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Analysis of Parametric Studies on the Impact of Piston Velocity Profile On the Performance of a Single Cylinder Diesel Engine

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Abstract: *in this project, attention is focused on studying the impact of the piston velocity profile on the thermodynamic, heat transfer and gas exchange processes of a single cylinder, 4-stroke diesel engine. The piston velocity profile dictates the rate of pressure rise during compression and the pressure drop rate during the power stroke. The other factors such as combustion characteristics, ignition delay, compression ratio, etc., are maintained constant and the engine performance is analyzed for different piston velocity profile. It is possible to obtain different piston velocity profiles by altering the connecting rod and crank mechanism. The sinusoidal piston velocity profile that is obtained with the existing connecting rod and crank mechanism has its own inherent disadvantages some of these disadvantages can be overcome by adopting new mechanism that can be alter the velocity profile. This report discusses one such mechanism in which the resultant velocity profile is trapezoidal instead of sinusoidal. Its impact on the performance of the engine is discussed in this report.*

I. Introduction

The most significant improvements in I.C. Engines have taken place in fuels, combustion chamber designs, valve train mechanisms, fuel injection mechanisms, emission control, etc. Thus, much attention has been focused on the zone above the piston and there have been relatively less improvements in the zone below the piston. The power produced by an engine takes place in two stages. The first stage involves the combustion and release of energy above the piston and the second stage involves the transfer of this energy into rotational energy of the drive shaft. In this paper, attention is focused on the second stage to achieve the objective of improving the overall efficiency of the engine. An innovative connecting rod and drive shaft mechanism is suggested to replace the conventional connecting rod and crank mechanism. This new mechanism will extract maximum energy from the gases during power stroke and will minimize the frictional losses in all the four strokes along with reducing heat loss from the engine.

Improvement Of Engine Efficiency

The performance of an I.C. engine can be improved by either increasing the Indicated power or by decreasing the frictional power. The alternate connecting rod and drive shaft mechanism proposed here accomplishes both simultaneously. The following sections discuss the types of frictional losses and some of the inherent drawbacks in the existing connecting rod and crank mechanism.

Reduction Of Frictional Losses

Frictional losses in the engine can further be classified into the following three types: (Figure 1)

1. Friction between piston and cylinder, which occurs during all the four strokes with different magnitudes.
2. Suction and pumping losses occurring during suction and delivery strokes.
3. Journal bearing friction.

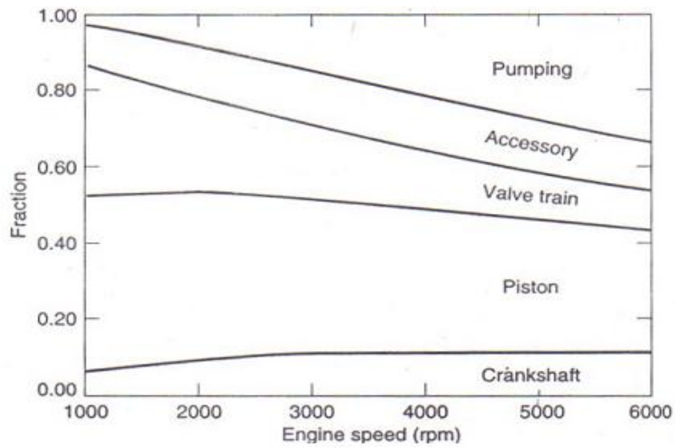

Figure 1. Fractional distribution of friction

Even though there are other frictional losses, they are minor in nature and cannot be minimized economically. The above-mentioned three frictional losses can be minimized to a considerable extent by suitable redesign. It is evident from figure 1 that the frictional losses caused by the rubbing force between the piston and cylinder contributes the biggest portion among the other sources of friction.

Friction between Piston and Cylinder

The cylinder friction between cylinder and piston is due to two factors:

- Sealing pressures of piston rings to prevent gas leakage.
- Rubbing force component due to inclination angle of oscillating connecting rod.

