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Modeling And Optimization Of Single Piston I.C Engine Crank Shaft With Different Materials And Loads By Using Fea

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ABSTRACT

Crankshaft is a component in an engine which converts the reciprocating motion of the piston to the rotary motion. Where as in a reciprocating compressor, it converts the rotational motion into reciprocating motion. In order to do the conversion between two motions, 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. The design of a crankshaft is of 4 stroke single cylinder S.I engine. So that two revolution of crankshaft for each stroke. The peak pressure acting on the engine crankshaft. The crankshaft of the located model is designed using CAD SOFTWARE CATIA V5 with the accurate dimensions and material standards. CATIA V5 is one of the best design software in design tools were we can easily design components based on it dimensions and analysis in annoys with accurate results. In this project to compare the optimization of crank shaft on two different materials(aluminum alloy & e-glass epoxy composite) .The results are taken and evaluated with the given load conditions and following deformation results are shown.

1.Introduction

Today's automotive industries are faced with a number of issues, which require them to be responsive in order to be competitive. To be competitive, one has to produce components with low cost and high quality. The advent of high performance computers, CAD tools and Optimization techniques has helped realize the demand of global market. With the help of Optimization techniques and numerical methods, one can design a component, create a solid model using CAD tools, simulate the operating conditions and find out if the component meets the expectations and feasibility before starting the actual production, thereby saving time and resources.

The general considerations in designing a crankshaft are;

The type of loads and stresses caused by it, selection of material, motion of parts or kinematics of the crankshaft, form and size of parts, convenient and economical features like minimization of wear, and use of standard parts. Failure of the Crankshaft will result in the failure of the engine.

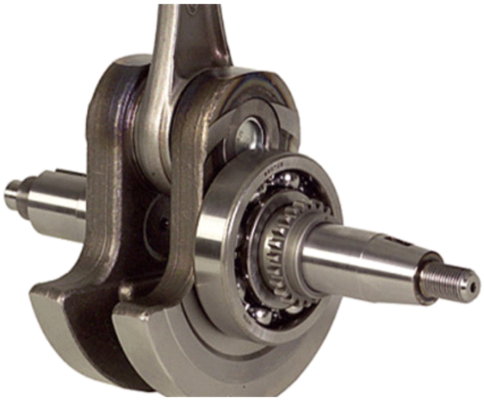

Figure 1: crankshaft

CRANK MECHANISM

A **crank** is an arm attached at a right angle to a rotating shaft by which reciprocating motion is imparted to or received from the shaft. It is used to convert circular motion into reciprocating motion, or vice versa. The arm may be a bent portion of the shaft, or a separate arm or disk attached to it. Attached to the end of the crank by a pivot is a rod, usually called a connecting rod . The end of the rod attached to the crank moves in a circular motion, while the other end is usually constrained to move in a linear sliding motion.

The term often refers to a human-powered crank which is used to manually turn an axle, as in a bicycle crank set or a brace and bit drill. In this case a person's arm or leg serves as the connecting rod, applying reciprocating force to the crank. There is usually a bar perpendicular to the other end of the arm, often with a freely rotatable handle or pedal attached.

A **crankshaft** related to crank is a mechanical part able to perform a conversion between reciprocating motion and rotational motion. In a reciprocating engine, it translates reciprocating motion of the piston into rotational motion, whereas in a reciprocating compressor, it converts the rotational motion into reciprocating motion. In order to do the conversion between two motions, 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 is typically connected 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 torsional 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.

Large engines are usually multi cylinder to reduce pulsations from individual firing strokes, with more than one piston attached to a complex crankshaft. Many small engines, such as those found in mopeds or garden machinery, are single cylinder and use only a single piston, simplifying crankshaft design.

I.C Engines

A crankshaft is subjected to enormous stresses, potentially equivalent of several tones of force. The crankshaft is connected to the fly-wheel (used to smooth out shock and convert energy to torque), the engine block, using bearings on the main journals, and to the pistons via their respective con-rods. An engine loses up to 75% of its generated energy in the form of friction, noise and vibration in the crankcase and piston area. The remaining losses occur in the valve train (timing chains, belts, pulleys, camshafts, lobes, valves, seals etc.) heat and blow by.

Piston stroke

The distance the axis of the crank throws from the axis of the crankshaft determines the piston stroke measurement, and thus engine displacement. A common way to increase the low-speed torque of an engine is to increase the stroke, sometimes known as "shaft-stroking." This also increases the reciprocating vibration, however, limiting the high speed capability of the engine. In compensation, it improves the low speed operation of the engine, as the longer intake stroke through smaller valve(s) results in greater turbulence and mixing of the intake charge. Most modern high speed production engines are classified as "over square" or short-stroke, wherein the stroke is less than the diameter of the cylinder bore. As such, finding the proper balance between shaft-stroking speed and length leads to better results.

