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Diesel Engine Cylinder Liner Distortion Analysis

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Abstract. Internal Combustion Engine is the heart of any automobile. Hence its performance directly affects the performance of automobile. To measure the performance of engine is an important aspect. When the engine is in working, due to high combustion gas pressure and temperature heat is generated inside the cylinder that heat is transferred to the cylinder wall, crank case oil and piston. In this report, the distortion of cylinder bore has been analyzed. As for the tri biological system, the ideal conditions for the function and durability, shape of liner should be circular as possible. The distortion of the cylinder liners of internal combustion engines has significant effect on engine operation .It can affect the oil consumption, the blow-by, the wear behavior and due to friction, fuel consumption. In order to achieve future requirements regarding exhaust emissions and fuel consumption the development of low distortion engine blocks will play significant role. The calculation of engine heat transfer is difficult, due to the periodic air and fuel flow and the complex geometry of theengine.Werelyprimarilyonexperimentalresults.Withrecentadvances in computational fluid dynamics, computation of engine heat transfer is becoming more possible

1. Introduction

For Ideal conditions for the function & durability of piston, piston rings, liner the shape of liner should be as circular as possible. Apart from manufacturing to clearances thermal and mechanical loading can deviate the liner from ideal geometry. The loads acting on liner come from variety of conditions are Assembly of the cylinder head and cylinder head gasket, Thermal expansion variations between the cylinder block and cylinder head, Gas pressure during fired operation and Temperature gradient during fired operation Thermal distortion has larger effects on the cylinder bore distortion during engine operation than distortion head clamping distortion. Analysis of bore distortion during engine operation is more complex because of the influence of wall temperature and combustion and gas pressure and also the frictional forces acting between the cylinder head & the block Again the heat transfer coefficient is function of crank angle .Hence the local heat transfer coefficient has no meaning. The instantaneous heat transfer coefficient is to be found and using woshi's universally applicable equation. Then the average heat transfer coefficient is calculated and that is used for analysis. Cylinder liner distortion is difficult to measure in actual operation with old measuring instruments .Hence direct ,contact less measurement is used .the cylinder contour is scanned corresponding to the axial movement of piston .8 inductive censored are installed in a production piston. The cylinder bore distortion is practically measured in most automobile industries by using "Inco meter" because the advantage of this system are described with particular emphasis on the mathematical editing of the data, an essential prerequisite for determining different influence factors and implementing carefully targeted measures. As it was detailed in the preceding sections, particularly in Section 1.3and1.4, the PCU accounts for the largest part of the frictional losses in a HDDE and it is in the PRCL contact where most of those losses occur. Investigating the mechanisms related to friction losses in the PRCL contact, focusing on the reduction of such was, therefore, define dto be the main objective of this work. Isis believed that this can enable reduction of fuel consumption and consequently CO_2 emissions by a few percent. To acquire the understanding required to answer the above mentioned research questions, both numerical and experimental tools, for simulation of piston ring friction will be developed and utilised for friction estimation. The TLOCR is responsible for the majority of the piston ring frictional losses. There was no model available in the literature where the TLOCR is modelled fully in 3D and with consideration to elastic deformation of the ring, motion inside the ring groove, and the tribological interfaces against both the cylinder liner and the piston ring groove. To achieve accuracy in predicting friction losses of the TLOCR consideration to mass conserving cavitation will be implemented .Moreover, in order to predict the friction power loss from the TLOCR the entire engine cycle needs to be simulated. For investigating effects caused by textured cylinder liners, there was no previous model available where mass conserving cavitation, inertia of the TLOCR and mixed lubrication were considered. For the numerical investigation of the effects of cylinder liner texture, an objective is set todevelopasimulationmodelconsideringallthesefactorssimultaneously.

2. Experimentation

There was no equipment available exhibiting the features required to find the answers to the research questions of this thesis work. Therefore, anoveltestmethodwhichfitsinthegapbetweenatypicalcomponenttest-rigs and full engine tests will be designed and built with the following specifications: Operation at realistic engine speeds, mounting of piston rings similar to real engine, Direct measurement of friction from one or more piston ring with- out influence of piston, Fast replacements of specimens in the form of standard piston rings and cylinder liners without modification, heated cylinder liner and oil, and Oil supply similar to real engine. The objective of the test-rig is two-fold, i.e., it should be used for validation of numerical simulation models and to investigate the influence on the tribological system from: Different piston ring design, coating and tangential load, and Cylinder liner roughness and coating. Effect on Lubrication Oil Consumption (L.O.C):-

