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GEOMETRIC OPTIMIZATION OF CRANK SHAFT FOR OPTIMUM DESIGN AND IMPROVEMENT OF LIFE

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Abstract

Crankshaft is a component in an engine which converts the reciprocating motion of the piston to the rotary motion. Design of a crankshaft of Honda engine, it is assembled by the connecting rod and piston components in Pro engineering. The designed model of engine crankshaft is analyzed in pro engineering by using its mechanism. Piston generates the forces due to the combustion. These forces acting on the piston are analyzed by using their mechanisms with respect to crank angle.

The aim of the project is to generate efficient model within low weight and good structural ability for the improvement of life.
Initially da ta collection and literature survey will be done to understand methodology and selection of material.
3D model will be prepared according to the dimensions' obtained from theoretical calculations.
Analysis will be done to validate structural and thermal behavior; design modifications will be according to the obtained results to improve the structural stability, material will be removed at stress non effecting areas to reduce the weight.
Analysis will be done to compare modified with existing model, conclusion will be made after comparing results

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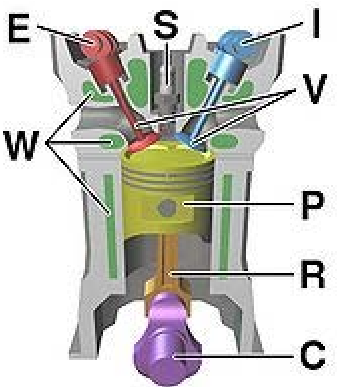
INTRODUCTION

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crankshaft has "crank throws" or "crankpins", additional bearing surfaces whose axis is offset from that of the crank, to which the "big ends" of the connecting rods from each cylinder attach.

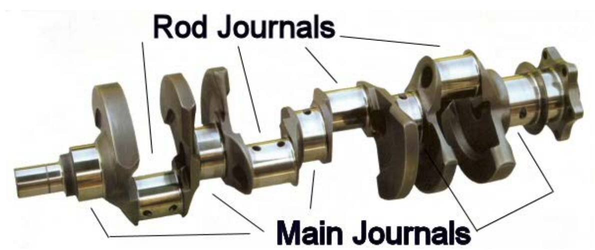
Design

Components of a typical, four stroke cycle, DOHC piston engine. (E) Exhaust camshaft, (I) Intake camshaft, (S) Spark plug, (V) Valves, (P) Piston, (R) Connecting rod, (C) Crankshaft, (W) Water jacket for coolant flow.



Stress on crankshafts

The shaft is subjected to various forces but generally needs to be analysed in two positions. Firstly, failure may occur at the position of maximum bending; this may be at the centre of the crank or at either end. In such a condition the failure is due to bending and the pressure in the cylinder is maximal. Second, the crank may fail due to twisting, so the conrod needs to be checked for shear at the position of maximal twisting. The pressure at this position is the maximal pressure, but only a fraction of maximal pressure.
A crankshaft contains two or more centrally-located coaxial cylindrical ("main") journals and one or more offset cylindrical crankpin ("rod") journals. The two-plane V8 crankshaft pictured in Figure 1 has five main journals and four rod journals, each spaced 90° from its neigbors.



The crankshaft main journals rotate in a set of supporting bearings ("main bearings"), causing the offset rod journals to rotate in a circular path around the main journal centers, the diameter of which is twice the offset of the rod journals. The diameter of that path is the engine "stroke": the distance the piston moves up and down in its cylinder. The big ends of the connecting rods ("conrods") contain bearings ("rod bearings") which ride on the offset rod journals.

FORCES IMPOSED ON A CRANKSHAFT

The obvious source of forces applied to a crankshaft is the product of combustion chamber pressure acting on the top of the piston. High-performance, normally-aspirated Spark-ignition (SI) engines can have combustion pressures in the 100-bar neighborhood (1450 psi), while contemporary high-performance Compression-Ignition (CI) engines can see combustion pressures in excess of 200 bar (2900 psi). A pressure of 100 bar acting on a 4.00 inch diameter piston wil produce a force of 18,221 pounds. A pressure of 200 bar acting on a 4.00 inch diameter piston produces a force of 36,442 pounds. That level of force exerted onto a crankshaft rod journal produces substantial bending and torsional moments and the resulting tensile, compressive and shear stresses.

