Analysis of Offset Crankshaft Mechanism In The Internal Combustion Engines.

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ABSTRACT: *This paper enlightens about the use of offset crankshaft mechanism in the internal combustion engines. Now days in most of the I C engines, the offset mechanisms are used to increase the mechanical efficiency, increase the net torque output, reduce the lining contact between piston and cylinder inner lining, reduce the power loss due to friction, to produce smooth acceleration designs. The mechanism includes the piston-cylinder arrangement, crankcase, rotating crankshaft longitudinally attached within crankcase and offset with some predetermined length from vertical piston-cylinder axis. It also consists of arrangement of one ormore connecting rods to attach piston with the crankshaft. The procurement of the offset connecting rod is done in such a way that during the power stroke, offset crankshaft is mutually perpendicular to vertical axis of piston-cylinder and stroke length of modified engine remains same. Generally, long connecting rods increase the combustion chamber pressure at TDC and reduce the return stroke angle which reduces the friction between the piston-cylinder and promotes quick return action by reducing time for return stroke.*

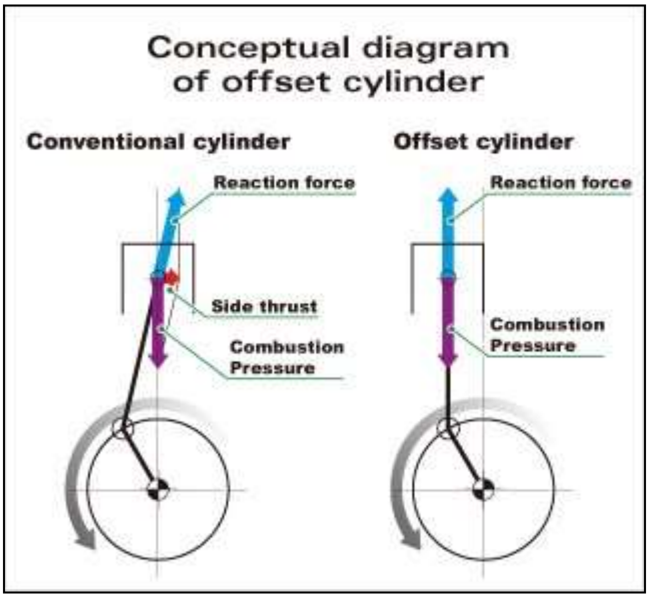
KEYWORDS:- Offset crankshaft mechanism, computational analysis, twin crankshafts, friction mean effective pressure(FMEP), kinematic and dynamic analysis, computational analysis, evaluation of torque, quick return action.

INTRODUCTION:-

Today's modern market is opting for the automobiles which consumes less specific fuel resulting into high power transmission. Also industries accelerate fuel economy; some special techniques have been used likewise: gasoline direct injection, variable valve timing, and variable valve lift resulting in improved thermal efficiency.Earlier, during 1940's the offset engines were considered mainly for slow speed engines. But in today's generation Honda and Kawasaki used the offset of 4mm and 2mm of piston and crankshaft in high speed 4-stroke I C engines. Automobile industry, pump industry as well as research communities uses the I C engines for yielding better efficiency. By reducing the friction loss will improve the mechanical efficiency and will contribute to improvement in fuel economy by 1-1.5% at full load. During the engine operation the major friction losses are prevailed at piston ring assembly, crankshaft and other moving parts. Only 40-65% of the power loss due to friction is observed at piston ring assembly while the loss in the piston skirt is nearly about 40-50%. These values can reduce the mechanical efficiency and hence the offset crank mechanism is studied. When the crank is kept offset then it has been observed that fuel economy is greatly improved by 3%. This effect is largely due to piston side force and sliding speed.
The present study helps us to analyze about the offsetting conditions to be kept for the different operating conditions in concerned with side thrust force and its effect on piston sliding movement by reducing the friction at considerable value.

HOW IT HAPPENS?

