STATIC STRUCTURAL ANALYSIS OF 2-CYLINDER CRANKSHAFT USING ANSYS

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Abstract: One of the most basic components of the IC engine is the crankshaft, which performs the crucial task of converting reciprocating motion to rotary motion. The crankshaft has to sustain the load from other parts such as the connecting rod, piston etc and perform operation to make the engine work. This makes the crankshaft liable to structural damages. In this paper, static structural analysis is performed on a 2-cylinder crankshaft using ANSYS. The 3D model of the crankshaft is imported in ANSYS, which is analyzed mainly for stress, deformation and fatigue. The results of the analysis can be useful to determine the life of the crankshaft and for its design optimization.
Keywords: crankshaft, stress, deformation, fatigue, ANSYS

I. INTRODUCTION

Crankshaft, being a vital component of the IC engine has to be maintained and analyzed regularly as it is prone to structural deterioration. Static structural analysis is executed on the crankshaft to acquire information about the stresses that are affecting the crankshaft [1]. It is mainly the Von misses stress. It also gives the information about the structural deformation that the crankshaft will undergo after experiencing a certain amount of stress due to the force and the load that crankshaft has to hold up. Due to high level of progression in the computational technology, the contortion in the structure of the crankshaft at various stress levels can be computed. The ability of the crankshaft to keep up with the huge forces acting on it mainly due to the downward piston movement, ascertains the productive and uninterrupted performance of the crankshaft [2]. This ability of the crankshaft depends upon its strength and the amount of stress it can undergo without deforming, which is estimated by static structural analysis.

II. LITERATURE REVIEW

In [1], it is stated that, static structural analysis can be used for design optimization of the crankshaft, as it provides details on the total stress and deformation of the crankshaft which can be checked for various materials and designs. In [2], it is stated that as the load at different times differs at various areas of the crankshaft, the structural dynamic analysis should be performed. The crankshaft can undergo different types of vibrations due to the load and the stress it undergoes, the vibrations can be torsional, flexural, axial and coupled [3][4][5]. Analysis have been performed on various types of crankshafts by modelling them either in Pro-E, Solidworks or CATIA-V5 and performing the analysis in ANSYS or CATIA-V5 [5][6][7][8][9]. In most of the analysis it is observed that the maximum stress and deformation occurs at the centre of the crankshaft i.e., at the centre of the crankpin and the fillet areas [10][11][12][13]. The decrease in the weight of the crankshaft by optimizing the design can improve the life span and performance[14][15][16].

III. PROCESS

The following process can be followed when one wishes to perform static analysis on a crankshaft. Specifying the correct details of the geometry and the material of the structure is very an important step, as it decides on which parts of the structure will the stress actually act. The geometry of the structure can either imported from any of the modelling softwares or it can be directly designed in ANSYS. The analysis begins with meshing which is an important step as it forms the basis of making the structure a Finite element structure i.e.; it is segmented into a finite number of element. After which the boundary conditions have to be specified, which include specifying the parts of the structure which will be fixed and the parts which will be affected by the force or stress. The parts which can be affected by force will be subjected to the appropriate amount of force by applying directed forces on those parts. Finally, the crankshaft structure can be analyzed for stress, deformation and fatigue by using the appropriate analysis tools in ANSYS.

IV. IMPORT GEOMETRY

The 3D geometry of the crankshaft is imported in ANSYS. The type of file is IGES. The following table gives the details about the geometry of the crankshaft. It is a two cylinder crankshaft with flywheel and gear as shown in figure 1. below.

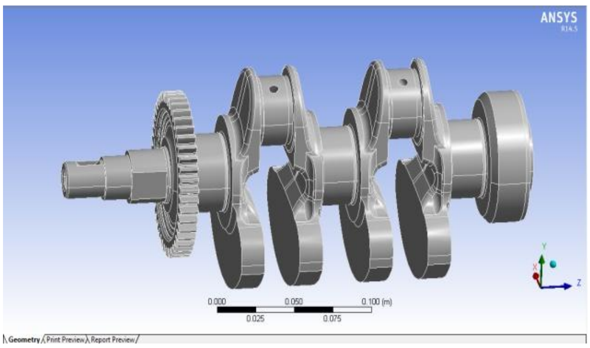

Figure 1. 3D model of crankshaft

Figure 2. and Figure 3. below show the details about the geometry including its volume, mass, moment of inertia etc.

