Modal Analysis of A Single Cylinder 4-Stroke Engine Crankshaft

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Abstract- The crankshaft is an important component of an I.C engine. This converts the reciprocating displacement of the piston in to a rotary motion of the crank. An attempt is made in this paper on a single cylinder 4-stroke I.C engine. The 3-d modelling of the crankshaft and the analysis is to done by using CATIA-V5 software. And applying the boundary conditions on the crankshaft. The modal analysis is to be done in two cases i.e free-frequency and frequency analysis. Then the results are in free frequency analysis the resonance frequency is 1150.967Hz occurred at the 7^{th} node. In frequency case minimum frequency occurred at the fillet areas is 890.735Hz maximum frequency is 5539.023Hz.

Index Terms- CATIA-V5, Frequency analysis.

I. Introduction

Crankshafts are common machine elements which transfer rotational movement into linear. Crankshaft design in modern internal combustion engines is driven by the desire for more power at higher efficiency rates and reduced weight. The demands on crankshaft material, therefore, are increasing, while the crankshafts themselves become smaller. The many different designs of crankshaft vary considerably, and even during mass production there can be subtle differences from one to another. Crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crank shaft, the force will be transmitted to the crankshaft. The magnitude of the forces depends on many factors which consist of crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin.

Crankshaft must be strong enough to take the downward force of the power stroke without excessive bending so the reliability and life of the internal combustion engine depend on the strength of the crankshaft largely. While the converting the reciprocating motion into rotary motion by the crankshaft, it is subjected to both vertical load and vibrations. The study to be carried out to check the load carrying capacity of the crank shaft subjected to both vibration and rotation. Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis. Analysis of vibration modes is a critical component of a design, but is often overlooked. Inherent vibration modes in structural components or mechanical support systems can shorten equipment life, and cause premature or completely unanticipated failure, often resulting in hazardous situations. Detailed modal analysis determines the fundamental vibration mode shapes and corresponding frequencies.

II. LITERATURE REVIEW

Mr.S.J. Patil et al [1] have been described the analytical and FE modal analysis of a crankshaft. The 3-dimentional model were constructed in pro/E and the analysis has to be done in ansys. Crankshaft considered as two rotor system to caluculate the six modes of frequency. The results show that the crank shaft is not running in critical speed.

Momin Muhammad Zia Muhammad Idris et al [2] has been discussed the optimization of crankshaft using strength analysis. The 3-dimentional model was created using PRO-E software, and the analysis is to be done in ANSYS.The results are modal analysis of modified design is also done to investigate possibility of resonance.

Rinkle garg and Sunil Bahal. et al [3] have been studied the static analysis of a single cylinder 4-stroke engine crankshaft and using FEM technique and obtain the stress distribution at critical location .The model was created in pro-e and analysis concerned in ansys, obtained optimization of crank shaft.

B.D.N S Murthy et al [4] has been analysed the Modeling, analysis and optimization of crankshaft. The analysis is done on two different materials are Annealed 4340 steel,Inconel x750 alloy. The model were created in catia-v5 and the analysis is to be done in ansys. The results are in strength point of view Inconel x750 is better than Annealed 4340 steel for crankshaft.

III. OBJECTIVE

An attempt in this paper, the crankshaft is modelled by using CATIA-V5 software, and frequency analys is done by using Catia-v5 analysis software. To evaluate the natural frequency with different cases.

IV. MODELING AND ANALYSIS OF CRANKSHAFT

The main objective of this study to analyze the frequency in different cases over the crankshaft using CATIA software.