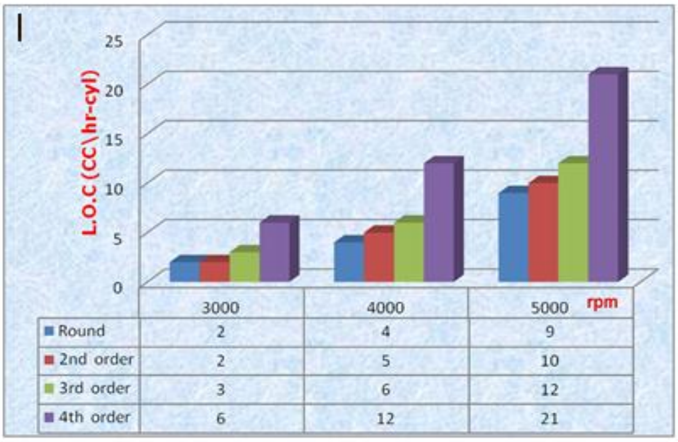

Figure 1

From above Graph it can be easily conclude that as the order of distortion increases the Lubrication Oil Consumption also increases. Distortion is more critical for higher rpm as there is more L.O.C. The bore deformation caused by the head clamping and thermal load in the high engine power range was suppressed to an extremely small amount as confirmed by the measurement. The difference in LOC between the round bore and the deformed four-crest type bore is quite large, and becomes larger as the engine speed becomes higher. Although some differences from the round bore are also found in two-crest and three-crest bores, the effect of the difference is smaller than that of the four-crest bore. This isprobably due to deterioration of the piston ring follow-upper for mance where the curvature becomes greater than that of the round bore. The authors are currently studying the mechanism that increases LOC. Of various issues related to automobile engines, cylinder bore deformations involve a number of problems in terms of lubrication. The deterioration of piston ring follow- up performance in particular caused by bore deformation has a major negative impact on the lubricating oil consumption (LOC). It is also said that lubricating oil accounts for 20 to 50% of particulates contained in diesel engine exhaust gas. Thus emissions from engine are more. LOC increases markedly in the four-crest type bore shape that may occur upon clamping of the head bolts. LOC becomes greater as the engine speed becomes higher. On the other hand, LOC can be reduced for dry liner bore also, if the structure is so designed that bore deformations would not occur easily. Such a design can have a significant effect. In case of the dry liner with the standard specification A, no significant difference is found in LOC, as the bore profile tends to show similar tendencies regard less of the size of the liner/block clearance in the high power range of the engine. In case of the O-ring seal type specification B, a much greater effect on the reduction of LOC is found as the bore does not deform easily owing to the liner structure. The effect of the circumferential bore deformation on LOC is quite great, and the development of proper technology for the reduction of cylinder bore deformation is hence required. Effect on Blow by gases: - The crank case, that which contains the crank shaft and connecting rods, is the bottom side of the engine – you can see the bottom of the pistons from under there. Compressed fuel and air mixture burns in the cylinder on the top of the pistons. When the rings become tired and worn they allow some of this compressed and burning mixture to leak past and escape into the crank case. That is called "blow by". Conventional cylinder liners are mounted in an engine cylinder to provide a smooth, durable surface for seemingly cooperating with piston rings to create a gaseous seal between the combustion chamber and the engine crankcase. Excessive loading overtime results in undesirably rapid wear of the liner disadvantageously causing blow-by problems.

3. Mechanism of Bore distortion

The bore stretches to the thrust side regardless of the size of the liner/block clearance in the high engine power range, and the cylinder to cylinder portion of the liner curls inward toward the cylinder center. This deformation is caused by the effect of the block bore being deformed by the restraint of the liner collar between the block and the gasket. Hence the size of the liner/block clearance has no significant effect on the reduction of bore deformation. The block bore is subject to deformation due to the restraint of the cylinder to cylinder wall toward the crankshaft, the compressive thermal stress caused by temperature difference between the outer wall and the cylinder wall and the temperature is eat the cylinder to cylinder wall. For the block bore longitudinal deformation in engine operation, the outward expansion becomes more significant towards the upper bore portion due to the clamping head bolts. Where the liner/block clearance is larger, the 2rid deformation expanded toward the thrust side occurs as the lower portion of the liner curls more inward than the upper portion on the cylinder to cylinder side. The thermal stress caused by the increased head bolt clamping force is the major factor of this deformation.

