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Study of Thermal Stresses on Cast Iron and Aluminum Alloy V8 Cylinder Blocks for A Four Stroke CI Engine Without any Application of Cooling Systems

Sai Sandeep Illuri*

Abstract

The purpose of this paper is to investigate the thermal stresses experienced by a V8 cylinder block of a four stroke CI engine at a specific point in time during the engine's operation. Two case studies were performed for the cylinder block with different materials. Aluminum A356 T6 and Iron Cast are the materials used in these case studies for the cylinder block. Pressures and temperatures were applied only to the design's cylinder walls, which were produced by each stroke, with no lubrication or cooling systems used. 1-8-4-3-6-5-7-2 firing order of the engine is taken into account in the design simulation. Various factors i.e., safety factor, stress, displacement, reaction force, strain, temperature, heat flux, thermal gradient is analyzed for each material of cylinder block. Fusion 360 software is used for the analysis.

Keywords: Cylinder block, four stroke CI engine, thermal analysis, structural analysis, simulation, stress, strain, displacement, mechanics, automobile, car

INTRODUCTION

A four-stroke CI engine is an internal combustion engine in which the piston completes four separate strokes while the crankshaft is turned and the elevated temperature of the air in the cylinder caused by mechanical compression causes the fuel to ignite. The CI diesel engine has a higher mechanical efficiency, which eliminates pumping losses at part load. It doesn't need to manage air intake therefore it can run with a heterogeneous mixture and adjust the load with the amount of fuel injected into the cylinder. The cylinder block is an important part of the engine. It is critical to the engine's lubrication, temperature control, and stability. It holds the piston, connecting rod, and crankshaft in place [1–5]. They complete their tasks within the bounds of the block. A V8 engine, in particular, is an eight-cylinder piston engine with two banks of four cylinders arranged in a V and sharing a common crankshaft. The engine components, including auxiliary devices, are supported by the block. A/C compressor, alternator, intake, and exhaust manifolds, and so on. It is quite important for engine cooling. The engine cooling system includes engine coolant, passages inside the engine block and cylinder head, a water pump to circulate the coolant, a thermostat to control the coolant's temperature, a radiator to cool the coolant, a fan to pull air through the radiator, a radiator cap to control the system's pressure, and interconnecting hoses to transfer the coolant from the engine to the radiator. Three important functions are served by these systems. It does three things: first, it removes surplus heat from the engine; second, it keeps the engine running temperature where it is most efficient; and third, it swiftly brings the engine up to the proper operating temperature.

Overheating without a cooling system can cause cylinder head gaskets to blow and, in severe cases,

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engine blocks to shatter. And all this heat must be combated. So, the thermal stress analysis of this V8 cylinder block aids in understanding the requirement for cooling systems for various engine block materials [6–9].

Aim

The aim of this work is to perform thermal stress analysis for a V8 Cylinder block of a four stroke CI Engine without cooling system.

Geometry of Cylinder Block

The V configuration of an engine block has become more popular in recent decades [10, 11]. This angle produces superior engine balance, resulting in fewer vibrations; yet, it has a wider breadth than V8 engines with a smaller V-angle as shown in Figures 1, 2, 3.

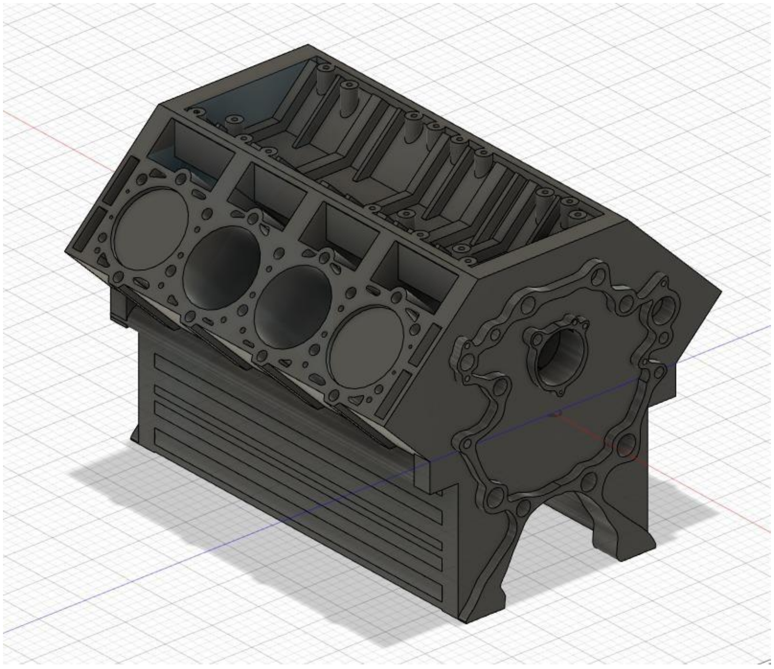

Figure 1. Design of V8 cylinder block.

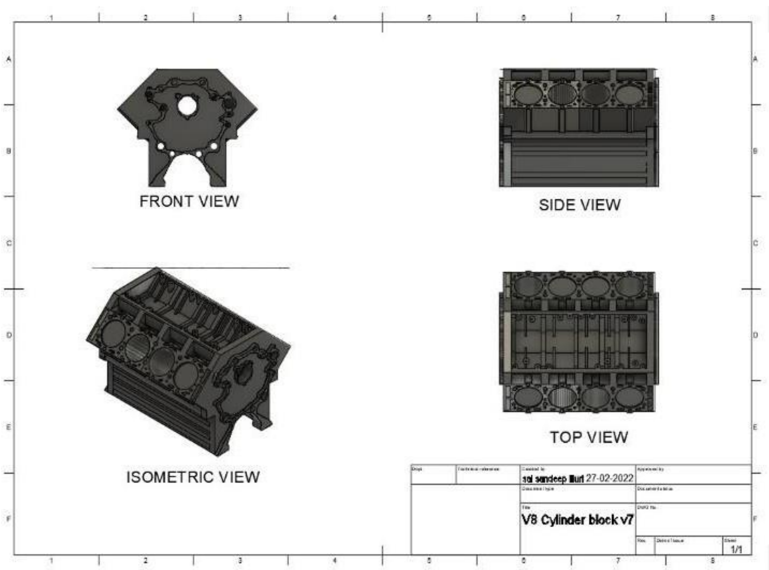

Figure 2. Views of V8 cylinder block.

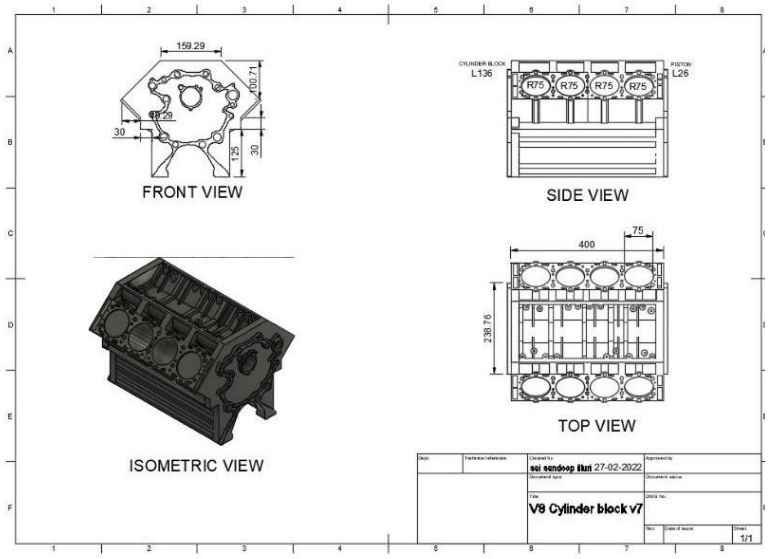

Figure 3. Dimensions of V8 cylinder block.

Considered Time of Simulation

The simulation is conducted at a point of time during engine working as shown in Figure 4.

