ANALYSIS of PARTICLE REINFORCED METAL MATRIX COMPOSITE CRANKSHAFT

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Abstract:Crankshaft is one of the vital elements of the internal combustion engine. The main purpose of crankshaft in automobiles is to transform reciprocating linear motion to rotary motion i.e. it is used to translate from piston to crank. This work is about evaluating and comparing the load and fatigue performance of two vying production techniques for crankshaft viz. forged steel and Ti-6Al-4V+12%TiC (Particle Reinforced Metal Matrix Composite) used in automobiles. Three dimensional model of crankshaft shaft is created using Pro-Engineer. Static simulation has to be conducted on two crankshafts, forged steel and Ti-6Al-4V+12%TiC, from similar single cylinder four stroke engines. Finite element analysis (FEA) is to be performed to obtain the variation of stress magnitude at critical locations. The static analysis is done and is verified by simulations in finite element analysis software ANSYS. Comparisons for the properties such as equivalent stress, equivalent strain, total deformation, life and damage of crankshafts made up of forged steel and Ti-6Al-4V+12%TiC were determined and the results were tabulated. Model theoretical calculations are performed for clear analysis. The output of result would provide a possible theoretical base for optimization and development of engine design.

***Keywords*—** ANSYS, Crankshaft, Finite Element Analysis, Metal Matrix Composite, Strength Analysis

INTRODUCTION:

Crankshaft is one of the significant components of an engine which has a four bar link mechanism. The crankshaft is prominent in size and complicated in geometrical structure and it is used to transubstantiate from reciprocating motion into rotary motion. It induces the engine to rotate. Main bearing is rotated along with the shaft parts subsequently connecting rod is associated along with connecting pins and shaft parts and connecting pins are linked with the aid of crank pins. Nonlinear displacement occurs in the engine due to creation of shocks, so to compensate it flywheel is used. Downward force is created during the cycle of power stroke, crank shaft must be firm enough to withstand the force. Strength of crankshaft becomes a crucial thing in the working of internal combustion engine. Torsional and bending forces are two forces acting on crankshaft. Magnitude of forces depends upon the weight of connecting rod, crank radius, weight of piston, connecting rod dimensions. During the rotation of engine, power impulse contacts the crank pin in the fore terminal of the engine then torsional vibration is acquired. If it is irrepressible then engine performance cuts down. For avoiding torsional vibrations, dampers are catered in antonym terminal. Thus the performance of engine depends upon the efficiency, power and weight of crankshaft. Efficiency should be high, weight must be low and power to transfer should be certainly high. Key factor in determining the life of engine is stress computation. In the past beam and space chassis were used but as it contains minimal nodes it become cumbersome for calculations so new technique (finite element analysis (FEA)) was adopted to make calculation simpler. New advancement was computer based approach.

1.1 Literature Review

Gu Yingkui, Zhou Zhibo. [1] have discussed about the 3-Dimensional crankshafts of a diesel engine which was created using PRO-E software's and ANSYS software, these indicated that the regions concentrating on high stress which mainly included the knuckles of the crank arm & the main journal and the crank arm & connecting rod journal, were the areas easily broken. Momin Muhammad Zia Muhammad Idris et al [2] have used strength analysis in optimization of crankshafts. The 3-D model was developed applying ANSYS (Finite Element Analysis Software) and Pro-Engineer software. Possibility of resonance is checked using the outputs of the analysed model designs. Outputs are used to examine the possibilities for resonance by using analysed model design. Abhishekchoubey and Jamin Brahmbhatt [3] have done analytic models of crankshaft and three dimensional framework of the crankshaft which was modelled using SOLID WORKS software and working it in Finite Element Method (FEM) ANSYS. The greater values of stresses occur at central point journal, crank cheeks of the crank shafts. Maximum deformation of the crankshafts appears at the midpoint of crank neck surface.B.D.N S Murthy et al [4] have described about the modelling and optimization of crankshaft. Annealed 4340 steel, Inconel x 750 alloys are two different elements which are used for conducting the experiments. CATIA-V5 is used for designing the modal and the analysis aspect is performed in Ansys. With respect to strength outputs were shown. Results shows that crankshafts made up of Annealed 4340 steel has lower grade compared to Inconel x750 alloy. Gongzhi et al. [5] started his analysis using diesel engines subjecting to dynamic strength of crank shafts. The finite element models of bearing, piston, crankshaft and connecting rod was developed using ANSYS and the techniques of sub structure is further used to simplify the existing models. The result was introduced into EXCITE software to evaluate the multi-body dynamics and valuate the calculations of per working cycle of a crankshaft. Both ANSYS finite element method and AVL-EXCITE multi-body dynamics are analysed for the dynamic properties of the crankshaft. Thus, under normal circumstances the journal fillet is undergone with the majority stress. R. J. Deshbhratar, and Y.R Suple.[6] have analysed crankshafts consisting of four cylinders and the framework of crankshafts were created by Pro-Engineer Software which was later imported to ANSYS software. The majority of the deformation accumulates at the midpoint of the crankshaft surface. The crank cheeks, the central point journal and the crankshaft are the areas where the majority of the stresses appear. Stresses are extremely concentrated at the edges of the journal. Due to this, bending and cracks/breaks are formed on these areas. Meng et al. [7] have discussed about the four cylinder modals indulged in stress analysis. Finite Element Method Software (FEM) ANSYS is used here to evaluate the vibrations produced in the modal analysis of crankshafts. Thus, the optimization and the advancement of the engine design were provided with a valuable theoretical foundation. Deformation mainly occurs at crank neck surface. Area within the crank pin and crank cheeks are highly prone to deformation. Fillet between the crank cheeks, crankshafts journal and midpoint of the journal are the areas where stresses are induced to a maximum extent.

