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Crank Shaft Design And Thermal Analysis Of Forged Steel And Metal Matrix Composite Materials Using ANSYS

M.Naveen Ram
M.Tech Scholar,
Department of Mechanical Engineering,
Aditya Institute of Technology & Management,
Srikakulam, India.

A.Satish Kumar
Assistant Professor,
Department of Mechanical Engineering,
Aditya Institute of Technology & Management,
Srikakulam, India.

D.Sreeramulu
Professor,
Department of Mechanical Engineering,
Aditya Institute of Technology & Management,
Srikakulam, India.

M. Venkatesh
Assistant Professor,
Department of Mechanical Engineering,
Aditya Institute of Technology & Management,
Srikakulam, India.

Abstract:

The overall objective of this paper is to evaluate and compare the fatigue performance of two competing manufacturing technologies for automotive crankshafts, namely forged steel and composite material. In this study a dynamic simulation was conducted on crankshaft, matrix material and forged steel, from similar single cylinder four stroke engines. Finite element analysis was performed to obtain the variation of stress magnitude at critical locations. The pressure-volume diagram was used to calculate the load boundary condition in dynamic simulation model, and other simulation inputs were taken from the engine specification chart.

The dynamic analysis has been done analytically and was verified by simulations in ANSYS. Results are achieved from aforementioned analysis were used in optimization of the forged steel crankshaft. Geometry, material, and manufacturing processes were optimized considering different constraints, manufacturing feasibility, and cost. The optimization process included geometry changes compatible with the current engine, fillet rolling, and the use of metal matrix composite, resulting in increased strength of the crankshaft, without changing connecting rod and/or engine block.

Keywords:

Connecting rod, Structural analysis, Thermal analysis, Forged steel, 6061-T6, Modeling, Analysis of connecting rod.

I. INTRODUCTION:

Crankshaft is one of the most important moving parts in internal combustion engine. Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston into a rotary motion. This study was conducted on a single cylinder 4- stroke diesel engine. It must be strong enough to take the downward force during power stroke without excessive bending. So the reliability and life of internal combustion engine depend on the strength of the crankshaft largely. And as the engine runs, the power impulses hit the crankshaft in one place and then another. The torsional vibration appears when a power impulse hits a crankpin toward the front of the engine and the power stroke ends. If not controlled, it can break the crankshaft.

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crankshaft has “crank throws” or “crankpins”, additional bearing surfaces whose axis is offset from that of the crank, to which the “big ends” of the connecting rods from each cylinder attach.It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsional elasticity of the metal.Large engines are usually multicylinder to reduce pulsations from individual firing strokes, with more than one piston attached to a complex crankshaft.

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Many small engines, such as those found in mopeds or garden machinery, are single cylinder and use only a single piston, simplifying crankshaft design. This engine can also be built with no riveted seam.The shaft is subjected to various forces but generally needs to be analyzed in two positions. Firstly, failure may occur at the position of maximum bending; this may be at the centre of the crank or at either end. In such a condition the failure is due to bending and the pressure in the cylinder is maximal. Second, the crank may fail due to twisting, so the connecting rod needs to be checked for shear at the position of maximal twisting. The pressure at this position is the maximal pressure, but only a fraction of maximal pressure.

II. LITERATURE SURVEY:

Jian Meng et al.[1] analyzed crankshaft model and crank throw were created by Pro/ENGINEER software and then imported to ANSYS software. The crankshaft deformation was mainly bending deformation under the lower frequency. And the maximum deformation was located at the link between main bearing journal, crankpin and crank cheeks. Farzin H [2]. Montazersadgh et al. Investigated first dynamic load analysis of the crankshaft. Results from the FE model are then presented which includes identification of the critically stressed location, variation of stresses over an entire cycle, and a discussion of the effects of engine speed as well as torsion load on stresses.

