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Static and Materialistic Analysis of Crankshaft

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***Abstract*- Crankshaft is one of the large components with a complex geometry in internal combustion engine which converts the reciprocating displacement of the piston into a rotary motion. the main reason of failure was determined as lower surface hardness followed by rapid wear due to the contact of crankpin and bearing surface. The contact was resulted due to absence of oil and improper lubrication The modeling of the single cylinder petrol engine crankshaft is created using Auto-Cad Software. Finite element analysis (FEA) is performed to obtain the variation of stress at critical locations of the crank shaft using the ANSYS software. The material of the crankshaft EN-19 has been changed to ADI (Austempered Ductile Iron) and then the properties were compared with previous material.**

***Keywords*- Digital Image Processing, Image Enhancement, Information Extraction, visibility restoration.**

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, it changes the up and down motion that is the linear (reciprocating) motion of the pistons into rotary motion. To convert the motion, the crankshaft has one or more offset shafts.

The pistons are connected by these shafts to the crankshaft. When the piston moves up and down, it pushes the offset shaft. This in turn rotates the crankshaft. The crankshaft is the main rotating component of an engine and is commonly made of ductile iron, forged steel and other alloy material. In order to convert two motions, the crankshaft has " crank throws " or "crankpins".

Fig. 1 Crankshaft of Hero splendor with crankpin.

II. LITERATURE RIVIEW

Jayesh Kumar 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 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.

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 is 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.

Kristin R. Brandenberg, John Ravenscroft, Dr. Arron Rimmer and Kathy L. Hayrynen, PhD [7]
TVR Engineering selected an Austempered Ductile Iron (ADI) crank shaft for its combination of low cost, low weight and high tensional strength ADI presents a useful set of properties for the design engineer. With ever increasing specific power requirements for new engine designs, new material/process combinations for engine components are being explored.

This paper will discuss the properties of ADI, the reason for its selection for this crankshaft, and its suitability for this application. car. Due to the density of the materials, ADI was lighter than steel. Being a cast product, ADI was more cost effective to produce than steel. This crankshaft was sufficiently strong compared to ductile iron to handle the loads of a high performance engine. The internal dampening effects of ADI also added the benefit of better NVH properties resulting in a quieter engine. By using ADI, TVR was able to save cost and weight while gaining better NVH properties, and still

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maintaining the strength and wear resistance needed in this application.

K. Thriveni1 Dr.B.Jaya Chandraiah [9]

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 [10]

This paper presents the design analysis of a crankshaft used in tractor made in pakistan. The finite element simulation techniques are utilized to analyze the crankshaft made up of chromoly steel. A two dimensional static stress analysis is performed in ANSYS APDL to obtain von-mises stress, that produced results which are significant to improve the component design at early development stage. Harmonic analysis used to determine the steady state response to sinusoidal (harmonic) loads of known frequency. Modal analysis is carried out to determine the natural frequencies of the crankshaft and the mode shapes is examined.

J.R Keough And K.L Hayrynen [11]

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. The crank web connects the crank pin to the shaft portion. The maximum gas pressure on the piston will transmit maximum force on the crankpin in the plane of the crank causing only bending of the shaft. The crankpin as well as ends of the crankshaft will be only subjected to bending moment. 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 crankshaft failure occurs due to decrease in the fatigue strength.[1]

Most crankshafts fail due to progressive fracture, repeated bending or reversed tensional stresses. Thus the type of loading on the crankshafts is fatigue loading therefore, the design should be based on endurance limit. To avoid stress concentration and fatigue failure, abrupt changes in the section of the shaft connection should be avoided. This makes the web weak and to compensate for it, the width is increased. Since the failure of the crankshaft is serious for the engine, and also because of the inaccuracy in determining all the forces and stresses, a high factor of safety based on endurance limit from 3 to 4 should be used. To be on the safe side, the endurance limits for complete reversal of bending and tensional stresses are taken. The reasons of the failure of the crankshaft are many

- Shaft misalignment
- Vibration cause by bearings application
- Incorrect geometry(stress concentration)
- Improper lubrication
- High engine temperature
- Overloading
- Crankpin material & its chemical composition
- Pressure acting on piston.

