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Design and Optimization of IC Engine Crankshaft

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Abstract

The globalization and economic reforms have changed the face and pace of world economy in the last two decades. The main thrust is on product quality, faster design and development and finally cheaper product.At the same time, for optimal use of these technologies, one has to converge them in a better way. To sustain in the competitive market, industries have to update their knowledge, acquire new skills to offer world-class products. Design and analysis of complex components has reached new heights with the application of Finite Element Method.Automobile Industry has benefited a lot with the development of CAD/CAM technologies, from engine performance to aesthetic appeal. The lead time to manufacture automobiles has drastically reduced in the recent times, because of advancements in Geometric modeling and Computer Integrated Manufacturing (CIM).Design of Internal Combustion (IC) Engine parts plays a crucial role in improving the functioning of an automobile. Design and modifications of all the important components are carried out to increase the performance and thereby efficiency. Many redesign concepts have been emerged for cylinder head, connecting rod,crankshaft, piston, carburetor, Fuel injection pump and other engine components. specially redesign of Crankshaft is carried out to get enough strength to sustain the gas pressure and to have the better thermal stability. Also new researches are going on to select an alternate material to cope up with the existing load cases, to get higher compression ratio, to reduce the inertia forces to increase the speed of the vehicle (by reducing the weight of the reciprocating masses).

Keywords:Hardness,finite element method,materials.

Introduction

The objectives of this project are to identify the method to increase the hardness of crankshaft and to select a suitable material for the crankshaft which can produce lower values of stress and deformations for which structural analysis is carried out

Crankshaft

Sl.No	Materials	Name
1	Material-1	080M40 or EN8 or AISI/SAE 1042
2	Material-2	Nodular cast iron or Ductile cast iron
3	Material-3	SAE/AISI 8640 or SNCM240 or nickel chromium molybdenum steel

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine that translates reciprocatinglinearpiston 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.

It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsional elasticity of the metal.

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Table1 grade name of materials

Crankshaft Materials

Crankshafts materials should be readily shaped, machined and heat-treated, and have adequate strength, toughness, hardness, and high fatigue strength. The crankshaft are manufactured from steel either by forging or casting. The main bearing and connecting rod bearing liners are made of babitt, a tin and lead alloy. Forged crankshafts are stronger than the cast crankshafts, but are more expensive. Forged crankshafts are made from SAE 1045 or similar type steel. Forging makes a very dense, tough shaft with a grain running parallel to the principal stress direction. Crankshafts are cast in steel, modular iron or malleable iron. The major advantage of the casting process is that crankshaft material and machining costs are reduced because the crankshaft may be made close to the required shape and size including counterweights. Cast crankshafts can handle loads from all directions as the metal grain structure is uniform and random throughout. Counterweights on cast crankshafts are slightly larger than counterweights on a forged crankshafts because the cast metal is less dense and therefore somewhat lighter.

Generally automobile crankshafts were forged in past to have all the desirable properties. However, with the evolution of the nodular cast irons and improvements in foundry techniques, cast crankshafts are now preferred for moderate loads. Only for heavy duty applications forged shafts are favoured. The selection of crankshaft materials and heat treatments for various applications are as follows.

Material-1

ORGINAL MATERIAL

(080M40 or EN8 or AISI/SAE 1042).

COMPOSITION

Carbon	0.18 - 0.23 %
Manganese	0.6 - 0.85 %
Silicon	0.15 – 0.35 %
Sulphur	0.00 – 0.03 %
Phosphorous	0.00 – 0.03 %
Molybdenum	0.15 – 0.30 %

Table2 Material Property

Youngs Modulus	20,0000 – 21,0000 MPa
Density	7700 kg/m^3
Poission ratio	0.27
Tensile stress	650 MPa
Yield stress	450 MPa
% of elongation	15%
Hardness	50 – 55 HRC

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Material-2

(Nodular cast iron or Ductile cast iron)

These cast irons are also known as speroidal-graphite irons or ductile irons.

