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# Design and Analysis of Engine Block Using Ansys Workbench

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**ABSTRACT:** The engine block is the linchpin of vehicles that run on internal combustion, providing the powerhouse for the vehicle. It is called a "block" because it is usually a solid cast car part, housing the cylinders and their components inside a cooled and lubricated crankcase. This part is designed to be extremely strong and sturdy, because its failure results in failure of the car, which will not function until the engine block is replaced or repaired. Most engine blocks are made of cast iron, although in the late 1990s, some made from plastic and other experimental materials were being used in prototype cars with the hope of developing more lightweight, efficient vehicles. Cylinders blocks are under goes high thermal and structural loads. The main objective of the project is to study the thermal and structural load determination in engine blocks. The engine block design is done in solid works simulation and analysis of structural and thermal analysis carried out in ANSYS workbench 2024.

## I. INTRODUCTION

### 1.1 Background

Nowadays, the suppliers of engine block are constantly striving to manufacture a better and lighter block in order to improve and enhance the efficiency of automobile. The engine block is the largest and more intricate single piece of metal used in an internal combustion engine on to which other important part are mounted. It also can be otherwise called a cylinder block. A cylinder block is the central working part of a reciprocating engine which houses the piston to create compression needed to generate power. The cylinder holes (for piston) and other hole for passage of coolants. The engine block (cylinder block accommodates the following components, these are: piston, camshaft, turning chains, rocker arms. It accounts for about 25%-30% of total weight of the engine (Ngugen, 2005). The first successful internal combustion engine which was used in automobile was built by Siegfried Marcus in (1864), it was an upright single cylinder, two stroke petrol engine. Today, engines have come to their maximum development and skill developed for years to come. This development has caused increase in power, durability, resistance to wear, and efficiency of the engine. (ASME 2005).

However, during operation, the engine block (cylinder block) is subjected to excessive-heating, stroke loading of a piston and compressive forces of the interconnecting chamber. The block must therefore, consist of the following:

- Resistance to wear as a result of reciprocating actions of the piston.∞
- Resistance of compressive stresses imposed by the loads on the block.∞
- Resistance to elongation under action of excessive heat that may alter the geometry of the block.∞
- Resistance to corrosion due to actions of steam and combustion products.∞

Hence for the engine-block to withstand the above conditions, it must be built with cast iron due to its strength, low cost and wear resistance. But as the engine becomes more complicated, Engineers found new materials to reduce its weight as well as to increase strength and wear resistance. And a common alloy which was used is Aluminum Alloy.

This is more popular due to its low weight, its better thermal conductivity compared to grey cast iron, durability, fatigue strength, corrosion resistance, accuracy of measurement due to excellent machinability and finally good recycling possibilities to make manufacturing inexpensive. In addition to reduction of weight, thermal balance of the engine and also the engine warms up faster and more evenly. (Anyalebechi, 2005).

Furthermore, the functional requirement of an engine block should have the following:

- High resistance thermal expansion∞
- High compressive strength∞
- Good thermal conductivity∞
- Good machinability and cast ability combined with shock loading and thermal stresses.∞

Also, to manufacture the engine-block using material with the above requirements, casting processes are used. A sand mold is prepared and molten Aluminum is poured into a pattern. The pattern is the main tool required to form the mold which when the molten Aluminum is poured into, it solidifies to give the engine-block. After casting processes are over, the casted engine-block is passed through few machines to get to a surface finish and it required features. The resulting engine-block contains all features on the pattern lighter in weight and good surface finish. This then forms the prototype of the model.

### 1.2 Statement of Problem

Every engine requires maintenance to increase its efficiency or to restore it to working-order; this requires that certain proactive measures or activities be conducted on the engine. These activities are often difficult when it involves operations on the engine-block. When an I.C engine knocks due to overheating problem, it is often required that the engine-block be replaced with a new one or reground. And acquiring a new engine-block from a manufacturer involves serious financial losses; time loses from placement or order to time of delivery and prolonged downtime of facilities awaiting repairs. An attempt to overcome these problems requires the local technology on casting/fabrication of the engine-block be encouraged.

Design and maintenance of a three-cylinder block (prototype) for I.C engine-block based on an already designed pattern. Hence, any shape of engine block can be casted with ease enhancing its local fabrication and preventing over dependence on imported ones.

### 1.3 Aim and Objectives

To design and manufacture a 3-cylinder Engine Block proto-type using Aluminum material by means of casting method as viable method to produce a cylinder block using local technology; to achieve this goal, thus below are the objectives:

- To adapt theoretical knowledge and skill acquired by years of engineering study into practice as to bridge the gap between theory and practical works.∞
- To advance skills in casting technology in the production of complicated shapes.∞

### 1.4 Significance of Study

This project seeks to promote acquisition of skills in indigenous casting technology and manufacturing. It affords researchers review advancement, opportunities to improve/boost up an existing casting design and maintenance of engines. This practice is of particular benefit to society as it advances skills which promotes or integrates local technology level of an internal combustion engine (I.C.E.).

### 1.5 Scope of Study

Design and manufacture of a 3-cylinder Engine Block is intended to use low cost, lightweight, cast able material (Aluminum) to cast an engine-block model whose pattern is already in design. This however does not include the practical application of the cast-block in engine as to ascertain its workability. This product is only a prototype model.

An Engine block, also referred to as a cylindrical block, is a critical component in the design and construction of internal combustion engines. This robust piece of machinery serves as the foundation for an engine's key components, including the cylinders, pistons, and crankshaft. By housing these critical elements and providing a secure structure for their operation, the cylinder block plays a pivotal role in the functioning of various types of engines, from those found in automobiles to industrial machinery and even power generators. This article presents all the answers related to what is Cylinder block.