It seems like forged steel and other types of steel are mainly used as raw material for making crankshafts. But, the performance of crankshafts seems to be declining with the aspect of deformation, stress, strain, life and damage. So, the raw material can be changed to decrease the above stated problems.

1.2. Proposed Methodology

Ti-6Al-4V+12% TiC alloy, which has relatively, eminent strength, higher corrosion resistance and modest value of modulus. Due to this crankshaft is produced using Ti-6Al-4V+12% TiC. Crankshaft is made up of Ti-6Al-4V+12% TiC alloy and forged steel is designed using design software pro-engineer and the properties and performance of crankshaft is determined. The analysis works were carried out in ANSYS and the number of properties such as stress, strain, total deformation, life and damage are obtained as per the recommendation of design of experiments.

1.3 Calculation

Dimensions for crankshaft (Table 1)

Length of crank pin	12.7 mm
Diameter of crank pin	25.4 mm
Shaft diameter	19.05 mm
Bore diameter	68.3 mm
Stroke length	51.8 mm
Maximum pressure	3.15 N/mm^2

Force on the piston = 11.53KN

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

$\sin\phi = \sin\theta/(l/r)$

F_p= Area of the bore x Max. Combustion pressure

$= \pi/4 * D^2 * P_{max}$

Take $l/r=5$, The maximum value of tangential force lies when the crank is at an angle of $\theta=35^o$ (from 30^0 to 40^0 for diesel engines)

$\phi=6.35^o$

We know that Thrust Force in the connecting rod,

$F_Q = F_P/\cos\phi$

From we have thrust on the connecting rod,

F_Q =11.60KN

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

1. Tangential force on the crankshaft,

$F_T = F_Q \sin(\theta + \phi) = 7.66KN$

2. Radial force on the crankshaft,

$F_R = F_Q \cos(\theta + \phi) = 8.70KN$

Reactions at bearings due to tangential force is given by

$H_{T1} = H_{T2} = F_T/2 = 3.83KN$

Similarly, reactions at bearings due to radial force is given by

$H_{R1} = H_{R2} = F_R/2 = 4.35KN$

We know that bending moment at the centre of the crankshaft

$M_C = H_{R1} * b_2 = 41.977KN\text{-}mm$ $[b_2 = 9.65mm]$

Twisting moment on the crankpin

$T_C = H_{T1} * r = 48.641KN\text{-}mm$

Where r is the radius of the crank pin,r=12.7mm

According to distortion energy theory

The von Misses stress induced in the crank-pin σ_v is,

$M_{ev} = \sqrt{(K_b * M_c)^2 + 0.75(K_t * T_c)^2} = 105.1$ KN-mm

Here, K_b = combined shock and fatigue factor for bending (Take K_b=2)

K_t = combined shock and fatigue factor for torsion (Take K_t =1.5)

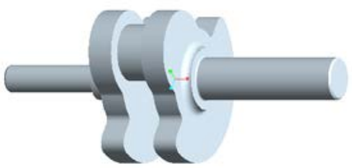
$M_{ev} = \pi/32 * d^3 * \sigma_v$

σ_v= 131.20N/mm^2

1.4 Design and Analysis of Crankshaft

Crankshaft is designed using Pro-Engineer software. The design of crankshaft is shown below:

Crankshaft (Figure 1)



Analysis of Crankshaft for studying various properties such as stress, strain, deformation and damage. Properties of forged steel and Ti-6Al-4V+12%TiC are tabulated below.

