Static & Materialistic Analysis of Crankpin

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Abstract— the main function of the crank pin is to transmit power and motion to the crankshaft that comes from piston through connecting rod. Crank pin is made much stronger so as to meet the requirements of rigidity and vibrations. This study aims at increasing strength by following process. The initial phase follows changing of the material of the crankpin along with crankshaft by doing comparison with the old material used by the crankpin. To compare the hardness between them. Follows with static and dynamic analysis of the crankshaft along with crankpin. Further elongation of the side hole of the crankpin model of a crank shaft to increase in life of the crankpin and study the results obtained by it.

Key words: Crankpin

I. Introduction

The crankshaft is the backbone of the internal combustion engine. It is responsible for the proper operation of the engine it is an engine component sometimes called the crank. Crank pin plays a vital role in the smooth running of the engines. In a reciprocating engine, the crank pins are the bearing journals of the big end bearings and the ends of the connecting rods opposite to the pistons. The engine has a crankshaft, and the crank pins are the journals of the off centre bearings of the crankshaft. Crank Pin is generally a high precision item, having round cylindrical shape. It is generally of two types' hole or solid type, but must have a high surface finish, to serve as running surface for needle bearings. Three holes are drilled in the crank pin. It changes the up and down motion that is the linear (reciprocating) motion of the pistons into rotary motion. In order to convert two motions, the crankshaft has "crank throws "or "crankpins. The surface must be free from nick marks and must be hard, to bear the normal wear and tear of the vehicle. It is firmly connected to the connecting rod and as such the geometry of the outer diameter as well as side faces play a vital role in fitment and running.

In every technical field cranks are used where manual motion Is converted into rotary motion. Fishing reels, manual winches, meat grinders, and garden hose reels all use cranks to allow people to easily create continuous rotary motion. Bicycle pedals function as crank pins between the rider's foot and the pedal crank that drives the chain. There are two types of cranks. The first type is the continuously rotating crank, such as in engine crankshafts, where the crank can continuously turn through more than 360 degrees without reverse. The second is the partial circle crank, where the entire rotary motion of the main shaft may be 90 degrees or less, as with steering linkages or ventilation damper adjustments.

Fig. 1: Crankpin

II. Literature review

Jayeshkumar J. Joshi & Dr. Dipak M. Patel [1] they found that the crankshaft failure occurs due to decrease in the fatigue strength. Thus, when the crank is at the dead center, the bending moment on the shaft is maximum and the twisting moment is zero. The maximum possibility of failure of crankshaft at crank pin because of load of piston and connecting rod are indirectly induced on crankshaft shaft. The Study was made about crankshaft material properties and calculated the loads which are responsible for the failure of crankshaft. After design of crankshaft to analyze crankshaft using ANSYS Software using different materials and found the critical point at crankshaft failure. There is total three material used for analysis and got the different result with parameter, from that the nickel chromium molybdenum steel is best of them. Usually crankshaft is made from steel by using casting or forging but we can use nickel chromium molybdenum steel as a material for crankshaft make.

Avadhut B. Bhosale and Prof. P. R. Kale [2] The FEA analysis of crankpin is carried out over conventional model. The crankpin including the induction hardening with different case depth is analyzed for the given operating conditions. The best of all the iteration is chosen for the fabrication which is less than permissible value. The model is fabricated and tested for the same loading conditions as that of the conventional. A comparative study of FEA and Experimental results was made.From the results they concluded that the validation of results show close resemblance with a % error of 8.53%.

M Senthil Kumar, S Ragunathan and M Suresh [3] A survey taken on petrol engine crankshafts used in two wheeler made from C45 (EN8/AISI 1042) steel. It was reported that abnormal sound was heard in crankshaft while it is in operation and identified as failure of crankshaft. A very high wear has been seen at crankpin bearing location where the oil hole was provided. Crankpin was found as tempered. Mechanical and metallurgical properties of the crankshaft including chemical composition, micro-hardness, microstructure and tensile properties were studied and compared with the specified properties of the crankshaft material. As a result of analysis, the main reason of failure was determine as rapid wear leaded by lower surface hardness due to the contact of crankpin and bearing surface. The

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contact between the two was resulted due to absence of oil and improper lubrication. They found that the chemical composition of the crankshaft material and crankpin are in general within the range of the technical specifications and no obvious manufacturing and machining defects were found. The crankpin was not case hardened except tempering followed by general hardening.

