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FEM Analysis and Optimization of Piston of Different Material Using ANSYS

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Abstract: FEA approach is used in this study to analyze the performance of piston with different material and compression ratio. Static-thermo based FEM technique is used using ANSYS. Aluminum alloy and SiC-reinforced ZrB2 composite material is selected for analysis and performance comparison. The model of piston is designed in CATIA software. Stress, strain, deformation, temperature and heat flux were the main performance characteristics. Results indicate that performance of SiC reinforced ZrB2 piston is found better than aluminum alloy piston in terms of Stress, strain, deformation, temperature and heat flux.

Index Terms - **Stress, four stroke engine piston, Finite element analysis, Aluminium alloy and SiC reinforced ZrB2, CATIA, ANSYS.**

1. INTRODUCTION

The piston is an alternative component in an engine that Converts chemical energy to mechanical energy since fuel has been burned. The piston 's function is just to pass energy into the drive shaft through most of the connecting rod. That piston ring forms a barrier here between piston and also the nozzle. It appears to be trying to work at low friction, Strong explosive loads and temperatures between 20000 ° C and 2800 ° C. The piston must also be sturdy although its weight must also be lower in order to prevent inertial forces due to all the reciprocating action. A piston is among the reciprocating engines, among several other similar mechanisms, Motors, petrol compressors, and pneumatic tubes. This is the rotating component of a circle, which is hermetic across elastic bands. The purpose within an engine is to transfer the force of both the expanding gas to just the cylinder through with a connecting rod and/or another connection rod to just the crankshaft. The pistons are generally made of aluminum alloy and cast iron. But compared to cast iron, Al alloy is more preferred due to its light weight, which is also ideal for an alternative component. There are also some disadvantages of alloys compared to cast iron, which are Al alloys which have been reduced in strength and wear quality. The thermal conductivity of Al would be about three times Motors, petrol compressors, including pneumatic tubes. This is now the rotating component of a circle, which would be hermetic across elastic bands. The purpose within an engine is just to transfer through force of both the expanding gas to just the cylinder thru the connecting rod and/or another connection rod to just the piston. The area of the piston pin is subjected to tremendous force due to sudden changes of direction. Therefore, thermal expansion occurs due to the heat transfer from the head to both piston cores. That field of the piston pin undergoes greater thermal expansion Rather than piston zones. It is due to both the thermal expansion characteristics of either the aluminum die-cast alloy and also the density also in piston pin region.

2. LITERATURE REVIEW

Kumar et al.(2019) The present investigation explains the distribution of stresses and thermal stresses of five different piston materials using the "finite element method (FEM), which measures mechanical properties. The parameters used for the simulation are the operating pressure of the gas, the temperature, and the properties of the piston material".

Sivaramakrishnan et al.(2019) Piston is a major component of the engine reciprocating mechanism. The power is passed from either the piston into the crank. Through the connecting rods the crank is used to transfer the power from either the piston to the motor. A piston is the bulk of the internal combustion engine that converts the fuel's chemical energy into to the mechanical energy.
Sakthivel et al.(2018) In this project, We are perfecting the piston material and developing the 3D model of the piston using the pro-e software, analyzing various materials and analyzing the ANSYS software. In this project, we examine the piston pressure of both materials.

Tamboli et al.(2018) The Gudgeon pin connects the piston and, in fact, the small end of the engine connecting rod. The same wear of the Gudgeon pin and the customer's interest in the connecting rod. In this way, the friction stress and also the von Mises stresses are generated on the pin and are calculated using the ANSYS finite element analysis method.

Kumar et al.(2018) Present study deals with the past literature survey which explains that piston is the part of the internal combustion engine and sustains a high range of temperature inside the engine cylinder. Piston gas pressure, temperature, and material functions are parameters considered for the purpose of the inquiry. As a result, piston would also have to be in decent working order to for engine should run smoothly. Within an I.C. Piston, car, is far more nuanced and critical.

Sagare et al.(2018) The piston corresponds to the cylinder that completes the cyclic events and transmits the gas force through the connecting rod to the crankshaft. "For an internal combustion engine, the piston is the most critical part". The operating conditions of the internal combustion of the piston are worse.

Manusha et al.(2018) The whole research primarily deals with design and installation of the I.C piston motor, piston rings, including connecting rod. Piston is typically a part of reciprocating engines, gas compressors, as well as pneumatic cylinders among several other related mechanisms.