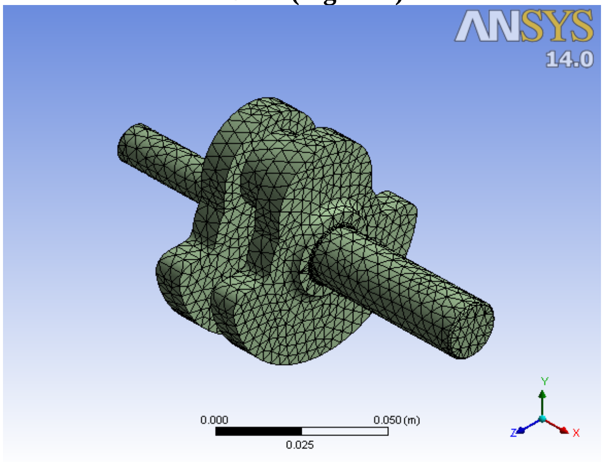
Material Properties (Table 2)

Material	Ti-6Al-4V+12%Tic	Forged Steel
Young's Modulus	1.14E14 Pa	2.21E11 Pa
Density	4430kg/m^3	7833kg/m^3

Poison's Ratio	0.342	0.3

Meshed view obtained utilising ANSYS is exhibited below.

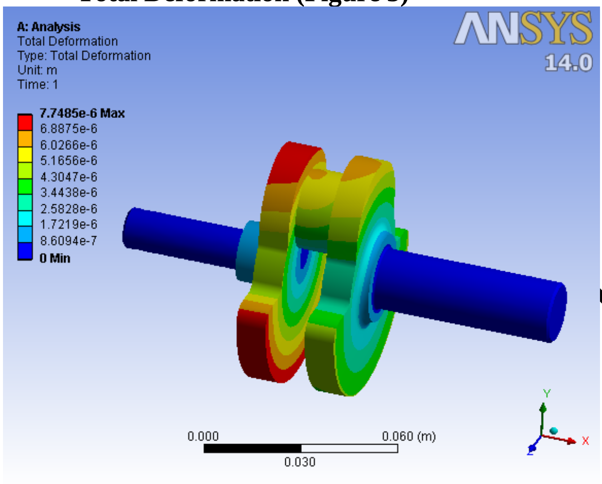
Meshed View (Figure 2)



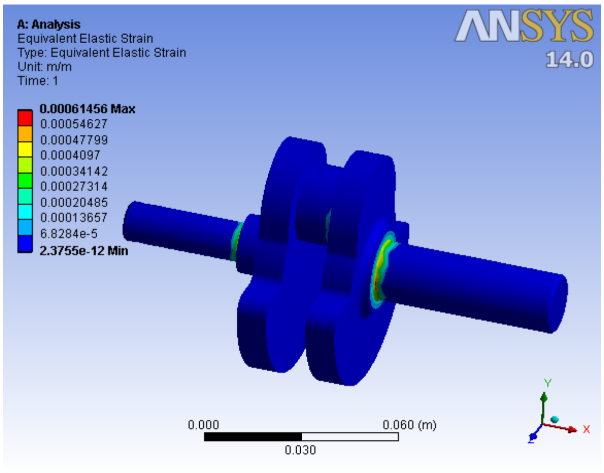
Results found using ANSYS comparing both forged steel and Ti-6Al-4V+12%TiC are indicated below.

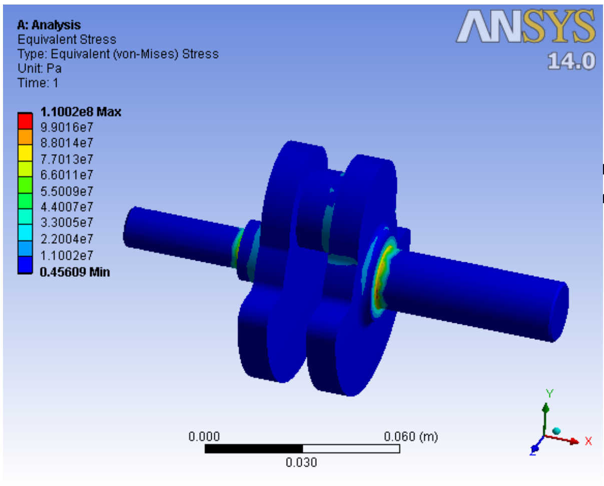
Forged Steel

Total Deformation (Figure 3)



