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"A FATIGUE LIFE ESTIMATION OF MAIN BEARING CAP OF DIESEL ENGINE"

Ninad P. Dhage[1], Prof. P. R. Kale[2], Mr. D. S. Butala[3]
[1]*(Sinhgad Academy of Engineering, Pune)*
[2]*(Asst. Prof. Sinhgad Academy Of Engineering, Pune)*
[3]*(DGM R&D, Greaves Cotton Limited (DEU), Pune)*

ABSTRACT: - *The Engine can be called the heart of a car and the block may be considered the most important part of an engine. The objective of this study was to do the stress analysis and study the fatigue performance of the casting and forging component like MB-Cap. An essential part of diesel engine assembly is crankcase i.e.; engine block and the MB-Cap. The MB-Cap is modeled in PRO-E. The whole model is preprocessed in Altair HyperMesh-11.0. The static analysis of MB-Cap was done in ABAQUS 6.10. Before modifications in MB Cap the stress induced was found much closed to the yield stress, which is not acceptable. So the new model was developed by removal of tapping hole. The modified design is found safe and can be implemented on engine block. Fatigue-life estimation is done in MSC Fatigue module of PATRAN. Strain-life approach is used to calculate the fatigue-life. S-W-T life approach was used to solve fatigue life calculation. The new modification reduces the stress in MB Cap and thus improves the fatigue life.*

Keywords -*Abaqus, Fatigue, Hyper Mesh, Patran, Static*

I. INTRODUCTION:

With the development of computer, more and more advanced techniques and software's of simulation are developed. The application of numerical simulation for the designing engine block and components helped engineers to efficiently improve the process development avoiding the cost and limitations of compiling a database of real world parts. Finite element analysis allows us to study and compare different arbitrary input parameters without doing any costly experimental work.

In many industries, especially the automotive industry, there is a constant demand for components that are stronger with less cost. Physical testing of the component involves considerable cost and time. So it becomes one of the important factors that get added to the cost of component. Also if anybody wants to sustain in this competitive market, the timely delivery of the project is very important. Physical testing also involves lot of time which could even delay the project. Finite element analysis can be considered as the alternative to the physical testing. The objective of the study was to assess the fatigue-life of the six cylinder engine block by simulation. Among the various tests, the structural worthiness tests are very important from the safety point of view.FEM is applied to detect modes of failure before prototype stage. The present study focuses on the FEM based structural evaluation of one of the critical component - the Crankcase [1] The global loads applied to the crankcase were used to study the stresses on this component, by means of FEM calculations. The study of the stresses across the entire complex geometry of the crankcase takes high priority in motorcycle applications, especially when manufacturers are seeking maximum performance and reliability, as in case at the bike Ducati 999. [2] Various approaches to estimating mean stress effects on stress-life and strain-life behaviour are compared with test data for engineering metals. The modified Goodman equation with the ultimate tensile strength is found to be highly inaccurate, and the similar expression of Morrow using the true fracture strength is a considerable improvement. The Smith, Watson, and Topper (SWT) method is a reasonable choice that avoids the above difficulties. [3]

II. THEORY:

The Stain Life approach is widely used at present. Strain can be directly measured and has been shown to be an excellent way of accessing low-cycle fatigue. Strain Life is typically concerned with crack initiation, whereas Stress Life is concerned with total life and does not distinguish between initiation and propagation. In terms of cycles, Strain Life typically deals with a relatively low number of cycles and therefore addresses Low Cycle Fatigue (LCF), but works with high numbers of cycles as well. Low Cycle Fatigue usually refers to fewer than 10^5 cycles. Stress Life is based on S-N curves (Stress – Cycle curves) and has traditionally dealt with relatively high numbers of cycles and therefore addresses High Cycle Fatigue (HCF), greater than 10^6 cycles. The S-W-T analysis method is important method for the fatigue analysis of the cast-iron material. S-W-T method is the most conservative method. [4]

III. SIMULATION:

3.1 MODELLING:

The model of the Main Bearing Cap modeled in Pro-E. The model is based on the actual drawing given by the design department.