Mr.B.Varun [3] focused on the optimization possibilities in the crankshaft. A crankshaft made from AISI 1035 Steel was selected to utilize the form flexibility of the forging process and the cost benefits of using steel. The results illustrate that even a production crankshaft possesses enough potential for further optimization in friction and weight reduction. According to the outputs of the simulations, the goals defined by the optimization are realizable, without encountering fatigue problems. Additional reductions in bearing diameters or larger inner diameters would lead to a loss in durability, which can cause the crankshaft to operate under the safety limit, even at lower speeds.Gu Yingkui et al [4] described a three-dimensional model of a diesel engine crankshaft was established by using PRO/E software. Using ANSYS analysis tool, it shows that the high stress region mainly concentrates in the knuckles of the crank arm & the main journal and the crank arm & connecting rod journal ,which is the area most easily broken.

Xiaorong Zhou et al [5] described the stress concentration in static analysis of the crankshaft model. The stress concentration is mainly occurred in the fillet of spindle neck and the stress of the crankpin fillet is also relatively large. Based on the stress analysis, calculating the fatigue strength of the crankshaft will be able to achieve the design requirements. W.Y. Chien [6] was described the influence of the residual stresses induced by the fillet rolling process on the fatigue process of a ductile cast iron crankshaft section under bending is investigated. Farzin H. Montazersadgh et al. [7] investigated first dynamic load analysis of the crankshaft. Results from the FE model are then presented which includes identification of the critically stressed location, variation of stresses over an entire cycle, and a discussion of the effects of engine speed as well as torsion load on stresses.J.sun and Han Songtao [8, 9] was proposed that the Crankshaft is a complicated continuous elastomer. The vibration performance of crankshaft has important effect to engine. The calculation of crankshaft vibration performance is difficult because of the complexity of crankshaft structure, the difficult determinacy of boundary condition.

III. PROPOSED WORK:

The figure 1 shows the block diagram for process planning. Initially the model of the structure has been created by using CATIA. The pressure-volume diagram is used to calculate the load boundary condition in dynamic simulation model and other simulation inputs were taken from the engine specification chart. The dynamic analysis was done analytically and verified by simulations in ANSYS. To analyze crankshaft by forged steel (conventional) and metal matrix composite (optimized) materials in ANSYS workbench. The results of deformation, stress and strain values are obtained from ANSYS to find suitable material for crank shaft.

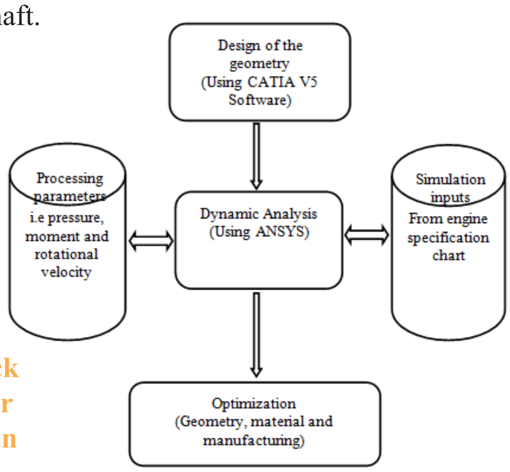

Fig. 1. Block diagram for process plan

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IV. METHODOLOGY

A. Procedure of static Analysis

•The design of crankshaft has been done in CATIA and is save the part in ICGS file format. The file has been exported in to ANSYS workbench simulation module.
•Forged steel has been used as material for crank shaft.

The following initial parameters of forged steel material are given for analysis and the simulation has been obtained as shown in figure 2 i.e
Material Type - Forged Steel
Designation - 42CrMo4
Yield strength (MPa) - 680
Ultimate tensile strength (MPa) - 850
Elongation (%) - 13
Poisson ratio - 0.3

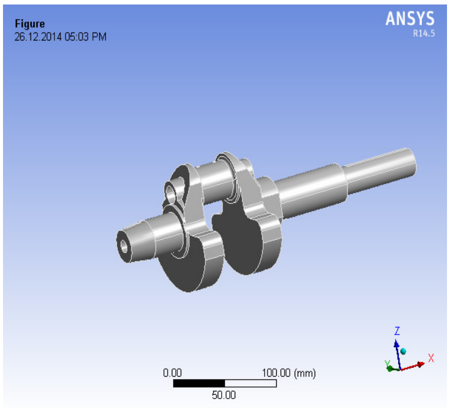

Fig. 2. Crank Shaft in ANSYS

For meshed the crank shaft tetrahedron element has been selected. The total number of nodes 17119 and the total number of elements 9605 are obtained as shown in figure 3.

