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Modelling and Thermal Analysis of Four Stroke Four Cylinder IC Engine by using ANSYS

Singu Srinivas[1], Rangu Mohan[1], Shaik Mahaboob Subhani[1], Devarapu Ganesh[1], Podili venkata veera vasu[1] , Shaik Chand Mabhu Subhani[2]

[1]Department of Mechanical Engineering, Eswar College of Engineering, Narasaraopet, AP.
[2] Assistant Professor, Dept of Mechanical Engineering, Eswar College of Engineering, Narasaraopet, AP.

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ABSTRACT

A cylinder engine body is an integrated structure comprising the cylinder(s) of a reciprocating engine and often some or all of their associated surrounding structures. The present aim of the project is to study the effect of the materials being used for the Piston, Connecting rod and Crank Shaft assembly for an engine of a four wheeler vehicle. The engine speed was desired to be increased. The effect of the materials used for the assembly and its behavior was required to be studied. The parts piston, connecting rod and crankshaft are designed using theoretical calculations. The designed parts are modeled and assembled in 3D modeling software (Catia). The Finite Element Analysis is done in Ansys.

The FE Analysis involves structural and analysis of the assembly. The parts of the assembly should be rigid. And, when they are connected together, they should perform as a mechanism. This requires calculation of the forces acting on the components and the dynamic stresses. As the assembly will be working under high temperatures, so thermal analysis also has to be done.

From the results, it is observed that a change in the piston material will allow the engine to operate at the new high speed. Modelling assembly of 4-stroke 4-cylinder IC Engine components took place in Catia V5 R19 and thermal analysis of Engine is in ANSYS WORKBENCH 2019 R3. In this thermal analysis thermal stresses and heat flux were determined. Basic materials used are Aluminum alloy, Titanium alloys, magnesium alloys and stainless steel for I.C. engine components. The comparison of a study among those materials was taken place.

KEYWORDS: Engine components, IC engine, CATIA v5, ANSYS, Thermal analysis

1. INTRODUCTION

An **internal combustion engine** (**ICE**) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high- pres-sure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

The first commercially successful internal combustion engine was created by Étienne Lenoir around 1859[1] and the first modern internal combustion engine was created in 1876 by Nikolaus Otto (see Otto engine).

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with vari-ants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal com-bustion engines use continuous combustion: gas turbines, jet engines and most
Rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine.

4-Stroke IC engine is reciprocating type whose base is engine block. The engine block contains cylinder and inside that cylinder piston, and crankshaft are connected by connecting rod. The con-necting rod is held in position by piston pin or gudgeon pin. One working cycle consists of 2 revolutions of crankshaft of 4 strokes of the piston.

These strokes are
1. Suction Stroke
2. Compression stroke
3. Expansion Stroke
4. Exhaust Stroke

2. LITERATURE REVIEW

Rudolf Diesel was born in Paris in 1858. His parents were Bavarian immigrants. Rudolf Diesel was educated at Munich Polytechnic. After graduation he was employed as a refrigerator engineer. However, his true love lay in engine design. Rudolf Diesel designed many heat engines, including a solar-powered air engine. In 1893, he published a paper describing an engine with combustion within a cylinder, the internal combustion engine.

In 1894, he filed for a patent for his new invention, dubbed the diesel engine. Rudolf Diesel was almost killed by his engine when it exploded. However, his engine was the first that proved that fuel could be ignited without a spark. He operated his first successful engine in 1897.In 1898, Rudolf Diesel was granted patent #608,845 for an "internal combustion engine" the Diesel engine. The diesel engines of today are refined and improved versions of Rudolf Diesel's original concept. They are often used in submarines, ships, locomotives, and large trucks and in electric generating plants.

Though best known for his invention of the pressure-ignited heat engine that bears his name, Rudolf Diesel was also a well-respected thermal engineer and a social theorist. Rudolf Diesel's inven-tions have three points in common: They relate to heat transference by natural physical processes or laws; they involve markedly creative mechanical design; and they were initially motivated by the inventor's concept of sociological needs. Rudolf Diesel originally conceived

Solanki et al. [6] presented literature review on crankshaft design and optimization. The ma-terials, manufacturing process, failure analysis, design consideration etc. were reviewed. The design of the crankshaft considers the dynamic loading and the optimization can lead to a shaft diameter satisfying the requirements of the automobile specifications with cost and size effectiveness. They con-cluded that crack grows faster on the free surface while the central part of the crack front becomes straighter. Fatigue is the dominant mechanism of failure of the crankshaft.