Engine configuration

The configuration, meaning the number of pistons and their placement in relation to each other leads to straight, V or flat engines. The same basic engine block can sometimes be used with different crankshafts, however, to alter the firing order. For instance, the 90° engine configuration, in older days sometimes derived by using six cylinders of a V8 engine with a 3 throw crankshaft, produces an engine with an inherent pulsation in the power flow due to the "gap" between the firing pulses alternates between short and long pauses because the 90 degree engine block does not correspond to the 120 degree spacing of the crankshaft. The same engine, however, can be made to provide evenly spaced power pulses by using a crankshaft with an individual crank throw for each cylinder, spaced so that the pistons are actually phased 120° apart, as in the GM 3800 engine. While most production V8 engines use four crank throws spaced 90° apart, high-performance V8 engines often use a "flat" crankshaft with throws spaced 180° apart, essentially resulting in two straight four engines running on a common crankcase. The difference can be heard as the flat-plane crankshafts result in the engine having a smoother, higher-pitched sound than cross-plane (for example, IRL Indy Car Series compared to NASCAR Sprint Cup Series, or a Ferrari 355 compared to a Chevrolet Corvette). This type of crankshaft was also used on early types of V8 engines. See the main article on cross plane crankshafts.

Engine balance

For some engines it is necessary to provide counterweights for the reciprocating mass of each piston and connecting rod to improve engine balance. These are typically cast as part of the crankshaft but, occasionally, are bolt-on pieces. While counter weights add a considerable amount of weight to the crankshaft, it provides a smoother running engine and allows higher RPM levels to be reached.

1.8 Flying arms

In some engine configurations, the crankshaft contains direct links between adjacent crank pins, without the usual intermediate main bearing. These links are called *flying arms*. This arrangement is sometimes used in V6 and V8 engines, as it enables the engine to be designed with different V angles than what would otherwise be required to create an even firing interval, while still using fewer main bearings than would normally be required with a single piston per crank throw.

2. HOW TO DRAW CRANK SHAFT IN CATIA

Fig 2: Step 1

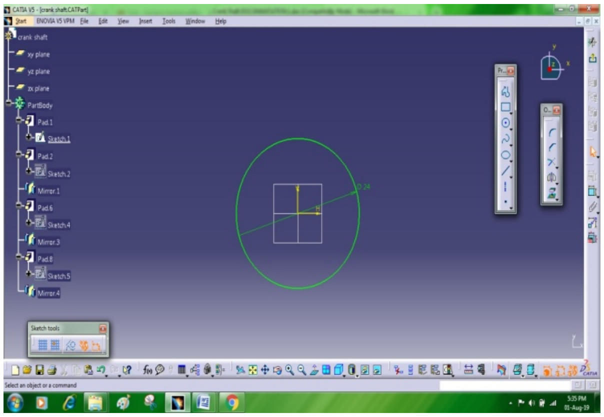

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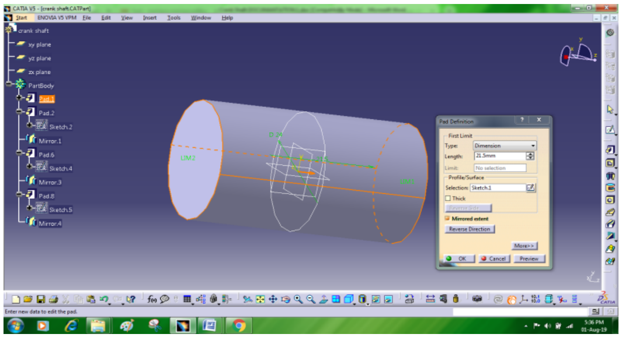
Fig 3: Step 2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More>>
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Fig 4: Step 3

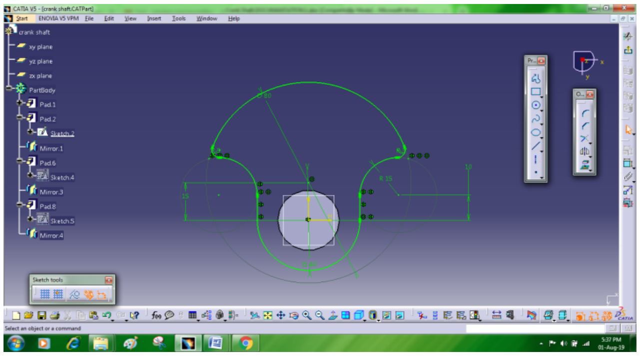
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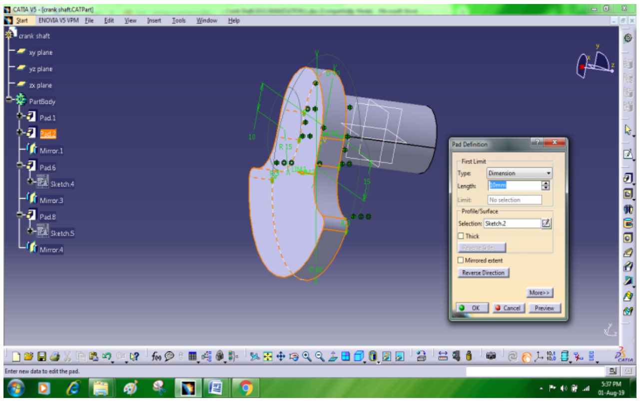
Fig 5: Step 4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☐ Mirrored extent
Reverse Direction
More>>
OK Cancel Preview

Enter new data to edit the pad.

