Fatigue Failure Analysis of an Automotive Crankshaft and to Find Its Behavior under Different Operating Loads.

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ABSTRACT:

Crankshafts in automotive engines experience a significant number of cyclic loads during its service. Mechanical fatigue failures are the most common cause of crankshaft failures. Crankshafts fail at the fillet regions of main journal and crankpin. The project highlights how to predict & improve the fatigue life of crankshaft using FEA technique. I will take the data for crank shaft such as dimensions and loads and torque for maximum and minimum rpm .Then create a CAD model of crankshaft by using Uni-Graphis. Then the fatigue failure analysis will be carried out by using ansys software. The crankshaft will be modified by using sufficient radius to the fillets regions where the stress concentration occurs. Then the structural analysis is to be carried out for the finite element model for Modified crankshaft. Then, the fatigue failure analysis is carried out by using ansys software. Then the results are compared for the existing and modified crank shaft all speeds and torques. Fatigue life, Total deformation and Factor of safety are the outcome of the Fatigue failure analysis. Project establishes the procedure for predicting and improvement the fatigue life of any component.

INTRODUCTION:

Fatigue cracking is one of the primary damage mechanisms of structural components. Fatigue cracking results from cyclic stresses that are below the static yield strength of a material. It is estimated that 50-90% of structural failure is due to fatigue. A significant amount of applied technology pertaining to fatigue analysis has emerged to significant levels in the last few decades. The literature review that follows has some of the research papers where in the fatigue analysis is done through FEA.

W. Y. Chien et al [1] have investigated the stress concentration near the fillet of the crankshaft section under bending without consideration of residual stresses by a two dimensional elastic finite element analysis. The plastic zone development and the residual stress distribution near the crankshaft fillet induced by the fillet rolling process were then investigated by a two dimensional elastic-plastic finite element analysis. After the rolling process, a bending moment is applied to the crankshaft section. With consideration of the stresses due to the rolling process and the bending moment, the fatigue failure near the fillet was investigated based on linear elastic fracture mechanics approach. The results indicated that the cracks initiated on the surface of the fillets.

Erich Payer et al [2] have presented the nonlinear transient stress analysis for the rotating crankshaft of a 6-cylinder-inline engine. A method has been shown which enables such analysis to be both highly sophisticated and efficient for determining the fatigue behaviour of crankshafts using micro computers. Static finite element analysis of crankshafts was used for basic determination of the stress behaviour due to maximum gas load, mass forces, and maximum torque loading cases.

V. Prakash et al [3] has generated a systematic procedure to design crankshafts for finite life. For accurate results crankshaft was modelled using solid finite elements. The simulated boundary conditions represent both radial and bending stiffnesses on the bearings, which has a large effect on crankshaft dynamics. Time varying radial and tangential forces acting on the crankpin were derived from the cylinder pressures. The displacements and stresses at all locations of the crankshaft were found using mode superposition method. They have considered the peak stresses and predicted life using SN curves or Goodman diagrams. The load duty cycle of engines corresponding to automotive applications was considered. A variable stress time histories were generated based on the duty cycle. Life of crankshafts was estimated as certain number of repetitions of duty cycle using rain flow counting and Miners damage rule.

F.S. Silva [4] has carried out an investigation on two damaged crankshafts. They were diesel van crankshafts that were sent to be ground, after a life of about 300000 km each. Some journals were damaged on each crankshaft. After grinding, and assembling on the diesel van, the crankshafts lasted about 1000 km each, and the journals were damaged again. The cause of the damaged journals was found to be wrong grinding process that originated small thermal fatigue cracks at the centre of journals, on both crankshafts. These almost invisible cracks, with sharp edges, acted as knives originating a very quick damaging of the journal bearings, and as a consequence damage the journals themselves.

Elena Galindo [5] describes two methods for predicting crankshaft loading and bearing performance in multi-cylinder engines in his research. The first, the so-called statically determinate method, has been employed in the motor industry for the last three decades. The second, known as the statically indeterminate method, is based on a sequential solution to the hydrodynamic and structural FEM equations. This method allows for more accurate calculation, owing to the smaller number of assumptions upon which it is based. Similarly, by enabling detailed analysis of crankshaft stresses and calculation of the influence of crankshaft flexibility on engine performance, design of lighter crankshafts is also rendered possible.

Shinichi Chiba et al [6] have predicted the fatigue strength of a truck cab. This research introduces the method of combining cab input load estimated by multi body simulation and fatigue life estimation by FEM analysis and fatigue life analysis. This paper discussed a fatigue strength prediction method that was developed to simulate the bench durability test and examined the cases of its application. Multi-body simulation using an elastic body model enabled cab input loads to be calculated with sufficient accuracy for practical application. The fatigue life simulation that supported stress history allowed the locations of cracks to be predicted both in no welded panel sections and spot welds, although the prediction was not sufficiently accurate in quantitative terms for spot welds. The study using the CAE simulation method on the effects caused by installing on the cab, a roof deck on fatigue life revealed the mechanism of changes in the input mode and changes in the crack life that resulted from the difference in the test condition. In future studies, the team will seek to improve the accuracy of the fatigue life simulation, with the ultimate objective of building a CAE simulation system that can predict the fatigue strength under rough-road durability test conditions.

