IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Tribological Behaviour of Stainless Steel, Grey Cast Iron and Al2014 under Labrotary Simulated Conditions for Cam Follower mechanism

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Abstract: A. Cam is a mechanical device used to transmit motion to a follower by direct contact. The driver is called the cam and the driven member is called the follower. In a cam follower pair, the cam normally rotates while follower may translate or oscillate. The cam is a rotating part that provides reciprocating or oscillating motion to the follower by direct contact. Jumping happens when cam rotates at critical speed above certain value. At jumping, the speed is so high that the follower does not follow the cam and we get a sound of different type. The Cam-Follower material should have good thermal conductivity, thermal resistance and withstand high contact pressures. Friction composites mainly consist of about ten classes of ingredients such as, binder, fibres, friction modifiers and fillers. The proper selection of cam profile is the most important aspect in a diesel engine, as it determines the magnitude of valve lift. Hence in this case study, the cam follower material of Grey Cast Iron is tested with Stainless steel and Al2014. The main objective of the research is to find the alternative material for Grey cast iron so as to reduce the weight and maintain the strength. Hence wear analysis is done on Tribometer for wear rate and wear volume analysis.

***Index Terms* – Impact Strength, Polymer Composite Materials, Natural Fibre Materials.**

I. INTRODUCTION

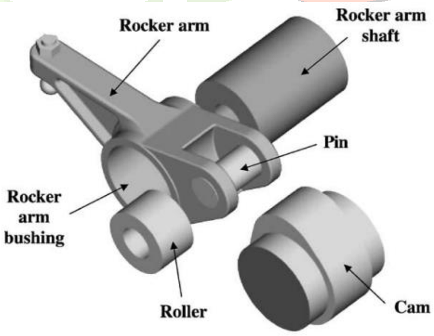


Figure 1. Cam Follower Mechanism [2]

A Cam is a mechanical device used to transmit motion to a follower by direct contact. The driver is called the cam and the driven member is called the follower. In a cam follower pair, the cam normally rotates while follower may translate or oscillate. [1] A familiar example is the crankshaft of an automobile engine, where the cams drive the push rods where push rods are followers to open and close the valves in synchronization with the motion of pistons. [1] Design of cam is difficult and tough job for a design engineer as each and every competitor in industry market always looks for the better performance of mechanical system. So, a designer has to look for objective of mechanism, where it can be used, suitable material, suitable dimensions and its calculations and the most important is to how to apply the cam follower mechanism innovatively [1].

The engine performance is greatly influenced by the adjustment of valve lift duration during the cycle, which controls the flow rates into and out of the cylinder. The characteristics of valve lift motion are mainly determined by the geometry of the contact between the cam and the follower [8]. The proper selection of cam profile is the most important aspect in a diesel engine, as it determines the magnitude of valve lift. [8].

A Cam-follower pair under rolling-sliding contact conditions suffers from surface fatigue failures because of the repetition of contact load. This is characterized by pitting and spalling of the surfaces, and it rather occurs suddenly without any prior visible warning [8].

Figure 2. Pitting of Surface under Wear

When the surface fatigue wear occurs, the particles are removed and the resulting pits are relatively large, as shown in Figure 1.10 [8]. This is the failure of a surface manifested by breaking-out of small rough portions of the material surface. This failure is primarily due to high stresses causing fatigue failure at a point below the surface where the highest combined stresses occur. The heavily loaded surface will continue to pit with increasing severity under abusive operation [8].

The destructive nature of surface fatigue cracks increase due to high contact stresses and sliding action, constitutes a stress raisers and hastens the fatigue failure of follower surface. The surface flakes leave the parent surfaces and damaging the soft follower surfaces, Figure 1.11.

