Structural and Thermal Analysis of Disc Brake

Vinayak G. Kachare[1] Jagdish M. Kacha[2] Pritesh S. Jamodkar[3] Prateek S. Mokashi[4] Nikhil G. Koyande[5]

[1]Assistant Professor [2,3,4,5]Student

[1,2,3,4,5]Department of Mechanical Engineering

[1,2,3,4,5]B. R. Harne College of Engineering & Technology, India

Abstract— The purpose of this research is to analyze different types of disc brake rotor material, Analysis of brake rotor material includes Structural analysis and Steady state Thermal analysis for each suggested material. A comparison between the existing materials is carried out and based on the results the best material is suggested by ANSYS software.

Key words: Disc Brake

I. INTRODUCTION

A brake disc rotor is the rotating part of a disc brake assembly normally located on the front axle which is most important safety feature of an automobile. The disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, is forcedme chanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes convert motion to heat, and if the brakes get too hot, they become less effective, a phenomenon known as brake fade.[5]

II. LITERATURE REVIEW

Disc brake design plays as an important role in heat transfer as other variable like plate & vane thickness, fin material and flow pattern. There is a scope of improvement in heat transfer in ventilated disc brake if vane is angled and of alternate length other than straight radial vane. Contact time between air flow and vanes (time between air inlet and outlet flow through vanes) is also important factor in heat transfer from Disc rotor. There is also scope of research in improvement of heat transfer of rotor by increasing the contact time between vanes and air flow by design modification of vanes in such a way that fulfills the requirement [7].

According to the displacement analysis, the aluminium ventilated disc has more displacement when compared to solid disc of same material differed by a value of 0.26012. After observing the stress analysis results, the steel ventilated disc withstands to more stress when compared to solid disc of same type differed by a value of 134.036 N/mm^2. According to the results obtained from temperature analysis, it is observed that the amount of temperature produced in the cast iron ventilated Page[1].

III. MATERIAL CONSIDERED FOR THE DISC ROTOR

1) Gray Cast Iron
2) Stainless Steel
3) Titanium Alloy

MATRL / PROP	Gray cast iron	Stainless steel	Titanium alloy
Density (kg m^-3)	7200	7750	4620
Coeff of thermal expn (c^-1)	1.1e^-5	1.7e^-5	9.4e^-6
Sp heat (j kg^-1)	447	480	522
Thermal conductivity (w m^-1 c^-1)	52	15.1	21.9
Resistivity (Ohm m)	9.6e^-8	7.7e^-7	1.7e^-6
Compressive ultimate strength (pa)	8.2e^8	-	-
Tensile ultimate strength (pa)	2.4e^8	5.86e^8	1.07e^9
Compressive yield strength (pa)	-	2.07e^8	9.3e^8
Tensile yield strength (pa)	-	2.07e^8	9.3e^8

Table 1: Material data in ANSYS

IV. DESIGN MODEL OF DISC ROTOR

We take basic dimension of Rotor disc of Suzuki SX4 Saloon (GY)1.6(RW 416)

Characteristic	Dimension(mm)
Outer Diameter	280
Height	47
BrakeDisc Thickness	22
Minimum Thickness	20
Centrering Diameter	62
Bolt Hole Circle	114.3
Wheel Bolt Bore	12.7
No. of Holes	5

