Importance of Tribology in Internal Combustion Engine: A Review

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Abstract - *This paper presents studies related to engine tribology in internal combustion engine. Friction loss is the main portion (48%) of the energy consumption developed in an engine. Lubricants are used to reduce the friction and wear and fuel consumption, increased power output of the engine, reduced oil consumption, a reduction in exhaust emissions in the engine. From the Analysis of the tribologist this means increasing specific loads, speeds and temperatures for the major frictional components of the engine, namely, the piston assembly, the valve train and the journal bearings, and lower viscosity engine oils with which to lubricate them. The literatures revealed that the most important parameter in the engine is lubricant, speed and load and with help of many different methods like blending the engine oil, remove the compression ring , additives are added to engine oil and analysis of piston ring assembly it can get the control on to the friction and wear and achieve almost all the objective that mention above.*

Key Words: *Engine, Tribology, Friction, Lubricant, wear*

1. INTRODUCTION

1.1 AUTOMOBILE ENGINE

The motor car is one of the most common machines in use today, and it is no exaggeration to state that it is crucial to the economic success of all the developing and developed nations of the world and to the quality of life of their citizens. The motor car itself consists of thousands of component parts, many of which rely on the interaction of their surfaces to function. There are many hundreds of tribological components, from bearings, pistons, transmissions, clutches, gears, to wiper blades, tires, and electrical contacts. The application of tribological principles is essential for the reliability of the motor vehicle, and mass production of the motor car has led to enormous advances in the field of tribology. For example, many of the developments in lubrication and bearing surface technology have been driven by requirements for increased capacity and durability in the motor industry. For the purpose of classifying the tribological components, one can divide the motor vehicle into engine, transmission, drive line, and ancillaries such as tires, brakes, and windshield wipers. [14, 16]

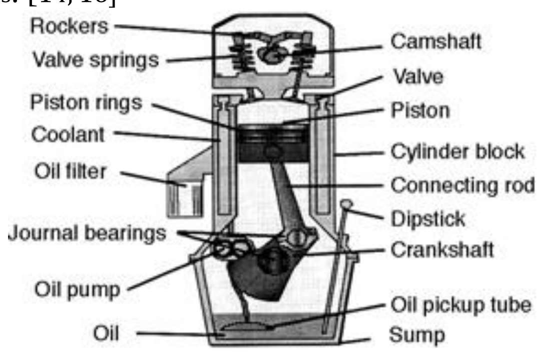

Fig 1 Main engine components in a reciprocating internal combustion engine

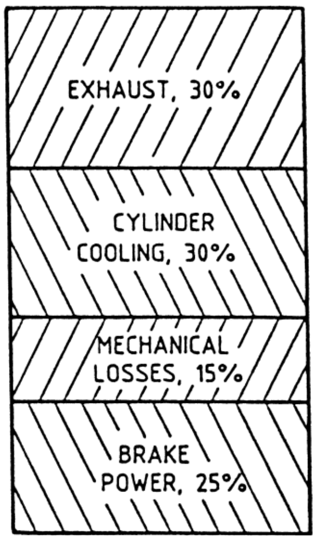

Fig 2 Typical fuel energy distribution in an internal combustion engine

1.2 TRIBOLOGY

1.2.1 What is Tribology?

Tribology comes from the Greek word, "**tribos**", it meaning is "rubbing" or "**to rub**" And from the suffix, "ology" means "the study of" Therefore, Tribology is the study of rubbing, or "the study of things that rub". [21, 22]

1.2.2 Definition:

Tribology is the science and technology of interacting surfaces in relative motion (and the practices related thereto), including the subject of friction, wear and lubrication. [23]

This includes the fields of:
- Friction,
- Lubrication
- Wear

FRICTION

When one solid body is slid over another so there is a some resistance to the motion which is called friction. Considering friction as a nuisance, attempts are made to eliminate it or to diminish it to as small a value as possible. No doubt a considerable loss of power is caused by friction (e.g. about 20% in motor cars, 9% in airplane piston engine and (1 ½ -2) % in turbojet engines) but more important aspect is the damage that is done by friction – the WEAR or SEIZURE of some vital parts of machines. This factor limits the design and shortens the effective working life of the machines. [22, 34]