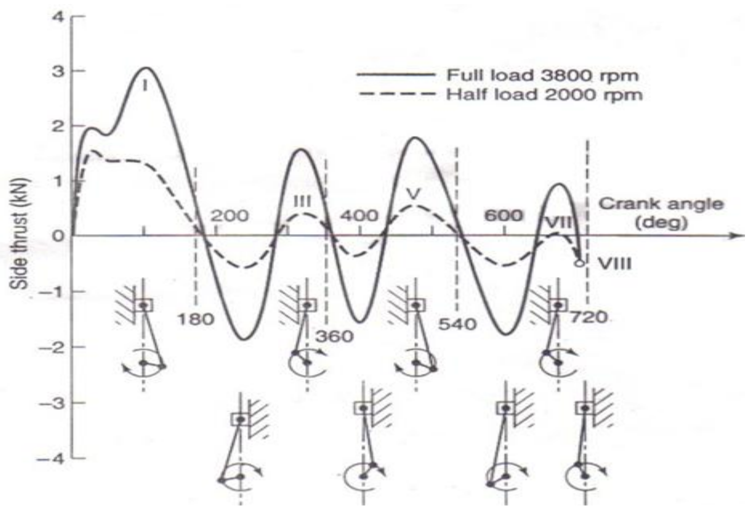

Figure 2. Piston side thrust load

Special additives are being used in lubricating oils to minimize the friction coefficient. But the problem of rubbing force friction has not been addressed yet. In the present day automobiles, the connecting rod oscillates about 15° to 18° on either side of the cylinder axis. This higher inclination angle causes higher rubbing force on the cylinder walls during all the four strokes wasting considerable energy in friction and heat loss to the cylinder walls. If the oscillating angle can be reduced to less than 5°, the reduction in rubbing force will be around 70%! Also, nearly half of the heat rejected from the piston to the cylinder wall is due to this rubbing force.

Suction and pumping losses

The sinusoidal variation of piston velocity induces highly fluctuating gas velocities during suction and exhaust strokes. Higher mean piston velocity causes higher pressure drops in the suction and exhaust systems since pressure drop is proportional to square of the mean piston velocity. The higher piston velocity during suction stroke also tends to reduce the volumetric efficiency. Reduction in the mean piston velocity can cut these pressure drops by 25%.

Journal friction losses

The transmission angle between the connecting rod and the crank varies continuously from 180° to 0°. But the best transmission angle for maximum transmission of force is 90° and this angle occurs only for an instant during each crank revolution. During the rest of the crank revolution, unproductive forces cause high bearing forces in crankshaft bearings resulting in frictional heat that is absorbed by the lubricating oil. These unproductive forces can be converted into useful shaft rotations by employing a suitable mechanism that provides a 90° transmission angle during maximum part of the stroke.

Drawbacks In Existing Connecting Rod - Crank System

All the energy losses mentioned earlier can be attributed to the drawbacks in the existing connecting rod and crank arrangement. About 70% of work done during the power stroke occur during a crank rotation of 15 to 70 degrees after TDC. During this crucial period, the connecting rod and crank possess an inefficient transmission angle, which prevents the maximum extraction of energy. To minimize the above-mentioned losses a new mechanism is devised, which will:

1. Minimize the connecting rod oscillating angle to less than five degrees.
2. Decrease mean piston velocity.
3. Provide better transmission angle during the four strokes.

These three actions are simultaneously achieved by the new mechanism resulting in reduced frictional and heat losses.

Piston Velocity Profile –Thermal Analysis

Velocity Profile :

The sinusoidal velocity profile is obtained by the following formula which is obtained by Approximate Analytical Method. Consider the motion of a crank and connecting rod of a reciprocating engine as shown in the figure. Let OC be the crank and PC the connecting rod. The crank rotates with angular velocity of ω rad/s and the crank turns through an angle θ from the inner dead center (I.D.C). Let x be the displacement of a reciprocating body P from I.D.C after time t seconds, during which the crank has turned through an angle θ.

$V_P = \omega * r * [\sin\theta + \sin 2\theta / 2n]$

The sinusoidal piston velocity profile of the conventional engines lead to a high mean piston velocity. But the new mechanism provides a trapezoidal profile and uniform velocity occurs for maximum part of stroke, leading to lower mean piston velocity as shown in figure-3.

