Design Analysis of Crankshaft by Equivalent Beam Method

Sanjay Bhaskar Zope[1] Patil Amol S[2] Mahendra Dhere[3]
[1,2]Professor [3]Student
[1,2,3]Department of Aeronautical Engineering
[1,2,3]SVCET Rajuri

Abstract—In design and analysis industry, plenty of the time is spent on preparation of geometric models, meshing and analysis. Various design and analysis software are used for this purpose. For complex geometry components, most of the time is required for the analysis of component by Finite Element Method. Also, while modelling the component, it becomes difficult to capture all the features for complex parts. The thesis focuses on crank shaft with very complex geometry to be represented by simple beam by equivalent beam method. The equivalent beam method is used to replicate the static structural behaviour of the component by simple equivalent beam. Proposed geometry is verified through comparison of dynamic behaviours of both components. The thesis also focuses on the time reduction achieved by the application of equivalent beam method.
Key words: Crankshaft, Beam Method

I. Introduction

Crankshaft is most vital component of an IC engine. It should be able to sustain the forces generated during the power stroke of an IC engine with very little bending. So the crankshaft strength is the key factor for the service life and reliability of IC engine. The vibration analysis of the crankshaft has severe effects on the performance of the engine. Vibration calculation is also a critical task due to its intricate structure and difficulties in assigning boundary conditions. The design analysis of the crankshaft can be carried out using finite element method but due to the presence of large number of fillets, variable cross sections and oil holes, the meshing of the crankshaft becomes very fine which increases the total number of node greatly, ultimately increasing the computational time required for the analysis [5]. The present thesis focuses on the minimization of the computational time required for the analysis .The equivalent beam method used in this analysis provides equivalent uniform beam with simpler geometry which will reduce the number of elements, nodes and finally computational time [3].

In the past few years, finite element analysis has become much reliable as compared to actual experimental analysis. The results obtained by finite element method are having about 3.2 % error as compared to experimental results in a research carried out by Tianxin Zheng, Tianjian Ji. [1] While carrying out the finite element analysis method simplification of geometry was based on method suggested by Yoonhwan Woo. [2] Jian Meng et Al has given the detailed procedure to carry out stress analysis and frequency analysis of crankshaft of four cylinder engine and obtained results are used for optimization of the component. [5] J.G. Kim et Al have applied equivalent beam method for curved flexible pipes. When straight beam elements are considered for modeling, it’s bending characteristics are underestimated. So in this report equivalent beam method is used to determine the bending characteristics of flexible pipes. [4]

The model was created using CATIA V6/R2012 software. Then the model was imported to the Altair Hyperworks 13.0 and finally it was analyzed in solver MSC Nastran 20130.

II. Problem Statement

In mechanical industry, the computational time required for the design analysis with present methods of analysis is a crucial part. The computational time required for solving the analysis with large number of nodes and with fine mesh is excessively high as compared to remaining design process. In case of crankshaft analysis, this problem is faced with more effect due to the intricacy of geometry and total number of elements and nodes during the meshing. Higher the fineness of meshing higher is the computational time required. To solve this problem Equivalent Beam Method is used in this project which represents the behavior of crankshaft by simple equivalent beam to reduce the computational time.

III. Methodology

The paper focuses on representing very complex geometry of crankshaft into equivalent simple geometry beam to reduce complexity in modeling and analysis. The static behavior of the crankshaft is represented by cantilever loading condition and used to propose the cross section of equivalent beam. The dynamic behavior of the equivalent beam is verified with original component.

The geometry modeling is done in CATIA V6/R2012. Finite element model is prepared in Altair Hyperworks 13.0. This finite element modeling is done with tetragonal 3d elements. The element size used in this procedure is 5 mm to capture all the features of crankshaft and finally it was analyzed in solver MSC Nastran 20130.

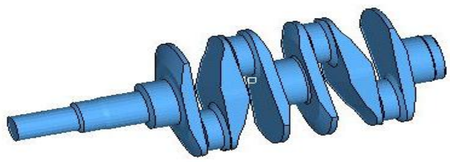

Fig. 1: 3-D entity model of crankshaft

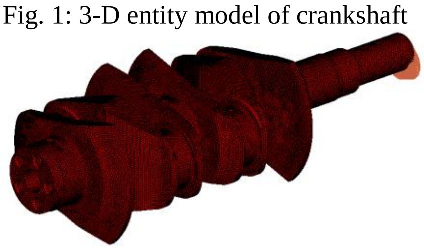

Fig. 2: Crankshaft finite element 3D mesh (X-Y-Z view)

IV. Equivalent Bending Stiffness

As proposed by Tianxin Zheng et Al [1], equivalent bending stiffness of the beam is calculated. Where one end is fixed in all degrees of freedom and load of 100N is applied on each node of the other face. As 55 nodes are present on the face, the total load applied is 55 KN. This load is applied to examine bending stiffness of crankshaft.