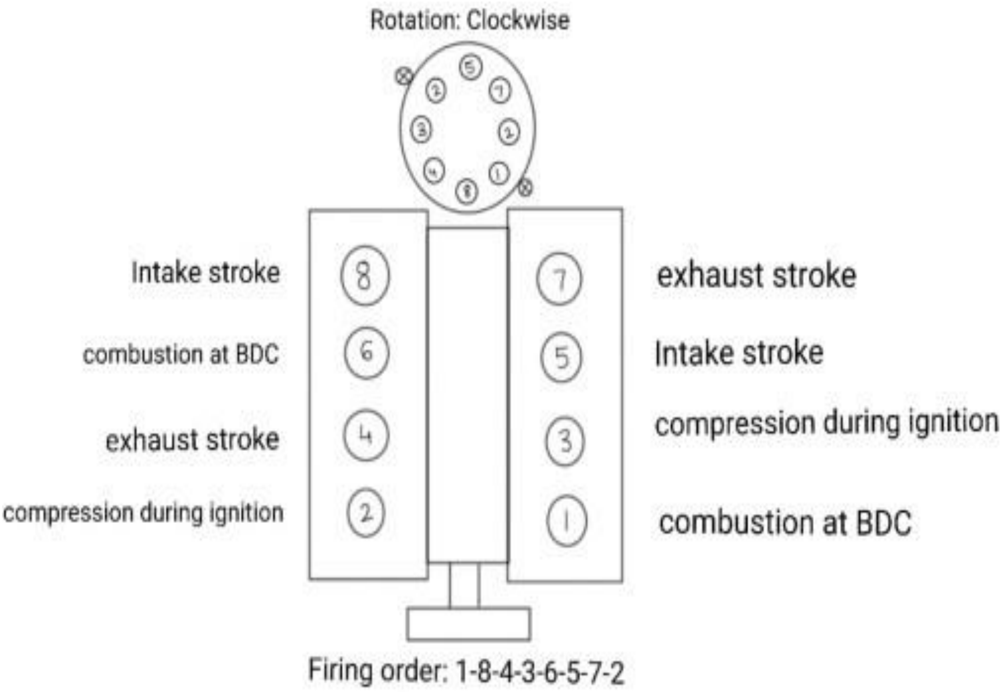

Figure 4. Study time.

Table 1. Parameters.

Position	**Thermal load**	**Structural load**
Intake stroke	240 C	15 psi
Compression during ignition	1500 C	2000 psi
Combustion at BDC	600 C	500 psi
Exhaust stroke	500 C	15 psi

RESULTS

Case study 1—Aluminum A356 T6, and Case study 2—Iron cast as shown in Figures 5–20 and Table 1.

Safety Factor of Cylinder Block

A measure of a design's dependability is the ratio of a structure's absolute strength (structural capacity) to the actual applied load. Because complete testing is prohibitive on many projects, it describes how much more powerful a system is than it needs to be to handle a given load. Rigid analysis is widely used to calculate safety factors. However, the structure's load-bearing capability must be determined with some precision. In order to accommodate emergency occurrences, unplanned loads, misuse, or deterioration, many systems are built significantly stronger than they need to be for everyday operation (reliability). Tables 2, 3 shows the safety factor of cylinder block.

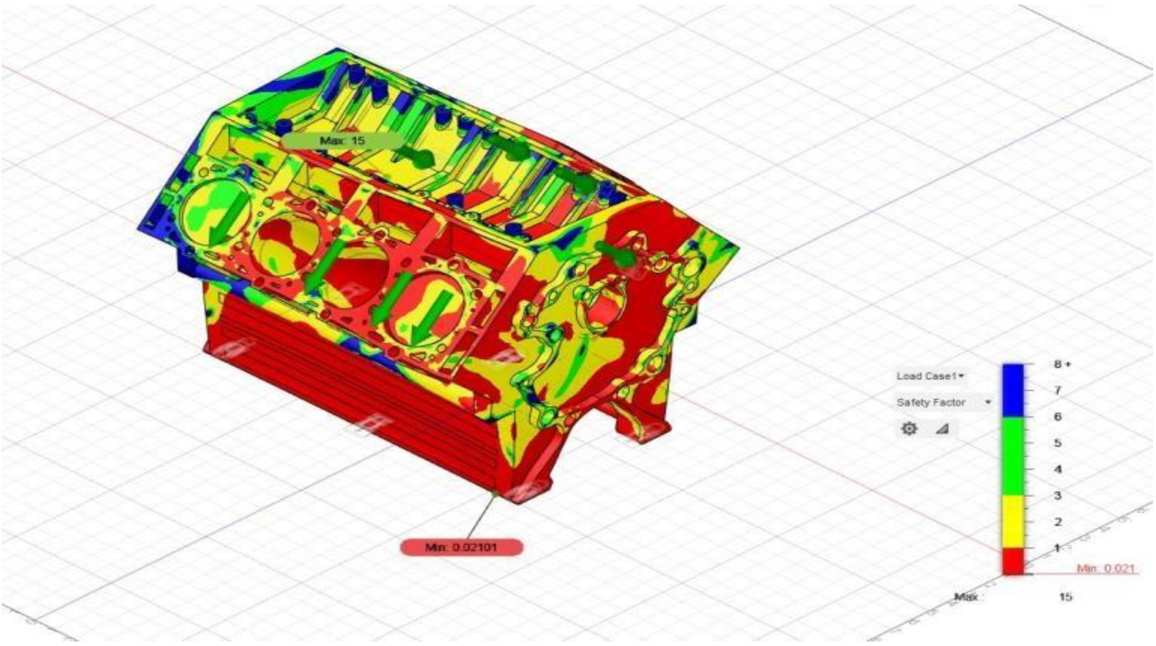

Figure 5. Case study 1—Safety factor for aluminum A356 T6.

Table 2. Case study 1 Safety factor.

Safety factor	**Maximum**	**Minimum**
Safety factor	15	0.02101

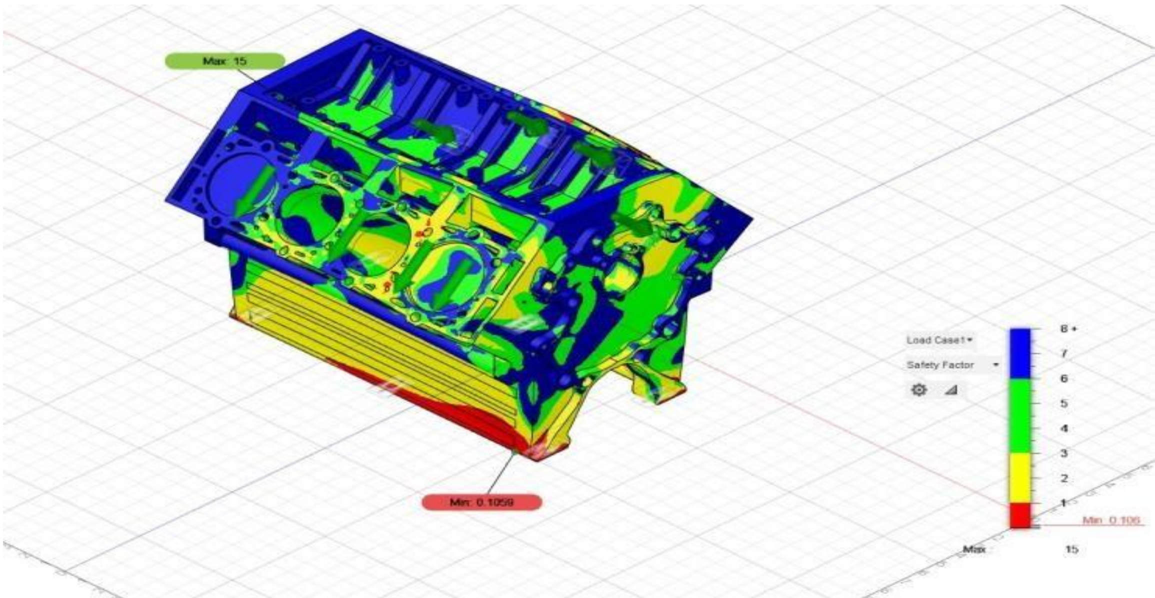

Figure 6. Case study 2—Safety factor for iron cast.

