MODELLING AND ANALYSIS OF CRANKSHAFT FOR FOUR STROKE DIESEL ENGINE BY USING COMPOSITE MATERIALS

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY IN

MECHANICAL ENGINEERING

Submitted By

ANNAMREDDI VENKATA VINAY	317126520180
MADATHINGALA UDAY SHANKAR	317126520207
LANKA PRANEETH SATYA	317126520205
YEDLA SUNIL KUMAR	318126520L51
MATTHALA SRIKANTH	318126520L42

Under the esteemed

guidance of

Dr. K SATYANARAYANA M.TECH, Ph.D.

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

Autonomous status accorded by UGC and Andhra University (Approved by AICTE, Permanently Affiliated to Andhra University, Accredited and reaccredited by NBA , Accredited by NAAC-'A' Grade) Sangivalasa, Bheemunuipatnam Mandal, Visakhapatnam(District)-531162

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ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A)

(Affiliated to Andhra University, Approved by AICTE, Accredited by NBA & NAAC with A grade)

SANGIVALASA, VISAKHAPATNAM (District) – 531162

PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the Project Report entitled **"MODELLING AND ANALYSIS OF CRANKSHAFT FOR FOUR STROKE DIESEL ENGINE BY USING COMPOSITE MATERIALS"** being submitted by ANNAMREDDI VENKATA VINAY (317126520180), MADATHINGALA UDAY SHANKAR (317126520207), LANKA PRANEETH SATYA (317126520205), YEDLA SUNIL KUMAR (318126520L51), MATTHALA SRIKANTH (318126520L42) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.K SATYANARAYANA**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

	Approved By
PROJECT GUIDE	**HEAD OF THE DEPARTMENT**
(DR.K SATYANARAYANA)	**(Dr. B. Naga Raju)**
Assistant Professor	**Head of the Department**
Mechanical Engineering Department	**Mechanical Engineering Department**
ANITS, Visakhapatnam.	**ANITS, Visakhapatnam.**

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162 VISAKHAPATNAM Dist A.P

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ANNAMREDDI VENKATA VINAY	317126520180
MADATHINGALA UDAY SHANKAR	317126520207
LANKA PRANEETH SATYA	317126520205
YEDLA SUNIL KUMAR	318126520L51
MATTHALA SRIKANTH	318126520L42

ABSTRACT

The static simulation is conducted on a crankshaft from a single cylinder 4- stroke diesel engine. A three-dimension model of diesel engine crankshaft is created using CATIA V5 software. Static structural analysis is performed to obtain the stress magnitude at critical locations of crankshaft in. The static analysis is done using Software ANSYS 2021R1 which resulted in the stresses, deformation and elastic strain. This boundary conditions are applied at bearings**.**

Crankshafts find many applications in various branches of engineering. They are used whenever there is the need to translate reciprocating linear motion into rotation or vice-versa. In their more varied configurations, crankshafts are usually used in internal combustion engines but also in piston steam engines. It lays on the former the vaster and varied range of applications of crankshafts. The internal combustion engines cover various fields of uses, from small scale model planes to large maritime engines.

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CHAPTER-1

INTRODUCTION

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. In a reciprocating engine, it translates reciprocating motion of the piston into rotational motion; whereas in reciprocating, 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 torsion or vibration damper at the opposite end, to reduce the tensional vibrations often caused along the length of the crankshaft by the cylinder's farthest from the output end acting on the tensional elasticity of the metal.

Crankshafts find many applications in various branches of engineering. They are used whenever there is the need to translate reciprocating linear motion into rotation or vice-versa. In their more varied configurations, crankshafts are usually used in internal combustion engines but also in piston steam engines. It lays on the former the vaster and varied range of applications of crankshafts. The internal combustion engines cover various fields of uses, from small scale model planes to large maritime engines. So, crankshafts produced by the various methods apply to: e.g., engines for road, rail and maritime transport, portable machinery, electrical generators, agricultural and industrial machinery. Crankshafts are also used in driven machinery such as air compressors and reciprocating pumps. The industrial potential for a new crankshaft manufacturing process is huge, as the existing and common methods, forging; casting and machining are very costly. The former two

Fig 1.1 Crank shaft of four stroke single cylinder diesel engine

Fig 1.2 Crank shaft

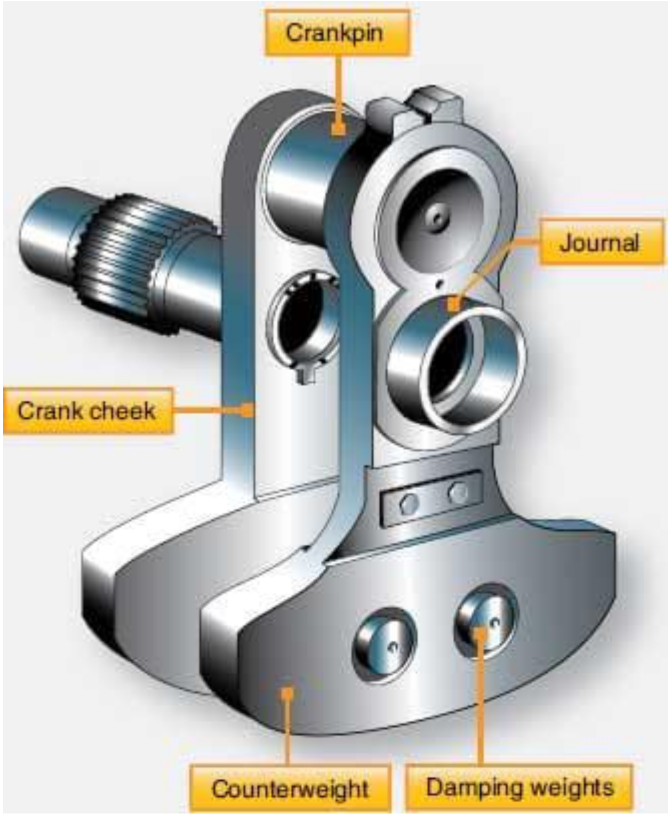


Fig 1.3 Nomenclature of Crank shaft

demand high volume production to be cost effective, as the investment in tools and machinery is huge.

1.1 Functions

Translatory motion of the pistons which is changed into rotational motion. In the combustion of the fuel-air mixture, power is produced. This power is transformed into rotary movement of the crankshaft. The linear motion of the pistons is converted via the connecting rod into torque. It's then passed to the flywheel.

The crankshaft's shaft is bored with some holes that feeds the motor with oil. This oil smoothens the movement. The counterweights aid the adjustment of the framework and the heaviness of the connecting rod.

Crankshafts also function as load bearing as some load is withstand during the process. One of the loads is the severe bending and torsional stress.

As the rotary movement of the crankshaft is constantly being accelerated and decelerated, further loads from torsional vibration is added. Bearings also experience high degree of wear.

1.2 Crankshaft Components & Design

The componential parts of crankshaft include:

- Main Journals
- Crank pins
- Crank webs
- Counterweights

Main journals carry the main bearings and declare the axis of rotation of the shaft.

Crankpins allows the connecting rod to be attached to it.

Crank webs connect the crankpins to the main journals.

Counterweights offers balancing and are mounted to the webs.

The design of a crankshaft is based on the firing ability of the engine and number of cylinders. It is also determined by the design of the engine, numbers of crankshaft bearing and stroke size.

In multi-cylinder engine more complex engine crankshaft is used while in small engine simple design is sufficient.

A crank throw or crank pin to which connecting rod's big end is attached completes the conversion between two motions. This is an additional bearing surface whose axis is offset from that of the crank.

The flywheel or crankshaft pulley is mounted on the crank to store the generated *energy* and to use for further work. A flywheel will also reduce the pulsation characteristic of the four-stroke engine.

For smooth and vibration free running of the engine, the crankshaft is mounted in Main Bearing. Engine Bearings quantity depends upon various factors as like design of an engine, a number of cylinders, the design of crankshaft etc.

But there are always at least two such bearings, one at the drive end and other at the non-drive end are used. If everything works fine, there is a rare need for *engine* bearing replacement required.

In general, the crankshaft of a four-cylinder engine has three main journals, four crank pins, four counterweights and two crank webs.

The counterweight reduces the bending load on the crankshaft and also helps the engine not to shake when the crank mechanism is rotating. Crankshaft balancing mostly depends on counterweights.

Engine crank web is the portion of a crank between the crankpin and the shaft or between adjacent crankpins. It is also known as a crank arm.

A crankshaft seal is there to avoid the lube oil leakage from the crankcase.

1.2.1Types of Crankshafts

There are three different types of cranks you can use in an engine.

- **Cast Cranks**

These types of cranks are around for a long time and are found in a lot of diesels and petrol engine. As the name suggests, these are made from Malleable Iron through a casting process.

These are pretty cheap to make and works fine too hence they are a common choice for manufacturers.

A flat plane crank is one where the journals are 180 degrees apart common in all in-line four engines. Whereas a cross-plane crank, on the other hand, needs a mold of multiple parts because the journals and counterweights are not symmetrical.

Cast cranks can be flame hardened to improve wear resistance in particular areas.

Forged Cranks

These are a more robust crankshaft than a cast crank. They are more commonly found in higher stressed engines and come standard with some 16v engine.

A forged crank is made in a totally different way. A set of dies are machined to the approximate shape of the crank.

These dies to sit in a very large hydraulic press having a clamping force of many tons. A hot bar of high-grade steel alloy is placed onto the bottom die and the dies are closed.

Once the dies are closed the metal is squeezed in very tightly. The material is then both compacted and aligned better than the casting process.

These type cranks are also hardened like the cast types but it uses Induction Hardening.

Billet Cranks

Billet cranks are the best type of crank you can have in your engine if you want to get the most from it.

4340 steel is normally used to manufacture this kind of crank. This contains nickel, chromium, aluminum, and molybdenum amongst other elements.

These cranks are popular because of lowest crankshaft machining time. They also require minimal balancing due to the uniform makeup of the material.

1.3 COMPOSITE

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. Composite materials are generally used for buildings, bridges and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and marble sinks and counter tops. The most advanced examples perform routinely on spacecraft in demanding environments.

1.4 CHARACTERISTICS OF COMPOSITES

Composites are strongly heterogeneous materials. That is, the properties of a composite vary considerably from point to point in the material, depending on which material phase the point is located in. The new materials may be preferred for many reasons common examples a include materials which are stronger, lighter, or less expensive when compared to traditional materials. Composites are important materials which are now used widely, not only in the aerospace industry, but also in a large and increasing number of commercial mechanical engineering applications, such as internal combustion engines; machine components; thermal management and electronic packaging; automobile, train, and aircraft structures and mechanical components, such as brakes, drive shafts, flywheels, tanks, and pressure vessels; dimensionally stable components; process industries equipment requiring resistance to high-temperature corrosion, oxidation, and wear; offshore and onshore oil exploration and production; marine structures; sports and leisure equipment; ships and boats; and biomedical devices. Composites are made up of individual materials referred to as constituent materials. There are two main categories of constituent materials: matrix (binder) and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties.

The roll of the reinforcement in a composite material is fundamentally increasing the mechanical properties of the neat resin system. All of the different fibers used in composites have different properties and so, Effect, the properties of the composite in different ways. For most of the application, the fibers need to be arranged into some form of sheet known as fabric, to make handling possible. Different ways for assembling fibers into sheets and the variety of fiber orientation's possible to achieve different characteristics. Many materials when they are in fibrous form exhibit very good strength properties but to achieve the properties the fiber should be bonded by a suitable matrix. The matrix isolates the fibers from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibers in place. A good matrix should process ability to deform easily under applied load, transfer the load onto fibers and evenly distributive stress concentration.

1.5 CLASSIFICATION OF COMPOSITES:

The two broad classes of composites are

- Particulate composites
- Fibrous composites

1.5.1 PARTICULATE COMPOSITES:

As the name itself indicates, the reinforcement is of particle nature. It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape. In general particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve performances at elevated temperatures reduce friction, increased wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

1.5.2 FIBROUS COMPOSITES:

A fiber is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing properties to the composite. Fibers are very effective in improving the fracture resistance of the matrix since the reinforcement having a long dimension discourages the growth of the incipient cracks normal to the reinforcement they might otherwise lead to failure. In the Case of polymeric material, orientation of the molecular structure is responsible for high strength and stiffness. Fibers, because of their small cross-sectional dimensions, are not directly usable in engineering applications. They are, therefore embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads o the fibers, and protect them against environmental attack and damage due to handling.

1.6 TYPES OF COMPOSITES:

There are three main types of composite matrix materials:

Ceramic matrix - Ceramic matrix composites (CMCs) are a subgroup of composite materials. They consist of ceramic fibers embedded in a ceramic matrix, thus forming a ceramic fiber reinforced ceramic (CFRC) material. The matrix and fibers can consist of any ceramic material. CMC materials were designed to overcome the major disadvantages such as low fracture toughness, brittleness, and limited thermal shock resistance, faced by the traditional technical ceramics.

Polymer matrix - Polymer matrix composites (PMCs) can be divided into three sub-types, namely, thermoset, thermoplastic, and rubber. Polymer is a large molecule composed of repeating structural units connected by covalent chemical bonds. PMCs consist of a polymer matrix combined with a fibrous reinforcing dispersed phase. They are cheaper with easier fabrication methods. PMCs are less dense than metals or ceramics, can resist atmospheric and other forms of corrosion.

Metal matrix - Metal matrix composites (MMCs) are composite materials that contain at least two constituent parts – a metal and another material or a different metal. The metal matrix is reinforced with the other material to improve strength and wear. Where three or more constituent parts are present, it is called a hybrid composite. In structural applications, the matrix is usually composed of a lighter metal such as magnesium, titanium, or aluminum.

In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. Typical MMC's manufacturing is basically divided into three types: solid, liquid, and vapor. Continuous carbon, silicon carbide, or ceramic fibers are some of the materials that can be embedded in a metallic matrix material. MMCs are fire resistant, operate in a wide range of temperatures, do not absorb moisture, and possess better electrical and thermal conductivity. They have also found applications to be resistant to radiation damage, and to not suffer from outgassing. Most metals and alloys make good matrices for composite applications.

Metallic matrix composites (MMCs) reinforced with ceramic particles are very promising materials for structural applications due to excellent combination of properties. MMCs combine the properties of the metallic alloys (ductility and toughness) and the ceramic reinforcements (high strength and high modulus) leading to a superior profile of characteristics. The aluminum matrix composites (AMCs) represent a class of MMCs possessing properties like low density, high stiffness and strength, superior wear resistance, controlled coefficient of thermal expansion, higher fatigue resistance and better stability at elevated temperature. Due to this, these composites are used for the design of a wide range of components for advanced applications. It has been found that the use of AMCs in engine applications can reduce the overall weight, fuel consumption and pollution in the automobile sand aircrafts. AMCs reinforced with either silicon carbide (3.18 g/cm3) or alumina (3.9 g/cm3) particles are attractive materials for such applications. These reinforcements are denser than those of aluminum alloys (2.7 g/cm3) and increases the weight of the composites depending on the reinforcement's contents. Moreover, the addition of ceramic particles to the Al-alloy increases the hardness of composite and makes machining of developed composite more difficult. Such problems can be solved by the use of multiple reinforcements in the aluminum alloy. The ceramic reinforcements possess superior strength than any other type of reinforcement and because of the fact, these are used as a primary reinforcement primary reinforcement for development of hybrid composites. How-ever, the secondary reinforcements reduce the cost as these are readily available and weight as they have lower density of the hybrid composites. Moreover, the use of stir casting technique for fabrication of AMCs reduces the cost the composites, as it is economical, simple to perform and highly productive method use of stir casting technique for fabrication of AMCs reduces the cost of the composites, as it is economical, simple to perform and highly productive method used in industries.