COMPOSITION:

Carbon	3 - 4 %
silicon	2.2 – 2.8 %
Manganese	0.1-0.5%
Magnesium	0.03-0.05%
Phosphorus	0.005-0.04%
Sulphur	0.005-0.002%

Table3 material property

Youngs Modulus	165 GPa
Density	7100 kg/m^3
Poission ratio	0.275
Tensile stress	414 - 827 MPa
Yield stress	330 MPa
% of elongation	18%
Hardness	130 – 335

Material-3

(SAE/AISI 8640 or SNCM240 or nickel chromium molybdenum steel)

COMPOSITION

Carbon	0.30 %
Nickel	2.5 %
chromium	0.65 %
Molybdenum	0.55 %

Table4 material property

Youngs Modulus	210 GPa
Density	7910 kg/m^3
Poission ratio	0.30
Tensile stress	540 – 1280 MPa
Yield stress	650 MPa
% of elongation	13%

Table6 Engine Specification

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Engine	4 Stroke, Single Cylinder, Air Cooled
Displacement	97.2 cc
Bore and Stroke	50 X 49.5
Compression Ratio	9:1
Max. Power	7.5 PS (5.5 KW) @ 8000rpm
Max. Torque	7.95 N @ 8000rpm
Transmission	4 Speed, constant mesh, 4 up

Crankshaft Design Considerations And Calculations

The present design consideration is to increase the stiffness of the crankshaft and reduce its overall length by corporating narrow journals of larger diameter. For the required wall thickness and coolant passages, the minimum cylinder canters can be around 1.2 times the cylinder bore diameter for an engine having its stroke equal to the bore. The maximum diameter of the big-end for the connecting-rod assembly that can pass through the cylinder is 0.65 times of the bore.

The Proportions Of The Crankshaft

Cylinder bore diameter = D

Cylinder centre distance = 1.20 D

Big-end journals diameter = 0.65 D

Main-end journal diameter = 0.75 D

Big-end journal width = 0.35 D

Main-end journal width = 0.40 D

Web thickness = 0.25 D

Calculation

Single Cylinder Engine

To find volume,

$$V = \prod/4 \times D^2 \times L$$

$$= \prod/4 \times 50^2 \times 49.5$$

$$\mathbf{V = 97.19 \times 10^3\ mm^3}$$

To find pressure,

$$\text{Mean effective pressure} = (P \times 60 \times n) / (N \times v)$$

$$= (60 \times 2 \times 5500)(97.19 \times 10^3)$$

$$\mathbf{p = 0.85 Mpa}$$

To find force,

$$\text{Force} = \prod/4 \times d^2 \times P$$

$$\mathbf{F = 1.669\ KN}$$

Results and Analysis of Crankshaft

Problem Statement

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The gas load is the major load coming on the crankshaft. Hence the objective of analysis is to locate maximum stressed area and to select suitable material for least stress under the effect of static load comprising the peak gas load, such that equivalent stresses are within the limit of allowable stress.

Ansys Diagrams

Material-1

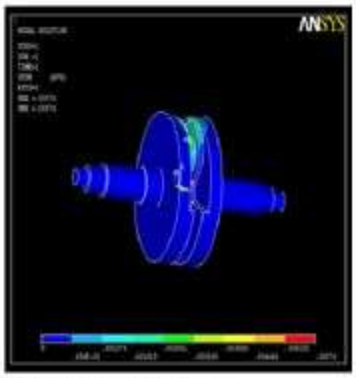
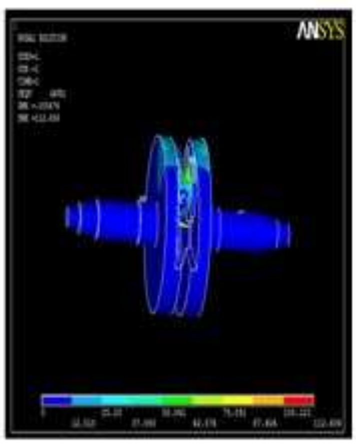


Fig.1.Displacement Diagram



(ii)Stress diagram

Material-2

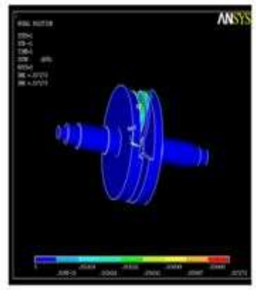
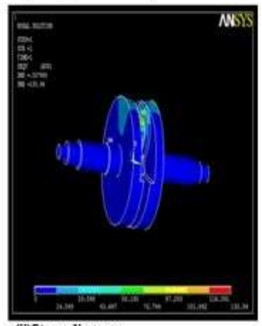