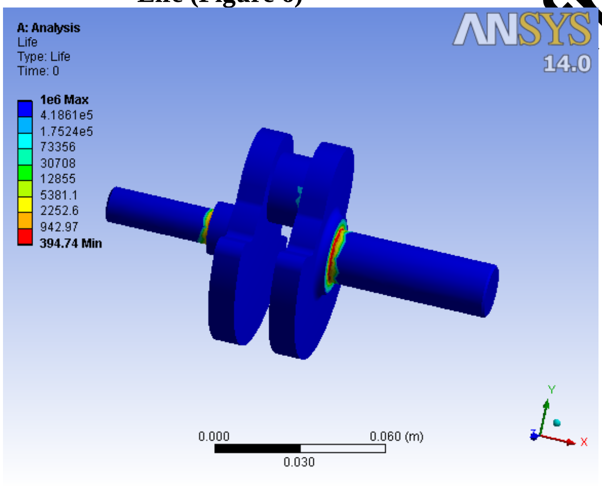
Equivalent Strain (Figure 4)



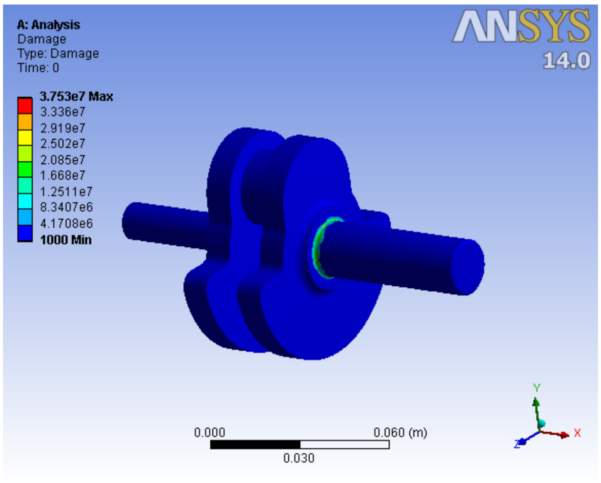


EquivalentStress(Figure5)

Life (Figure 6)

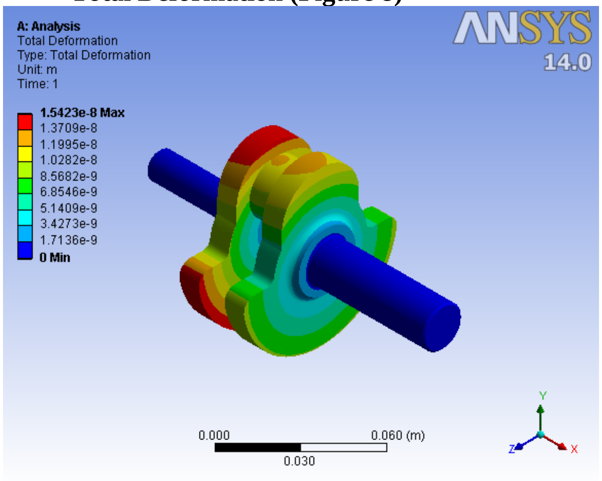


Damage (Figure 7)

