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THERMAL ANALYSIS OF CONNECTING ROD

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ABSTRACT

The objective of this work is to carry out the thermal analysis of a rod made up of three differing kinds of alloys mainly aluminium, magnesium and titanium. Connecting Rods are generally used altogether kinds of automobile engines acting as a midpoint between the piston and thus the crankshaft of an engine of an automobile. It supervises the transmission of the upward and downward motion of the piston to the crankshaft of the engine, by converting the reciprocating motion of the piston to the rotation of crankshaft. The performance of a connecting rod in an engine is determined by its layout and mass. Hence, for the assembly of a long-lasting, economical and lightweight rod, analysis and optimization become necessary. The initial material "structural steel" of the connecting rod is replaced with the Aluminium alloy, Magnesium alloy and Titanium alloy material for rod. The model of rod is formed in catia v5 and imported in ANSYS 2021 R1 workbench for thermal analysis. After analysis, a comparison is made between an existing steel rod and thus the three composite rods in terms of temperature, total heat flux and directional heat flux. All these parameters are also found analytically and compared with results of Finite Element Analysis. All those results are within the range and thus the values of those materials are found as compared of steel. The overall work is split into three phases. First, concept and review of existing material. Second, we do modeling and its thermal analysis. Third, is comparison of temperature, total heat flux and directional heat flux value in alloy connecting rods.

Keywords: Connecting Rod, Piston, Crankshaft, Thermal Analysis, FEA, Structural Steel.

I. INTRODUCTION

One resource of energy in automobile sector is combustion engine. Combustion engine transforms energy within the type of upward and downward movement of the piston right into energy. Combustion engine has numerous components like cylinder, piston, rod, crank and also crank shaft. Connecting rod is just one of the vital driving components of light engine; it creates an easy device that transforms direct movement right into rotating movement. Thus, a rod is used to transform reciprocating movement of the piston right into rotating activity of the crankshaft. Hence, the rod has to be sufficiently strong to confront to forces without damages because of the pressure created from the burning. A rod could also be a framework that sustains the axial compressive tons that features a bent to stop working because of inelasticity. Devastating damages would definitely happen to the engine needing costly repair services if the rod was to stop working. Because the latest created combustion engine began to be standardized, the importance of the rod alongside the crank shaft was necessary to the procedure of a dependable engine. Generally the connecting rods are being made up of stainless steel and aluminium alloy through the forging process, as this method provides high productivity that too with the lower cost. Forces generated on the connected rod are generally by weight and combustion of fuel inside cylinder acts upon piston then on the rod , which finishes up in both the bending and axial stresses.

Fig. 1.1 Connecting Rod

II. LITERATURE REVIEW

BOGA SUDHA, Dr. I SATYANARAYANA and C.SIVAKANDHAN- The connecting rod acts as the midpoint between the piston and the crankshaft. It transfers the rotation of the crank to the upward and downward motion of piston in the cy1inder. In this project, the comparison is takes place for the best material between Carbon steel & Aluminum alloy. The connecting rod is modeled in 3D modeling software knows as Solid works. Then these designs are carried for thermal analysis. This thermal analysis is done in software called Ansys. By thermal analysis we can get the heat flux values & by that we can select the best material for connecting rod.

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Kumbha Sambaiah, Dr. A Rama Rao and Dr. M Mahesh - This article describes the study of optimization for rod of combustion engine by using two different types of the materials like forged steel and C-70 connecting rods. The performance of connecting rod are going to be evaluated with two sorts of materials. The typical forged steel or ultra-high strength steel is taken as the connecting rod material. This steel has strength level above 900MPa and this steel generally have carbon content ranging from 0.01-0.45%. It's documented that, as strength increases, toughness reduce. Ultra high strength steels are classified according to their composition microstructure. Hence a comparative study of those two materials for fatigue loading is that the main goal of this study. The replica was generated in Pro/E wildfire 5.0 and then imported as parasolid (IGES) form in ANSYS workbench.

Mr. Shubham Chougale - In the study, a connecting rod is designed for two wheeler by analytical method. On the basis of that design a physical replica is created in CATIA V5. Structural system of connecting rod has been analyzed using FEA. The thermal analysis is then carried out and thus the obtained results are compared on the basis of various performances with considerable reduction in weight.