4. Design Procedure

For small engines operating at low speeds, the cylinder block is cast as one piece. However for large engines a separate cylinder liner is used. It facilitates easy repair or replacement of the liner in the event of wear and tear of the cylinder. Competitive pressures have increased the reliability and durability requirements for heavy duty diesel engines. In addition, performance and exhaust emission improvements have increased the thermal and mechanical loading on critical heavy duty diesel engine components. In particular, the loading on piston rings and thus cylinder liners has increased causing excessive wear. Conventional cylinder liners are mounted in an engine cylinder to provide a smooth, durable surface for sealingly cooperating with piston rings to create a gaseous seal between the combustion chamber and the engine crankcase. Excessive loading overtime results in undesirably rapid wear of the liner disadvantageously causing blow-by problems and requiring liner replacement there by unnecessarily increasing costs. Conventionally, the wear resistance of liners has been improved by using a base material for forming the entire liner which has high wear resistance qualities. However, this strategy may sacrifice other important mechanical properties and/or significantly increase costs. Another possible improvement is to apply a wear resistant coating to the inner surface of the liner base material. However, this method significantly increases the costs of the manufacturing process due to the coating and the process of applying the coating. There are two types of liners: 1.DryCylinderLiner– A cylinder liner which does not experience any direct contact with the engine cooling media. This type of liner is in contact with the cylinder block material over its entire length or nearly its entire length. Dry liners may be of flanged type.

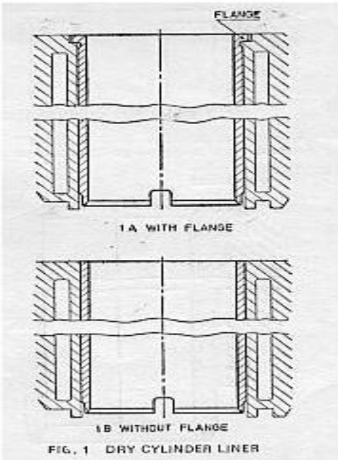

Figure 2

Wet Cylinder Liner – A cylinder liner which experiences direct contact with the engine cooling media. This type of liner is supported by the block only over narrow belts between which the engine cooling media circulates. Wet cylinder liners can be of three different types depending on the system of sealing. The basic dimensions of the cylinder liner are determined on the basis of strength & rigidity to prevent ovalisation of the liner during assembly & operation. The dimensions should confirm to IS: 6750-1972

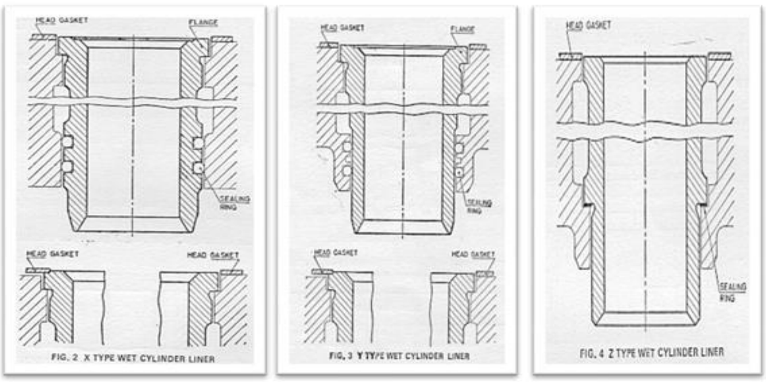

Figure 3

Structural Analysis: The main output of the structural analysis is the deformation and stress field on the engine. A first kind of analysis regards the simulation of the "cold" conditions that is performed taking into account only the mechanical loads.

