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Analysis of Multi- layered Al-Cu Composite Material for Crankshaft by using ANSYS

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Abstract

Crankshaft is an extensive segment with a perplexing (complex) geometry in the engine, which changes over the reciprocating displacement of the piston into a rotating movement with a four-link mechanism. Since the crankshaft encounters countless cycles amid its service life, fatigue performance and toughness of this part must be considered in the design procedure. Design improvements have dependably been an imperative issue in the crankshaft creation industry, so as to fabricate a more affordable component with the base weight conceivable and appropriate fatigue strength and other useful prerequisites. These enhancements result in lighter and smaller engine with better fuel efficiency and higher power output.

The static analysis is done utilizing FEA Software ANSYS which brought about the heap range connected to crank pin bearing. This load is applying to the FE model in ANSYS, and boundary conditions are applying by the engine mounting conditions. Finite Element Analysis (FEA) is to be performing to obtain the variation of stress magnitude at critical locations. The static, random vibration analysis is done and is verifying by simulations in finite element analysis software ANSYS.

In this paper a static simulation is led on a crankshaft from a single cylinder 4-stroke diesel engine. A three-dimensional model of diesel engine crankshaft is made utilizing CREO Parametric software. Static analysis to determine the deformation, stress and strain at al-cu reinforced material. Present steel material used for crank shaft replace with the al-cu reinforced material.

Multi-layer analysis to determine the deformation, stress and strain to comparing the existing material, Random vibration analysis to determine the directional deformation.

Keywords: crank shaft; design; analysis; static; fatigue; random vibration; composite

1. Introduction to Crankshaft

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston 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.

2. Literature Review

Much research work has been done in the field of vibration analysis of crank shaft. The literature review of some papers gives more information about their contribution in design and vibration analysis of crank shaft Shin-Yong Chen, et al [1] in their research paper “Dynamic Analysis Of a Rotating Composite Shaft” One of the key factors in designing a motor built-in high speed spindle is to assemble the motor rotor and shaft by means of hot-fit. Presented in this paper is a study of the influence of a hot-fit rotor on the local stiffness of the hollow shaft. Dynamic analyses of the rotorhollow shaft assembly using contact elements are conducted.

Azoury et al [2] presented a report on the experimental and analytical modal analysis of a crankshaft. The effective material and geometrical properties are measured, and the dynamic behavior is investigated through impact testing.

R. J. Deshbhratar, et al [3] analyzed 4- cylinder crankshaft and model of the crankshaft were created by using Pro/E Software and then imported to ANSYS software. The maximum deformation appears at the centre of crankshaft surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks, and near the central point.

Abhishek choubey, and et al [4] have analyzed crankshaft model and 3-dimentional model of the crankshaft were created by SOLID WORKS Software and imported to ANSYS software.

Rinkle garg et al. [5] analyzed crankshaft model and crank throw were created by using Pro/E Software and then imported to ANSYS software. The result shows that the improvement in the strength of the crankshaft as the maximum limits of stress, total deformation, and the strain is reduced. The weight of the crankshaft is reduced

Sanjay B Chikalthankar et al [6] investigated stresses developed in crankshaft under dynamic loading. In this study a dynamic simulation was conducted on crankshaft, Finite element analysis was performed to obtain the variation of stress magnitude at critical locations.

Sagar R Dharmadhikari, et al [7] made modest attempt to review the optimization of Genetic Algorithm and ANSYS in their research report “Design and Analysis of Composite Drive Shaft using ANSYS and Genetic Algorithm”. Drive shaft is the main component of drive system of an automobile.

K.Thriveni et al [8] made an attempt this paper to study the Static analysis on a crankshaft from a single cylinder 4-stroke I.C Engine. The model of the crankshaft is created using CATIA-V5 Software. Finite element analysis (FEA) is performed to obtain the variation of stress at critical locations of the crank shaft using the ANSYS software and applying the boundary conditions.

