MODELLING AND STRESS ANALYSIS OF FOUR STROKE FOUR CYLINDER CRANK SHAFT WITH COMPOSITE MATERIALS BY USING CATIA AND ANSYS TOOLS

Project Guide
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ABSTRACT: As we know Crankshaft is a back bone of the engine. Crank shaft is a major component in IC engine which converts reciprocating motion of piston into rotary motion with a four link mechanism. Crankshaft experiences large number of loads during its service period. Crankshaft should be able to take large downward force of power stroke without excessive bending. The model of Crankshaft is prepared by modeling software CATIA V 5.Different load conditions are analyzed in ANSYS software at different working conditions .as we know the crank shaft should have to withstand more resistance forces .So for that we have to select suitable materials. Here we are taken the materials used for making Crankshaft are Cast Iron and Forged Alloy Steel.

Key words : CATIA V5, ANSYS 14.5 , IC Engine

INTRODUCTION: Crankshaft is important component with a complex geometry in the engine. The crankshaft consists of the shaft parts revolve in the main bearing; big ends of the connecting rod are connected to the crank pins, the crank arms or webs, which connect the crankpins, and the shaft parts. Since the crankshaft experiences a large number of load cycles during its service period, fatigue performance and durability of this component has to be considered in the design process. Design and development of crankshaft is major issue in industry because it is main power transmitting element. Crankshaft of an engine should able to sustain high downward force with negligible bending. The reliability and life of the internal combustion engine depend on the strength of the crankshaft largely. As the engine runs, the power strokes hit the crankshaft in one place and then another. The crankshaft is the main part of the crank train or crank assembly, which latter converts the reciprocating motion of the pistons into rotary motion. It is subjected to both torsional and bending stresses, and in modern high-speed, multi-cylinder engines these stresses may be realty increased by resonance, which not only renders the engine noisy, but also may fracture the shaft. In addition, the crankshaft has both supporting bearings (or main bearings) and crank pin bearings, and all of its bearing surfaces must be sufficiently large so that the unit bearing load cannot become excessive even under the most unfavorable conditions. At high speeds the bearing loads are due in large part to dynamic forces-inertia and centrifugal forces. Fig shows crankshaft which is a central component of any internal combustion engine and is used to convert reciprocating motion of the piston into rotary motion or vice versa.

PROBLEM DEFINTION: Some of them are using CI as a material .But it is more weight and less resisting forces. But crank shaft should resist more forces. For that we are going to select forged alloy steel as a material for manufacturing of the crankshaft.

TYPES OF CRANKSHAFT: -

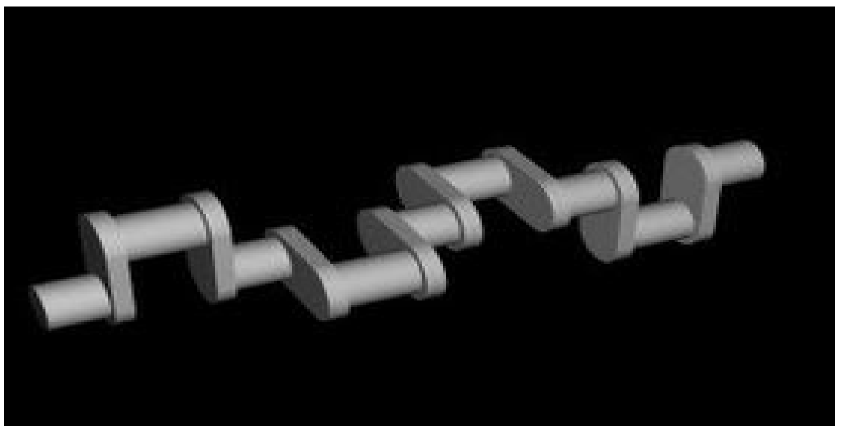
There are three different manufacturing processes used in order to make crank shafts.

