DESIGN AND ANALYSIS OF CRANK SHAFT

[1] MR D. CHANAKYA GUPTA [2] MR CHAITANYA JOSHI. [3] MR B RAMAKRISHNA.

[1] Bachelor of technology, Department of Mechanical Engineering, Mahatma Gandhi institute of technology, Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

2 Bachelor of technology, Department of Mechanical Engineering, Mahatma Gandhi institute of technology Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

[3] Assistant Professor, Department of Mechanical Engineering, Mahatma Gandhi institute of technology Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

ABSTRACT

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.

Crankshaft is one of the critical components for the effective and precise working of the internal combustion engine. In this paper a static simulation is conducted on a crankshaft from a single cylinder 4-stroke diesel engine.

In this project a three- dimensional model of diesel engine crankshaft is created using solid works 2016 design software. Finite element analysis (FEA) is performed on the crank shaft. The static analysis is done using Ansys work bench 14.5 software by applying load and various materials on it and stress strain deformation will be noted as result due to applied load on different materials..

Thus the part which is modelled is converted into igs file to import in ansys work bench and static structural analysis is carried out at 35 MPA of pressure load by applying various materials, materials used in this project are such as aluminum alloy (which is already existing), 42CrMo4 (Special alloy steel), magnesium alloy and Al+B4C (aluminium alloy+ 5% Boron carbide)

1. INTRODUCTION

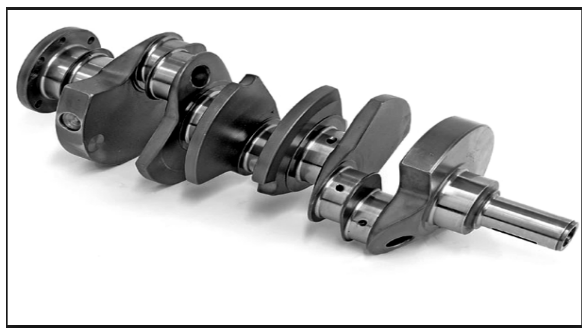


Fig1. Crank shaft

Crank shaft is a large component with a complex geometry in the I.C engine, which converts the reciprocating displacement of the piston to a rotary motion with a four bar link mechanism. Crankshaft consisting of shaft parts, two journal bearings and one crankpin bearing. The Shaft parts which revolve in the main bearings, the crank pins to which the big end of the connecting rod are connected, the crank arms or webs which connect the crank pins and shaft parts. In addition, the linear displacement of an engine is not smooth; as the displacement is caused by the combustion chamber therefore the displacement has sudden shocks. The concept of using crankshaft is to change these sudden displacements to as smooth rotary output, which is the input to many devices such as generators, pumps and compressors. It should also be stated that the use of a flywheel helps in smoothing the shocks.

1.1 Major Forces Applied On Crank Shaft

Crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crank shaft, the force will be transmitted to the crankshaft. The magnitude of the forces depends on many factors which consist of crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin.

Combustion and inertia forces acting on the crankshaft. 1. Torsional load 2.Bending load. Crankshaft must be strong enough to take the downward force of the power stroke without excessive bending so the reliability and life of the internal combustion engine depend on the strength of the crankshaft largely.

The crank pin is like a built in beam with a distributed load along its length that varies with crank positions. Each web is like a cantilever beam subjected to bending and twisting. 1. Bending moment which causes tensile and compressive stresses. 2. Twisting moment causes shear stress.

There are many sources of failure in the engine one of the most common crankshaft failure is fatigue at the fillet areas due to the bending load causes by the combustion. The moment of combustion the load from the piston is transmitted to the crankpin, causing a large bending moment on the entire geometry of the crankshaft. At the root of the fillet areas stress concentrations exist and these high stress range locations are the points where cyclic loads could cause fatigue crank initiation leading to fracture.

1.2 Principle of Crankshaft

A crankshaft is a fundamental feature in a vehicle's engine. It is the system that converts linear energy into rotational energy. This enables the wheels to drive the car forward. All the pistons in the engine are attached to the crank which is also connected to the flywheel. The crank works in association with other engine components to achieve a synchronized motion. This process, which enables the vehicle's engine to run, is explained below.

1.3 Cylinder Arrangement

The crankshaft is found below the cylinders of a vehicle's engine. On V-type engines it is found at the base but on flat engines it is found between the cylinder banks. Motor vehicles may have 3 to 12 cylinders inside the engine although most have four. Inside each cylinder is a piston which moves up and down the cylinder. All the engine's pistons are connected to the crankshaft by individual rods. The cylinders work in concert as well as with other engine parts. This is referred to as the four-stroke cycle and occurs in each of the four cylinders. This cycle is what drives a vehicle's engine.