Ashwani Kumar Singh et al [9] conducted statics analysis on a nickel chrome steel and structural steel crank shafts from a single cylinder four stroke engine. Finite elements analysis was performed to obtain the variation of stress magnitude at critical locations. Three dimensional model of crankshaft was created in Pro/E software

Abhishek Sharma et al [10] in the present research work vibration analyses have been focused to detect crankshaft fault at the early stage, followed by the literature review of the shaft and the experimental methodologies. A simulation for the study of crankshaft is carried out by acquiring its fault signal and its fast Fourier transform is plotted to show the characteristics frequencies and its harmonics.

Neepa M. Patel 1, G.M. Karkar conducted kinematic and dynamic analysis to design high speed Beat-up mechanism shuttle loom, which is third primary operation of shuttle loom. Basically beat-up mechanism is the reciprocating motion of the reed which is used to push every weft thread to the fabric fell, because the only drawback of shuttle loom is its low speed, current shuttle looms are running at 120 ppm(pick per minute), and due to this its productivity is less The table below gives the information about the methodology and parameters used by various researchers

Literature Gap

Review of literature [1-12] suggested that many authors have reported determination of stress, deflection and modal frequencies of the crank shaft for different boundary conditions and some researchers have worked on the calculation of critical points in the crank shaft, still there exists to redesign and modify the geometry of the crank shaft to optimize the weight of the crank shaft and check the physical properties under given condition for safer work.

2.1 Construction

Crankshafts can be monolithic (made in a single piece) or assembled from several pieces. Monolithic crankshafts are most common, but some smaller and larger engines use assembled crankshafts.

2.2 Forging And Casting

Crankshafts can be forged from a steel bar usually through roll forging or cast in ductile steel. Today more and more manufacturers tend to favor the use of forged crankshafts due to their lighter weight, more compact dimensions and better inherent dampening. With forged crankshafts, vanadium microalloyed steels are mostly used as these steels can be air cooled after reaching high strengths without additional heat treatment, with exception to the surface hardening of the bearing surfaces. The low alloy content also makes the material cheaper than high alloy steels. Carbon steels are also used, but these require additional heat treatment to reach the desired properties. Iron crankshafts are today mostly found in cheaper production engines (such as those found in the Ford Focus diesel engines) where the loads are lower. Some engines also use cast iron crankshafts for low output versions while the more expensive high output version use forged steel.

2.3 Stress on crankshafts

The shaft is subjected to various forces but generally needs to be analyzed in two positions. Firstly, failure may occur at the position of maximum bending; this may be at the center of the crank or at either end. In such a condition the failure is due to bending and the pressure in the cylinder is maximal. Second, the crank may fail due to twisting, so the conrod needs to be checked for shear at the position of maximal twisting. The pressure at this position is the maximal pressure, but only a fraction of maximal pressure.

A crankshaft contains two or more centrally-located coaxial cylindrical ("main") journals and one or more offset cylindrical crankpin ("rod") journals. The two-plane V8 crankshaft pictured in **Figure 1** has five main journals and four rod journals, each spaced 90° from its neighbors.

Figure 2.1: Example (2-plane) Crankshaft

The crankshaft main journals rotate in a set of supporting bearings ("main bearings"), causing the offset rod journals to rotate in a circular path around the main journal centers, the diameter of which is twice the offset of the rod journals. The diameter of that path is the engine "stroke": the distance the piston moves up and down in its cylinder. The big ends of the connecting rods ("conrods") contain bearings ("rod bearings") which ride on the offset rod journals.

2.4 Forces Imposed on A Crankshaft

The obvious source of forces applied to a crankshaft is the product of combustion chamber pressure acting on the top of the piston. High-performance, normally-aspirated Spark-ignition (SI) engines can have combustion pressures in the 100-bar neighborhood (1450 psi), while contemporary high-performance Compression-Ignition (CI) engines can see combustion pressures in excess of 200 bar (2900 psi). A pressure of 100 bar acting on a 4.00-inch diameter piston will produce a force of 18,221 pounds. A pressure of 200 bar acting on a 4.00-inch diameter piston produces a force of 36,442 pounds. That level of force exerted onto a crankshaft rod journal produces substantial bending and torsional moments and the resulting tensile, compressive and shear stresses.