B.N.Parejiya, D.B.Morabiya, Amit Solanki [4] they had modified the design of the crankpin considers the dynamic loading and the optimization can lead to a pin diameter satisfying the requirements of automobile specifications with cost and size effectiveness. The review of existing literature on crankpin design and optimization was presented. Three-dimension models of crankshaft and crankpin forces were created using Pro/ENGINEER software and software ANSYS was used to analyze the stress status on the crankpin. The dangerous areas as are found by stress analysis, maximum deformation, maximum stress point and are found. The materials, failure analysis, manufacturing process, design consideration etc. of the crankpin were reviewed.

V. Mallikarjuna, Dr.B. James Prasad Rao, G.kishore [5] An attempt made in this Project to study the Static analysis onf the crankshaft from a 4 cylinder I.C Engine. A three-dimensional model of IC engine crankshaft is created using CATIA V5 software. Finite element analysis is performed to obtain the variation of stress magnitude at critical locations of crankshaft. Inputs are taken from the engine specification chart for simulation. The Static analysis was performed using FEA Software ANSYS which resulted in the load spectrum applied to crank pin bearing. This load applied to the Finite Element model in ANSYS, and boundary conditions are applied according to the engine mounting conditions. The analysis is done for finding critical location in crankshaft. Stress variation over the engine cycle and the effect of torsion and bending load in the analysis are investigated. Shear Stresses, Von-mises stress are calculated using theoretically and FEA software ANSYS.

Mr. Mathapati N. C and Dr. Dhamejani C. L. [6] A crankshaft is often designed with a fillet radius to improve the fatigue life of crankshaft. The fatigue life of crankshaft is depended on the proper fillet radius. This fillet radius change than fatigue life is also changed of crankshaft. In most of the time fatigue failure is occur in crank-pin web fillet region. The crankshaft fillet rolling process is one of the commonly adopted methods in engineering to improve fatigue life of the crankshaft. A finite element analysis (FEA) is implemented to approximate the stress distribution induced in the crankpin fillet region. The modelling of crankshaft is created by Creo-parametric. Finite element analysis (FEA) is performed to obtain the variation of stress at critical locations and fatigue life of the crank shaft using the ANSYS software and applying the boundary conditions. Radius of fillet is changes in model of crankshaft to improvement in fatigue life. This work in done for optimization of a crankshaft in crank-pin web fillet region with fatigue life as well as to study a relation between fillet radius/diameter of crankpin to fatigue life.

Prof. NP. Doshi [7] studied connecting rod used in light commercial vehicle of tata motors is selected. In present work analytical result compared with numerical result among all load conditions the maximum value of equivalent stress was found to be 197.41 MPa while crank end of connecting rod is in tension. This stress is less than yield strength of material. It provides a factor of safety of 3.2.So the existing design is safe. The minimum stresses among all loading conditions, were observed at crank end cap as well as at piston end. So the material can be reduced from those portions. For additional optimization, dynamic analysis of connecting rod is needed. After considering dynamic load conditions once again FEA will have to be done. It will give more accurate results than existing.

K. Thriveni1 Dr.B.JayaChandraiah [8] an attempt made in this paper to study the Static analysis on a crankshaft from a single cylinder 4-stroke I.C Engine. The modeling of the crankshaft is created using CATIA-V5 Software. Finite element analysis is performed to obtain the variation of stress at critical locations of the crank shaft using the ANSYS software and applying the boundary conditions. Then the results are drawn Von-misses stress induced in the crankshaft is 15.83Mpa and shear stress is induced in the crankshaft is 8.271Mpa. The Theoretical results are obtained von-misses stress is 19.6Mpa, shear stress is 9.28Mpa. The validation of model is compared with the Theoretical and FEA results of Von-misses stress and shear stress are within the limits. Further it can be extended for the different materials dynamic analysis & optimization of crank shaft.