1.7 MANUFACTURING METHODS:

Stir Casting

BRINELL HARDNESS TEST

TENSILE TESTING

COMPRESSION TEST

Referred from MTech project: The values of ultimate tensile strength ultimate compressive strength and hardness for the materials are referred from the MTech Project

1.8 FINITE ELEMENT ANALYSIS

The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM). Engineers use it to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster.

It is necessary to use mathematics to comprehensively understand and quantify any physical phenomena such as structural or fluid behaviour, thermal transport, wave propagation, the growth of biological cells, etc. Most of these processes are described using Partial Differential Equations (PDEs). However, for a computer to solve these PDEs, numerical techniques have been developed over the last few decades and one of the prominent ones, today, is the Finite Element Analysis.

Differential equations can not only describe processes of nature but also physical phenomena encountered in engineering mechanics. These partial differential equations (PDEs) are complicated equations that need to be solved in order to compute relevant quantities of a structure (like stresses (ϵϵ), strains (ϵϵ), etc.) in order to estimate a certain behaviour of the investigated component under a given load. It is important to know that FEA only gives an approximate solution of the problem and is a numerical approach to get the real result of these partial differential equations. Simplified, FEA is a numerical method used for the prediction of how a part or assembly behaves under given conditions. It is used as the basis for modern simulation software and helps engineers to find weak spots, areas of tension, etc. in their designs. The results of a simulation based on the FEA method are usually depicted via a colour scale that shows for example the pressure distribution over the object.

Depending on one’s perspective, FEA can be said to have its origin in the work of Euler, as early as the 16th century. However, the earliest mathematical papers on Finite Element Analysis can be found in the works of Schnellbacher [1851] and Courant [1943].

FEA was independently developed by engineers in different companies and industries to address structural mechanics problems related to aerospace and civil engineering. The development for real life applications started around the mid-1950s as papers by Turner, Clough, Martin and Top [1956], Argyris [1957] and Babushka and Aziz [1972] show. The books by Sienkiewicz [1971] and Strang and Fix [1973] also laid the foundations for future developments in FEA.

Finite element analysis (FEA) is a computerised method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects. Finite element analysis shows whether a product will break, wear out or work the way it was designed. It is called analysis, but in the product development process, it is used to predict what's going to happen when the product is used.

FEA works by breaking down a real object into a large number (thousands to hundreds of thousands) of finite elements, such as little cubes. Mathematical equations help predict the behaviour of each element. A computer then adds up all the individual behaviours to predict the behaviour of the actual object.

Finite element analysis helps predict the behaviour of products affected by many physical effects, including:

Mechanical stress

Mechanical vibration

Fatigue

Motion

Heat transfer

Fluid flow

Electrostatics

Plastic injection moulding

1.8.1 Applications of FEA

The **Finite Element Analysis** started with significant promise in modelling several mechanical applications related to aerospace and civil engineering. The applications of Finite Element Method are just starting to reach their potential. One of the most exciting prospects is its application to coupled problems like fluid-structure interaction; thermo-mechanical, thermo-chemical, thermo-chemo-mechanical problems piezoelectric, ferroelectric, electromagnetics and other relevant areas:

Static

With static analysis, you can analyse linear static and nonlinear quasi-static structures. In a linear case with an applied static load, only a single step is needed to determine the structural response. Geometric, contact and material nonlinearity can be taken into account. An example is bearing pad of a bridge.

Dynamic

Dynamic analysis helps you analyse the dynamic response of a structure that experienced dynamic loads over a specific time frame. To model the structural problems in a realistic way, you can also analyse impacts of loads as well as displacements. An example is the impact of a human skull, with or without a helmet.

Modal

Eigenfrequencies and eigenmodes of a structure due to vibration can be simulated using modal analysis. The peak response of a structure or system under a given load can be simulated with harmonic analysis. An example is the start of an engine.

CHAPTER-2

LITERATURE REVIEW

- **Solanki and Dodia et al [1]** in their research, performed the numerical analysis of the crankshaft. They observed the stresses occurring in critical cross-sections of the crankshafts. The obtained stress values were compared with the previously analytically calculated values. By comparing the results, they found that the numerical results were very close to analytical and can be used as such for calculations, taking into account the numerical method requires a much shorter time.
- **Zissimos P.Mourelatos et al[2]** A system model for analysing the dynamic behaviour of an internal combustion engine crankshaft is described. The model couples the crankshaft structural dynamics, the main bearing hydrodynamic lubrication and the engine block stiffness using a system approach. A two-level dynamic sub structuring technique is used to predict the crankshaft dynamic response based on the finite-element method. The dynamic sub structuring uses a set of load-dependent Ritz vectors. The main bearing lubrication analysis is based on the solution of the Reynolds's equation. Comparison with experimental results demonstrates the accuracy of the model. Numerical results also show the capabilities and significance of the model in engine crankshaft design.
- **M.Fonte, P. Duarte, V. Annes, M. Freitas, L. Reis et al [3]**The fatigue strength and its correct assessment play an important role in design and maintenance of marine crankshafts to obtain operational safety and reliability. Crankshafts are under alternating bending on crank pins and rotating bending combined with torsion on main journals, which mostly are responsible for fatigue failure. The commercial management success substantially depends on the main engine in service and of its design crankshaft, in particular. The crankshaft design strictly follows the rules of classification societies. The present study provides an overview on the assessment of fatigue life of marine engine crankshafts and its maintenance taking into account the design improving in the last decades, considering that accurate estimation of fatigue life is very important to ensure safety of components and its reliability. An example of a semi-built crankshaft failure is also presented and the probable root case of damage, and at the end some final remarks are presented.
- **Farzin H Montazersadgh et al[4**] proposed dynamic analysis and were investigated the effect of torsional load and the variation of stress magnitude at critical location by using the finite element analysis techniques.
- **Amarjeet Singh et.al.[5]**Analysed and optimized strength, the main intention of this method was conducted static analysis on four cylinder engine crankshaft. In this method after getting out the stress results, the critical points identified were the knuckle of crank arm and extreme left bearing.
- **Jian Meng et al [6]**Revived and analysed crankshaft model and crank throw. The crankshaft distortion was mainly bending distortion under the lower frequency. Higher deformation was located at the link between main bearing journal, crankpin and crank cheeks.

- **Gu Yingkui et al[7]** The crankshaft is an important component of diesel engine. In this paper, a three-dimensional model of a diesel engine crankshaft was established corresponding to the practical conditions by Using PRO/E software. Using ANSYS analysis tool, the finite element analysis for the crankshaft was conducted under extreme operation conditions, and the stress distribution of the crankshaft was presented. The static rigidity and intensity of crankshaft was analysed in detail. The crank stress change model and the crank stress biggest hazard point were found by using finite element analysis, and the improvement method for the crankshaft structure design was given.
- **G.B. Veereshkumar et al [8]** has done experiment on metal matrix components of Al7075and properties are divided from this paper. "Journals of minerals and materials characteristic and engineering"-jmmee.org.
- **C.M.Balamurugan et al [9]** has done computer aided modelling and optimization of crankshaft. "International journal of scientific engine research".

CHAPTER-3

MATERIAL OF CONSTRUCTION

3.1 ALUMINIUM 7075 ALLOY:

3.1.1 Chemical Composition:

Table-3.1 chemical composition of Al 7075

Chemical composition	**Al7075**
Si	0.62
Fe	0.23
Cu	0.22
Mn	0.03
Mg	0.84
Cr	0.22
Zn	0.10
Ti	0.1
Al	Bal

3.1.2 Mechanical Properties:

Table-3.2 mechanical properties of Al7075

Properties	**Al 7075**
Elastic Modulus (Gpa)	70-80
Density (g/cc)	2.81
Poisson’s Ratio	0.33
Hardness (HB500)	60
Tensile Strength (T) (Mpa)	220

3.1.3 APPLICATION:

The uses of Al 7075 are Aircraft fittings, gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, keys, aerospace and defence applications; bike frames, all-terrain vehicle (ATV) sprockets. It possesses high heat dissipation capacity due to its high thermal conductivity and is suitable for high strength and high temperature applications as well.

The world's first mass production usage of the 7075 aluminium alloy was for the Mitsubishi A6M Zero fighter. The aircraft was known for its excellent manoeuvrability which was facilitated by the higher strength of 7075 compared to former aluminium alloys.

7000 series alloys such as 7075 are often used in transport applications due to their high Specific strength, including marine, automotive and aviation. These same properties lead to its use in rock climbing equipment, bicycle components, inline skating-frames and hang glider airframes are commonly made from 7075 aluminium alloy. Hobby grade RC models commonly use 7075 and 6061 for chassis plates. 7075 is used in the manufacturing of M16 rifles for the American military as well as AR-15 style rifles for the civilian market. In particular high quality M16 rifle lower and upper receivers as well as extension tubes are typically made from 7075-T6 alloy. Desert Tactical Arms, SIG Sauer, and French armament company PGM use it for their precision rifles. It is also commonly used in shafts for lacrosse sticks, such as the STX sabre, and camping knife and fork sets. It is a common material used in competition yo-yos as well.

Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mould tool manufacturing. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020.

3.2 SILICON CARBIDE (Sic):

Silicon carbide behaves almost like a diamond. It is not only the lightest, but also the hardest ceramic material and has excellent thermal conductivity, low thermal expansion and is very resistant to acids and lye.

With silicon carbide ceramics the material properties remain constant up to temperature above 1400 c. the high young modulus > 400 GPa ensures excellent Dimensional stability. These material properties make silicon carbide predestined for use as a construction material silicon carbide master's corrosion, abrasion and erosion as skilfully as if stands up to frictional wear. Components are used in chemical plants, mills, expanders and extruders or as nozzles

Key Properties:

- It is a refractory material (high melting point)
- High Thermal conductivity
- Low thermal expansion

- Good thermal shock resistance

3.2.1 Typical properties of Silicon Carbide:

Properties	**SiC**
Elastic Modulus (Gpa)	410
Density (g/cc)	3.1
Poisson's Ratio	0.14
Hardness (HB500)	2800
Compressive strength(c) (Mpa)	3900

Silicon Carbide

3.2.2 APPLICATIONS OF Sic:

Automobile parts:

Silicon infiltrated carbon-carbon composite is used for high performance ceramic brakes, as they are able to withstand extreme temperature. The brake disks are used in sports cars, super cars like Bugatti Veyron, Bentley, Ferrari and other performance Audi cars. Silicon carbide is also used in sintered form for diesel particulate filters and also used as an oil additive to reduce friction, emissions and harmonics.

Abrasives and cutting tools:

Silicon carbide is a popular abrasive in modern lapidary due to durability and low cost of the material. In manufacturing, it is used for its hardness in abrasive machining processes such as grinding, honing, water-jet cutting and sand blasting. Particles of silicon carbide are laminated to paper to create sandpapers and grid tape on skateboards.

Astronomy: The low thermal expansion coefficient, high hardness, rigidity and thermal conductivity makes silicon carbide a desirable mirror material for astronomical telescopes

Power electronic devices:

Silicon carbide was the first commercially important semiconductor material. as in the first commercially used LEDs based on Sic and it is mostly used in high temperature and high voltage devices

CHAPTER-4

MODELING AND ANALYSIS OF CRANKSHAFT

4.1 INTRODUCTION TO CATIA

CATIA, stands for **Computer Aided Three-dimensional Interactive Application**, it is the most powerful Knowledge based and widely used CAD (computer aided design) software of its kind in the world.

CATIA has been created by Dassault Systems of France and is marketed & technically supported worldwide by IBM. The most commonly CATIA users are generally Aerospace, Appliances, Architecture, Automotive, Construction, Consumer Goods, Electronics, Medical, Furniture, Machinery, Mold and Die, and Shipbuilding industries. CATIA has played a major role in NASA's design of the various Space equipments. Beside this it has also been used as Vital tool for designing "jet-fighter" aircraft, aircraft carriers, helicopters, tanks and various other forms of weaponry extensively used by the Defense Sector.

CATIA is used throughout the North American and European continents, as well as Australia. Apart from this CATIA is increasingly being used by Asian countries like India, Japan etc.

Fig 4.1 Catia Interface

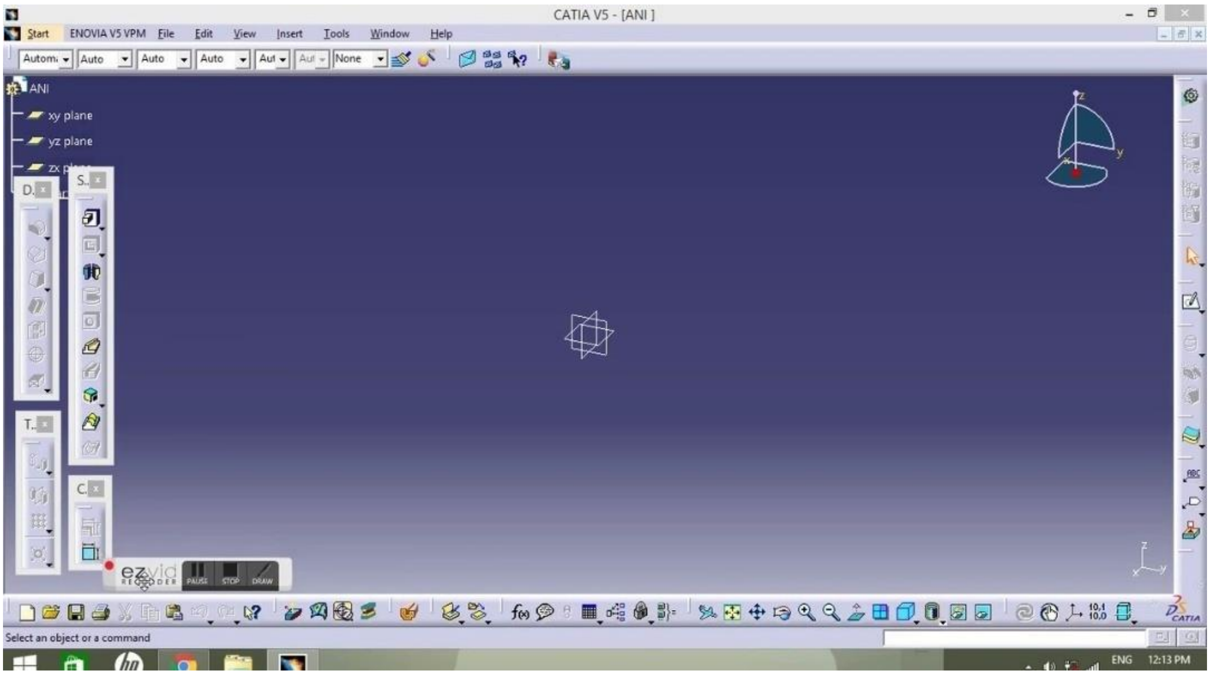


Fig 4.2 Catia Workbench

French Dassault Systems is the parent company and IBM participate in the software's and marketing, and Catia is invades broad industrial sectors, and has been explained in the previous post position of CATIA between 3d modeling software programs.