As shown in the figure-1 in the crank offset mechanism the arrangement of crankshaft center is positioned towards the piston thrust side with respect to cylinder bore. The crank-offset ischosen in such a way that during the operation, the crankshaft rotation is not disturbed by the cylinder block. Also it is necessary to choose the offset value such that by adjusting the connecting rod length the crank radius fits to the combustion chamber volume and compression ratio. Another computational analysis for the same offset crankshaft engine are given by:Dr. taj elssir for theoretical



comparison of inline, offset, and twin crankshaft engine and P. Ragot & M. Rebbert for the influence of crankshaft offset on piston friction.

Dr. Taj Elssir said that twin crankshaft engine was introduced to reduce the problem of engine wear problem, increase the efficiency of engine. After performing the computational analysis for the inline, offset, and twin crankshafts for the same parameters like: cylinder bore, speed, crank arm, piston mass and heat transfer, and side thrust force and output torque. In comparison to conventional I C engine, offset engine decreases the side thrust force while that for twin crankshaft torque increases compared to offset engine and hence efficiency. Also the side thrust force equals to zero.

Another analysis by P. Ragot & M. Rebbert uses the strobes curve approach for the prediction of friction between cylinder lining and piston group and the influence of crankshaft on this parameter. The friction due to piston group is caused due to the addition of piston friction and piston ring friction.

This friction parameters were reduced to friction mean effective pressure (FMEP). It is obvious that crankshaft offset has great tendency to reduce the frictional losses in the expansion stroke and improving the fuel economy, reducing the vibrations, noise and harshness.

Edward Garvin proposes that greater efficiency and comparatively increased torque than conventional I c engine can be achieved by offset crankshaft mechanism. The mechanism procures about engine block, crankcase, piston-cylinder arrangement in which piston is reciprocating disposed off in the crankcase and relative offset at an predetermined distance from vertical axis of piston-cylinder and connecting rod that connects piston to the crankshaft. The offset crankshaft is located at such a point that during the power stroke the crankshaft is perpendicular to the vertical airs of piston cylinder and connecting rod is collinear to the vertical axis to the piston cylinder axis. The offsite crankshaft is located far below the piston-cylinders that it increases the combustion chamber pressure at TDC and reduces the return stroke angle promoting the quick return action. This results in to decrement of friction between piston and piston-cylinder and hence increases in efficiency of the engine. The use of long connecting rods in offset mechanism will never reduce the friction between piston and piston cylinders which is the result of reduction in average angle between connecting rod and axis of pistoncylinder. It will add the benefit of increased angle of dwell of piston at TDC. This will generate the higher combustion pressure within the combustion chamber at TDC with proper ignition of fuel. Higher the combustion pressure and will exert high thrust on piston generating greater amount of torque and horse power resulting in greater mechanical efficiency. When the crankshaft is rotating in clockwise direction, distance of piston travels the top of the stroke to the bottom of the stroke. The angle through which crankshaft moves during downward stroke is greater than 180 degrees. This results in greater time power stroke than exhaust stroke improving the aspiration of the engine.

The concept can be successfully applied to Otto cycle engines, diesel engines, 2 stroke engines as well as to compressors. When applied to the compressors the intake (suction) stroke is extended rather than conventional compressors. The reason for this asperity of the engine is that: in conventional's during the operation the time taken by piston to travel from top to bottom is equal for the piston to travel form bottom to top. While in offsets the time taken by piston to return from bottom to top is reduced which results in quick return action and the intake cycle timing is greater than exhaust cycle timing which improves the asperity of the engine.But, if return stroke is greater than power stroke thannon-adiabatic compression should be greater than conventional I C engine then resulting compression ratio would be more than normal air temperature which would result in more effective combustion of fuel.

Takiguchi also analyzed the effect of crankshaft effect on piston friction for offset engines by using the floating linear method which measures the frictional force of piston. He made arrangement of offsetting the crankshaft up to 15mm which helps to reduce the piston frictional force during the exopansio0n stroke and also piston side force. Analysis showed that with this offset value frictional force can be reduced up to 10%.