Fig 6: Step 5

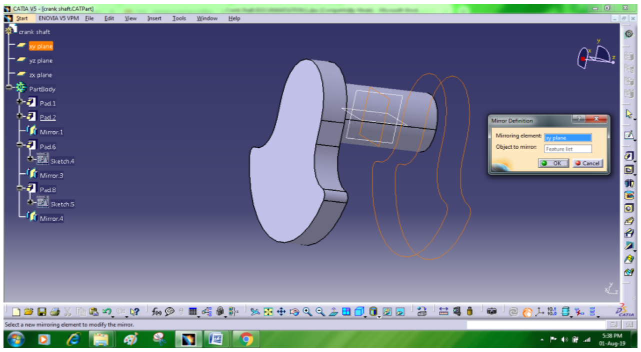
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Fig 7: Step 6

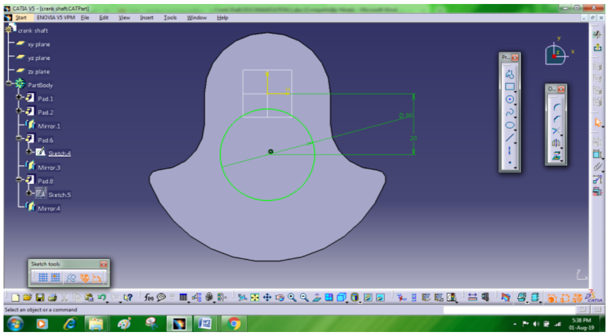
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Fig 8: Step 7