Fig4.3 Different Modules in Catia

4.1.1 Sketcher:

This module is responsible for the implementation of two-dimensional shapes, in preparation for make a three-dimensional command on it.

4.1.2 Part Design:

This module is responsible for converting two-dimensional graphics to three dimensional objects which is most famous in Catia and is closely linked with sketcher module. The part design Module it is considered from most important modules, that used by the designer to get the additional advantage from cad programs, which is stereotaxic drawing or three-dimensional drawing

4.1.3 Assembly:

This module is responsible for assembling the parts previously produced in part design, and it is most important for those who work in the field of machinery design or design in general, because it is the one who shows the inter-relationships between the parts of the machine or any mechanical establishment.

4.1.4 Drafting:

This module is responsible, for converting what you see on the screen to standard engineering drawings can be traded in the workshop for manufacturing or save them for documentation.

4.1.5 Surface and Wire Frame:

With this module surfaces can be drawing with zero size and weight and has its uses in the aerospace, automotive, ships and Mold Design.

4.1.6 Simulation:

This module is responsible for obtaining a similar movement of the natural movement, which is expected to occur during the actual operation of the machine or mechanical establishment whatever

4.1.7 Free Style:

Which is a free drawing, product designers need it, such as Mobile or furniture or antiques designers and other modules such as

4.1.8 Sheet Metal, Mold Design, Welding, Aerospace Sheet Metal:

The surprise is that all of the above follows the one field which is mechanical design field, while there are other fields such as:

1. **Analysis**
2. **Machining**
3. **Ergonomics**

Each of them containing modules, even electronic circuit design, that is mean CATIA have too many modules, and it is covers almost everything you need, so I prefer to work on it more than others.

CATIA is considered as a CAM program, in addition to it is CAD program, in the meaning that you can export files to CNN machines and then manufactured, CATIA Also supports graphics from other programs such as AutoCAD, for example, it is possible to copy a drawing from AutoCAD and enter it to CATIA and then make on it CATIA operations, CATIA files can be kept with dwg extension which is supported by AutoCAD or the default extension has.