IV.RESEARCH METHODOLOGY

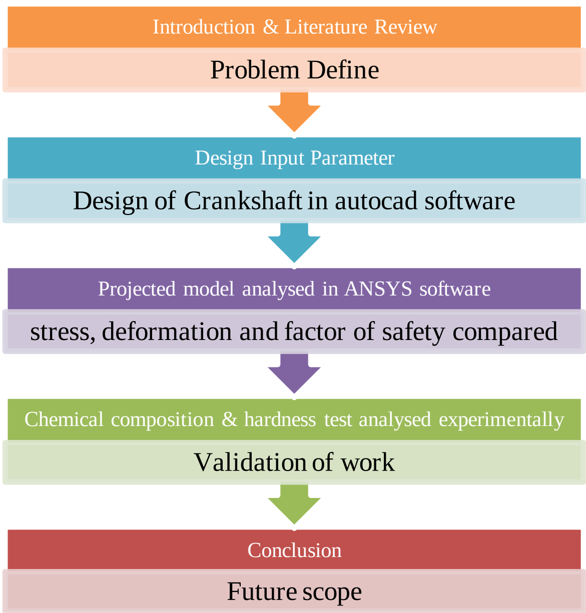

Fig.1 Flow Diagram of Methodology.

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V. ENGINE SPECIFICATIONS.

1. Bike model - Hero splendor +

Table 1 Engine Specification.

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 2 Engine Dimensions.

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

1. Pressure Calculations

- Density of petrol (CgH18) :
  ρ = 750 kg / m3
  = 750 × 10-9 kg / mm3
- Operating Temperature :
  T = 20 0C
  = 20 + 273.15
  = 293.15 0k
- Mass of displacement : m = ρ × V
  Where,
  ρ = Density
  V = Volume
  $= (750 \times 10^{-9}) \times (97.2 \times 10^3)$
  ○ = 0.0729 kg
- Molecular mass of petrol : $M = 114.228 \times 10^3$ kg / mole
- Gas constant for petrol : $R = 72.7868 \times 10^3$ J / kg / mol K
  We know that PV = mRT
  $p \times 97.2 \times 10^3 = 0.072 \times 72.7868 \times 10^3 \times 293.15$
  $p = \frac{0.072 \times 72.78 \times 10^3 \times 293.15}{97.2 \times 10^3}$
  p = 15.791 MPa

2. Design calculation

Gas Force (Fp) : Fp = p × A
Where, p = Pressure
A = Cross Section Area of Piston

$Fp = 15.791 \times (\pi/4 \times D^2)$
$= 15.791 \times (\pi/4 \times 50^2)$
$= 15.791 \times (0.7857 \times 2500)$
$= 15.791 \times 1964.25$
= 31017.47 N
$= 31.017 \times 10^3$ N

- Moment on pin:
  $Mmax = \frac{Fp}{2} \times \frac{lc}{2}$

Where,
lc = Length of crank pin, mm
= 31017.47/2 × 43/2
= 333437.802
$= 333.43 \times 10^3$ Nmm

- Section Module of crankpin :
  $Z = \frac{\pi}{32} \times (dc)^3$
  $= 0.0982 \times 25^3$
  $= 1534.37\ mm^3$
- Torque obtained at maximum power of Hero splendor Engine :

$$P = \frac{2\pi Nt}{60}$$

$$8.36 \times 103 = \frac{2 \times \pi \times 8000 \times T}{60}$$

$$T = \frac{60 \times 8.36 \times 10^3}{2 \times \pi \times 8000}$$

$T = 0.0099 \times 10^3$ Nmm

- Von misses Stress :
  $\sigma\ von = \frac{Meq}{z}$

Where,
Meq = Equivalent bending moment
So, Equivalent bending moment
$Meq = [(kb \times Mmax)^2 + 3/4\ (kt \times T)^2]^{1/2}$

Where,
Kb= Combined shock & fatigue for bending = 1
Kt= Combined shock & fatigue for torsional = 1
Mmax= Bending moment
$= [(1 \times 333.43 \times 10^3)^2 + 3/4\ (1 \times 0.0099 \times 10^3)^2]^{½}$
$= [(111175.56 \times 10^6) + (74.75 \times 10^6)]^{½}$
$= [111250.31 \times 10^6]^{½}$
$= 333.54 \times 10^3$ Nmm

Now,
$\sigma\ von = \frac{Meq}{z}$
$\sigma\ von = \frac{333.54 \times 10^3}{1534.3}$
$\sigma\ von = 217.35$ Mpa