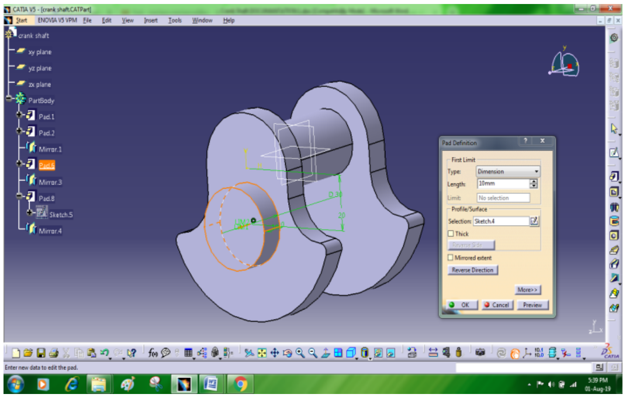

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Fig 9: Step 8

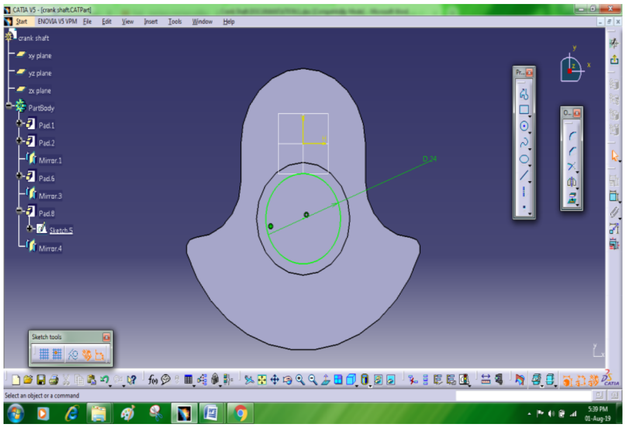

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Fig 10: Step 9

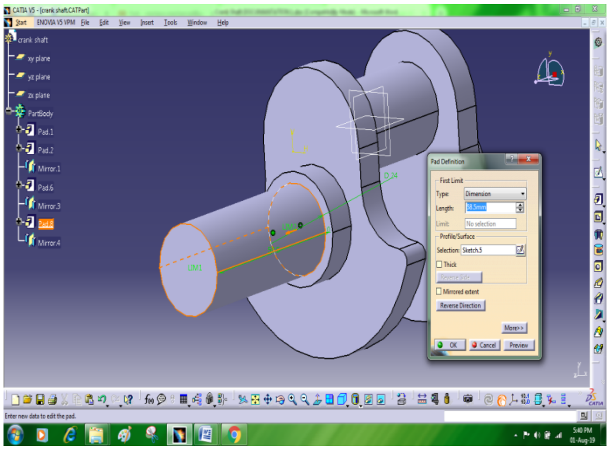

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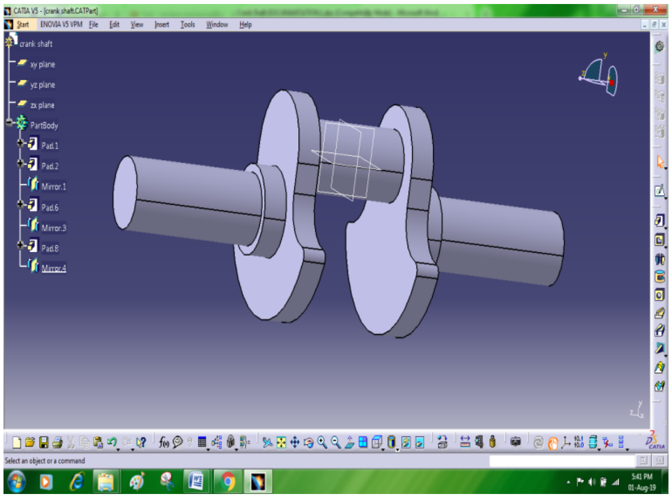
Fig 11: Final model single crank shaft



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3. INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)
- There are multiple loading conditions which may be applied to a system. Some examples are shown:
- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads
- Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:
- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements
- Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:
- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

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Types of Engineering Analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

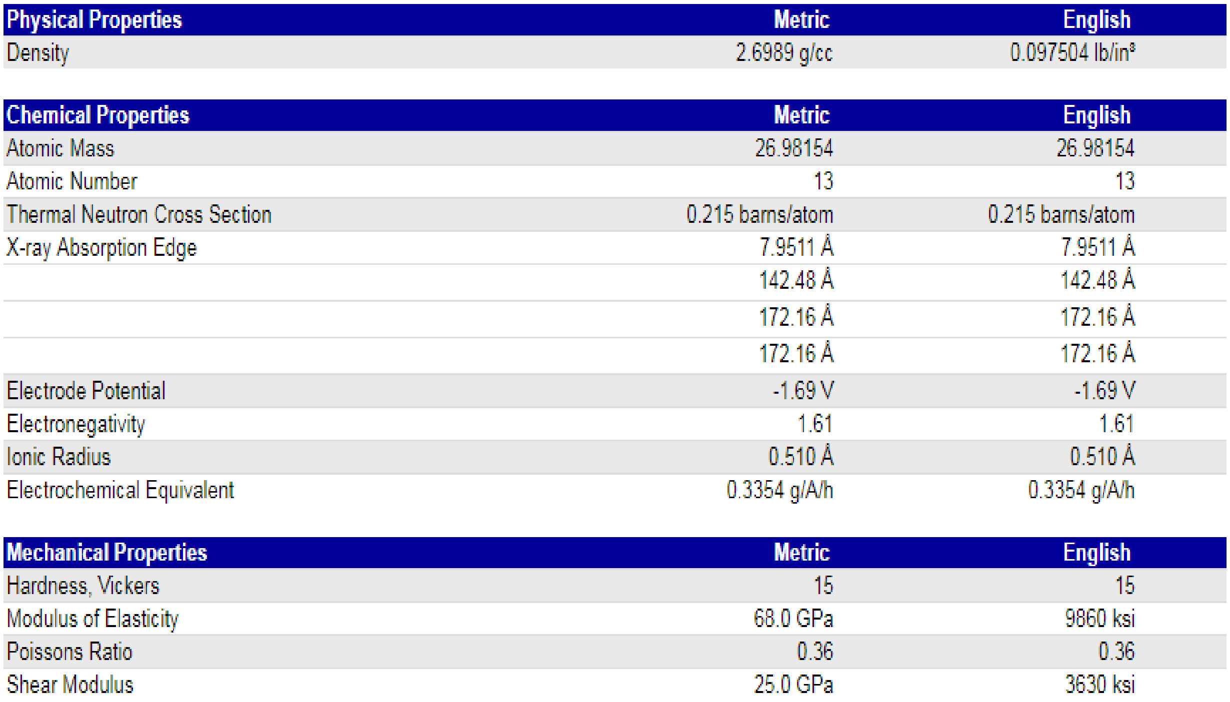
Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