4.2 3D DESIGN OF CRANK SHAFT IN CATIA

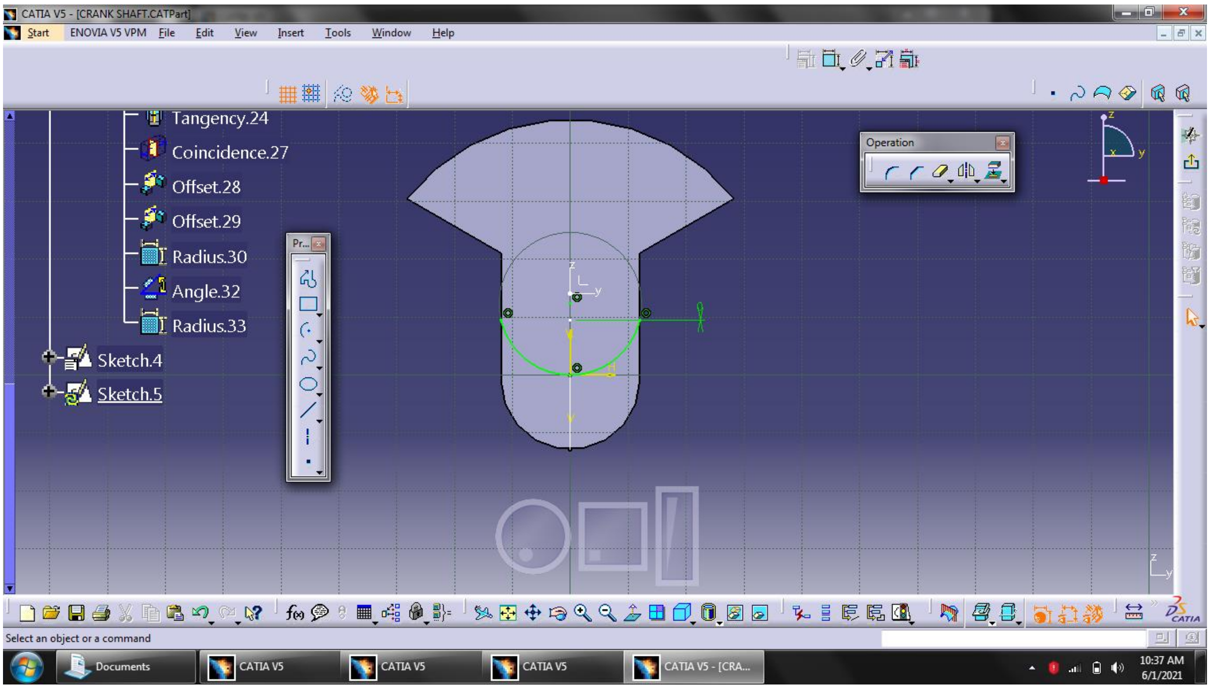


Fig4.4 Sketch of crank web

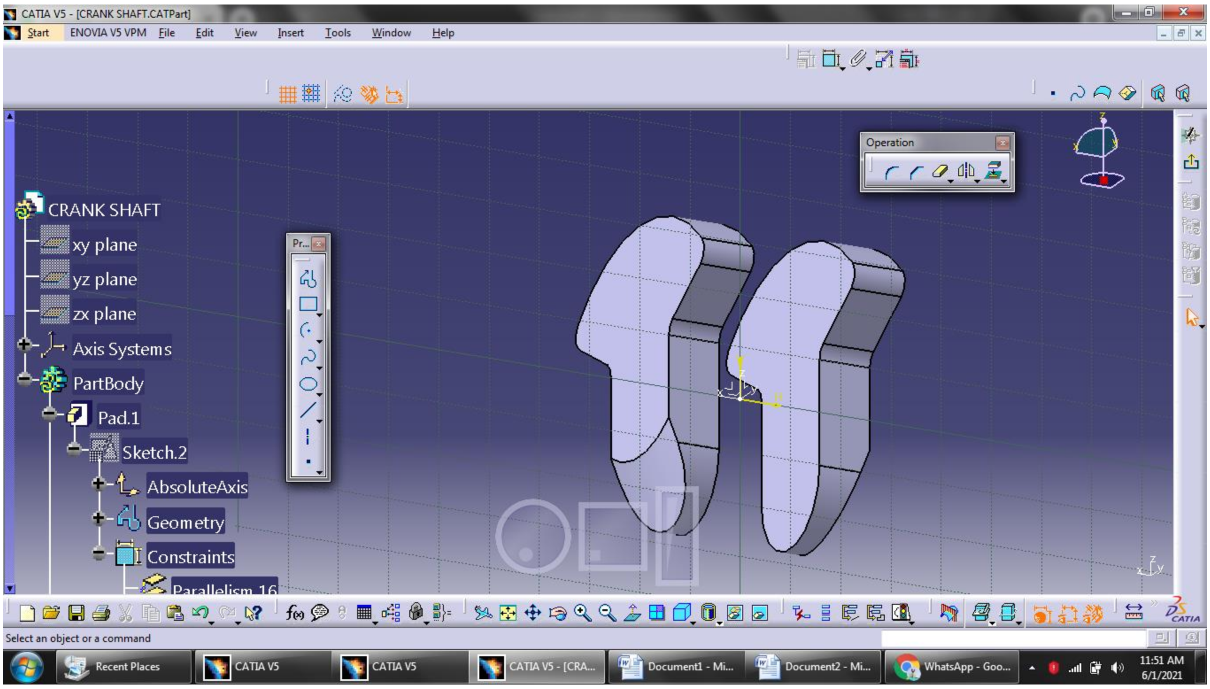


Fig4.5 Mirror image in Catia

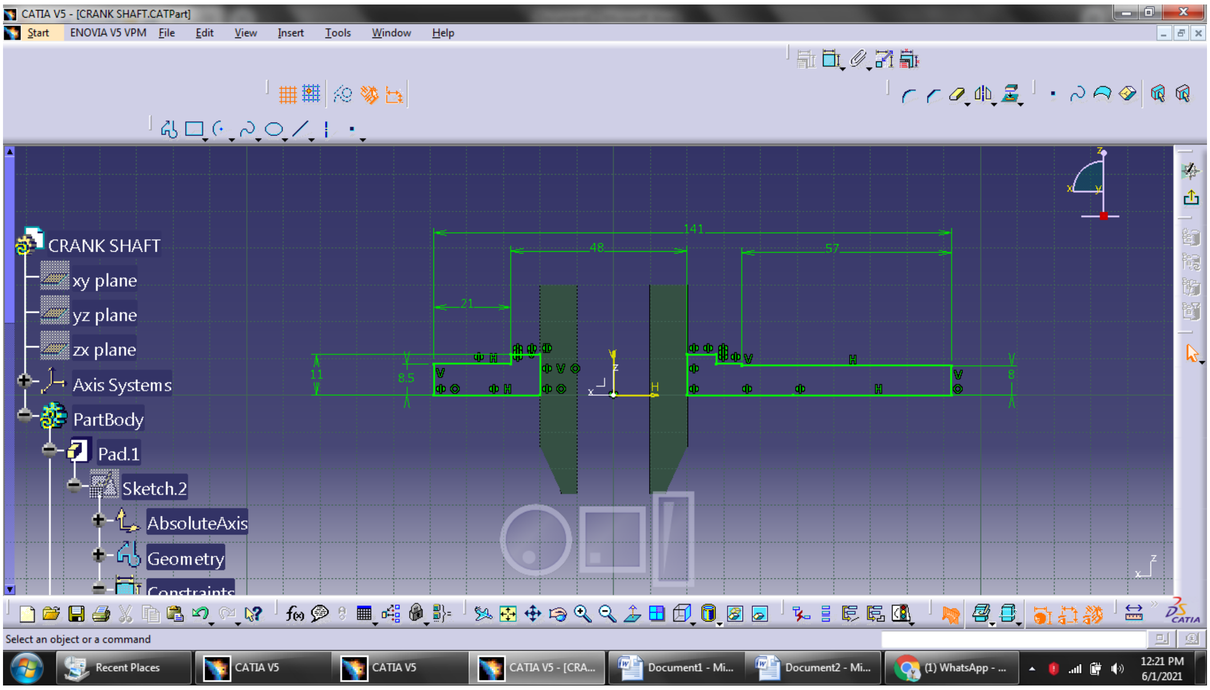


Fig4.6 Design of the shaft in Catia

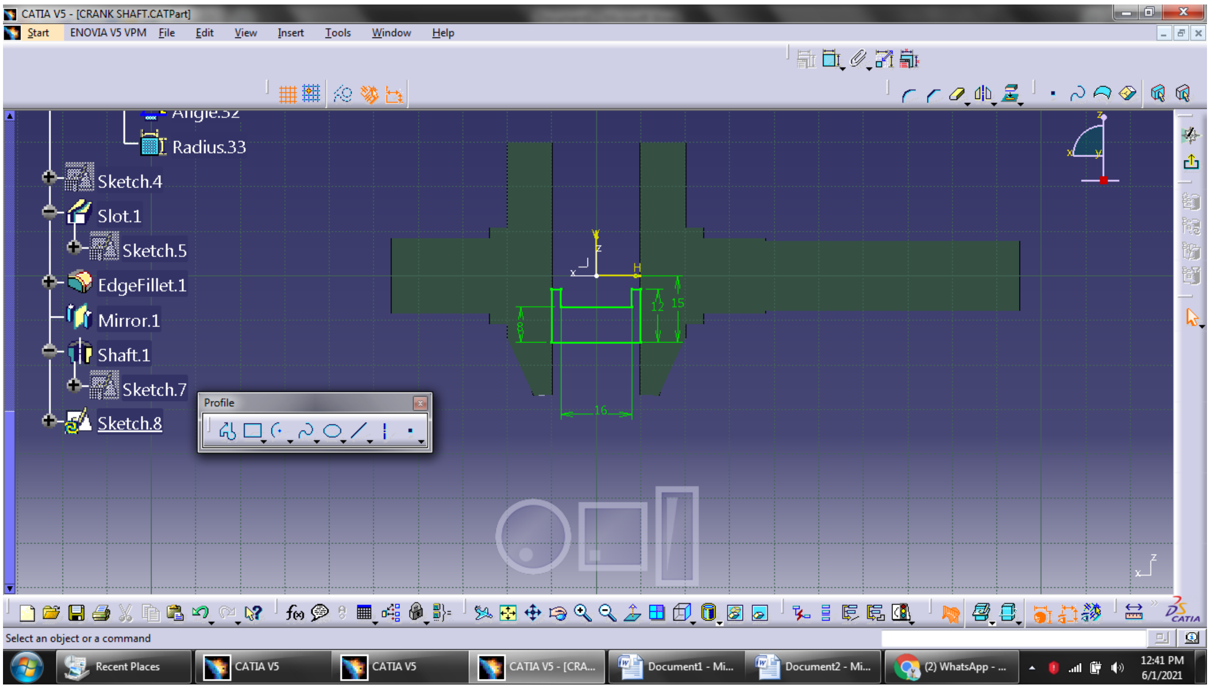


Fig4.7 Design of crank pin in Catia

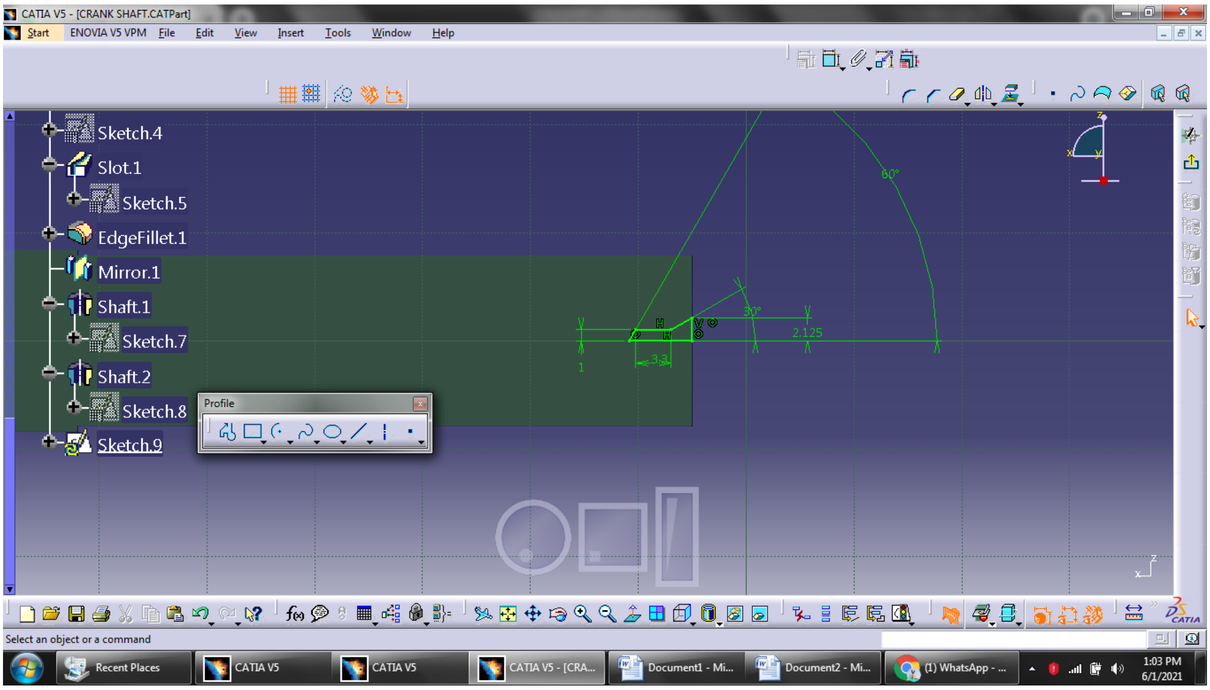


Fig4.8Sketch of groove in Catia

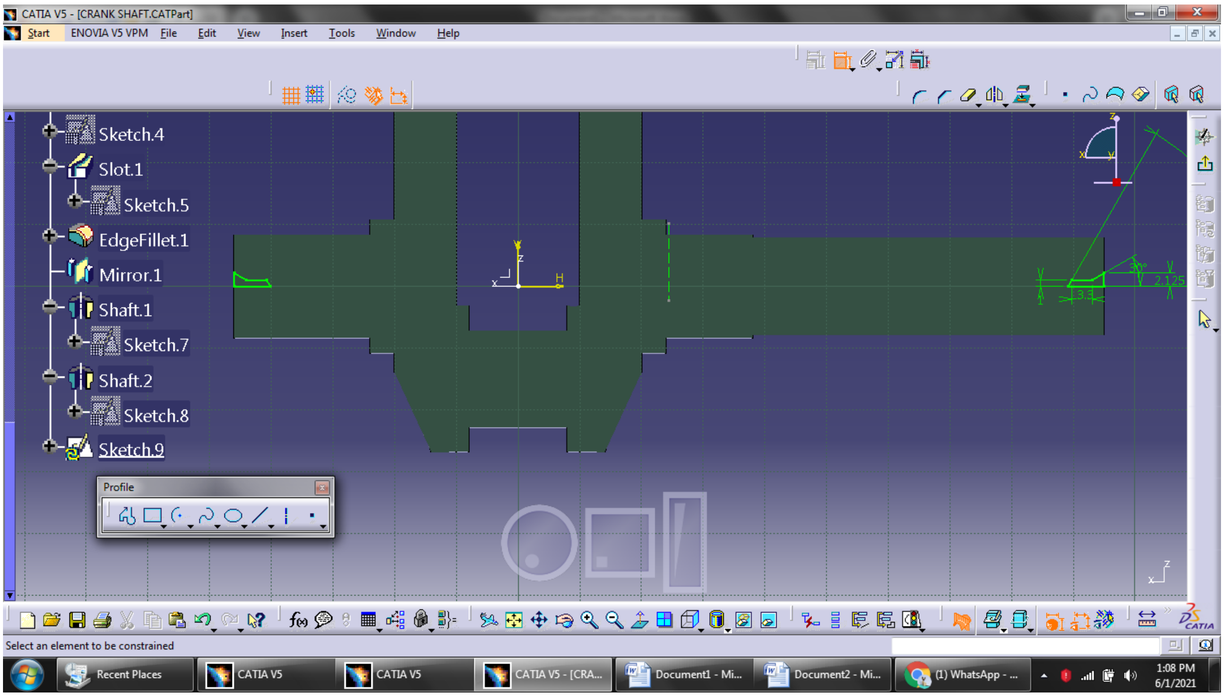


Fig4.9 Design of Groove in Catia

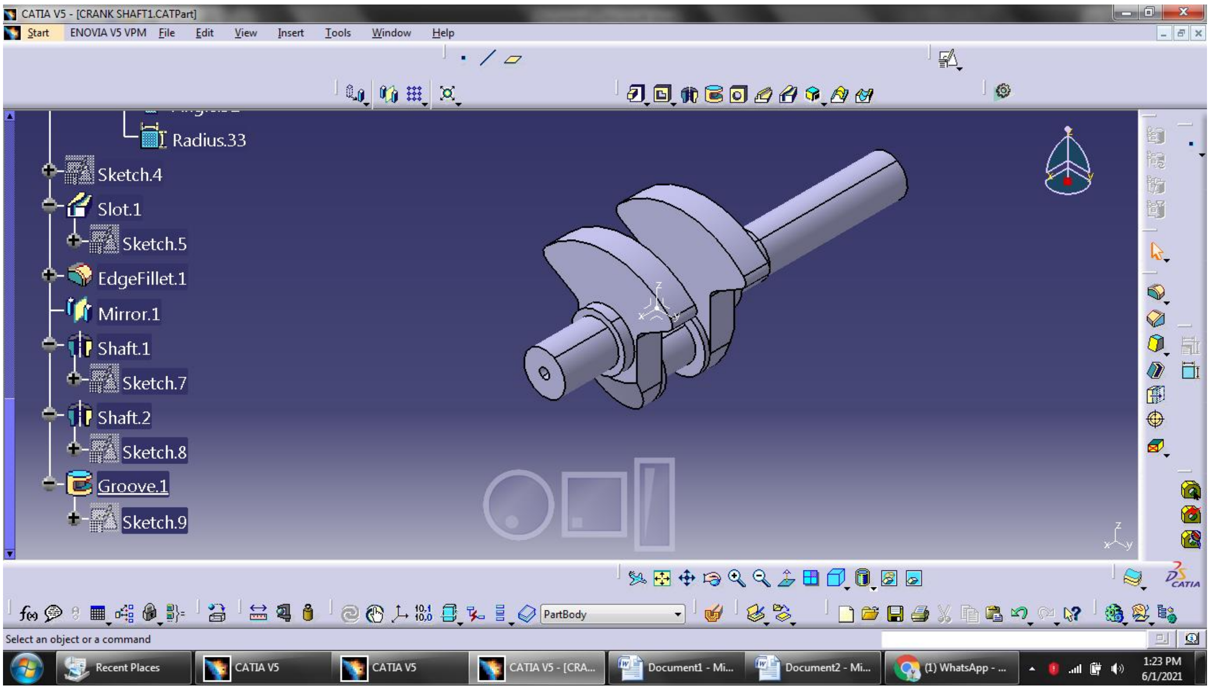


Fig4.10 crank shaft design

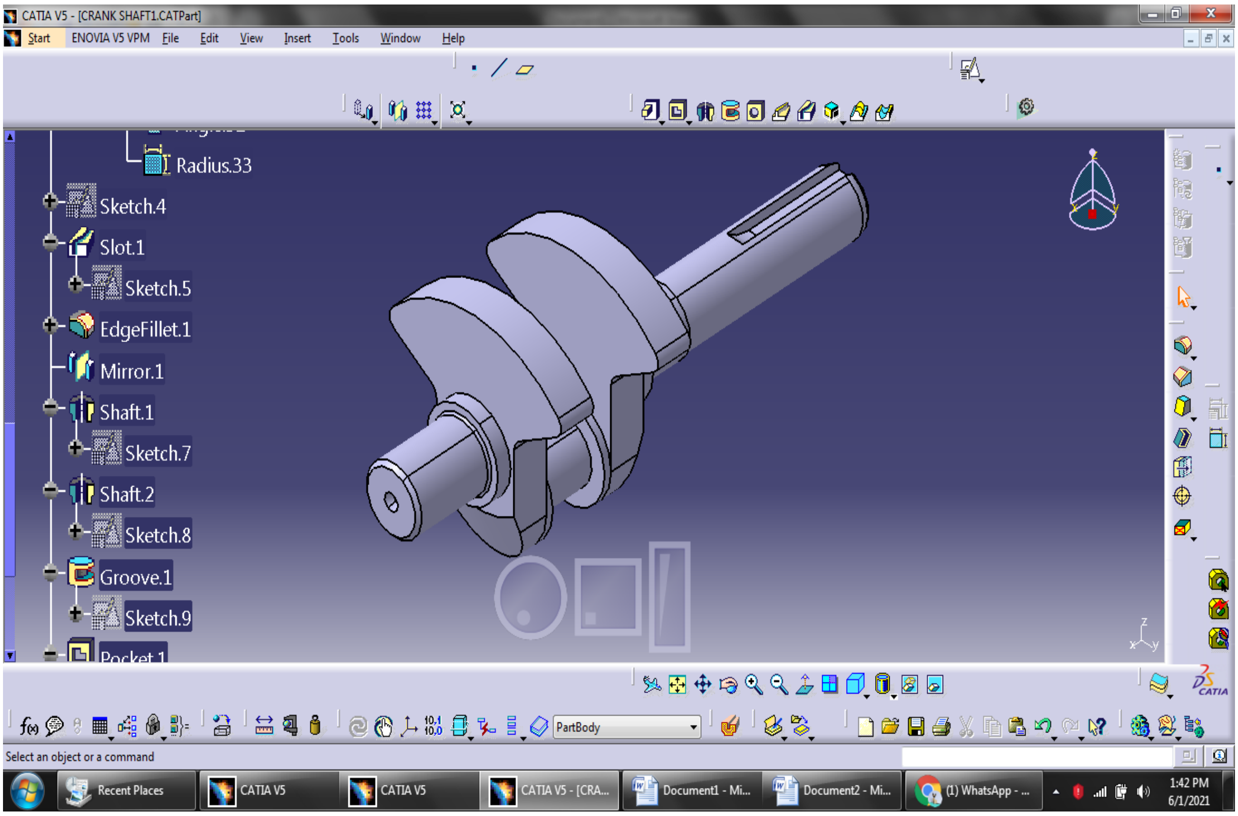


Fig4.11 Crankshaft model in Catia

4.3 Introduction to finite element analysis:

Approximate solutions to a wide variety of engineering problems although originally developed to study stresses in complex airframe structures, it has since been extended and applied to the broad field of continuum mechanics. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and industry. The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. Advances in computer technology and CAD systems, has led to increased use of FEM in research as well as industry as complex problems can be modeled and released with relative ease.

4.4 Basic Steps in the Finite Element Analysis:

The basic steps involved in finite element analysis consist of the following

a) **Pre-Processing Phase:**

Create and discretize the solution domain into finite elements i.e. subdivide the problem into nodes and elements.

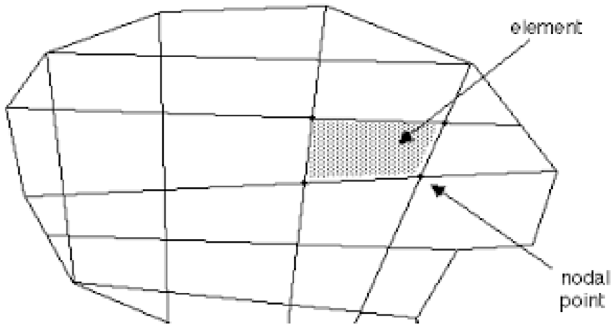


Fig 4.12Discretization of Real Continuum with Node and Element

- Assume a shape function to represent the physical behavior of an element; that is an approximate continuous function is assumed to represent the solution of an element.
- Develop equations for all the elements in the mesh.
- These generally take form
- [K]{U} = {F}
- Where '[K]' is a square matrix, known as stiffness matrix
- '{U}' is the vector of (unknown) nodal displacements or temperature
- '{F}' is the vector of applied nodal forces
- Assemble the elemental equations to obtain the equations of the whole problem. Construct the global stiffness matrix.
- Apply boundary conditions, initial conditions, and loading.

b) **Solution Phase:**

Solve a set of linear or nonlinear algebraic equations simultaneously to obtain nodal results of primary degrees of freedom or unknowns, such as displacement values at different nodes in structural problem or temperature values at different nodes in heat transfer problem.

c) Post processing phase:

- Computation of any secondary unknowns or variables e.g. the gradient of the solution.
- Interpretation of the results to check whether the solution makes sense.
- Tabular and/or graphical presentation of the results.

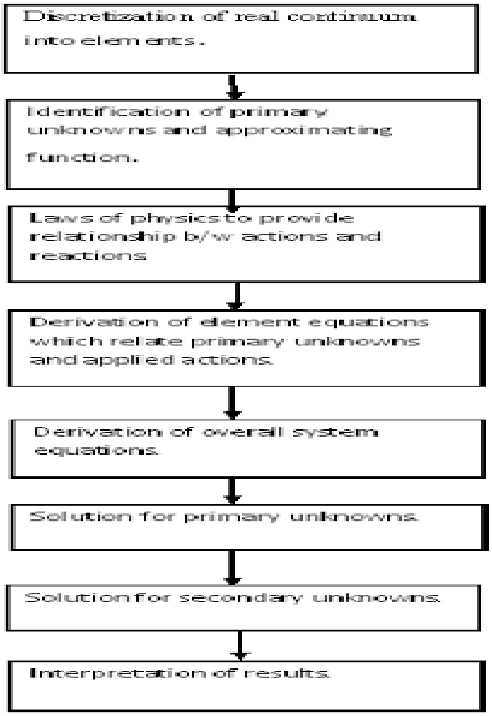


Fig 4.12.1Tabular presentation of results

4.5 Introduction to ANSYS Workbench:

ANSYS Workbench is the framework upon which the industry's broadest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user every step of the way. Even complex multi physics analysis can be performed with drag-and-drop simplicity.

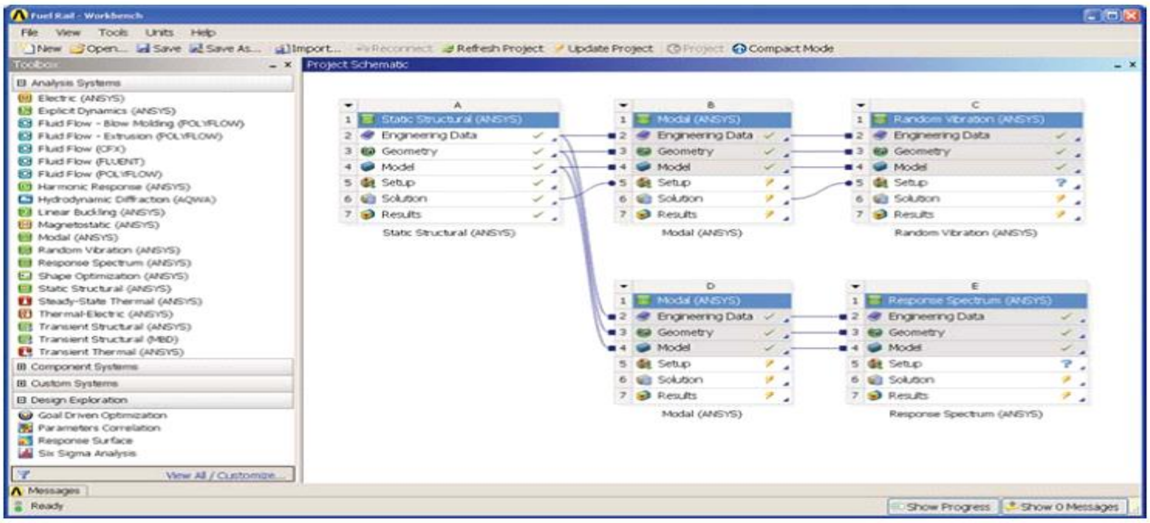


Fig 4.13Workbench 19.2 Interface

The ANSYS Workbench platform automatically forms a connection to share the geometry for both the fluid and structural analysis, minimizing data storage and making it easy to study the effects of geometry changes on both analyses. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

The ANSYS Workbench interface is arranged into two primary areas: The toolbox and the project Schematic. The toolbox contains the system templates that you can use to build a project. The project Schematic is the area if the interface where you will manage your project. The new project schematic view shows an overall view of the entire simulation project. Engineering intent, data relationships and the state of the entire project are visible at a glance, even for complex analyses involving multiple physics. In addition to this, you will see a menu bar and a toolbar with frequently used functions. You can also use context menus, accessible via a right- mouse click, on schematic items, and cells. Context menus provide capabilities to add to and modify projects. The entire process is persistent. Changes can be made to any portion of the analysis and the ANSYS Workbench platform will manage the execution of the required applications to update the project automatically, dramatically reducing the cost of performing design iterations.