Kumar et al. (2017) The piston is the engine's most critical feature. We can use light materials like aluminum and titanium to build the piston to minimize weight, as improved engine design requires optimized engine components. Besides the piston's lower weight, waste rejection is also a big concern.

Shetty et al.(2017) This article explains the structural study of four Pistons constructed from aluminium alloy use the finite element method (FEM). The piston design specifications apply to the Bajaj Pulsar 220cc four stroke single cylinder engines as well as the simulation parameters are the piston operating gas pressure, certain temperature and also the material parameters. The tests estimate high stress and tension on several FEA aluminium alloy pistons. Modelling of various aluminium alloy pistons with CATIA V5R20. The static structural survey uses "ANSYS WORKBENCH 14.5. The best aluminium alloy material is selected by stress analysis. Tests are used to determine the correct geometry of the aluminium alloy piston".

KUMAR et al.(2017) The piston plays a crucial part in transmitting electricity. Thermal and hydraulic tension triggers a piston breakdown. Which Piston's employment conditions are much greater than in certain sections of the combustion engine at all. This research will have the main objective of studying and evaluating the piston tension distribution. Production and analysis of an IC piston motor utilizing three separate materials.

Shrivas et al.(2017) This study involves 3D numerical Simulation for internal combustion engine with 4-stroke. The main goal of this research is to have an interpretation of how to model heat transfer in either a diesel piston and between the piston as well as the surrounding cylinder liner through presenting a detailed report as well as a reliable and thorough modelling methodology.

Kesavan et al.(2017) Pistons are very critical sources of energy in engines. Piston failure due to mechanical stress and thermal stress. This research presents and analyzes an analysis of thermal stress and damage due to the application of temperature. Aluminium alloy selected for the thermal investigation of the pistons.

Sinha et al.(2017) The performance of the car Has various things to rely on. Engine performance can be improved whilst also minimizing this same vehicle's weight and maximizing this same thermo-mechanical capacity of both the engine components, especially the piston.

Viswabharathy et al.(2017) For the this paper That wok has been used to measure the distribution of pressures and temperatures upon this top surface of both the piston. By I.C. This same engine piston is by far the most complex part and should be throughout good condition also for smooth running of both the vehicle piston. Pistons often fail because of mechanical stress and thermal stress.

3. METHODOLOGY

Throughout operation, that piston was subjected to combustion exposed to high air heat and temperature. Around about the same time, the broad end of both the connecting rod is protected only with assistance of both the piston pin (Gudgeon pin). The technique for piston analysis is then considered; the specified 20 MPa gas load is generated uniformly upon this upper surface of both the piston (crown) and prevents every degrees of freedom. for the knots in the upper half of the protrusion of the piston pin where the piston pin will be fixed. Considering that the type of coupling between the piston pin and the piston is free, during the analysis only the upper half of the protrusion of the piston pin is considered. The element chosen to match the piston model is the solid form tetrahedron187 element which is a higher order tetrahedral element. Counting of the model links includes node numbers 71910 and unit numbers 41587. The materials chosen for this work are Aluminium alloy and Silicon carbide reinforced Zirconium diboride for an internal combustion engine piston.

4. RESULTS And DISCUSSION

In this study, the compression ratio is increased from 14.1:1 to 15.1:1 to examine the effect of compression ratio on total deformation, Equivalent Stress, Equivalent Elastic Strain, Total Heat Flux, and Directional Heat Flux. For increasing the compression ratio, the pressure of the gas was increased from 20 MPa to 22 MPa