III. OBJECTIVE

The objectives of this project are to:

1. Develop a geometrical model of connecting rod using CATIA V5 software.
2. Carry out the thermal analysis in Ansys 2021 R1 software.
3. Compare the result.

IV. METHODOLOGY

Step.1: Modelling of connecting rod as per the dimensions in Catia v5.

Step.2: The 3-D model was imported in ANSYS 2021 R1 workbench.

Step.3: The materials were assigned to the connecting rod in the mechanical interface.

Step.4: Mesh was generated for connecting rod with high refinement.

Step.5: Inner section of piston end was decided for the heat flux application.

Step.6: In the thermal analysis, Heat Flux is founded by applying radiation.

Step.7: Analysis solution was performed and thermal values were checked for the connecting rod. Temperature and total heat flux was used to compare the results.

Step.8: Then the initial material is replaced by alloys of Aluminium, Magnesium and Titanium and all the steps from step.1 to step.8 were repeated again to get the results. For the revised geometry, the results of existing connecting rod and with modified geometry were compared.

V. MATERIALS

5.1 Structural Steel:

Structural steel is a category of steel used for creating construction materials of various shapes. The connecting rods are most typically made from steel or aluminium alloy for production engines. These materials have different properties and suitable for various engines.

Table 5.1.1 Represents The Structural Steel Properties

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

5.2 Aluminium Alloy:

Aluminium rods are popular among high rpm race engines. They're Very light and powerful, but they a brief fatigue lift. During a limited use situation, they will last an extended time and typically those sorts of engines see frequent tear downs anyway. High rpm is where aluminium rods offer advantages, so they are often preferred by most of the company's. The aluminium alloys are less in weight and are expensive as compared to other materials.

Table 5.2.1 represents the aluminium alloy properties

Density	2770 kg m^-3
Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat	875 kg^-1 C^-1

5.3 Magnesium Alloy:

Magnesium alloys are the mixtures of magnesium with other metals; it is the lightest structural metal available. Magnesium alloys have a hexagonal crystal lattice structure, which affects the elemental properties of the alloys formed. Cast magnesium alloys are used for the several components of the recent automobiles and are utilized in some high-performance vehicles.

Table 5.3.1 represents the magnesium alloy properties

Density	1800 kg m^-3
Coefficient of Thermal Expansion	2.6e-005 C^-1
Specific Heat	1024 J kg^-1 C^-1
Thermal Conductivity	156 W m^-1 C^-1
Resistivity	7.7e-007 ohm m

5.4 Titanium Alloy:

Titanium alloys are metals which contain a mixture of titanium and some other chemical elements. These alloys have very high lastingness and toughness. They're light in weight, have extreme corrosion resistance and therefore the ability to face up the very high temperatures. However, the expensiveness of both raw materials and processing, limit their use to military applications, aircraft, spacecraft, medical devices, connecting rods. This mixture features a solid solubility which varies dramatically with temperature, allowing it to undergo precipitation strengthening.

Table 5.4.1 represents the titanium alloy properties

Density	4620 kg m^-3
Isotropic Secant Coefficient of Thermal Expansion	9.4e-006 C^-1
Specific Heat Constant Pressure	522 J kg^-1 C^-1
Isotropic Thermal Conductivity	21.9 W m^-1 C^-1
Isotropic Resistivity	1.7e-006 ohm m

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VI. DIAGRAM OF PROJECT

The project is designed in CATIA V5 and later imported to ANSYS software.