CRANKSHAFT MANUFACTURING PROCESSES

Many high performance crankshafts are formed by the forging process, in which a billet of suitable size is heated to the appropriate forging temperature, typically in the range of 1950 - 2250°F, and then successively pounded or pressed into the desired shape by squeezing the billet between pairs of dies under very high pressure. These die sets have the concave negative form of the desired external shape. Complex shapes and / or extreme deformations often require more than one set of dies to accomplish the shaping.
Originally, two-plane V8 cranks were forged in a single plane, then the number two and four main journals were reheated and twisted 90° to move crankpins number two and three into a perpendicular plane. Later developments in forging technology allowed the forging of a 2-plane "non-twist" crank directly

INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER is the industry's standard 3D mechanical design suit. It is the world's leading CAD/CAM /CAE software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model, because the Pro/E technology is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Pro/Engineer is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Pro/Engineer provides easy to use solution tailored to the needs of small, medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly, electrical and electronics goods, automotive, aerospace etc.

DESIGN OF MULTI CYLINDER ENGINE CRANK SHAFT (DIESEL ENGINE)

Number of cylinders=4
Bore diameter (D) = 85 mm
Stroke length (l) = 96mm
Maximum combustion pressure=2.5 N/mm^2
We know that force on the piston i,e: gas load

$$F_P = \left(\frac{\pi}{4}\right) d^2 \times p$$

$$= \left(\frac{\pi}{4}\right) \times 85^2 \times 2.5$$

$$=14186.25N$$

$$=14.18KN$$

In order to find the thrust in connecting rod we should find out angle of inclination of connecting rod with line of stroke

$$\mathrm{Sin}\phi = \sin\theta \left(\frac{l}{r}\right) = \left(\frac{\sin\theta}{n}\right) = \frac{\sin 35}{4}$$

$$\phi = 8.24°$$

Assume that the distance (b) between the bearings 1 and 2 is equal to twice the piston diameter (D).
b = 2D = 2 × 85 =170mm
Due to this piston gas load (FP) acting horizontally, there will be two horizontal reactions H1and H2 at bearings 1 and 2 respectively, such that
b1 = b2= 85mm

$$H1 = F_P \times \frac{b_1}{b}$$

$$= 14.18 \times \frac{85}{170} = 7.09\ KN$$

$$\text{And} \quad H2 = F_P \times \frac{b_2}{b}$$

$$= 14.18 \times \frac{85}{170} = 7.09\ KN$$

Assume that the length of the main bearings to be equal, i.e.,
c1 = c2 = c / 2.
We know that due to the weight of the flywheel acting downwards, there will be two vertical reactions V2 and V3 at Bearings 2 and 3 respectively, such that

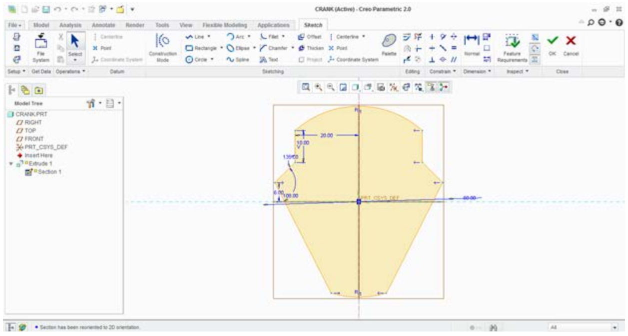
$$V_2 = W \times \frac{C_1}{c}$$

$$= W \times \frac{C_1}{2c} = \frac{W}{2} = \frac{85}{2} = 42.5 \text{ KN}$$

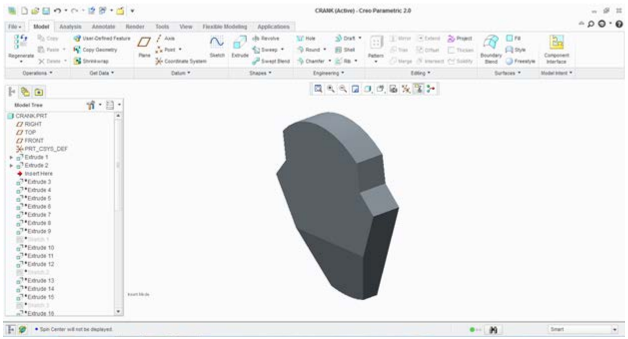
$$\text{And } V_3 = W \times \frac{C_2}{c}$$