However, there is another major source of forces imposed on a crankshaft, namely Piston Acceleration. The combined weight of the piston, ring package, wristpin, retainers, the conrod small end and a small amount of oil are being continuously accelerated from rest to very high velocity and back to rest twice each crankshaft revolution. Since the force it takes to accelerate an object is proportional to the weight of the object times the acceleration (as long as the mass of the object is constant), many of the significant forces exerted on those reciprocating components, as well as on the conrod beam and big-end, crankshaft, crankshaft, bearings, and engine block are directly related to piston acceleration.

2.5 Crankshaft Materials

The steel alloys typically used in high strength crankshafts have been selected for what each designer perceives as the most desirable combination of properties. shows below table the nominal chemistries of the crankshaft alloys discussed here.

Medium-carbon steel alloys are composed of predominantly the element iron, and contain a small percentage of carbon (0.25% to 0.45%, described as ‘25 to 45 points’ of carbon), along with combinations of several alloying elements, the mix of which has been carefully designed in order to produce specific qualities in the target alloy, including hardenability, nitridability, surface and core hardness, ultimate tensile strength, yield strength, endurance limit (fatigue strength), ductility, impact resistance, corrosion resistance, and temper-embrittlement resistance. The alloying elements typically used in these carbon steels are manganese, chromium, molybdenum, nickel, silicon, cobalt, vanadium, and sometimes aluminum and titanium. Each of those elements adds specific properties in a given material. The carbon content is the main determinant of the ultimate strength and hardness to which such an alloy can be heat treated.

Chemistry of Crankshaft Alloys
Nominal Percentages of Alloying Elements

Material	AMS	C	Mn	Cr	Ni	Mo	Si	V
4340	6414	0.40	0.75	0.82	1.85	0.25		
EN-30B		0.30	0.55	1.20	4.15	0.30	0.22	
4330-M	6427	0.30	0.85	0.90	1.80	0.45	0.30	0.07
32-CrMoV-13	6481	0.34	0.55	3.00	<0.30	0.90	0.25	0.28
300-M	6419	0.43	0.75	0.82	1.85	0.40	1.70	0.07
Key:	C = Carbon		Mn = Manganese			Cr = Chromium		
	Ni = Nickel		Mo = Molybdenum			Si = Silicon		
	V = Vanadium			AMS = Aircraft Material Spec Number				

3. Materials And Methods

Mechanical properties for forging alloys, like physical properties, are listed in standard reference sources. In some cases, they are not affected by subsequent manufacturing operations, and can be used with reasonable confidence to predict real world performance. In other cases, mechanical properties are altered by subsequent processes, in varying amounts and with varying degrees of predictability in the end product. Variations are caused by factors such as:

- Forging temperature
- Forging reduction (deformation) which, in turn, affects grain size
- Heat treatment.

In some cases, an experienced forging engineer can predict properties, such as yield strength, in critical areas of the forging with reasonable accuracy. Predictability is enhanced by two characteristics of forgings.

1. Forgings are fully dense and not subjected to discontinuities, such as porosity in castings.

2. Forging alloys are homogeneous, and not subject to variations in composition, such as orientation of reinforcing fibers in composites.

Forging steel is a metal-working process which involves the use of hammering or pressing techniques to alter the steel’s shape, followed by heat treatment. This method produces in the steel a number of properties which distinguish it from other treatments of this metal, for example casting, where liquid metal is poured into a mold and then left to solidify.

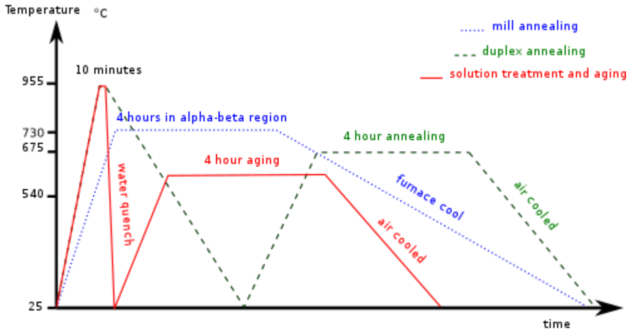
Ti-6Al-4V

Ti-6Al-4V (UNS designation **R56400**), also sometimes called **TC4**, **Ti64**, or ASTM **Grade 5**, is an alpha-beta titanium alloy with a high strength-to-weight ratio and excellent corrosion resistance. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and excellent corrosion resistance are necessary such as e.g. aerospace industry and biomechanical applications (implants and prostheses).