KINEMATIC ANALYSIS:-

ANALYTICAL METHODOLOGY:-

The basic governing equation for the offset crankshaft engine proposed by Rollins is given by:

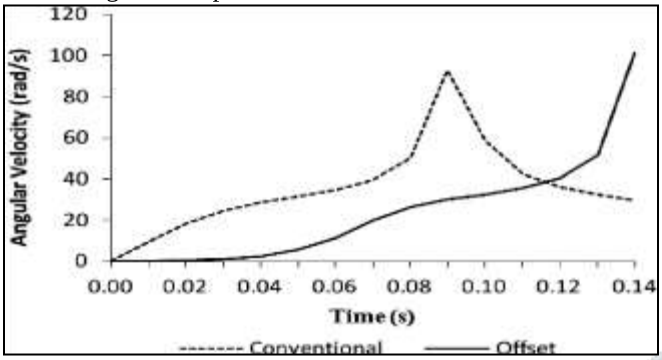
Displacement: $x(t) = r\cos(2\pi\omega t) + [b^2 - (r\sin(2\pi\omega t) - d)^2]^{1/2}$

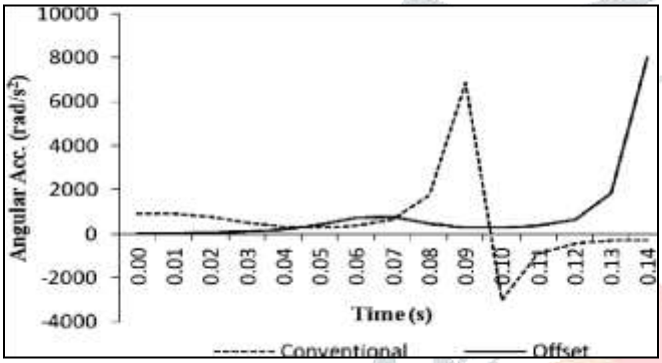
Velocity : $$v(t) = -2r\,\omega\pi\sin(2\pi\omega t) - \frac{2(r\sin(2\pi\omega t) - d)\,r\cos(2\pi\omega t)\,\omega\pi}{[b2 - (r\sin(2\pi\omega t) - d)2]1/2}$$

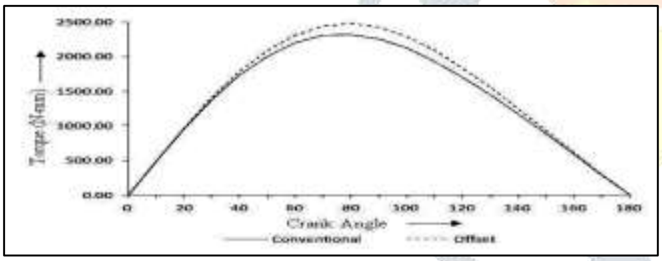
Acceleration: $$a(t) = -4r\,\omega^2\pi^2\cos(2\pi\omega t) - \frac{4(r\sin(2\pi\omega t) - d)^2 r^2\cos(2\pi\omega t)^2\omega^2\pi^2}{\{[b2 - (r\sin(2\pi\omega t) - d)2]1/2\}^3}$$

GRAPHICAL METHODOLOGY:-

Torque produced at the crankshaft is a function of angular speed as well as angular displacement (angular positions) of the connecting rod at a particular instant and thrust force exerted on piston during power stroke