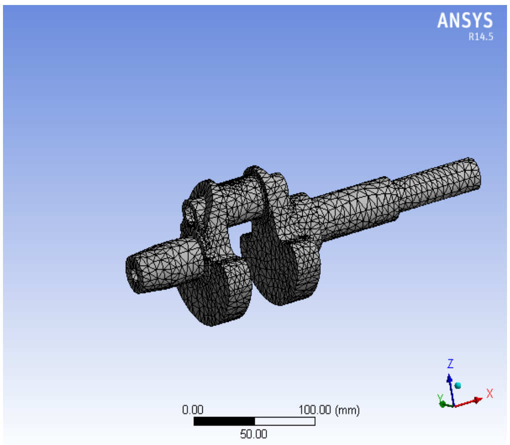

Fig. 3. Meshed model of Crank shaft

The crankshaft bears the constraints of main journals and longitudinal thrust bearing. Because of the effect of load, crankshaft main journals appear bend deformation between the lower main-bearing half and upper main-bearing half. And the longitudinal thrust bearing can prevent effectively the crankshaft axial movement and ensure the piston-and-connecting-rod assemblies normally work. Five surface radial symmetry constrains were exerted on the five main journals surface respectively, axial displacement constrains were exerted on the two end face of crankshaft. Then the modal analysis was carried out using the ANSYS software [10]Boundary conditions play an important role in finite element calculation. Both remote displacements for bearing supports are fixed.Load & Boundary conditions are given in model. Load applied on position show in fig of A (Rotational velocity), B(Moment) & D (pressure). Fixed inside portion of shaft location C (fixed)

Define type of Analysis:

Type of Analysis:-Static Structural

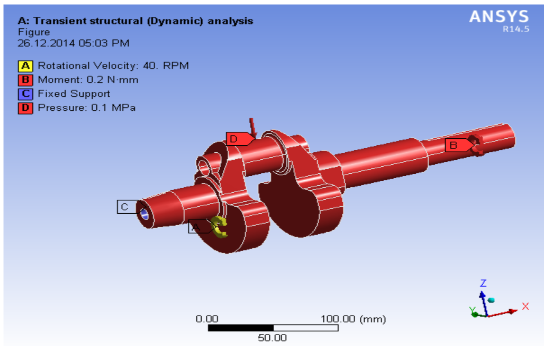

Fig. 4. Load & Boundary condition is given in model.

Load applied on position show in fig of A (Rotational velocity), B(Moment) & D (pressure). Fixed inside portion of shaft location C (fixed) After running the analysis and we will get the results.

B. Results of the Analysis for forged steel:

The maximum value obtained 9.3054e-5.On left and right side of shaft position maximum strain formed as shown in figure 5.

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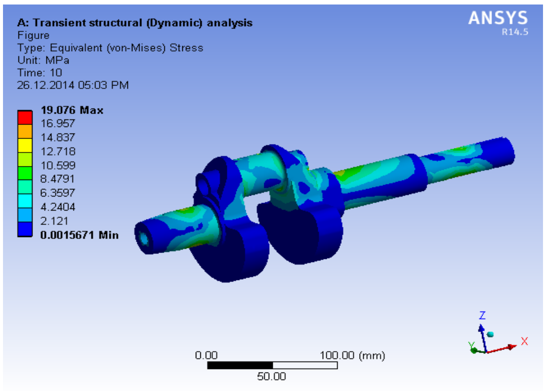

Fig. 5. From Structural analysis, Strain for material no.1 .

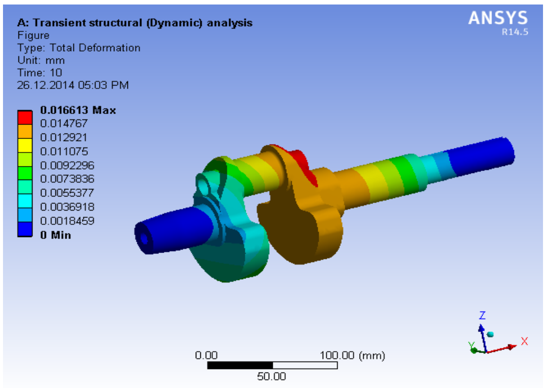

Fig. 6. From Structural analysis, Total deformation for material no.1

Maximum value obtained 0.0166mm. Right position of crank got maximum deformation. On shaft position it gives minimum deformation.