Assad Anis [9] Sandip M.Sorte, [6] worked on stress analysis of a single cylinder crank pin of TVS Scooty Pep crankshaft assemblage. Three dimensional models of crankshaft and crankpin forces were generated using Pro/ENGINEER software and ANSYS was used to analyze the stress level on the crank pin. The maximum deformation, maximum stress point and dangerous areas are decided by the stress analysis. The relationship between the crank rotation and load acting on crank pin would provide a valued theoretical foundation for the stress calculation and enhancement of crankpin and engine design.

J.R KEOUGH AND K.L HAYRYNEN [10] this full study is dedicated on production of the austempered ductile iron from ductile iron by explaining all the parameters like temperature, alloys casting process required. This paper reviewed the design consideration for ADI to help mechanical designer in his/her material/process selection activity early in the design process. It also emphasize on relative machinability between certain materials like aluminium, ductile iron and steel and also about cost consideration.

III. PROBLEM STATEMENT

The crankshaft consists of three parts these are crank pin, crank web, and shaft. The big end the connecting rod is connecting to the crank pin when the crank is at the dead center, the bending moment on the shaft is maximum and the twisting moment is zero. The maximum possibility of failure of crankshaft at crank pin because of load of piston and connecting rod are indirectly induced on crankshaft shaft. The crankshaft failure occurs due to decrease in the fatigue strength.[1] some of the other reasons of crankpin failure are-

- Shaft misalignment
- Vibration cause by bearings application
- Incorrect geometry(stress concentration)

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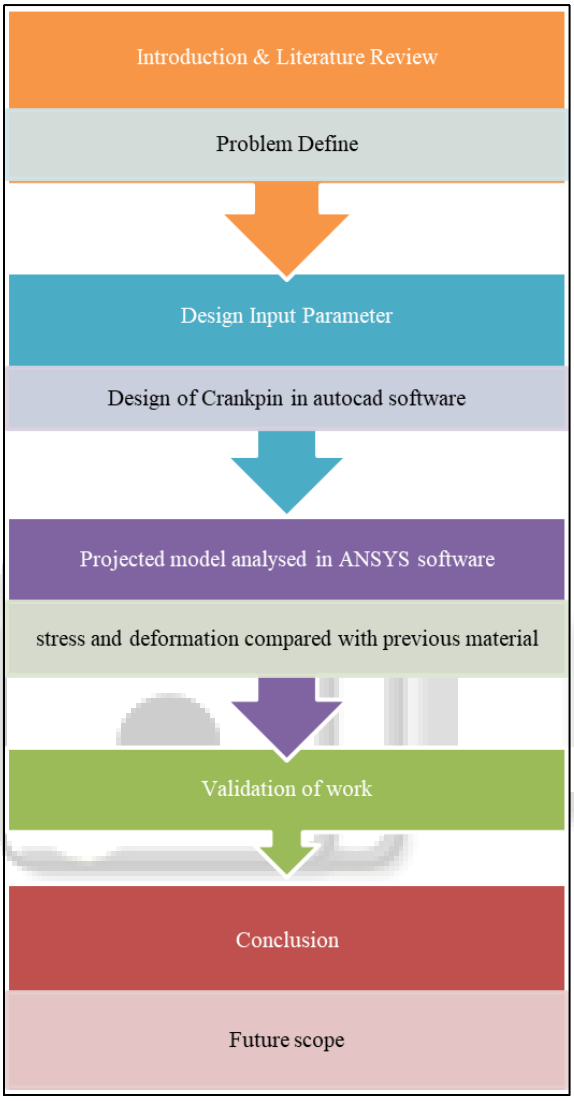
- Improper lubrication
- High engine temperature
- Overloading
- Crankpin material & its chemical composition
- Pressure acting on piston.

IV. RESEARCH METHODOLOGY



V. MATERIAL USED

While selecting the material, the main properties of concern are strength, stiffness, specific gravity, ductility, fatigue resistance, available joining methods, cost of material, and cost of machining. The relative importance of these properties depends on the purpose for which the machine is intended. For example, low cost is much more important for a mass produced moped than it is for a works grand prix racer, where cost is secondary to low weight.