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Table 3. Case study 2 Safety factor.

Safety factor	Maximum	Minimum
Safety factor	15	0.1059

Stress Analysis of Cylinder Block

The study of stresses and strains in materials and structures when force is applied is known as stress analysis. It's a specialized topic. Materials can deform or fracture as a result of stress. The goal of stress analysis is to figure out how much stress causes material deformation. This is used to create a variety of constructions, including machines. The maintenance of these structures, as well as the investigation of structural breakdowns, rely on stress analysis. Tables 4 and 5 show the stress analysis.

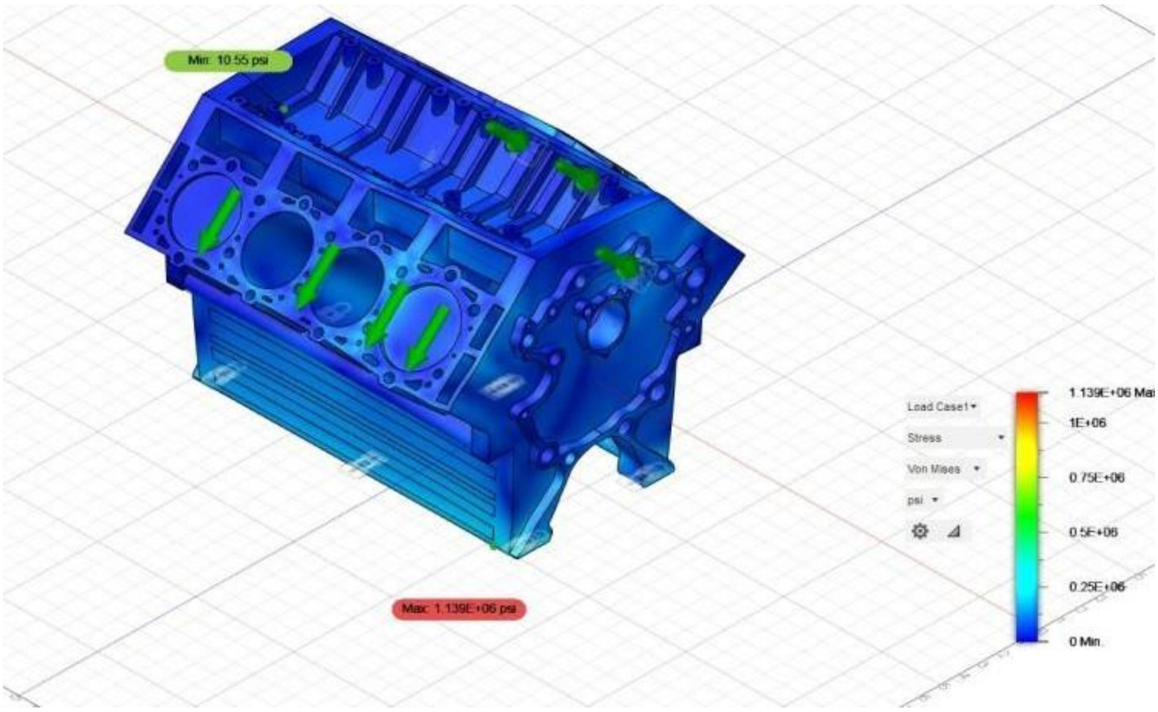

Figure 7. Case study 1—Stress analysis for aluminum A356 T6.

Table 4. Case study 1—stress analysis.

Stress	Maximum	Minimum
Von mises	1.39E+06	10.55
1st principal	577338	-447272
3rd principal	58695	-1.638E+06
Normal XX	293653	-736770
Normal YY	203834	-1.234E+06
Normal ZZ	519162	-805044
Shear XY	496901	-305209
Shear YZ	567633	-581440
Shear ZX	103317	-146575

Table 5. Case study 2 stress analysis.

Stress	Maximum	Minimum
Von mises	1.38E+0.6	6.217
1st principal	537740	-354062
3rd principal	0.048E+06	-1.441E+06
Normal XX	273158	-588330
Normal YY	0.183E+06	-1.097E+06
Normal ZZ	484720	-659256
Shear XY	438257	-275870
Shear YZ	505411	-508873
Shear ZX	96406	-135285

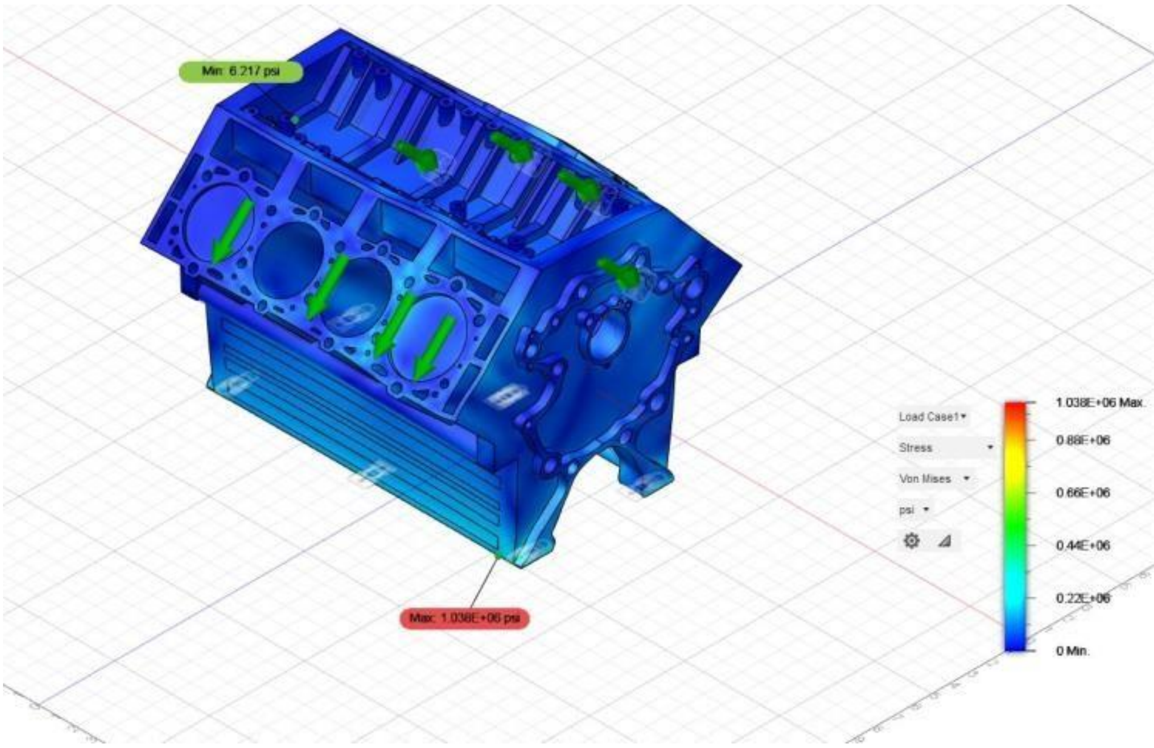

Figure 8. Case study 2—Stress analysis for iron cast.

Displacement Analysis of Cylinder Block

Displacement analysis is a technique for assessing the total consumer worth of competing businesses. In most cases, the part of the business that creates the most total customer value is chosen. Forces are the primary unknown in the force method of analysis. These equations are used to determine redundant forces. Equilibrium equations are used to assess the remaining reactions once the redundant forces have been calculated. Figures 6 and 7 show the displacement analysis.