4.5.1. ANSYS Workbench Features:

- Bidirectional, parametric links with all major CAD systems.
- Integrated, analysis-focused geometry modeling, repair, and simplification via ANSYS Design Modeler.
- Highly-automated, physics-aware meshing.
- Automatic contact detection.
- Unequalled depth of capabilities within individual physics disciplines.
- Unparalleled breadth of simulation technologies.
- Complete analysis systems that guide the user start-to-finish through an analysis.
- Comprehensive multi physics simulation with drag-and-drop ease of use.
- Flexible components enable tools to be deployed to best suit engineering intent.
- Innovative project schematic view allows engineering intent, data relationships, and the state of the project to be comprehended at a glance.
- Complex project schematics can be saved for re-use.

- Pervasive, project-level parameter management across all physics.
- Automated what-if analyses with integrated design point capability.
- Adaptive architecture with scripting and journaling capabilities and API's enabling rapid integration of new and third-party solutions.

4.5.2 Structural Analysis:

Structural analysis is probably the most common application of the finite element method. The term *structural* (or *structure)* implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

4.5.3 Types of structural analyses:

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Structural, and ANSYS/Linear Plus programs only.

One can perform the following types of structural analyses

1) **Static Analysis:**
   Used to determine displacements, stresses, etc., under static loading conditions. It comprises of both linear and non-linear static analysis. Non-linearity can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.
2) **Model Analysis:**
   Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.
3) **Harmonic Analysis:**
   Used to determine the response of a structure to harmonically time-varying loads.
4) **Transient Dynamic Analysis:**

Used to determine the response of a structure to arbitrarily time-varying loads. All non-linearity mentioned under Static Analysis above are allowed.

5) Spectrum Analysis:

An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

6) Buckling Analysis:

Used to calculate the buckling loads and determine the buckling mode shape. Both linear(Eigen value) buckling and nonlinear buckling analyses are possible.

7) Explicit Dynamics Analysis:

ANSYS provides an interface to the LS-DYNA explicit finite element program and is used to calculate fast solutions for large deformation dynamics and complex contact problems.

- In addition to the above analysis types, several special-purpose features are available
- Fracture mechanics
- Composites
- Fatigue
- p-Method

4.5.4 Thermal Analysis:

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are

- The temperature distributions
- The amount of heat lost or gained
- Thermal gradients
- Thermal fluxes

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions).

Only the ANSYS/Multi physics, ANSYS/Mechanical, ANSYS/Thermal, and ANSYS/FLOTRAN programs support thermal analysis.

The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution one performs via ANSYS calculates nodal temperatures and then uses the nodal temperatures to obtain other thermal quantities.

The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation.

4.5.5 Types of thermal analysis

ANSYS supports two types of thermal analysis

I. A **steady-state thermal analysis** determines the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a situation where heat storage effects varying over a period of time can be ignored.

II. A **transient thermal analysis** determines the temperature distribution and other thermal quantities under conditions that vary over a period of time.

4.6 PROCEDURE FOR PERFORMING STATIC STRUCTURAL ANALYSIS:

STEP 1: Engineering Data

The data to be calculated is to be submitted in this module. Properties such as yield strength, young’s modulus, Poisson’s ratio, factor of safety are to be provided.

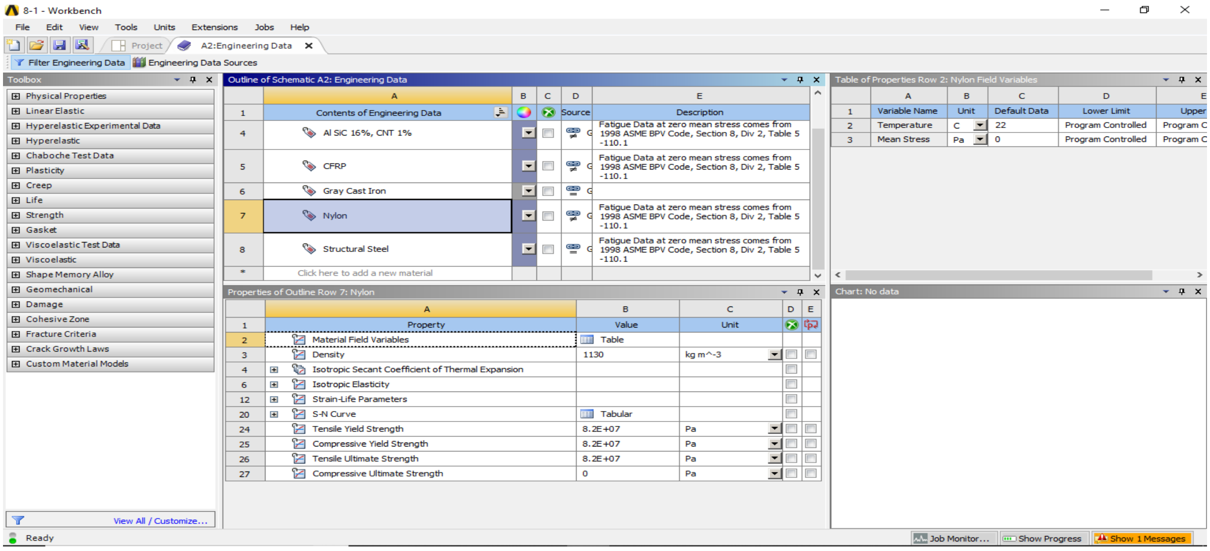


Fig 4.14ANSYS interface

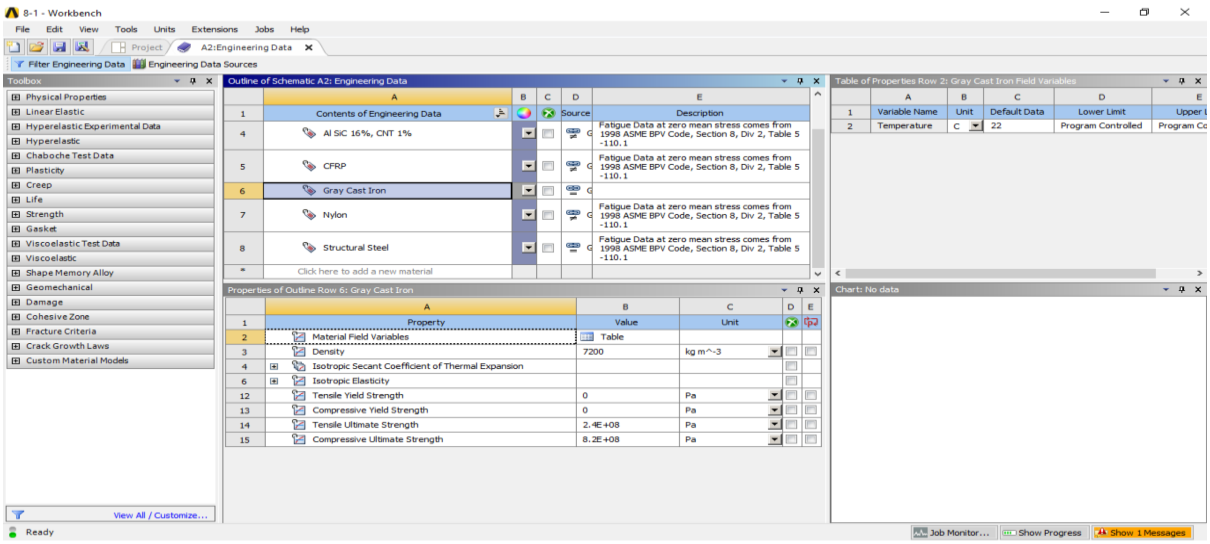


Fig 4.15 Insertion of data in ANSYS

STEP 2: INSERTION OF GEOMETRY

Right click on the geometry and then click on **Import Geometry**. Then close the present tab and again right click on the geometry then click on the **Modify Designer Tool**.

STEP 3: CONSTRAINTS

Right click on the model and apply the constraints on the gear and then apply the loads.

STEP 4: MESHING

Click on mesh option and extend the sizing option then the required data is given as follows:

Mesh size = 0.0001m

STEP 5: INSERTION OF SUPPORTS AND FORCES

Right click on **Static structural** icon. Click on **INSERT**. Then select fixed support and click on apply.

Again, right click on **Static structural** icon. Click on **INSERT.** Then select force and click on apply. Then the force is defined by the component i.e. in which direction the force is to be applied.

ANALYSIS OF CRANKSHAFT

4.7 Structural static analysis: A static analysis is used to calculate the effects of steady loading conditions ignoring the effects of inertia and damping. In static analysis loading and response conditions doesn't vary with time. The input loading conditions that can be given in a static analysis are moment, applied force and pressure and the output can by displacement, forces in a structure, stress and strain. If the values obtained in static analysis crosses the allowable values it will result in the failure of structure. The static structural analysis is carried out on the recent Ansys 2021R1 version