C. Results for optimized metal matrix composite material:

The maximum value obtained 18.521 MPA. On left and right side of shaft position maximum strain formed as shown in figure 7.The maximum value obtained 0.016298mm. Right position of crank got maximum deformation. On shaft position it gives minimum deformation as shown in figure 8.

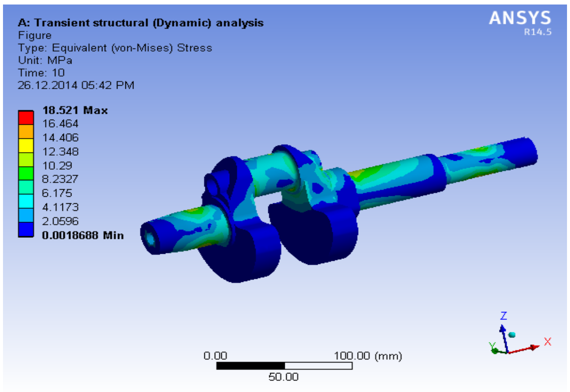

Fig. 7. From Structural analysis, Stress for material no.2

Fig. 8. From Structural analysis, Total deformation for material no.2 Finally the results for conventional material forged steel, optimized metal matrix composite material and weights of the forged steel can be shown in table I, II and III.

TABLE I: RESULTS FOR CONVENTIONAL MATERIAL FORGED STEEL

	MIN	MAX
Total deformation	0	0.016613
Equivalent Elastic Strain	7.644e-9	9.3e-5
Equivalent stress	1.567e-3	19.076

TABLE II: RESULTS FOR OPTIMIZED METAL MATRIX COMPOSITE MATERIAL

	MIN	MAX
Total deformation	0	0.016298
Equivalent Elastic Strain	8.89e-9	8.82e-5
Equivalent stress	1.868e-3	18.521

TABLE III: WEIGHTS OF FORGED STEEL AND COMPOSITE MATERIAL

CRANK SHAFT MATERIALS	WEIGHT (Kg)
FORGED STEEL	3.8228
METAL MATRIX COMPOSITE	2.1635

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V. DESIGN CALCULATION FOR CRANK-SHAFT

The configuration of the diesel engine for this Crankshaft is:

Specifications of Atul Shakti Engine
Capacity-395 cc
Number of Cylinders-1
Bore × Stroke- 86 × 68 mm
Compression Ratio-18:1
Maximum Power-8.1hp @ 3600 rpm
Maximum Torque-16.7 Nm @ 2200 rpm
Maximum gas pressure-25 bar

A. Design of crankshaft when the crank is at an angle of maximum twisting Moment

Force on the Piston FP = Area of the bore × Max.
Combustion pressure =Pi/4×D2×Pmax = 14.52 KN
In order to find the thrust in the connecting rod (FQ),
We should first find out the angle of inclination of the connecting rod with the line of stroke (i.e. angle Ø).
We know that
Sin Ø = Sin θ/ (L/R) = sin 35°/4
Which implies Ø = 8.24°
We know that thrust in the connecting rod
FQ = FP/ cos Ø
From this we have,
Thrust on the connecting rod FQ = 14.67 KN
Thrust on the crank shaft can be split into Tangential Component and the radial component.
1) Tangential force on the crank shaft, FT = FQ sin (P+ Ø) =10.05 KN
2) Radial force on the crank shaft, FR = FQ cos (P+ Ø) = 10.68 KN
Reactions at bearings (1 & 2) due to tangential force is given by,
HT1=HT2 = FTxb1/b = 5.02KN (Since b1=b2=b/2)
Similarly, Reactions at bearings (1 & 2) due to radial force is given by,
HR1 = HR2 = FRxb1/b =5.34 KN (Since b1=b2=b/2)

RESULTS:

Diameter of the crankpin = 44 mm
Length of the crankpin = 24 mm
Diameter of the shaft = 41 mm
Web thickness (both left and right hand) = 23 mm
Web width (both left and right hand) = 63 mm

VI. THERMAL ANALYSIS

A. For Case 1: Forged Steel

Load conditions for first material as shown in figure 9.