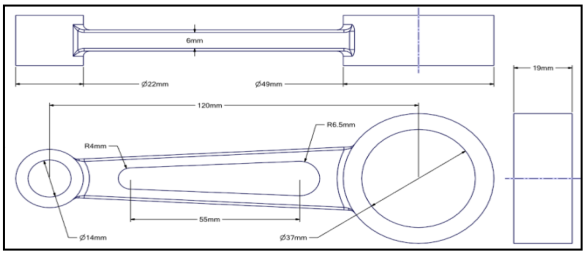


Fig. 6.1 represents the taken dimensions

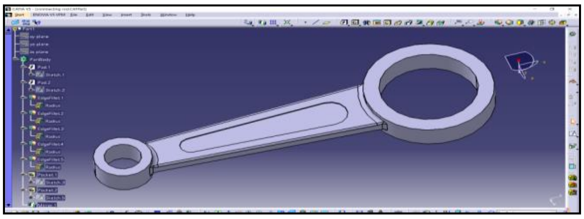


Fig. 6.2 represents the geometry model in CATIA V5

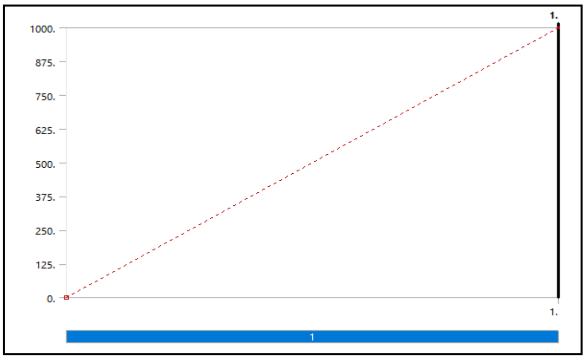
VII. CALCULATION

7.1 HEAT FLUX

Sometime also called as heat flux density, heat-flow density or heat flow rate intensity is a flow of energy per unit of area per unit of time. In SI units are watts per square meter. It has both a direction and a magnitude, and so it is a vector quantity.

Table 7.1.1 represents magnitude conditions of heat flux

Magnitude	1000. W/m^2 (ramped)



Graph 7.1.1 represents application of heat flux

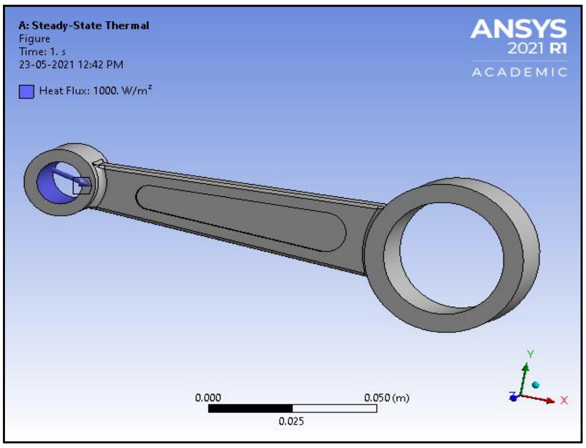


Fig 7.1.1 represents heat flux at smaller end

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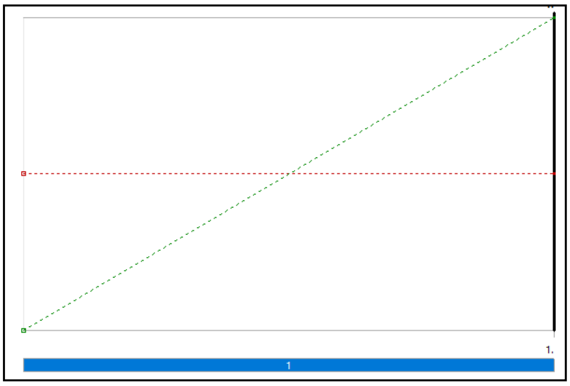
7.2 HEAT CONVECTION

Convection is the process of heat transfer of molecules by the bulk movement within fluid. The movement that occurs within a fluid due to increase in temperature of hotter materials paired. So, it becomes a crucial part for study in connecting rod analysis. The applied heat convection on connecting rod is 28 °C and 30 W/m² - °C.

Table 7.2.1 represents the heat convection on connecting rod

Steps	Time [s]	Convection Coefficient [W/m²·°C]	Temperature [°C]
1	0.	= 30.	= 22.
	1.	30.	28.