LUBRICATION

It is evident that lubrication is required to minimize sliding friction in complete bearings. An additional function of the lubricant is to act as a protection for the accurately-ground and highly-polished surfaces of the balls, rollers and rings. If free moisture is allowed to contact the bearing elements, corrosion and pitting will follow and the bearing life will be considerably shortened. At the same time, a suitable lubricant should prevent the entry of external contaminating matter in the form of dirt or abrasive dust. [25]

WEAR

Wear is the actual removal of surface material due to the frictional force between two mating surfaces. This can result in a change in component dimension which can lead to looseness and subsequent improper operation. The adhesion mechanism of friction enables us to understand the basic mechanism of metallic wear, when a junction shears during sliding it may shear in one or other of four ways. It produced by the processes of abrasion, adhesion, erosion, tribochemical reaction and metal fatigue. [22]

1.2.3 TRIBOLOGICAL PROPERTIES:

In characterization of tribology, the friction & the wear can expressed as a function of temperature, additive concentration, normal load or cycle time separately. Although by plotting the stribeck curves for friction coefficient & wear scar diameter as a function of all rotation speed, viscosity & normal force. [21]

1.2.4 TRIBOSYSTEM:

Tribosystem consists of six elements .they are two contacting parts (base objects and opponent body), environment condition, intermediate materials, load & motion. Humidity, environmental temperature & pressure are the main environment condition.[21]

2 LITERATURE REVIEW

Ashkan Moosavian et al. (2016) [1] in this paper's study the effects of piston scuffing fault on engine performance and vibrations are investigated in an internal combustion (IC) engine ran under a specific test procedure. Three-body abrasive wear mechanism was employed to produce piston scuffing fault it caused the engine performance to reduce significantly. According to Continuous wavelet transform (CWT) analysis ''dmey'' wavelet, piston scuffing fault appeared in the scales of 7–14 (frequency band of 2.4–4.7 kHz) and more at the scale of 9 (frequency of 3.7 kHz)

P.C. Mishra et al. (2014) [2] in this paper's study the piston compression ring tribology and the theoretical and experimental works developed to analyze ring liner contact friction. Because of micro conjunction effect The friction is comparatively less in case of a rough liner 80 % Power Loss is in compression and power stroke together of total power loss in an engine cycle. Broad literature survey is carried out in the research area of piston compression ring to know about the simulation and experimental methods developed to study its performance.

Dr. D. V. Bhatt et al. (2014) [3] Measure the Piston Ring Assembly friction by the measuring the ''Power consumption'' under the different operating parameter like speed and lubricant on a motorized multi cylinder engine test rig. Initially the power consumption is reduces till 900 rpm but then it increases with increase in speed of the engine and lubricants properties varies with different manufacture.

Santhalia and Kumar (2013) [4] studied the effect of compression ring profile on friction force of Internal combustion engine. Three different ring profiles were selected and analyzed of ring film thickness, the ring twist angles, the friction force and the friction coefficient using Secant method, for the compression ring. Hydrodynamic lubrication occurs for most part of the stroke except at the dead center where mixed lubrication regime was found due to reduced film thickness resulting in increased friction force

Dr. D. V. Bhatt (2013) [5, 32, 34] have used Sewing machine oil as blend oil in the Castrol GTX oil for oil analysis on the four ball tribotester. The coefficient of friction, wear scar diameter and frictional torque these parameters are measured with five different blending ratios two different loads and of oils. Coefficient of friction decreases and Wear scar diameter increases with the increases of the blending ratio of oil.

P.C. Mishra (2013) [6, 28] have used a four stroke four cylinder engine is modeled for lubrication performance. The detailed parameters related to engine friction and lubrication is computed numerically for the 1-3-4-2 engine firing order. To avoid friction and subsequent wear, the liner surface is textured with cross h pattern and the ring is coated with thermal and wear resistant coatings.