Residual imbalances along the length of the crankshafts are Crucial to performance. Meng et al. [7] discussed the stress analysis and modal analysis of a 4-cylinder crankshaft. FEM software ANSYS was used to analyze the vibration modal and distortion and stress status of crank throw.

The relationship between frequency and the vibration modal was explained by the modal anal-ysis of crankshaft. This provides a valuable theoretical foundation for the optimization and improvement of engine design. Maximum deformation appears at the Centre of the crankpin neck surface. The maximum stress appears at the fillet between the crankshaft journal and crank cheeks, and near the central point journal. The crankshaft deformation was mainly bending deformation was mainly bending deformation under the lower frequency. Maximum deformation was located at the link between main bearing journal and crankpin and crank cheeks. So, the area prone to appear the bending fatigue crack.

Monetizers' and Fatemi [8] choose forged steel and a cast iron crankshaft of a single cylinder four stroke engine. Both crankshafts were digitized using a CMM machine. Load analysis was per-formed and verification of results by ADAMS modeling of the engine. At the next step, geometry and manufacturing cost optimization was performed. Considering torsional load in the overall dynamic loading conditions has no effect on von-mises stress at the critically stressed location. Experimental stress and FEA results showed close agreement, within 7% difference. Critical locations on the crank-shaft are all located on the fillet areas because of high stress gradients in these locations. Geometry optimization results in 18% weight reduction of the forged steel.

3. MODELLIMG AND ASSEMBLY OF I.C ENGINE COMPONENTS USING CATIA

The piston is designed according to the procedure and specification which are given in ma-chine design and data hand books. The dimensions are calculated in terms of SI Units. The pressure applied on piston head, temperatures of various areas of the piston, heat flow, stresses, strains, length, diameter of piston and hole, thicknesses, etc., parameters are taken into consideration

