Tribological behavior of Clutch Plate Material in Laboratory Simulated Conditions

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Abstract- A Clutch is a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft. While riding the clutch, it simply means keeping the clutch pedal, fully, or partially pressed down. Hence, the pressure on the pad is creating a huge amount of friction which will very quickly produces the wearing in Clutch plate material. The concept is to understand material behavior and wear and friction criteria. The clutch plate is made of material usually of Grey Cast Iron with Asbestos used as Friction Lining Material. In this research, an attempt is made to try out Composite material clutch plate. Composite are of polymer, ceramic and metal matrix type. The use of composites is motivated because of good friction co-efficient and wear resistant properties. The aim of this present work is to identify a heat resistant clutch material for optimum friction coefficient (µ) and to decide a perfect composite material which has low wear rate at different temperature, load and velocity conditions. The Clutch Plate is modelled and analyzed using Creo and FEA software. The Experimental investigation of plate is done by Pin on Disc Apparatus for validation of wear rate and Friction Co-efficient.

Key words: Clutch Plate, Wear Rate Analysis, Pin on Disc Setup.

I. INTRODUCTION

Wear is damage to a surface as a result of relative motion with respect to another substance. One key point is that wear is damage and it is not limited to loss of material from the surface. However, loss of material is definitely one way in which apart can experience wear. In the older definitions of wear there used to be a greater stress on the “loss of material” Wear causes an enormous annual expenditure by industry and consumers. For some industries such as agriculture, as many as 40% of the components replaced on equipment’s have failed by wear. Estimates of direct cost of wear to industrial nations vary from 1% to 4% of GNP and it is estimated that 10% of all energy generated by man is dissipated in various friction processes. Thus the magnitude of losses caused to mankind (which can be expressed in percentage points of GDP) makes it absolutely necessary to study ways to minimize it. Thus minimizing wear, affects the economics of production in a major way

A clutch mainly consists of two parts, i.e. friction plates and separator plates. These plates engage and disengage to transmit speed and torque. The transmitted torque is proportional to the overall friction coefficient of the clutch plates. The friction behavior of clutch plates is critical for overall performance of the transmission and it depends on the sliding velocity, the normal pressure, the lubrication, the temperature and the surface topography of the clutch plates. It is necessary to investigate the effect of surface topography on the friction behavior of the clutch plates. Study of various research paper, the surface characteristics of clutch plate materials have been investigated since it is closely related to friction[1]. describes Engagement characteristics of a friction pad for commercial vehicle clutch system[2]. analyze the effect of different material composition on friction & wear of Clutch Plate material[3]. the effect of load, Velocity of sliding and sliding distance on friction and wear of materials made of Polytetrafluoroethylene (PTFE) and PTFE composites[11].

In the present work the wear behavior of various clutch materials at different operating conditions is carried out using pin on disc apparatus. Additionally, the wear volume is calculated and hardness was carried out. Further finite element analysis of clutch plate was carried out.

II. EXPERIMENTAL DETAILS

Wear is a process of removal of material from one or both of two solid surfaces in solid state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys.[1]

Pin on disk wear testing is a method of characterizing the coefficient of friction, frictional force and rate of wear between two materials. As a particularly versatile method for testing wear resistance, pin on disk can be configured in multiple scenarios depending on the goals of your project. Pin on disk testing can simulate multiple wear modes, including unidirectional, bidirectional, omnidirectional and quasi-rotational wear. Our equipment allows us to test virtually any combination of materials to determine the effect of wear on a medical device.[3]

In this experiment, the test was conducted with the following parameters:
1. Load
2. Speed
3. Distance

| Parameters | Values |
|------------|--------|
| Specimen pinsize | Dia. 12mm & 30mm height |
| Wear Disc Size | Dia. 165 mm, 8 mm thick |
| Disc rotation | 1000 rpm |
| Sliding speed | 0.5 to 10 m/s |
| Normal load | 5N to 200N. In steps of 5N |
• **Pressure plate:**
The Pressure plate is generally made from grey cast iron (FG 300). Because of its high heat and wear resistant but its cost is too high. In this experiment, use Pressure plate Grey Cast iron Material properties & Chemical composition given below.[2]

### TABLE 1 MATERIAL PROPERTIES OF GREY CAST IRON

| Material and Properties           | Value  |
|----------------------------------|--------|
| Ultimate Tensile Strength (MPa)  | 1015   |
| Ultimate Yield Strength (MPa)    | 979    |
| Young’s Modulus (MPa)            | 2e^5   |
| Poisson’s Ratio                  | 0.29   |
| Density (kg/m^3)                 | 7850   |
| Elongation (%) [EL]              | <1     |
| Hardness (BHN)                   | 160 to 210 |
| Crack growth resistance (MPa m)  | 11-19  |

### TABLE 2 CHEMICAL COMPOSITION OF GREY CAST IRON

| No. | Material   | Composition |
|-----|------------|-------------|
| 1   | Silicon    | 0.4%        |
| 2   | Silicon    | 1.1%        |
| 3   | Phosphorus | 0.68%       |
| 4   | Manganese  | 4.2%        |
| 5   | Copper     | 0.5%        |
| 6   | Chromium   | 0.07%       |
| 7   | Nickel     | 0.02%       |
| 8   | Molybdenum | 0.007%      |

- **Al6061:**
  It has Good Strength in terms if Impact, Fatigue and Shearing. Good Machinability and Weldability. The material can be casted into desired shape and hence good actability. Good Corrosion resistant to corrosive environment. Good surface finish and wear resistant.