Y. Liu et al [7] has proposed a new methodology to account for uncertainties in fatigue life prediction, named the stochastic S-N curve approach in his research paper. A wide range of fatigue data available is used which covers metals and composites under constant and different spectrum loadings. The fatigue data under constant amplitude loading is represented using the Karhunen-Loeve series expansion technique. The covariance structure of fatigue damage accumulation under variable loading is considered using an exponential function. The prediction results are also compared with existing fatigue models. The prediction based on the proposed model agrees very well with the experimental observations. The proposed methodology was suitable and validated for stationary variable loading and certain types of non-stationary variable loading (step loadings).

Senthilvel Vellaichamy et al [8] have proposed a method in which the modal transient equations are solved outside finite element methods. A novel approach was developed in which the transient solution is obtained more efficiently without using any commercial FEA code. A new transient solution was proposed using time elements, which takes into account proper initial conditions. This solution was very elegant and had strong potential for solving variety of complex dynamic problems associated with automobiles.

PROBLEM MODELLING:

The crankshaft of the car was modeled using UG version through reverse engineering technique. The crankshaft was discredited using hexahedral dominant elements. The 3D CAD model was imported into ANSYS 11.0 in and meshed using 3D solid element

Specifications of the vehicle selected:

Type: FORD ESCORT ZX2 .4 CYLINDER INLINE ENGINE;
Max. Output: 97kw@5750rpm
Max.Tarque: 1770 N-m@5750 rpm
Displacement: 1988 cc
Bore: 84.8 mm
Stroke: 88 mm

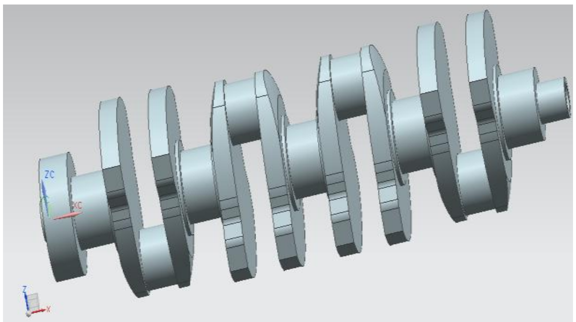

Fig-1: Geometric model of Crankshaft

ELEMENT TYPE:

Linear Solid (Solid 45)
No. of Elements - 53053
Hexahedral Dominant
No. of Nodes – 155457

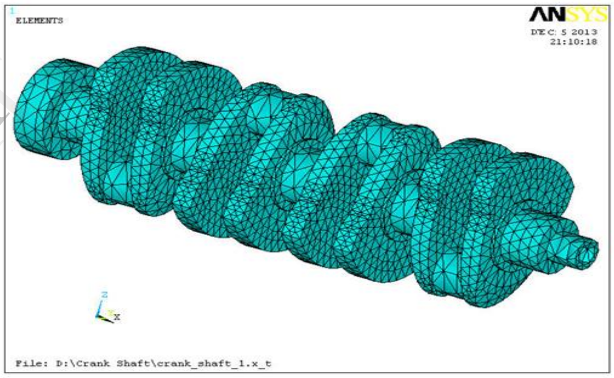

Fig-2:Full Meshed Model of Crank Shaft

LOADING:

Torques(N-m) : 956, 1356, 1770
Speeds(RPM) : 2750, 4250, 5750

BOUNDARY CONDITIONS:

In order to carry out the static structural analysis the crankshaft was constrained at the flywheel end for all degrees of freedom. A frictional support was given at the main journal bearing areas which act as bearing support. A combination of Y and Z-direction forces, 425N and 35530N respectively were applied on crankpins 1 and 4.

MATERIAL PROPERTIES:

Structural Properties	Values
Young's Modulus	$2X10^5$ Mpa
Poisson's Ratio	0.3
Density	7850 Kg/mm^3
Tensile Yield Strength	698 Mpa
Tensile Ultimate Strength	778 Mpa

RESULTS AND DISCUSSIONS:

From (Fig.6), It is observed that the fatigue life of the modified crankshaft is more than the existed crankshaft and is maximum at a speed of 2750rpm, and fatigue life is decreasing while the speed is increasing. From the fig-7, it is observed that the fatigue life of the modified crankshaft is more than the existed crankshaft and is maximum at a torque of 1770N-m, and the fatigue life is decreasing while the torque is increasing.