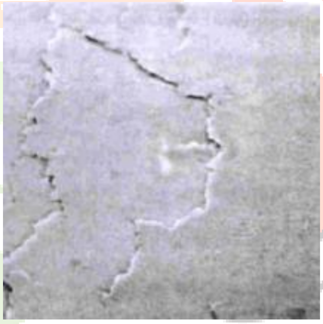


Figure 3. Surface Flaking under Cyclic Loading [8]

Polish Wear or Scuffing, as shown in Figure 1.12 is the general attrition of a contacting surface. Visually the surfaces have mirror finish appearance and the dimensional check quantifies the wear. This is the local welding of two heavily loaded surfaces, particularly when a high degree of relative sliding occurs under poor lubrication conditions, followed by tearing apart of the welded material. It particularly starts at highly stressed zones due to poor surface finish, and generally at running-in period of new parts [8].

II. Wear Requirement of Cam-Follower MATERIAL:

The Cam-Follower material should have good thermal conductivity, thermal resistance and withstand high contact pressures. Friction composites mainly consist of about ten classes of ingredients such as, binder, fibres, friction modifiers and fillers. Binder known as resin or matrix provides the mechanical integrity to the composite apart from contributing to the friction and wear. Fibres being multi-functional play a critical role in absorbing stresses generated at the mating interfaces, while simultaneously retaining the integrity of the composite at elevated temperatures and influencing wear also.

Figure 4. Worn-out Cam

Friction modifiers are added to moderate them and to minimize its fluctuations. The category of fillers is again subdivided as functional fillers (to enhance the specific function, such as resistance to fade, porosity, thermal conductivity, etc.) and space inert fillers (mainly to cut the cost).Among various fillers, metallic fillers are important in friction materials (FMs), since they control the conductivity of composites apart from additional functions, such as: wear resistance; strength, etc.

III. Objectives of Study:

The Present Work is undertaken to accomplish the following Objectives:

- To study different loading constraint subjecting to wear for Cam Mechanism.
- To study the failure of cam material under Wear rate Investigation.
- To understand Tribological Properties of cam-follower Material using laboratory scale experiment.
- To fabricate a perfect composite material having low wear rate at different temperature, load and velocity conditions.
- Wear Analysis is to be carried out.

IV. Fabrication of Specimen :

Figure 5. Sample Specimen of Grey Cast Iron, Stainless Steel

- The Cam with Followers are made of cast iron material which is specially used for casting purpose. For casting, there are many factors to be considering for better result such as material properties, mechanical properties, chemical composition, fluidity, boundary clearance, thermal properties etc. The current Cam Joint is made of Grey Cast Iron.
- The automobile Bearing is used for Stainless Steel. Stainless steels are notable for their corrosion resistance, which increases with increasing chromium content. Molybdenum additions increase corrosion resistance in reducing acids and against pitting attack in chloride solutions. Thus, there are numerous grades of stainless steel with varying chromium and molybdenum contents to suit the environment the alloy must endure.
- Al 2014 Alloy is an aluminium-based alloy often used in the aerospace industry. It is the second most popular of the 2000 series aluminum alloys, after 2024 aluminum alloy. It is commonly extruded and forged. The corrosion resistance of this alloy is particularly poor.

V. EXPERIMENTAL SETUP FOR WEAR TESTING

- 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.
- In this experiment, the test was conducted with the following parameters:

i. Load

ii. Speed

iii. Distance

Figure 6. Sample Specimen of Grey Cast Iron, Stainless Steel

Table 1. Setup Specifications and Testing Conditions

Parameters	Values
Manufacturer	Dulcom
Type	Rotary and Reciprocating
Specimen pin size	12 dia. & 35 mm long
Specimen Holder	Diameters of 4 to 20 mm
Wear Disc Size	Dia. 165 mm, 10 mm thick
Disc rotation	Min 1000 Rpm, Max - 2000 rpm
Sliding Velocity	0.5 to 10 m/s
Normal load	3 to 5 Kg, 29.43 to 49.05 N
Frictional Force	0N – 200N
Total Weight of Setup	235 Kg.
Motor	0.3 hp

Figure 7. Variations in Graph of Frictional Force and Co-efficient of Friction

- 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.
- 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.