3.2 FINITE ELEMENT MODELLING:

FE step should be considered as the pre-processing stage to the fatigue life prediction and not the converse, i.e., fatigue life prediction is the post processing stage to FE analysis. This focuses on the need to ensure careful FE modeling. The objective of the stress/strain analysis is to obtain the complete three dimensional stress and strain distributions at a potential failure site, facilitating fatigue life predictions. Linear elastic analysis is the most common type of stress analysis pursued in automotive design and analysis. The use of HyperMesh-11.0 helped in expediting the whole design process and the results were achieved before the target date.

The Functional Assignment applications assign element properties, material properties, loads and boundary conditions, and load cases. They include all the actions that are necessary to turn a collection of finite elements into a complete, ready-for-analysis model. The solid model is created in Pro-E. The pre-processing is done in HyperMesh-11.0. Tetrahedral elements are stiffer than the hexahedral elements, the meshing plan of the assembly is shown in figure 1.The meshing of an intricate component like MB-Cap was the challenge in itself. But the HyperMesh made the task easier with its flexibility in handling complex geometries. The boundary conditions as applicable with the machining process, assembly process, the operating condition and the life test conditions were applied the FE model was solved for the static analysis in Abaqus-11.0 software. The physical testing is always not a good solution if the cost is the constraints. So we need to rely on the FEA results which are not accurate but approximate.

3.3 MATERIAL PROPERTIES:

MB-Cap is made of Cast-Iron. Poisson ratio is about 0.3. The young's modulus is $1.1\times e^{5}$ and density of material is about $7.2\times e^{-9}$. Material model and material properties play an important role in the result of the FE method. The material properties are one of the major inputs which is the definition of how a material behaves under the cyclic loading conditions. The cyclic material properties are used to calculate the elastic-plastic stress-strain response and the rate at which fatigue damage accumulate due to each fatigue cycle. The materials parameters required depend on the analysis methodology being used.

Fig. 1 Meshing and Boundary Conditions

3.4. STATIC ANALYSIS:

Pre-processing:

It is done in ABAQUS profile of HyperMesh. The meshing and boundary conditions are as shown in figure 1. Geometry cleanup, high quality mesh has been done in the meshing process in Hypermesh. The model is then imported in ABAQUS 6.10 for static analysis. The contour plots of Principal stress are as shown in figure 2. The maximum stress for MB-Cap is 153Mpa. As when the tapping hole gets removed the stresses developed were 90Mpa. The Static analysis is done to know sudden failure of the given component. It is also used to know exact critical location of the component. The sample contours of stress and deflection are shown in the figure below.

Boundary Conditions:

The boundary conditions are applied such that it will be same as the physical test and it will not add any numerical error in the analysis. Boundary conditions are as shown in fig. 1.

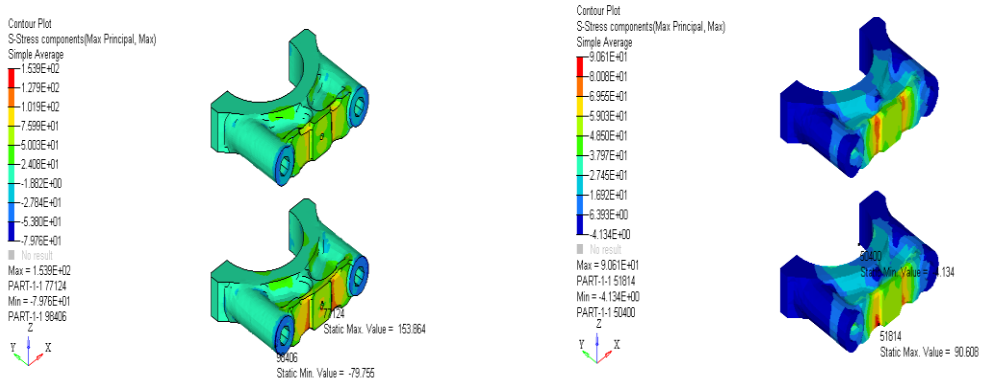


Fig. 2 Static analysis result's in ABAQUS 6.10 with and without hole.