Graph 7.2.1 represents convection and temperature

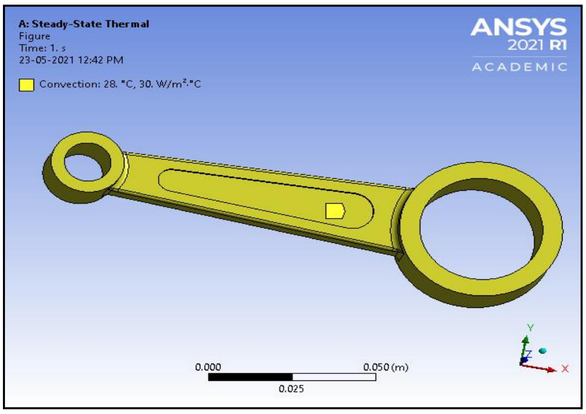


Fig 7.2.1 represents convection of 28 °C, 30 W/m² - °C

7.3 THERMAL ANALYSIS

7.3.1 Connecting rod analysis using structural steel

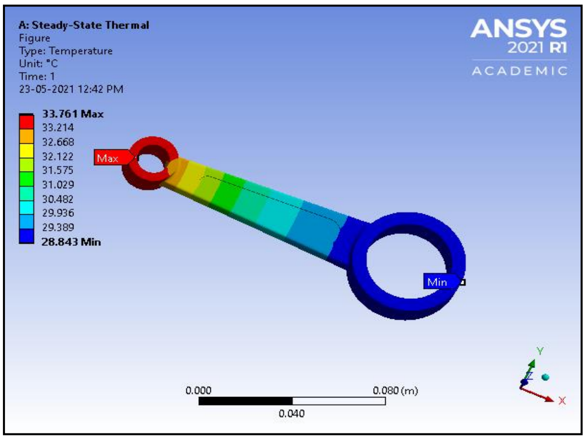


Fig 7.3.1.1 represents temperature

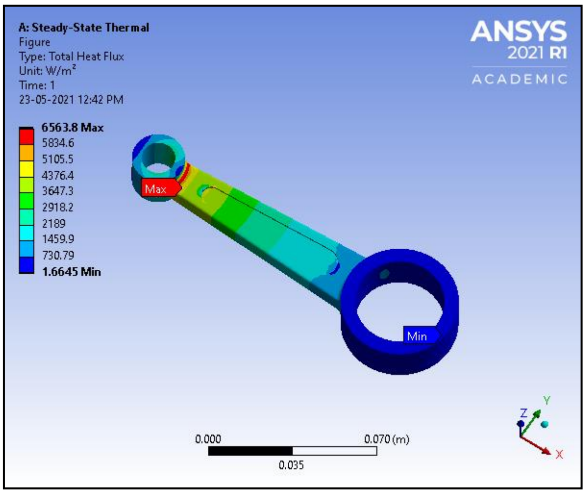


Fig 7.3.1.2 represents total heat flux

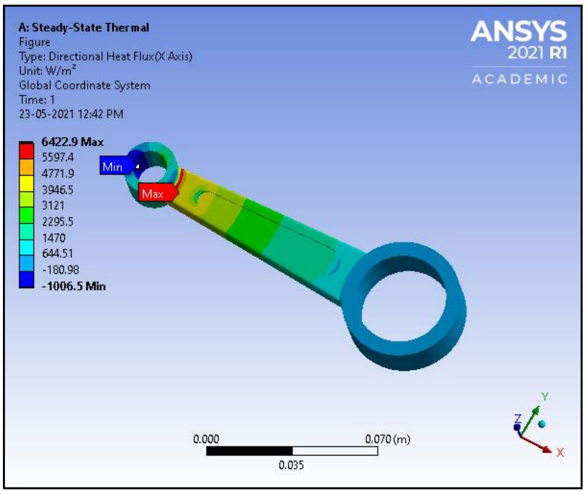


Fig 7.3.1.3 represents directional heat flux (x-axis)

Table 7.3.1.1 represents temperature

	Temperature
Minimum	28.843 °C
Maximum	33.761 °C
Average	30.476 °C

Table 7.3.1.2 represents total heat flux

	Total Heat Flux
Minimum	1.6645 W/m^2
Maximum	6563.8 W/m^2
Average	1573. W/m^2

Table 7.3.1.3 represents directional heat flux

	Directional Heat Flux
Minimum	-1006.5 W/m^2
Maximum	6422.9 W/m^2
Average	1368.2 W/m^2