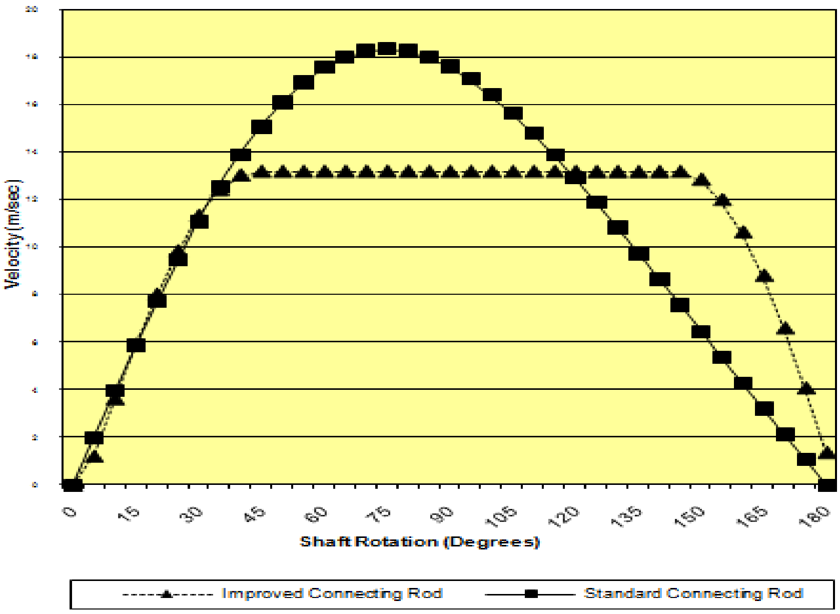

Figure 3. Shaft rotation (180°) Vs Piston Velocity

In the conventional case, the transmission angle is continuously varying and most favorable angle of 90° occurs for one instant alone. But the new mechanism offers the most favorable transmission angle for a much longer period of the stroke

Forces On The Reciprocating Parts Of The Engine :

The various forces acting on the reciprocating parts of a horizontal engine. The expressions for these forces neglecting the weight of the connecting rod are derived as follows :

Piston effort :

Piston effort is the net force acting on the piston or crosshead pin, along the line of stroke.

Let m_R = Mass of the reciprocating parts in kg

W_R = Weight of the reciprocating parts innewtons = m_R*g.

The acceleration of the reciprocating parts,

$a_R = a_P = \omega^2 * r\,[\cos\theta + \cos 2\theta / n]$

The accelerating force or Inertia force of reciprocating parts,

$F_I = m_R * a_R = m_R * \omega^2 * r\,[\cos\theta + \cos 2\theta / n]$

If P is net pressure of gas on the piston and D is diameter of the piston, Then Net load on the piston ,

$F_L = P * \pi * D^2 / 4$

Then , the piston effort ,

F_P = Net load on the piston + Inertia force

$= F_L + F_I - R_F$ … (Considering frictional resistance)

where R_F - Frictional resistance

F_Q – Force acting along Connecting rod

The force acting along the connecting rod is

$F_Q = F_P / \cos\Phi = F_P / \sqrt{(1 - \sin^2\theta) / n^2}$

P- θ Diagram :

$dQ/d\theta - PdV/d\theta = C_v/R\,[PdV/d\theta + VdP/d\theta]$

Now Solve for Pressure

$dP/d\theta = -\gamma P/V\, dV/d\theta + (\gamma - 1)/V\, dQ/d\theta$

Here the Volume is

$V(\theta) = V_d/(\gamma-1) + V_d/2 * [R + 1 - \cos\theta - (R^2 - \sin^2\theta)^{1/2}]$

Differentiating,

$dV/d\theta = V_d/2 * \sin\theta\,[1 + \cos\theta\,(R^2 - \sin^2\theta)^{-1/2}]$

The instantaneous variation in cylinder pressure at different crank angle is plotted for the two cases, and is shown in figure 4. A gradual pressure rise during the compression stroke and an equally gradual drop in pressure during the expansion stroke are achieved in the new system. This is in contrast with the steep rise and drop in pressure encountered in the conventional design. The area enclosed between the compression curve and expansion curve is indicative of the net work done during the cycle. It is evident from figure 4 that the work output in the new design is considerably higher indicating that more heat energy is converted to useful work

