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Contact Fatigue Analysis using Finite Element Analysis for 6 Station 2 Lobe Cam Shaft

KEYWORDS: Cam shaft, Intermediate bearing, Hypermesh, Modal Analysis, Fatigue Analysis.

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ABSTRACT *The advances in the fast computing technology, the designer has the flexibility in selecting the suitable size and material for the structure due to virtual simulation which was earlier totally depending on prototype testing which was costly and time consuming. In the present work, a 6 station 2 lobe cam will be analysed for wear conditions for the given loads. Finite element analysis will be carried out to prove the same. Further fatigue analysis will be carried out by both theoretical and finite element analysis. Intermediate bearing s will be considered to reduce the wear and improve the fatigue life of the cam shaft.*

1. Introduction

Common-rail direct fuel injection (CRDi) is a modern variant of direct injection system for diesel engines, It features a high-pressure (over 1,000 bar) fuel rail feeding individual solenoid valves, as opposed to low-pressure fuel pump feeding unit injectors (pump nozzles) or high-pressure fuel line to mechanical valves controlled by cams on the camshaft. Modern common-rail systems, work on the same principle, are governed by an engine control unit (ECU) which opens each injector electronically rather than mechanically.

Cam-box

A Cam-box is a structural component used for housing of cam during the testing process of fuel injection pumps. It is a testing device which locates, orients and holds the pump in position and drives the camshaft and pump to check the various functional aspects of pump.

Camshaft

Cam is a mechanical timing device converting rotary motion to reciprocating motion. Cams find usage in majority of mechanical timing devices with different phase logs. Cams with its eccentric shape help in converting rotary motion to linear motion. Conversion of rotary to linear motion is obtained through oval shape provided on the cam called lobe. Number of lobes on cam varies with reference to its requirements.

Cam lobes are the special arrangement on cams which converts rotary motion to linear motion camshaft lobe wear is caused by friction between the cam lobe and the cam follower. Insufficient lubrication, excessive valve spring tension, excessive valve lash, hydraulic lifter failure and dirty oil will contribute to early and rapid wear. Worn cam lobes retard valve timing which is detrimental to engine power and performance. Higher contact pressure increase the wear rate and also results into either plastic deformation failure or crack based fatigue failure.

II. Problem Definition And Methodology

Definition of the problem

Contact Fatigue analysis using Finite element Analysis for 6 station 2 lobe cam shaft under intermediate bearing support condition is the main definition of the problem. In the present work, .Finite Elemental Analysis (FEA) of Cam shaft is performed which is subjected to fuel pump loads (Both Vertical and Torsional) and also fatigue and contact loads is performed for camshaft due to the follower(plunger) loads.

From the literature review, it can be said that extensive and active research work is being carried out on the prediction of Hertzian stresses on camshaft and follower mechanisms with normal loads. The contact equations are developed based on Lagrangian and Eulerian algorithms. Here Prediction of structural safety, contact pressure between cam lobe and follower and stress concentration zones due to structural loads are the main objective of study. Any design should be properly checked for complete functionality. So following steps are followed.

Objectives of the Project

The project is carried out with the following objectives.

1. The modeling and meshing of camshaft (Hexa meshing of the structure for better accuracy).
2. Load calculations based on fuel pump inlet, outlet pressure and spring tensions.
3. Calculations for load acting on the camshaft.
4. Modal analysis of camshaft to find the resonance frequency.
5. Fatigue analysis of camshaft due to follower loads.
6. Contact pressure estimation through ANSYS between cam lobe and plunger.
7. Intermediate bearing supports analysis and load distribution.

Geometric Model of Camshaft

The figure shows geometrical modeling of the camshaft. It consists of two cams with 3 lobe positions to operate the plunger. Catia solid modeling features are used for building the geometry of the problem. Cam profile is built after importing 2D representation of drawing file format to Catia and usage of sketcher option. Finally extrusion is done for cam. Revolving options are also used to built the remaining geometry

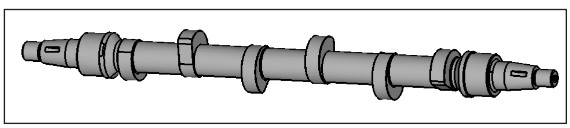

Figure: Geometric model of camshaft

III. Material Properties.

Properties	Symbols	Camshaft
Material	-	Alloy Structural Steel case hardened
Specification	-	16MnCr5
Young's modulus	E	206000N/mm²

Properties	Symbols	Camshaft
Density	ρ	7800 Kg/m^3
Yield strength	σ_y	588 N/mm²
Tensile Strength	σ_t	785 N/mm²
Mean hardness of the core	H	51 HRC

Materials and Its Properties for Camshaft.