Fig.2.Displacement Diagram



(ii)Stress diagram

Material-3

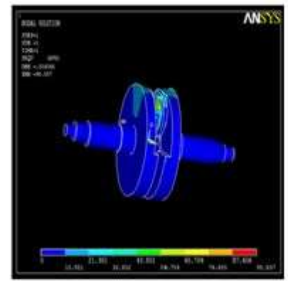


Fig.3.Displacement Diagram

(ii)Stress diagram

Table7 Ansys Results

S. N	Materials	Induced stress(N/m m^2)	Deformation(mm)
1	Material-1	112.636	0.005740
2	Material-2	130.940	0.007273
3	**Material-3**	**98.557**	**0.004892**

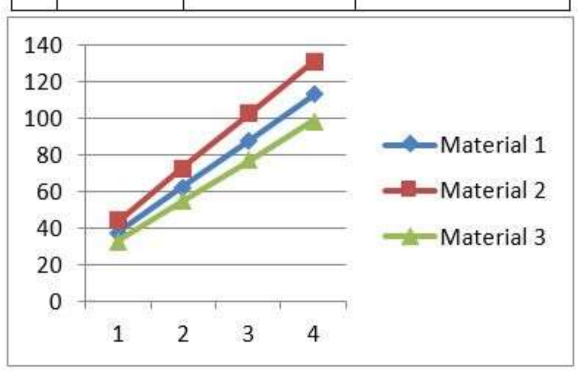


Fig.4. Displacement Vs Materials

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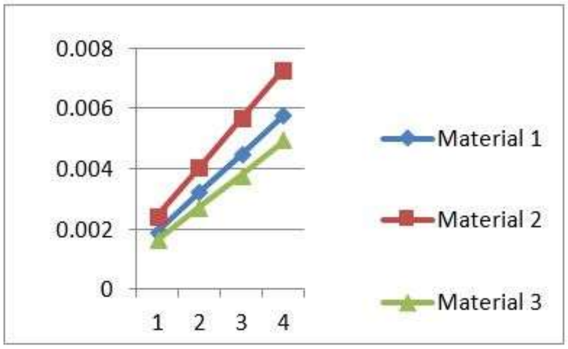

Fig.5. Stress Vs material

Analysis For The Selected Material

Even though the load applied on the crank shaft is increased by 200% , crank shaft made from the best material(SAE/AISI 8640 or SNCM240 or nickel chromium molybdenum steel) is able to withstand that load. In addition the stress produced by this load on the crank shaft is very much lesser than permissible stress. So, it is clear that the amount of wear occurring on the crank pin can be reduced to a greater extend. Thus , the life time of the engine will be increased.

Table8 Comparison Of Ansys Results With Material Properties

Sl. No	Material	ANSYS Results		Material properties	
		Maximum Deformation (mm)	Maximum Induced Stress (N/mm^2)	Permissible Stress (fos=3) (N/mm^2)	Yield Stress (N/mm^2)
1.	Material-1	0.005740	112.636	150.00	450
2.	Material-2	0.007273	130.940	110.00	330
3.	**Material-3**	**0.004892**	**98.557**	**216.67**	**650**

Conclusion

It was observed from failure analysis that the wear region was with lower hardness value ie.650, 652, 640(HV1kg load) than the specified value and after Induction hardening over the contact region the hardness value has been increased to 720.8,728.4,720.7 (HV 1kg load) at three different locations

By comparing Induced Stress and Deformation values, **Material 3 (SAE/AISI 8640 or SNCM240 or nickel chromium molybdenum steel)** has higher strength and shows lower stress value (98.557N/mm^2) than other materials. Because of the more strength, nickel chromium molybdenum steel crankshaft can withstand load even up to 200% of the original load value. Thus it can able to give maximum life than other selected materials. Due to the higher strength and considerable deformations, nickel chromium molybdenum steel can be used as the alternate and suitable crankshaft material for four stroke I.C. engine.

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