- Equivalent twisting moment:
  $Teq = (Mmax^2 + T^2)^{1/2}$
  $= [(111175.00 \times 10^6) + (0.00009801 \times 10^6)^6$
  $= [111175.00 \times 10^6]^{1/2}$
  $= 333.51 \times 10^3$ Nmm
  Now,

$$Teq = \frac{\pi \times dc3 \times \tau}{16}$$

$$333.51 \times 10^{3} = \frac{\pi \times 15625 \times \tau}{16}$$

$$\tau = 108.7 \text{ N/mm}^2$$

- Strain for ADI = $\varepsilon = \frac{\sigma von}{E}$

$$\varepsilon = 0.013$$

- Strain for EN -19 = $\varepsilon = \frac{\sigma von}{E}$

$$\varepsilon = 0.020$$

VI. SIMULATION AND MODELLING

1. Crankshaft Model in AutoCAD

Crankshaft of Hero splendor is procured from market and it is selected for research work. The dimensions of the crankshaft are carryout by using instrument like vernier caliper and micrometer. Crankshaft was modeled with the help of Auto-cad Software

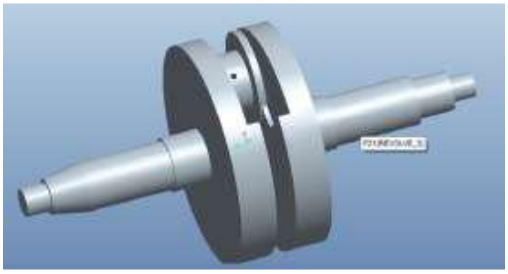

Fig. 2 solid model of crankshaft.

2. Material Properties are as below

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

Table 3 EN- 19 properties

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 4 ADI 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

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.

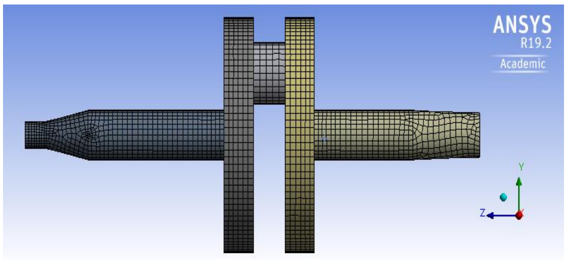

Fig. 3 Meshed model of crankshaft.

3. Boundary and loading conditions

The crankshaft is fixed at both side with cylindrical support using baring which show in Blue color in all the degree of freedom and the load of 31017N generated due to maximum gas pressure is applied at crankpin in vertical downward direction.

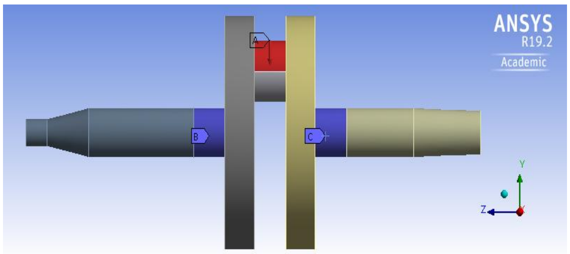

Fig. 4 Boundary and loading conditions.

4. Software Analysis Solution

The crankshaft is checked for von-mises stress and analytical calculation with deferent three materials for the validation of work.

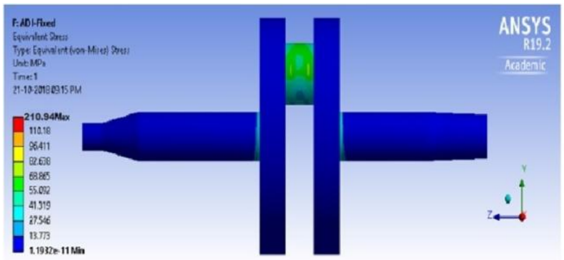

Fig. 5 von mises stress of EN- 19.

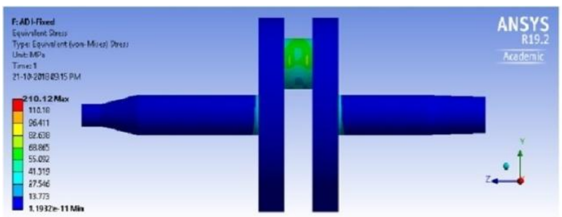

Fig. 6 von mises stress of ADI.

Now, when applied the gas force due to maximum gas pressure to crankshaft, it may be deform to checked the total deformation of crankshaft due to maximum gas load on crankshaft. 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 crankshaft with deferent three material and compare it in result.