2. FOUR-STROKE CYCLE

The four strokes refer to intake, compression, power and exhaust. On the intake stroke, the piston starts down as the intake valve opens to allow air and fuel into the cylinder. As soon as the piston arrives at the base of the intake stroke, it triggers closure of the intake valve. The air-fuel mixture is retained in the cylinder. This mixture is compressed severely by the piston as it moves up. The cylinder contents are ignited by the spark plug during which process expansion occurs. The combustion process lowers the piston which turns the crank to yield power to drive the vehicle. The exhaust valve then opens to release the exhaust once the piston gets to the bottom of the cylinder.

3. CRANKSHAFT-CAMSHAFT OPERATIONS

The crank moves the pistons up and down inside the cylinders. The movement of the pistons is regulated by the crank. A component known as the camshaft also ensures that the pistons work properly. Whenever the crank rotates, the camshaft must also rotate along with it. This is because the two components are linked together. The two engine parts have a synchronized movement. When the camshaft rotates it causes the intake and outtake valves to open. This allows a flow of air which is important to cause explosions in the cylinder. Explosions are created inside the cylinders in the engine. The explosions exert pressure on the pistons so that they maintain their movement. These explosions result in movement of the wheels. The moving pistons give rise to jerky movements. The flywheel which is found at the end of the shaft helps to ease the erratic movement. When the shaft moves, it causes the flywheel to adopt a circular motion. Notches in the flywheel help it to achieve a more regular motion. This motion eventually causes the vehicle's wheels to turn since the flywheel is connected to other engine parts.

4. WORKING OF CRANK SHAFT

Power from the burnt gases in the combustion chamber is delivered to the crankshaft through the piston, piston pin and connecting rod. The crankshaft changes reciprocating motion of the piston in cylinder to the rotary motion of the flywheel. Conversion of motion is executed by use of the offset in the crankshaft. Each offset part of the crankshaft has a bearing surface known as a crank pin to which the connecting rod is attached. Crank-through is the offset from the crankshaft centre line. The stroke of the piston is controlled by the throw of the crankshaft. The combustion force is transferred to the crank-throw after the crankshaft has moved past top dead centre to produce turning effort or torque, which rotates the crankshaft. Thus all the engine power is delivered through the crankshaft. The cam-shaft is rotated by the crankshaft through gears using chain driven or belt driven sprockets. The cam-shaft drive is timed for opening of the valves in relation to the piston position. The crankshaft rotates in main bearings, which are split in half for assembly around the crankshaft main bearing journals.

Both the crankshaft and camshaft must be capable of withstanding the intermittent variable loads impressed on them. During transfer of torque to the output shaft, the force deflects the crankshaft. This deflection occurs due to bending and twisting of the crankshaft. Crankshaft deflections are directly related to engine roughness. When deflections of the crankshaft occur at same vibrational or resonant frequency as another engine part, the parts vibrate together. These vibrations may reach the audible level producing a "thumping" sound. The part may fail if this type of vibration is allowed to continue. Harmful resonant frequencies of the crankshaft are damped using a torsional vibration damper. Torsional stiffness is one of the most important crankshaft design requirements. This can be achieved by using material with the correct physical properties and by minimizing stress concentration. The crankshaft is located in the crankcase and is supported by main bearings. Figure 3.62 represents schematic view of a typical crankshaft. The angle of the crankshaft throws in relation to each other is selected to provide a smooth power output. V-8 engines use 90 degree and 6 cylinder engines use 120 degree crank throws. The engine firing order is determined from the angles selected. A crankshaft for a four cylinder engine is referred to a five bearing shaft. This means that the shaft has five main bearings, one on each side of every big end which makes the crankshaft very stiff and supports it well. As a result the engine is normally very smooth and long lasting.