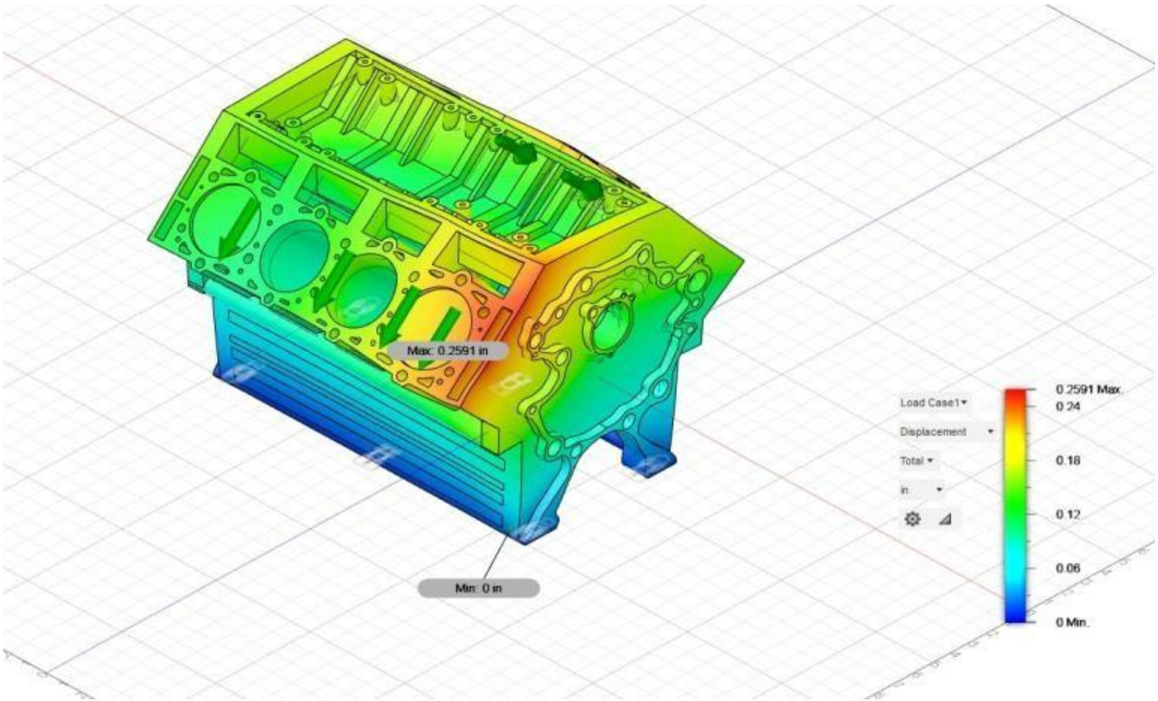

Figure 9. Case study 1—Displacement analysis for aluminum A356 T6.

Table 6. Case study 1—Displacement analysis.

Displacement	Maximum	Minimum
Total	0.2591	0
X	0.1541	-0.1231
Y	0.2309	-0.0065
Z	0.1658	-0.1758

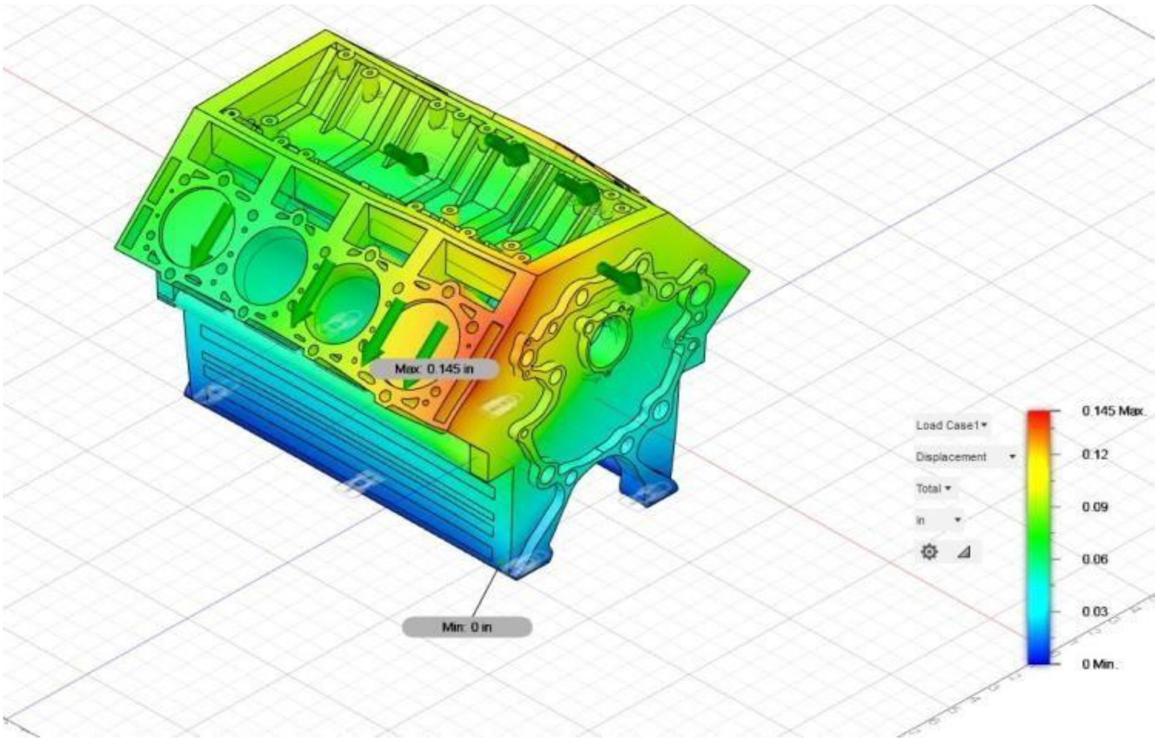

Figure 10. Case study 2—Displacement analysis for iron cast.

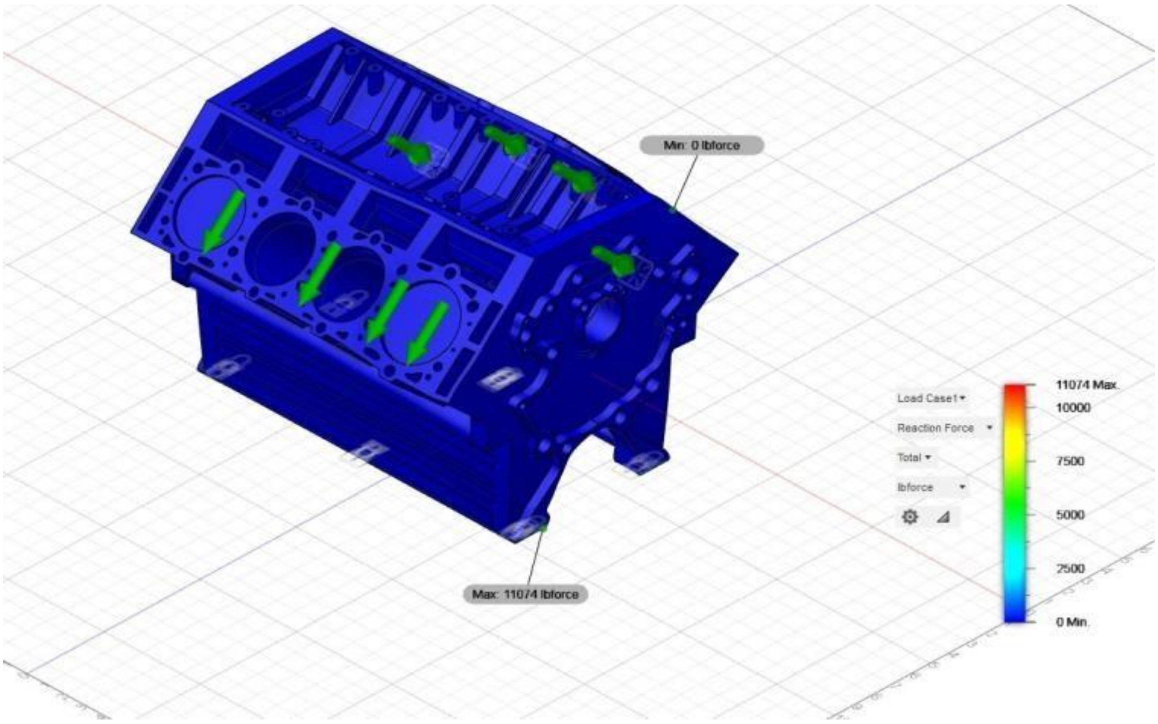

Figure 11. Case study 1—Reaction force for aluminum A356 T6.