1. Casting
2. Forging
3. Billet machined

The first two are common in the Volkswagen and Audi range. The last one being common in super cars or race cars. Questions often arise as to which type crank shaft is fitted to an engine you have opened given the fact that both 1 and 2 are fitted to power plants we're used to dealing with.

1. CASTING CRANKSHAFT: -

These are around for a long time and are found in a lot of engines and in both petrol and diesels. As the name suggests these are cast and made from Malleable Iron. The shape being defined by a sand mould as with many other engine parts. These are pretty cheap to make and hold up fairly well too so they are a common choice for manufacturers. A sand mould is made comprising of a top and bottom half, a pattern is made in wood or other material and this forms the required shape the mould halves contain once they are brought together. The molten metal flows into this mould relying on gravity alone. Both flat plane (single plane) and cross plane cranks can be made this way fairly easily. A flat plane crank is one where the journals are 180 degrees apart common in all in-line four engines. Therefore, only two mould halves are needed to make them as the pattern can be withdrawn from the sand mould without locking. This leads to fairly quick production times. A cross plane crank on the other hand needs a mould of multiple parts because the journals and counter weights are not symmetrical either side of the parting line (where both mould halves meet) Therefore withdrawing the pattern from just two halves would be impossible. This isn't a major issue all the same as once the mould are figured out production is just as fast as for a single plane crank.



2. FORGED CRANKS: -

These are a more robust crank than a cast crank for a few reasons. They are more commonly found in higher stressed engines and come standard in some 16v engines and almost all of the 1.8T engines. I do believe they feature in the new engines too, although I have not yet got the pleasure of getting my hands on one>yet. A forge crank is made in a totally different way to a cast one. A set of dies are machined to the approximate shape of the crankshaft as below. These dies sit in a very large hydraulic press having a clamping force of many tons. A hot bar approximately 150mm in diameter is placed onto the bottom die and the dies are closed. The bar is of high grade steel alloy containing all the various metals needed in order for the finished crank to fulfil its job. One benefit of this is the metal does not need to have certain properties required for casting, fluidity when molten, etc. Once the dies are closed the metal is squeezed in very tightly, this has the effect of making the metal denser, packing the arrows closer together if you like, and also given the fact the entire bar is pressed into the shape of the dies the grain structure also follows the shape of the crank throughout too. The material is then both compacted and aligned better than with the casting process. The dies are pressed together until the limit stops on the dies come into contact, once this happens the blank has been completely pressed and any excess is squeezed out the gap between the dies. It is this excess metal, or flash that makes a forged crank very easy to recognize. This flash is quite thick, sometimes as much as 10mm, as a result it has to be ground off before any finish machining can be done. This so-called part line then ends up being quite wide and can be recognized instantly over a cast cranks faint part line.

3.BILLET CRANKS: -

Billet cranks are the best type of crank you can have in your engine if you want to get the most from it. They start off again as a very high-grade steel containing all the correct alloys needed to meet the demands. 4340 steels are normally used which contains nickel, chromium, aluminums, and molybdenum amongst other elements. The Steel blank is then forged to align the grain and compact all the molecules closer together as in the case of the forged crank. These cranks are the dearest of all for many reasons. The main one being the amount of time needed to machine them, and also the fact that approximately 70% of the billet will end up as swarf. Here you can see a billet crank in various stages of production, it is from a Ferrari.

LITERATURE REVIEW:-

Solanki et al. presented literature review on crankshaft design and optimization. The materials, manufacturing process, failure analysis, design consideration etc. were reviewed. The design of the crankshaft considers the dynamic loading and the optimization can lead to a shaft diameter satisfying the requirements of the automobile specifications with cost and size effectiveness.

Jian Meng et al. 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.

Rajesh M. Metkar et al. have evaluated FEM based fracture mechanics technique to estimate life of automobile crankshaft of single cylinder diesel engine.

Xiaorong Zhou et al. prepared Crankshaft Dynamic Strength Analysis for Marine Diesel Engine, 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.

