DYNAMIC LOADING ANALYSIS OF AUTOMOBILE COMPONENTS FOR INCREASING EFFICIENCY

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Abstract : Connecting rod and crankshaft is the one of the most critical and now days most of researchable point of elements. The main objective of this work is to develop higher capacity (Breathing) four stroke four cylinder inline petrol engines by increasing from the existing capacity engine for the design and manufacture of engines in probable any manufacturer. Main focus of this project is the modeling and doing analysis of crankshaft and connecting rod of an automobile engine to increase its efficiency in form of breathing capacity. For that purpose here choosing engine is modified by increasing its breathing capacity from 1.8 to 2.6 liter. So to doing this work I select Catia and Hypermesh software to prepared model and doing its analysis by FEM.
Keywords: FEM, Hypermesh, Crankshaft, Analysis

I. INTRODUCTION

The internal combustion engine development process required CAE method. CAE methods are most efficient at the beginning of engine development process, when different concept has to be compared or no hardware is yet available. This is why they are mainly used in early in an idealized development process. CAE result determines the two primary ones: the concept check (identifying the best approach) and the virtual check (transferring the chosen concept to the series of development) another requirement concern how details the computer model to be. Complexity of the model increase CAE time. As the capacity of engine is increased, in accordance with the capacity the maximum pressure acting on the piston top is also increased.. The connecting rod is used in 2.6L Engine is of some different diesel engine so it is also required to be crosschecked for proper functioning in the 2.6L petrol Engine. The main concern is to perform structural analysis of the crankshaft & connecting rod to crosscheck its failure by Finite Element Analysis. There is two ways by which forces are applied on crankshaft among them one is the compressive force due to combustion process and it will transfer to shaft by four bar mechanism. This is the main source of loading in the engine. And other one is the dynamic parameters of this mechanism. Due to this forces as well as because of centrifugal force which acted on different elements there may be create both of torsional and bending effect on crankshaft.

H. Bayrakceken, S. Tasgetiren, F. Aksoy [1] (2006) study, failure analyses of crankshafts of two single cylinder diesel engines are carried out. Both engines are used in some auxiliary agricultural vehicles which is not considered using area in the design stage of the engines. However the crankshafts have some miner design differences, both failures are occurred after a fatigue process. Both shafts are made from the same material however one of them has undergo a surface hardening heat treatment and the other is used under the annealed conditions. Zhiwei Yu, Xiaolei Xu [2] (2004) perform failure investigation on a diesel- engine crankshaft used in a truck, which is made from 42CrMo forging steel. The crankshaft was nitrided. The fracture occurred in the web between the 2nd journal and 2nd crankpin. The depth of the nitrided layer in various regions of the crankshaft particularly in the fillet region close to the fracture was determined by SEM observation and micro-hardness (HV0.1) measurement, combined with nitrogen content analysis by EDAX.

Fig. 1: Failed Crankshaft

II. FINITE ELEMENT ANALYSIS OF CRANKSHAFT

There are two major approaches for stress calculation :(a) Based on entire crank. (b) Based on single throw.

The first procedure can be described as follows: Run full crank reduced model (dynamic) to calculate main bearing reactions and torques. Run analysis applying all possible loads (at the pin and main bearing locations) (pressure distributed over bearing area) one at a time. Another approach is published can be described as follows: Run dynamic analysis on a reduced model. Cut out one throw of the crank through the main journal middle cross-sections (detailed FE). Constrain one cross-section and apply the forces i.e. bending as well as torsional forces and obtain corresponding stress states. Another approach is to constrain the main bearings for all degree of freedom & applying the bending & torsional force at the crankpin end.

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III. BOUNDARY CONDITIONS STATIC FEA

The crank and piston pin ends are assumed to have a sinusoidal distributed loading over the contact surface area, under tensile loading. This is based on experimental results .The normal pressure on the contact surface is given by:

$P = Po \cos \varphi$

The load is distributed over an angle of 180o. The total resultant load is given by: is given by P_t

In this equation r is indicate crank pin radius while t is nomenclature of the length of crank pin.