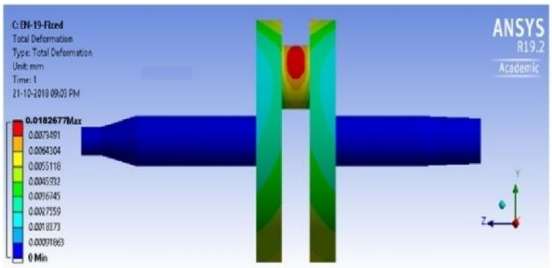

Fig.7 deformation of EN-19.

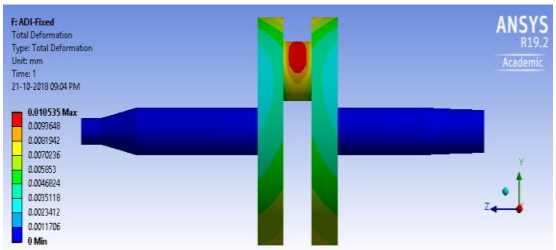

Fig. 8 Deformation of ADI.

VII. EXPERIMENTAL METHOD

The experimental study of the crankshaft on both the material has been considered by checking the chemical composition and 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**.**

Table 5 chemical composition

Material	ADI	EN- 19
carbon	3.5 - 3.7	0.35-0.44
Silicon	2.3 - 2.6	0.10-0.35
Manganese	0.2-0.4	0.45-0.70
Phosphorus	≤0.04	0.035 max
Sulphur	≤0.02	0.040 max
Copper	0.6 - 0.8	
Nickel	0.8 - 1.0	1.30-1.70
Molybednum	0.25 - 0.35	0.20-0.35
Chromium		1.00-1.40

Table 6 Hardness result

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	

VIII. RESULTS

The initiation of failure is consequently propogated 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.VThe 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

Materials 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 crankshaft make. Von-mises stress of austempered ductile iron is got 210.10 MPa and deformation is 0.0105 mm. The crankshaft chosen for this project is Hero Splendor regular model. Comparing chat of three materials is as below.

Table 7 Properties of different material.

Material	Tensile strength Mpa	Yield strength Mpa	Elongation in %
ADI	900-1030	650	9
EN-19	775-925	555	13
EN-24	850-1000	680	13

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Table 8 comparing the analytical and FEM results.

Material	Von Mises Stress In Mpa		% Error
	Analytical result	software result	
ADI	217.35	210.12	3.4
EN – 19	217.35	210.94	3.0

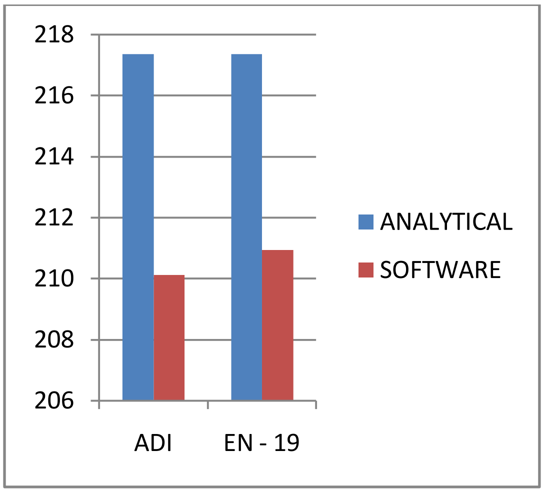

Fig.9 Von mises stress result in MPa.

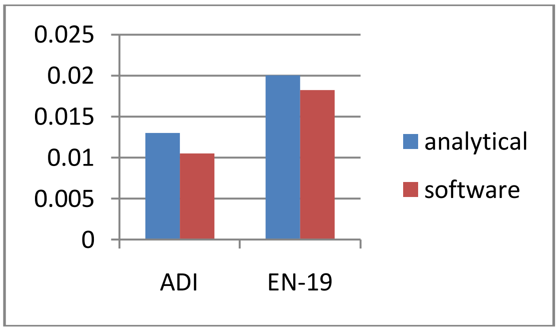

Fig.10 Deformation graph of both material.

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 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.

Table 9 Weight of produced crankshaft

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

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. Castings can put the metal right where you need it. Castings process allow us to cast holes and complex passages allow us to cast holes and complex passages into parts that cannot be forged in.

IX. 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

X.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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