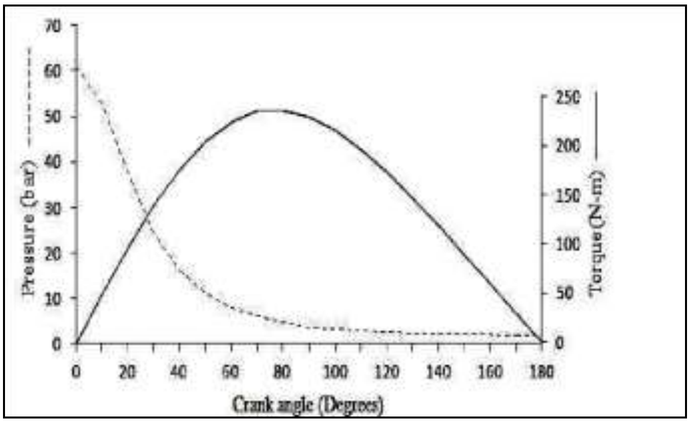


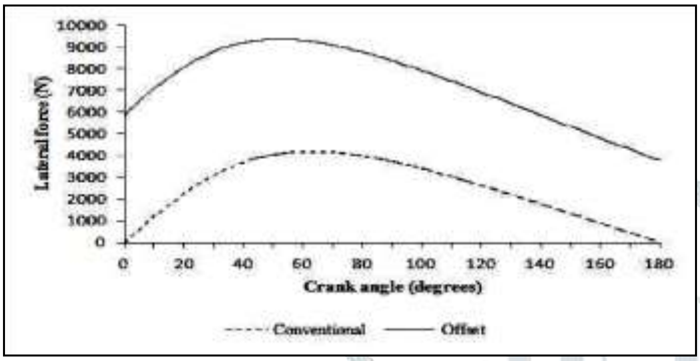


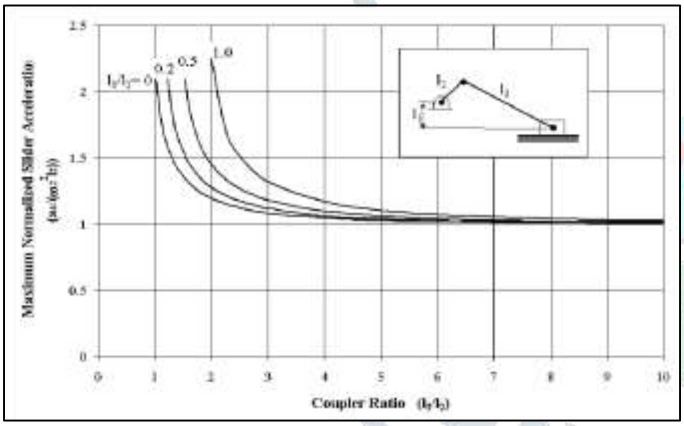


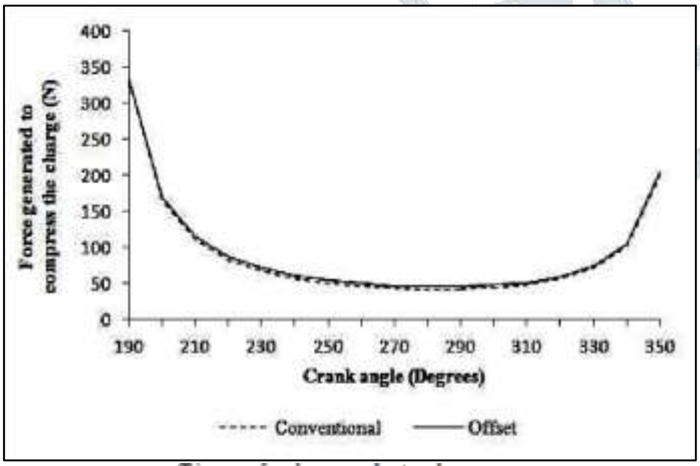
DYNAMIC ANALYSIS :-

Dynamically we can conclude that by the use of offset crankshaft mechanism rather than conventional engines, reduces the vibrations, harshness, and improves the smoothness of operation of the engine and relative specific fuel consumption. For estimating the dynamic analysis, parameters like: crank length to produce smooth acceleration, quick return action, time ratio, imbalance angle is necessary to be known.









Time ratio $Q = \dfrac{\text{Time of adnanced stroke}}{\text{Time of return stroke}} \geq 1.$

For the slider crank offset mechanism, at initial stage the transmission efficiency is relatively low near TDC and less amount of crankshaft torque is available from the available gaseous pressure which will increase gradually with the amount of angular rotation but during expansion stroke it may tend to reduce due to reducing gaseous pressure.Minimizing the weight of engine and friction between the moving parts helps in improving the efficiency of the engine. The use of Aluminum alloy-1060 and cast alloy steel will reduce engine weight improving the efficiency of the I C engine. In order to perform the numerical analysis of effect of crankshaft offset compared to conventional I C engines following parameters are needed to be considered such as: work done during the power stroke, lateral reactive forces, force generated to compress the charge and angular velocity and angular acceleration at the crankshaft.