Dr. D.V. Bhatt et al. (2013) [7, 31] added Titanium dioxide and P25 additives to re-refined base oil and the friction and wear characteristics were examined at a constant applied load and rate of reciprocation using reciprocating pin-on-disk apparatus. From this investigation it was found that the nanoTiO2 particles addition to the base oil slightly reduced the coefficient of friction.

N. Morris et al. (2012) [8] compared an analytic solution to the average flow model is presented for this contact with a new analytical thermal model. Analysis carried out here corresponds to a typical cylinder of a V12 engine with an output power of 510 BHP. The combustion pressure variation piston sliding speed for engine speeds of 2000 and 6000 rpm respectively .These parameters are analyzed and compare between isothermal and thermal condition.

Murat Kapsiz et al. (2011) [9,24,26] In this paper's study The Taguchi design method with three process parameters sliding velocity, applied load and oil type was applied to optimize the reciprocating wear test for different commercial oil conditions of cylinder liner (CL)/piston. It was observed that the interactions between the control factors do not have significant influence on the weight loss and friction of the CL and PR pair.

D V Bhatt (2011) [10] in this paper's study paper reports a set of experiments were carried out on developed experimental setup at laboratory scale to measure PRA friction of multi cylinder 800 cc engine system indirectly by measurement of power consumption by Strip Method with variable frequency drive (VFD) is used to vary the engine speed. Frictional power loss contribution by individual piston ring varies under different speed.

Mishra et al. (2008) [11] studied the compression ring tribology at the vicinity of top dead center in Compression and power stroke transition. The aim is to attain full fluid film lubrication, thus reducing friction because of boundary interactions.

George et al. [2007] [12] predicted and compared their results with results from other semi-empirical models. In early studies, the squeeze film effect was neglected and a simplified hydrodynamic lubrication theory was applied to predict the oil film thickness. The model proposed by the authors considers that the complete ring pack can be reduced to a set of several compression rings and one twin-rail oil control ring. Each rail of the oil control ring is manipulated as a separate single ring. For the simulation of the oil film action between the piston ring and the cylinder liner, the one-dimensional Reynolds equation is used, considering sliding and squeeze ring motion.

Jaana Tamminena(2006) [13] used a commercial six-cylinder, medium speed diesel engine as a test engine to investigate the oil film thicknesses between the compression rings and the cylinder liner at different load conditions. The engine speed for all measurements was 900 rev/min.

Simon C.(2004) [14] In this paper 's study the current status and future trends in automotive lubricants including discussion of current and anticipated future requirements of automotive engine oils review the current standard ASTM (American Society for Testing and Materials) test methods for engine lubricants and other compilations of automotive standards.Overview of various lubrication aspects of a typical power train system including the engine, transmission, driveline, and other components to improve the efficiency and productivity.

Hugh Spikes et al. (2001) [15] this paper attempts to predict and discuss some of the many challenges facing fundamental research in tribology over the first twelve years based on extrapolation of existing trends, and then, more speculatively considering possible driving forces over subsequent decades. Applications of tribology become more disparate, extending from conventional engineering machines and manufacture to micro electro mechanical systems (MEMS) and hair conditioners, groups working in various areas may lose communication or interest in one another.

C.M. Taylor (1998) [16] In this paper's study Simulate and modeling the major frictional components of the automobile engine, that is, the bearings, the valve train and the piston assembly and Prediction of overall engine friction will be addressed and the specific issues of modeling of lubricant behavior and the role of surface topography touched upon for greater efficiency and reduced environmental impact.

Tateishi (1994) [17] has experimented to reduce piston ring friction losses by applying two-ring package instead of the standard three ring packages and by developing low viscosity engine oil, reduction in piston mass, piston ring width and piston ring tension. Reduction of piston ring tension and using two ring packages are effective in reducing piston ring friction and reduction of piston ring friction can contribute to reducing the fuel consumption by several percentages.