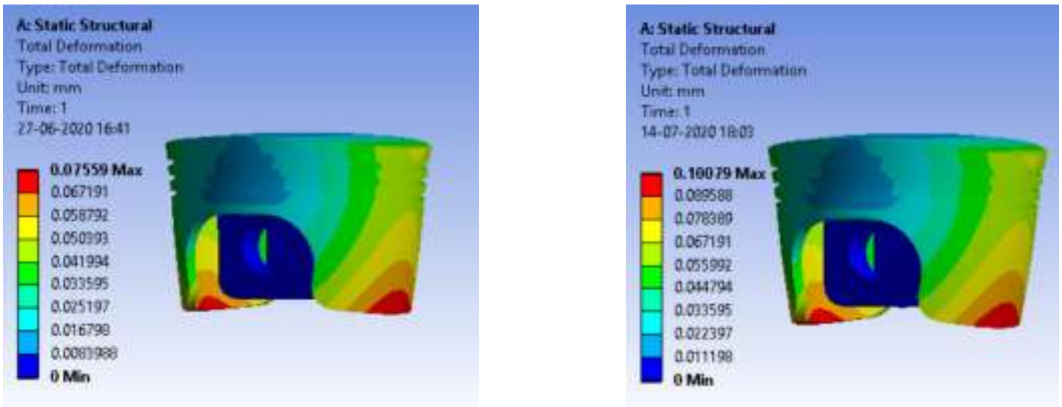

Fig.4.1: Total Deformation of aluminium piston for CR 14.1:1 and 15.1:1

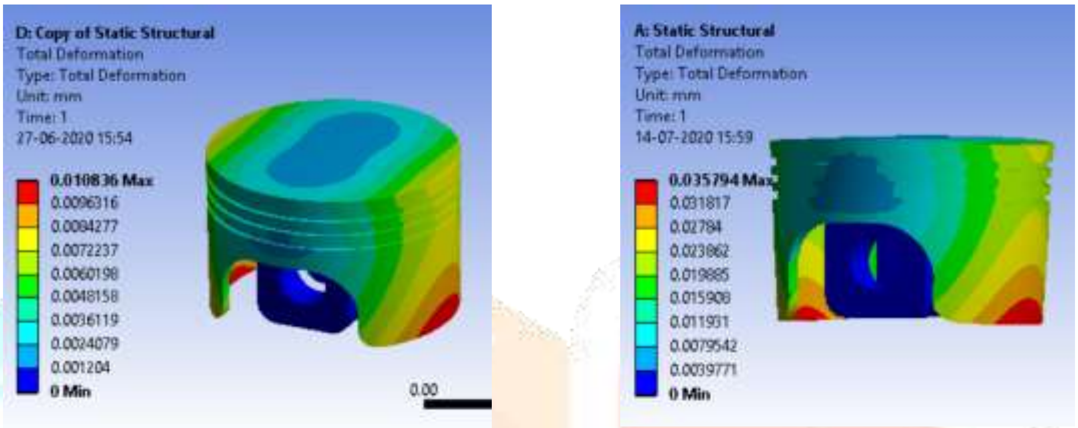

Fig.4.2: Total Deformation of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