VI. Loading Conditions :

Load in Kg (W) = 3 kg

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.

Hence Normal Force can be said as,

Normal Force (FN) = Load x 9.81 = 29.43 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.

Sliding Velocity:

The Sliding Velocity can been given as,

$VS = (\pi DsN)/(60*1000)$

Where.

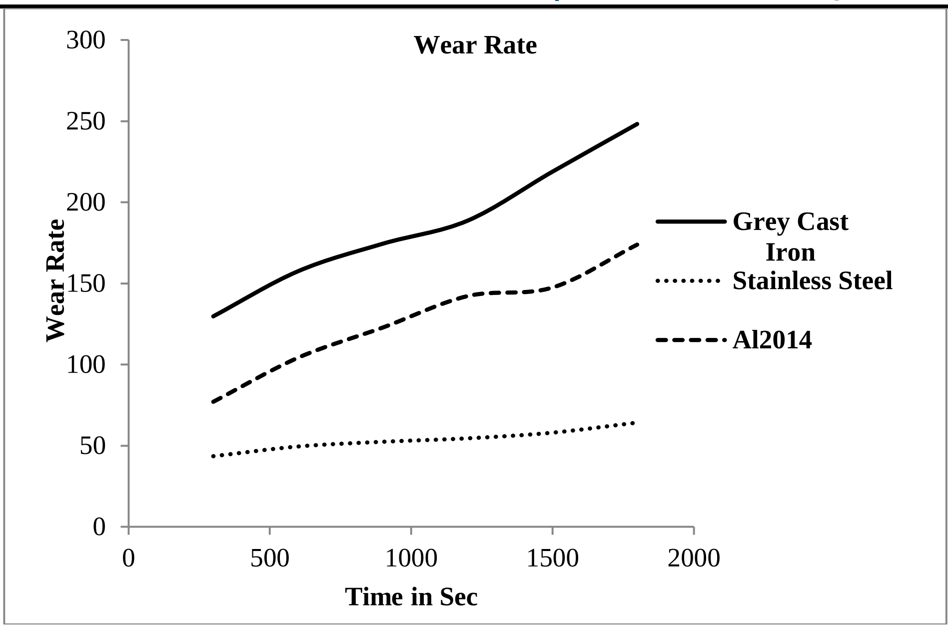
Ds = Sliding phase diameter = 80mm

Hence, VS = 4.18 m/s

VII. Result And Discussion :

7.1. Wear Rate Analysis :

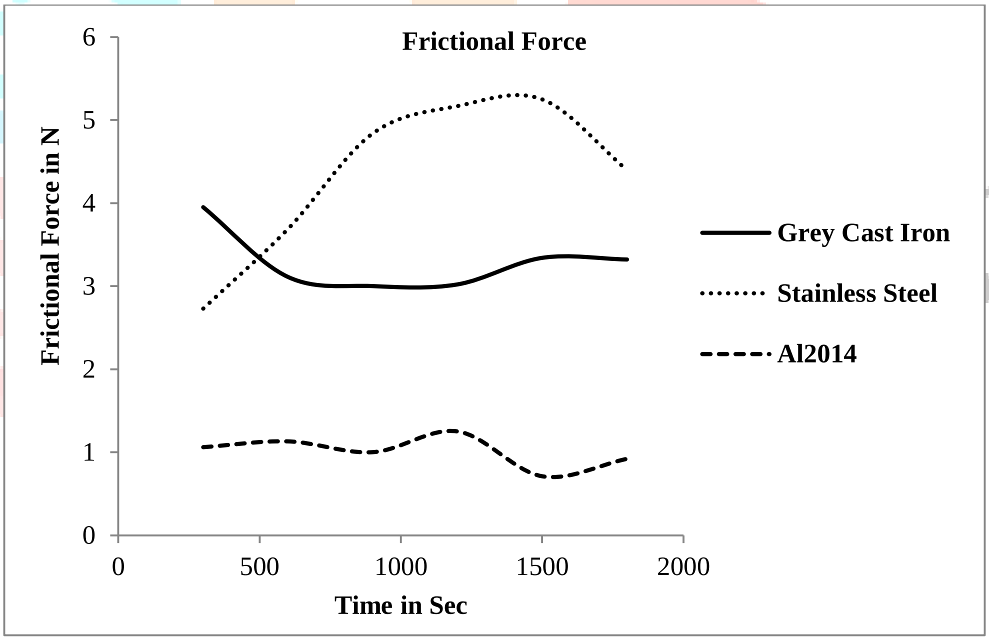
Wear rate is volume loss per unit distance and its unit is (m^3/m). It is independent of load applied. Specific wear rate depends on applied on to cause wear; it is volume loss per unit meter per unit load. Its unit is (m^3/Nm). The readings are selected for 30 minutes and the recordings are done for every five minutes (300 Seconds)