$$= W \times \frac{C_2}{2c} = \frac{W}{2} = \frac{85}{2} = 42.5 \text{ KN}$$

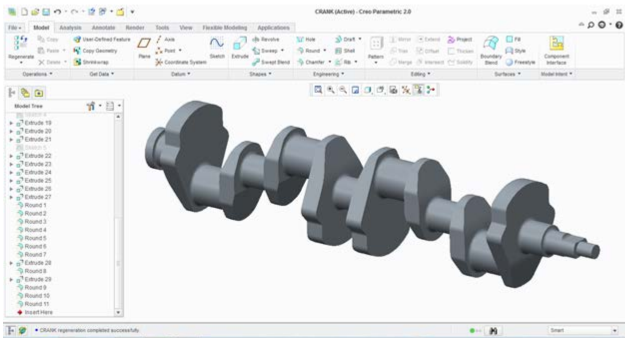
MODEL OF CRANK SHAFT



The above image shows sketcher



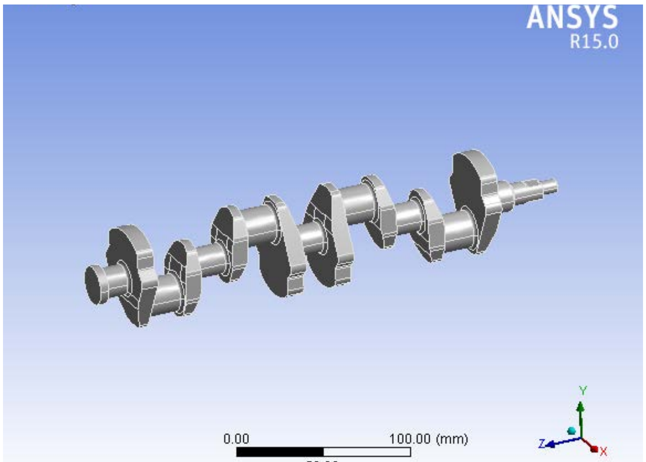
The above image shows crank web



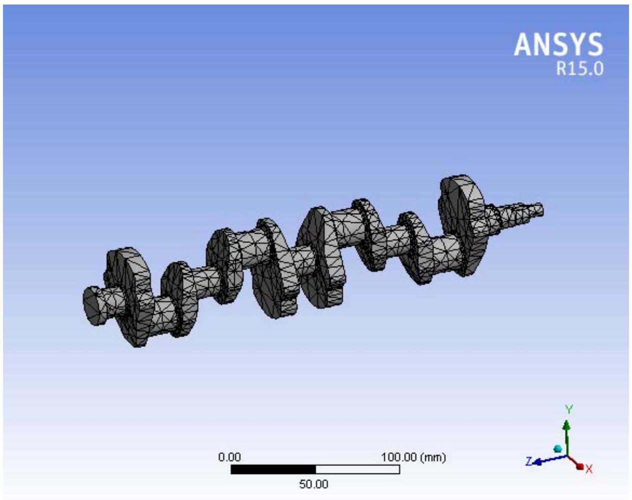
The above image shows crank shaft final model