Properties	ADI
Young's modulus Mpa	1.66e+5
Poisson's ratio	0.250
Tensile yield strength Mpa	862
Ultimate yield strength Mpa	1210
Density Kg/m^3	7077.9

Table 1: Properties of Material

VI. ENGINE SPECIFICATIONS

Bike model - Hero splendor +

Engine type	Air cooled 4 stroke single cylinder
Valve system	OHC, 2 valve
Cylinder bore	50 mm
Stroke	49 mm
Displacement	97.2 cm^3
Compressor ratio	9:9:1
Maximum power	6.15 kW (8.36 Ps) @ 8000 RPM
Maximum torque	0.82Kgm (8.05N-m) @5000 RPM

Table 1: Engine Specification

SYMBOL	PARAMETER	VALUE
D	Piston diameter	50 mm
lc	Length of the crankpin	43 mm
dc	Diameter of the crankpin	25 mm
L	Stroke	49 mm
ds	Shaft diameter	22 mm
t	Thickness of the crank web	14 mm
w	Width of the crank web	28 mm
r	Shaft centre to web centre	35 mm

Table 2: Engine Dimensions

VII. DESIGN & ANALYSIS

A. *Crankshaft Model in AutoCAD*

This chapter design and analysis of crankpin of dissertation includes design and analysis of existing crankpin of Hero splendor engine. Dimensions of the existing crankpin assembly have been extracted from the available data and CAD model has been prepared in CATIA as shown in figure. The finite element analysis is carried out by using Hypermesh and ANSYS. In this project the crankpin which is of Hero splendor is taken. CAD model then is made by the commands in CATIA of Pad, pocket, fillet, and geometrical selections in part design module. Parametric generation of drawings will help to get the dimensions useful in forces calculations in static loading conditions on a component.

1) *Cadmodelling*

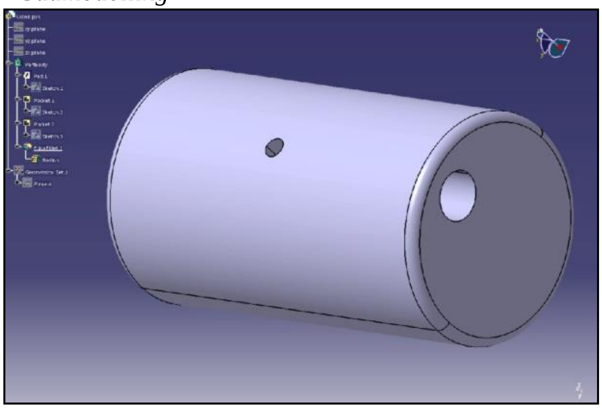


Fig. 2: Solid Model of Crankshaft

Material Properties are as below:

There are total two model materials are used for this solid model forged steel EN- 19 and au tempered ductile iron (ADI). The material properties of the crankshaft is given below in table

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EN- 19 properties	
Density	7800 Kg/m^3
Yield tensile strength	555 MPa
Ultimate tensile strength	775 MPa
Poisson's ratio	0.279
Young's modulus	213 GPa

Table 3: EN- 19 Properties

Austempered Ductile Iron	
Density	7077.9 Kg/m^3
Yield tensile strength	862 MPa
Ultimate tensile strength	1210 MPa
Poisson's ratio	0.250
Young's modulus	166 GPa

Table 4: ADI Properties

2) Meshing

Here, I have chosen tetrahedral mesh because of the tetrahedral meshing methodology is utilized for the cross section of the strong district geometry and meshing delivers fantastic cross section for boundary representation of solid auxiliary model. Meshing of solid is as below