Type of meshing: Tetrahedral

Element size: 0.001m

No of nodes: 62284

No of elements :38844

Pressure :3.5Mpa

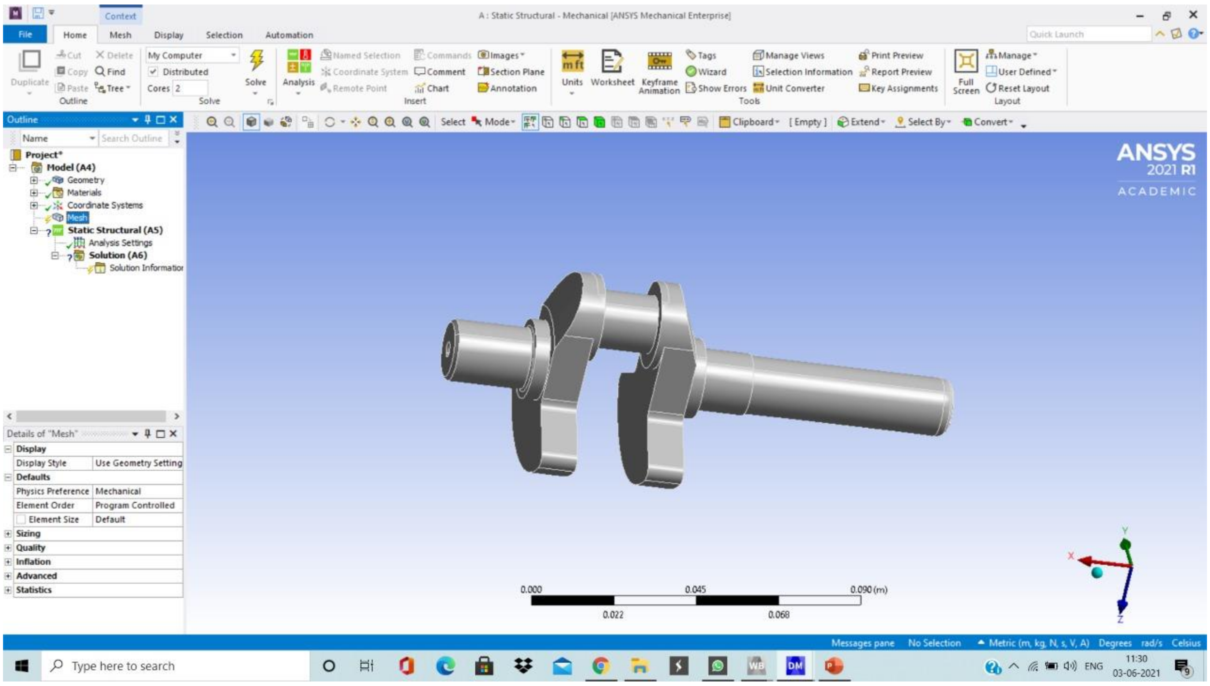


Fig 4.16 IGES model of crank shaft

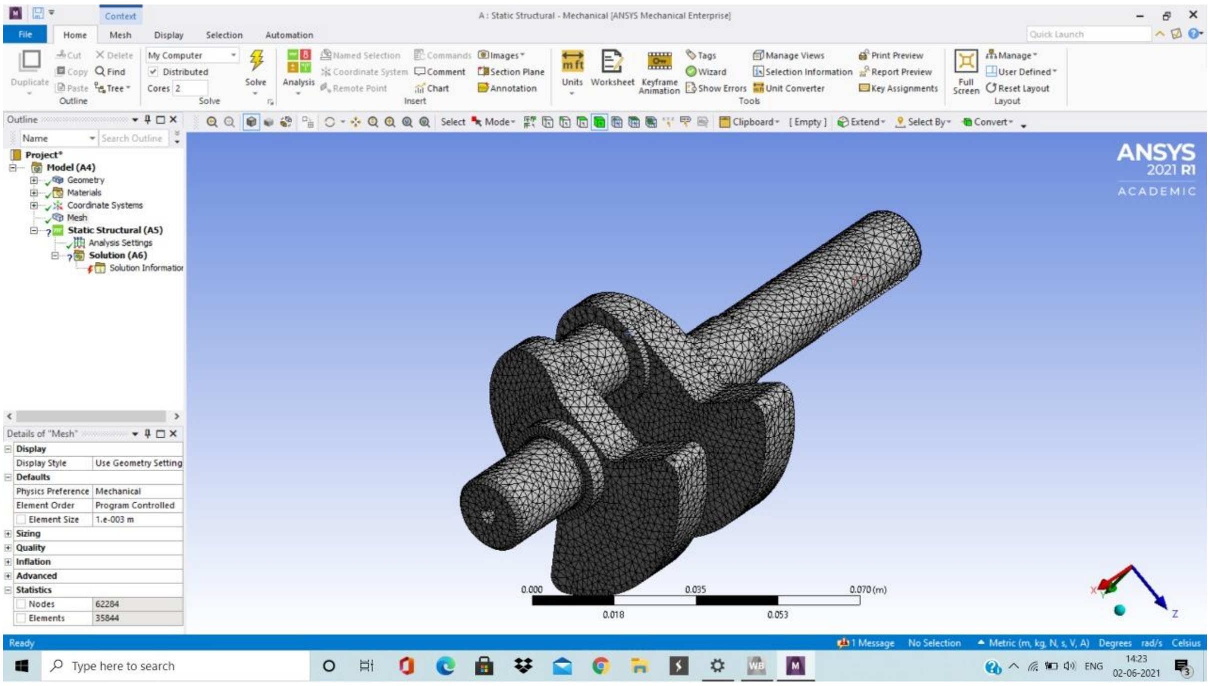


Fig 4.17 Meshed model of crank shaft

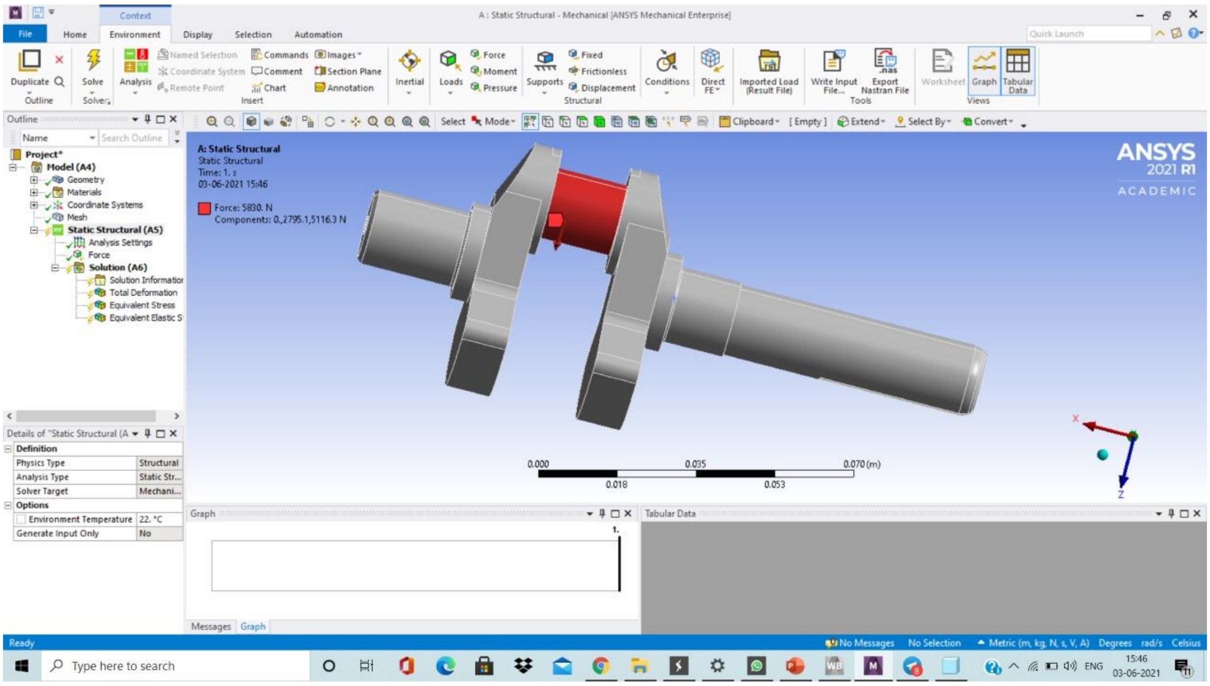


Fig 4.18 Load applied on the crank shaft

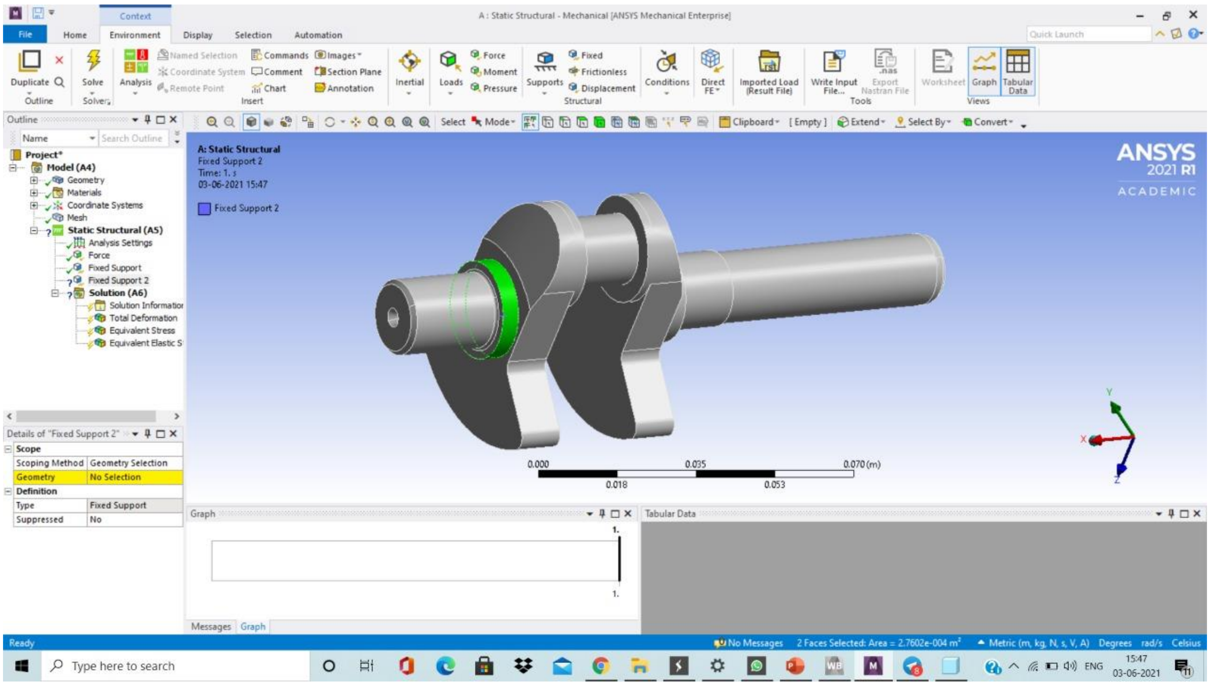


Fig 4.19 First boundary condition of crank shaft

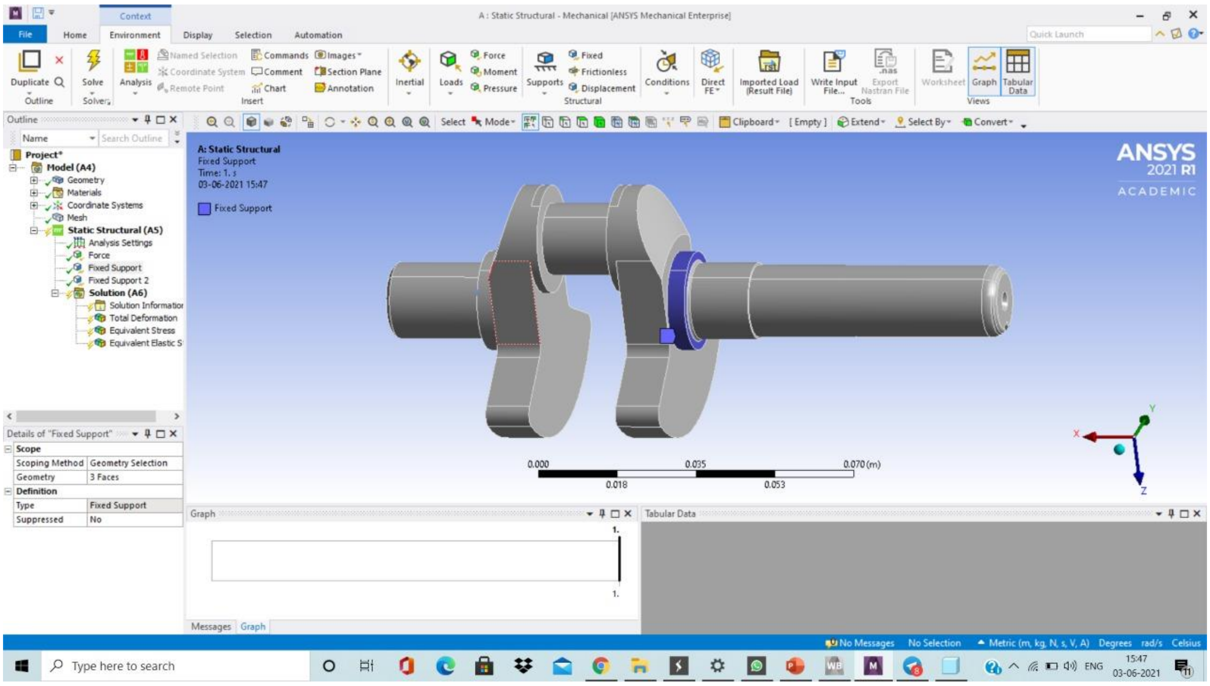
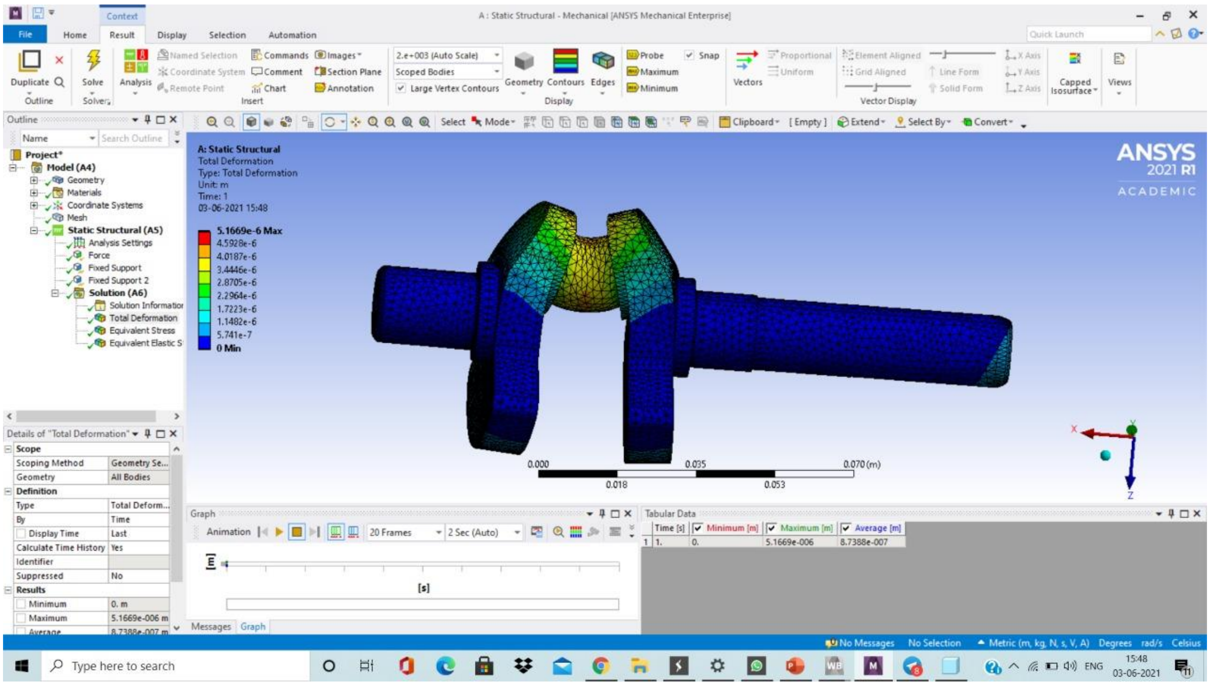