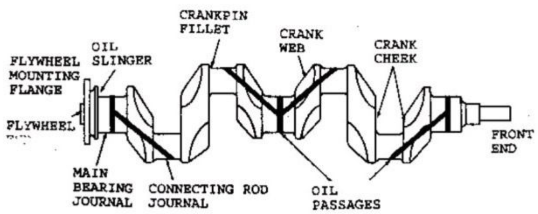


Fig 4.1 Parts Attached To Crank Shaft

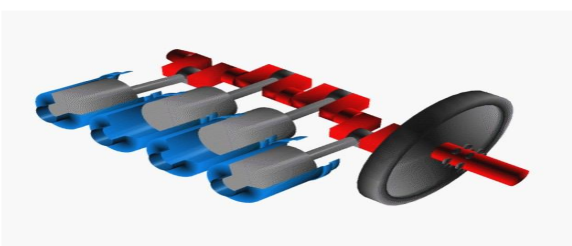


Fig 4.2 Inline cylinder piston arrangement to crank shaft

This Figure describes that how a crankshaft is fitted in a car.Its joining from Cylinders to piston to crankshaft to itself and then to the wheels of the car. Because of the additional internal webs required to support the main bearings, the crank case itself is very stiff. The disadvantages of this type of bearing arrangement are that it is more expensive and engine may have to be slightly longer to accommodate the extra main bearings. Counter weights are used to balance static and dynamic forces that occur during engine operation.Main and rod bearing journal overlap increases crankshaft strength because more of the load is carried through the overlap area rather than through the fillet and crankshaft web. Since the stress concentration takes place at oil holes drilled through the crankshaft journals, these are usually located where the crankshaft loads and stresses are minimal. Lightening holes in the crank throws do not reduce their strength if the hole size is less than half of the bearing journal diameter, rather these holes often increase crankshaft strength by relieving some of the crankshaft's natural stress. Automatic transmission pressure and clutch release forces tend to push the crankshaft towards the front of the engine. Thrust bearings in the engine support this thrust load as well maintain the crankshaft position. Thrust bearings may be located on any one of the main bearing journals. Experience shows that the bearing lasts much longer when the journal is polished against the direction of normal rotation than if polished in the direction of normal rotation. Most crankshafts balancing is done during manufacture by drilling holes in the counterweight to lighten them. Sometimes these holes are drilled after the crankshaft is installed in the engine.

5. CRANK SHAFT MECHANISM:

A crank is an arm attached at right angles 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.

6. CRANK SHAFT DESIGN SPECIFICATION (For single cylinder)

Design of crankshaft when the crank is at an angle of maximum twisting Moment

Force on the Piston F_p = Area of the bore x Max. Combustion pressure = $^{\pi}$ x D^2 x P_{max} = 14.52 KN

In order to find the thrust in the connecting rod (F_Q), we should first find out the angle of inclination of the connecting rod with the line of stroke (i.e. angle Ø).

We know that

$$\text{Sin } \emptyset = \frac{\text{Sin } \theta}{(L/R)} = \sin 35^0/4$$

Which implies Ø = 8.24°

We know that thrust in the connecting rod

$$F_Q = \frac{FP}{\cos \emptyset}$$

From this we have,

Thrust on the connecting rod F_Q KN

Thrust on the crank shaft can be split into Tangential component and the radial component.

1) Tangential force on the crank shaft, FT = F_Q sin (θ+ Ø) KN

2) Radial force on the crank shaft, $F_R = F_Q \cos(\theta + \emptyset)$ KN

Reactions at bearings (1 & 2) due to tangential force is given by

$H_{T1=}H_{T2}$= (FT*b_1)/b KN (Since b1=b2=b/2)

Similarly, Reactions at bearings (1 & 2) due to radial force is given by,

$H_{R1=}H_{R2}$= (FR*b_1)/b KN (Since b1=b2=b/2)

Design of crankpin

Let dc = Diameter of crankpin in mm. We know that the bending moment at the centre of the crank pin

Mc = HR1 x b2 KN-mm

From this we have the equivalent twisting moment

Te = $\sqrt{(Mc^2 + Tc^2)}$

We know that equivalent twisting moment (Te)

Te = $(\pi/16)*(d_c)\ 3 * \tau$

7. DESIGNING OF A CRANK SHAFT ROD BY USING SOLID WORKS

7.1 Introduction to Solidworks:

Solidworks mechanical design automation software is a feature-based, parametric solid modelling design tool which advantage of the easy to learn windows TM graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent

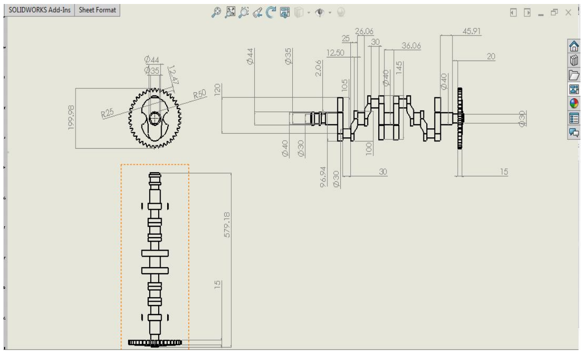
A Solid Works model consists of parts, assemblies, and drawings.

- Typically, we begin with a sketch, create a base feature, and then add more features to the model. (One can also begin with an imported surface or solid geometry).
- We are free to refine our design by adding, changing, or reordering features..