Montazersadgh and Fatemi et al.choose forged steel and a cast iron crankshaft of a single cylinder four stroke engine. Both crankshafts were digitized using a CMM machine. Load analysis was performed and verification of results by ADAMS modeling of the engine. At the next step, geometry and manufacturing cost optimization was performed. Experimental stress and FEA results showed close agreement, within 7% difference.

YV. Mallikarjuna Reddy et al. [6] has work on Design, Analysis and Optimization of a 6 cylinder Engine Crank shaft This paper deals with; the problem occurred in six cylinders four stroke engine crankshaft. It consist of static structural analysis of six cylinder engine crank shaft. It identifies and solves the problem by using the modeling and simulation techniques.

COMPARISON STATEMENT OF CRANKSHAFT MATERIALS

PROPERTIES	*CAST IRON*	*FORGED ALLOY STEE*
YOUNGS MODULUS	2.11e+0.11 N/m^2	2e+011N/m^2
POISSON RATIO	0.291	0.200
DENSITY	7870Kg/m^3	7860kg/m^3
THERMAL EXPANSION	1.21e-005deg K	1.17e-0.05 deg K
YIELD STRENGTH	3.1e+008N/m^2	2.5e+008N/m^2

ANALYSIS OF THE CRANKSHAFT WITH APPLING OF CAST IRON: -

MATHEMATICAL MODEL FOR CRANKSHAFT

Force on the piston:

Bore diameter (D) =53.73mm, Fq= Area of the bore ×Max. Combustion pressure

$F_q=\pi/4 \times D^2 \times P_{max}=7.93KN$

Where, D = diameter of crankshaft

In order to find the Thrust Force acting on the connecting rod (FQ), and the angle of inclination of the connecting rod with the line of stroke (i.e. angle Ø).

Sin Ø=sin Ɵ/L/R

Where, Ɵ=30 □

L/R =4

Sin Ø=sin Ɵ/L/R

Sin Ø=sin 35/2

=> Ø=8.24□

Which implies =8.24□

We know that thrust Force in the connecting rod, $F_Q = F_P/\cos\theta$

From we have

Thrust on the connecting rod, F_Q =8.01KN

Thrust on the crankshaft can be split into tangential component and radial component.

1. Tangential force on the crankshaft,

$F_T = F_Q \sin(\theta+Ø) =5.48KN$

2. Radial force on the crankshaft,

$F_R = F_Q \cos(\theta+Ø) =5.83KN$

Reactions at bearings (1&2) due to tangential force is given by

$H_{T1}=H_{T2} = F_T/2$

Similarly, reactions at bearings (1&2) due to radial force is given by

$H_{R1} = H_{R2}= F_R/2$

Design of crankpin: -

Let d= diameter of crankpin in mm

We know that bending moment at the centre of the crankshaft

$M_C=H_{R1}\times b_2=156.62KN\text{-}mm$

Twisting moment on the crankpin

$(T_C)=61.94KN\text{-}mm$

From this we have equivalent twisting moment

$T_e= =168.42KN\text{-}mm$

Von-misses stress induced in the crankpin

$M_{ev}=\sqrt{(K_b+M_c)^2+3/4(K_t+T_c)^2}$

177.860KN-m

$M_{ev}=\pi/32*d3c*\sigma v$

$\sigma_V= 19.6N/mm2$

Shear stress

$\tau\ e=\pi/16\ d3c*\ \tau$

$\tau=9.28N/mm^2$

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Twisting moment on the crankpin