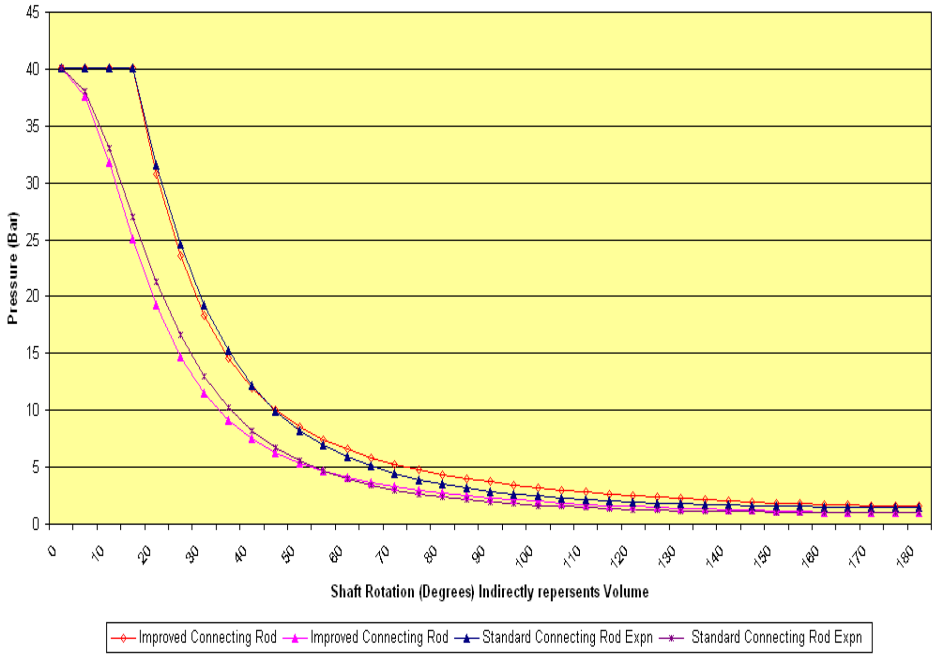

Figure 4. Shaft rotation Vs Pressure – indicator diagram

For Hear Transfer:

The heat transfer rate at any crank angle θ to the exposed cylinder wall at an engine speed N is determined with a Newtonian convection equation

$dQ_w/ d\theta = (h_g(\theta)*A_w(\theta)* (T_g(\theta)-T_w)) / N$

Thus, the new mechanism will impact the thermodynamic and heat transfer processes of the single cylinder engine as described by the above governing equations.

Detailed analysis is to be carried out to analyze the impact of similar trapezoidal profiles (with slightly different slopes) on the thermal and heat transfer aspects. The pressure losses in the intake and exhaust manifold will also be studied critically for the different velocity profiles.

In all the parametric studies, it will be ensured that the stroke length, valve timing and combustion characteristics remain unaltered for the sake of comparison with baseline performance.

II. Conclusion

- A summary of the impact of the piston velocity profile on the thermodynamic, heat transfer and gas exchange processes of a single cylinder, 4-stroke diesel engine was studied.
- If the trapezoidal velocity profile is achieved by this mechanism will lead to a increase in the diesel engine efficiency.
- Lower the wear and tear of the cylinder.
- Lower the suction and pumping loss.
- Lower the break specific fuel consumption.
- The velocity profile for existing engine will be compared with new system of diesel engine.
- The heat transfer profile for existing engine will be compared with new system of diesel engine.

References

[1]. Chironis. P., Mechanism , Linkages and Mechanical Control .
[2]. Ferguson & Kirkpatrick, John Wiley &sons., Internal Combustion Engines Applied Thermosciences .
[3]. GatowskiJ.A ., Balls E.N, Chun K.M, Nelson F.E, Ekchian, J.A and Heywood J.B, " Heat Release Anyltsis of Engine Pressure Data ", SAE Journals 841359.
[4]. John B. Heywood ,Internal Combustion Engines –Tata-McGraw Hill.,
[5]. Kelvin.L. Hoal, "Measurement and Analysis of the effect of wall temperature on Instataneous Heat Flex ", SAE Journals 860312.
[6]. Kirpal Singh, Automobile Engineering –Volume 2, Standard Publishers, 2000.,
[7]. Maitra,, Handbook of Gear Design –Tata-McGrawHill.