Studies of titanium alloys used in armors began in the 1950s at the Watertown Arsenal, which later became a part of the Army Research Laboratory.

Increased use of titanium alloys as biomaterials is occurring due to their lower modulus, superior biocompatibility and enhanced corrosion resistance when compared to more conventional stainless steels and cobalt-based alloys. These attractive properties were a driving force for the early introduction of a (cpTi) and a#b (Ti—6Al—4V) alloys as well as for the more recent development of new Ti-alloy compositions and orthopedic metastable b titanium alloys. The later possess enhanced biocompatibility, reduced elastic modulus, and superior strain-controlled and notch fatigue resistance. However, the poor shear strength and wear resistance of titanium alloys have nevertheless limited their biomedical use. Although the wear resistance of b-Ti alloys has shown some improvement when compared to a#b alloys, the ultimate utility of orthopedic titanium alloys as wear components will require a more complete fundamental understanding of the wear mechanisms involved.

Heat Treatment of Ti-6Al-4V



Mill anneal, duplex anneal, and solution treatment and aging heat treatment processes for Ti-6Al-4V. Exact times and temperatures will vary by manufacturer.

Ti-6Al-4V is heat treated to vary the amounts of and microstructure of and phases in the alloy. The microstructure will vary significantly depending on the exact heat treatment and method of processing. Three common heat treatment processes are mill annealing, duplex annealing, and solution treating and aging

Applications

- Implants and prostheses (wrought, cast or by Solid Freeform Fabrication (SFF))
- Additive Manufacturing
- Parts and prototypes for racing and aerospace industry. Used extensively within the Boeing 787 aircraft.
- Marine applications
- Chemical industry
- Gas turbines

Specifications

- UNS: R56400
- AMS Standard: 4911
- ASTM Standard: F1472
- ASTM Standard: B265 Grade 5

AL-CU Reinforcement Composite Material

Al–Cu composite metallic materials are produced by dispersing copper particulates in an aluminium matrix using stir casting technique. In order to know the effect of reinforcement content, composites with varying weight fractions were fabricated. For comparison purpose, Al–Cu alloy is also fabricated and investigated. Increased densities have been observed with increasing particulate contents. Homogenization treatment has improved the hardness to a larger extent for both alloy and composites, particularly for rich composites.

Material properties

Material	Density (kg/m3)	Youngs modulus (MPa)	Poisson's ratio
Forged steel	7833	2.21E11 Pa	0.3
Ti-6Al4V+12%TiC	4430	1.14E14 Pa	0.342
Al-cu reinforced composite	**4700**	**1.05e14Pa**	**0.312**

4 Introduction TO CAD

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

Introduction to Catia

CATIA is an abbreviation for Computer Aided Three-dimensional Interactive Application. It is one of the main 3D programming utilized by associations in various enterprises going from aviation, vehicle to purchaser items.

CATIA is a multi-stage 3D programming suite created by Dassault Systems, incorporating CAD, CAM just as CAE. Dassault is a French designing monster dynamic in the field of flight, 3D plan, 3D computerized models, and item lifecycle the board (PLM) programming. CATIA is a strong displaying instrument that joins the 3D parametric highlights with 2D devices and furthermore addresses each plan to-assembling measure. Design procedure