7.3.2 Connecting rod analysis using aluminium alloy

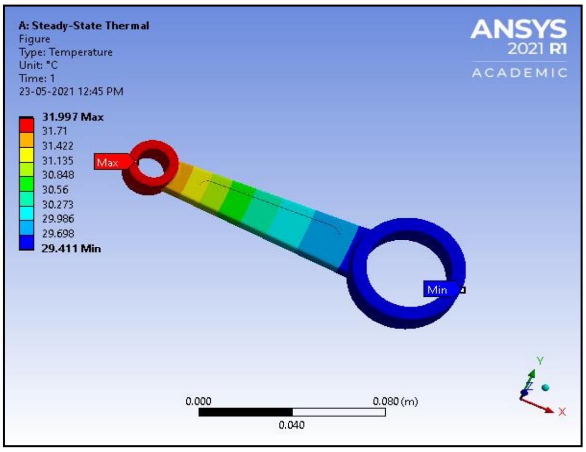


Fig 7.3.2.1 represents temperature

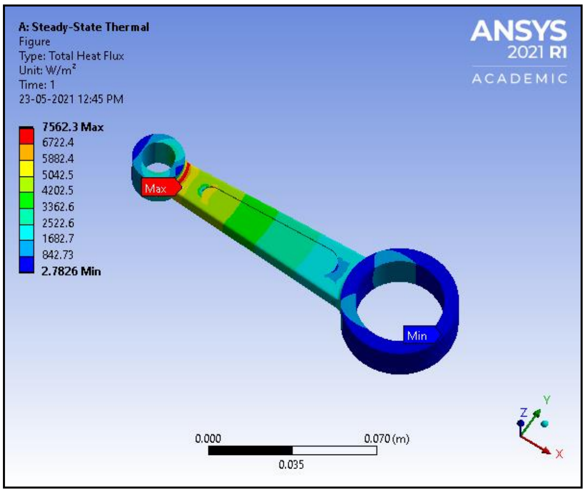


Fig 7.3.2.2 represents total heat flux

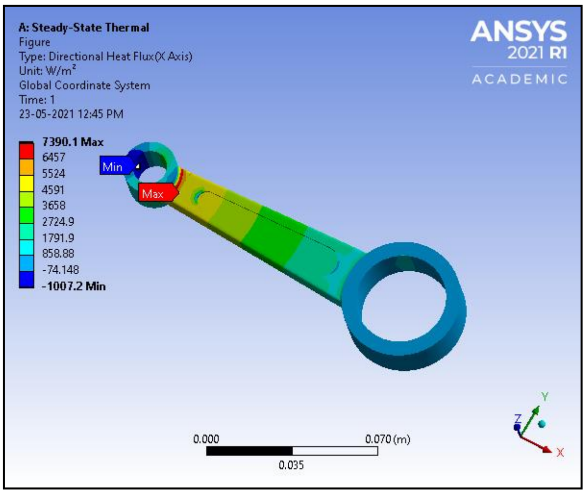


Fig 7.3.2.3 represents directional heat flux (x-axis)

Table 7.3.2.1 represents temperature

	Temperature
Minimum	29.411 °C
Maximum	31.997 °C
Average	30.311 °C

Table 7.3.2.2 represents total heat flux

	Total Heat Flux
Minimum	2.7826 W/m^2
Maximum	7562.3 W/m^2
Average	2016.4 W/m^2

Table 7.3.2.3 represents directional heat flux

	Directional Heat Flux
Minimum	-1007.2 W/m^2
Maximum	7390.1 W/m^2
Average	1757.7 W/m^2