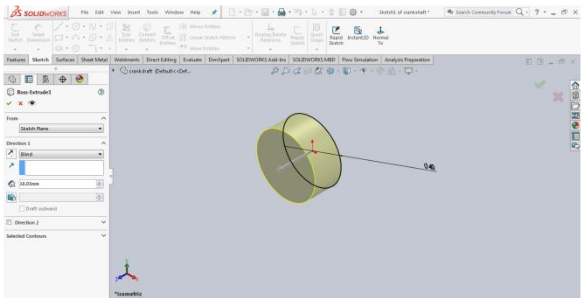
7.2 Design procedure of Crank shaft

For designing the Crank shaft the following procedure has to be follow

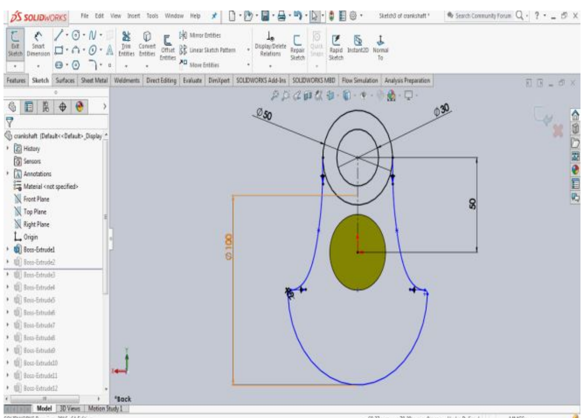
Dimensions of crank shaft



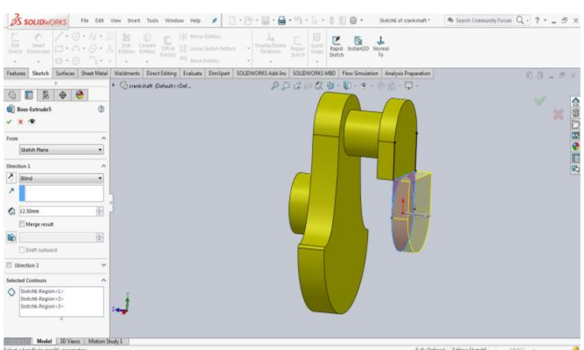
First early draw a circle and extrude



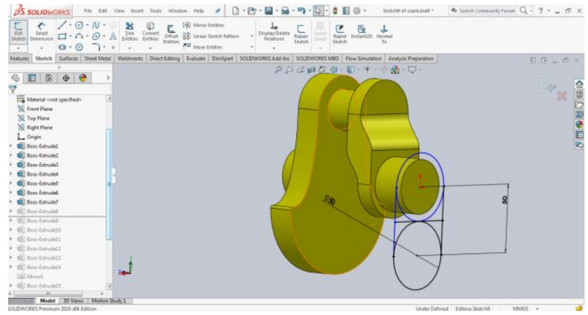
Then select the face and draw the following sketch



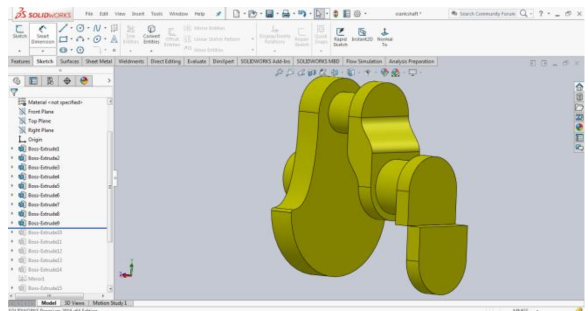
Draw below part drawing and make extrude it as follows upto 12.50mm



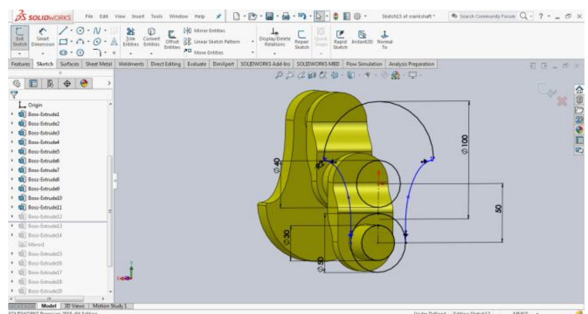
Draw sketch and extrude



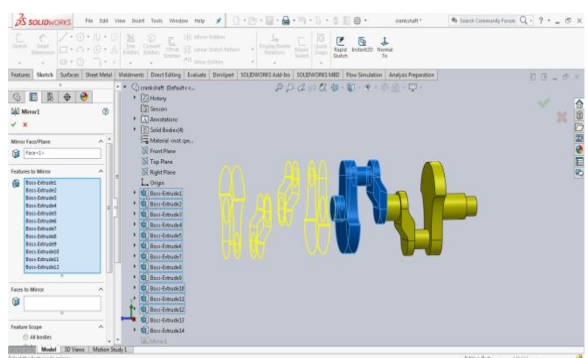
The go to features and extrude the above part then again draw the below and make extrude as above



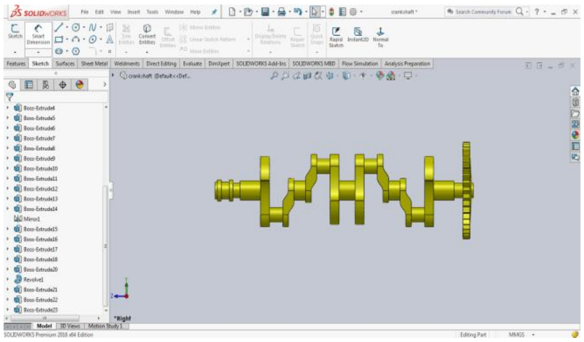
Select the face and draw the following sketch as follows and extrude.



