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Design and Analysis of Crankshaft

Kevin Patel[1], Darshan Rathod[2], Dhaval Patel[3], Vishal Patil[4], Mit Patel[5], Kalpan Desai[6]
[1,2,3,4,5]*Student, Dept. of Mechanical Engineering, S. S. Agrawal Institute of Engg. & Technology, Navsari, India*
[6]*HOD & Prof., Dept. of Mechanical Engineering, S. S. Agrawal Institute of Engg. & Technology, Navsari, India*

***Abstract*: Crankshaft is one of the critical component for the effective and precise working of the internal combustion engine. A three-dimension model of diesel engine crankshaft is created using Pro-E software. Simulation inputs are taken from the engine specification chart. The static analysis is done using FEA software ANSYS which resulted in the load spectrum applied to crank pin bearing. This load is applied to the FE model in ANSYS, and boundary conditions are applied according to the engine mounting conditions. The analysis is done for finding critical location in crankshaft. Stress variation over the engine cycle and the effect of torsion and bending load in the analysis are investigated. Von-misses stress is calculated using theoretically and FEA software ANSYS. The relationship between the frequency and the vibration model is explained by the model and harmonic analysis of crankshaft using FEA software ANSYS.**

***Keywords*: Crankshaft, Design, Modal and Harmonic Analysis of Crankshaft.**

1. Introduction

A crankshaft related to crank is mechanical part able to perform a conversion between reciprocating motion and rotational motion. In a reciprocating engine it translate reciprocating motion of the piston into rotational motion. In reciprocating compressor it converts the rotational motion into reciprocating motion. In order to do the conversion between two motions the crankshaft has "crank throw" or "crank pin". Additional bearing surface whose axis is offset from that of the crank to which the big end of the connecting rod from each cylinder attach. In reciprocating engine it's typically connected to flywheel to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional and vibrational damper at the opposite end to reduce the torsional vibrations often caused along the length of the crankshaft by the cylinder farthest from the output end acting on the torsional elasticity of the metal.

2. Construction

Crankshafts can be monolithic (made in a single piece) or assembled from several pieces. Monolithic crankshafts are most common, but some smaller and larger engines use assembled crankshafts.

A. Forging and casting

Crankshafts can be forged from a steel bar usually through roll forging or cast in ductile steel. Today more and more manufacturers tend to favor the use of forged crankshafts due to their lighter weight, more compact dimensions and better inherent damping. With forged crankshafts, vanadium micro alloyed steels are mostly used as these steels can be air cooled after reaching high strengths without additional heat treatment, with exception to the surface hardening of the bearing surfaces. The low alloy content also makes the material cheaper than high alloy steels. Carbon steels are also used, but these require additional heat treatment to reach the desired properties. Cast iron crankshafts are today mostly found in cheaper production engines (such as those found in the Ford Focus diesel engines) where the loads are lower. Some engines also use cast iron crankshafts for low output versions while the more expensive high output version use forged steel.

B. Machining

Crankshafts can also be Machine out of a billet, often a bar of high quality vacuum remitted steel. Though the fiber flow (local in homogeneities of the material's chemical composition generated during casting) doesn't follow the shape of the crankshaft (which is undesirable), this is usually not a problem since higher quality steels, which normally are difficult to forge, can be used. These crankshafts tend to be very expensive due to the large amount of material that must be removed with lathes and milling machines, the high material cost, and the additional heat treatment required. However, since no expensive tooling is needed, this production method allows small production runs without high costs. In an effort to reduce costs, used crankshafts may also be machined. A good core may often be easily reconditioned by a crankshaft grinding process. Severely damaged crankshafts may also be repaired with a welding operation, prior to grinding, that utilizes a submerged arc welding machine. To accommodate the smaller journal diameters a ground crankshaft has, and possibly an over-sized thrust dimension, undersize engine bearings are used to allow for precise clearances during operation.