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	Crankshaft with gear.igs
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	0.1074 m
Length Y	0.129 m
Length Z	0.3061 m
Properties	
Volume	8.5564e-004 m^3
Mass	6.7167 kg
Scale Factor Value	1.

Figure 2. Chart for model geometry information (from ANSYS report)

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Structural Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Centroid X	-2.8092e-005 m
Centroid Y	-6.6935e-003 m
Centroid Z	-0.12128 m
Moment of Inertia Ip1	3.963e-002 $kg \cdot m^2$
Moment of Inertia Ip2	3.6807e-002 $kg \cdot m^2$
Moment of Inertia Ip3	8.1579e-003 $kg \cdot m^2$

Figure 3. Chart for model geometry parts information (from ANSYS report)

V. MATERIAL DETAILS

The following chart gives the details about the materials of the crankshaft and its properties.

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	2.e+011	0.3	1.6667e+011	7.6923e+010

Figure 4. isotropic elasticity (from ANSYS report)

Specification of the material details is important as the yield stress is obtained from the parameters mentioned in it, which will be compared to decide the failure or optimization of the structure. As the some parts of the crankshaft are considered as flexible during the analysis, it is necessary to define young's modulus, bulk modulus and shear modulus.

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m
Compressive Yield Strength Pa	2.5e+008
Tensile Yield Strength Pa	2.5e+008
Tensile Ultimate Strength Pa	4.6e+008
Relative Permeability	10000

Figure 5. Chart for material details (from ANSYS report)

VI. MESHING

The name Finite element analysis has become common now-a-days in the field of Computer Aided Engineering. When analyzing complex structures, it is necessary to divide the complex geometry of the structure into small parts, as the stress or the effect of force and load will not be the same on all the parts of a huge and complex structure. Finite element analysis basically consists dividing a given structure into a finite number of elements, which is done by meshing also called as discretization. Figure 6. shows the meshed geometry of crankshaft. The shape of the mesh elements is a tetrahedron. Each element is analyzed for the effect of stress and deformation. The number of nodes in the mesh are 50281 and there are 28874 elements.

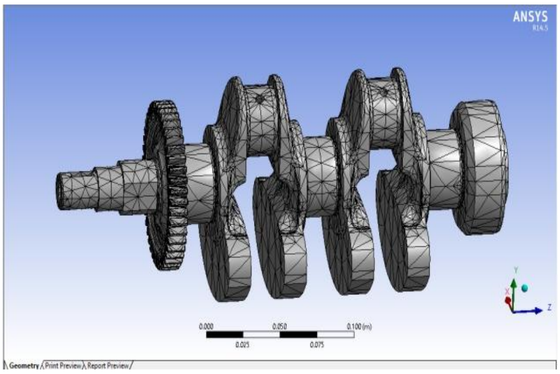

Figure 6. Meshed geometry of crankshaft

Minimum Edge Length	9.3386e-005 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Advanced	
Shape Checking	Standard Mechanical
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Statistics	
Nodes	50281
Elements	28874

Figure 7. Mesh details (from ANSYS report)

VII. BOUNDARY CONDITIONS

Boundary conditions play an important role in the analysis. It decides the degrees of freedom of different parts of the crankshaft. The material also should be specified as rigid or flexible depending upon the type of parts. The main bearing journals, crankshaft nose and flywheel are kept as fixed supports. The force is applied at the centre of the crankshaft that is mainly at the centre of the crankpins, as according to the literatures; these areas of the crankshaft are more prone to deformation and undergoes maximum stress. Also, when the entire crankshaft is analyzed for structural behaviour these areas show more deformation. Figure 8. shows the diagram of the boundary conditions applied to crankshaft.