$$T_C=248.36KN\text{-}mm \text{ (FORM TABLE)}$$

From this we have equivalent twisting moment

$$T_e =293.62KN\text{-}mm$$

Von-misses stress induced in the crankpin

$$M_{ev}=\sqrt{(Kb+Mc)^2+3/4(Kt+Tc)^2}$$

$$376.32KN\text{-}m$$

$$M_{ev}=\pi/32*d3c*\sigma v$$

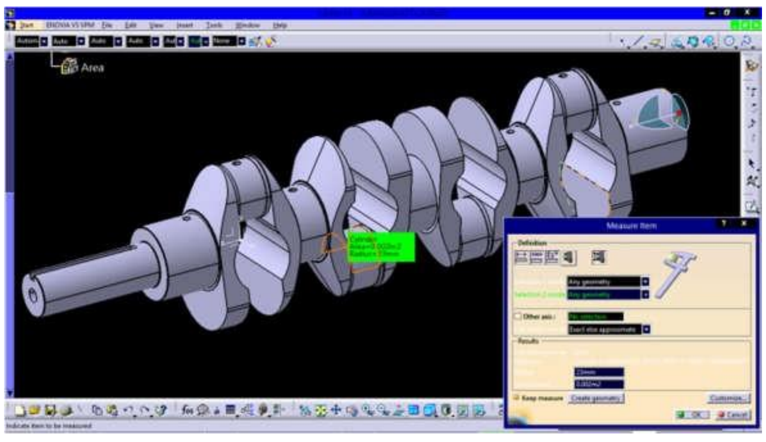
$$\sigma_V= 41.5N/mm^2$$

Shear stress

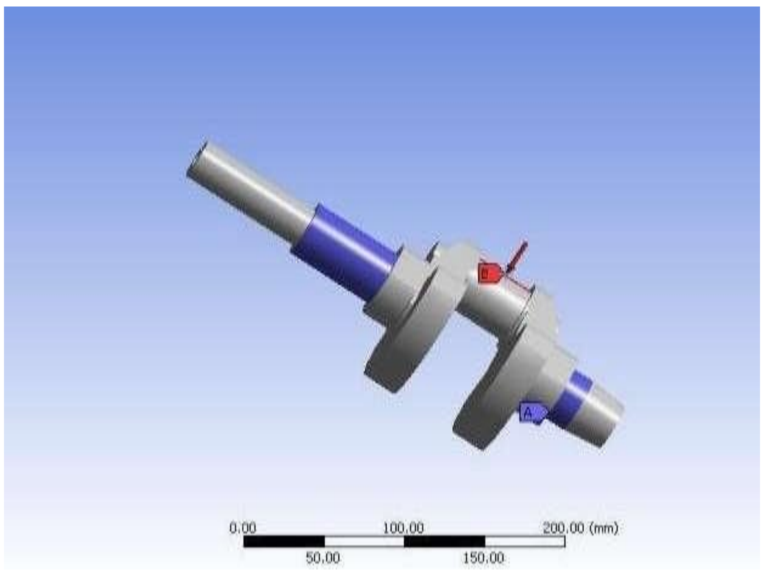
$$\tau_e=\pi/16\ d3c*\ \tau$$

$$\tau=20.69N/mm^2$$

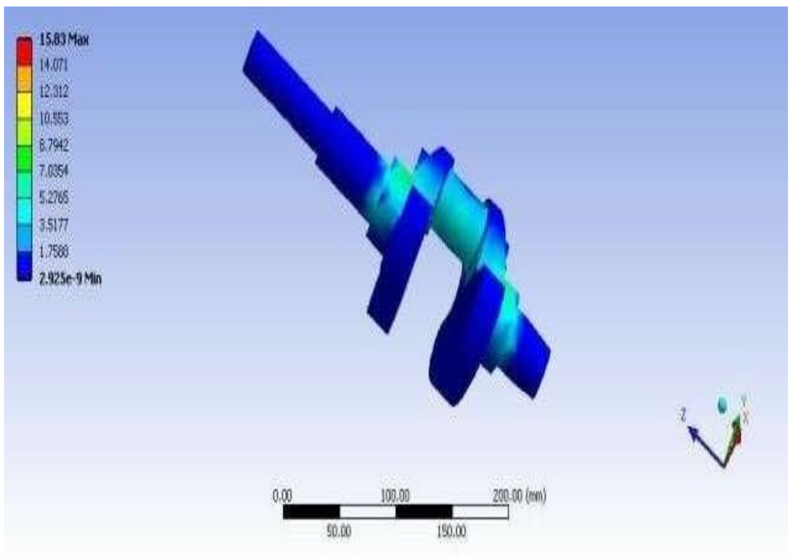
EVALUATION AND RESULT :