### 1.6 What is a Cylinder Block?

The cylinder block, commonly referred to as the engine block, serves as the heart of an engine, comprising one of its central components. Crafted from high-quality materials to fulfil the specific functions of its various elements, the

Engine block plays a pivotal role in the lubrication system of IC Engine, temperature regulation, and overall stability. Consequently, its construction demands top-tier materials to avert any potential shortcomings. Engine blocks are meticulously engineered to endure a wide range of temperatures and mechanical stresses, ensuring the engine's longevity and efficient lubrication. Within these blocks, numerous oil galleries facilitate the essential oil circulation throughout the engine. Additionally, water galleries are strategically incorporated to manage engine temperature and maintain optimal operational conditions. It's worth noting that the design of an Engine block is tailored to the particular type and specifications of the engine model it houses, encompassing features such as cylinder walls, cylinder sleeves, and coolant pathways. In essence, the Engine block is the foundational structure that houses the engine's cylinders and various other internal combustion engine components.

### 1.7 Cylinder Block Diagram

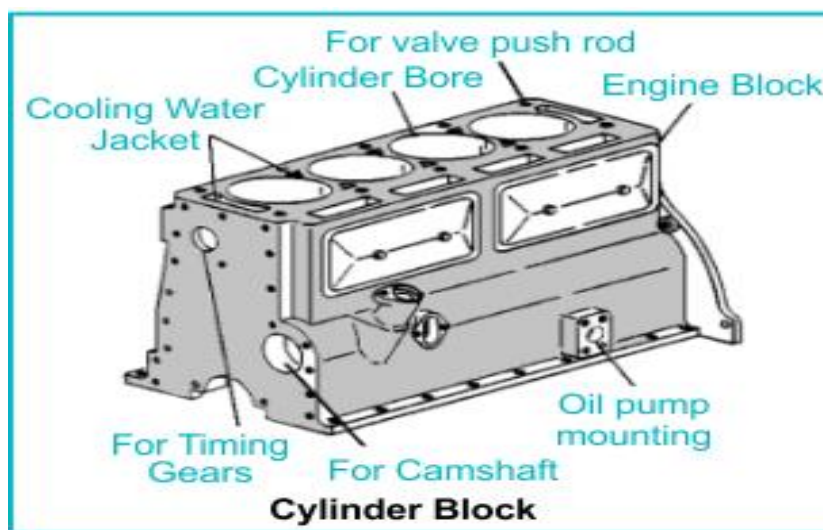


Fig.1 cylinder block

## II. LITERATURE SURVEY

Research papers are studied to find the new method and new area of study that increases the efficiency, performance and life of connecting rod. So various design are studied to reach the appropriate conclusion. **B. Anusha et al [1]** presented work on "Comparison of materials for Two-wheeler Connecting Rod using ANSYS. The modeled connecting rod imported to ANSYS software for analysis. Analysis is done to determine von mises stresses, shear stresses and strain. In this study two materials are selected and analyzed. The result is helpful and utilize in designing the connecting rod. **Singh [2]** had conducted a study in which the conventional material of connecting rod i.e. steel or cast iron is replaced with composite material (E-Glass/Epoxy). By using FEA method von mises stresses, distortion and other effective parameters are ascertained. There was reduction of 33.9% of stresses when comparing with present material replaced with (E-Glass/Epoxy). **Leela Krishna Vegi [3]** had carried out a study in which the present material of the connecting rod is replaced by forged steel material. By comparing both the material on ANSYS the result indicates the factor of safety and stiffness increases comparable to carbon steel connecting rod. Also, there is a reduction in weight and an increase in life cycle of connecting rod having forged steel material. **Ramakrishna and Venkat [4]** had carried out a study of connecting rod of petrol engine of LML freedom. The work focused on optimization of the material in which current 4340 alloy steel connecting rods are replaced by AL Sic 9 results in a 61.65 % reduction in weight. **Prem Kumar [5]** had carried out a study in which the present material Al 6061 is replaced by Al 6061 + B4C. When compared with present material, Al 6061 + B4C have lower deformation and also sustain a low Von mises strain. Thus result in high hardness. **Fernando Allan [5]** simulated the heat transfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analysed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition. Starting from a zero-dimensional combustion model developed in previous works, the cooling system geometry of a two-stroke air cooled internal combustion engine has been optimized in this paper by reducing the total volume

occupied by the engine. A total reduction of 20.15% has been achieved by reducing the total engine diameter  $D$  from 90.62 mm to 75.22 mm and by increasing the total height  $H$  from 125.72 mm to 146.47 mm aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved. **G. Babe and M. Lava Kumar [6]** analysed the thermal properties by varying geometry, material and thickness of cylinder fins. The models were created by varying the geometry, rectangular, circular and curved shaped fins and also by varying thickness of the fins. Material used for manufacturing cylinder fin body was Aluminium Alloy 204 which has thermal conductivity of 110-150W/me and also using Aluminium alloy 6061 and Magnesium alloy which have higher thermal conductivities. They concluded that by reducing the thickness and also by changing the shape of the fin to curve shaped, the weight of the fin body reduces thereby increasing the efficiency. The weight of the fin body is reduced when Magnesium alloy is used and using circular fin, material Aluminium alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more and using circular fins the heat lost is more, efficiency and effectiveness is also more. **Ajay Paul et.al. [7]** Carried out Numerical Simulations to determine heat transfer characteristics of different fin parameters namely, number of fins, fin thickness at varying air velocities. A cylinder with a single fin mounted and explained it was tested experimentally. The numerical simulation of the same setup was done using CFD. Cylinders with fins of 4 mm and 6 mm thickness were simulated for 1, 3, 4 & 6 fin configurations. They concluded that 1. When fin thickness was increased, the reduced gap between the fins resulted in swirls being created which helped in increasing the heat transfer. 2. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence and hence higher heat transferrin. **Phani Raja Rao et.al [8]**. Analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. Different material used for cylinder fin were Aluminium Alloy A204, Aluminium alloy 6061 and Magnesium alloy which have higher thermal conductivities and shown that by reducing the thickness and also by changing the shape of the fin to circular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin. The results show, by using circular fin with material Aluminium Alloy 6061 is better since heat transfer rate, Efficiency and Effectiveness of the fin is more.