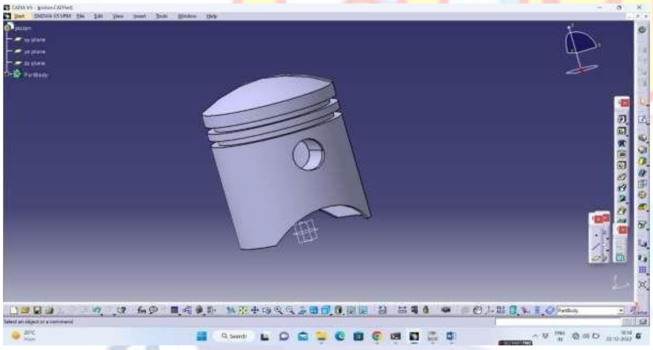


Fig1: Modeling of piston in catia

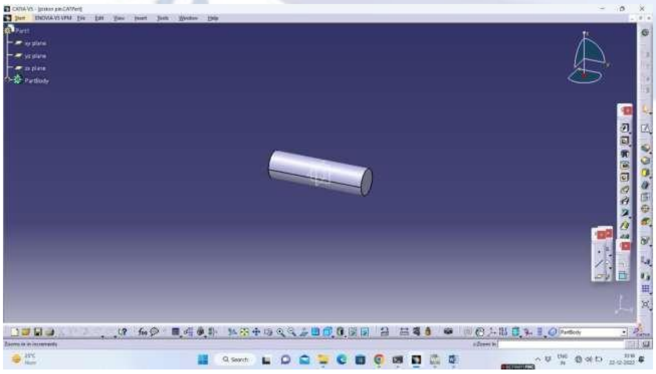
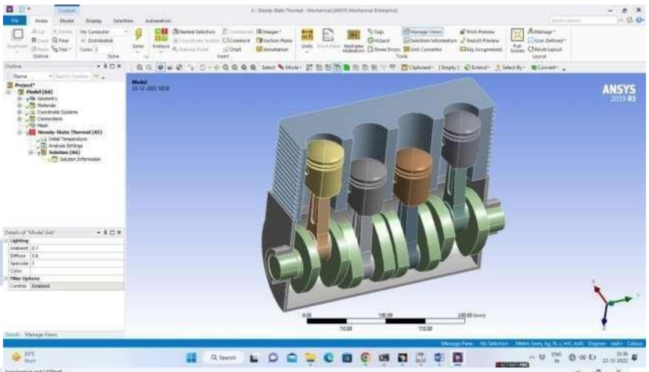
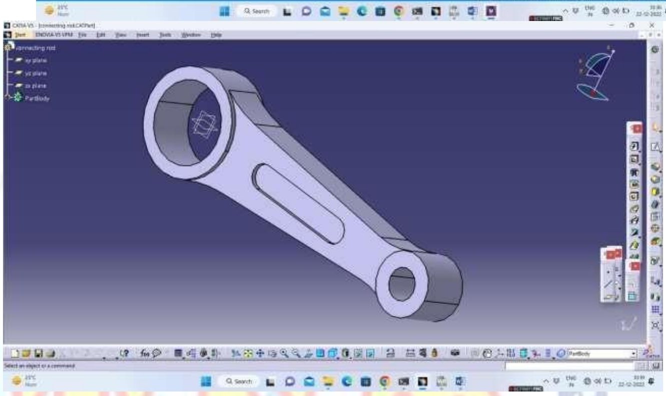


Fig.2: Engine cylindrical pin in catia v Connecting rod





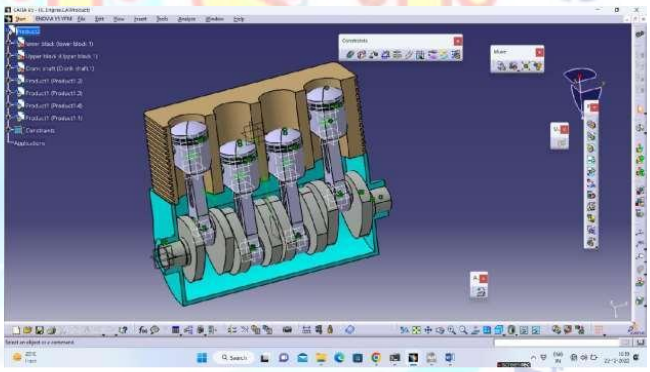


Fig:3 Connecting rod in catia v5

Fig.no.4: Assembly of a connecting rod and piston

Figno5: Assembly of ic engine

4. RESULTS AND DISCUSSION

Ansys Launch Workbench from the Start menu and drag the Geometry module from the Toolbox into the Project Schematic. Then double-click on Geometry to open the Design Modeler window. To import your femur model, click on File > Import External Geometry File

Select your femur IGES file. Click on Generate to complete the import. This step may take a while because of the large number of triangles in your model. You should see the figure to the right. When working with a biomedical implant, the normal steps would be to create the geometry in Solid-Works, then export the part as an IGES file. For this tutorial, a femoral implant is provided on the website. Download this file to your directory. Import the FemoralImplant.IGS model using the same steps as before. Click on Generate to complete the import.