3. Finite element analysis

A. Introduction

To Solved the engineering problem or mathematically solution, the finite element analysis is use. Finite element analysis is a one type of numerical analysis technique for obtain approximate solution. It is very flexible as an analysis code. In all industry this technique is get much attention nowadays in engineering industry. We find that it is necessary to obtain approximate solution of engineering problem, there are many hard problem to find analytically and mathematically solution. The finite element code is a very powerful for numerical solution of a wide range of engineering problem. The finite element analysis is use to know whether or product will break, wear out or work the way it was designed. Mathematically or numerical equation help to know behavior of each element. The finite element analysis is use to decrease the time significantly to take product from concept to the production line. One most take the advantage of the faster generation of personal computers for the design and analysis of engineering product with precision level of accuracy.

1) Geometric definition

Key point, line, area and volume are the geometric input in pre-processor. To obtain the geometric representation of structure this for geometric input will use. All input or entities have different identification symbols.

B. Mesh generation

First step in the finite element analysis to divide the body or structure into finite number of smaller units known as elements. This process of dividing the body or structure into finite number of elements is known as meshing or discretization. In addition to the cross section the body force and the surface traction should be constant within each element. While dividing the body, it is necessary to define a node at each location where a point load is applied.

C. Finite element generation

Finite element analysis required maximum amount of time to generating elements and nodal data. Pre-processing allow user to generate node and element automatically at the same time allowing and control over size and number of elements. The pre-processing involves modelling of the body selection of the element type, meshing of the body, inputting the material information, applying the boundary condition and applying the loads.

D. Boundary condition

In boundary value problems, a solution is need the region of the body or structure, while the values of certain variables are prescribed on the boundaries of the region. The value of variables prescribed on the boundaries of the region are called as boundary condition.

E. Solution

As per the pre-processor data the solution phase deal with solution of problem according to problem definition. All the work of formulating metrics by the computer automatically and displacement stress value are given in output.

F. Post processor

The post processing stage deals with the presentation of result. The results are presented in the graphical as well as textual forms. Post processor is use for providing visualization of computed result. The data will shows in tabular form in post processing output result.

4. Crankshaft material

A. Titanium alloy

Titanium alloys are metals that contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness (even at extreme temperatures). They are light in weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. However, the high cost of both raw materials and processing limit their use to military applications, aircraft, spacecraft, medical devices, highly stressed components such as connecting rods on expensive sports cars and some premium sports equipment and consumer electronics.

Properties of Titanium Alloy:
Young's Modulus: 96000Mpa
Poisson's ratio : 0.36
Density : 4.62e-006 Kg/mm^3
Tensile ultimate Strength: 1070Mpa

B. Cast iron

This is a good choice for high volume production. A chilled iron camshaft has a resistance against wear because the camshaft lobes have been chilled, generally making them harder. When making chilled iron castings, other elements are added to the iron before casting to make the material more suitable for its application. Chills can be made of many materials, including iron, copper, bronze and aluminum, graphite, and silicon carbide. Other sand materials with higher densities, thermal conductivity or thermal capacity can also be used as a chill. For example, chromate sand or zircon sand can be used when molding with silica sand.

Properties of Cast Iron:
Young's Modulus: 1.2e+005Mpa
Poisson's ratio : 0.275
Density : 7.2e-006 Kg/mm^3
Tensile ultimate Strength: 414Mpa