4.. Material properties

Table 1:AluminumMaterial Properties

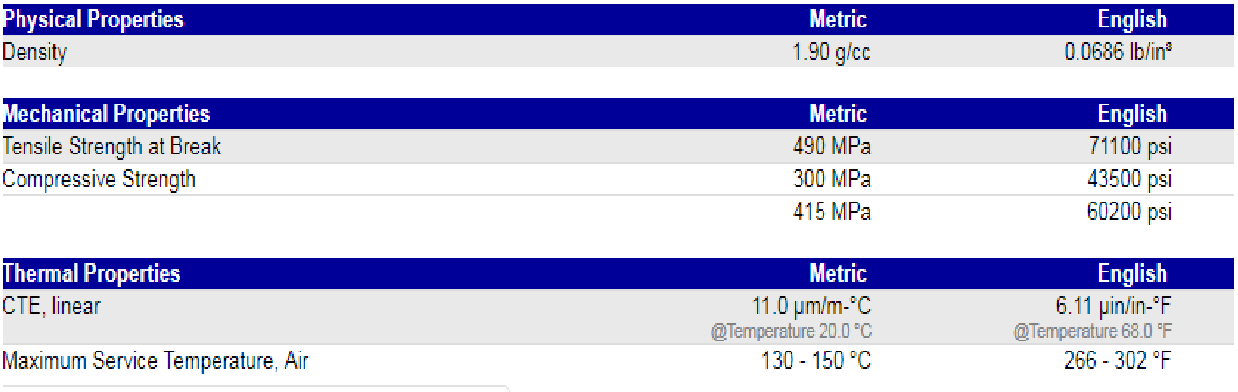


Physical Properties	Metric	English
Density	2.6989 g/cc	0.097504 lb/in³

Chemical Properties	Metric	English
Atomic Mass	26.98154	26.98154
Atomic Number	13	13
Thermal Neutron Cross Section	0.215 barns/atom	0.215 barns/atom
X-ray Absorption Edge	7.9511 Å	7.9511 Å
	142.48 Å	142.48 Å
	172.16 Å	172.16 Å
	172.16 Å	172.16 Å
Electrode Potential	-1.69 V	-1.69 V
Electronegativity	1.61	1.61
Ionic Radius	0.510 Å	0.510 Å
Electrochemical Equivalent	0.3354 g/A/h	0.3354 g/A/h

Mechanical Properties	Metric	English
Hardness, Vickers	15	15
Modulus of Elasticity	68.0 GPa	9860 ksi
Poissons Ratio	0.36	0.36
Shear Modulus	25.0 GPa	3630 ksi

Table 2:E-glass epoxy Material Properties



Physical Properties	Metric	English
Density	1.90 g/cc	0.0686 lb/in^3

Mechanical Properties	Metric	English
Tensile Strength at Break	490 MPa	71100 psi
Compressive Strength	300 MPa	43500 psi
	415 MPa	60200 psi

Thermal Properties	Metric	English
CTE, linear	11.0 µm/m-°C @Temperature 20.0 °C	6.11 µin/in-°F @Temperature 68.0 °F
Maximum Service Temperature, Air	130 - 150 °C	266 - 302 °F