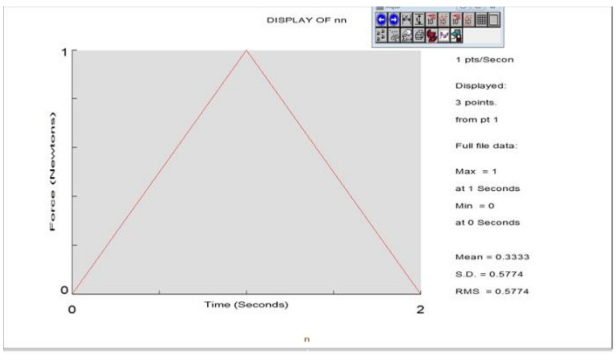
The following figure shows the old model of the MB-Cap. The model gets cracked when implemented. Because it cannot sustain the high stress and vibrations developed at the tapping hole section on MB-Cap.

Fig. 3 Cracked MB-Cap Model.

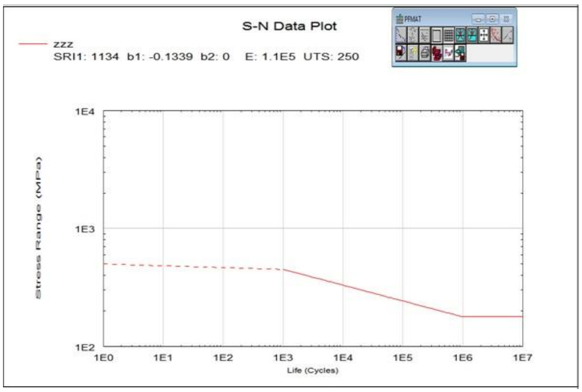
So the company need to developed new design of main bearing cap model. The newly developed model of the MB-Cap which shows less stress as shown in figure 2. The model is implemented on the engine for the use.

3.5. FATIGUE ANALYSIS:

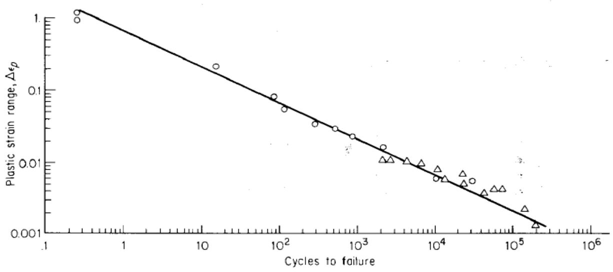
The Material curve shown in the graph 1 (b). From material curve it is seen that at certain stress range the curve becomes straight, this means that material is having infinite life below that stress. Generally in industry if the component servives for 10^6 cycles is taken as infinite life condition.Fatigue analysis of MB-Cap is done by strain-life approach. The results obtained in by static analysis are used as input to the fatigue software. MSC Fatigue module in PATRAN is used as the fatigue life estimation software. [4] The results obtained by ABAQUS are static results but the fatigue is the phenomenon occurs with the tensile loading. So the time history should be defined to vary the results to have effect of tensile loading. The loading is tensile loading so time history in the form of triangular with unit amplitude is defined as shown in graph 1 (a).



Graph 1 (a) loading time history curve used for the analysis,



(b) Material Curve for cast-iron



Graph 3: Low Cycle Fatigue Curve

The low cycle fatigue cycle are used when the cycles are about 10^4 and below it. This type of fatigue failure can be considered in the design of pressure vessels, engine components and steam turbine. Low cycle fatigue conditions are created where the repeated stresses developed. It mostly used strain life approach method. Mean stress correction is calculated in strain life approach method. [5]