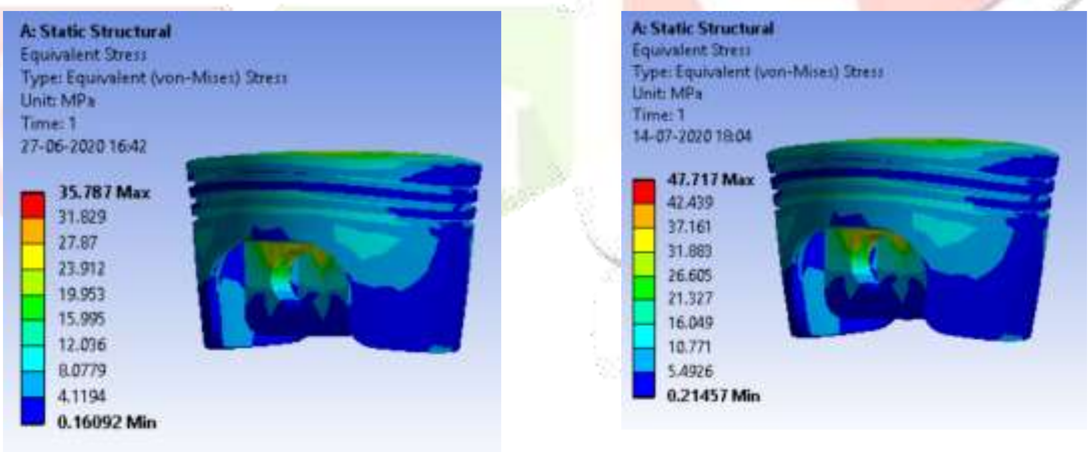

Fig. 4.3: Von Mises stress of aluminium piston for CR 14.1:1 and 15.1:1

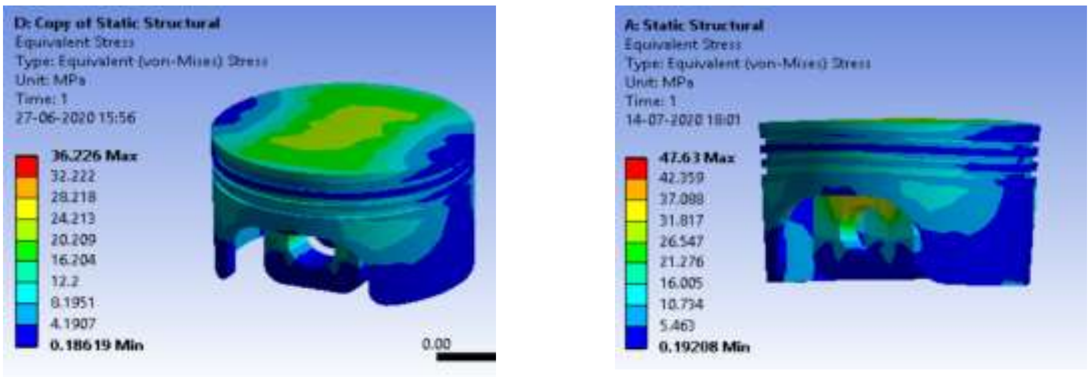

Fig. 4.4: Von Mises stress of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

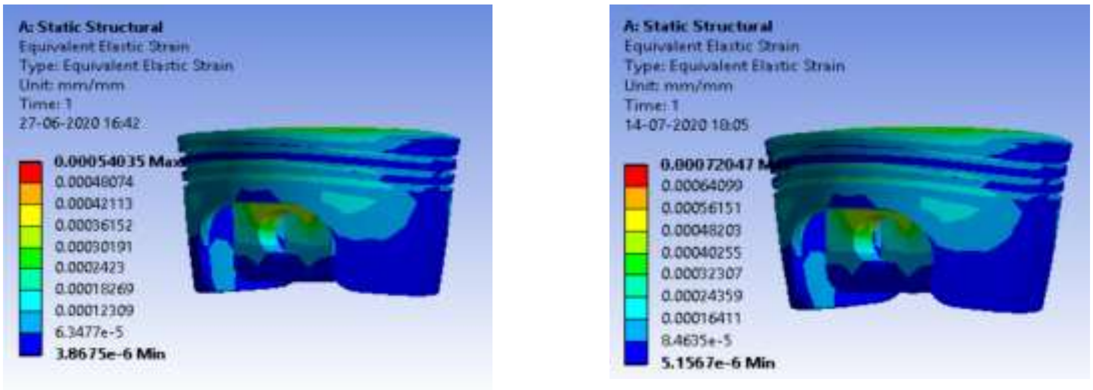

Fig. 4.5: Equivalent elastic strain of aluminium piston for CR 14.1:1 and 15.1:1

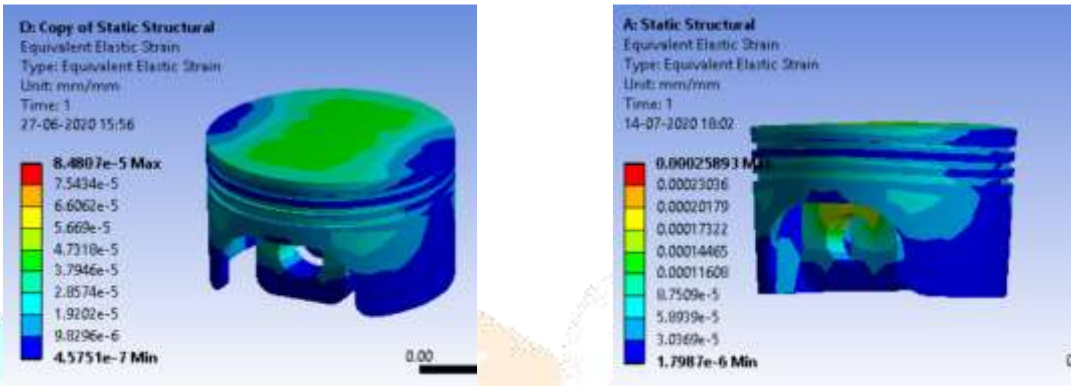

Fig.4.6: Equivalent elastic strain of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