7.3.3 Connecting rod analysis using magnesium alloy

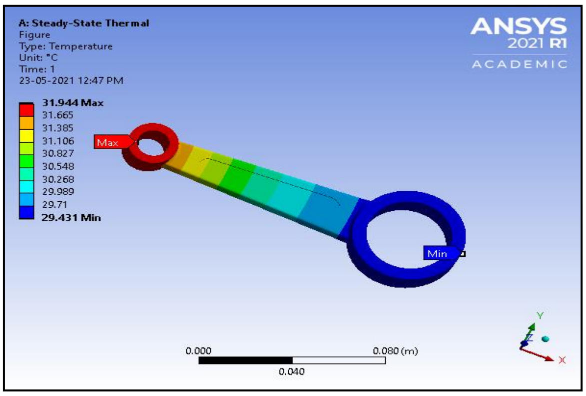


Fig 7.3.3.1 represents temperature

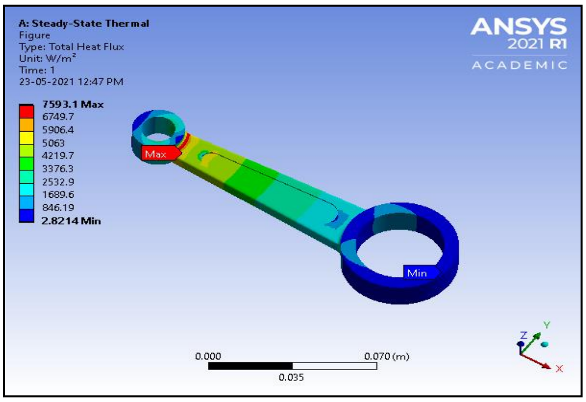


Fig 7.3.3.2 represents total heat flux

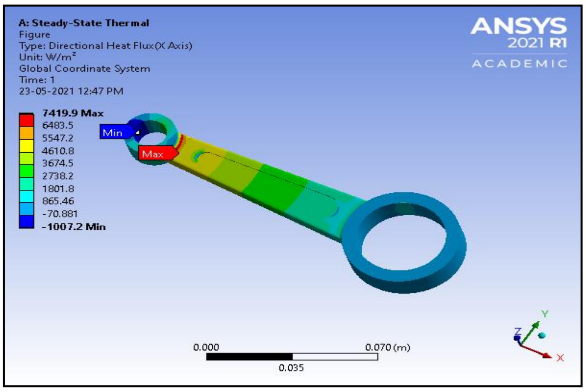


Fig 7.3.3.3 represents directional heat flux (x-axis)

Table 7.3.3.1 represents temperature

	Temperature
Minimum	29.431 °C
Maximum	31.944 °C
Average	30.306 °C

Table 7.3.3.2 represents total heat flux

	Total Heat Flux
Minimum	2.8214 W/m^2
Maximum	7593.1 W/m^2
Average	2030.9 W/m^2

Table 7.3.3.3 represents directional heat flux

	Directional Heat Flux
Minimum	-1007.2 W/m^2
Maximum	7419.9 W/m^2
Average	1770.4 W/m^2

7.3.4 Connecting rod analysis using titanium alloy

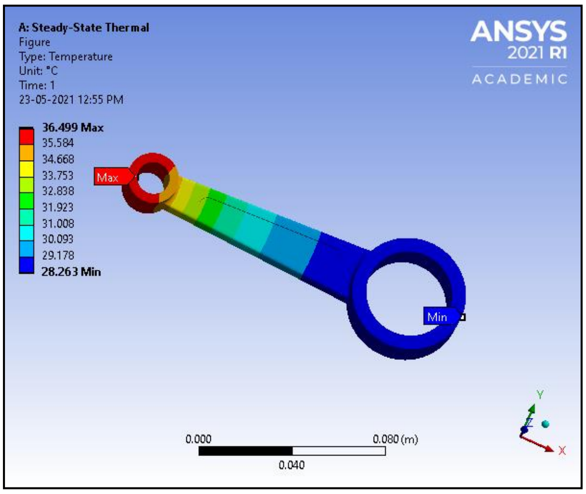


Fig 7.3.4.1 represents temperature

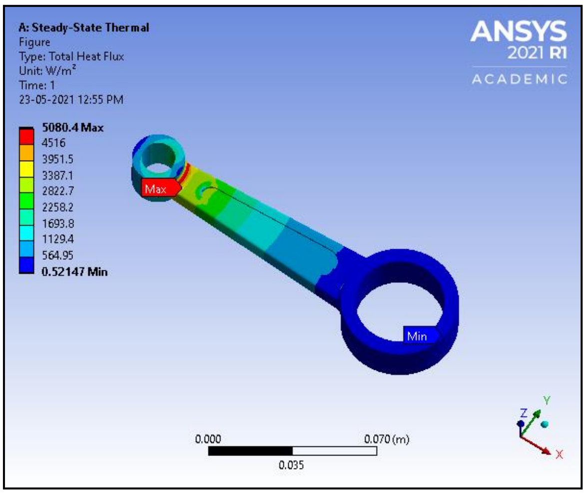


Fig 7.3.4.2 represents total heat flux

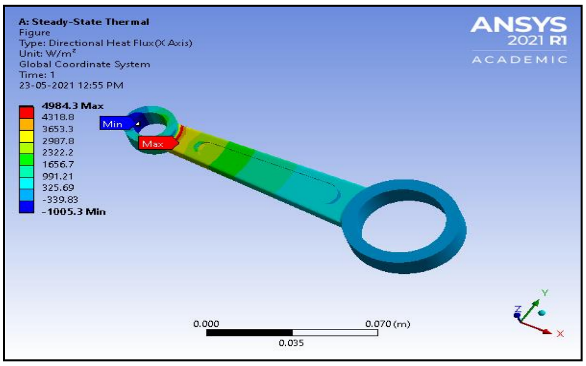


Fig 7.3.4.3 represents directional heat flux (x-axis)