The normal pressure constant *Po* is, therefore, given by:

$Po = Pt / (r\, t\, \pi / 2)$

The tensile load acting on the connecting rod, Pt, can be obtained using the expression from the force analysis of the slider cranks mechanism. For compressive loading of the connecting rod, the crank and the piston pin ends are assumed to have a uniformly distributed loading by 120 degree contact surface.

The normal pressure is given
by: p = po
The total resultant load is given by:

$$P_t = \int_{-\pi/2}^{\pi/2} Po\ (\cos^2 \phi)\, r\, t\, d\phi = = Po\, r\, t\, \pi\ /\ 2$$

$$Pc = \int_{-\pi/3}^{\pi/3} Po\ (\cos\phi)\, r\, t\, d\phi = Po\, r\, t\, \sqrt{3}$$

The normal pressure constant is then given
by: $Po = Pc / (r\, t\, \pi 3)$

Pc can be obtained from the indicator diagram, such as the one shown in Figure-1, of an engine. In this study four finite element models were analyzed. FEA for both tensile and compressive loads were conducted. Two cases were analyzed for each case, one with load applied at the crank end and restrained at the piston pin end, and the other with load applied at the piston pin end and restrained at the crank end. In the analysis carried out, the axial load was 55KN in compression & 11kN in Tensile Loading Compressive Loading:

Crank pin End: Po = 2.5MPa Piston pin End: Po = 74MPa
Tensile Loading:
Crank End: Po= 11000/ [24 x17.056 x (π/2)] = 13.6 MPa

IV. FEA OF CRANKSHAFT

In this FEA analysis, whole crankshaft finite element model is used, applying the bending force acting on the crank of four cylinder inline engine, reaction forces acting on the on all the main journal bearings & torsional moment is applied on each crank separately, The value of Bending & torsional force was obtained from the dynamic simulation of the crankshaft for whole 720 degree rotation of the crankshaft as shown in Figure-2. Applying the respective forces on each cylinder as got from the firing order of the cylinders is one-four-three-two.

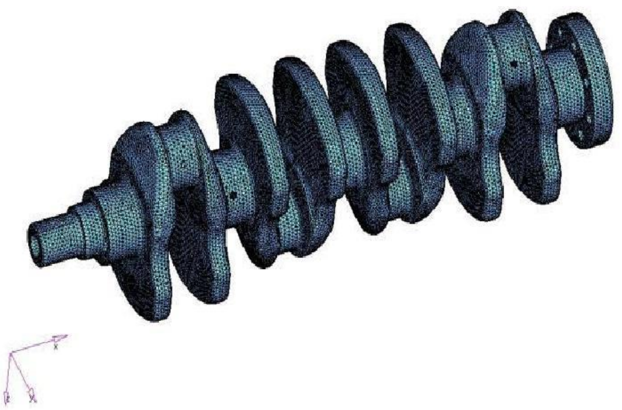

Fig. 2: Crankshaft Meshed Geometry

Forces & moment are applied by making rigid element by selecting the nodes of the surface over which forces & moments are applied. The cylinder which is fired have maximum bending compressive force applied over 120 degree on the top surface of crank. All other all tensile force is applied over 180 degree over the surface in considering by same methodology of rigid elements. Torsional moment was obtain b y multiplying the torsional force of the respective cylinder & crank throw. (47.5mm)Torsional moment is applied by selecting the node at the periphery where crank web & main journal are in contact of both end of crank & making the rigid with nodes

.The FEA for the case of whole crankshaft with constrain at the flywheel end is shown in figure. The maximum Bending force is applied 55KN, Maximum Torsional Moment applied on the crank is 1425050 N-mm on one of the crank having maximum torsional force & other moments on the respective crank as obtain from the graph.