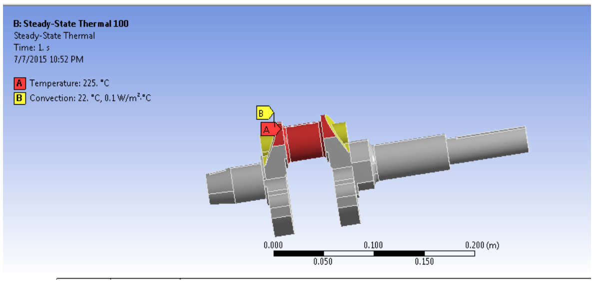

Fig. 9. Load and B.Cs for material no.1

The maximum heat flux 225 W/m2 obtained at connecting portion of connecting rod and remaining portion at mean temperature as shown in figure 10.

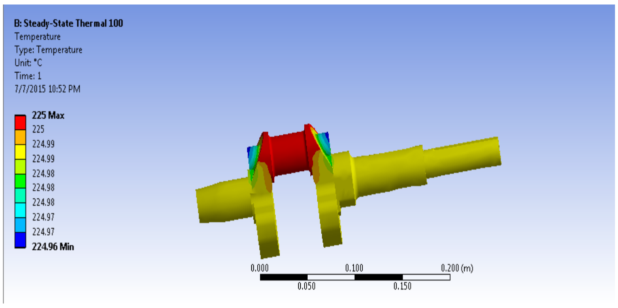

Fig 10. Temperature for output for Material no.1,

The maximum heat flux 59.131 W/m2, obtained at sides of crank pin and remaining position is normal low temperature as shown in figure 11.

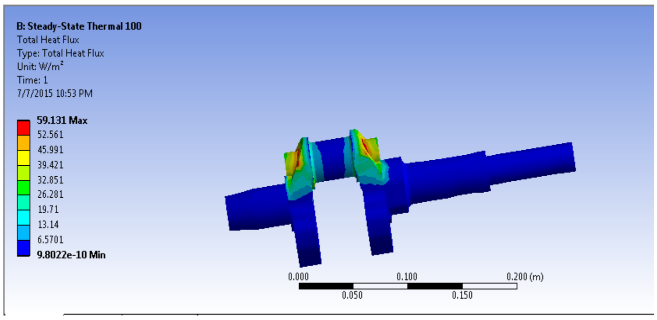

Fig 11. Heat flux for output for Material no.1,

B. For Case 2: Metal Matrix Composite:

The load conditions for material no 2 as shown in figure 12, the Maximum heat flux 485 W/m2 .obtained at connecting portion of connecting rod and remaining portion at mean temperature as shown in figure 13 and Maximum heat flux 186.96 W/m2 . Obtained at sides of crank pin and remaining position is normal low temperature as shown in figure 14.