Table 2: Dimension of Rotor Disc

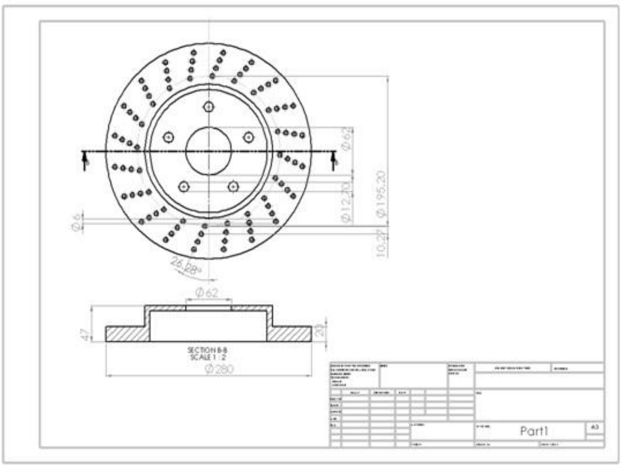

Fig. 1: Draft of Disc Rotor

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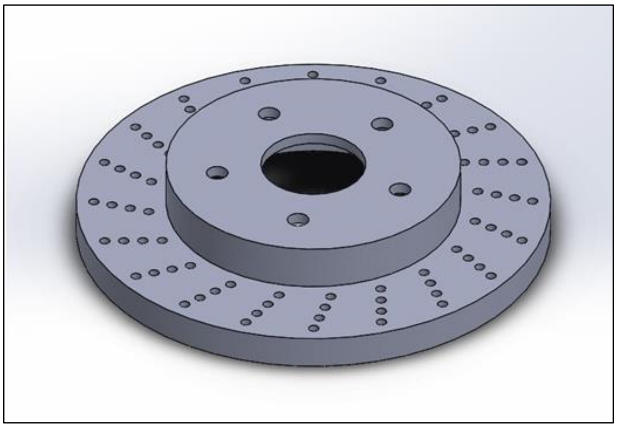
Fig. 2: 3D Model of Disc Brake

V. CALCULATION OF DISC BRAKE ROTOT

Total force generated during braking to stop the car,
F = m*a, a = deceleration during braking = $v^2/2s = (11.12)^2/(2x5)= 12.34\ m/s^2$
F= 500 x 12.34
F= 6173 N.
Kinetic Energy developed during braking, KE = ½ mv^2
KE = $0.5x500x11.12^2$
KE= 30913.6 J
Total Braking Energy/Heat required for the vehicle is equal to the total Kinetic Energy generated by the vehicle,
Thus Heat (Q) generated,
Q_g = 30913.6 J
Since assumption of 50-50 wheel bias is made, this heat will be equally distributed in the 4 wheels of the car, thus equally distributed in the 4 rotors. So, heat generated in 1 rotor,
Q_g = 7728.4 J
Now, the stopping time of the vehicle will be velocity/deceleration, t = v/a
t = 12.34/11.12
t = 0.9011 sec.
Hence, power generated in one rotor
P = Q_g/t
P = 7728.4/0.9011
P= 8576.62 W
Heat Flux = P/A
A = $\pi/4 *(D^2 - d^2) = \pi/4 *(0.28^2 - 0.16^2)$
A = 0.041469 m^2
Heat flux = 206819.919 W/m^2
Convective Heat Transfer Coefficient of Air
Imperical Equation Convective Heat Transfer Coefficient of Air
h = $10.45 - V + 10*V^{0.5}$
Where, V=Relative Speed Between Object Surface And Air(m/s)
Assumed V = 22.22m/s
h = $10.45 - 22.22 + 10*22.22^{0.5}$
h = 35 W/m^2k
Moment = (F*D/2) = 864.19 N