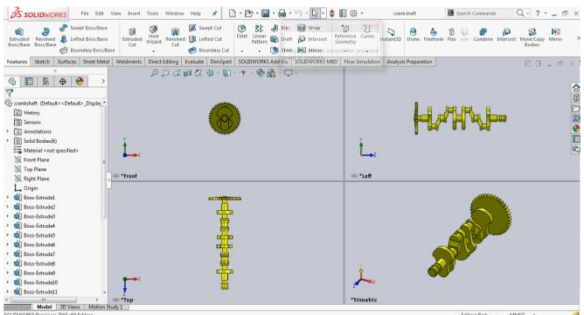
Now go to features and make mirror the remaining part as follows



Model of crank shaft



Four views of crank shaft



8. ANALYSIS DEFINATION & STEPS:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties.
- Specify restraints and loads.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.
- View results.

8.1 Analysis on crank shaft by using ansys 14.5 work bench software

The analysis of crank shaft models is carried out using ANSYS software using Finite Element Method. Firstly the model files prepare in the SOLIDWORKS SOFTWARE.

Then are exported to ANSYS software as an IGES files as shown in figure

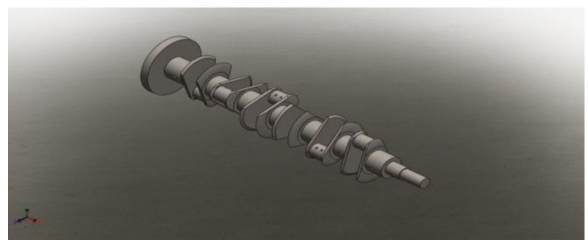


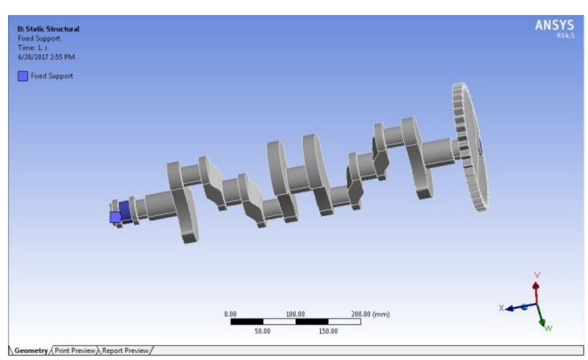
Fig 8.1 Crank shaft model

8.2 Materials and their properties

Material	Density (kg/m³)	Young's modulus (Mpa)	Poison's ratio	Bulk modulus (Mpa)	Shear modulus (Mpa)
Aluminum alloy	2770	71000	0.33	69608	26692
42CrMo4	7830	2.1E+05	0.30	1.75E+05	80769
Magnesium alloy	1800	45000	0.35	50000	16667
Al+B4C	2680	1.97E+05	0.32	1.8241E+05	74621

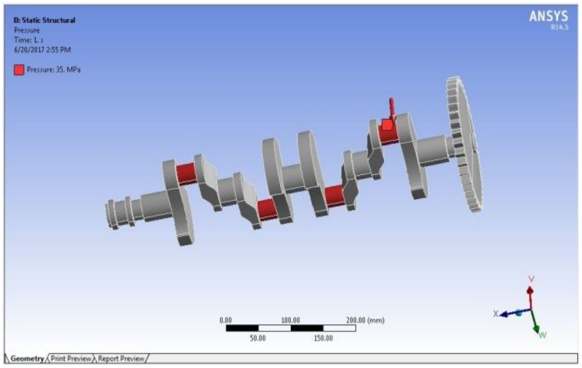
8.3 Load & fixed support

• Fixed support



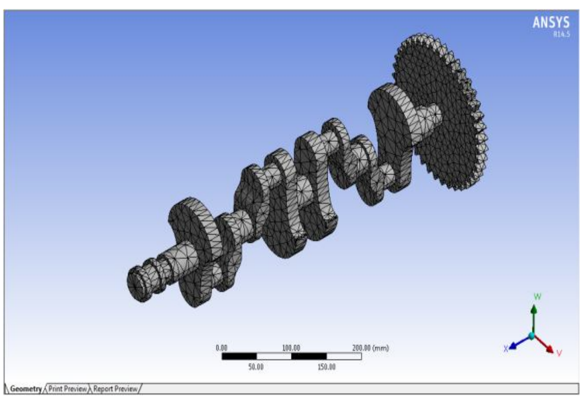
• Load

Load at 35 MPA



8.4 Meshing

Meshing is probably the most important part in any of the computer simulations, because it can show drastic changes in results you get. Meshing means you create a mesh of some grid-points called 'nodes'. It's done with a variety of tools & options available in the software. The results are calculated by solving the relevant governing equations numerically at each of the nodes of the mesh. The governing equations are almost always partial differential equations, and Finite element method is used to find solutions to such equations. The pattern and relative positioning of the nodes also affect the solution, the computational efficiency & time.