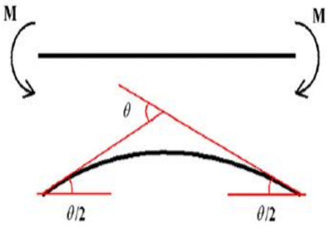

Fig. 3: Deformation of the beam in bending.

Let

l = length of crankshaft model,

l_{eq} = Equivalent length of beam model,

I= Moment of inertia crankshaft model

I_{eq}= Moment of inertia beam model

E= Modulus of Elasticity

M=bending Moment

θ = angle of deflection

Rotation of the crankshaft will be

$$\theta = \frac{M \times l}{E \times I}$$

Length of two beams is kept same i.e. $l = l_{eq}$

Now rotation of the equivalent beam will be

$$\theta_{eq} = \frac{M \times l}{E \times I_{eq}}$$

Now we know that

$$l = R \times \theta \qquad \therefore \; R = \frac{l}{\theta}$$

We know the bending equation for beam as

$$\frac{M}{I} = \frac{E}{R}$$

If $\theta_{eq} = \theta$ then,

$$I = \frac{M \times l}{E \times \theta}$$

$$\therefore \; I_{eq} = \frac{M \times l_{eq}}{E \times \theta}$$

…………in perpendicular Y direction

$$I_{eq} = \frac{(55000 \times 420)420}{210000 \times 0.1804}$$

Now this value is used to find out the diameter of the equivalent beam

$$I_{eq} = \frac{\pi \times d^4}{64}$$

$d = 24\,mm$

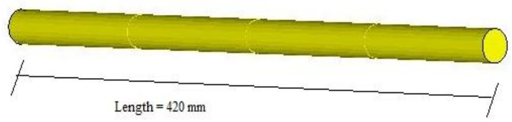

Fig. 4: 3D model of proposed beam

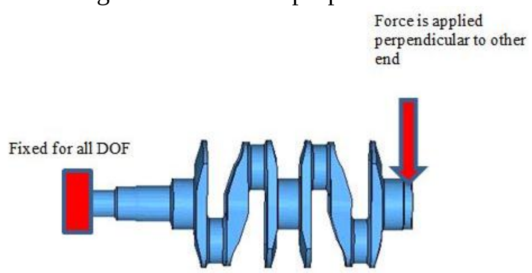

Fig. 5: Loading conditions of crankshaft

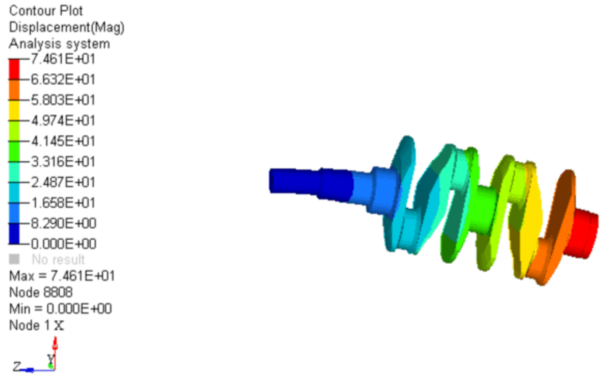

Fig. 6: Crankshaft bending characteristics

V. MODAL ANALYSIS

The modal analysis is carried out to obtain the vibration characteristics of the crankshaft. This modal analysis is carried out for first 4 modal parameters.

Free - Free position analysis is carried out on the crankshaft to obtain the modal parameters which means that constraints in the all directions were kept zero.[7] The obtained results are given in the below figures. First two natural frequencies were applied to find out the lateral bending and bending. The values obtained are tabulated below.