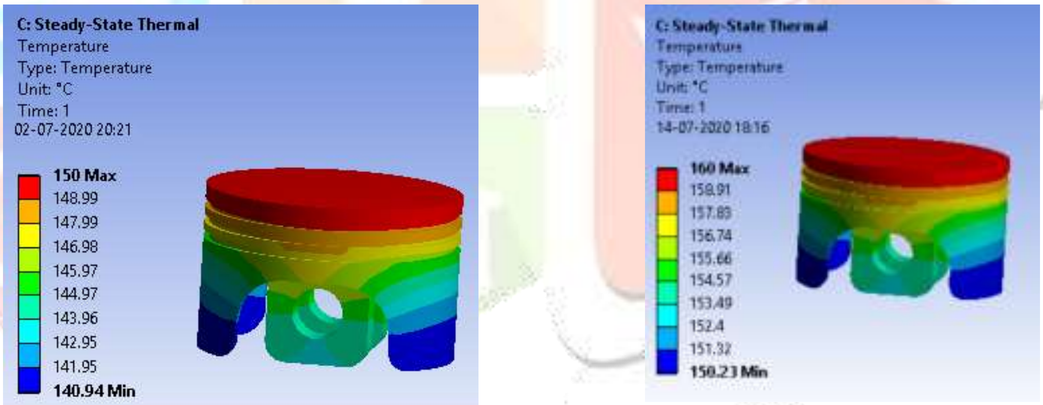

Fig.4.7 Temperature Distribution of aluminium piston for CR 14.1:1 and 15.1:1

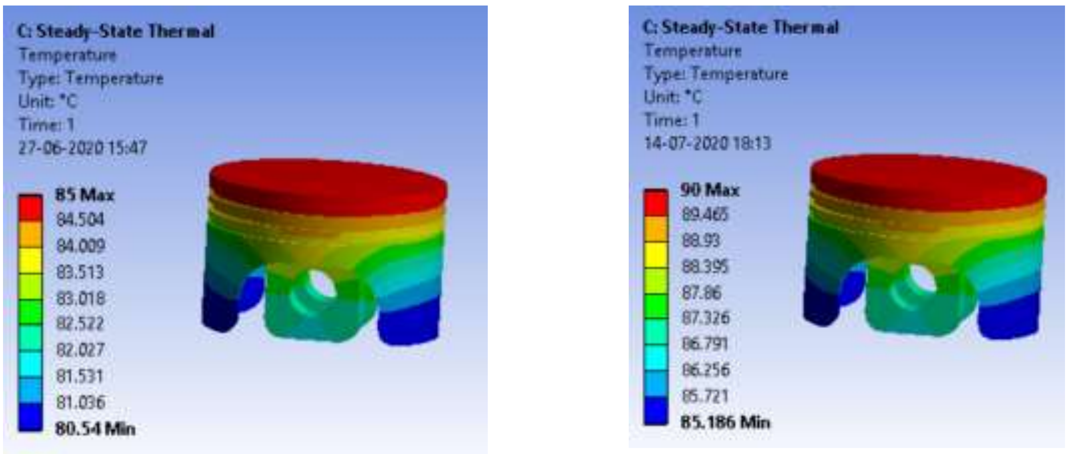

Fig.4.8 Temperature distribution of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