Table 7. Case study 2—Displacement analysis.

Displacement	Maximum	Minimum
Total	0.145	0
X	0.08639	-0.06896
Y	0.129	-0.0036
Z	0.09362	-0.0986

Reaction force Analysis of Cylinder Block

The primary unknown in the force method of analysis is forces. For displacements and rotations, compatibility equations are created. These equations are used to determine redundant forces. Equilibrium equations are used to assess the remaining reactions once the redundant forces have been calculated. Tables 8 and 9 show the reaction force analysis.

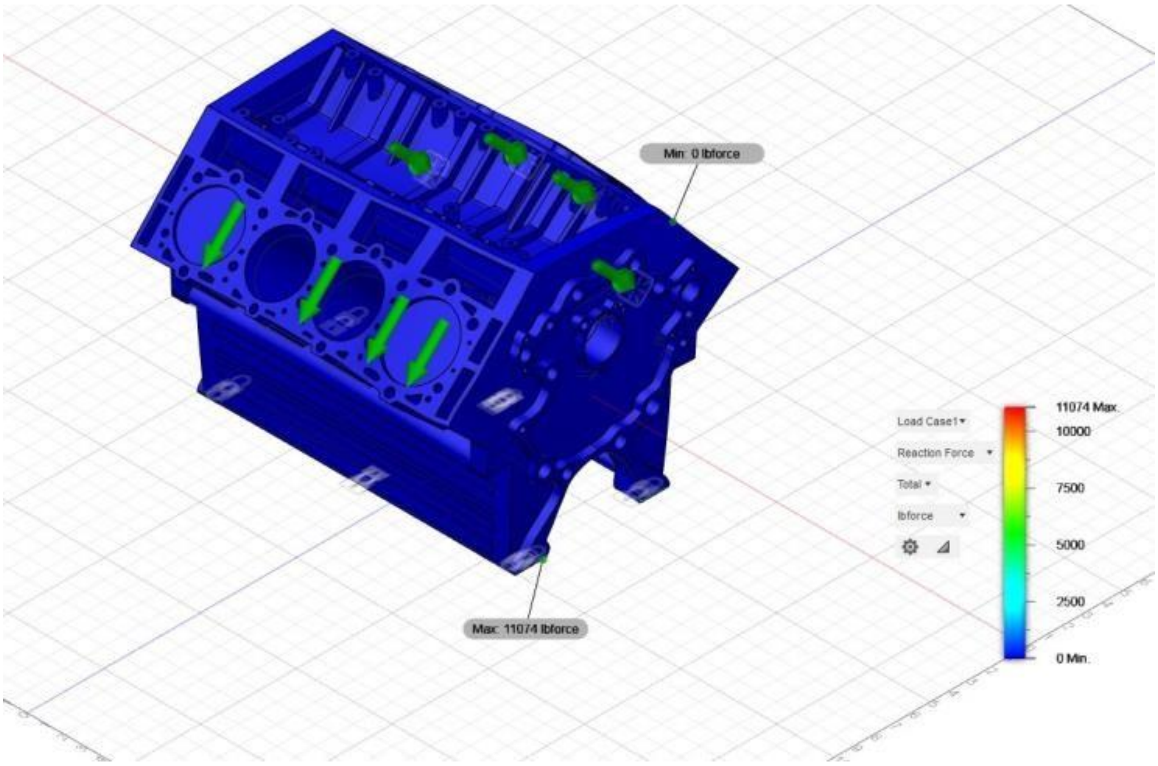

Figure 12. Case study 2—Reaction force for iron cast.

Table 8. Case study 1—Reaction force analysis.

Reaction force	Maximum	Minimum
Total	12190	0
X	6282	-8172
Y	8417	-5030
Z	7893	-6212

Table 9. Case study 2—Reaction force analysis.

Reaction force	Maximum	Minimum
Total	11074	0
X	5442	-7284
Y	7773	-4649
Z	7034	-5479

Strain Analysis of Cylinder Block

Strain analysis is a useful method for determining how a material reacts to different loading circumstances. In a variety of working circumstances, this technology can be used with both physical and optical testing procedures. Static and dynamic loading, as well as other environmental factors including load, torque, pressure, vibration, and temperature, can all affect components. Our strain analysis services assist you in making informed judgments about the performance of your product, such as its strength, load limitations, usable life, and operational performance factors. Tables 10 and 11 show the strain analysis.

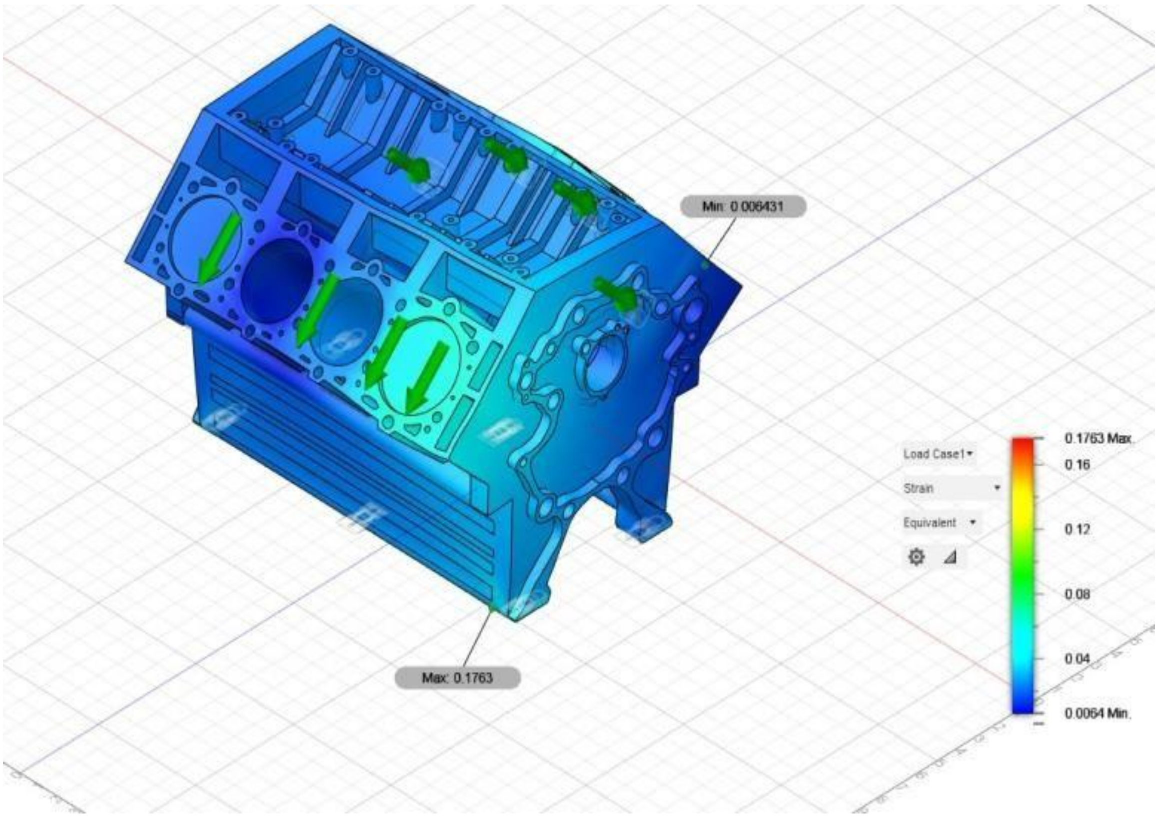

Figure 13. Case study 1—Strain analysis for aluminum A356 T6.