Condition	Crankshaft Model	Proposed Beam
Lateral Bending	65.75 H_Z	63.61 H_Z
Bending	68.49 H_Z	63.61 H_Z

Table. 1: First natural Frequency

Condition	Crankshaft Model	Proposed Beam
Lateral Bending	65.75 H_Z	63.61 H_Z
Bending	68.49 H_Z	63.61 H_Z

Table 2: Second natural Frequency

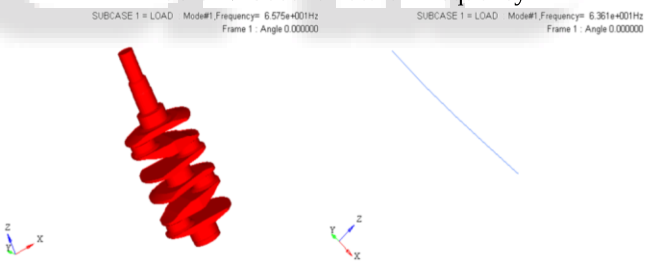

Fig. 7: First vibration modal of crankshaft

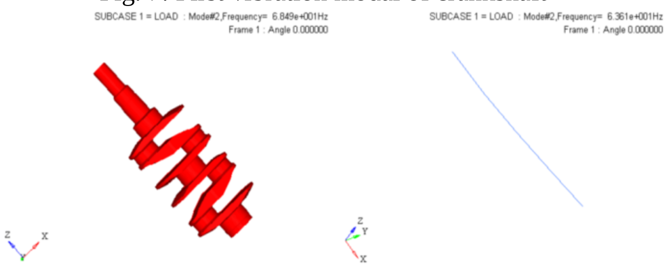

Fig. 8: Second vibration modal of crankshaft

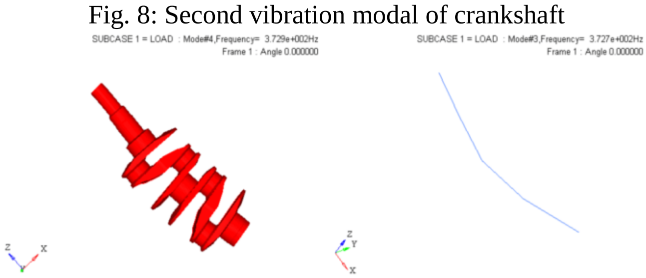

Fig. 9: Third vibration modal of crankshaft

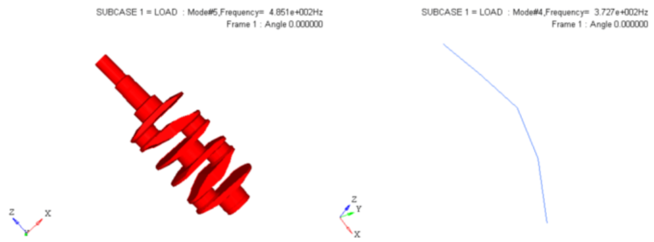

Fig. 10: Fourth vibration modal of crankshaft

VI. RESULTS AND DISCUSSIONS

The results obtained are tabulated with respect to the computational time required for the analysis of crankshaft.

Method	Nodes	Elapsed time
Solid model analysis	53352 Number	51 Sec
Equivalent Beam Method	1023 Number	02 Sec

Table 3: Comparison of solid model and proposed model results

VII. CONCLUSIONS

Comparing the results of the equivalent beam method and solid modeling method the time required to perform the analysis by existing method is minimized by proposed method. The simplicity of the equivalent beam method helps the designer in modeling and meshing of complex geometries. The obtained results from the equivalent beam method show good match within the limits with solid modelling.

REFERENCES

[1] Tianxin Zheng, Tianjian Ji, Equivalent representations of beams with periodically variable cross-sections, Engineering Structures 2011; vol. 33, pp. 706–719
[2] Yoonhwan Woo. Abstraction of mid-surface from solid model of thin walled parts a divide & conquer approach. Computer Aided Design 2014; vol. 41: pp. 1-11.
[3] F.Cluni, M.Gioffre, V.Gusella. Dynamic response of tall buildings to wind loads by reduced order Equivalent shear Beam Models. Journal of wind engineering and industrial aerodynamics 2013; vol. 123: pp. 339-348.
[4] J.G.Kim, J.K.Lee. A modified Beam Modeling method considering dynamic characteristics for curved flexible pipes. International Journal of pressure vessel and piping 2011; vol. 88: pp. 262-267.
[5] Jian Meng, Yongqi Liu, Ruixiang Liu, Finite Element Analysis of 4-Cylinder Diesel Crankshaft, International Journal of Image, Graphics and Signal Processing, 2011, vol. 5, pp. 22-29.
[6] M.Maleki, H.Sereshteh M.Mousivand M.Bayat. An Equivalent Beam model for the analysis tunnel building interaction. International Journal of Tunneling and underground space technology 2011; vol. 26, pp. 524-533.
[7] R. G. Desavale , A. M. Patil, Theoretical and Experimental Analysis of Torsional and Bending Effect on Four Cylinders Engine Crankshafts by Using Finite Element Approach, International Journal of Engineering Research 2013; vol. 2, pp : 379-385.