STRUCTURAL ANALYSIS OF CRANKSHAFT EXISTING MODEL

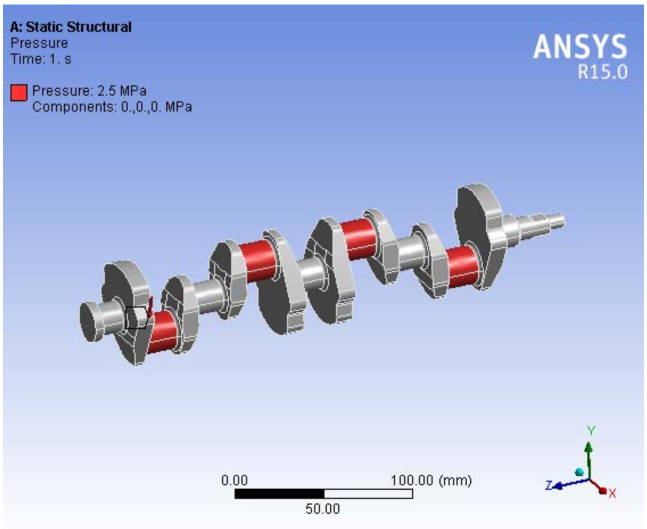
MATERIAL: CARBON STEEL



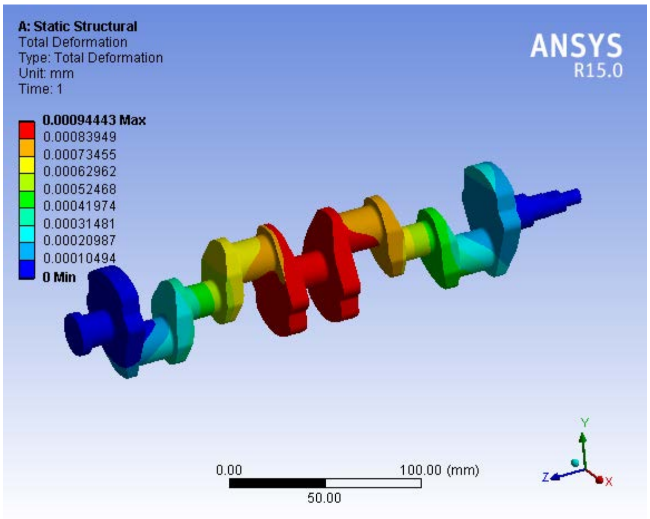
The above image shows imported model



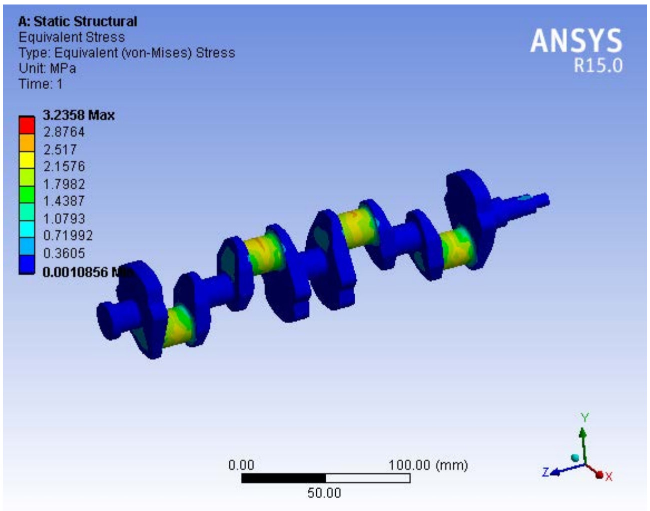
The above image shows meshed model



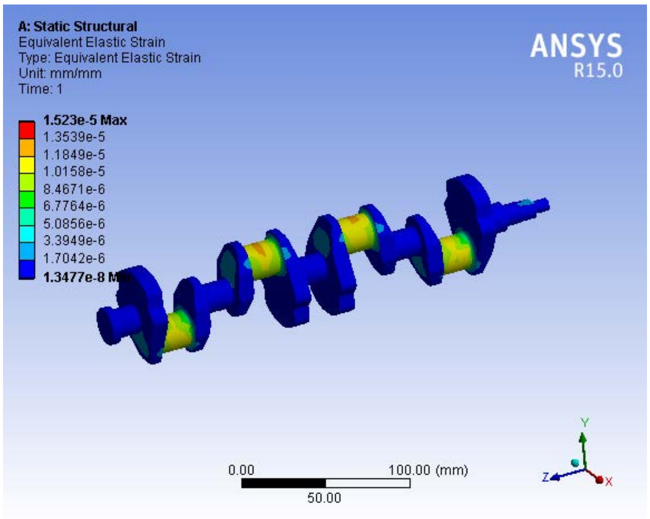