Fig 4.20 Second boundary condition of crank shaft

4.7.1 Analysis of crank shaft for structural steel material



4.21 Total Deformation

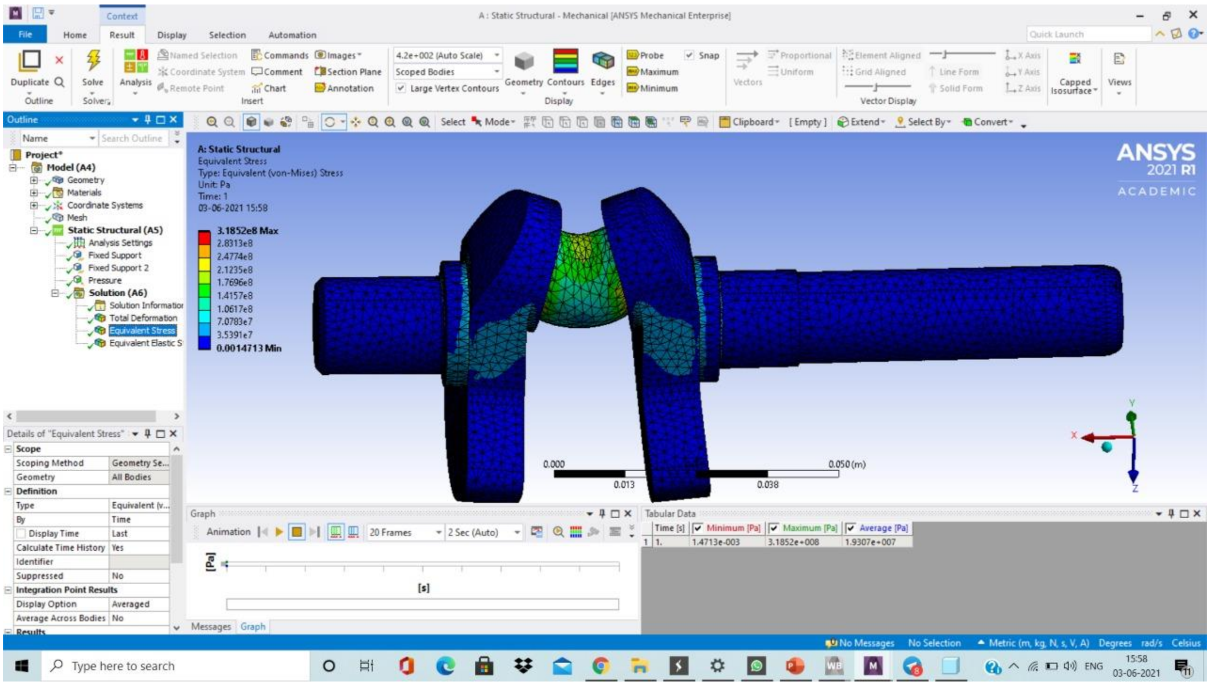


Fig 4.22 Equivalent Von-Mises Stress

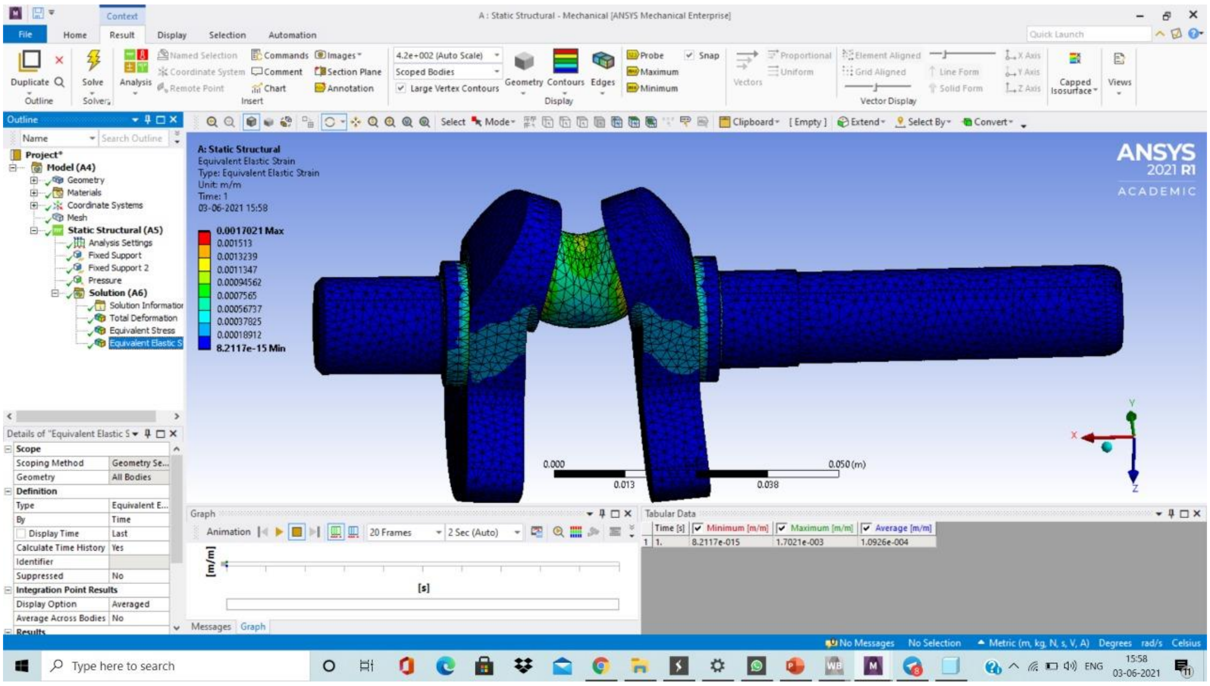
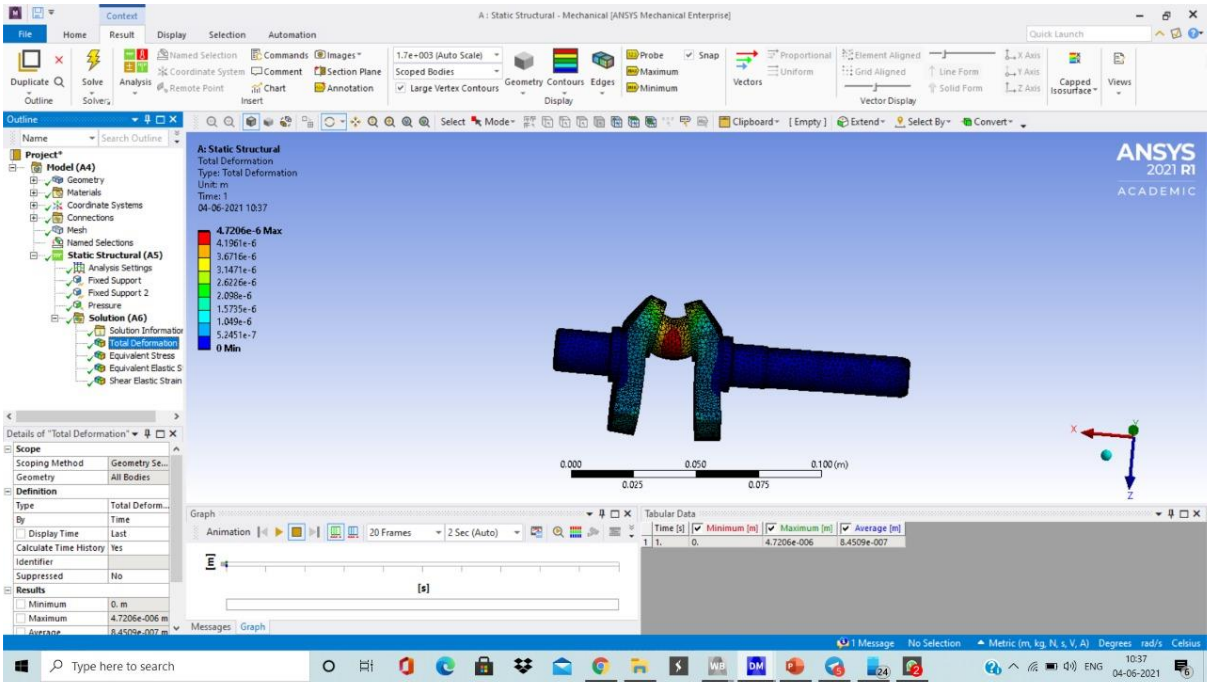


Fig 4.23 Equivalent Elastic Strain

4.7.2 Analysis of crank shaft for composite material Al7075+2%SiC



4.24Total Deformation

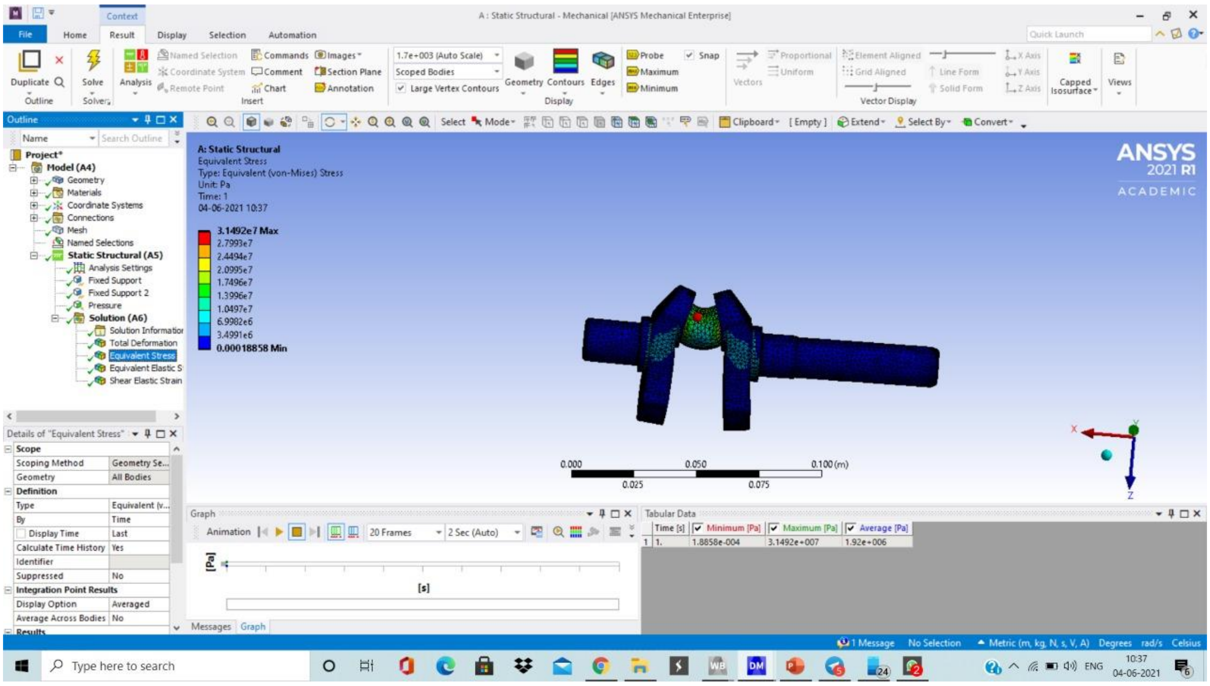


Fig 4.25Equivalent Von-Mises Stress

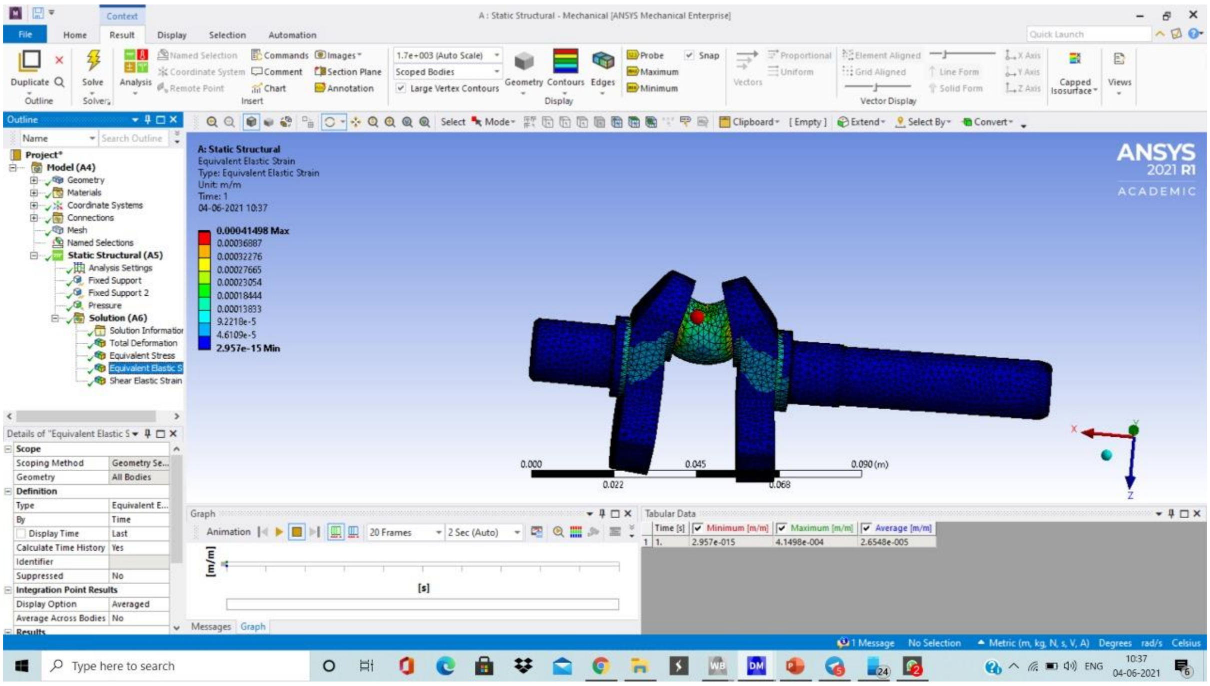
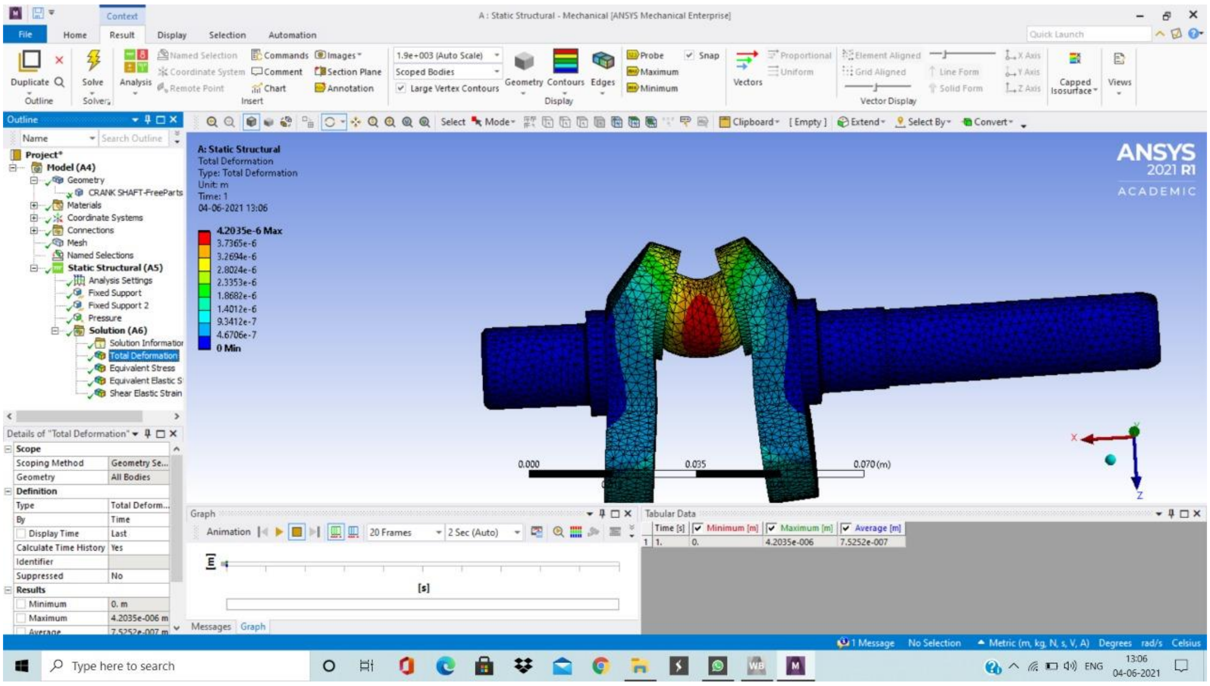