5. Figures of ANSIS results

A. Titanium alloy

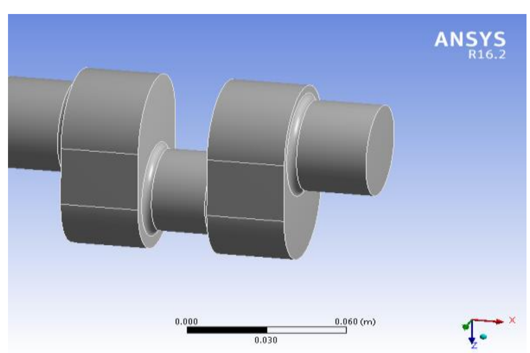

Fig. 1. Crankshaft

1) Total deformation

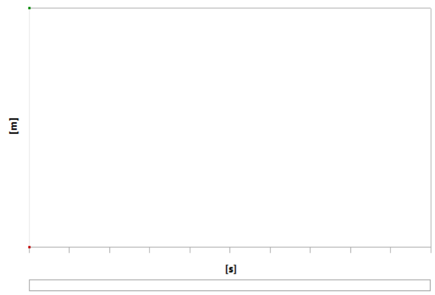

Fig. 2. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

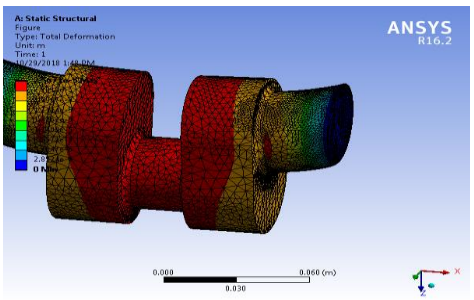

Fig. 3. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Figure

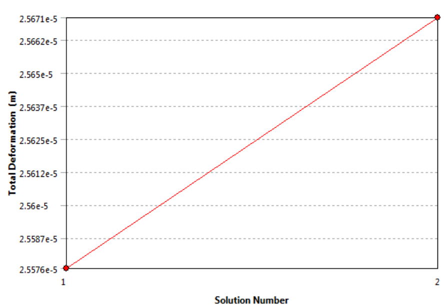

Fig. 4. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Convergence

Table 1
Total deformation

	Total deformation	Change (%)	Nodes	Element
1	2.5576e-005		36580	21319
2	2.5671e-005	0.37362	12139	79383

2) Equivalent stress

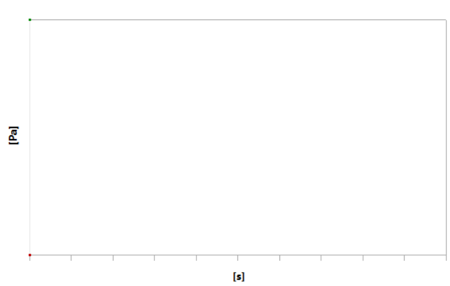

Fig. 5. Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

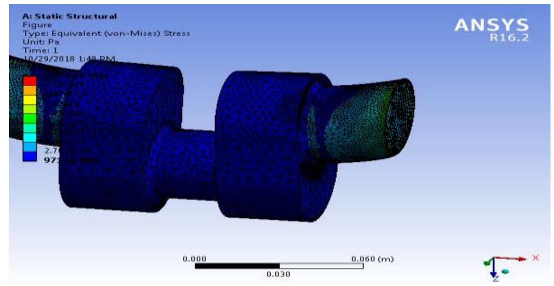

Fig. 6. Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress > Figure

Table 2
Total deformation and equivalent stress

	Time(s)	Minimum(m)	Maximum(m)
Total deformation	1.	0.	2.5671e-005
Equivalent stress	1.	717.6	2.436e+008