The above image shows load applied



The above image shows total deformation

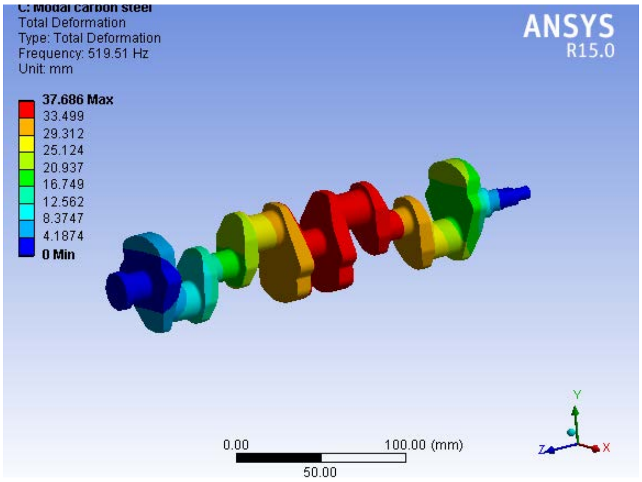


The above image shows stress

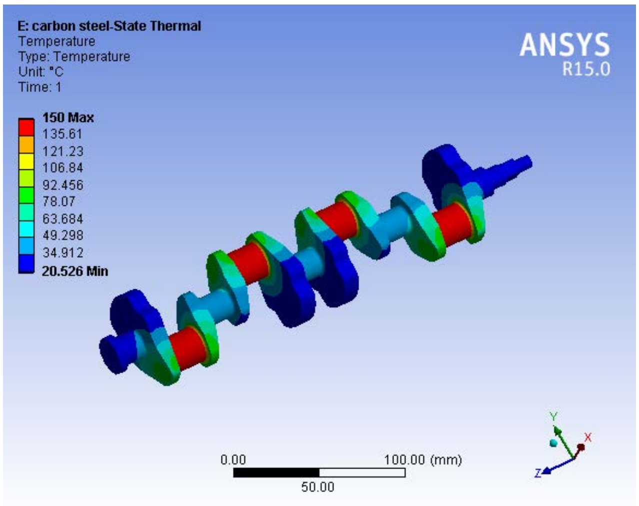


The above image shows strain

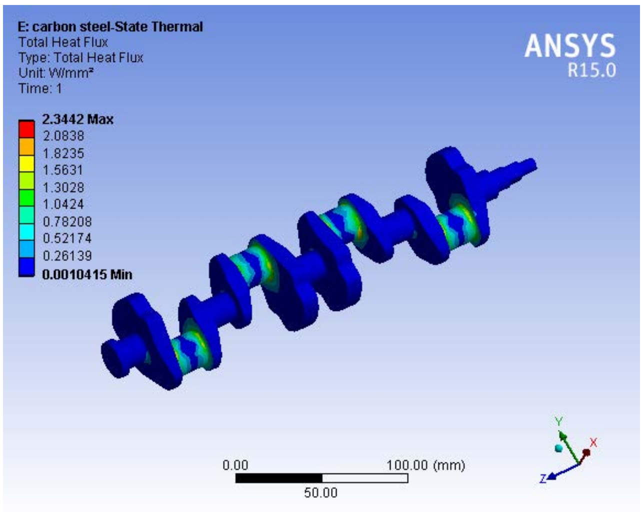
MODEL ANALYSIS OF CRANKSHAFT EXISTING MODEL