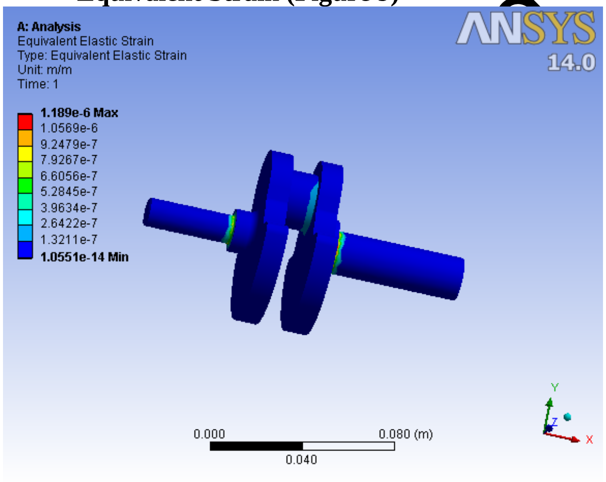


Ti-6Al-4V+12%TiC

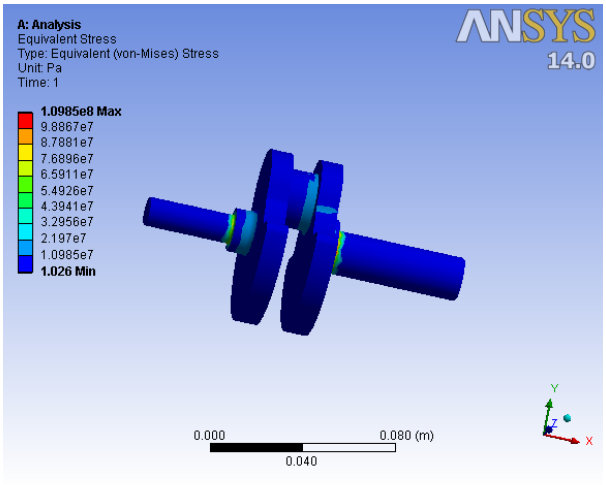
Total Deformation (Figure 8)



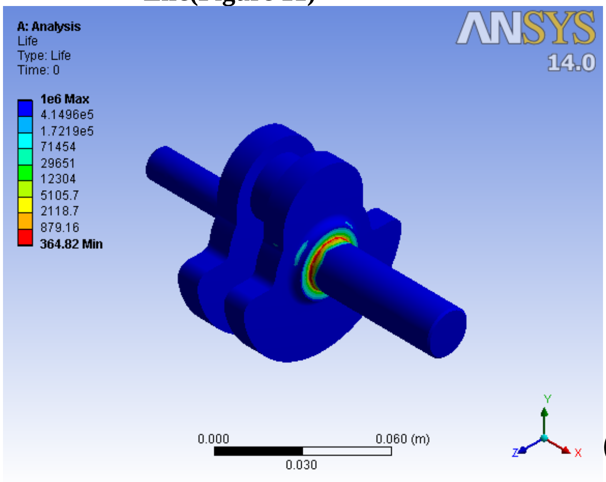
Equivalent Strain (Figure 9)



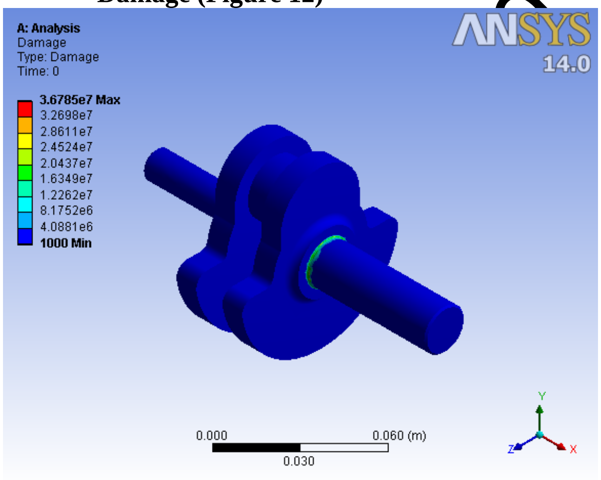
Equivalent Stress (Figure 10)



Life(Figure 11)



Damage (Figure 12)



CONCLUSION

The analysis of crank shaft were found that the Ti-6Al-4V+12% TiC material have a good physical properties and it has a appreciable deformation under the moment then forged material steel and finally the deformation, stress, strain of the Ti-6Al-4V+12% TiC is low compared to the forged steel material. Crankshaft is usually made of forged steel, but the performance of crankshaft is less than what is estimated so Ti-6Al-4V+12% TiC came into consideration as it have many advantages over forged steels. Comparison between properties of forged steel and Ti-6Al-4V+12% Tic are shown below,

Table 1 Comparison between Forged steel and Ti-6Al-4V+12% TIC using ANSYS

Material	Forged steel		Ti-6Al-4V+12% TIC	
	MIN	MAX	Min	Max
Total deformation (m)	0	7.749E-6	0	1.54E-8
Equivalent Elastic Strain(m/m)	2.38E-12	0.0006146	1.05E-14	1.18E-6
Equivalent stress (Pa)	0.4561	1.1E8	1.02	1.09E8
Life(cycles)	394.74	1E6	364.82	1E6
Damage	1000	3.753E7	1000	3.68E7

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