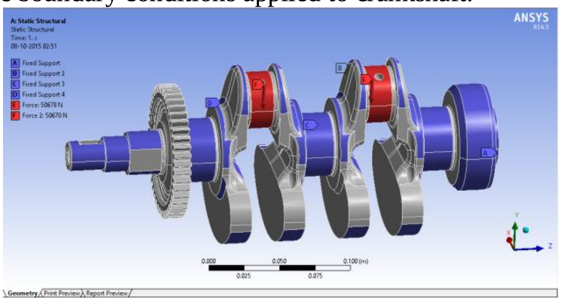

Figure 8. Boundary conditions applied

Object Name	*Fixed Support*	*Fixed Support 2*	*Fixed Support 3*	*Fixed Support 4*	*Force*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	48 Faces	33 Faces	38 Faces	119 Faces	2 Faces
Definition					
Type	Fixed Support				Force
Suppressed	No				
Define By					Vector
Magnitude					50678 N (ramped)
Direction					Defined

Figure 9. Static structural load information (specified during analysis in ANSYS)

VIII. EQUIVALENT STRESS

The equivalent stress is obtained which is basically the Von Misses stress. The Von misses stress is fundamentally a standard that decides whether the structure is in a state of failure or not. It primarily defines a formula using which the stresses in different directions of the three axis x, y and z are combined to give von misses stress. The criterion which decides whether the structure is in a condition of failure is that, if the von misses stress is greater than the yield stress of the material, then the structure is in a condition to breakdown. The maximum von misses stress obtained was 172.97 MPa.

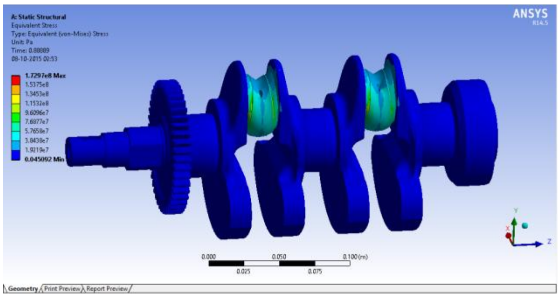

Figure 10. Simulation obtained for equivalent (Von misses) stress

Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	4.5092e-002 Pa	0. m
Maximum	1.7297e+008 Pa	5.7979e-006 m
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

Figure 11. Results obtained in ANSYS for equivalent stress

IX. TOTAL DEFORMATION

It can be seen that the maximum deformation takes place at the centre of the crankpin.

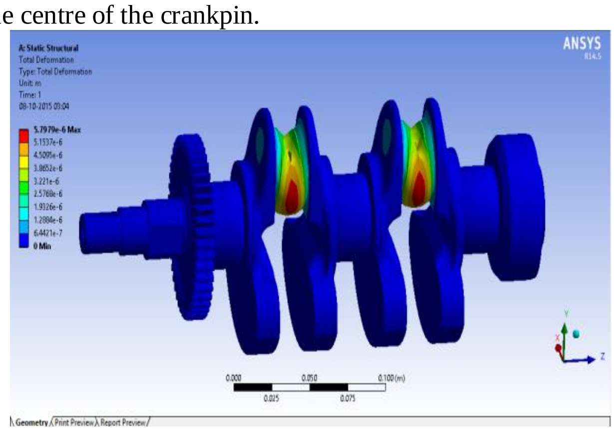

Figure 12. Simulation obtained for total deformation

Fatigue

Object Name	*Life*	*Damage*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Life	Damage
Identifier		
Suppressed	No	
Design Life		1.e+009 cycles
Results		
Minimum	43664 cycles	
Maximum		22902

Figure 13. Results obtained after fatigue analysis in ANSYS

Life & Damage

After applying the fatigue tool in ANSYS, it is seen that the life of the crankshaft lasts for 43664 cycles and when the stress and deformation takes place after 22902 cycles the crankshaft will get damaged.

X. CONCLUSION

It can be concluded that by static structural analysis the knowledge about the total deformation and stress can be obtained which can prevent damages in crankshaft and can also be helpful in designing good quality of crankshafts with optimum structural strength and reliability.

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