### III. METHODOLOGY OF ENGINE BLOCK

#### 3.1 The ANSYS Workbench Interface:

The ANSYS Workbench interface consists primarily of a Toolbox region, the Project Schematic, the Toolbar, and the Menu bar. Depending on the analysis type and/or application or workspace, you may also see other windows, tables, charts, etc. One way to work in ANSYS Workbench is to drag an item such as a component or analysis system from the Toolbox to the Project Schematic or to double-click on an item to initiate the default action. You can also use the context menus, accessible from a right-mouse click, for additional options. You will view your analysis systems -- the components that make up your analysis -- in the Project Schematic, including all connections and links between the systems. The individual applications in which you work will display separately from the ANSYS Workbench GUI, but the results of the actions you take in the applications may be reflected in the Project Schematic.

#### 3.2 Toolbox:

The ANSYS Workbench Toolbox presents the types of data that you can add to your project. The Toolbox is context-sensitive; as you select different items in the Project Schematic or other workspaces, the contents of the Toolbox may change to reflect the components and actions available to you. When working in other workspaces, such as Engineering Data or Parameters, you can return to the Project Workspace by clicking the Return to Project button on the Toolbar.

#### 3.3 ANALYSIS TYPES:

The different type of analysis that can be performed in ANSYS Structural static analysis:

1. Structural static analysis:
2. Thermal analysis

### IV. RESULTS AND DISCUSSION

#### 4.1 Introduction to CATIA V5R20

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As a new user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release. CATIA V5, developed by Dassault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-

use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs. CATIA V5 provides three basic platforms: P1, P2, and P3. P1 is for small and medium-sized process-oriented companies that wish to grow toward the large scale digitized product definition.

#### 4.2 Getting Started With CATIA V5R20: -

Install CATIA V5R20 on your system and then start it by double-clicking on the shortcut icon of CATIA V5R20 on the desktop of your computer. You can also choose **Start > All Programs > CATIA > CATIA V5R20** from the taskbar to start the program design applications and is basically for Automotive and Aerospace Industry, where high quality surfacing or Class-A surfacing is used. The subject of interpretability offered by CATIA V5 includes receiving legacy data from the other CAD systems and even between its own product data management modules. The real benefit is that the links remain associative. As a result, any change made to this external data gets notified and the model can be updated quickly.

#### 4.3 Static Structural (A5)

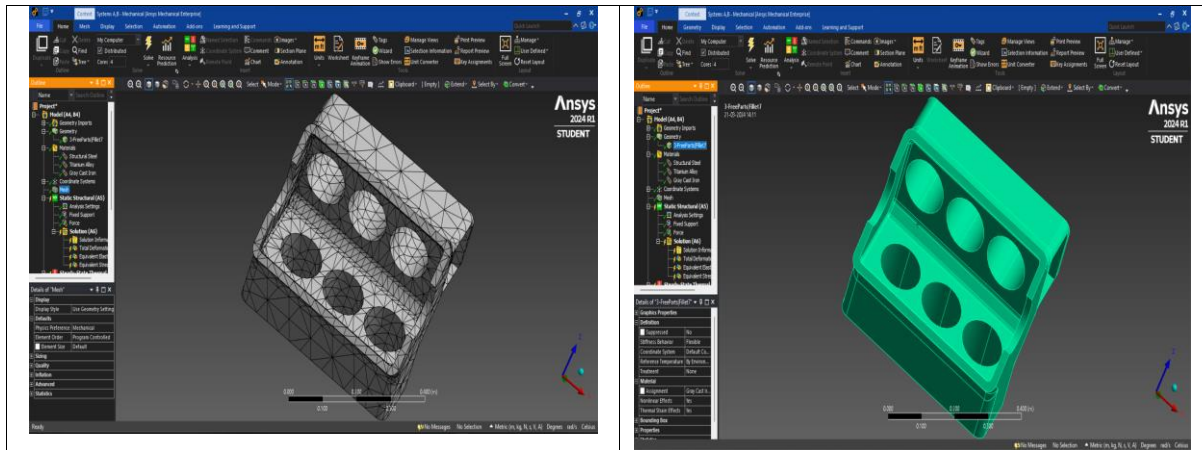


Fig.2 Static Structural

#### 4.4 Gray Cast Iron

##### (a) Total Deformation

$F = k\Delta L$ , where  $\Delta L$  is the amount of deformation (the change in length, for example) produced by the force  $F$ , and  $k$  is a proportionality constant that depends on the shape and composition of the object and the direction of the force. Figure 1. A graph of deformation  $\Delta L$  versus applied force  $F$ .

##### (b) Equivalent Elastic Strain

The equivalent elastic strain is defined as the limit for the values of strain up to which the object will rebound and come back to the original shape upon the removal of the load. Elastic limit is defined as the point on the stress-strain curve where the object changes its elastic behavior to plastic behavior.

##### (C) Equivalent Stress

In continuum mechanics, the maximum distortion energy criterion states that yielding of a ductile material begins when the second invariant of deviatoric stress reaches a critical value. It is a part of plasticity theory that mostly applies to ductile materials, such as some metals.