Table 7.3.4.1 represents temperature

	Temperature
Minimum	28.263 °C
Maximum	36.499 °C
Average	30.735 °C

Table 7.3.4.2 represents total heat flux

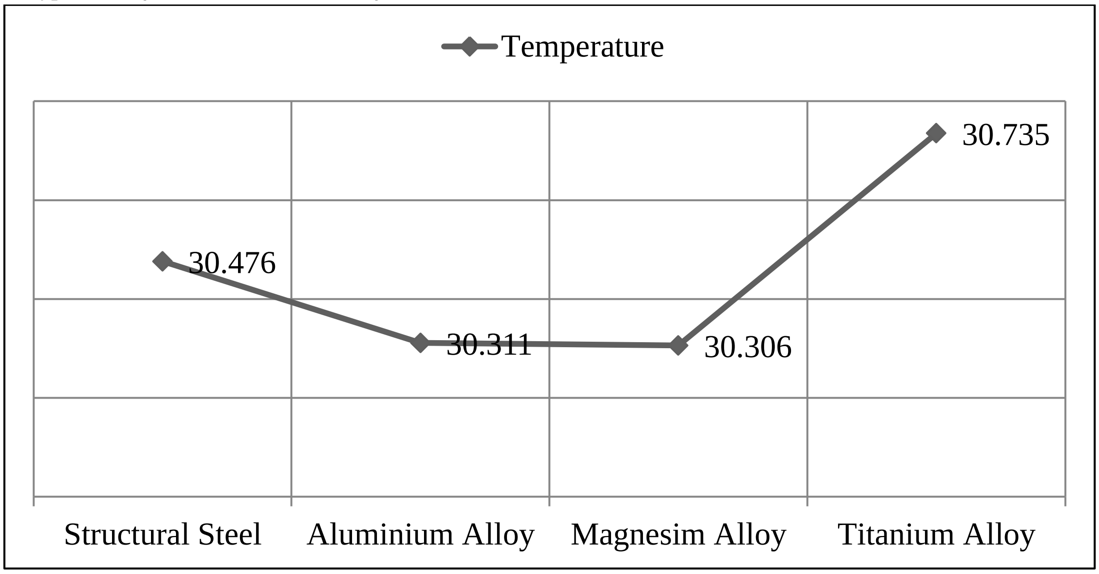
	Total Heat Flux
Minimum	0.52147 W/m^2
Maximum	5080.4 W/m^2
Average	1012.3 W/m^2

Table 7.3.4.3 represents directional heat flux

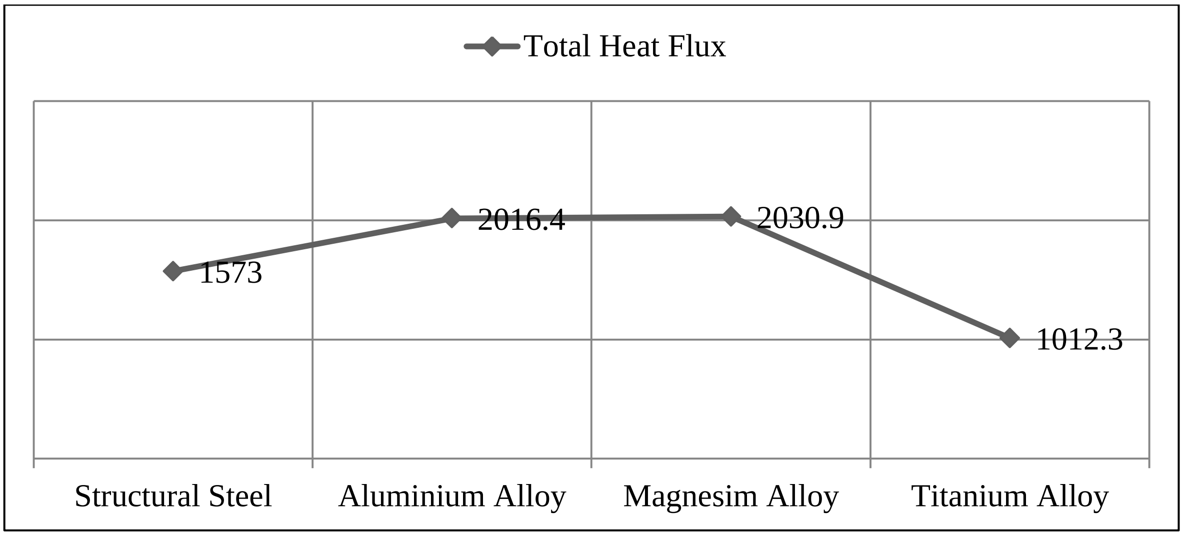
	Directional Heat Flux
Minimum	-1005.3 W/m^2
Maximum	4984.3 W/m^2
Average	870.45 W/m^2