Table 10. Case study 1—Strain analysis.

Strain	Maximum	Minimum
Equivalent	0.1763	0.0064
1st principal	0.1243	0.0048
3rd principal	0.0422	-0.1801
Normal XX	0.05619	-0.01525
Normal YY	0.04541	-0.0572
Normal ZZ	0.06195	-0.00699
Shear XY	0.1259	-0.0773
Shear YZ	0.1438	-0.1473
Shear ZX	0.02617	-0.03713

Table 11. Case study 2—Strain analysis.

Strain	Maximum	Minimum
Equivalent	0.09329	0.00356
1st principal	0.06193	0.00267
3rd principal	0.02362	-0.09693
Normal XX	0.03174	-0.00867
Normal YY	0.02537	-0.03391
Normal ZZ	0.03508	-0.00387
Shear XY	0.0652	-0.04104
Shear YZ	0.07519	-0.0757
Shear ZX	0.01434	-0.02013

Temperature of Cylinder Block

When a substance is heated or cooled, thermal analysis is a broad term that refers to a process for determining the time and temperature at which physical changes in the substance occur. The types of physical changes that are being researched define each technique. When analyzing material qualities, numerous approaches or a combination of methodologies may be necessary, depending on the goal. Tables 12 and 13 show the temperature.

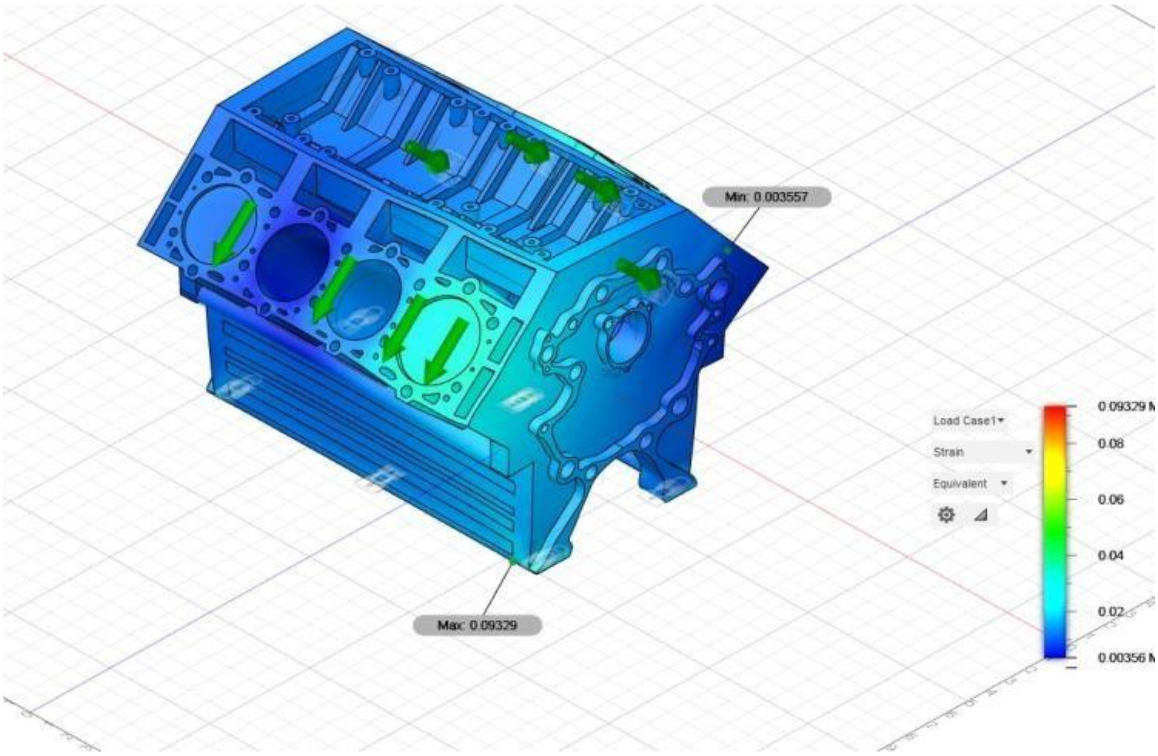

Figure 14. Case study 2—Strain analysis for iron cast.

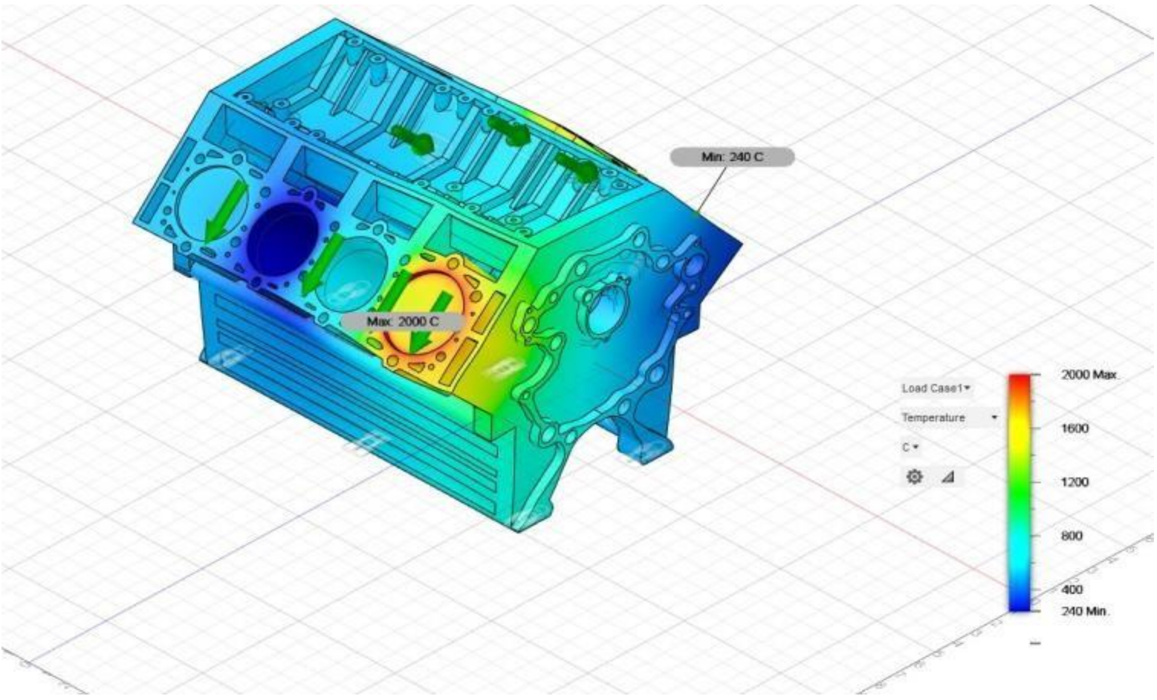

Figure 15. Case study 1—Temperature for aluminum A356 T6.

Table 12. Case study 1—Temperature.

Temperature	Maximum	Minimum
Temperature	240	2000

Table 13. Case study 2—Temperature.