5. RESULTS

ALUMINUM ALLOY

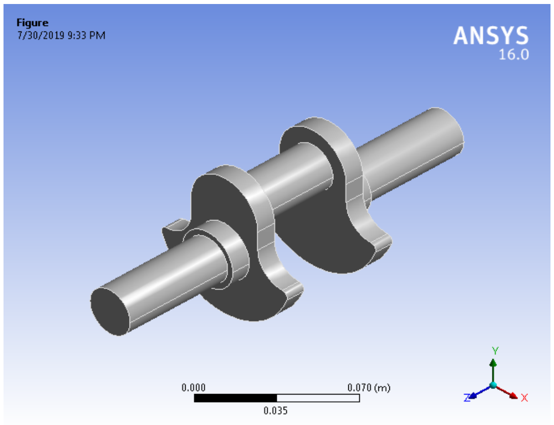


Fig 12: Model of crankshaft using Aluminum Alloy

MESH

Statistics	
Nodes	12395
Elements	6670

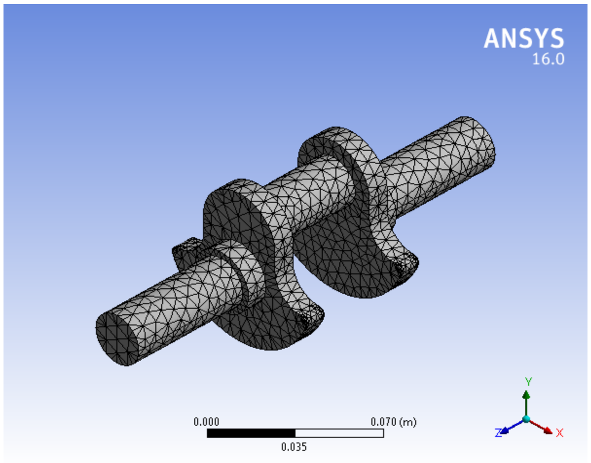


Fig 13: Meshof crankshaft using Aluminum Alloy

STATIC STRUCTURAL

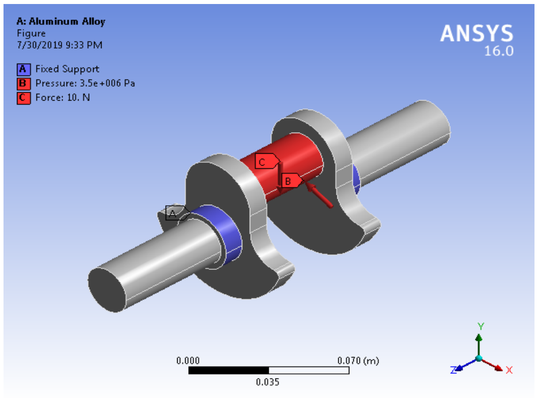


Fig 14: Structural analysis of crankshaft using Aluminum Alloy

TOTAL DEFORMATION

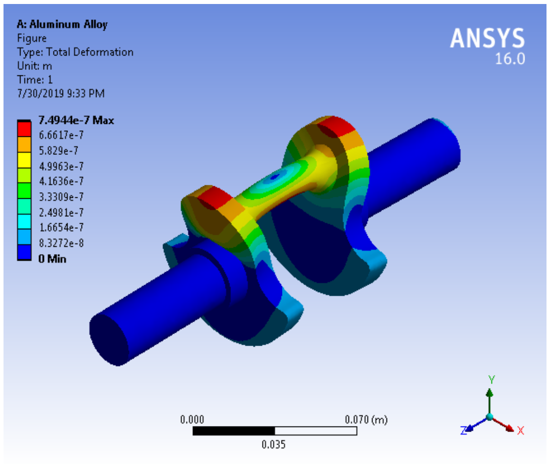


Fig 15: Deformation of crankshaft using Aluminum Alloy

EQUIVALENT ELASTIC STRAIN

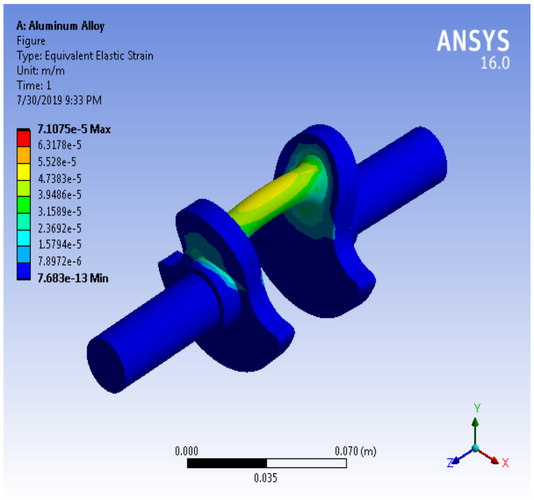


Fig 16: Equivalent Elastic Strain Analysis Of Crankshaft

EQUIVALENT STRESS

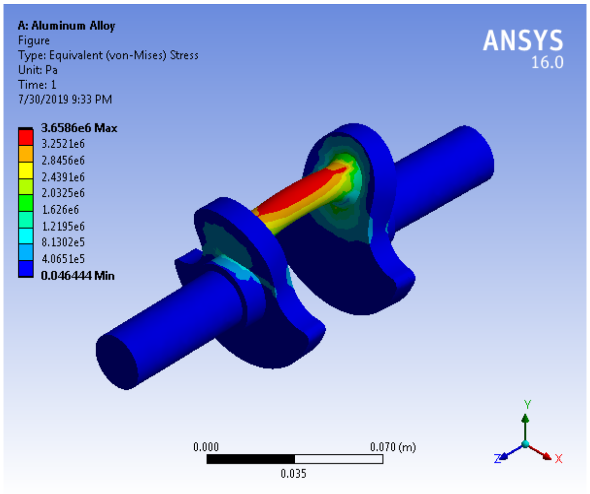


Fig 17: Equivalent Stress Analysis Of Crankshaft

EPOXY E GLASS UD

TOTAL DEFORMATION

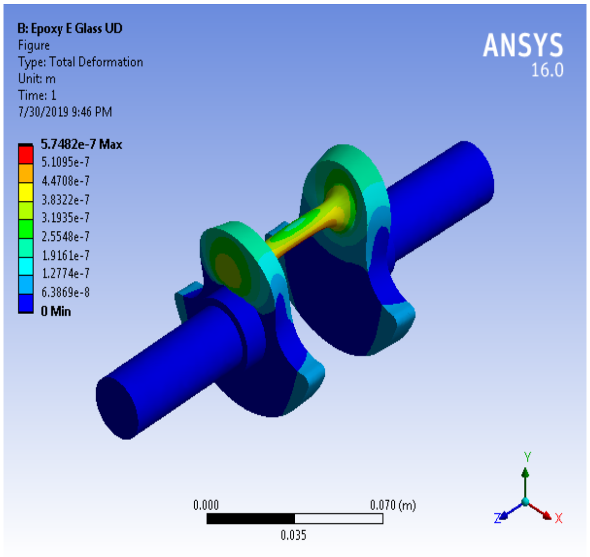


Fig 18: Deformation OfEpoxy E Glass Ud Crankshaft

EQUIVALENT ELASTIC STRAIN

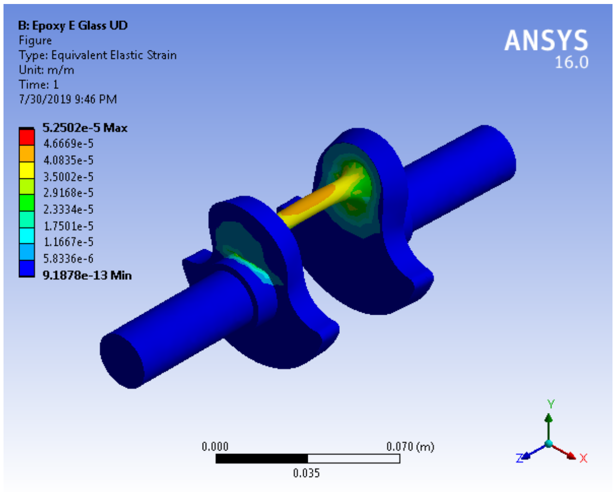