Wakuri et al. (1992) [18] developed a model to study IC engine piston ring friction. The instantaneous friction force of a piston assembly under firing engine conditions was measured by an improved floating liner method.

Zhou et al.(1988) [19] have proposed a model to simulate the effect of one dimensional roughness of the piston ring surface on lubrication and friction based on stochastic theory. The applications of the model to an actual diesel engine indicate that about 8.3%-9.4% increase in friction power loss can be expected when the rough surface (d = 0.6 μm) rather than the smooth surface is consider.

Sreenath & Venkatesh (1973) [20] in their analytical work have predicted the oil film thickness for a four stroke engine at full load and no-load conditions and have compared with the results of other researchers. The film thickness is predicted by solving Reynold's equation considering the "Squeeze film effect" at TDC and BDC where it is more significant. Full flooded lubrication is assumed for the entire stroke length.

2.1 Importance of Engine Tribology:

To reduce friction and wear, the engine tribologist is required to achieve effective lubrication of all moving engine components, with minimum adverse impact on the environment. This task is particularly difficult given the wide range of operating conditions of load, speed, temperature, and chemical reactivity experienced in an engine. [5, 33]

Improvements in the tribological performance of engines can yield:

• Reduced fuel consumption
• Reduced oil consumption
Increased engine power output
• A reduction in harmful exhaust emissions
• Improved reliability, durability, and engine life
• Reduced maintenance requirements and longer service intervals

It is interesting to consider where the energy derived from combustion of the fuel is apportioned in an engine. In a published paper, Anderson (1991) showed the distribution of fuel energy for a medium size passenger car during an urban cycle. Only 12% of the available energy in the fuel is available to drive the wheels, with some 15% being dissipated as mechanical, mainly frictional, losses. Based on the fuel consumption data in Anderson's publication, a 10% reduction in mechanical losses would lead to a 1.5% reduction in fuel consumption. The worldwide economic implications of this are startling in both resource and financial terms and the prospect for significant improvement in efficiency by modest reductions in friction is clear.[21, 29 ,30]

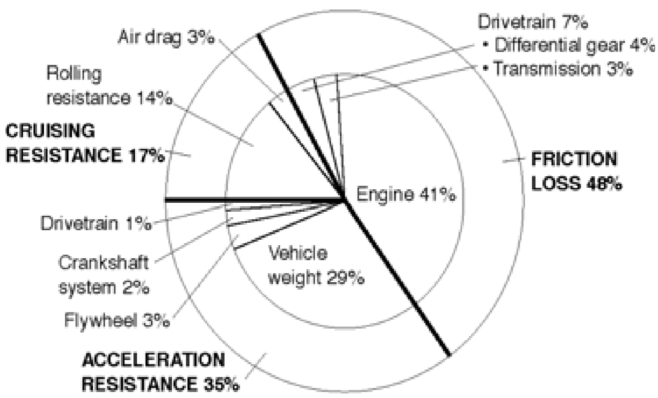

Fig 1 Energy consumption developed in an engine

Concerning energy consumption within the engine as shown in **Fig 1** friction loss is the main portion (48%) of the energy consumption developed in an engine. The acceleration resistance (35%) and the cruising resistance (17%) are the other portions. If one looks into the entire friction loss portion, engine friction loss is 41% and the transmission and gears are approximately 7%. Concerning engine friction loss only, sliding of the piston rings and piston skirt against the cylinder wall is undoubtedly the largest contribution to friction in the engine. Frictional losses arising from the rotating engine bearings (notably the crankshaft and camshaft journal bearings) are the next most significant, followed by the valve train (principally at the cam and follower interface), and the auxiliaries such as the oil pump, water pump, and alternator. The relative proportions of these losses, and their total, vary with engine type, component design, operating conditions, choice of engine lubricant, and the service history of the vehicle (i.e., worn condition of the components). Auxiliaries should not be overlooked, as they can account for 20% or more of the mechanical friction losses. For example, an oil pump in a modern 1600 cc gasoline engine can absorb 2 to 3 kW of power at full engine speed, while for a racing car this can rise to some 20 kW. [17, 21]