Fig no 6: Imported geometry from catiav5

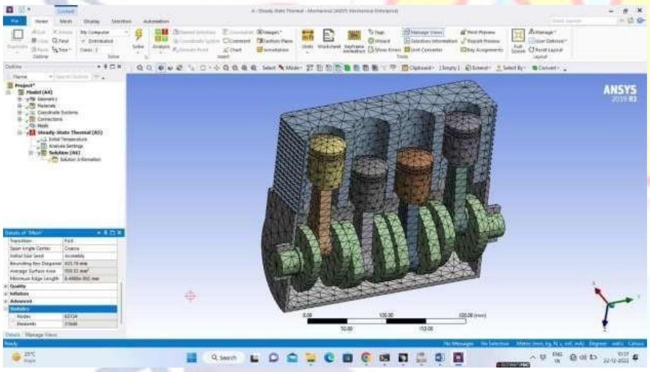


Fig no 7:Meshed body in ansys

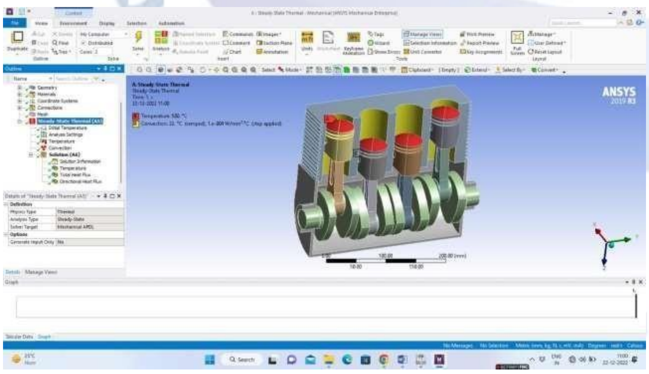


Fig no 8: Boundary conditions

4.1 TYPES OF MATERIALS

The Different Types of Materials Are Use In Analysis

1. Titanium Alloy
2. Stainless Steel
3 Magnesium Alloy
4 Aluminum Alloy

4.2 TITANIUM ALLOY

Titanium Alloy	
Density	4.62e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	96000 MPa
Poisson's Ratio	0.36
Bulk Modulus	1.1429e+05 MPa
Shear Modulus	35294 MPa
Isotropic Secant Coefficient of Thermal Expansion	9.4e-06 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	930 MPa
Tensile Ultimate Strength	1070 MPa
Tensile Yield Strength	930 MPa
Thermal	
Isotropic Thermal Conductivity	0.0219 W/mm·°C
Specific Heat Constant Pressure	5.22e+05 mJ/kg·°C
Electric	
Isotropic Resistivity	0.0017 ohm·mm

Table 1: Material properties of titanium alloy

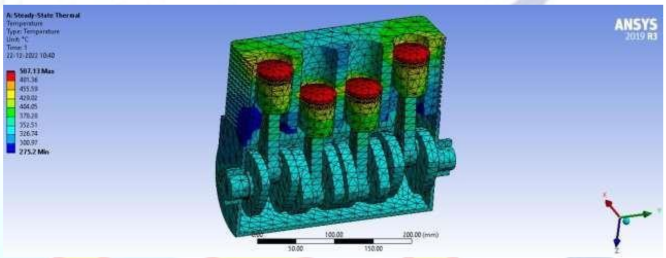


Fig 9: Total heat flux of titanium alloy

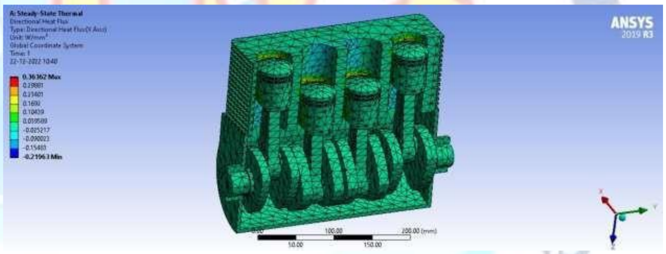


Fig10: Directional heat flux of titanium alloy

4.3 STAINLESS STEEL

Stainless Steel	
Density	7.75e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.93e+05 MPa
Poisson's Ratio	0.31
Bulk Modulus	1.693e+05 MPa
Shear Modulus	73664 MPa
Isotropic Secant Coefficient of Thermal Expansion	1.7e-05 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	207 MPa
Tensile Ultimate Strength	586 MPa
Tensile Yield Strength	207 MPa
Thermal	
Isotropic Thermal Conductivity	0.0151 W/mm·°C
Specific Heat Constant Pressure	4.8e+05 mJ/kg·°C
Electric	
Isotropic Resistivity	0.00077 ohm·mm