Mesh Type: Tetrahedral

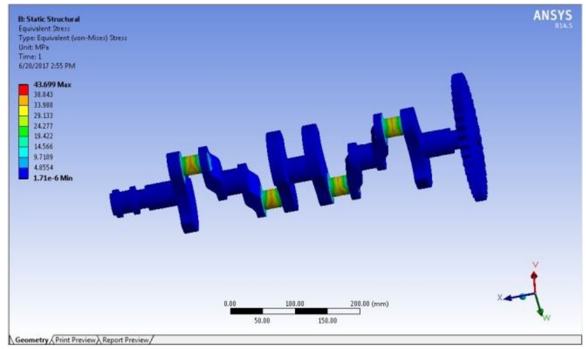
No. of nodes: 16722

No. of elements: 8575

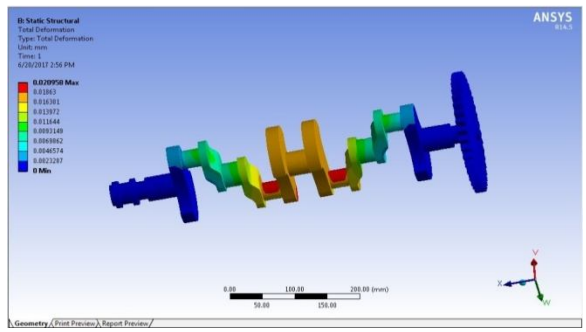
9. STRUCTRUAL ANALYSIS RESULTS

9.1 Material: Aluminium Alloy

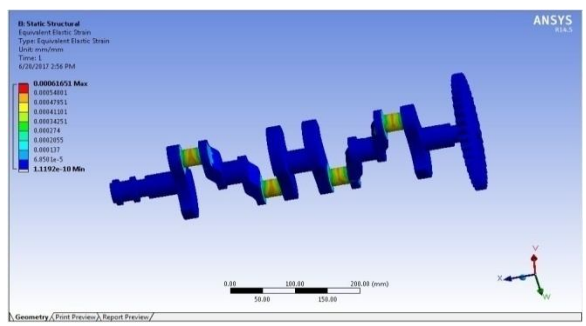
Maximum Stress



Total Deformation

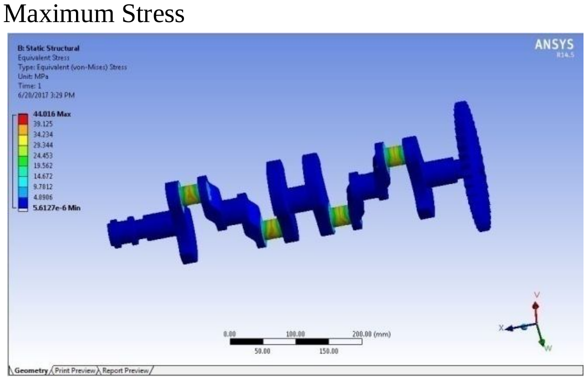


Maximum Strain

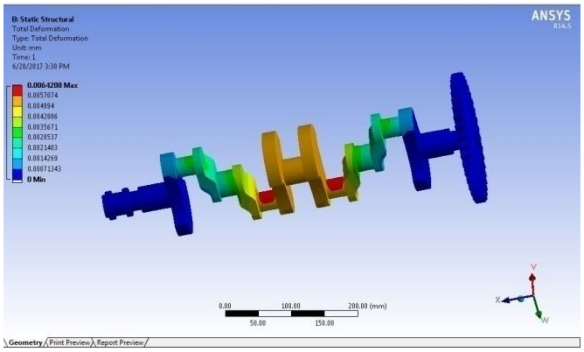


9.2 Material: 42CrMo4

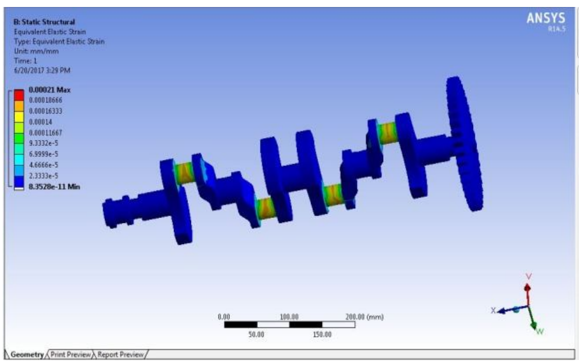
Maximum Stress



Total Deformation

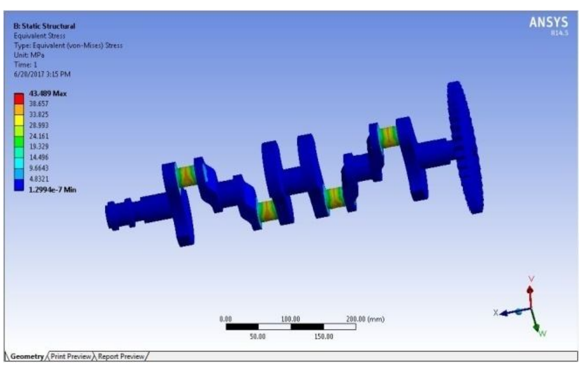


Maximum Strain

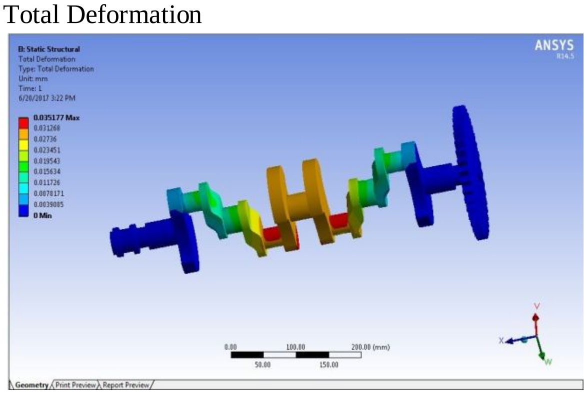