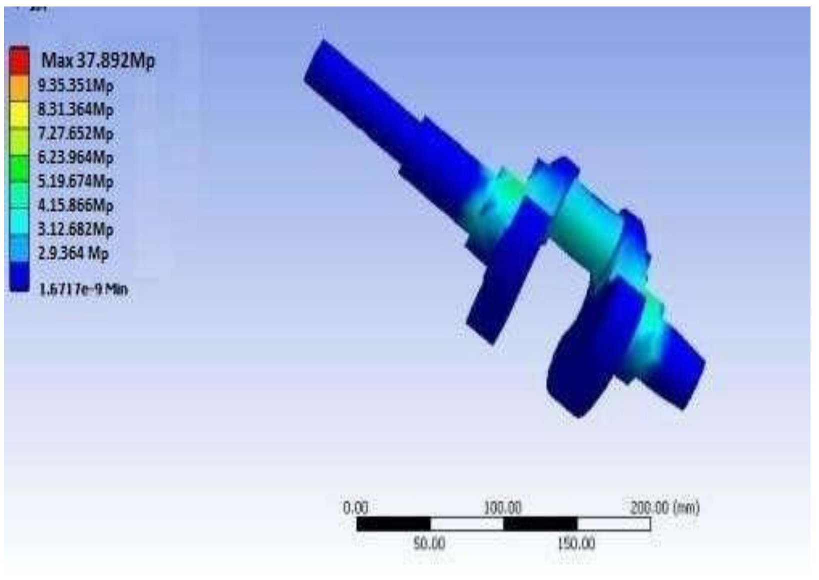
Applying boundary conditions to the shaft section