7.4 RESULT

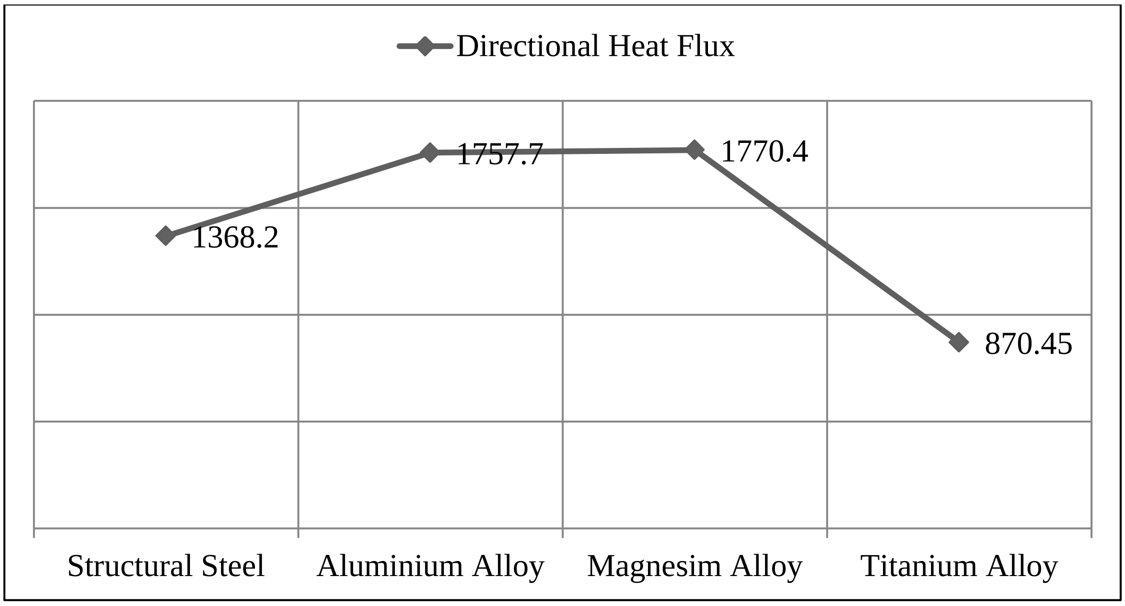
The following results comprise of all the factors of structural analysis [total deformation, equivalent elastic stress and equivalent (von-Mises) strain] and thermal analysis [temperature, total heat flux, directional heat flux (x-axis)] done by finite element analysis on ANSYS on different materials.



Graph 7.4.1 represents comparison of temperature on applied materials



Graph 7.4.2 represents comparison of total heat flux on applied materials



Graph 7.4.3 represents comparison of directional heat flux (x-axis) on applied materials

VIII. CONCLUSIONS

In this project, we are applying temperature to the different materials to the connecting rod and doing the connecting rod analysis and comparing steady state thermal analysis with 4 different materials. By the above result, we can conclude that:

1. From the chosen 4 materials, the aluminium alloy performed very well.
2. Increment in life cycle when aluminium alloy is chosen for production.
3. There is reduction in all risk factors for aluminium alloy.
4. Lowering the weight must include strength as well.
5. Without compromising with strength, one can use light weight production.

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