9.3 Material: Magnesium alloy

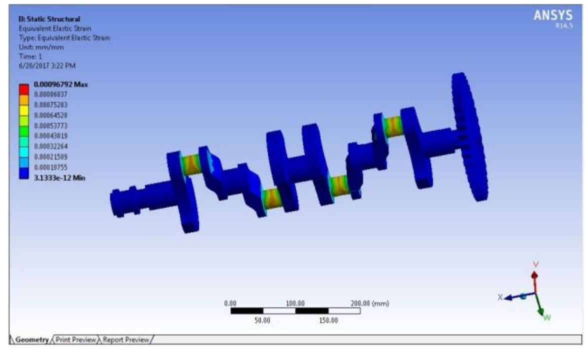
Maximum Stress



Total Deformation

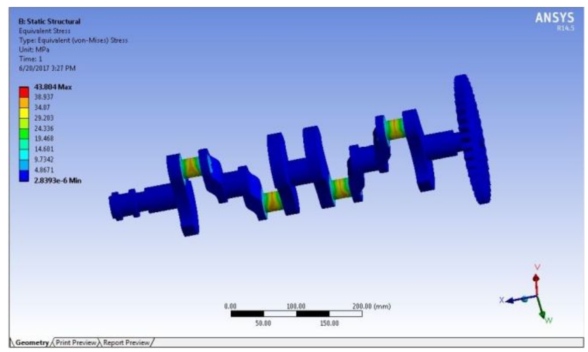


Maximum Strain

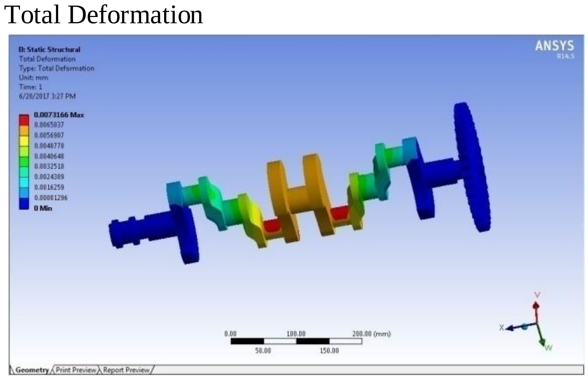


9.4 Material: Al+B4C (Aluminium alloy+5% Boron carbide)

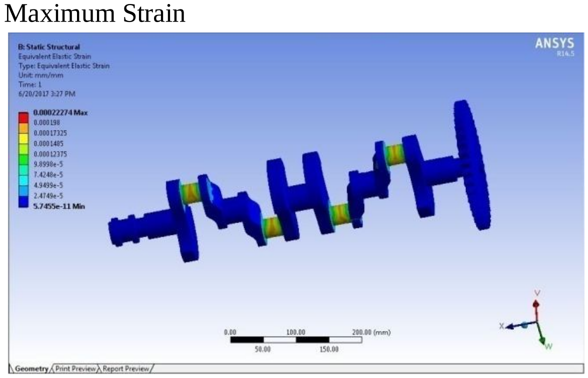
Maximum Stress



Total Deformation



Maximum Strain



RESULT TABLE

Materials	Stress (mpa)	Strain	Deformation(mm)
Aluminium alloy	43.699	0.00061651	0.020958
42CrMo4	44.016	0.00021	0.0064208
Magnesium alloy	43.489	0.00096792	0.035177
Al+B4C	43.804	0.00022274	0.0073166