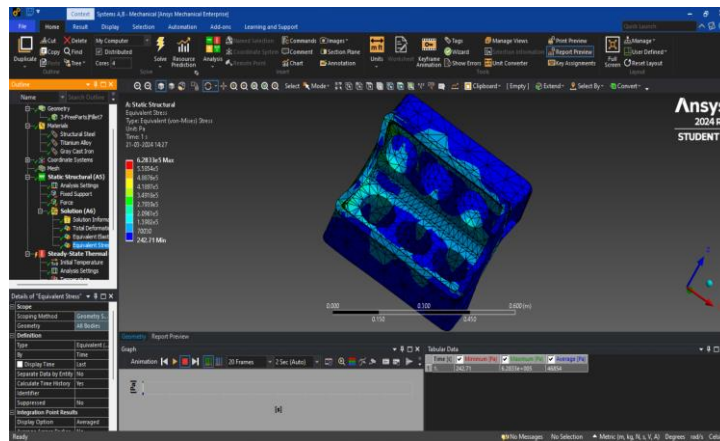
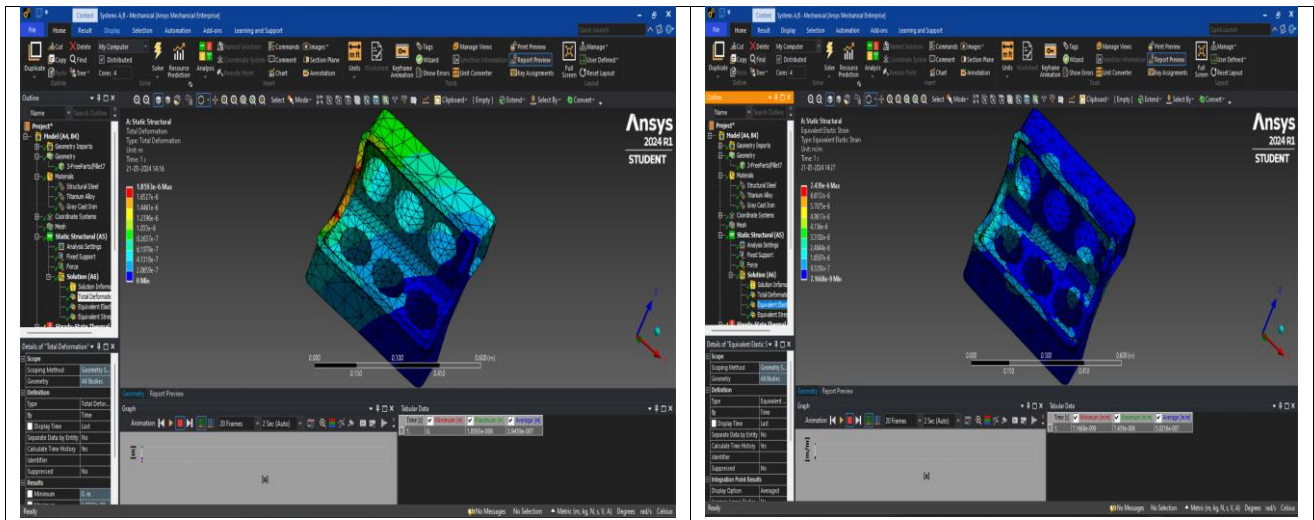


Fig.3 Gray Cast Iron, (a) Total Deformation, (b) Equivalent Elastic Strain, (C) Equivalent Stress

#### 4.5 Stainless Steel

##### (a) Total Deformation

$F = k\Delta L$ , where  $\Delta L$  is the amount of deformation (the change in length, for example) produced by the force  $F$ , and  $k$  is a proportionality constant that depends on the shape and composition of the object and the direction of the force. Figure 1. A graph of deformation  $\Delta L$  versus applied force  $F$ .

##### (B) Equivalent Elastic Strain

The equivalent elastic strain is defined as the limit for the values of strain up to which the object will rebound and come back to the original shape upon the removal of the load. Elastic limit is defined as the point on the stress-strain curve where the object changes its elastic behavior to plastic behavior.

##### (C) Equivalent Stress

In continuum mechanics, the maximum distortion energy criterion states that yielding of a ductile material begins when the second invariant of deviatoric stress reaches a critical value. It is a part of plasticity theory that mostly applies to ductile materials, such as some metals.

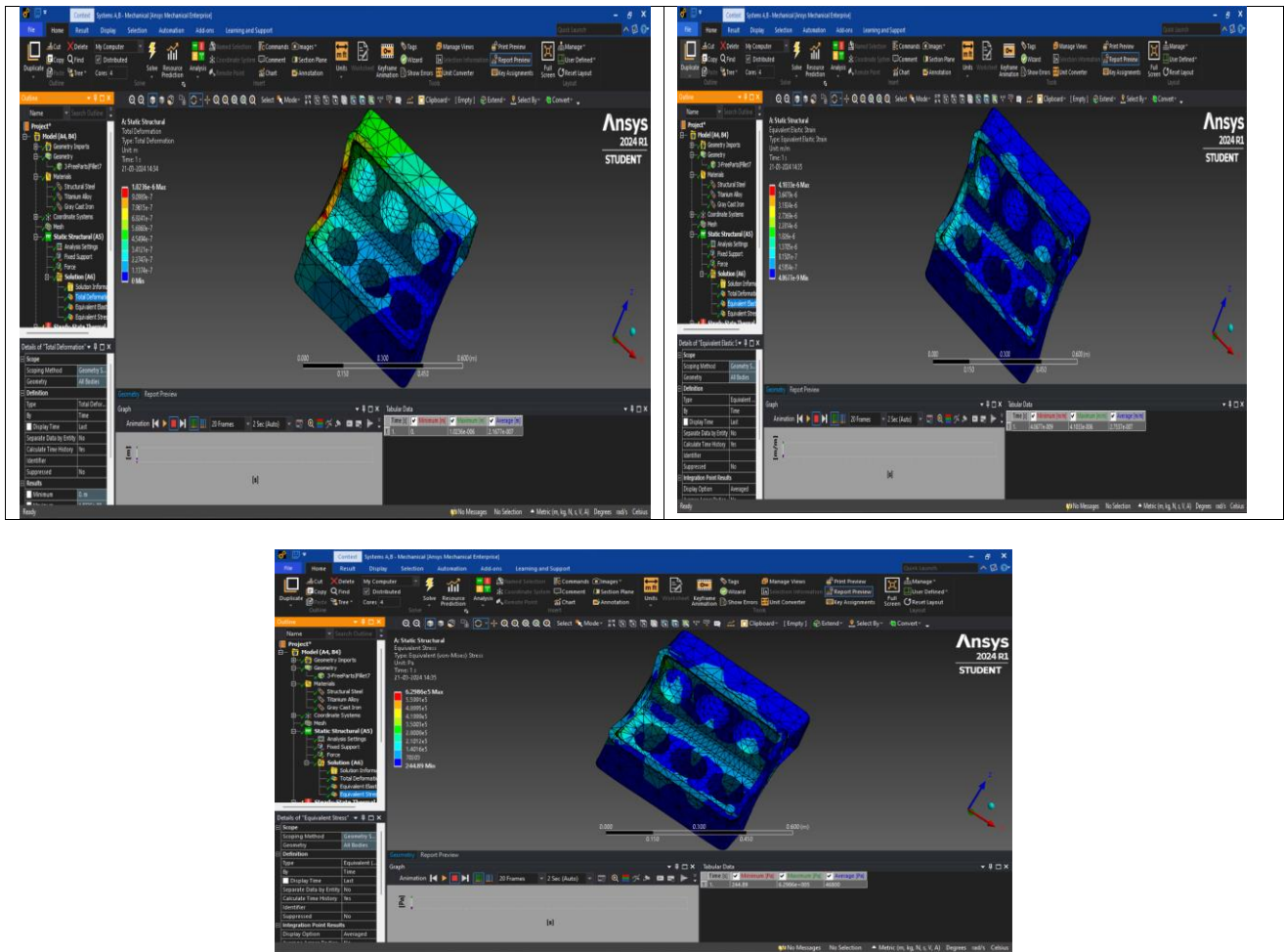


Fig.4 Stainless Steel, (a) Total Deformation, (b) Equivalent Elastic Strain, (C) Equivalent Stress