IV. RESULTS AND DISCUSSION

Structural Analysis has been carried out on Camshaft. Modal analysis is also carried out to find resonance frequencies. Camshaft is analyzed for fatigue and contact loads and finally the contact pressure developed due to the contact between cam lobe and roller is also analyzed. The wear of the cam is analysed. The results are presented as follows.

1.Modal analysis for Camshaft.

The modal analysis is carried out to find the natural frequency of the system. The results are as follows.

Table : Modal Frequencies for Camshaft

Mode No	Natural frequency(Hz)
1	314.07
2	451.53
3	1176
4	1241
5	2356

The table shows modal analysis results of the camshaft. From table the first natural frequency is 314 Hz which is higher than the operating frequency corresponding to the speed of the camshaft (20 Hz). So camshaft is safe for resonance condition.

Theoretical Validation for Natural Frequency of the Camshaft.

Considering the camshaft as simply supported Beam subjected to uniformly distributed load (Self weight of the structure), the member can be validated for natural frequencies.

Natural frequency [20] $f_n = \frac{0.5615}{\sqrt{\delta}}$

$$f_n = \frac{0.5615}{\sqrt{0.0031e-3}} = 318 \text{ Hz}$$

Comparing the theoretical values with finite element solution, a variation of around 1.2% can be observed in the results.

2. Fatigue Load Analysis For Cam Shafts

Total of 6 load cases are considered for the lobe position coming in contact with the plunger. When a lobe in contact with the plunger other plunger is subjected to minimum load…..

Fatigue Data.

For fatigue analysis, SN curve data is very important to find the life of the members subjected to cyclic loads. And S-N curve for 16MnCr5 is as follows.

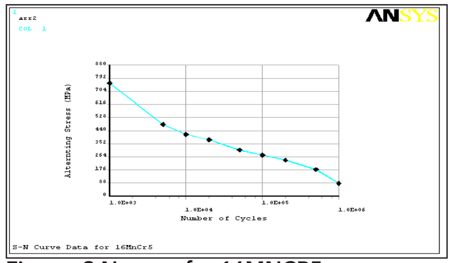

Figure: S-N curve for 16MNCR5

Figure shows the fatigue data which indicates the reduction of allowable fatigue stress as the number of cycles increases, 86.2 N/mm²is the fatigue limit corresponding to one million or 10 lakh cycles. The alternating stress induced in the fatigue analysis is 62 N/mm² which is less than the allowable fatigue limit stress of 86.2 N/mm². So structure is safe for the fatigue design. Stresses are captured for maximum stressed node 200327 on the cam lobe.

Fatigue Life Estimation:

FATIGUE DATA:

For fatigue or cyclic load analysis, S-N curve is required. The S_N curve for 16MnCr5 from the figure it is shown that 86.2 is the fatigue limit for safety.

FATIGUE LIFE ESTIMATION:

Alternating σal = 159 Mpa
Cycles used/allowed = = 0.6000E+06/ 0.1000E+07
Cumulative fatigue usage = 0.6

The above result indicates an alternating stress induce is 159N/mm² which is more then the allowable fatigue limit of 86.2 N/mm², so The camshaft is not safe for 1 million cycles. But the value of 0.6 indicates less safety factor in the estimation suggesting the necessity for better material or arrangement.

Fatigue Results with 2 intermediate bearings:

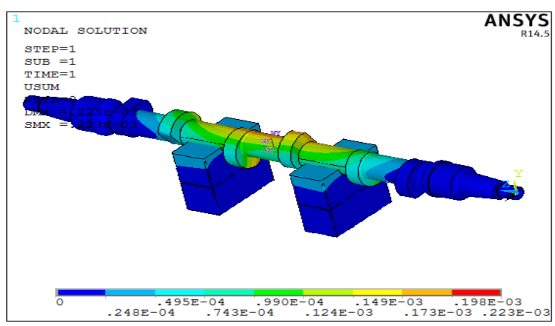

Fig5.10: Displacement Results with two intermediate bearings (maximum displacement is 0.223mm).

FATIGUE LIFE ESTIMATION:

Alternating σal = 78.6 Mpa
Cycles used/allowed = = 0.1000E+07/ 0.1000E+07
Cumulative fatigue usage = 1

The above result indicates an alternating stress induce is 78.6N/mm² which is less then the allowable fatigue limit of 86.2 N/mm², so The camshaft is safe for 1 million cycles. But the value of 1 indicates minimum safety factor in the estimation suggesting the necessity for either material improvement or increase number of supports.