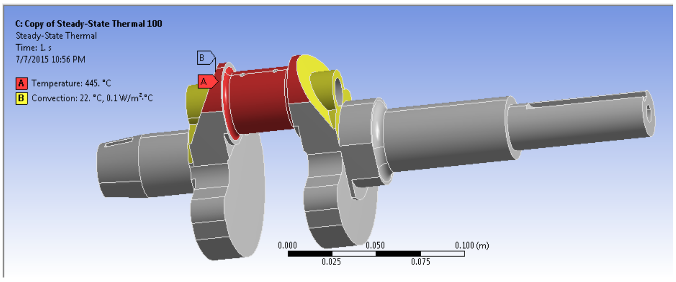

Fig. 12. Load and B.Cs for material no.2

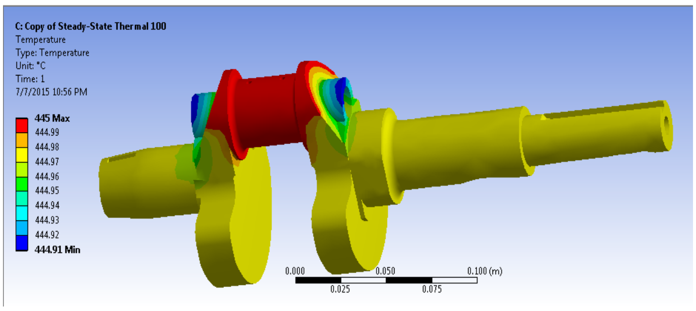

Fig. 13. Temperature for output for Material no.2,

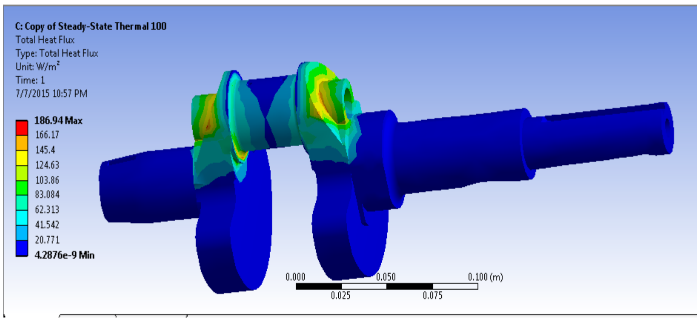

Fig. 14. Heat flux for output for Material no.2,

TABLE IV: COMPARISON TABLE FOR THERMAL ANALYSIS

S.NO.	MATERIALS	TEMPERATURE	HEAT FLEX
1	FORGED STEEL	225	59.13
2	METAL MATRIX COMPOSITE	445	186.94

VII. CONCLUSION:

Experimental results from testing the crank shaft under rotational velocity and moment are listed in the Table. Analysis has been carried out by optimizing the material metal matrix composite. The results such as total deformation, equivalent elastic strain and equivalent stress for each material are determined. Comparing the optimized materials and the conventional material, metal matrix composite has the low values of total deformation, stress and strain. And also weight of the crank shaft is reduced by 43.36%. Hence it is concluded that metal matrix composite is suitable for the crank shaft.The project carried out by us will make an impressing mark in the field of automobile. While carrying out this project we are able to study about the 3-D modeling software (PRO-E) and Study about the analyzing software (ANSYS) to develop our basic knowledge to know about the industrial design.

REFERENCES:

[1]Jian Meng,, Yongqi Liu, Ruixiang Liu., " Finite Element Analysis of 4-Cylinder Diesel Crankshaft", Modern education and computer science (2011).

[2]Farzin H. Montazersadgh and Ali Fatemi., "Stress Analysis and Optimization of Crankshafts Subject to Dynamic Loading", Americal iron and steel institute (2007).

[3]Mr.B.Varun, "Stress Analysis and Optimization of Crankshafts Subject to Static Loading" , International Journal Of Engineering And Computer Science (2014).

[4]Gu Yingkui, Zhou Zhibo.,2011,"Strength Analysis of Diesel Engine Crankshaft Based on PRO/E and ANSYS," Third International Conference on Measuring Technology and Mechatronics Automation

[5]Xiaorong Zhou., Ganwei Cai., Zhuan Zhang. Zhongqing Cheng., 2009, "Analysis on Dynamic Characteristics of Internal Combustion Engine Crankshaft System," International Conference on Measuring Technology and Mechatronics Automation.

[6]Chien, W. Y., Pan, J., Close, D., and Ho, S., 2005, "Fatigue Analysis of Crankshaft Sections Under Bending with Consideration of Residual Stresses," International Journal of Fatigue.

[7]Montazersadgh, F. H. and Fatemi, A., 2007, "Dynamic Load and Stress Analysis of a Crankshaft," SAE Technical 2007, Society of Automotive Engineers, Warrendale, PA, USA.

[8]J. Sun, C..L. Gui, and x. Li, "A Review of Crankshaft Strength Analysis for Internal Combustion Engines," Transactions of Csice,2002.

[9]Han Songtao, Hao Zhiyong, "Mode analysis of three-dimensional finite element and experimental study on a 6102B diesel engine crankshaft," Transactions of the Chinese Society of Agricultural Machinery, 2001.

[10]L. Wang, Y. Xiang, Y. H. Lu, W. F. Liu, "Modeling and Free Modal Analysis of the Crankshaft." Journal of Luoyang Technology College, 2004.

[11]http://en.wikipedia.org/wiki/crankshaft