#### 4.6 Titanium Alloy

##### (A) Total Deformation

$F = k\Delta L$ , where  $\Delta L$  is the amount of deformation (the change in length, for example) produced by the force  $F$ , and  $k$  is a proportionality constant that depends on the shape and composition of the object and the direction of the force. Figure 1. A graph of deformation  $\Delta L$  versus applied force  $F$ .

##### (B) Equivalent Elastic Strain

The equivalent elastic strain is defined as the limit for the values of strain up to which the object will rebound and come back to the original shape upon the removal of the load. Elastic limit is defined as the point on the stress-strain curve where the object changes its elastic behavior to plastic behavior.

##### (C) Equivalent Stress

In continuum mechanics, the maximum distortion energy criterion states that yielding of a ductile material begins when the second invariant of deviatoric stress reaches a critical value. It is a part of plasticity theory that mostly applies to ductile materials, such as some metals.



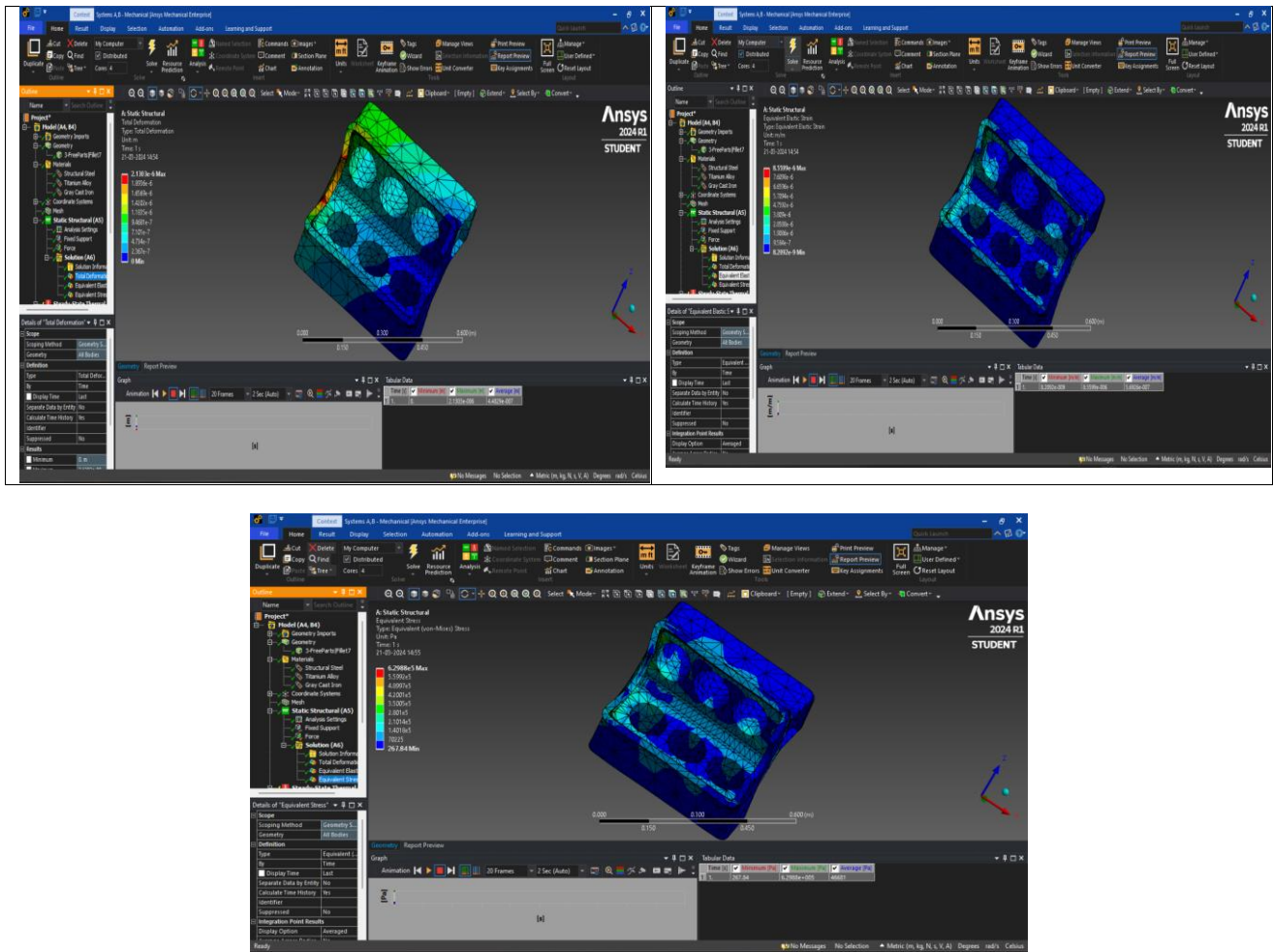


Fig.5 Titanium Alloy, (a) Total Deformation, (b) Equivalent Elastic Strain, (C) Equivalent Stress

## 4.7 Steady State Thermal Analysis

### 4.7.1 Gray Cast Iron

#### (a) Temperature

Temperature is the measure of hotness or coldness expressed in terms of any of several scales, including Fahrenheit and Celsius. Temperature indicates the direction in which heat energy will spontaneously flow—i.e., from a hotter body (one at a higher temperature) to a colder body (one at a lower temperature).