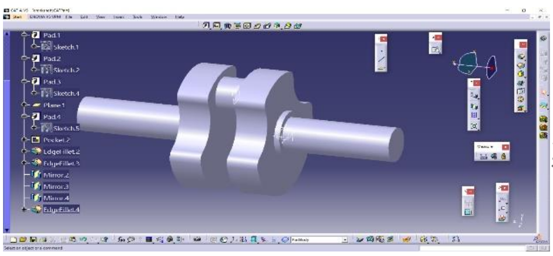


Fig 4.1 crank shaft 3d design

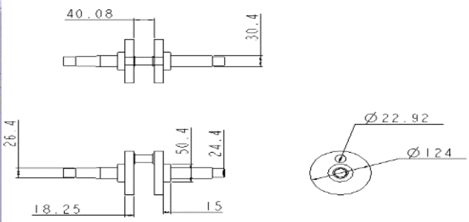


Fig 4.2 crank shaft 2d design

5. Finite Element Method

Limited Element Method (FEM) is additionally called as Finite Element Analysis (FEA). Limited Element Method is a major assessment strategy for settling and subbing complex inconveniences by utilizing simpler 1s, gaining inexact arrangements Finite component approach being an adaptable gadget is utilized in different enterprises to determine various down to earth designing issues. In limited component approach it is practical to create the relative results.

In the current day, limited detail strategy is 1 of the handiest and generally utilized instruments. By doing extra computational assessment the rough arrangement can be progressed or unpretentious in Finite component approach. In Finite detail approach, frameworks assume a significant part in managing enormous assortment of conditions. The methodology for FEM is a Variation strategy wherein this idea has contributed widely in defining the technique.