table 5.3 material properties of stainless steel

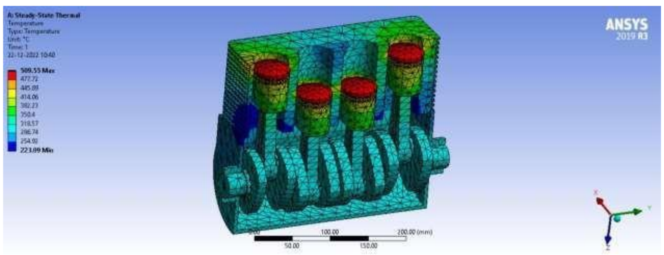


Fig.11: Temperature of stainless steel

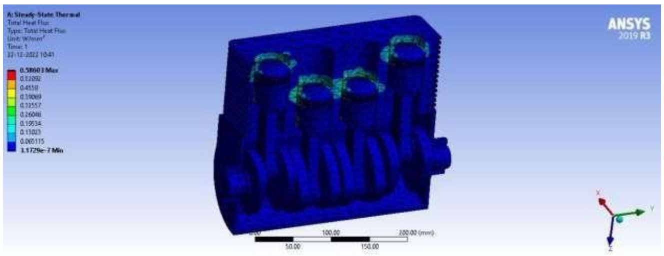


Fig.12: Total heat flux of stainless steel

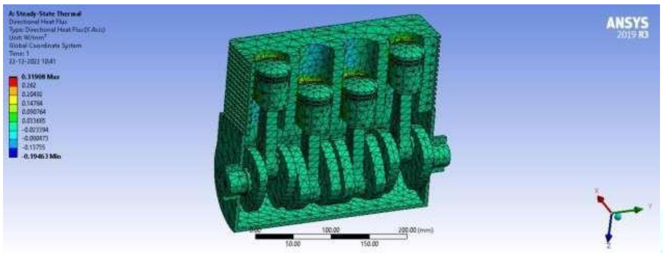


Fig.13: Directional heat flux of stainless steel

4.4 MAGNESIUM ALLOY

Magnesium Alloy

Density	1.8e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	45000 MPa
Poisson's Ratio	0.35
Bulk Modulus	50000 MPa
Shear Modulus	16667 MPa
Isotropic Secant Coefficient of Thermal Expansion	2.6e-05 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	193 MPa
Tensile Ultimate Strength	255 MPa
Tensile Yield Strength	193 MPa
Thermal	
Isotropic Thermal Conductivity	0.156 W/mm·°C
Specific Heat Constant Pressure	1.024e+06 mJ/kg·°C
Electric	
Isotropic Resistivity	0.00077 ohm-mm