VI. RESULTS

Steady state thermal analysis

A. *Gray Cast Iron*

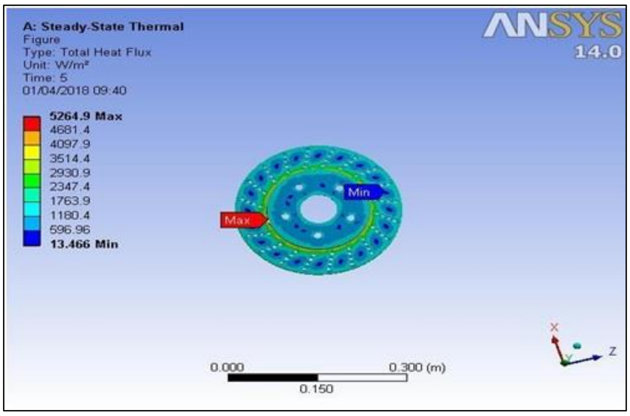

Fig. 3: Temperature Distribution

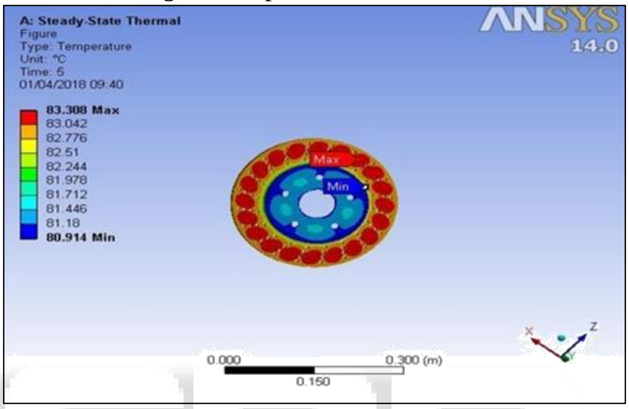

Fig. 4: Temperature Distribution

B. *Stainless Steel*

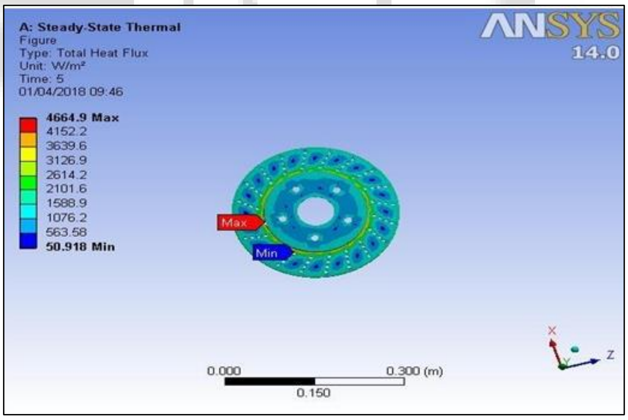

Fig. 5: Total Heat Flux

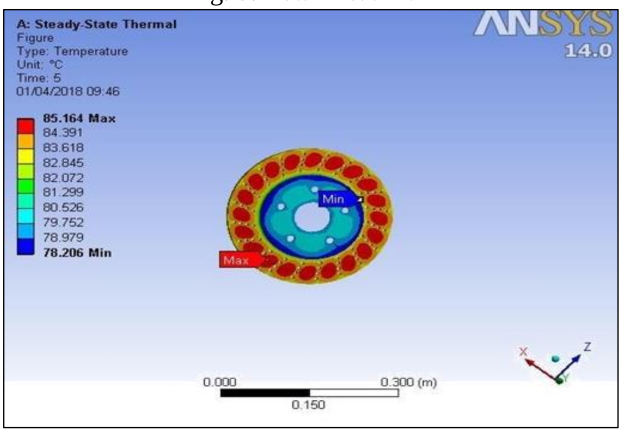

Fig. 6: Temperature Distribution

C. Titanium Alloy