The cold conditions analysis is of course faster and can lead to reliable results if the operating temperature of the simulated parts does not affect considerably their mechanical characteristics. If the temperature influence becomes important non-linear structural analysis (i.e. material non-linearity) will be performed .When more complex structures are to be analysed, apart from the question of the mesh quality, additional topics are critical to achieve results reliable and actually effective for the designer: to simulate the correct boundary and load conditions, especially in the case of non-linear material behaviour, to post-process the results in a form that allows a quick comparison with other data and in any case that is easily understandable by the designer. To satisfy these new features for the cylinder block, one of the main engine components, a dedicated CAE procedure was developed to evaluate the cylinder liner distortion due to the tightening of the bolts connecting the block and the cylinder head or to the thermal effects. In this case one of the targets was also the attempt to reproduce, even from a graphical point of view, the measurements and the same statistical and mathematical data analysis carried out in the actual metrological measurements. Thermal Analysis: - The thermal evaluations for the engine components still remains a not completely solved problem, mainly because of the uncertainties in the heat exchange between the combustion gas and the metallic structure. In fact the CFD codes used for combustion simulation are not able to predict correctly the local heat transfer coefficients: it is necessary to tune the numerical model using experimental data to obtain a realistic temperature field. Generally thermal analysis is performed in steady-state and transient condition depending on the kind of evaluation that it performs. Due to the complexity of the analysis, only in the last years the transient thermal analysis has been possible to perform: CRF uses this evaluations to study the warm-up phenomena when the engine, starting from cold conditions, reaches the normal operation conditions (i.e. approximately steady-state). Especially in the last periods the design engine with different architecture, materials and cooling strategies became important in order to have a more powerful and efficient powertrain. In this field a fundamental help comes from the transient thermal analysis. The steady-state thermal analysis is the more common one. This kind of evaluation is normally used to analyses the thermo-mechanical behaviour of engine components: from the thermal field calculation it calculates the stress field due to the thermal gradient. This excitations generally taken into account together with other mechanical loads to obtain a total stress field relative to the normal operating conditions. Thermo-structural Analysis: - To take the effect to the both clamping force, gasket pressure and the thermal gradients, thermo-structural analysis is done. Boundary conditions and loading should be given collectively and for the same run. Modal Analysis: The goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during free vibration. First six modes will be rigid modes so they will not show frequency. What is challenging: The system receives heat from combustion gases and dissipates it into the coolant and ambient air flow. Part of the heat actually passes through the pistons and rings before it is received by the cylinder bore and coolant. In addition frictional heat is generated between the rings and bores as well as the pistons and bores. In the wall facing the combustion gases heat transfer coefficients and ambient temperatures are strong functions of the crank angle. In the power stroke, a large amount of heat flows from the hot gases into the combustion chamber wall, while in the intake stroke a small amount of heat feeds back from the wall into the charge gases. To maintain the same amount of heat input to the combustion chamber wall in each engine cycle in steady state calculations, a mean effective heat transfer coefficient, eat transferrin engine cylinder involves solving phenomena occurring in a combustion chamber; diffusion, convection, pressure angle and radiation. The complexities of coupling of these terms as well as the insufficiency of information to solve basic equations have raised many difficulties in modelling heat transfer. There have been many approaches to predict heat transfer in cylinder. 1. Global Models: Woshni & Annad 2. Zonal Models: These are based on Nu-Re relation but Re & Nu calculated. Different method as Global. 3. 1D Models: based on Energy Equation. 4. Multi-dimensional models: Can predict local velocity& local gas temperature. Effective heat transfer coefficient can be determined by Woshni, s "A universally applicable equation for the instantaneous heat transfer coefficient in the internal combustion engine" The gas properties in the correlation equation are evaluated at the instantons average cylinder temperature determined from the ideal gas law: Flow of the Load: - Structural Load: - First the load is applied to the cylinder head bolts in terms of the bolt torque. That torque is transferred through bolt shank to cylinder head then to the gasket. As the gasket deforms some amount of load is utilized. And rest of force is transferred to the top face of the cylinder liner. Liner being simply supported at bottom acts as cantilever. That means for axial load it will bend or buckle depending on the L/D ratio. For our purpose we can say that liner will distort. 2. Thermal Load: - Inside the combustion chamber combustion takes place. The generated heat has to dissipate. Some part will go to crank case oil, some to cooling water and remaining will be to liner. Asinnersurfaceoflinerhashighertemperatureandouteratlowertemperature.Therehastobesomethermaldeformationduetothermal coefficient of expansion of material. We call it as Thermal distortion. Finite element analysis aspects: - Meshing Aspects:-

As the Model considered for analysis is not having uniform thickness we cannot use shell elements for meshing. So we considered solid meshing. Element Type selected for the Analysis Tetra because it has advantage of fitting into awkward shapes more easily than brick element. We preferred Tetra 10 (Second order Tetra) over Tetra 4 (linear Tetra) because Tetra 4 is more stiff &inaccurate. As we are interested in displacement it will show less displacement than actual. Element Quality Index:-Boundary Conditions:-3. Bolt Tension Calculation:-