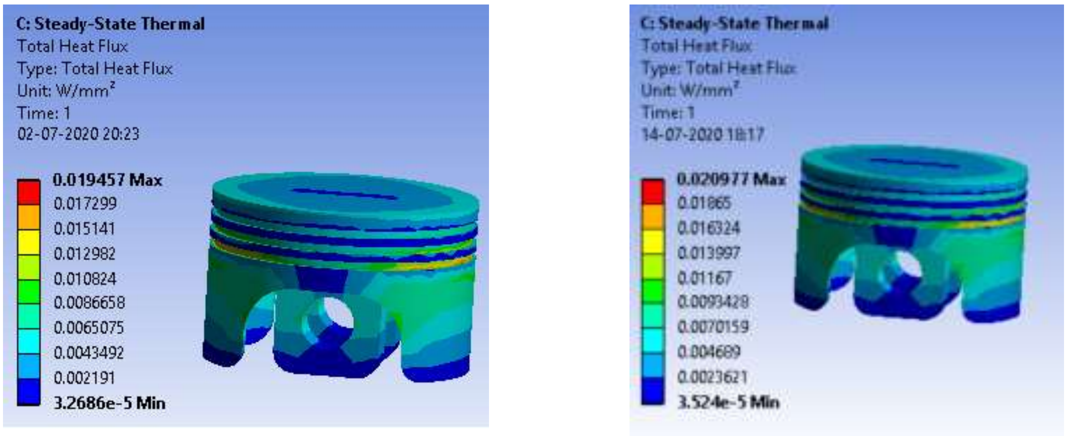

Fig.4.9 Total heat flux of aluminium piston for CR 14.1:1 and 15.1:1

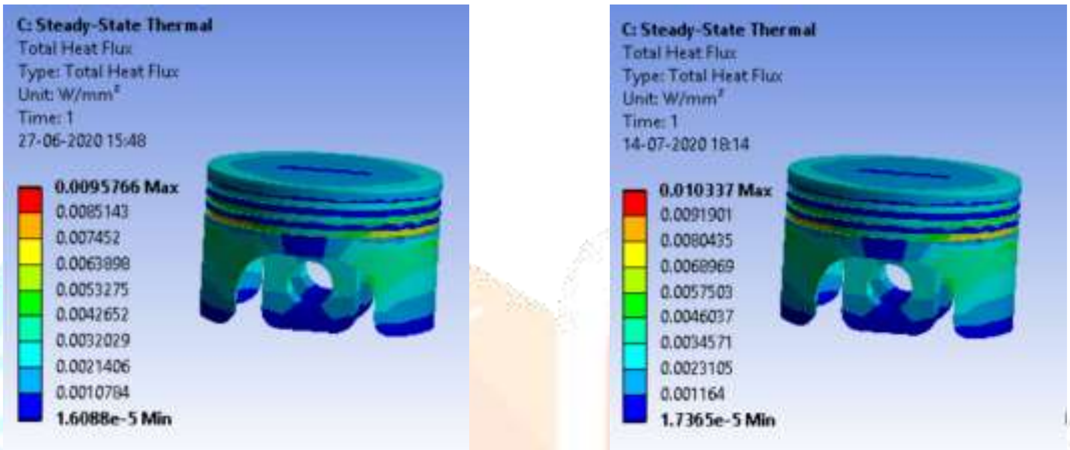

Fig.4.10 Total heat flux of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

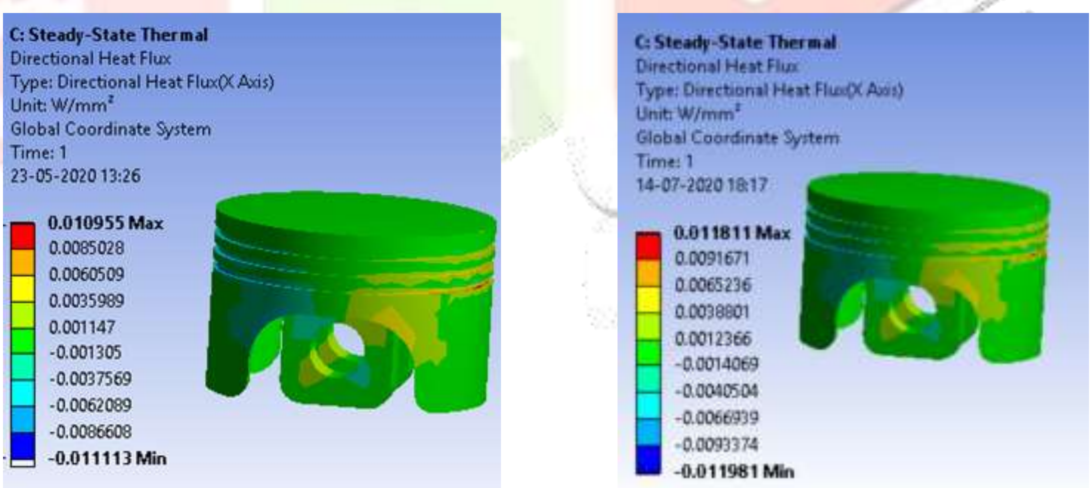

Fig.4.11 Directional Heat Flux of aluminium piston for CR 14.1:1 and 15.1:1

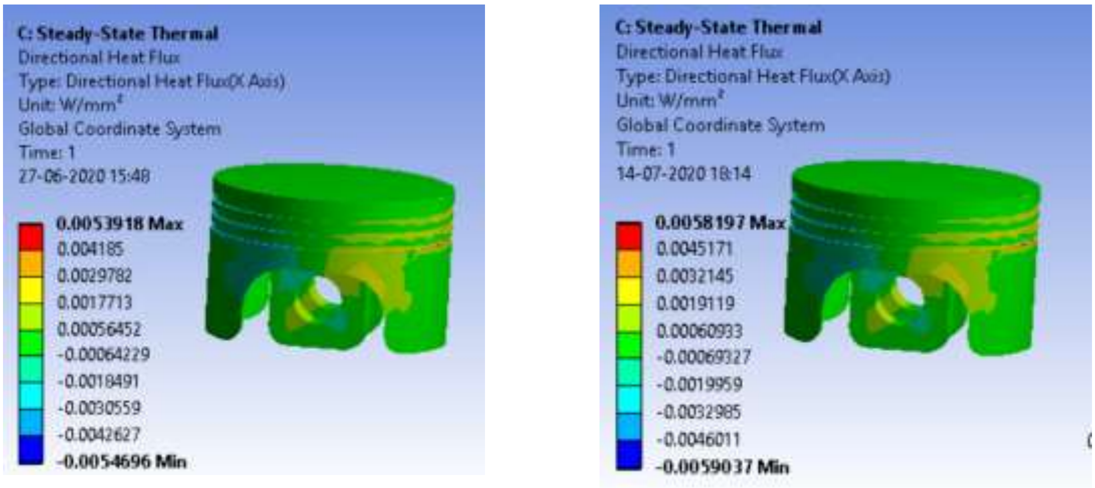

Fig.4.12 Directional Heat Flux of SiC reinforced ZrB2 piston for CR 14.1:1 and 15.1:1

1 Comparison Result of Static Analysis and Thermal Analysis of Piston

Table 4.1 Comparison for static analysis

Static Analysis						
Piston	**Total Deformation**		**Equivalent Stress**		**Equivalent Elastic Strain**	
	For CR 14.1:1	For CR 15.1:1	For CR 14.1:1	For CR 15.1:1	For CR 14.1:1	For CR 15.1:1
Aluminium	0.07559mm	0.10079 mm	35.787MPa	47.717 MPa	0.00054035 mm/mm	0.00072047 mm/mm
SiC reinforced ZrB2	0.010836mm	0.035794 mm	36.226MPa	47.63 MPa	4.5751e-7 mm/mm	0.0002589mm/mm

Table 4.2 Comparison for Thermal Analysis Of Piston

Thermal Analysis				
Piston	**Total Heat Flux**		**Directional Heat Flux**	
	For CR 14.1:1	For CR 15.1:1	For CR 14.1:1	For CR 15.1:1
Aluminium	0.019457 W/mm^2	0.020977 W/mm^2	0.010955 W/mm^2	0.011811 W/mm^2
SiC reinforced ZrB2	0.0095766 W/mm^2	0.010377 W/mm^2	0.0053918 W/mm^2	0.0058197 W/mm^2

4.2 FINAL RESULTS

Through analyzing above that the results, they might quickly infer that now the piston aluminum material becomes strongly deformed, having low deformation while the same research is performed for composite material. If the compression ratio increases, it raises the stress and temperature also at end of the development cycle, which results in more deformation to the piston when compared to lower compression ratio. Table 4.1 compares and tabulates the results of all studies on various materials. From the findings it is found that only the stresses for certain materials fall only within appropriate limits and also that the deflections are far less in Al-Alloy composite than for SiC-reinforced ZrB2.

5. CONCLUSION

Piston different materials such as aluminum alloys including ZrB2 strengthened with SiC were efficiently constructed or evaluated. An engine's Piston is planned, measured and programmed by using graphics tools. The CATIA V5R16, CAD tools and for design process, and ANSYS 11.0 should be used for the study and optimization techniques processes. This same finding shows an average stress of 35.787 MPa is observed in the aluminum piston and in case from the same load (von Mises). From both the analysis of displacement statistics it could also be found that the largest case of doubts in those materials close to a piston pin point. The key aim of this project work was just to research the performance of the aluminum alloy and also the composite material SiC reinforced ZrB2 under different compression ratio. Study indicate that only the SiC-reinforced ZrB2 composite piston exhibited less deformation. Because of greater dimensional rigidity of the SiC-reinforced ZrB2 composite material. Consequently, the piston with SiC-reinforced ZrB2 composite material tends to just be the best choice for piston material. That same diameter between both pistons decreases about 24 percent, the length with the cylinder decreases by 31 %, the width across all other lands also decreases approximately 25 % in the piston ring, the Von Mises tension rises by 16 percent and the deflection decreases after optimization. Because when people consider the definition, all parameters are fine.

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