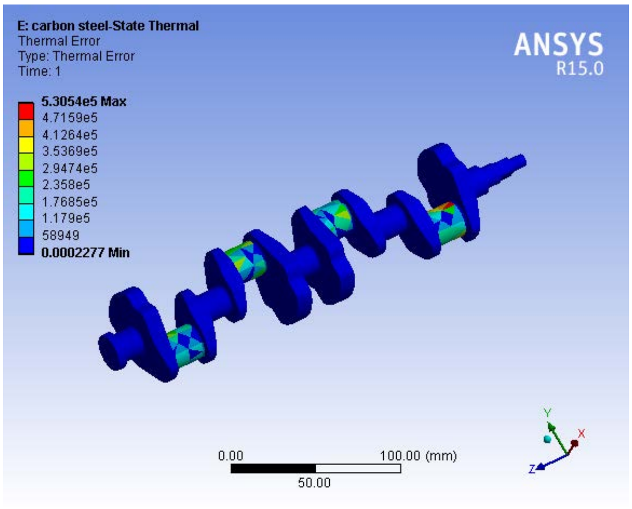
THERMAL ANALYSIS OF CRANKSHAFT EXISTING MODEL



The above image shows temperature

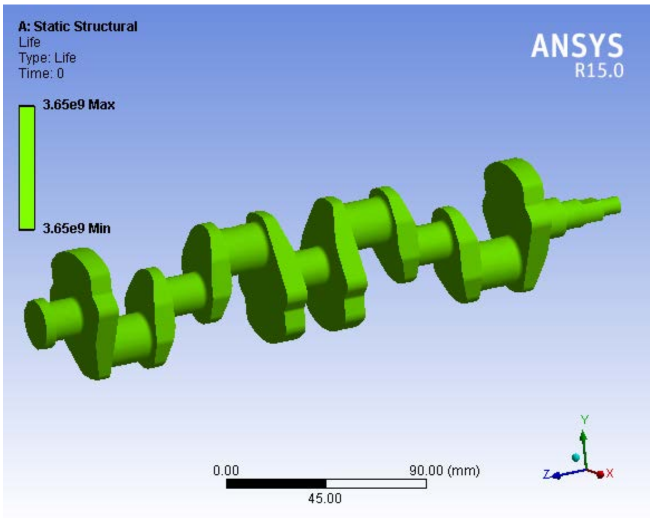


The above image shows total heat flux

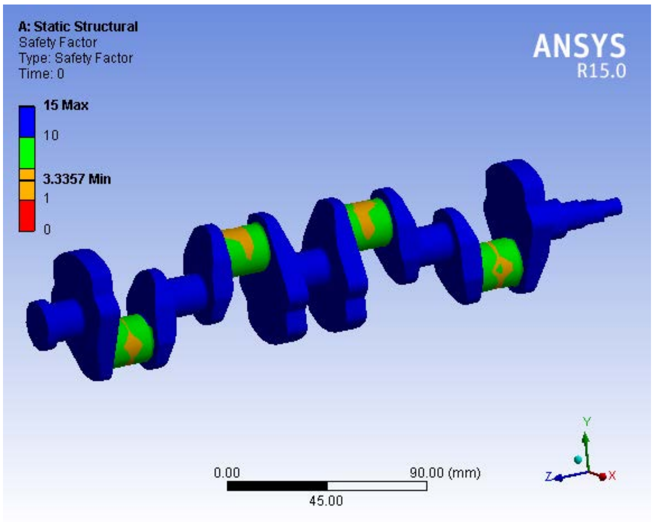


The above image shows thermal error

FATIGUE ANALYSIS OF CRANKSHAFT EXISTING MODEL



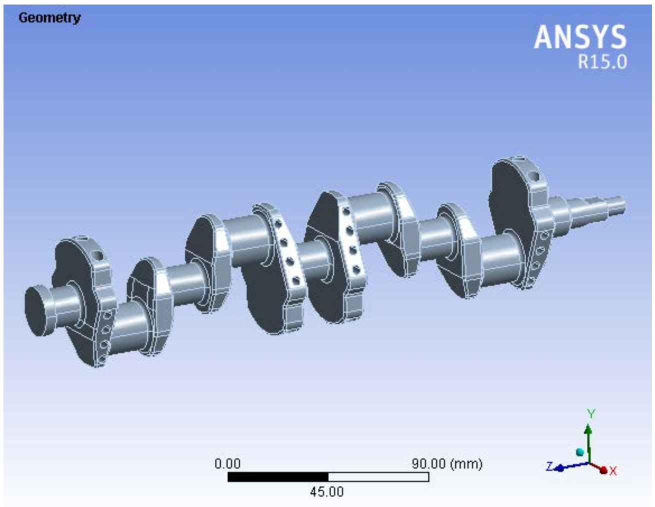
The above image shows life



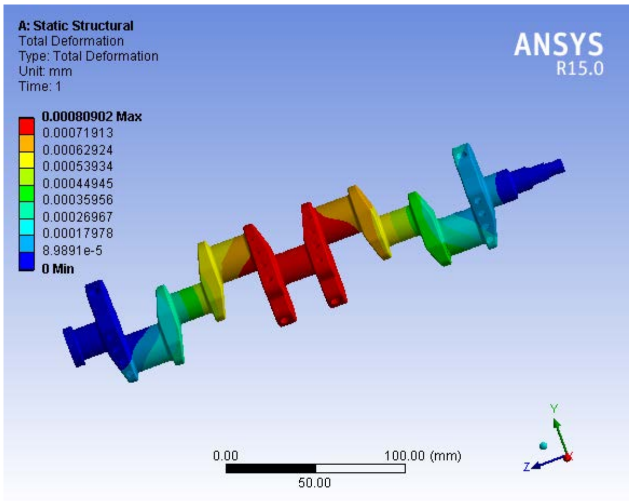
The above image shows safety factor

STRUCTURAL ANALYSIS OF CRANKSHAFT MODIFIED MODEL

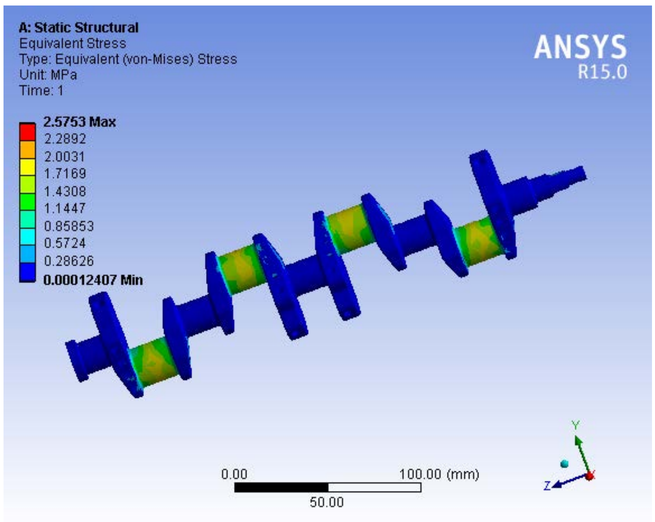
MATERIAL: CARBON STEEL



The above image shows imported model

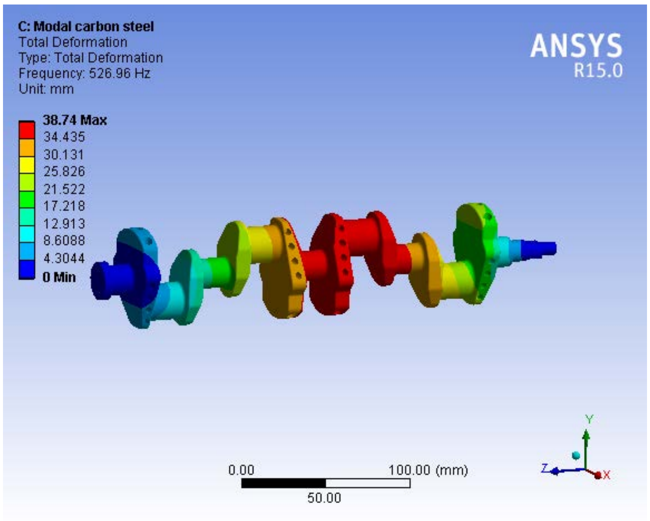


The above image shows total deformation



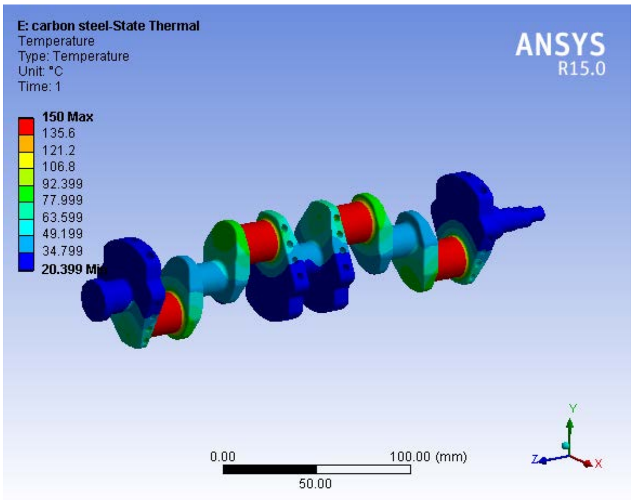
The above image shows stress

MODEL ANALYSIS OF CRANKSHAFT MODIFIED MODEL

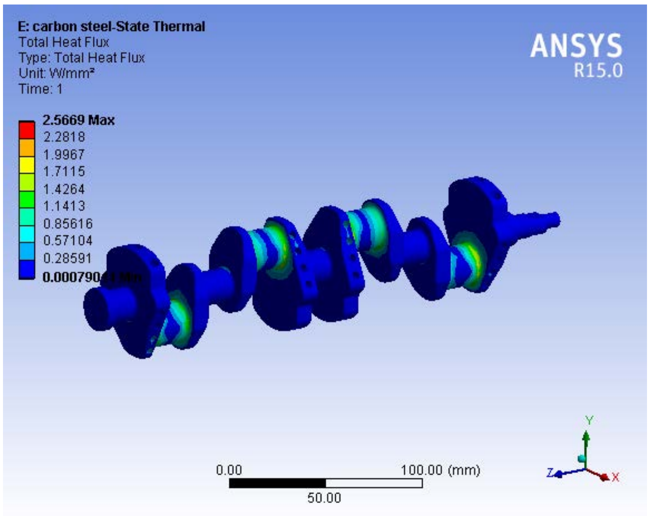


The above image shows total deformation mode 1

THERMAL ANALYSIS OF CRANKSHAFT MODIFIED MODEL



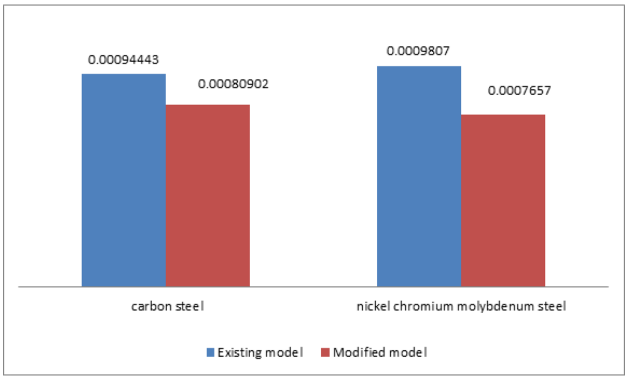
The above image shows temperature



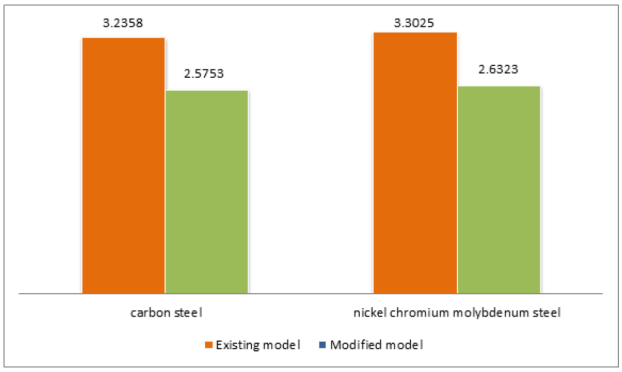
The above image shows total heat flux

RESULTS AND GRAPHS

STRUCTURAL ANALYSIS GRAPHS

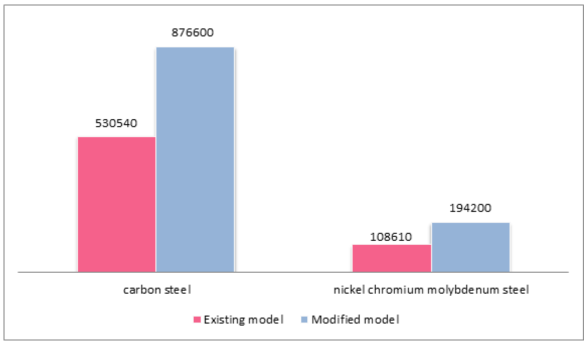


The above image shows displacement graph