CATIA Modelling showing cylinder diameter

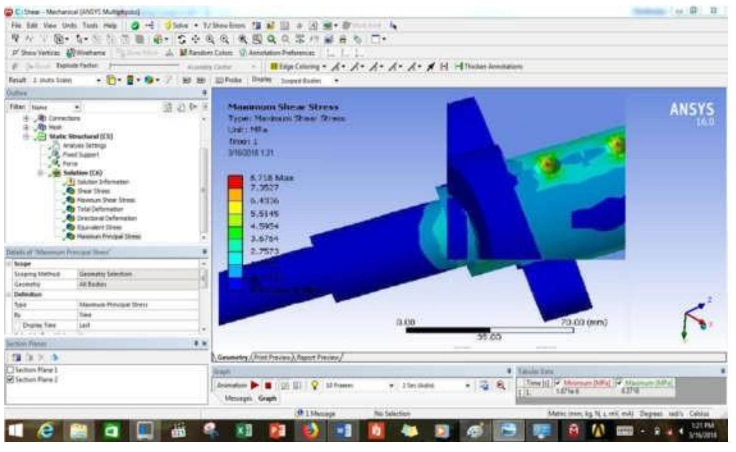


VON MISES STRESS DISTRIBUTION FOR CI

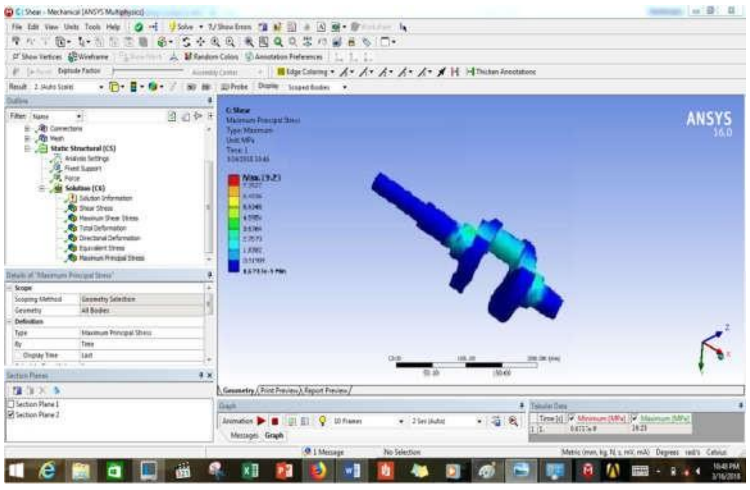


VON MISES STRESS DISTRIBUTION FOR FORGED ALLOY STEEL

MAXIMUM SHEAR STRESS:-



MINIMUM SHEAR STRESS:-

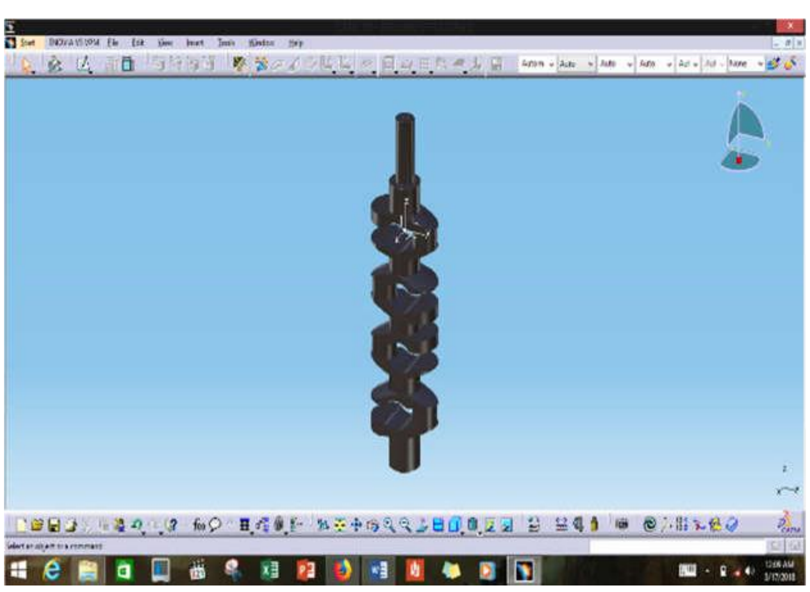


ANSYS RESULT OF THE CRANKSHAFT FOR CAST IRON

S.No.	PARAMETERS	RESULT
1	Maximum von mises stress	15.83 MPa
2	Min. von mises stress	2.925e – 9 MPa
3	Maximum shear stress	8.718 MPa
4	Min. shear stress	1.6717e – 19 MPa
5	Maximum elastic strain	8.39e – 5

ANSYS RESULT OF THE CRANKSHAFT FOR FORGED ALLOY STEEL

S.No.	PARAMETERS	RESULT
1	Maximum von mises stress	37.892MPa
2	Minimum von mises stress	1.6717e-9 MPa
3	Maximum shear stress	19.23 MPa
4	Minimum shear stress	1.672e-9 MPa
5	Maximum elastic strain	2.5e+.008



MESHING OF THE CRANKSHAFT

CONCLUSION:

1. From the above finite element analysis of the crank shaft for cast iron and forged steel , both the materials meet all the requirements of the crank shaft and both the designs are safe for functioning.

2. But the forged alloy steels generates more resisting forces then the cast iron i.e.., von mises and shear stresses are more compared to the cast iron.

3. Hence forged alloy steel is preferable for our designed crank shaft.

4. The value of von-misses stresses that comes out from the analysis is far less than material yield stress so our design is safe.

5. Use less or no oxidation heating billet, cooling forged crankshafts in the anti-oxidation medium, in order to prevent the secondary oxidation in alloy steel.

6. Use trimming correction compound die, reduce trimming deformation of forged crankshaft key sections in alloy steel.

7. Strict control of mold temperature, mold hardness, lubrication conditions, etc. Thus, to extend mould wear failure cycle in alloy steel

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