Temperature	Maximum	Minimum
Temperature	240	2000

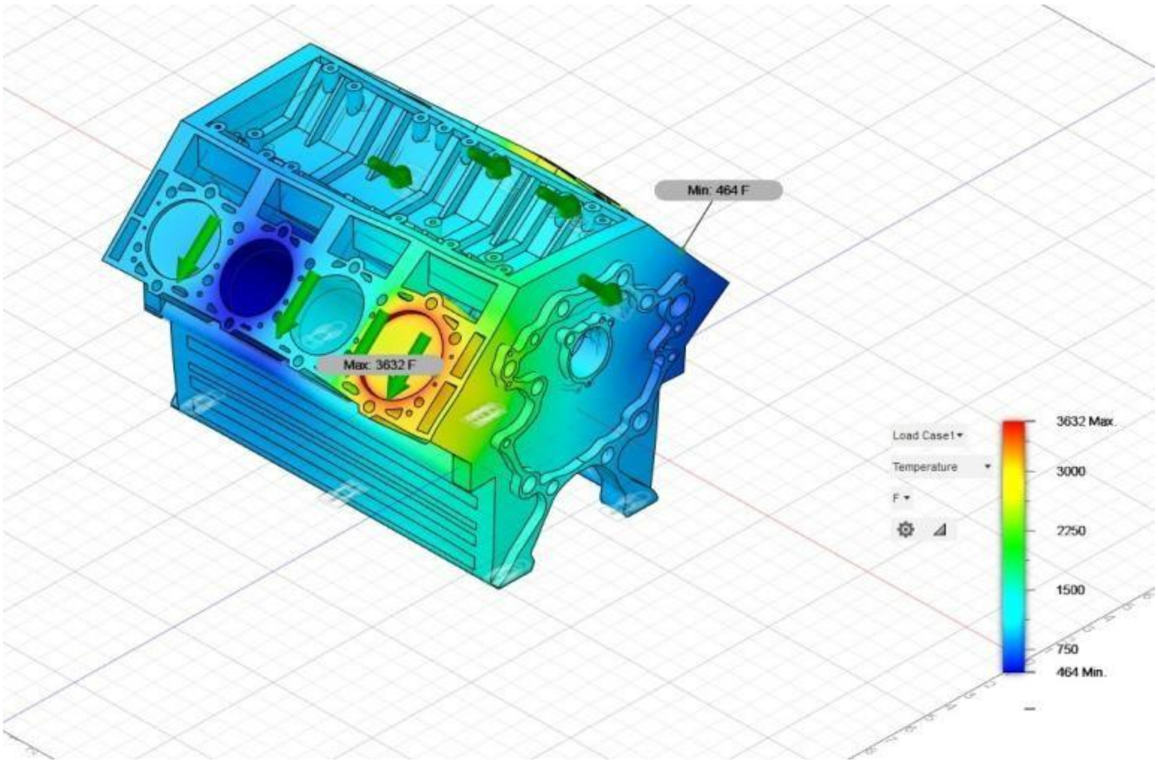

Figure 16. Case study 2—Temperature for iron cast.

Heat Flux of Cylinder Block

Heat flux is defined as a flow of energy per unit of area per unit of time. Because it has both a direction and a magnitude, it is a vector quantity. The heat flux at a particular place in space is defined by the limiting case, in which the size of the surface becomes infinitesimally small. The Heat Transfer simulation type can be used to calculate the temperature distribution and heat flow in solids under thermal loads. The amount of heat transported through a wall or a human body, as well as the amount of solar or laser radiant energy conveyed to a certain region, can be determined by measuring the heat flux of a design. Tables 14 and 15 show the heat flux.

Table 14. Case study 1—Heat flux.

Heat flux	Maximum	Minimum
Total	13.72	0
X	13.65	-10.95
Y	3.784	-4.386
Z	5.003	-3.701

Table 15. Case study 2—Heat flux.

Heat flux	Maximum	Minimum
Total	1.909	0
X	1.899	-1.523
Y	0.5263	-0.61
Z	0.6958	-0.5147

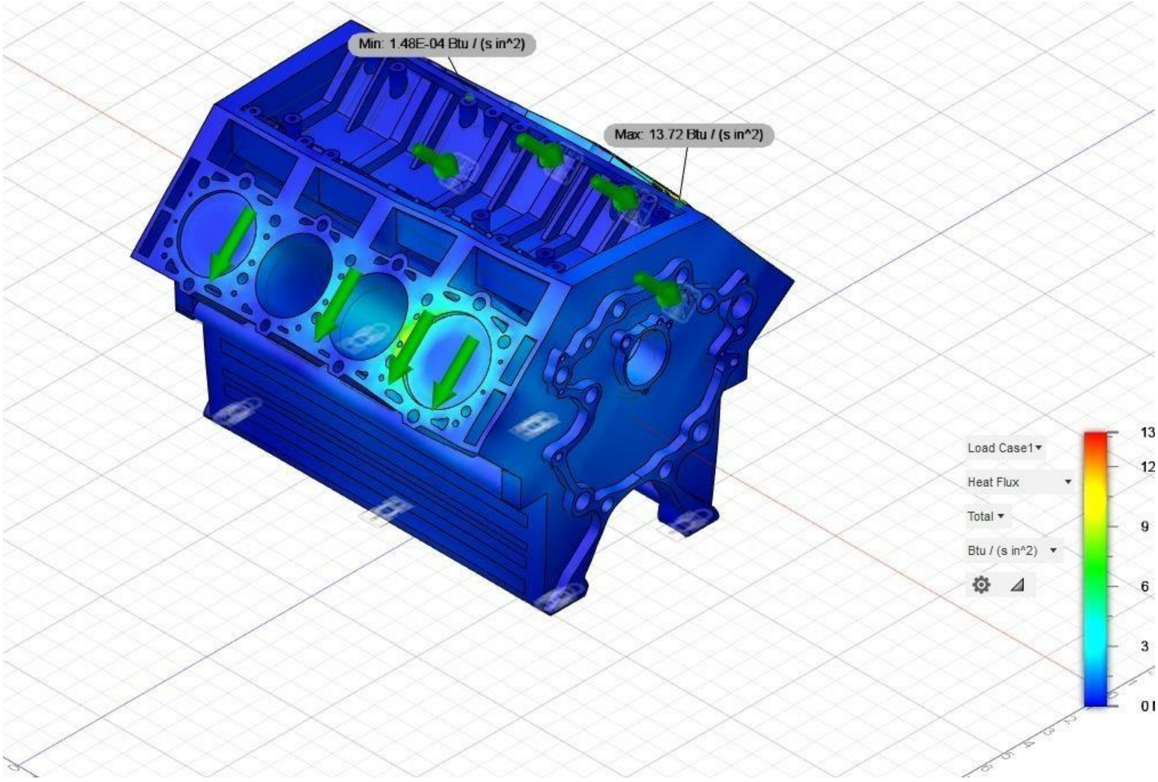

Figure 17. Case study 1—Heat flux for aluminum A356 T6.

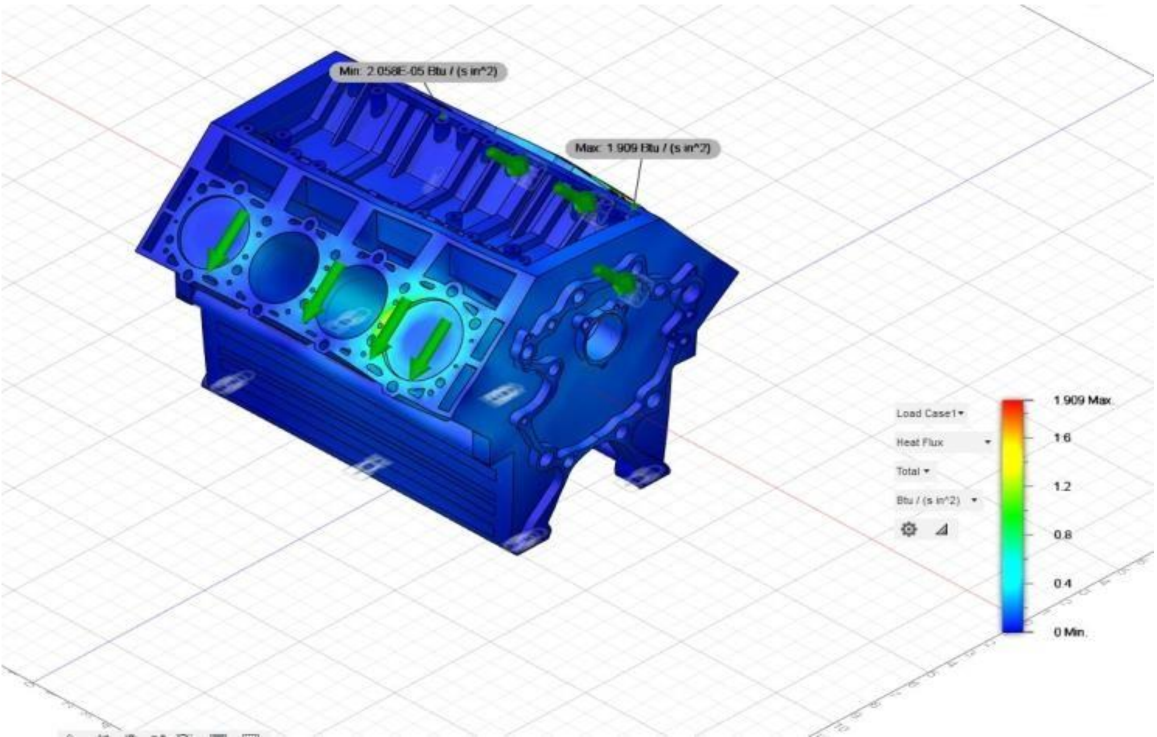

Figure 18. Case study 2—Heat flux for iron cast.