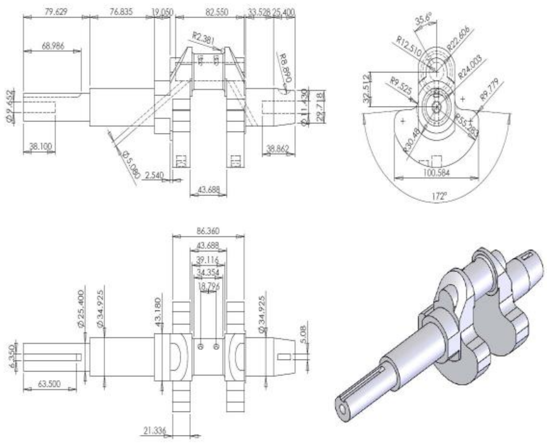

Fig: 1 2-Dimentional model of the crankshaft

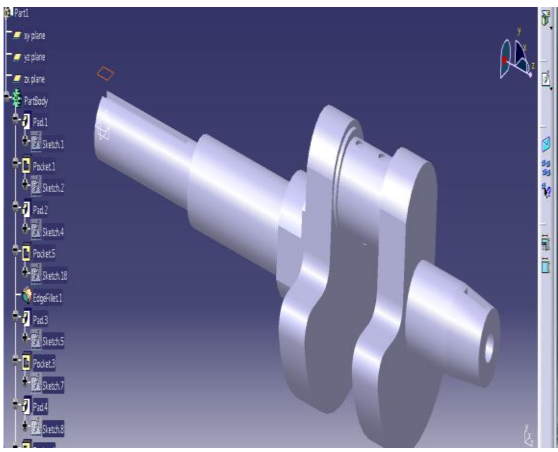

Fig: 1 design model of the crankshaft

The geometrical module of the crankshaft is created using CATIA V5 R19 software, CATIA is a pre-processor were the solid geometry is created using 2-D drawings, module created in CATIA is exported as IGES file for the next pre-processor for meshing. The figure:1 contains the shaft, crank web, crankpin. Modelling of crankshaft is done by importing modal data entered in Microsoft excel sheet into CATIA V5 generate shape design work bench by running on pading and pocketing micros. Meshing can be defined as the process of breaking up a physical domain into smaller sub-domains (elements) in order to facilitate the numerical solution of a partial differential equation. While meshing can be used for a wide variety of applications, the principal application of interest is the finite element method. Surface domains may be subdivided into triangle or quadrilateral shapes, while volumes may be subdivided primarily into tetrahedral or hexahedral shapes. T he design model of the crankshaft using tetrahedral shape of meshing and solid 187 element is used for the analysis part. No. of nodes: 841, No of elements: 2763.

APPLY MATERIAL FOR CRANKSHAFT:

Material details:
Material Type: cast iron
Young modulus: $1.7e^{+011}$N/m^2
Poisson's ratio: 0.291
Density: 7197kg/m³
Coeffient of thermal expansion : $1.2e^{-005}$k-deg
Yield strength : $3.1e^{+008}$ N-m^2.

V. RESULTS AND DISCUSSION

Analysis of crankshaft:

The analysis of crankshaft on free-frequency and frequency (modal analysis) by using CATIA-V5 Software, hence the results are tabulated below. There are generally two categories for the vibrations the free frequency vibrations and frequency vibrations, free vibrations occur when the system is under the action of oscillating systems and their inherent forces external forces there are controversial.

Case-1: Free-frequency case:

In free-frequency case there is no boundary conditions are applied in the crankshaft . In natural free-frequency the crankshaft should not be vibrating but some period of time vibrations are occurred because self weight of the crankshaft. The frequency occurred in 7th node . These frequency is known as resonance frequency .

S.No	MODE	FREQUENCY [Hz]
1	1-5	0
2	6	4.801e-004
3	7	1150.96
4	8	1370.633
5	9	2275.472
6	10	2435.688

Table:1 free-frequencies of vibration

Seventh Mode of vibration:

The seventh mode of vibration is bending vibration, the natural frequency is 1150.96Hz.

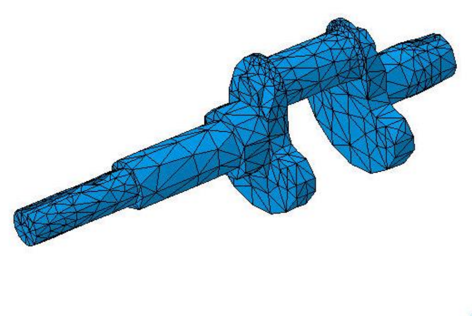

Fig: 1: 7th mode of vibration

8th Mode of vibration:

The eighth mode of vibration is occurred at the crankpin area .the frequency will be 1370.633Hz.

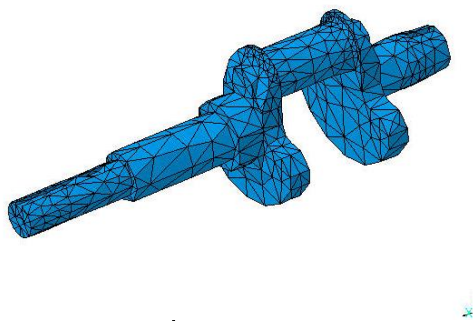

Fig:2: 8th mode of vibration

9th mode of vibration:
The nineth mode of vibration is occured at the left side shaft part and the left side web part, the freqquency is 2275.472Hz.

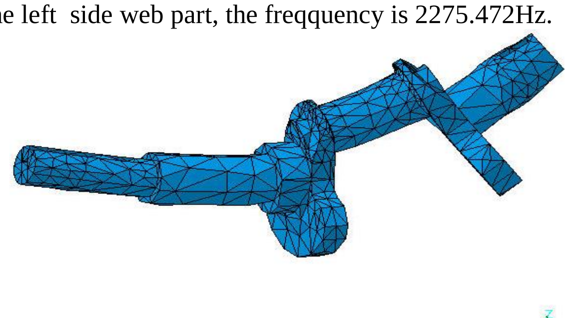

Fig: 3: 9th mode of vibration.

10th mode of vibration:
The 10th mode of vibration is bending vibration of crank pin area and the left side of the crank part , the frequency is 2435.688Hz.