For the analysis of work done during the power stroke, torque generated at the time of peak pressure is critically important. We know that torque produced at the crankshaft is directly proportional to force exerted at the piston assuming that constant force is exerted for evaluating the transmission efficiency and ease in experimental validation. This can be given by assuming the constant force of W kg exerted on piston (actually force on piston decreases in exhaust stroke).

$$T_{actual} = \frac{\text{Torque produced at the crankshaft with constant force of W kg at piston} \times \text{Actual force at piston}}{W}$$

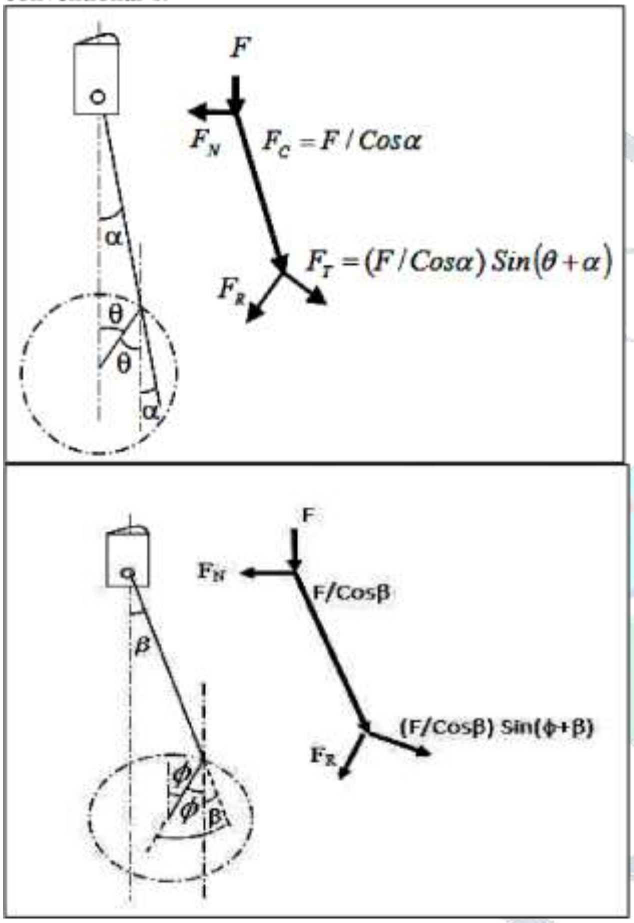
For the analysis of the slider crank mechanism assumingconstant force of W kg exerted on piston, crank radius of R, length of connecting rod L and for θ° of crank rotation. Inclination of connecting rod α can be formulated as:

$\alpha = \sin^{-1}\frac{\sin\theta}{n}$ and

Torque at the crankshaft can be determined by :

$$\text{Torque} = \frac{F}{\cos\alpha}\sin(\theta + \alpha) \times R$$

By calculation and analysis it has been observed that work done by offset engine is nearly 3.59% greater than conventional's.



In the above figure , *F* represents the force exerted on the piston due to gaseous pressure. α and θ represent the inclination of connecting rod to the line of motion of piston in conventional and offset IC engine respectively, β and ϕ
represent the angular
positions of crank in conventional and offset IC engine respectively. *Fc* is the force along the connecting rod, and *FT* perpendicular to the crank. *FN* and *FR* represent the thrust on cylinder wall and the crankshaft bearing respectively.

Similarly, lateral reactive forces (F_n)are the forces which act perpendicularly to the walls of cylinder which are dependent upon instantaneous angular position of the connecting rod and is formulated by the equation:

$F_n = F \tan \alpha$.

Due to the offsetting mechanism the lateral reactive forces acting on the cylinder wall will increase resulting in increase in side thrust and frictional resistance which can be reduced by minimizing the piston mass and piston skirt length.

The forces required to compress the charge remains nearly the same for both conventional and offset I C engines. Also the angular velocity and angular acceleration in case of offset I C engines will be smoother rather than conventional I C engines.

CONCLUSION :-

From the present analysis we can conclude that offset mechanisms used in the I C engines are used to increase the mechanical efficiency, increase the net torque output, reduce the lining contact between piston and cylinder inner lining, reduce the power loss due to friction, to produce smoother acceleration, increase the combustion chamber pressure at TDC and reduce the return stroke angle which reduces the friction between the pistoncylinder and promotes the quick return action by reducing time for return stroke.

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