Graph 1 Experimental response for Wear Rate Analysis

The wear rate for all the material is been described with respect to time. The Wear rate for Stainless steel proves to be the one with the lowest wear rate with respect to time. The Sample of Grey Cast Iron started wearing for a higher rate for and goes on proceeding with respect to time. The Wear rate Al2014 also finds lower than Grey Cast Iron.

7.2. Frictional Force :



Graph 2 Experimental response for Frictional Force

Frictional Force refers to the force generated by two surfaces that contacts and slide against each other. These forces are mainly affected by the surface texture and quantity of force requiring them together. The angle and position of the object affect the volume of frictional force. The material was tested on the setup for, 300minutes. The readings were calculated after each 300 second or 5 mints. The display gives the results for Frictional force. The Frictional Force is determined for all the readings. Frictional Force refers to the force generated by two surfaces that contacts and slide against each other.. The graph describes the generation of frictional force which will create the maximum resistance on the surface on which the material is mating. Stainless Steel explains the high generation of frictional resistance with respect to other materials. The Grey Cast Iron material started with High frictional force and with respect to time, the force resistant maintained a constant rate. The Frictional Force generated for Al2014 found to be the lowest. The Frictional force, in the start in case of Stainless was profound but later one goes on increasing and parallel with respect to Al2014 and Grey Cast Iron.

7.3. Co-Efficient of Friction

A coefficient of friction is a value that shows the relationship between two objects and the normal reaction between the objects that are involved. It is a value that is sometimes used in physics to find an object's normal force or frictional force when other methods are unavailable.

Mathematical the co-efficient of friction can be given as,

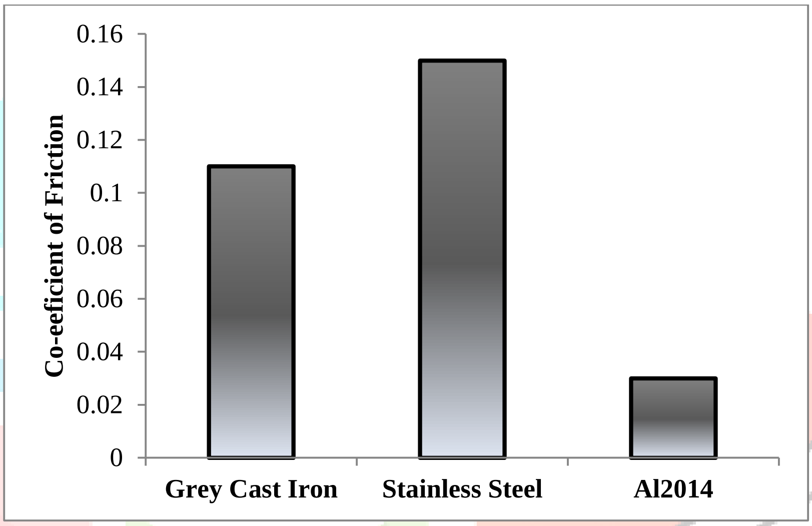
$\mu = F / F_n$

Where,

F = Frictional Force in Newton (From observation table 3.7)

F_n = Normal Load in N, = 29.43 N.