### TABLE 3 CHEMICAL COMPOSITION OF AL6061

| No.  | Material     | Composition     |
|------|--------------|-----------------|
| 1    | Aluminum Al  | 90.2499 – 94.9999 |
| 2    | Copper Cu    | 3.9 – 5.0       |
| 3    | Silicon Si   | 0.5 – 1.2       |
| 4    | Manganese Mn | 0.4 – 1.2       |
| 5    | Magnesium Mg | 0.2 – 0.8       |
| 6    | Iron Fe      | 0.0 – 0.7       |
| 7    | Titanium Ti  | 0.0 – 0.15      |
| 8    | Chromium Cr  | 0.1             |

- **Al7075:**
  Aluminium Alloy 7075 is one of the highest strength alloys available. It has Good thermal Shock resisting capacity, good impact and fatigue strength. It Good Corrosive to resistant.

### TABLE 4 CHEMICAL COMPOSITION OF AL7075

| No.  | Material  | Composition |
|------|-----------|-------------|
| 1    | Silicon Si| 0.40        |
| 2    | Iron Fe   | 0.50        |
| 3    | Copper Cu | 1.2-2.0     |
| 4    | Manganese Mn | 0.30   |
| 5    | Magnesium Mg | 2.1-2.9  |
| 6    | Chromium Cr | 0.18-0.28 |
| 7    | Zinc Zn   | 5.1-6.1     |
| 8    | Titanium Ti | 0.20       |

- **S-GlassFiber:**
  S-Glass is generally used for polymer matrix composites include, High production rates, improved mechanical properties compared to E-glass., High strength, High stiffness. Relatively low density, Non-flammable, Resistant to heat.

### TABLE 4 CHEMICAL COMPOSITION OF S-Glass FIBER

| No.  | Material         | Composition |
|------|------------------|-------------|
| 1    | Silicon dioxide  | 65wt%       |
| 2    | Aluminum Oxide   | 25wt%       |
| 3    | Magnesium oxide  | 10wt%       |

- **CarbonFiber:**
  The use of this as the reinforcement material in polymer matrix composites is extremely common. Optimal strength properties are gained when straight, continuous fibers are aligned parallel in a single direction.

### TABLE 4 CHEMICAL COMPOSITION OF CARBON FIBER

| No.  | Material         | Composition |
|------|------------------|-------------|
| 1    | Silicon Oxide    | 54wt%       |
| 2    | Aluminum Oxide   | 14wt%       |
| 3    | Calcium Oxide    | 22wt%       |
| 4    | Boron Oxide      | 10wt%       |
| 5    | Sodium Oxide     | 2wt%        |
• Loading Conditions:

Load in Kg (W) = 2kg
The Load has been considered just to verify the suitability of trials on the different composite materials. The Composites are lighter in weight hence considering the same point the load has been considered.[3]

Hence Normal Force can be said as,
Normal Force (F_N) = 19.62 N

Disc Rotation (N) = 1000Rpm.
The Speed of the disc has been selected on the basis of regular speed of engine clutch. The Regular speed is about 1000-2000 Rpm. The Engagement speed is 2000 Rpm hence to ensure the safety, 1000 Rpm speed has been considered.[4]

Sliding Velocity:
The Sliding Velocity can been given as , 
V_S = \pi D_S N / (60 * 1000)
Where, 
Ds = Sliding phase diameter = 100mm

Hence, 
V_S = 5.23 m/s

• Experimental Calculations:

1. Volume loss (V): The volume loss is actually the remaining material of pin which is left after the worn out of the pin. The Volume is the loss material of the pin which can be mathematically given as,[7]

\[ V = \frac{A H_2}{2} \text{ mm}^3 \]  

2. Wear rate: The wear rate per unit sliding distance in the transient wear regime decreases until it has reached a constant value in the steady-state wear regime. Hence the standard wear coefficient value obtained from a volume loss versus distance curve is a function of the sliding distance.[7]

\[ \text{Wear rate} = \frac{\text{Volume loss}}{\text{Sliding distance}} \text{ mm}^3/\text{Nm} \]  

3. Wear resistance: When material generally offer good resistance to sliding and impact abrasion, increases the hardness and toughness of the steel, making it an ideal material for applications that require high impact or high abrasion resistance.[7]

\[ \text{Wear resistance} = \frac{1}{\text{Wear rate}} \]  

4. Specific wear rate: At each loading condition, the wear rate is different. Hence the wear rate at particular loading condition is called as the Specific Wear rate. In can be defined as the ratio of wear rate to acting load. It can be given as,[7]

\[ \text{Specific wear rate} = \frac{\text{Wear rate}}{\text{Load}} \]  