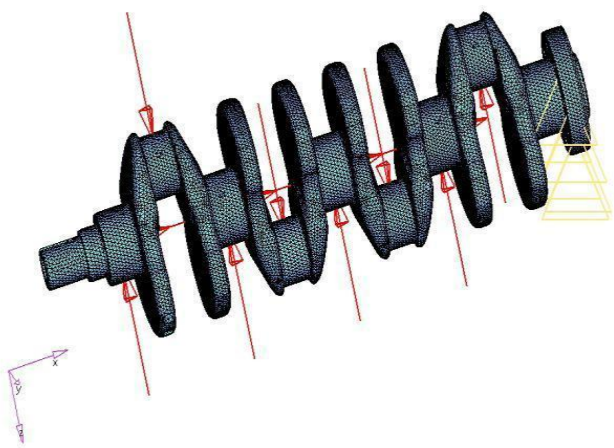

Fig. 3: FEA of whole Crankshaft with Constrain at Flywheel End

Cases for analysis, when maximum bending force acting on crank, maximum torsional moment acting on cylinder .when maximum bending acts on cylinder torsional moment is zero, whereas when maximum torsion force act there was

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both bending as well as torsional force

V. FEA OF THE SINGLE CRANK OF THE CRANKSHAFT CONSTRAIN AT FACE

In this FEA Analysis, Cut out one throw of the crank through the main journal middle cross-sections. Constrain one cross section for all Degree of freedom. Applying maximum Compressive load at the crank pin & bearing area as a pressure load, same boundary conditions are used as above. Torsional moment was applied on the rigid formed by selecting the nodes on the surface of the main journal of both the end. Maximum pressure load acting is 62.5Mpa whereas torsional moment is 1425000N-mm. The FEA model of Single crank is shown in figure-4 & figure-5

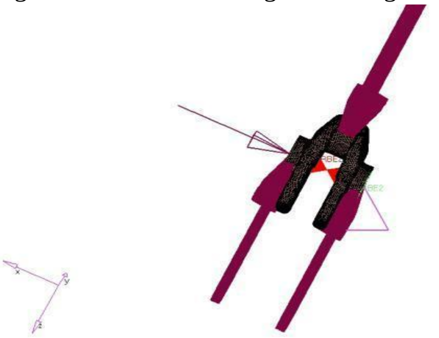

Fig. 4: FEA of the single Crank Constrain at Face

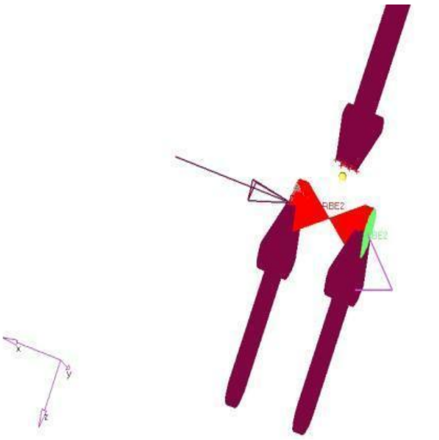

Fig. 5: FEA of the single Crank Constrain at Face

VI. FEA OF SINGLE CRANK CONSTRAIN AT BEARING AREA

In this analysis constrain the crank in its bearing area for all degree of freedom by forming the rigids & applying the bending as well as torsional force as a pressure load in the crank pin. The FEA model is shown in figure-6

VII. F I N I T E ELEMENT ANALYSIS R E S U L T S A N D DISCUSSION

The Finite Element Analysis is conducted on the crankshaft shows more stresses in the fillets and in the pin journal oil holes. Section changes in the crankshaft geometry result in stress concentrations at intersections where different sections connect together. Although edges of these sections are filleted in order to decrease the stress level, these fillet areas are highly stresses locations over the geometry of crankshaft. Therefore stresses were traced over these areas.