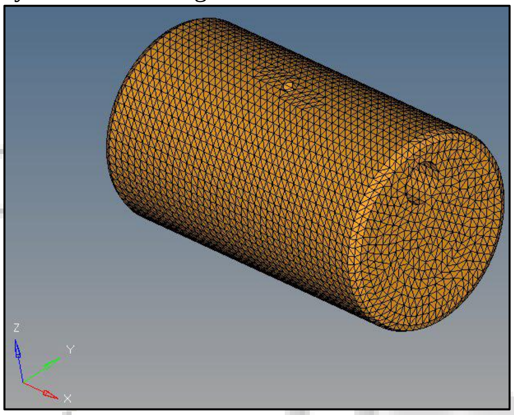


Fig. 3: Meshed Model of Crankshaft

3) Boundary and Loading Conditions

- ϴ= angle of inclination of crank from top dead center
- Ø= angle of inclination of connecting rod with the line of stroke
- dc= diameter of crank pin = 23mm
- lc= length of crank pin = 40mm
- FT= tangential force on crank pin, FQ sin (ϴ+Ø) ….(4)
- FR= radial force on crank pin, FQ cos (ϴ+Ø) ....(5)
- Using eqn (4) and (5) following results are calculated for the corresponding angles

B. Software Analysis Solution

The crankpin is checked for von-mises stress and analytical calculation with ADI materials for the validation of work.

Now, when applied the gas force due to maximum gas pressure to crankshaft, it may be deform to check the total deformation of crankpin due to maximum gas load on crankshaft.

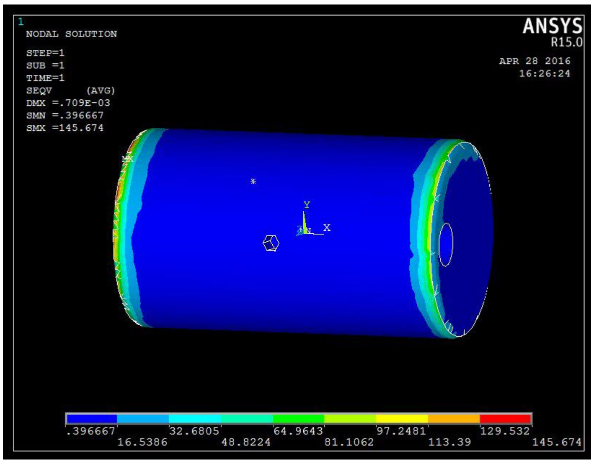


Fig. 4: Von Mises Stress of ADI for Crankpin

Normal deformation may be occur due to maximum load of crankshaft that should take for validation of work with von-mises stress as below the figure of total deformation of crankpin with ADI material.

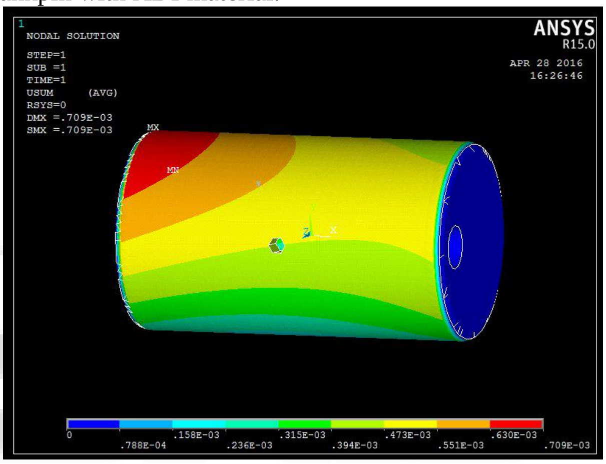
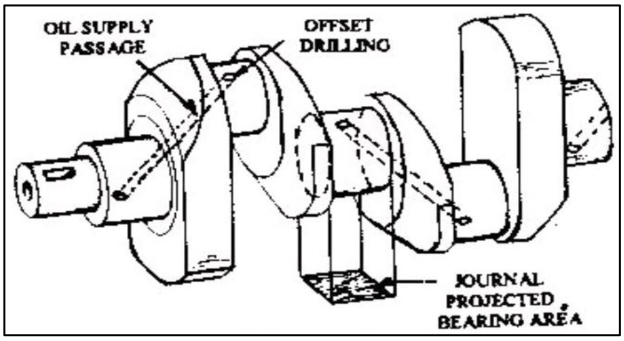


Fig. 5: Displacement Result of Crankpin

From the figure it can be concluded that the von mises stress in the crankpin is 145.67 N/mm^2 and the deformation in the crankpin is 0.7 e^{-3}

As it can be seen from the data figure that the stress occurs maximum at the fillet area and maximum at the place where the absence of the oil lubrication takes place. Since the lubrication is more in both the holes but the side hole is very less in depth so maximum deformation and stress takes place at the fillet area.