The material was tested on the setup for, 300minutes. The readings were calculated after each 300 second or 5 mints. The display gives the results for Frictional force. The Frictional Force is determined for all the readings. The Table 3.9 shows the co-efficient of friction for different material under different testing conditions.



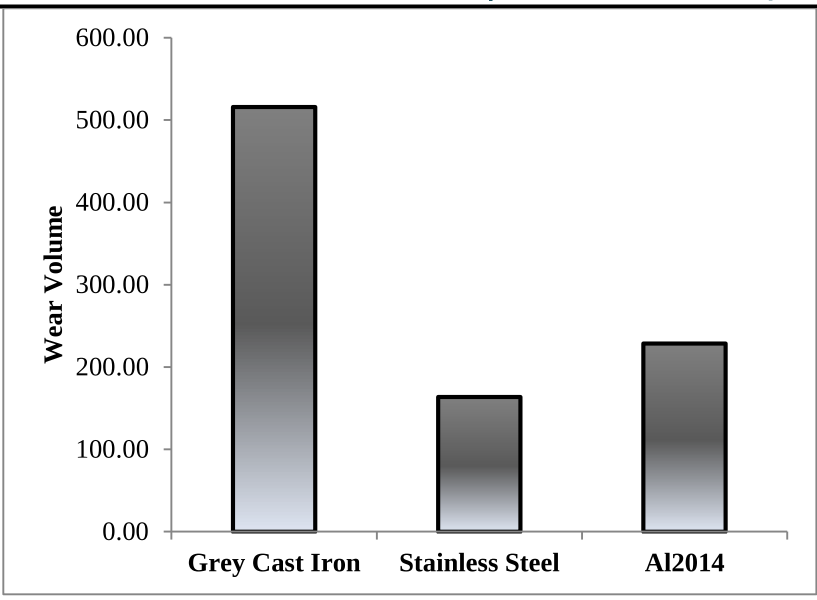
Graph 3 Response analyses for Co-efficient of friction

Coefficient of friction is defined as the ratio of the force required to move tow sliding surfaces over each other, and the force holding them together Coefficients of friction range from near zero to greater than one. Lower the co-efficient of friction, better the material for production of less friction. The material of Al2014 generated less amount of Co-efficient of friction whereas the COF in case of Stainless Steel is found to be largest. The COF of Grey Cast iron is found less than Stainless steel but more than Al2014.

7.4. Experimental Wear Volume :

The volume loss is actually the remaining material of pin which

is left after the worn out of the pin. Wear volume is calculated using the initial and after weight of specimen after each 30 minute. The weight of specimen is calculated using the load cell arrangement.



Graph 4 Response analyses for Experimental Wear Volume

Wear volume is actually the amount of loss of the material in the tribological test after a specific period of time or interval. The wear Volume for Stainless Steel is lowest amongst all the samples. Due their low density and good wear resistant property, the Al2014 also gives less wear out during the experimental test as compare to Grey Cast Iron. The volume of weight loss for Grey Cast Iron is comparatively larger due to undine's nature and composition.

VIII. CONCLUSIONS

- The Experimentation is done on three different pins for material Stainless Steel, Grey Cast Iron and Al2014.
- The Tribological Investigation for all the materials shows the result & calculations for wear Volume, Co-efficient of friction and Frictional Force.
- With respect to the Wear Rate, the alternatives of Al2014 composites showed the better results as that of Grey Cast Iron. But still amongst all stainless steel were found to be lowest.
- The co-efficient of friction is been calculated with respect to the experimental results of Frictional Force. The Least the value of Co-efficient of friction is determined from Al2014
- In all the process, Al2014 shown the best possible results amongst all as that of other material and stainless steel.
- A Successful approach is determined for determination of Frictional resistance for Aluminium Composite materials. The attempt can be successfully implement in case of Cam and Follower so as to increase the life and weight. The weight reduction of component can be vital factor in cost reduction.

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