Thermal Gradient of Cylinder Block

A temperature gradient is a physical quantity that describes how rapidly and in which direction temperature changes in a given area. In thermal gradient analysis, it is defined by two physical quantities. The first is the temperature issue. The second parameter that defines a thermal gradient is its

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length. It is defined as the temperature difference divided by the distance between two points. Tables 16 and 17 show the thermal gradient.

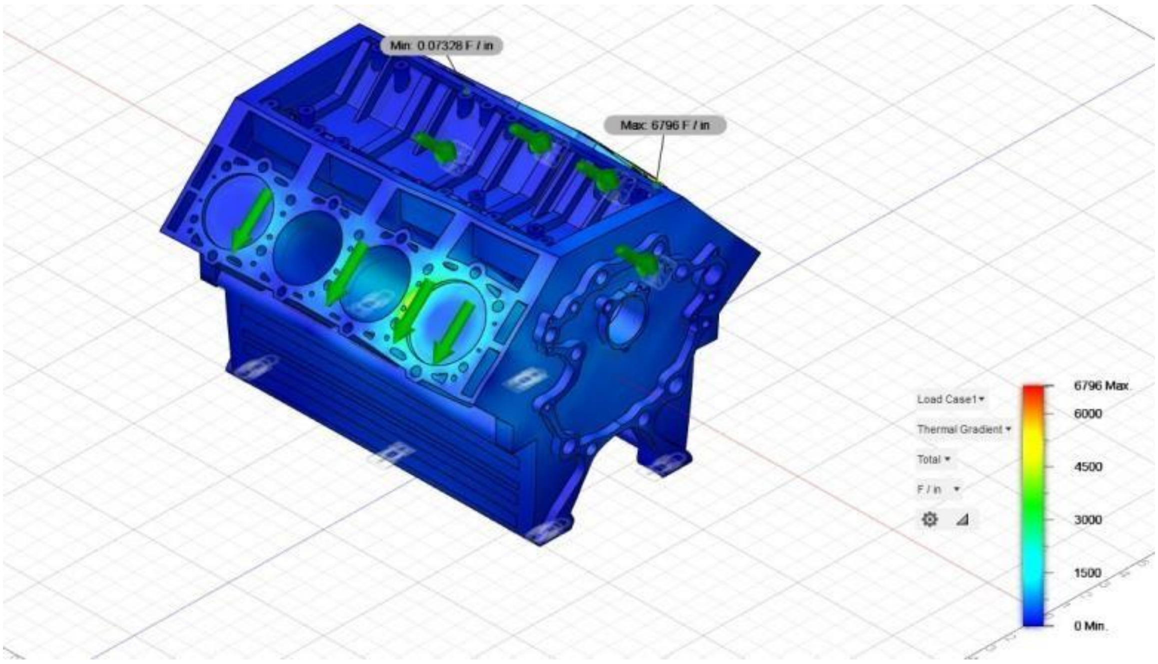

Figure 19. Case study 1—Thermal gradient for aluminum A356 T6.

Table 16. Case study 1—Thermal gradient.

Thermal gradient	Maximum	Minimum
Total	6796	0
X	5424	-6760
Y	2172	-1874
Z	1833	-2477

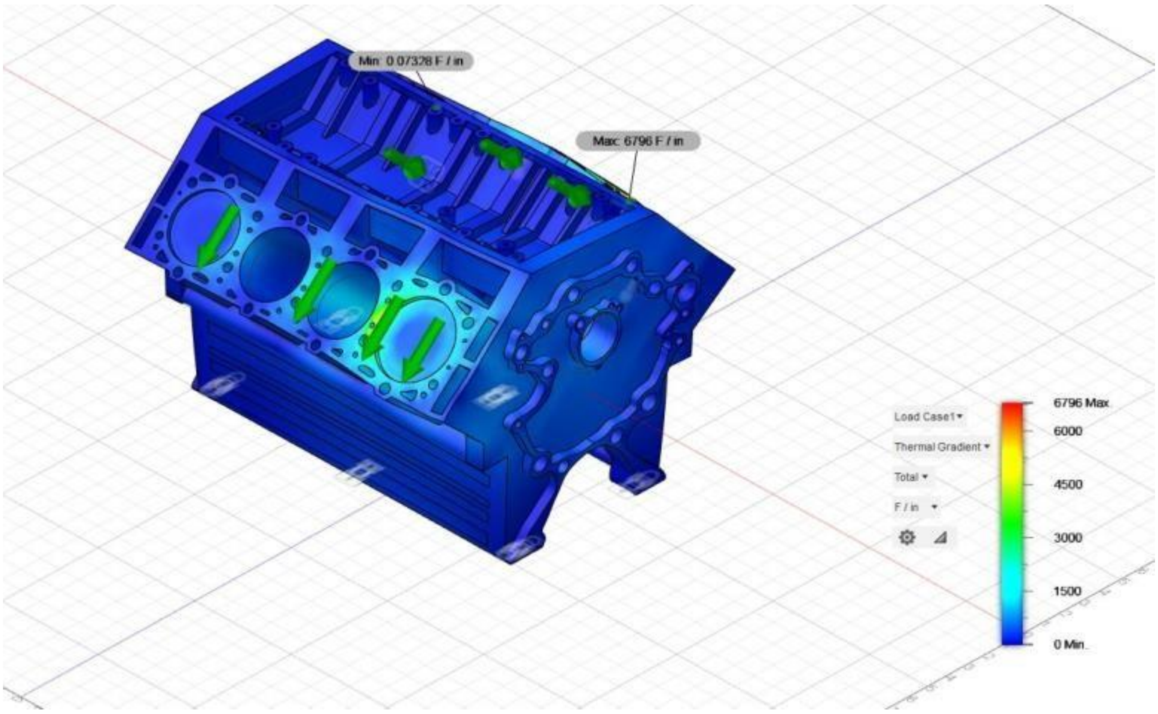

Figure 20. Case study 2—Thermal gradient for iron cast.

Table 17. Case study 2—Thermal gradient.

Thermal gradient	Maximum	Minimum
Total	6796	0
X	5424	-6760
Y	2172	-1874
Z	1833	-2477

CONCLUSION

The thermal stress differences for the selected materials of four stroke CI Engine's Cylinder blocks are analyzed under various factors. Requirement of cooling systems for the selected materials i.e., Aluminum A356 T6 and Cast iron can be assumed with the results. The thermal stress analysis of aluminum A356 T6 is carried out as Load case 1 and Iron cast is carried out as Load case 2. The thermal stress experienced in the load case 1 is more when compared to load case 2 where the dimensions used are exactly same for both cases. As a result, the action of coolant is required more from the aluminum A356 T6 when compared to iron cast. This study shows the thermal stresses experienced by the cylinder block materials which shown the requirement of cooling systems in both cases.

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