The analysis with various case depth is analysed and figures are shown for the deformation and von mises stress where the oil lubrication is less at the fillet area.



Here we have taken the image of four wheeler to understand the mechanism of oil hole

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C. Different Oil Holes in Crankpin

1) Oil hole –

These holes are generally provided in all types of crankpin of either vehicles, running from one end to other side of the surface. To provide clear passage, if it gets clogged with impurity the hole passes the residue exit from other end.

2) Side hole –

These can be as 12 'o' clock hole types, 10 'o' clock to 2 'o' clock or 9'o' clock to 3 'o' clock, connecting with the oil hole. So oil gets entered from the shaft travel through the crankweb and then by oil hole comes out to provide lubrication to connection rod.

Another hole is there whose depth is very less aprox 5mm to provide lubrication to the bearing and to avoid friction as no hole present in the crankweb

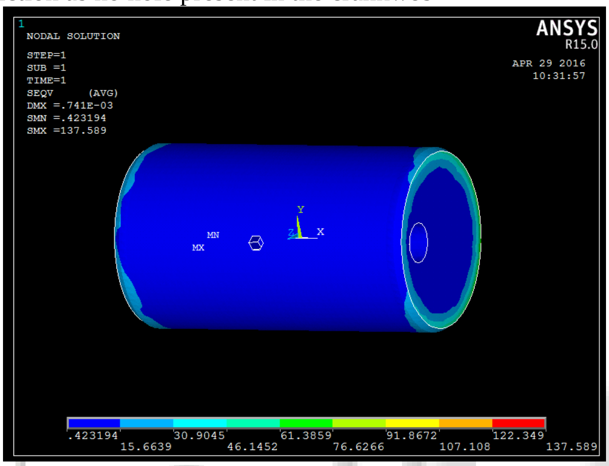

Fig. 6: Von Mises Stress at 1.5 mm Depth

Stress value for crankpin is 137.58 N/mm2 which is well below the critical value. Hence, design is safe.

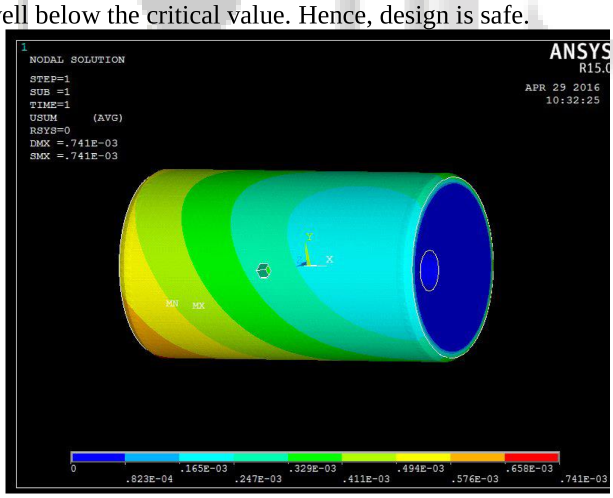

Fig. 7: Displacement Result of the Crankpin

The maximum displacement is coming out to be 0.69e3 mm. Measures to be adopted to avoid damage of the crankpin

- There can be 2 ways to prevent failure of the crankpin. First by increasing the oil hole so that there cannot be limitation of oil flow over connecting rod.
- Another step is to increase the hole which is connected with the bearing with aprox 1.5mm depth. Because high performance bearings generate greater friction and require more lubricant.

VIII. Experimental Method

The experimental study of the crankshaft on both the material has been considered by checking the hardness value of both materials. As the main intension of our dissertation is to reduce the weight of the crankshaft and to reduce the cost efficiency along with increasing strength.