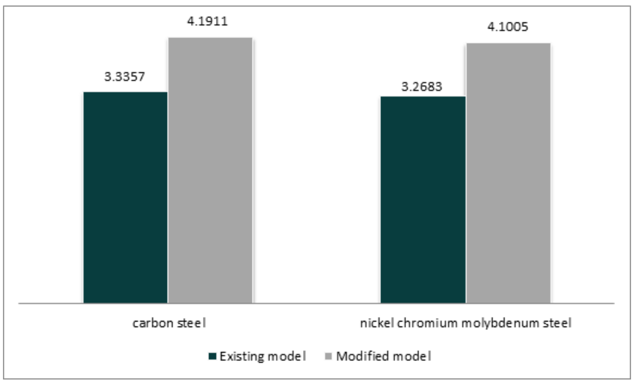
The above image shows stress graph

THERMAL ANALYSIS



The above image shows thermal error

FATIGUE ANALYSIS



The above image shows Safety factor

STRUCTURAL ANALYSIS				
	Existing model		Modified model	
	carbon steel	nickel chromium molybdenum steel	carbon steel	nickel chromium molybdenum steel
Total deformation	0.00094443	0.0009807	0.00080902	0.0007657
Stress	3.2358	3.3025	2.5753	2.6323
Strain	1.253e-5	1.6546e-5	1.2112e-5	1.3193e-5

THERMAL ANALYSIS				
	Existing model		Modified model	
	carbon steel	nickel chromium molybdenum steel	carbon steel	nickel chromium molybdenum steel
Temperature	150	150	150	150
Total heat flux	2.3442	0.87371	2.5669	1.0331
Thermal error	5.3054e5	1.0861e5	8.766e5	1.942e5

FATIGUE ANALYSIS				
	Existing model		Modified model	
	carbon steel	nickel chromium molybdenum steel	carbon steel	nickel chromium molybdenum steel
LIFE	3.65e9	3.65e9	3.65e9	3.65e9
Damage	0.27397	0.27397	0.27397	0.27397
Safety factor	3.3357	3.2683	4.1911	4.1005
Biaxiality indication	0.99899	0.99889	0.9993	0.99819
Alternating stress	32.358	33.025	25.753	26.323

CONCLUSION

This project works deals with "GEOMETRIC OPTIMIZATION OF CRANK SHAFT FOR OPTIMUM DESIGN AND IMPROVEMENT OF LIFE"
Initially literature survey and data collection was done to understand methodology.
Crank shaft parameters are calculated using empirical formals for 6 cylinder engine.
3d model is prepared according to the obtained valve from calculation,
Static, fatigue and dynamic analysis is done on crankshaft using low carbon steel. Same as been done using steel nickel chromium molybdenum steel material and to find out the failure locations and to evaluate results.
Geometric modifications are done on crank shaft model to reduce stress concentration by implementing stress reliving holes on web.
As per the Static, fatigue and dynamic analysis results, existing model is up to the mark only. Implementation of nickel chromium molybdenum steel material will increase life by 2%, while Appling stress reliving holes, life will be increased by 17.8%. Also material is removed from the crank web. So better to use modified model with nickel chromium molybdenum steel material.
This project concludes that modified model with nickel chromium molybdenum steel material increases the life and also weight will be reduced up to 15% which interns increases the mechanical efficiency

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7. Crankshaft Strength Analysis Using Finite Element Method
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