Fig 4.26 Equivalent Elastic Strain

4.7.3 Analysis of crank shaft for composite material Al7075+5%SiC



4.27 Total Deformation

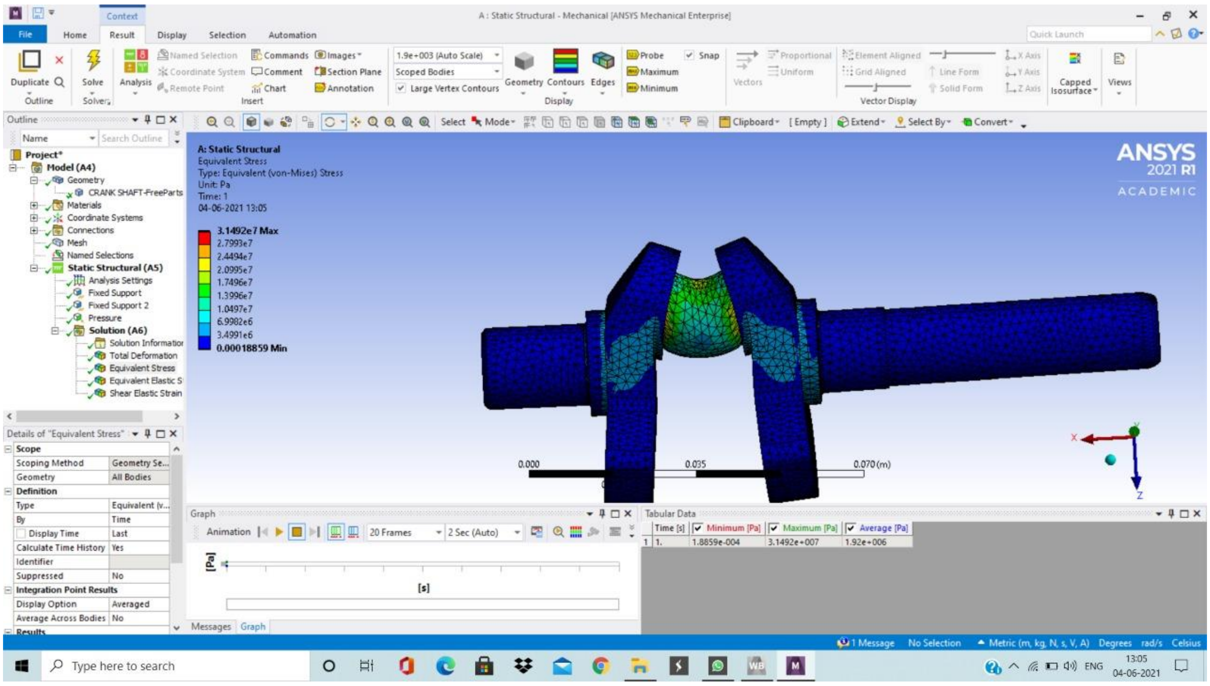


Fig 4.28 Equivalent Von-Mises Stress

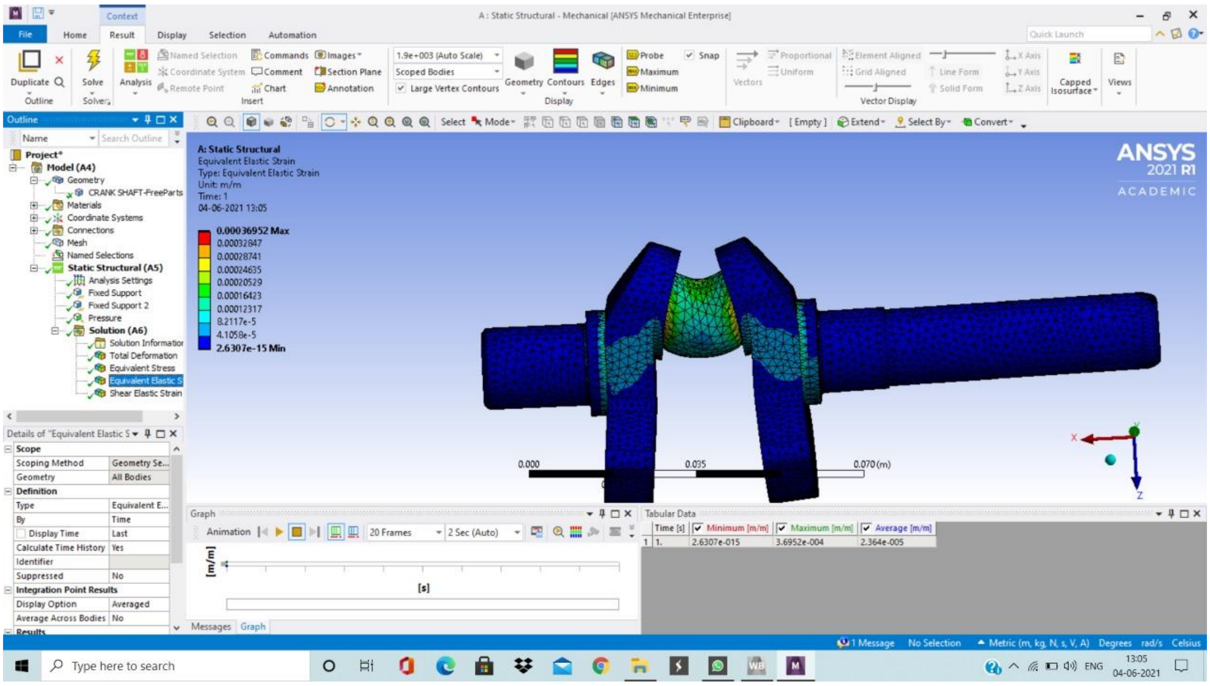


Fig 4.29 Equivalent Elastic Strain

CHAPTER 5

RESULTS AND DISCUSSION

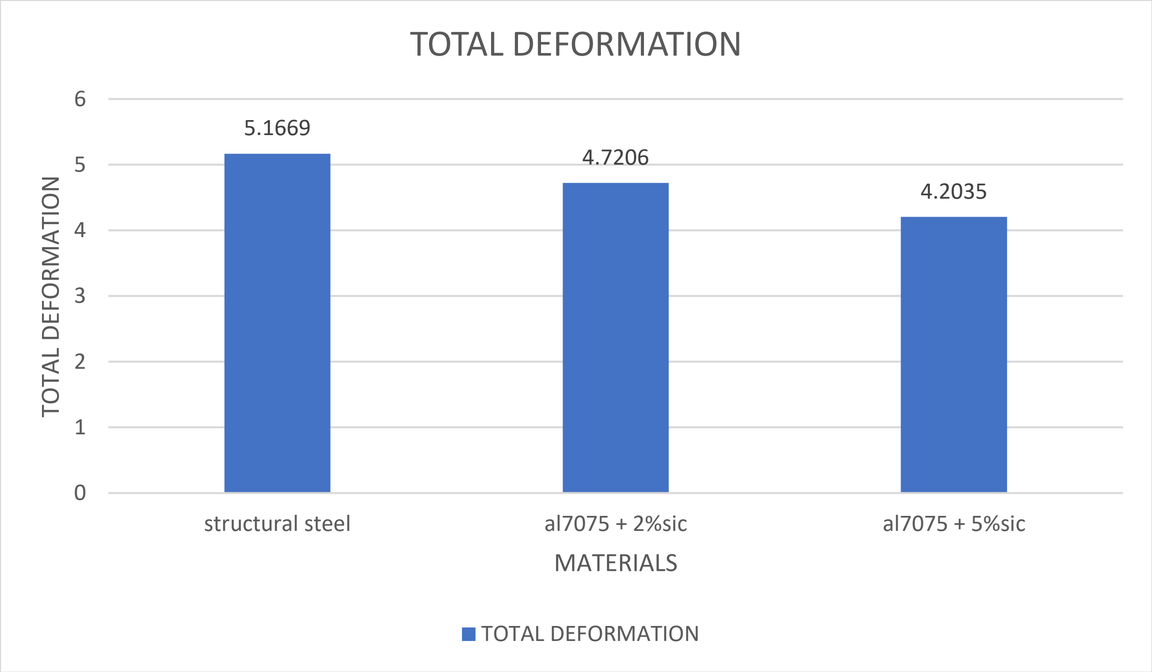
Materials Used For Crankshaft:

- Structural Steel
- Al7075+2%SiC
- Al7075+5%SiC

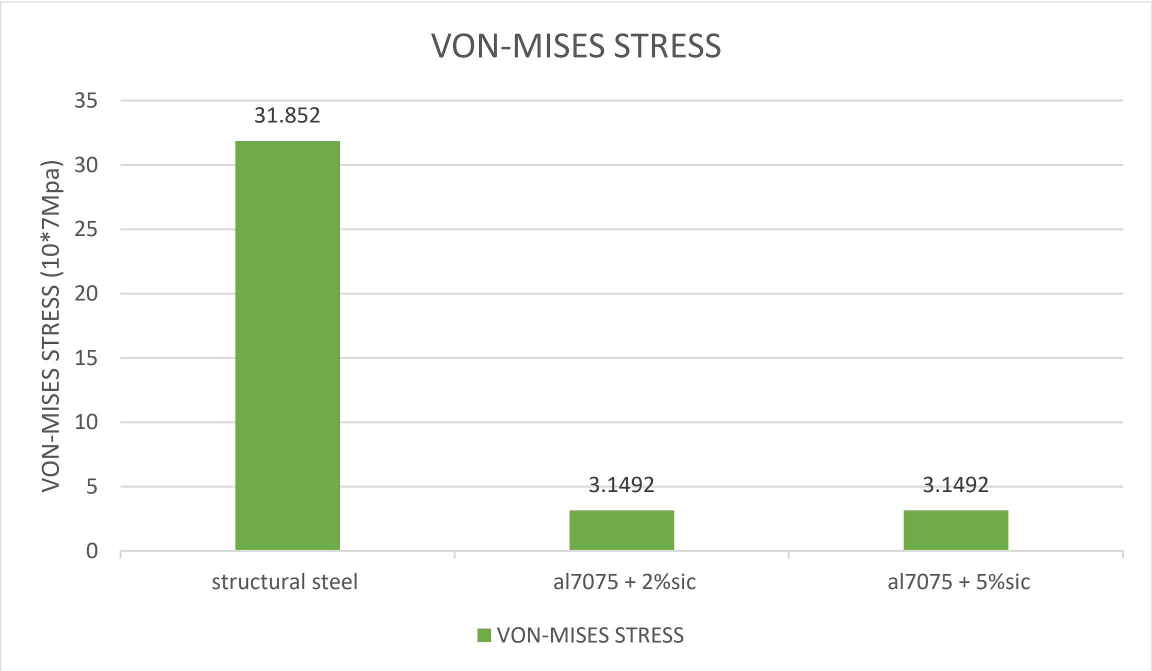
The structural static analysis is conducted on crankshaft by using these different materials .First the analysis is carried out by structural steel then the Parameters like von-mises stresses , deformation, equivalent elastic strain is found . Later the analysis is performed on crankshaft by Al7075+2%SiC and Al7075+5%SiC and above parameters are calculated.

Table 5.1 The obtained parameters are tabulated in the below table:

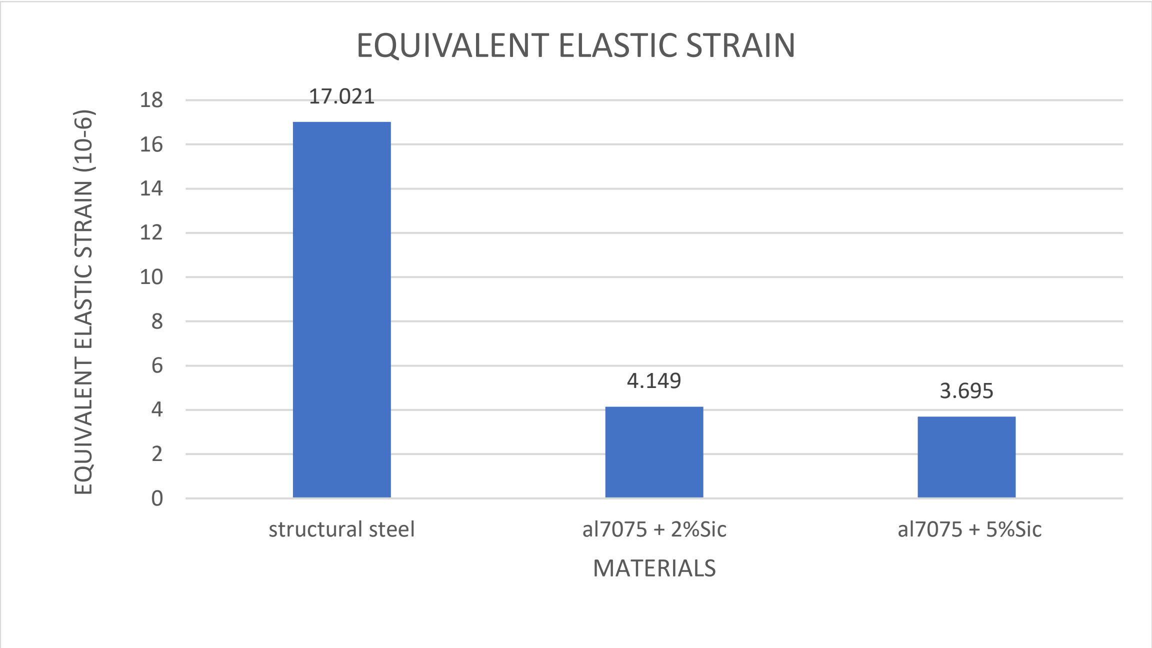
S.NO	MATERIAL	TOTAL DEFORMATION (m)	EQUIVALENT (VON-MISES) STRESS (Pa)	EQUIVALENT ELASTIC STRAIN
1	Steel	5.1669×10^-6	3.1852×10^8	0.0017021
2	Al7075+2%SiC	4.7206×10^-6	3.1492×10^7	0.0004149
3	Al7075+5%SiC	4.2035×10^-6	3.1492×10^7	0.0003695



Bar chart -5.1.1 TOTAL DEFORMATION



Bar chart -5.1.2 VON-MISES STRESS



Bar chart -5.1.3 EQUIVALENT ELASTIC STRAIN

By comparing the structural steel and Al7075+2%SiC from the above results it

Is obtained that the Al7075+2%SiC shows the less deformation, equivalent von-mises stress and strain while comparing to the structural steel.

Then after by increasing the content of percentage composition of Sic i.e.; Al7075+5%SiC Then it shows less deformation and less strain but same stress while comparing to the Al7075+2%SiC

CONCLUSION

1. Crankshaft is designed with three different materials from those three different designs it is concluded that it is very much useful to use Al7075+5%Sic rather than Al7075+2%Sic and structural steel.
2. Al7075+5%Sic and Al7075+2%Sic has got better equivalent stress.
3. The Al7075+5%Sic has shown less deformation and elastic strain when compared with structural steel and Al7075+2%Sic.
4. This Al7075+5%Sic has got less equivalent stress than structural steel.
5. So Al7075+5%Sic is best and convenient composite to be used.

FUTURE SCOPE

Fatigue analysis, vibration analysis and dynamic analysis are to carried out on four stroke single cylinder diesel engine

REFERENCES

1. C.M.Balamurugan.,R.Krishnaraj.,Dr.M.Sakthive.l,K.Kanthave.l,DeepanMarudachalamM.G.,R.Palani.,2011"Computer Aided Modeling and Optimization of Crankshaft, ''International Journal of Scientific & Engineering.
2. Yu Ding and Xiaobo Li.,2011, " Crankshaft Strength Analysis of a Diesel Engine Using Finite Element Method,"
3. Jian Meng., Yongqi Liu., Ruixiang Liu.,2011,"Finite Element Analysis of 4-Cylinder Diesel Crankshaft, " I.J. Image, Graphics and Signal Processing, 5, 22-29.
4. MENG Jian., LIU Yong-qi., LIU Rui-xiang., and ZHENG Bin.,2011,"Intension Analysis of 3-D Finite Element Analysis on 380 diesel crankshaft," International Conference on Computational and Information Sciences.
5. Yu Gongzh.i, Yu Hongliang., Duan Shulin., 2011, "Crankshaft Dynamic Strength Analysis for Marine Diesel Engine," Third International Conference on Measuring Technology and Mechatronics Automation.
6. Gu Yingkui, Zhou Zhibo.,2011,"Strength Analysis of Diesel Engine Crankshaft Based on PRO/E and ANSYS," Third International Conference on Measuring Technology and Mechatronics Automation.
7. Xiaorong Zhou., Ganwei Cai., Zhuan Zhang. Zhongqing Cheng., 2009, "Analysis on Dynamic Characteristics of Internal Combustion Engine Crankshaft System," International Conference on Measuring Technology and Mechatronics Automation.
8. FatiguePerformance Comparison And Life Prediction Of Forged Steel And Ductile Cast Iron Crankshafts," Published in Proceeding of the 27th Forging Industry Technical Conference in Ft.Worth,Texas.
9. Shenoy, P. S. and Fatemi, A., 2006, "Dynamic analysis of loads and stresses in connecting rods,"IMechE, Journal of Mechanical Engineering Science, Vol. 220, No. 5, pp. 615- 624.
10. Zoroufi, M. and Fatemi, A.,2005, "A Literature Review on Durability Evaluation of Crankshafts Including Comparisons of Competing Manufacturing Processes and Cost Analysis", 26th Forging Industry Technical Conference, Chicago.
11. Prakash, V., Aprameyan, K., and Shrinivasa, U.,1998, "An FEM Based Approach to Crankshaft Dynamics and Life Estimation," SAE Technical Paper No. 980565, Society of Automotive Engineers.

12. Payar, E., Kainz, A., and Fiedler, G. A., 1995,“Fatigue Analysis of Crankshafts Using Nonlinear Transient Simulation Techniques,” SAE Technical Paper No. 950709, Society of Automotive Engineers.

13. Referred from M-TECH project “DESIGN AND ANALYSIS OF WHEEL RIM OF SPORT UTILITY VEHICLE USING AL 7075 REINFORCED WITH SIC”