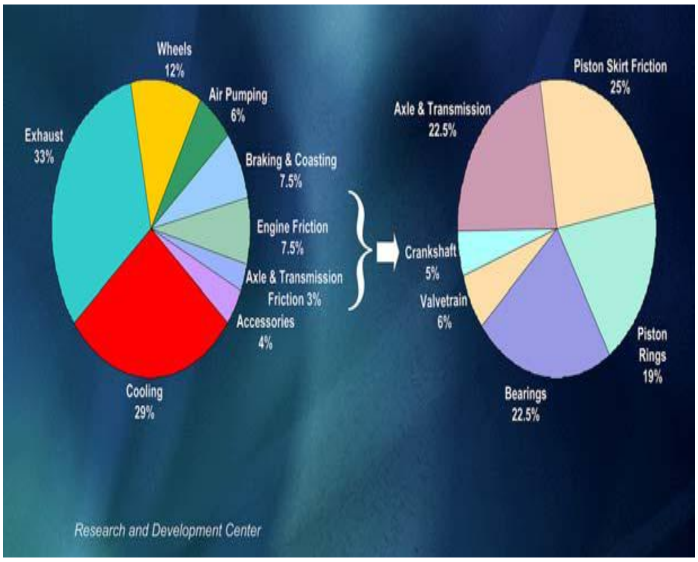

Fig 2- Distribution of energy consumption in a light-duty vehicle

Piston skirt friction, piston rings, and bearings is 66% of the total friction loss, and the valve train, crankshaft, transmission, and gears are approximately 34% In Engine friction loss. Concerning power train friction loss only, sliding of the piston rings and piston skirt against the cylinder wall is undoubtedly the largest contribution to friction in a power train system. Frictional losses arising from the rotating engine bearings (notably the crankshaft and camshaft journal bearings) are the next most significant, followed by the valve train (principally at the cam and follower interface), and the auxiliaries such as the oil pump, water pump and alternator. The relative proportions of these loss, and their total vary with engine type, component design, operating conditions, choice of engine lubricant and the service history of the vehicle, i.e. worn condition of the components. Auxiliaries should not be overlooked, as they can account for 20% or more of the mechanical friction losses.

3 CONCLUSION

A broad literature survey is carried out in the research area of engine tribology and in some research paper researchers conclude that in the area of piston compression ring to know about the simulation and experimental methods developed to study its performance. Many no. of experimental methods in compression ring is there in tribology.

In other research paper researches revealed that the temperature is increase and the viscosity of oil is decreases if the blend ratio of oil increases. It is found that 10 % blend oil shows the characteristic at higher load, while other oils of different percentage of blending oils are not shown good characteristics at higher load from the analysis of oil at both loads at 15 and 40 kg. It can be concluded that tribological performance is good in 10 % blend oil at 40 kg load.

Initially the power consumption is reduces till 900 rpm but then it increases with increase in speed of the engine. Same specified lubricants under different brand offers variation in PRA friction.

Referring the other research papers it can be conclude that Nature of curve of power consumption of PRA system with is in line with Stribeck curve nature, which means initially the system operates in boundary at 600 rpm or mixed lubrication condition at 900 rpm and later on after 900 rpm is mixed to hydrodynamic lubrication condition.

From other paper it can be conclude that if some additives like tio_2 and P25 are include in the oil than the coefficient of friction is slightly reduced because of the nanoTiO_2 particles but most importantly it stabilized it .It is might be due to its uniform film formation on the sliding surface.P25 increased coefficient of friction slightly and was higher than base for all the compositions. 0.25 wt% addition of TiO_2 to base oil.

From all this paper finally concludes that all the main reason of engine performance is depend on the wear and friction of the engine components so if lubrication is good than almost many problems is solved so lubrication is very important parameter in engine tribology.

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