TENSILE STRESS	ADI	EN-19
775-925	241-302	223-277
850-1000	269-341	248-302
925-1000	302-375	269-331
1200	341-444	
1400	388-477	
1600 max	402-512	

Table 6: Hardness Result

IX. Results

The initiation of failure is consequently propagated by absence of oil due to improper lubrication. Hence the stress and wear at the region of contact surface of crankpin and bearing becomes more. The automotive crankshaft, one of the more metal intensive components in the engine, provides an attractive opportunity for the use of alternate materials and processing routes.

From above analysis we can see that there is total two material used for analysis and got the different result with parameter, from that the austempered ductile iron is best of them. Usually crankshaft is made from steel by using casting or forging but we can austempered ductile iron as a material for crankpin. Comparing chat of three materials is as below.

Material	VON MISES STRESS IN N/mm^2	DEFORMATION IN mm
ADI	145.67	0.7×10^3
ADI WITH 1.5mm DEPTH	137.58	0.75×10^3

Table 8: Comparing the Analytical and FEM Results

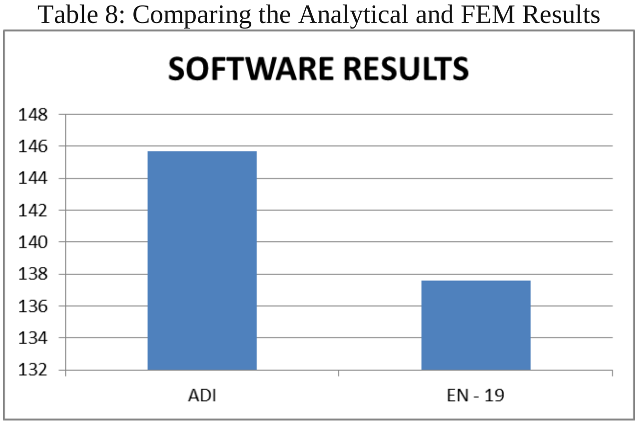

Fig. 8: Von mises stress result in N/mm^2

ADI can be cast to a near net shape, making manufacturing less difficult than that of steel. Even though some growth can occur during the heat treat process, the variation is predictable and can be accounted for in the design phase. The ADI crankshaft was rough machined prior to heat treat, and finish machine after heat treat to accommodate design tolerances. Rough machining is accomplished rather easily when done prior to the Austempering process, which adds to the manufacturability of this material. Note that the standard grades of ductile iron are easier to machine than ADI

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and most steels, thus it is advantageous to machine prior to Austempering. However, finish machining and fillet rolling done after heat-treating will increase the strength of the material. ADI is more expensive than ductile iron since a value added or heat treat process is included in the price. However, the cost of ADI is still lower than that of steel 30% cost savings using ADI over steel.

ADI is 10% less dense than steel. This lower density provides a weight reduction opportunity compared to the steel crankshaft as shown in Table. A weight savings was a specific advantage for this high performance application

	Weight
Steel	34 Kg (75 lbs)
Ductile Iron	29.9 Kg (66 lbs)
ADI	29.5 Kg (65 lbs)

Table 9: Weight of Produced Crankshaft

The casting process is the most direct, lower energy process from metal ore to finished component. All ductile iron and ADI grades can be produced from up to 100% recycled materials. Properly designed castings can combine multiple parts into one, simplified design, reduce weight and improve the appreance and functionality of component.

X. Conclusion

– Fatigue is the dominant mechanism of failure of the crankshaft.
– The maximum deformation appears at the center of crankpin neck surface.
– Improper lubrication increases the wear rapidly and hence noise is heard when the engine is in running. Hence, the life of crankshaft becomes shorter.
– The maximum stress appears at the fillet areas between the crankshaft journal and crank cheeks and near the central point journal.
– High performance bearings generate greater side leakage of lubricant due to higher rotation speeds & greater loads

XI. Future Scope

– Dynamic analysis or Vibration Analysis can be performed to estimate the life of the component.
– Optimization can be done with other material which is higher strength and other factors for the failure can be considered

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