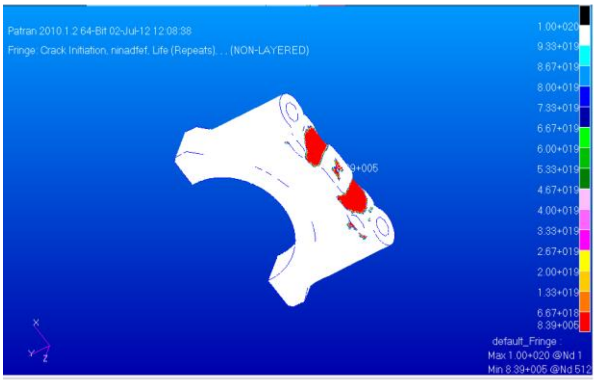
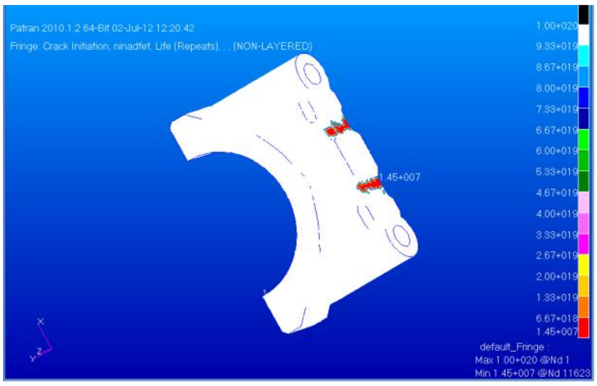


Fig. 4 (a) Contour plot of life with hole

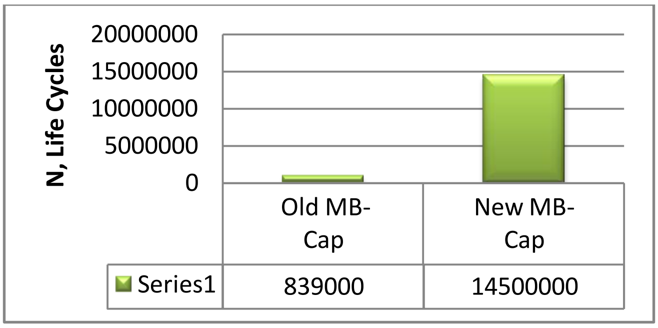


(b) Contour plot of life without hole

The results obtained using MSC Fatigue is shown in figure 4. As the stresses developed were about 153Mpa and therefore stress concentration is more and when the hole gets removed the stress concentration reduces so the stress induced were 90Mpa. The Smith, Watson, and Topper (SWT) mean stress equation is a good choice for general use. And it is very conservative method. It is quite accurate for aluminium alloys, and for steels it is acceptable, although not quite as good as Morrow. [4]

IV. RESULTS AND DISCUSSIONS:

The FE analysis in ABAQUS 6.10 shows the critical location. The maximum stress obtained on MB-Cap with hole is 153 Mpa and without hole is 90 Mpa. The static results are then used as input to the MSC Fatigue for life estimation. The fatigue life is calculated by Strain-life approach. The fatigue life of MB-Cap obtained by MSC Fatigue is 8.39E+05 with hole and 1.45E+07 cycles without hole. The stress concentration gets reduced by the elimination of the hole. The results shown below in graph are easy to understand the modifications.



Graph 4: Result Comparision Of Old and New Model

V. CONCLUSION:

A computational approach of the fatigue and static analysis methodology for the life prediction is presented. Based on the conducted study, several conclusions can be drawn with regards to static and fatigue analysis. The stresses on MB-Cap found by a finite element analysis. The stresses induced in the Main Bearing cap model are very high. After the modification (removal of strainer bracket support hole) the stresses are well below allowable stress. Stress concentration reduces at the hole. It can be concluded that the model is safe and can be implemented in actual practice. With the use of software simulation on any arbitrary condition and calculate different parameters with good accuracy and without much cost. The user friendliness and flexibility of HyperMesh-11.0 was the major advantage as it helped in achieving the results quickly.

VI. ACKNOWLEDEMENTS:

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