Table 2 :Material properties of magnesium alloy

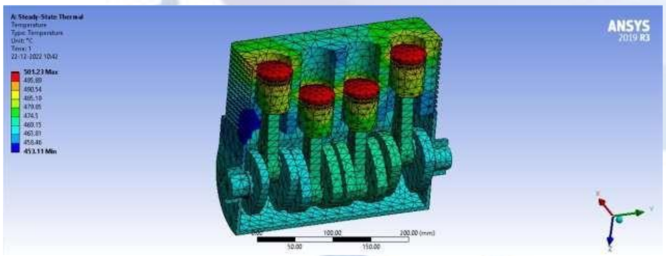


Fig 14 :Temperature of magnesium alloy

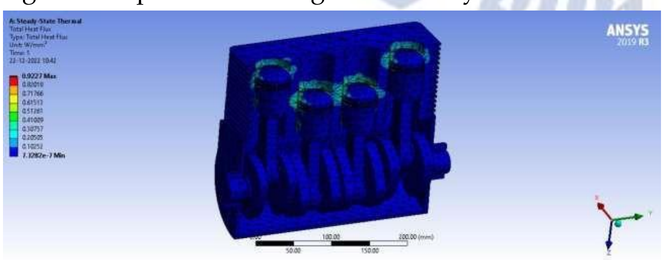


fig.15: Total heat flux of magnesium alloy

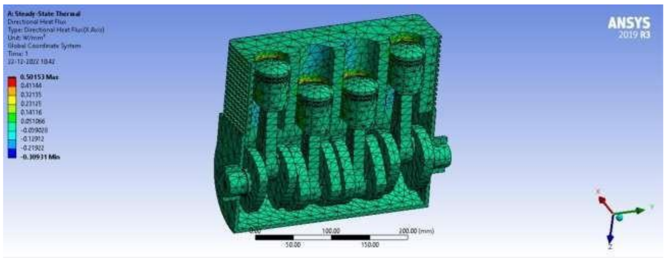


fig.16:Directional heat flux of magnesium alloy

4.5 ALUMINUM ALLOY

Aluminum Alloy

General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

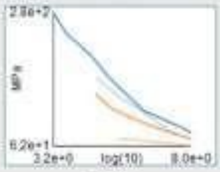
Density	2.77e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	71000 MPa
Poisson's Ratio	0.33
Bulk Modulus	69608 MPa
Shear Modulus	26692 MPa
Isotropic Secant Coefficient of Thermal Expansion	2.3e-05 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	280 MPa
S-N Curve	
Tensile Ultimate Strength	310 MPa
Tensile Yield Strength	280 MPa

Table 4: Material properties of aluminum alloy

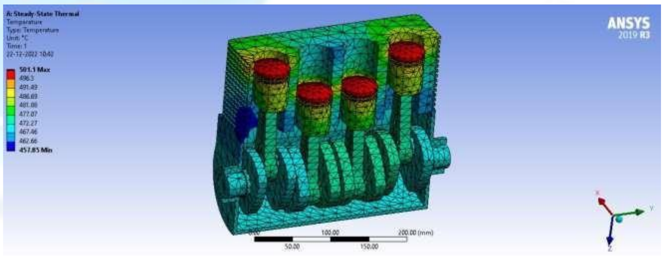


Fig.17: Temperature of aluminum alloy

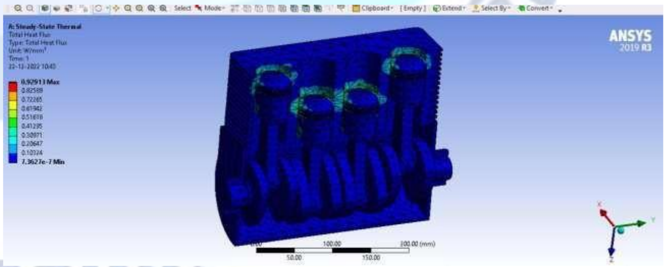


Fig.18 :Total heat flux of aluminum alloy

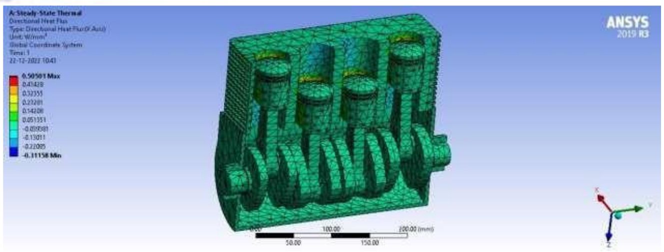


Fig 19 : Directional heat flux of aluminum alloy

	Temperature(°c)		Total heat flux (w/mm^2)		Directional heat flux (w/mm^2)	
	Min.	Max.	Min.	Max.	Min.	Max.
Stainless steel	223.09	509.09	3.1729e-007	0.58603	-0.19463	0.31908
Magnesium alloy	453.11	501.23	7.3282e-007	0.9227	-0.30931	0.50153
Aluminum alloy	457.85	501.1	7.3627e-007	0.92913	-0.31158	0.50501
Titanium al-loy	275.2	507.13	4.6257e-007	0.66809	-0.21963	0.36362

Table 5: results of materials

5. CONCLUSION

Familiarized with designing tool CATIA (sketcher, part assembly, drafting), analysis method ANSYS (Mechanical APDL, ANSYS workbench). Successfully completed designing components of IC ENGINE and assembling them by using CATIA, performed steady state thermal analysis on IC Engine using ANSYS.

The fundamental concepts and design methods concerned with four stroke four cylinder engine have been studied in this project Aluminum alloy is the best material and the results found by the use of this analytical method are nearly equal to the actual dimensions used now a days.

The materials used are aluminum alloy, titanium alloy, magnesium alloy, stainless steel among this materials aluminum alloy is the best material, because it have the properties of low weight, high thermal conductivity & greater flux.

Hence it provides a fast procedure to design a engine which can be further improved by the use of various software and methods. The most important part is that very less time is required to design the engine and only a few basic specifications of the engine.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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