CONCLUSION

- Brief study about crank shaft , construction & it's working principle is done in this project
- Modelling and analysis of crank shaft is done by given dimension
- Modelling of connecting rod is done in solid works 2016 design software by using various commands.
- The file is saved as igs to import in ansys workbench
- The analysis in ansys is extremely important prior to the fabrication of crank shaft.
- The static structural, has carried out in the ansys 14.5 software package for crank shaft by different materials like aluminium alloy,42CrMo4 (special steel alloy) and magnesium alloy and Al+B4C(aluminium alloy+5%Boran carbide)
- The utmost stress, strain and deformation values of static analysis are tabulated on load condition of 35 MPA.
- From result we conclude that on given load condition of 35MPA Magnesium alloy showing the least stress value compare to other materials.
- Mean while magnesium alloy has least weight ratio compare to other three materials.
- Hence the materials with low stress values and least weight ratio i.e. magnesium alloy is preferable for the fabrication of connecting rod.
- Design and analysis of crank shaft is done.

REFERENCES

[1.] Rincle Garg, Sunil Baghla, "Finite element analysis and optimization of crankshaft", International Journal of Engineering and Management Reaserch, vol-2,Issue-6,ISSN: 2250-0758, Pages:26-31, December 2012.

[2.] C.M Balamurugan, R. Krishnaraj, Dr.M.sakhivel, K.kanthavel, Deepan Marudachalam M.G, R.Palani, "Computer Aided modelling and optimization of Crankshaft", International Journal of scientific and Engineering Reaserach, Vol-2, issue-8, ISSN:2229-5518, August-2011.

[3.] Gu Yingkui, Zhou Zhibo, "Strength Analysis of Diesel Engine Crankshaft Based on PRO/E and ANSYS", Third International Conference on Measuring Technology and Mechatronics Automation, 2011.

[4.] Abhishek choubey, Jamin Brahmbhatt, "Design and Analysis of Crankshaft for single cylinder 4-stroke engine", International Journal of Advanced Engineering Reaserch and studies, vol-1, issue-4, ISSN:2249-8974, pages: 88-90, July-sept 2012.

[5.] R.J Deshbhratar, Y.R Suple, " Analysis and optimization of Crankshaft using FEM", International Journal of Modern Engineering Reasearch, vol-2, issue-5, ISSN:2249-6645, pages:3086-3088, Sept-Oct 2012.

[6.] Farzin H. Montazersadgh and Ali Fatemi " Stress Analysis and Optimization of Crankshafts Subjected to Dynamic Loading", AISI, August 2007.

[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]. Farzin H. Montazersadgh and Ali Fatemi., 2007,"Dynamic Load and Stress Analysis of a Crankshaft," SAE Technical Paper No. 010258, Society of Automotive Engineers

[9]. Jonathan Williams, Farzin Montazersadgh, and Alifatemi.,2007, "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

[10]. 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

[11]. 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,

[12]. 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

[13]. 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

[14]. Guagliano, M., Terranova, A., and Vergani, L., 1993,"Theoretical and Experimental Study of the Stress Concentration Factor in Diesel Engine Crankshafts, "Journal of Mechanical Design, Vol. 115, pp. 47-52

[15]. Henry, J., Topolsky, J., and Abramczuk, M., 1992,"Crankshaft Durability Prediction – A New 3-D Approach," SAE Technical Paper No. 920087, Society of Automotive Engineers

[16]. Stephens, R. I., Fatemi, A., Stephens, R. R., and Fuchs, H. O., 2001, "Metal Fatigue in Engineering,"2nd edition, John Wiley and Sons, New York, NY,USA co.

AUTHERS:

MR D. CHANAKYA GUPTA.

Bachelor of technology, Department of Mechanical Engineering, Mahatma Gandhi institute of technology, Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

Mobile: +918977686444

E.mail:Chanz.dontula9966@gmail.com

MR CHAITANYA JOSHI.

Bachelor of technology, Department of Mechanical Engineering, Mahatma Gandhi institute of technology

Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

Mobile: +918897562324

E.mail:chaitanyajoshi1996@gmail.com

MR B. RAMAKRISHNA.

Assistant Professor, Department of Mechanical Engineering, Mahatma Gandhi institute of technology, Gandipet Main Rd, Kokapet, Hyderabad, Telangana 500075

Mobile: +919985123955