T=K.F.D Where, K=.15to .20

F=Bolt tension in KN

D= Diameter of bolt in mm

T=Torque in Nm

Torque coefficient K is a function of thread geometry, thread coefficient of friction µt, and collar coefficient of friction µc. K for your specific thread interface and collar(bolt head or nut annulus) interface materials, surface condition, and lubricant (if any).("Torque specs for screws," Shigley, and various other sources discuss various K value estimates.) If you cannot find or obtain K from credible references or sources for your specific interfaces, then you would need to research to try to find the coefficients of friction for your specific interfaces, then calculate K yourself using one of the following two formulas listed below (Shigley, Mechanical Engineering Design, 5 ed., McGraw-Hill, 1989, p.346, Eq.8-19)

$$240=0.2\times F\times 13\times 10$$
$$F=92.30\times 10 \text{ N}$$

Table 1

	Cylinder head	**crankcase**	**Liner**	**Assembly**
Mode	Hz	Hz	Hz	Hz
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0.000014482
4	0	6.1876E-05	0	0.069881
5	0	7.6788E-05	0	0.07548
6	0	0.00010313	0	0.099758
7	119.57	19.512	73.304	20.535
8	175.45	32.73	73.675	29.855
9	178.22	35.699	80.207	32.162
10	187.14	40.222	80.555	35.56

From the result of modal analysis it is observed that natural frequencies for first 6 modes is zero. These are known to be “Rigid mode shapes”. Though the natural frequency for 7th mode of Crank case is very close to the excitation frequency 19Hz, after assembling oil pan and stiffner it may decrease further. We can say from the results obtained that the modal displacements are not hampering the liner. So liner distortions occurs only due to the loading viz. thermal, structural.

5. Results and discussion

The results are presented as ring friction and average minimum separation, meaning the minimum separation across the ring lands in the piston sliding direction averaged around the circumference. It is important to consider the effects on separation between the piston ring and cylinder liner since it will have an effect on how much oil is left behind for the scraper ring. If the oil control ring is not able to conform well to the bore it will lead to increased oil consumption [107]. It must be remembered that the piston ring systems main function is to act as a seal and therefore the focus should be to secure a high sealing capability. In Figures A. 5 and A. 6 results from the first part of the study are showed. Here only the amplitude of out-of-roundness was varied for the different loads and orders of out-of-roundness. The results are plotted as function of amplitude of out-of-roundness.It can be seen that neither total friction force nor average minimum separation is significantly affected by amplitudes of second order out-of-roundness lower than 50µm. However, the expected reduction in friction and the increased separation with decreased ring tension can be seen. The results in Figures A.5 and A.6 shows that the average minimum separation is nearly unaffected by the change in amplitude for the second order type of out-of-roundness. In other words, this means that the ring will conform very well to a cylinder liner with second order out-of-roundness amplitudes up to 50µm. Friction can be significantly reduced by lowering the ring tension, but the increase in separation between the piston ring and cylinder liner must be taken into account when doing this. For third order out-of-roundness both the total friction force and average minimum separation are affected by the amplitude of out-of-roundness, but not to any great extent. Only a minor increase in separation and total friction force is noticed, and the results are very similar to second order out-of-roundness.

6. Conclusion

Steganography techniques from antiquity of being used, of confidential communications further improvement in terms of information character needed. The rebirth of steganography is digital Enjoyed with the growth of the world. Of meta-analysis Results with increased reporting of CB and CV Exemplify Revealed several variables associated with depression and decreased life satisfaction and addiction and psychology such as behavioral variables such as alcohol including variables. Of associations in this meta-analysis widely accepted limit for validity widely accepted limit for validity Self-reporting for based algorithms, Functions should not automatically be considered viable alternatives. Available evidence suggests that. Data Used for a long time for compression. Mobile In the context of wireless devices, they are mostly energy efficient Are starving, which is of extra importance. Using the M-R Face Shift Giving (PSK) technique discusses the development of the communication system. The performance of the system is based on conventional Fourier as is better compared to systems Reported. And in fractal modulation proposed a method of recovering time. The most important disadvantage of the distance- time vector coding solution lies with the fact that the related calculation is complex. Incoming pockets the gateway provides that information when linked to. A news headline hop-by-hop is on the way, assigning channels as it progresses one between source and target routers Opens the path. All along that path Routers and towards its goal .The title may be blocked because the required exit operative pipeline Sending message. At any time, a message The title may be blocked because the required exit The channel is already used by another message Our goal in this meta-analysis is comprehensive, As many predictors as possible in the analysis and There must be consequences. Five or more of the many meta-analysis results included in the current article Based on samples less than that (k _ 5). The self-report of the digital media application after describing the included studies is ours in this meta-analysis The goal should be comprehensive, with as many predictors and outcomes as possible in the analysis The goal should be comprehensive, with as many predictors and outcomes as possible in the analysis Our goal in this meta-analysis is comprehensive, current Many of the meta-analysis results included in the article are based on five or fewer models Containing (k _ 5). After describing the included studies Self-reporting of digital media application and the relationship between recorded activities we consider.

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