Fig 19: Equivalent Elastic Strain Analysis OfEpoxy E Glass Ud Crankshaft

EQUIVALENT STRESS

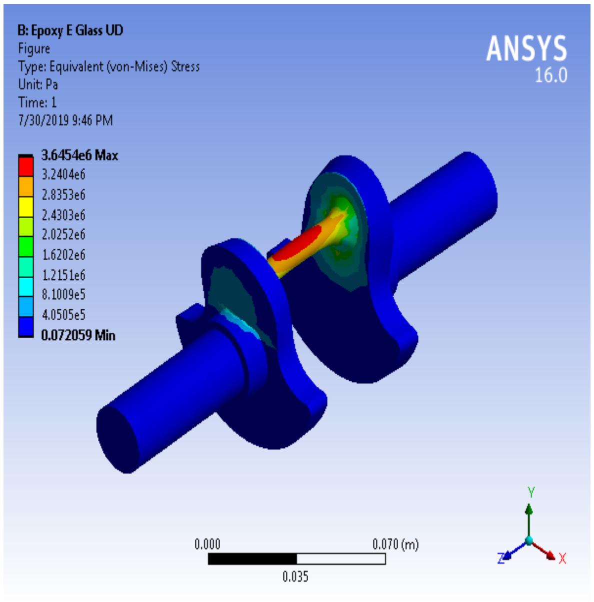
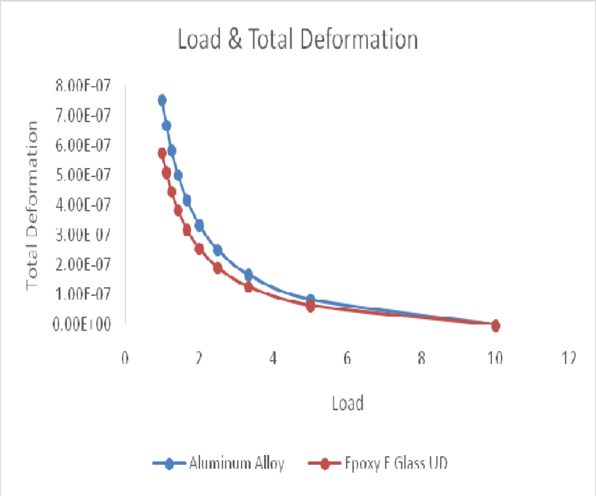


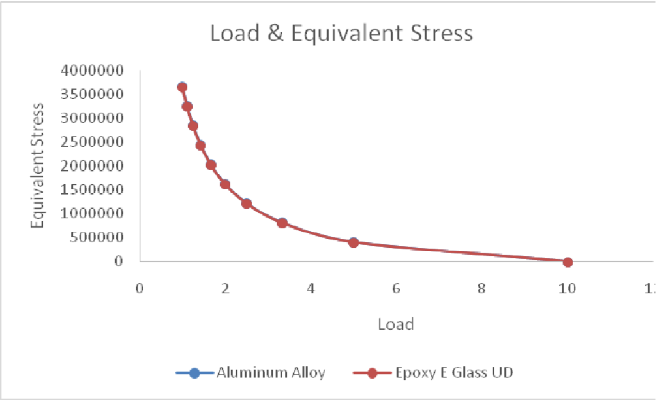
Fig 20:Equivalent Stress Analysis OfEpoxy E Glass Ud Crankshaft

GRAPHS

Graph 1: Graph of Deformation



Graph 2: Graph of Equivalent Elastic Strain

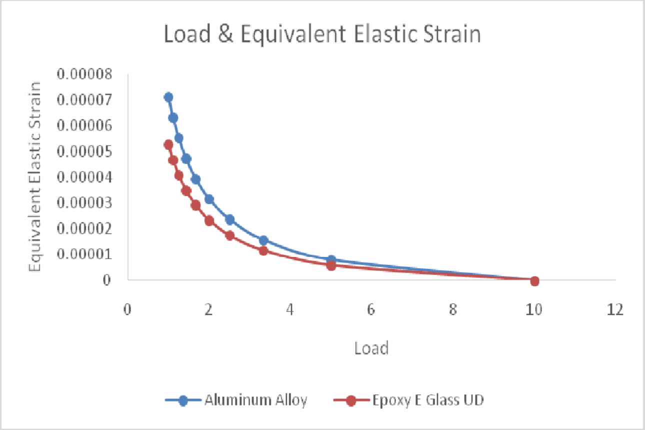


GRAPH 3:Graph of Equivalent Stress

6. CONCLUSION

Parameters	Aluminum Alloy	Epoxy E Glass
Total Deformation	7.4944E-07	5.7482E-07
Equivalent Elastic Strain	7.1075E-05	5.2502E-05
Equivalent Stress	3.6586E+06	3.6454E+06

Table 3: Comparison of Aluminum Alloy and Epoxy E Glass



The deformation is less in Epoxy E Glass when compared to that of the Aluminum Alloy, the maximum stress is induced in aluminum is more when compared to that of the aluminum alloy, the strain is more in Epoxy E Glass when compared to that of Aluminum Alloy

Hence the Epoxy E Glass is the best.