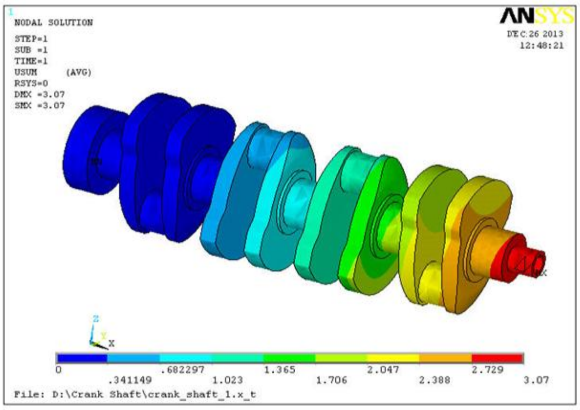

Fig-3: Total deformation plot at 2750 rpm

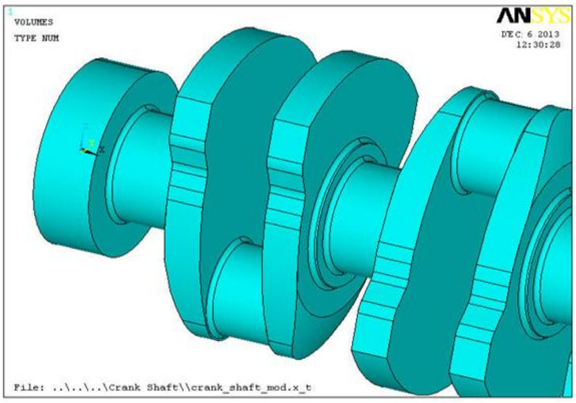

Fig-4: 3D model of the modified crankshaft

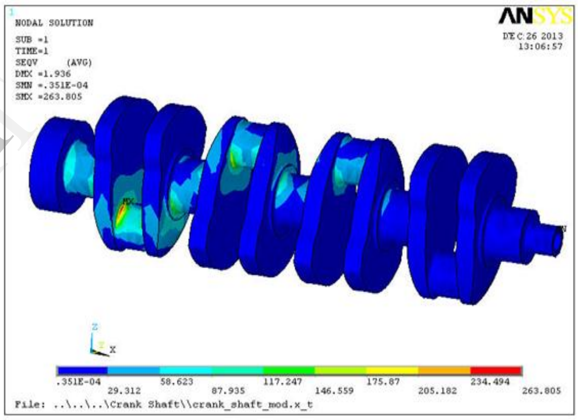

Fig-5: principle Stress plot at 2750 rpm

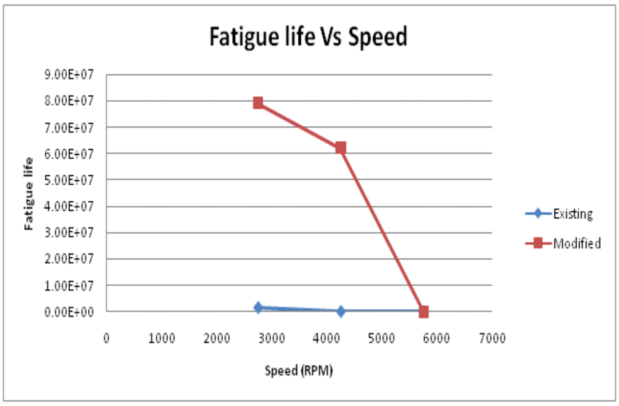

Fig-6: Graph for fatigue life Vs Speed

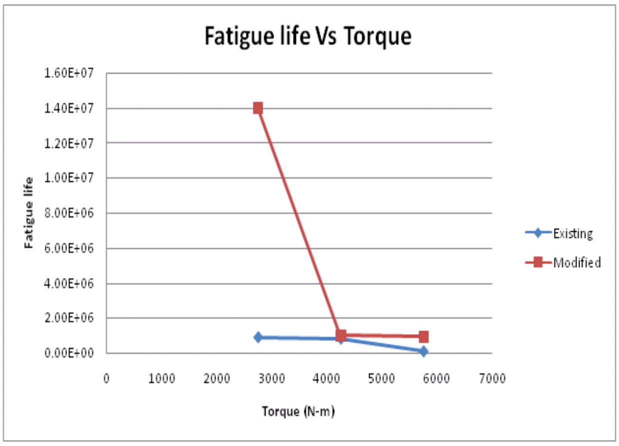

Fig-7: Graph for fatigue life Vs Torque

CONCLUSION:

From the results obtained in this paper, it can be concluded that the design analysis of any machine element is simple through the Ansys and also the values obtained in Ansys are very close to the theoretically calculated values. The maximum deformation occurs at the centre of the crank pin and fatigue failure occurs at the fillet regions. And also the fatigue strength of the modified in which the radii of fillets is more than that of the existed crankshaft.

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