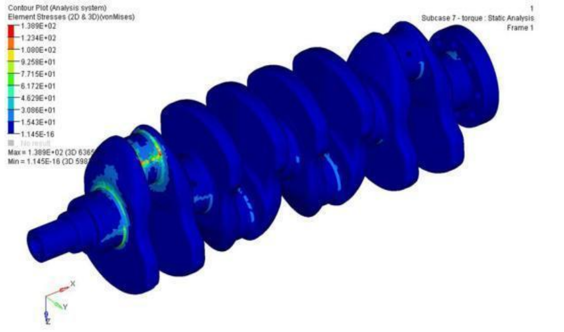

Fig. 6: Stress Contour

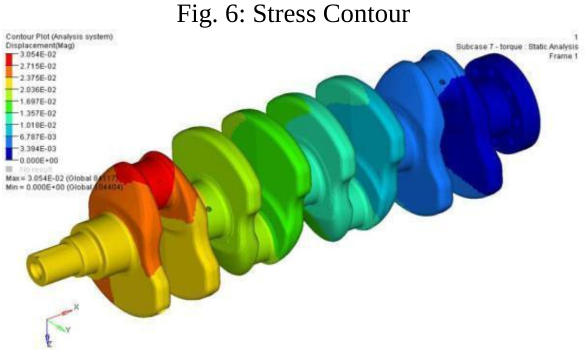

Fig. 7: Displacement Contours

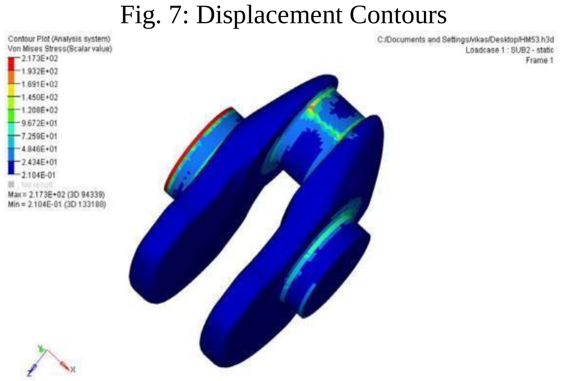

Fig. 8: Stress Contour for Bending Load

Fig. 9: Stress C o n t o u r for Torsional Load

The maximum Bending stress acting on the crankshaft is 330Mpa by taking both maximum torsional & bending together. Yield strength of the material of crankshaft is 584. FOS is coming about 1.76.

VIII. CONCLUSION

The IC engine for the intended application is upgraded from 1.8 L to 2.6 L to leverage its objective for dispensing

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better performance as regards the power generated for it application in four wheelers.

FEA is performed by applying dynamic loads to crankshaft. The following conclusions can be drawn from the analysis conducted in this study:

1. Dynamic loading analysis of the crankshaft results in more realistic stresses whereas static analysis provides overestimated results. Accurate stresses are critical input to fatigue analysis and optimization of the crankshaft.
2. There are two different load sources in an engine; inertia and combustion. These two load source cause both bending and torsional load on the crankshaft. The maximum load occurs at the crank angle of 360 degrees for this specific engine. At this angle only bending load is applied to the crankshaft.
3. Torsional force is maximum, when crank is at 250 from the top dead centre.
4. Critical (i.e. failure) locations on the crankshaft Geometry are all located on the Pin fillet & main fillet because of high stress gradients in these locations, which result in high stress concentration factors.
5. Maximum Stress acting on the crankshaft is 330Mpa approx by taking both maximum torsional & bending force together, Factor of safety of approx. 1.76.

IX. FUTURE SCOPE OF WORK

The critical components are modeled and Analyzed in FEA software to evaluate to maximum stresses and the points and conditions for failure of the same. But to design the critical components the designer should bear in mind that considerable heat is generated during the working of the critical components like the crankshaft and the connecting rod. In addition, the dynamic analysis should also be carried out to compute the natural frequencies of the crankshaft to estimate the vibration characteristics of the same. Moreover the critical components are designed taking into consideration the properties of one particular material stainless steel. The design of the critical components can also be accomplished by considering materials apart from the one considered in this dissertation.

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