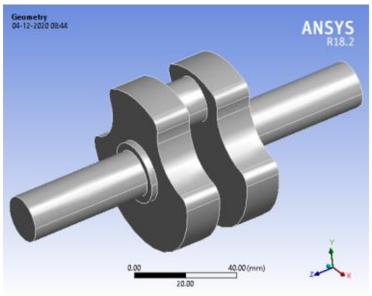


Fig 5.1 imported model in static analysis

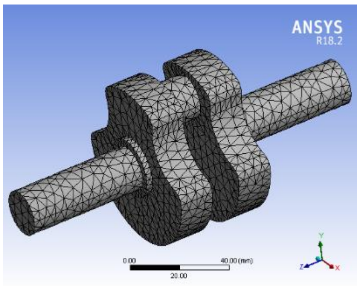


Fig 5.2 meshed model in static analysis

Static Analysis Of Crank Shaft

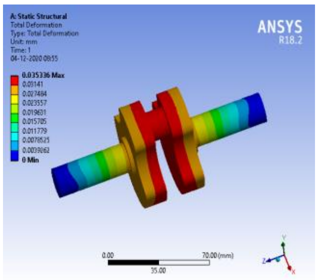


Fig 5.3 deformation at forged steel

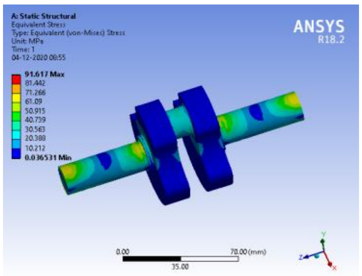


Fig 5.4 stress at forged steel

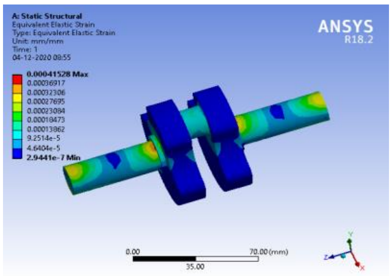


Fig 5.5 strain at forged steel

material- ti-6al4v+12%tic

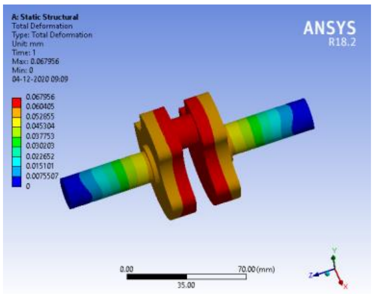


Fig 5.6 deformation at Ti-6Al4V+12%TiC

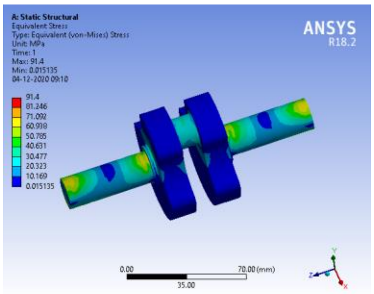


Fig 5.7 stress at Ti-6Al4V+12%TiC

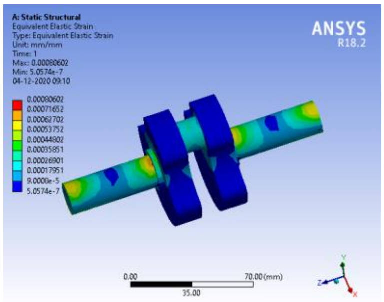


Fig 5.8 strain at Ti-6Al4V+12%TiC

Material- Al-Cu Reinforced Composite

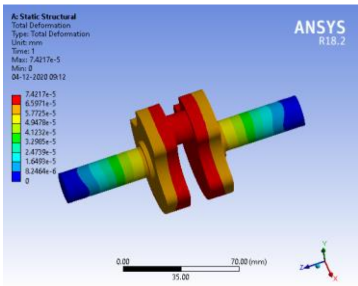


Fig 5.9 deformation at

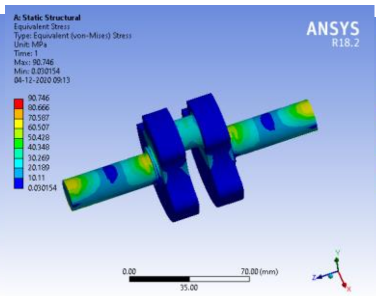


Fig 5.10 stress

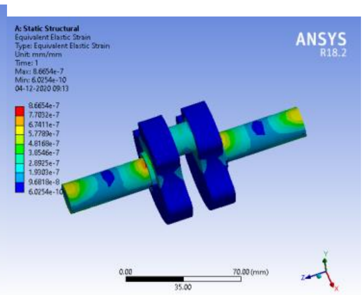


Fig 5.11 strain

Al-Cu Reinforced Composite

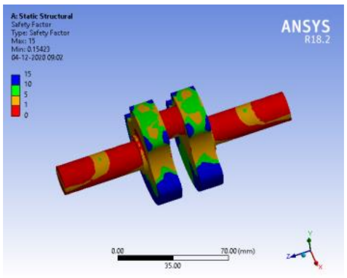


Fig 5.14 safety factor at forged steel

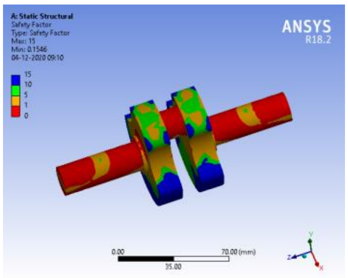


Fig 5.17 safety factor at Ti-6Al4V+12%TiC

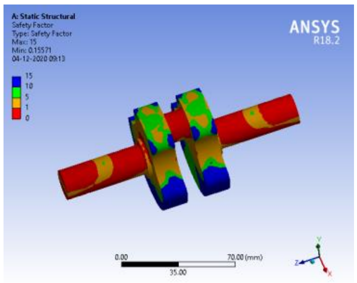
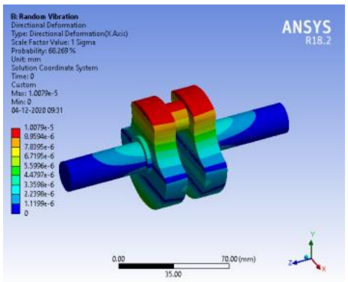
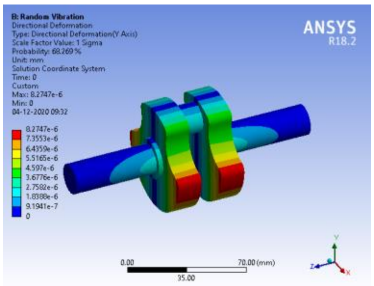