#### (b) Total Heat Flux

Total Heat Flux and Energy Flux. Where  $E$  is the internal energy. It is the sum of convective heat flux,  $\rho uE$ , conductive heat flux,  $q$ , and radioactive heat flux,  $q_r$ . Hence, the total heat flux accounts for all three kinds of heat transfer described in The Physical Mechanisms Underlying Heat Transfer.

#### (c) Total Heat Flux Directional

Heat flux, also known as thermal flux, is a term used to express an amount of energy transferred from one place to the other in the form of heat. Heat, the energy associated with the temperature of an object, travels from high temperature low temperature. Measuring this heat flux with heat flux sensors can be useful as these measurements can tell us whether the temperature of an object will go up, down or stay the same. It also tells why and how fast the temperature change is. More on this later.

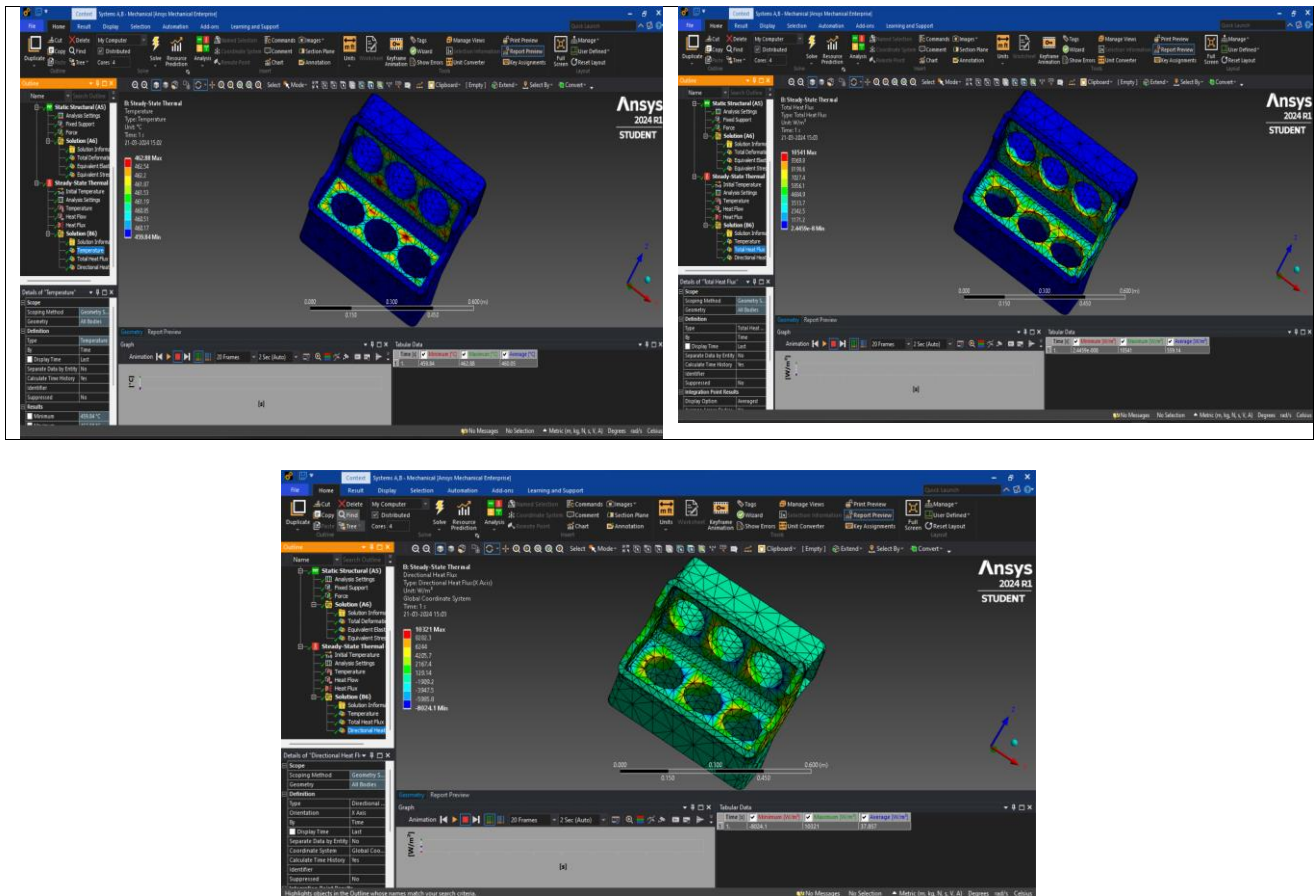


Fig.6 Gray Cast Iron, (a) Total Deformation, (b) Equivalent Elastic Strain, (c) Equivalent Stress

#### 4.7.2 Stainless Steel

##### (a) Temperature

Temperature is the measure of hotness or coldness expressed in terms of any of several scales, including Fahrenheit and Celsius. Temperature indicates the direction in which heat energy will spontaneously flow—i.e., from a hotter body (one at a higher temperature) to a colder body (one at a lower temperature).