REFERENCES

[1] K. L. Napolitano, W. Grippo, J. B. Kosmatka and C. D. Johnson, “A comparison of two cocured damped composite torsion shafts”, Composite Structures, Vol. 43, 1998, pp. 115- 125.

[2] J. M. Biggerstaff and J. B. Kosmatka, “Damping Performance of Cocured Composite Laminates with Embedded Viscoelastic Layers”, Journal of Composite Materials, Vol. 32, No.21/ 1998.

[3] Jin Kook Kim, Dai Gil Lee, and Durk Hyun Cho, 2001, “Investigation of Adhesively Bonded Joints for Composite Propeller shafts”, Journal of Composite Materials, Vol.35, No.11, pp. 999-1021.

[4] T. E. Alberts and Houchun Xia, “Design and Analysis of Fiber Enhanced Viscoelastic Damping Polymers”, Journal of Vibration and Acoustics, Vol. 117, October 1995, pp. 398- 404.

[5] K. J. Buhariwala and J. S. Hansen, "Dynamics of Viscoelastic Structures", AIAA Journal, Vol. 26, February 1988, pp 220-227.

[6] J. B. Kosmatka and S. L. Liguore, “Review of Methods for Analyzing Constrained Layer Damped Structures”,

Journal of Aerospace Engineering, Vol.6, No.3, July 1993, pp. 268- 283.

[7] T. C. Ramesh and N. Ganesan, "Vibration and Damping Analysis of Cylindrical Shells with Constrained Damping Treatment- A Comparison of Three Theories", Journal of Vibration and Acoustics, Vol. 117, April 1995, pp. 213 – 219.

[8] Conor D. Johnson and David A. Kienholz, "Finite Element Prediction of Damping in Structures with Constrained Viscoelastic Layers", AIAA Journal, Vol. 20, No. 3, September 1982, pp. 1284-1290.

[9] N. T. Asnani and NaiyarAlam, " Vibration and Damping Analysis of a Multilayered Cylindrical Shell, Part I: Theoretical Analysis", AIAA Journal, Vol. 22, No. 6, June 1984, pp 803-810

[10] N. T. Asnani and NaiyarAlam, " Vibration and Damping Analysis of a Multilayered Cylindrical Shell, Part II: Numerical Results", AIAA Journal, Vol. 22, No. 7, July 1984, pp 975-981

[11] D. A. Saravanos and J. M. Pereira, "Dynamic Characteristics of Specialty Composite Structures with Embedded Damping Layers", Journal of Vibration and Acoustics, Vol. 117, January 1995, pp. 62-69.

[12] C .D. Johnson, "Design of Passive Damping Systems", Transactions of the ASME, Vol. 117, June 1995, pp. 171-176.

[13] H. V. Panossian, "Structural Damping Enhancement Via Non- Obstructive Particle Damping Technique", Journal of Vibration and Acoustics, Vol.114, January 1992, pp.101-105.

[14] M. A. Trindade, A. Benjeddou and R. Ohayon, " Modeling of Frequency- Dependent Viscoelastic Materials for Active- Passive Vibration Damping", Journal of Vibration and Acoustics, Vol.122, April 2000, pp.169-174.

[15] John F. Baldwin and Stanley G. Hutton, " Natural Modes of Modified Structures", AIAA Journal, Vol. 23, No. 11, November 1985, pp.1737-1743.

[16] M. L. Soni and F. K. Bogner, "Finite Element Vibration Analysis of Damped Structures", AIAA Journal, Vol. 20, No. 5, May 1982, pp. 700-707.

[17] Y. P. Lu, B. E. Douglas and E. V. Thomas, "Mechanical Impedance of Damped Three- Layered Sandwich Rings", AIAA Journal, Vol. 11, No. 5, March 1973, pp. 300-304.

[18] E. R. Marsh and L. C. Hale, "Damping of Flexural Waves with Imbedded Viscoelastic materials", Journal of Vibration and Acoustics, Vol.120, January 1998, pp. 188-198.

[19] I. C. Finegan and R. F. Gibson, "Improvement of Damping at the Micro mechanical Level in Polymer Composite Materials under Transverse Normal Loading by the Use of Special Fiber Coatings", Journal of Vibration and Acoustics, Vol.120, April 1998, pp. 623-627.

[20] Mohan D. Rao and Shaulin He, "Dynamic Analysis and Design of Laminated Composite Beams with Multiple Damping Layers", AIAA Journal, Vol. 31, No. 4, April 1993, pp. 736- 745.