5. Coefficient Of Friction: The coefficient of friction is ratio of frictional force to normal load.[7]

\[ \mu = \frac{F}{F_N} \]

• Experimental Process:

Clean and dry specimen and disc using solvent. Weight Specimen and disc individually on weighing scale having accuracy 0.1 mg .Insert disc on fixture and tightens screws from sides to clamp, ensure the perpendicularity within +1 dig to the axis of rotation. Insert Specimen to jaw holder, ensure it is sitting properly and tighten two jaws to hold ball and tighten jaws to specimen holder .Switch on controller, allow 5 min for normalizing the display on controller. Press test start push button on controller after setting 10 min time on timer display, rotate speed knob till 60 rpm is displayed, ensure the speed is constant at 60, then press stop button. Press zero button of normal load,

frictional force and wear on controller.Open software on pc, select a new file, enter test parameters and sample id on screen and click on start icon to activate screen to receive data. Add 2 kg dead weight on loading pan to apply normal load .Set timer to 30min to achieve 1000mt sliding distance. Begin test by pressing on start push button, record the room temperature and relative humidity. Test stop after completion of test duration. Remove specimens , clean off loose wear debris , note the existence of feature on or near the wear scar such as :protrusions , displaced metal , discolorations, micro – cracking or spotting Weight the specimen and record the loss in weight .The loss in weight is negligible , alternately volume loss may be measured On the bottom disc no wear is observed
III. RESULTS AND DISCUSSION

3.1 Wear Volume:
Wear Volume is the volume which is lost by the material after rubbing of pin. This is actual weight lost by the material.[14]

Wear Volume can be determined as by,

\[ V_w = \frac{(W_1 - W_2)}{\text{Density}} \]

Hence for all the materials, wear can be determined as,

So as to determine the volume rate in mm³, the densities of materials are converted to g/mm³.

Hence forth the wear volume can be seen as follows,

| Material       | Initial Weight W₁ (gm) | Final Weight W₂ (gm) | Wear Volume (mm³) |
|----------------|-------------------------|----------------------|-------------------|
| Al6061         | 19.62                   | 18.97                | 240.7407          |
| AL7075         | 18.64                   | 17.23                | 470               |
| Carbon Fiber   | 10.22                   | 10.10                | 95                |
| S-Glass        | 10.91                   | 10.80                | 45.83333          |

From the experimentation results, it is clear that the polymer matrix composites shows better results as that of Aluminum Composites. The Aluminum Composites, also show better results. The Aluminum and polymer composites can be used as replacement for other friction lining materials so as to reduce the wear rate and also to increase the life of friction pads in case of clutch plates.

3.3 Hardness Analysis
The wear system is very important; the presence of corrosion or impact can have large influence on the relation between hardness and wear resistance. The relation between hardness and wear is actually inversely proportional. The Harder the material goes, the less the wear volume.

| No. | Material     | HardnessSh.D |
|-----|--------------|--------------|
| 1   | AL6061       | 81.8         |
| 2   | AL7075       | 82.9         |
| 3   | S-Glass Fiber| 92           |
| 5   | Carbon Fiber | 95           |

Hence from the table above, S-glass Fiber has highest amount of hardness amongst all and so the wear rate of S-glass fiber is less. So on if Aluminum composites are considered, it possess less hardness and hence the wear rate of aluminum composites are high.

3.4 Discussions:
- As per the experimentation, the wear rate of Carbon fiber and S-glass Fiber are the least. As well as the Aluminum composites are also up to better performance.
- The Wear Volume for Carbon fiber is validated for experimentation as well as the simulation.
- From experimentation as well as simulation, the difference in the results obtained are about 8%.
- Simulation always shows the results without considering any of the losses, hence it shows the theoretical results.
- The Experimentation knows the practical disabilities and hence shows the practical-actual results considering all the losses.
IV. SIMULATION APPROACH

a). Finite Element Analysis :
Simulation approach consists of considering the same test in Analysis software. For the Same Purpose, Ansys Version 18.1 is used. The analysis is done on Carbon Fiber Pin which is Rub on plate of Grey Cast Iron.

b). Validation with Experimental Results :
According to Simulation, The Deformation in the Length of Pin is 1.39mm. Consider it as, Deformed Length, L_d = 1.39 mm
Diameter of Pin, d = 10 mm
In such case, the Deformed Volume which is also the wear volume can be calculated as,
\[ V_w = \frac{\pi}{4} \times d^2 \times L_d \]
Hence according to Simulation, the wear volume can be stated as,
\[ V_w = 109.115 \text{ mm}^3 \]

V. CONCLUSIONS

In the present work the investigations of wear and friction characteristics of aluminum matrix and polymer matrix material for clutch plate is carried out on pin on disk apparatus under different testing conditions. It is observed that AL6061 shows very less coefficient of friction but wear volume is very high. As per requirement of clutch plate material S glass fiber shows significantly higher coefficient of friction i.e. about 0.2 and also it shows very less wear volume i.e. 45 mm\(^3\) compared to aluminum matrix. So it can be concluded that S Glass fiber can be used for clutch plate material.

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