##### (B) Total Heat Flux

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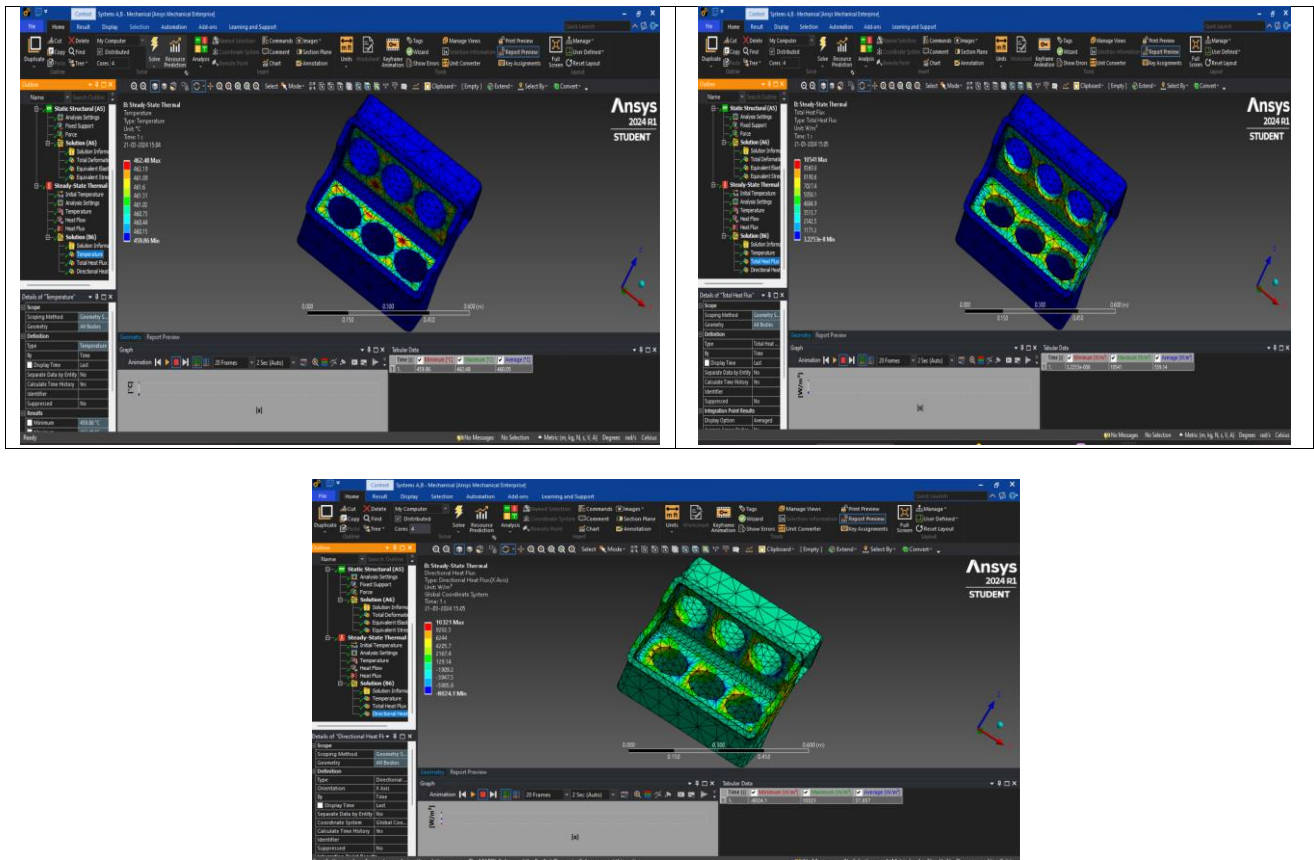


Fig.7 Stainless Steel, (a) Temperature, (B) Total Heat Flux, (C) Total Heat Flux Directional

### 4.7.3 TITANIUM ALLOY

#### (A) Temperature

Temperature is the measure of hotness or coldness expressed in terms of any of several scales, including Fahrenheit and Celsius. Temperature indicates the direction in which heat energy will spontaneously flow—i.e., from a hotter body (one at a higher temperature) to a colder body (one at a lower temperature).

#### (B) Total Heat Flux

Total Heat Flux and Energy Flux. Where  $E$  is the internal energy. It is the sum of convective heat flux,  $\rho uE$ , conductive heat flux,  $q$ , and radiative heat flux,  $q_r$ . Hence, the total heat flux accounts for all three kinds of heat transfer described in The Physical Mechanisms Underlying Heat Transfer.

#### (C) Total Heat Flux Directional

Heat flux, also known as thermal flux, is a term used to express an amount of energy transferred from one place to the other in the form of heat. Heat, the energy associated with the temperature of an object, travels from high temperature low temperature. Measuring this heat flux with heat flux sensors can be useful as these measurements can tell us whether the temperature of an object will go up, down or stay the same. It also tells why and how fast the temperature change is. More on this later.