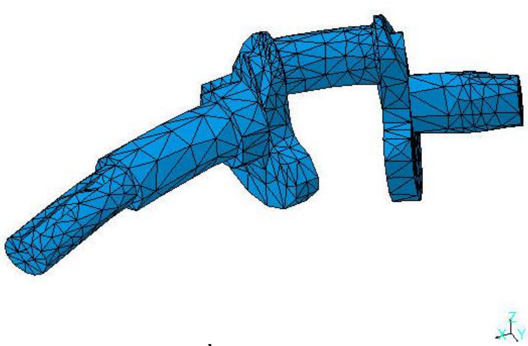

Fig: 4: 10th mode of vibration.

Frequency case :
In frequency case applied boundary conditions on the crankshaft, the two ends of the crankshaft is to be fixed at the shaft part and the bearing load applied on the crankpin area.

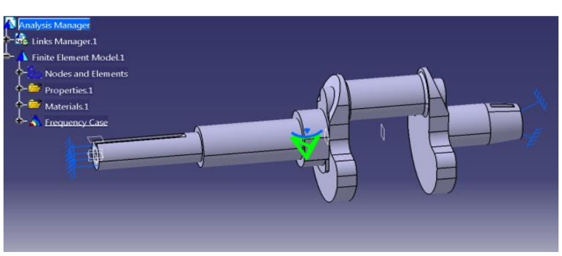

Fig: 5 boundary conditions appiled on the crankshaft

MODE	FREQUENCY [Hz]
1	890.735
2	990.53
3	1450.168
4	2413.328
5	2623.305
6	3035.357
7	3623.042
8	4678.819
9	5480.648
10	5539.023

Table:2 natural frequency case

First mode of vibration:
The first mode of vibration in x-direction at natural freqquency of 890.735Hz. Translation in y-axis is 77.37% , roation in x& z directions is 0.73% &0.22%.The maximum frequecy appears at the bottom of the crank web.

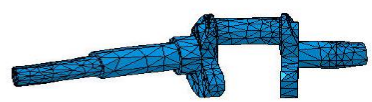

Fig: 6 First mode of vibration

Second mode of vibration
The second mode of vibration in y-direction is 990.53Hz. Translation in x-direction is 0.27% and y-direction is 78.11% , rotation in x-direction is 0.45. The maximum frequency appears at the left web and the left side of the shaft part.

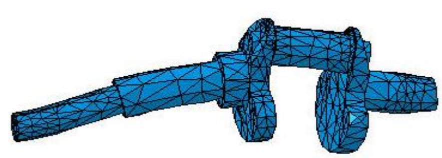

Fig:7 second mode of vibration.

Fifth mode of vibration:
The fifth mode of vibration in y-direction is 2623.3Hz. Translation in x-direction is 7.66% and x-direction is 1.51% , rotation in y-direction is 5.79%. The maximum ferqquency appers at the side of the crank web.

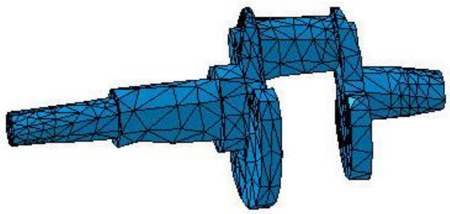

Fig: 7 fifth mode of vibration

10th mode of vibration:

The 10th mode of vibration in frequency is 5539Hz. Translation in x-direction is 13.69% and z-direction is 4.32% , rotation in y-direction is 1.44%. The bending occurred at the right side of the crank web,since the crankshaft has increase the no.of revolutions the force applied on the crankshaft wii be increased so that the frequency is also increased the bending of the crank web occurred.

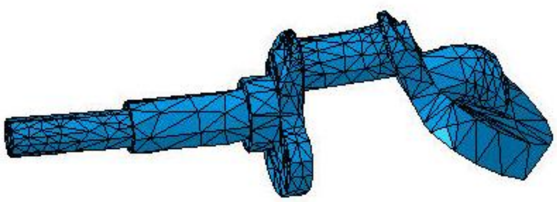

Fig: 8: 10th mode of vibration

VI. CONCLUSION

- In free-frequency case the resonance frequency is 1150.967Hz at 7th mode. When the engine running at the high speed, the driving frequency is merly 100Hz. As the lowest natural frequency is far higher than driving frequency, possibility of resonance is rare.
- In frequency case the minimum frequency occurred at 1st mode is 890.735Hz, the maximum frequency occurred at 10th node is 5539.023Hz.

REFERENCES

[1] Mr.S.J Patil " Modal analysis of compressor crankshaft", International Journal of Scientific Reasearch, vol-2, Issue:7, ISSN: 2277-8179, Pages: 155-158, July-2013.

[2] Momin Muhammad Zia Muhammad Idris " Optimization of crankshaft using strength analysis", International Journal of Engineering Reasearch and applications, Vol-3, Issue-3, ISSN:2248-9622, Pages: 252-258, May-Jun-2013.

[3] Rincle Garg, Sunil Baghla, "Finite element analysis and optimization of crankshaft", International Journal of Engineering and Management Reaserch, vol-2,Issue-6,ISSN: 2250-0758, Pages:26-31, December 2012.

[4] BDNS Murthy " Modeling analysis and optimization of crankshaft", vol-2, Issue-9, ISSN: 2278-0181, Pages: 749-753, September-2013.

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