V. CONCLUSIONS AND SCOPE FOR FUTURE WORK

CONCLUSION

Camshaft which is use to operate fuel pump for injection testing has been analyzed for structural safety with various loading conditions, using finite element Analysis. Initially the cad

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models of Camshaft is modeled, and meshed using hypermesh tool for high quality mesh and solved using Ansys.

Loads acting on the cam lobes are calculated based on the outlet and inlet pressure and plunger diameters. Spring loads are also added for the final loads. Based on the simply supported condition the reaction loads are calculated. And Camshaft is analyzed and results obtained is as follows

- Camshaft is analyzed for modal frequency. The first natural frequency value is around 815 Hz which is sufficiently high compared to the operating frequency of 20 Hz. So camshaft is free from resonance conditions.
- Further fatigue analysis is carried out. Six lobe positions are applied with plunger loads and stresses are calculated. Fatigue SN curve data is applied to the Ansys Fatigue module and stresses are captured for all the six load cases. The stresses are varying between 330 N/mm^2 to 427 N/mm^2 with contact loads and rotational loads. The resulting stresses are tabulated and fatigue life estimation is carried out for camshaft. The results shows an alternating fluctuating stresses of 159 N/mm^2 Which is more than alternating stresses of 86.2 $N/mm^2$from the SN curve data for 1 million cycles which results in lesser safety of the camshaft for given fatigue loads and cumulative usage factor indicating the value of '0.6' suggesting better material or increased supports.
- The fatigue analysis is carried out with two intermediate supports which shows improvement in the problem. The fatigue stress is reduced to 78.6Mpa which is less then allowable stress of 86.2 showing safety of the problem. But cumulative usage factor indicating the need of further improvement in the material quality as the safety factor is very less. So Instead of 16MnCr5, it is better to use 32MnCr5 whose yield stress is higher compared 16MnCr5.

Scope For Future Work

- Optimization can be carried out for Camshaft (From the results it can be observed that most of region of camshaft is subjected to stresses which are very less compared to the allowable stresses. So material can be optimized in these regions by topology or shape optimization techniques)
- Thermal effects also can be included in the problem. (Heat generation due to rubbing of surfaces is also important to decide the functionality of the cam assembly). Thermal stresses are also induced due to thermal expansion coefficient of the cam box assembly.
- Residual stress estimation along with fracture strength can be estimated for the camshaft. Grinding operation is mainly used during cam manufacturing to get the required shape.
- High strength fatigue and wear resistant materials helps in reducing the weight and dynamic effects in the structure.

REFERENCE

[1] J.A. McGeehanand P.R. Ryason "Preventing Catastrophic Camshaft Lobe Failures in Low Emission Diesel Engines", Chevron Products Company.SAE Paper, 2000, P 16-19. | [2] F.S. Silva "Analysis of a vehicle crankshaft failure".Volume10, 2003,P 605–616. | [3] Zhi-wei Yu AE Xiao-lei Xu"Failure Analysis on Fractured Diesel Engine Camshafts"ASM International 2008. | [4] Stefan DietzIntecGmbh, Klaus Knothe Technical University Berlin Aerospace Institute, Willi,Kortum Institute for Robotics and System Dynamics. "Fatigue Life Simulations Applied to Railway Bogies", 1998. | [5] H. Bayrakceken, I. Ucun, S. Tasgetiren "Fracture Analysis of a Camshaft made from nodular cast iron"Engineering Failure Analysis.Volume 13, 2006, P 1240–1245. | [6] R.K. Pandey"Failure of diesel-engine crankshafts" Engineering Failure Analysis.Volume 10, 2003,P 165–175. | [7] Osman Asi "Failure analysis of a crankshaft made from ductile cast iron"Engineering Failure Analysis.Volume 13, 2006, P 1260–1267. | [8] ZtyaQaka,YokselYilmaz"Torsional Vibrations ofCamshafts"Mech Mach Theory. Volume 27, 2003, P 225-233. | [9] Chun-Ping Zou, Hong-Xing Hua, Duan-Shi Chen "Modal synthesis method of lateral vibration analysis for rotor-bearing system" Computers and Structures.Volume 80, 2002, P 2537–2549. | [10] Jia-Jang Wu "Torsional vibration analysis of a damped shafting system using tapered shaft element" Journal of Sound and Vibration.Volume 306, 2007, P 946–954. | | [11] Lien-Wen Chen and Der-Ming Ku "Finite element analysis of natural whirl speed of rotating shafts" computers&Stnrctrures.Volume40, No.3, 1991,P741-747. |