Fig 5.20 safety factor at AL-CU

Material- Al-Cu Reinforced Composite





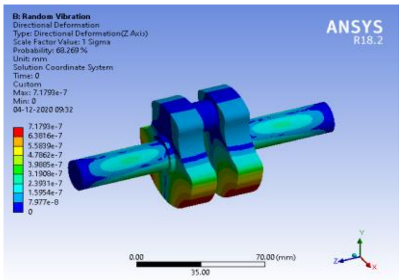
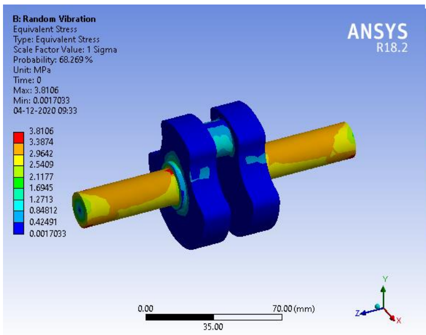


Fig 5.31 x- directional deformation at AL-CU REINFORCED COMPOSITE

Fig 5.32 Y- directional deformation at AL-CU REINFORCED COMPOSITE

Fig 5.33 Z- directional deformation at AL-CU REINFORCED COMPOSITE



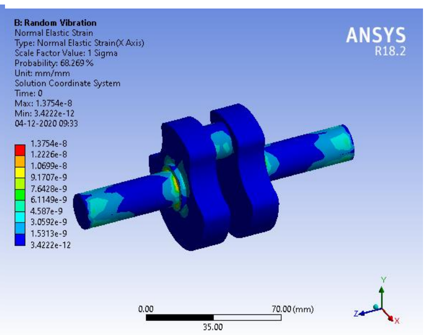


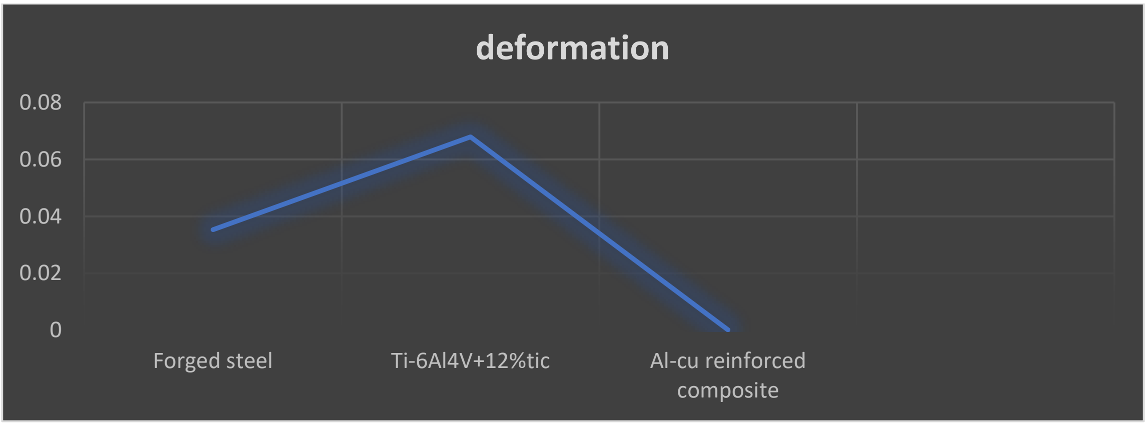
Fig 5.34 stress at AL-CU REINFORCED COMPOSITE

Fig 5.35 strain at AL-CU REINFORCED COMPOSITE

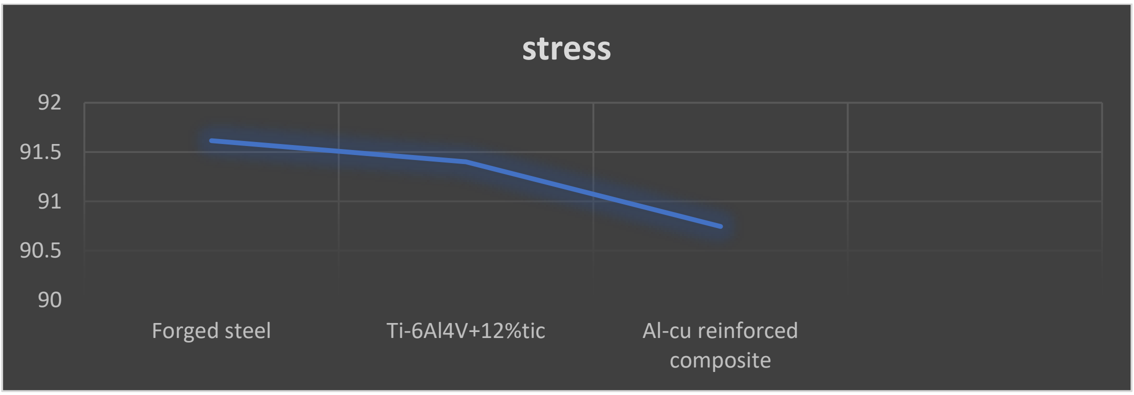
Table: 5.1 Static and fatigue analysis results