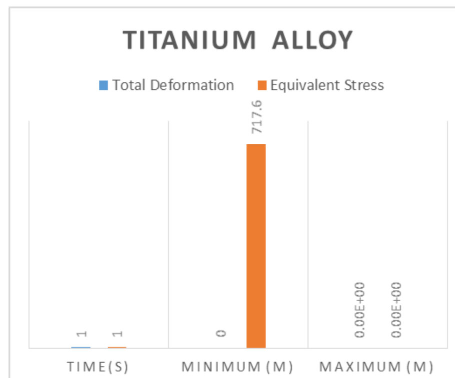

Fig. 7. Titanium alloy

B. Cast iron

1) Total deformation

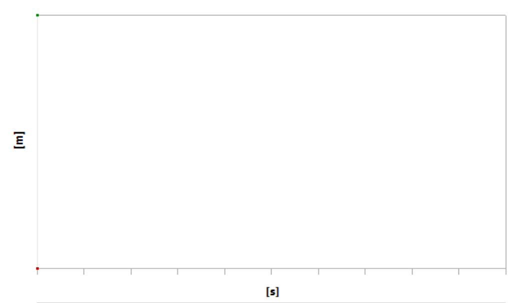

Fig. 8. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

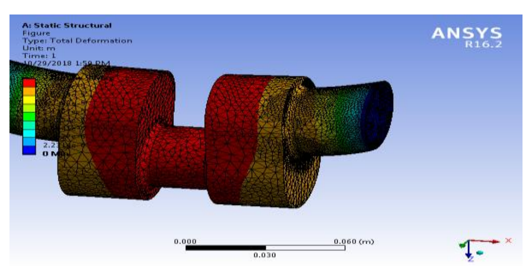

Fig. 9. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Figure

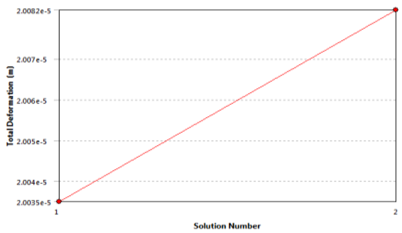

Fig. 10. Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation > Convergence

Table 3
Total deformation

	Total Deformation(m)	Change (%)	Nodes	Element
1	2.0035e-005		36580	21319
2	2.0082e-005	0.23376	141194	92933

2) Equivalent stress

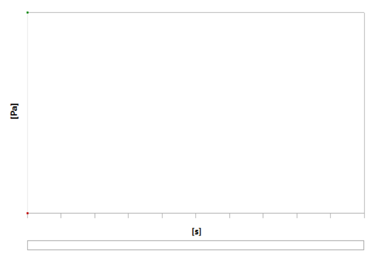

Fig. 12. Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

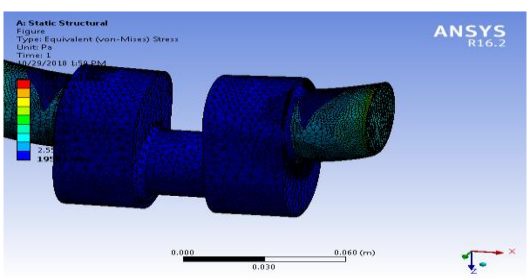

Fig. 13. Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress >Figure

Table 4
Time

	Time(s)	Minimum(m)	Maximum(m)
1	1	0	2.0082e-005
2	1	19587	2.3021e+008

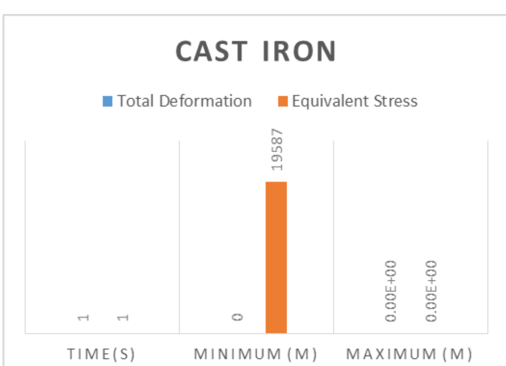

Fig. 14. Cast iron

6. Result

In this Project, the crankshaft model was created by Solid workV17 software. Then, the model created by Solid WorkV17 was imported to ANSYS software. The Value of Von-Misses Stresses that comes out from the analysis is far less than material yield stress so our design is safe and we should go for optimization to reduce the material and cost. After Performing Static Analysis I Performed the materials Titanium alloy. According to above discussion we concluded the Titanium Alloy is prepared one.

- The maximum deformation appears at the center of crankpin neck surface.
- The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point Journal.
- The edge of main journal is high stress area. Analysis Results. So we can Say that Dynamic FEA is a good tool to reduce Costly experimental work.

7. Conclusion

The crankshaft model is created by Solid workV17 software then the model created by Solid workv17 was imported to ANSYS software. The maximum deformation appears at the center of crankshaft surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point of journal. The edge of main journal is high stress area, under lower frequency the crankshaft will deform and maximum deformation was located at the link between main-bearing journal and crank cheeks. So this area prone to appear the bending fatigue crack. Based on results, we can forecast the possibility of mutual interference between the crankshaft and other parts. The result provide a theoretical basis to optimize the design and fatigue life calculation.

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