wear coefficient of the pin is greater for the tribo-pair of EN8 and Al 6061 in comparison to EN8 and Al 6061. Similar behaviour was found when the temperature and load was varied keeping other two parameters constant as shown in **Fig. 6**(**b**) and **Fig. 6**(**c**). It was found that the wear coefficient of EN24 steel was always less than the wear coefficient of EN8 steel.

Conclusion

Results showed that coefficient of friction and wear coefficient were affected by the variation of temperature, speed and load. Conclusion obtained from this study can be summarized as follows:

1. The coefficient of friction increased with increasing the temperature and decreased with load and speed under lubricated condition. The coefficient of friction of EN8 steel is lower than the coefficient of friction of EN24 steel when used as a tribo-pair with Aluminum alloy 6061 under the specified operating parameters.
2. Wear coefficient always increased with increase in the temperature. The wear coefficient of EN8 steel is higher than the wear coefficient of EN24 under each operating parameter, and aluminum alloy 6061 had greater wear coefficient when it is used with EN24 steel as a tribo-pair.
3. Wear volume of the tribo-pair is always increased increasing in any of the operating parameter i.e. Load, Speed or Temperature. Wear volume or wear rate of EN24 steel is less than the wear rate of EN8 steel. This is because the hardness of EN24 steel is greater than the hardness of EN8 steel. Aluminum alloy 6061 had greater wear volume when used with EN24 steel.

Since our concern is on light weight design of engine and lower coefficient of friction for lower energy losses, therefore the above summarized result show that the EN24-Al 6061 tribo-pair is suitable for the engine where wear is the main criteria and EN8-Al 6061 tribo-pair be used where efficiency is the main criteria.

References

1. Sahoo, R. R.; Biswas, S. K.; *Tribol Lett.*, **2014**, *53*, 157. **DOI:**10.1007/s11249-013-0253-4
2. Vilaseca, M.; Molas, S.; Casellas, D.; *Wear.*, **2011**, *272*, 105. **DOI:** 10.1016/j.wear.2011.07.007
4. Ramesh, R.; Gnanamoorthy, R.; *Journal Of Material Processing Technology.*, **2006,***171*, 61. **DOI:** 10.1016/j.jmatprotec.2005.06.048
5. Feyzullahoglu, E.; Sakiroglu, N.; *Materials and Design.*,**2010**, *31*, 2532. **DOI:** 10.1108/00368791111154968
6. Ayatollahi, M. R.; Alishahi, E.;Shadlou, S.; *Int J. Fract.*, **2011**, *170*, 95. **DOI:**10.1007/s10704-011-9600-3
7. Amol, B.;*Wear.*,**2013**, *302*, 1568. **DOI:** 10.1016/j.wear.2013.01.016
8. Chowdhury, M. A.; Khalil, M. K..; Nuruzzaman, D. M.; Rahaman, M. L.; *International Journal of Mechanical & Mechatronics Engineering, IJMME-IJENS* **2011**, *11*, 43. **DOI:**10.1.1.369.1903
9. Gwidon, W.S.; Andrew, W.B.; *Engineering Tribology*, Butterworth-Heinemann: U.K, **2010** **DOI:**10.1016/S0301-679X(01)00041-X