Material	Deformation(mm)	Stress (MPa)	Strain	Safety factor
Forged steel	0.035336	91.617	0.00041528	0.15423
Ti-6Al4V+12%tic	0.067956	91.4	0.00080602	0.1546
Al-cu reinforced composite	0.0000742	90.746	8.6654e-7	0.15571

Deformation plot



Stress plot



Strain plot

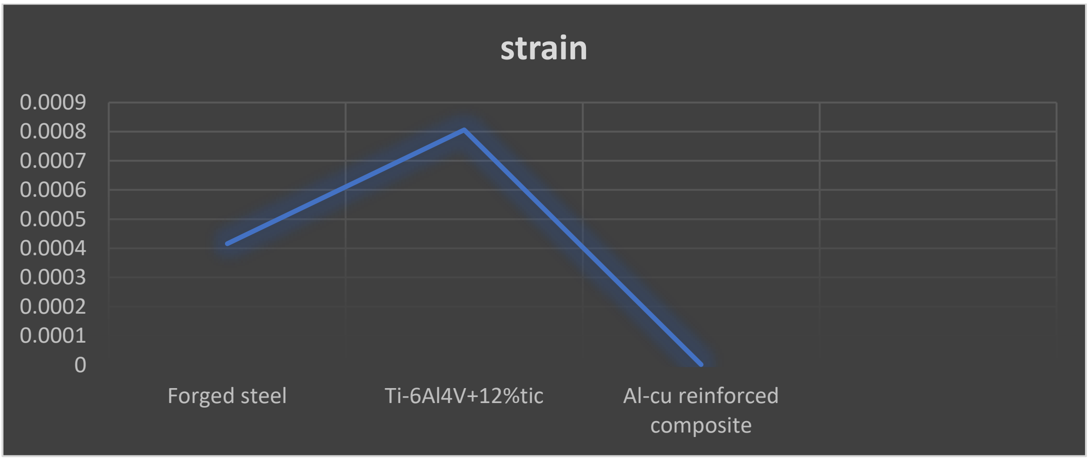


Table 5.2 Random vibration analysis results

material	deformation (mm)		stress (MPa)	strain
	direction	deformation(mm)		
forged steel	x-axis	0.062999	66.881	0.0001166
	y-axis	0.038595		
	z-axis	0.014659		
ti-	x-axis	8.4701e-6	8.3393	3.3963e-8

6al4v+12%tic	y-axis	7.6945e-6		
	z-axis	3.667e-6		
AL-CU reinforced composite	x-axis	1.0079e-5	3.8106	1.3754e-8
	y-axis	8.2747e-6		
	z-axis	7.1793e-7		

5 Conclusion

Analysis of forged steel , Ti-6Al-4V+12% Tic and Al-Cu reinforced materials under pin loading and bearing load condition have been carried out and the results were tabulated in above tables. The analysis of forged steel ,Ti-6Al-4V+12% TiC and Al-Cu reinforced properties were compared. The analysis of crank shaft was found that the Al-Cu reinforced material have a good physical property and it has an appreciable deformation under the moment than forged material steel and Ti-6Al-4V+12% TiC. The stress, strain and deformation of the Al-Cu reinforced is also low as compared to the forged steel material and Ti-6Al-4V+12% TiC. Crank shaft is usually made of forged steel, but the performance of the crankshaft is less than what is projected. So Al-Cu reinforced came into consideration for crankshaft as it has many advantages over the forged steels.

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