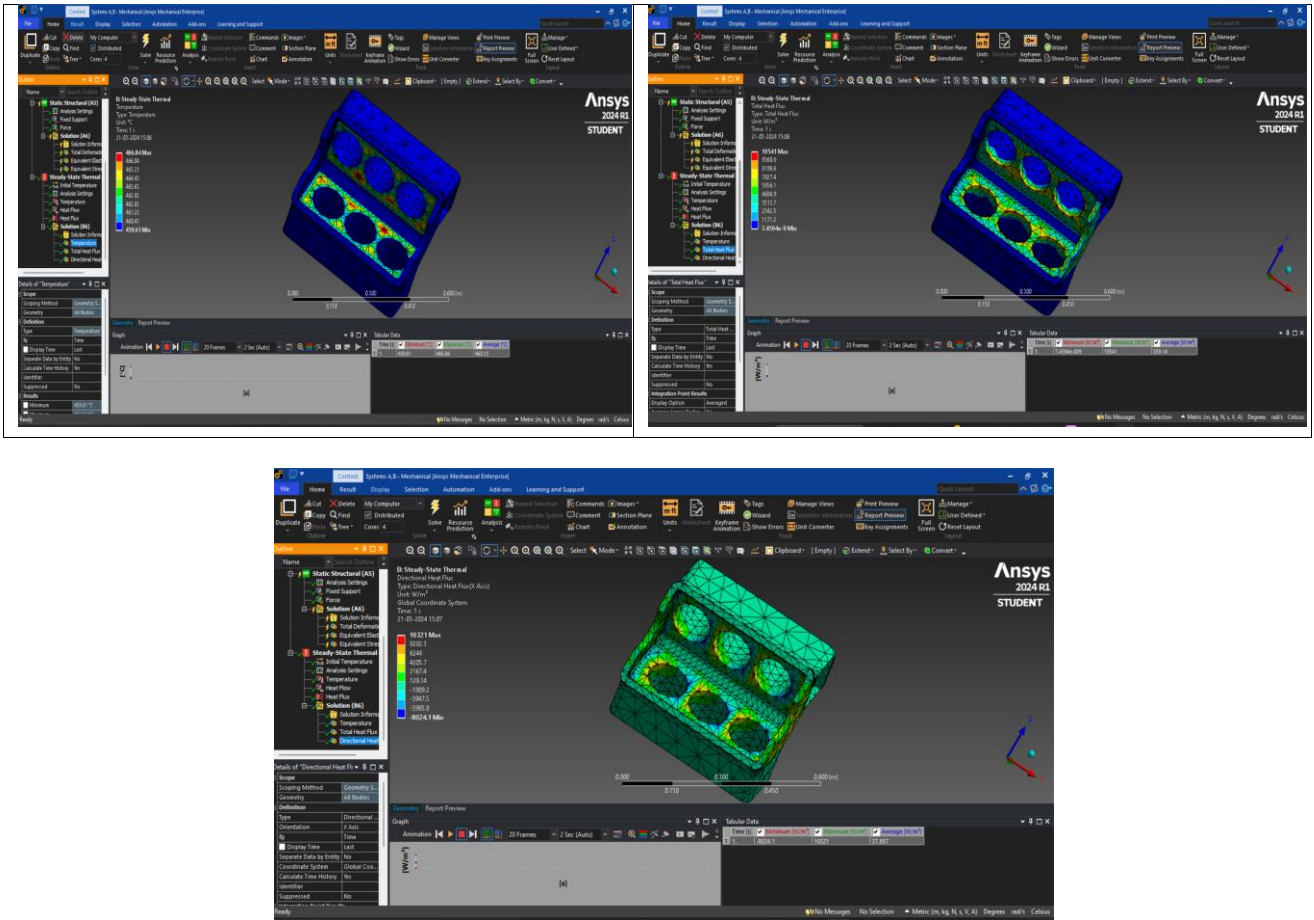


Fig.8 Titanium Alloy, (a) Temperature, (B) Total Heat Flux, (C) Total Heat Flux Directional

4.8 RESULTS

4.8.1 Static Structural (A5)

GRAY CAST IRON

Definition	Total Deformation	Equivalent Strain	Elastic	Equivalent (von-Mises) Stress
Type				
Results				
Minimum	0. m	7.1668e-009 m/m		242.71 Pa
Maximum	1.8593e-006 m	7.439e-006 m/m		6.2833e+005 Pa
Average	3.9459e-007 m	5.0216e-007 m/m		46854 Pa
Minimum Occurs On	3-FreeParts\Fillet7			
Maximum Occurs On	3-FreeParts\Fillet7			

STAINLESS STEEL

Definition	Total Deformation	Equivalent Strain	Elastic	Equivalent (von-Mises) Stress
Type				
Results				
Minimum	0. m	4.0677e-009 m/m		244.89 Pa
Maximum	1.0236e-006 m	4.1033e-006 m/m		6.2986e+005 Pa
Average	2.1677e-007 m	2.7537e-007 m/m		46800 Pa
Minimum Occurs On	3-FreeParts\Fillet7			
Maximum Occurs On	3-FreeParts\Fillet7			

TITANIUM ALLOY

Definition	Temperature	Total Heat Flux	Directional Heat Flux
Type			
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	459.61 °C	7.4594e-009 W/m²	-8024.1 W/m²
Maximum	466.84 °C	10541 W/m²	10321 W/m²
Average	460.13 °C	559.14 W/m²	37.857 W/m²
Minimum Occurs On	3-FreeParts\Fillet7		
Maximum Occurs On	3-FreeParts\Fillet7		



4.8.2 Steady State Thermal Analysis

GRAY CAST IRON

STAINLESS STEEL

TITANIUM ALLOY

Definition				Definition				Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux	Type	Temperature	Total Heat Flux	Directional Heat Flux	Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time			By	Time			By	Time		
Display Time	Last			Display Time	Last			Display Time	Last		
Separate Data by Entity	No			Separate Data by Entity	No			Separate Data by Entity	No		
Calculate Time History	Yes			Calculate Time History	Yes			Calculate Time History	Yes		
Identifier				Identifier				Identifier			
Suppressed	No			Suppressed	No			Suppressed	No		
Orientation			X Axis	Orientation			X Axis	Orientation			X Axis
Coordinate System			Global Coordinate System	Coordinate System			Global Coordinate System	Coordinate System			Global Coordinate System
Results				Results				Results			
Minimum	459.84 °C	2.4459e-008 W/m²	-8024.1 W/m²	Minimum	459.86 °C	3.2253e-008 W/m²	-8024.1 W/m²	Minimum	459.61 °C	7.4594e-009 W/m²	-8024.1 W/m²
Maximum	462.88 °C	10541 W/m²	10321 W/m²	Maximum	462.48 °C	10541 W/m²	10321 W/m²	Maximum	466.84 °C	10541 W/m²	10321 W/m²
Average	460.05 °C	559.14 W/m²	37.857 W/m²	Average	460.05 °C	559.14 W/m²	37.857 W/m²	Average	460.13 °C	559.14 W/m²	37.857 W/m²
Minimum Occurs On	3-FreeParts/Fillet7			Minimum Occurs On	3-FreeParts/Fillet7			Minimum Occurs On	3-FreeParts/Fillet7		
Maximum Occurs On	3-FreeParts/Fillet7			Maximum Occurs On	3-FreeParts/Fillet7			Maximum Occurs On	3-FreeParts/Fillet7		

V.CONCLUSION

1. Modeling and analysis of engine block is done
2. Modeling of engine block is done in catia v5 design software by using various commands and save as IGES file.
3. Analysis on engine block is carried out by using ansys work bench software.
4. First Static structural analysis is carried out on engine block at 400 MPa pressure with four different materials, such as Gray Cast Iron, Stainless Steel, Titanium Alloy.
5. Maximum stress, deformation and maximum strain are noted and tabulated
6. Then steady state thermal analysis is carried out at maximum temperature of 1000deg Celsius and convection is done by using fins from ambient temperature 27 deg Celsius.
7. Temperature distribution are noted for all four different materials and tabulated.
8. From the static analysis result tables, it is concluded that magnesium alloy show least stress and aluminum metal matrix shows least deformation & strain value on same static load condition.
9. From the thermal analysis result tables, it is concluded that grey cast iron shows heights temperature distribution i.e., minimum temperature and maximum heat flux on same thermal load condition followed by Stainless Steel metal matrix.

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