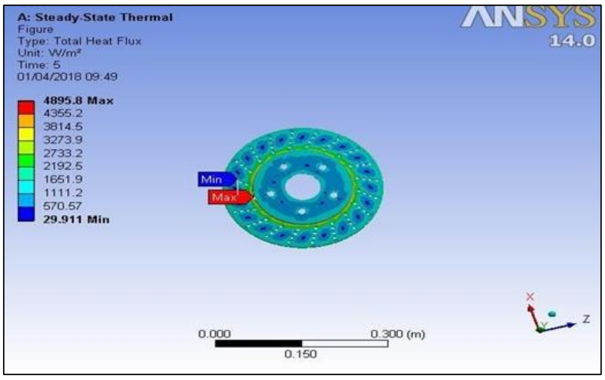

Fig. 7: Total Heat Flux

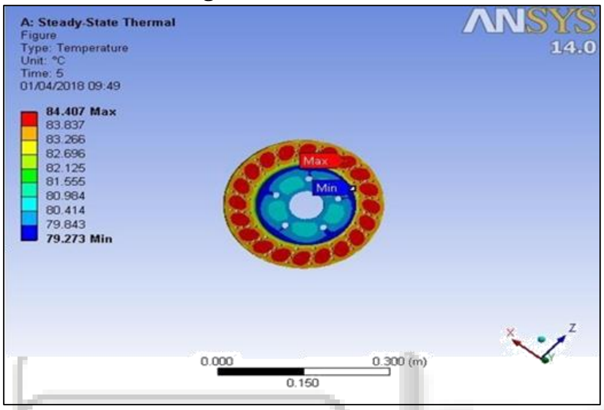

Fig. 8: Temperature Distribution

Static Structural analysis

1) Gray Cast Iron:

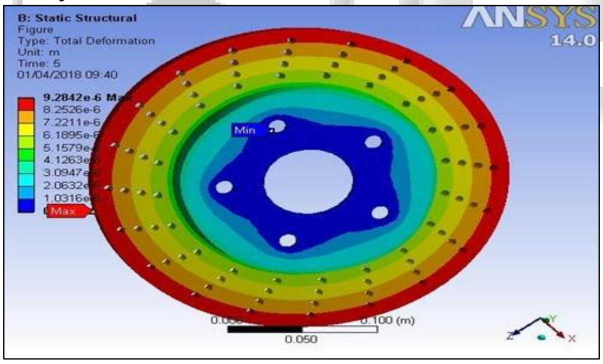

Fig. 9: Total Heat Flux

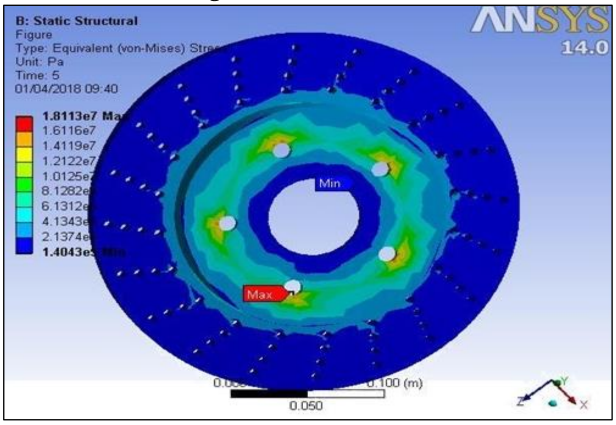

Fig. 10: Equivalent Strees

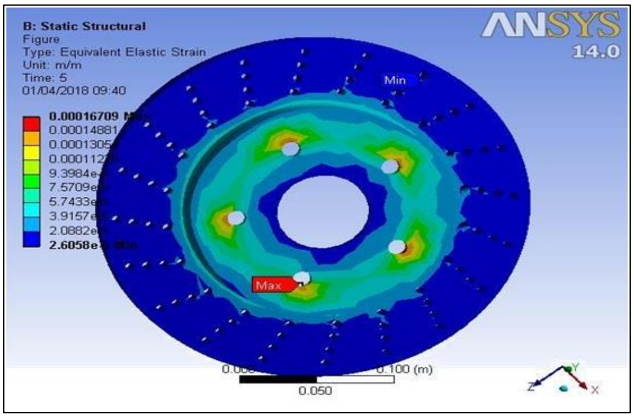

Fig. 11: Equivalent Strain

2) Stainless Steel:

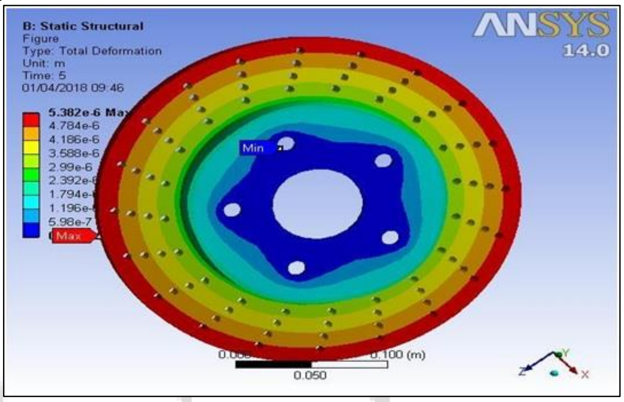

Fig. 12: Total Deformation

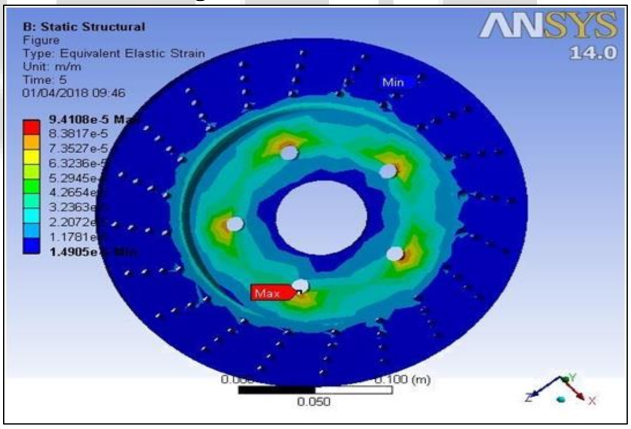

Fig. 13: Equivalent Strees

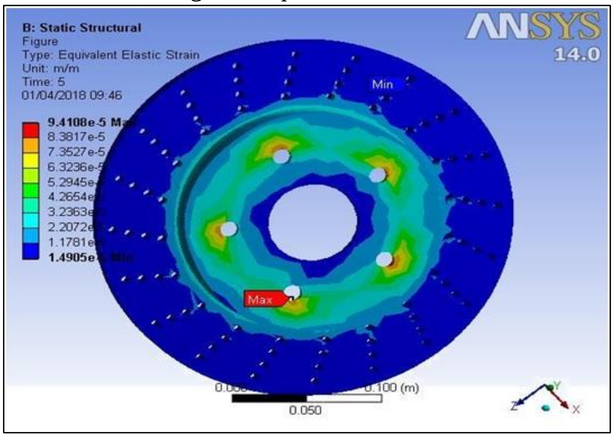

Fig. 14: Equivalent Strain

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3) Titanium Alloy:

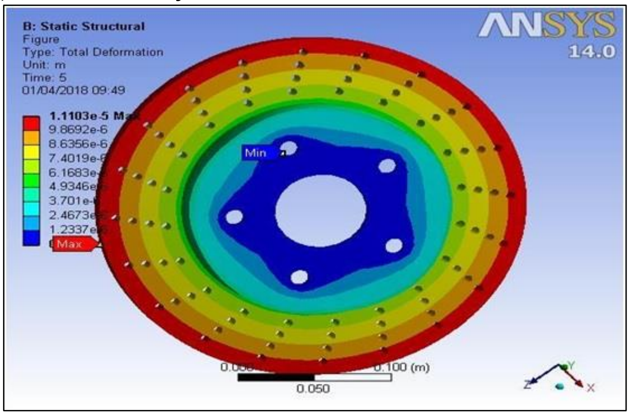


Fig. 15: Total Deformation

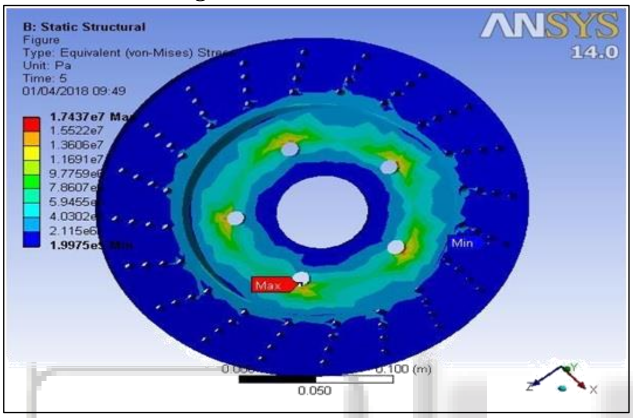


Fig. 16: Equivalent Strees

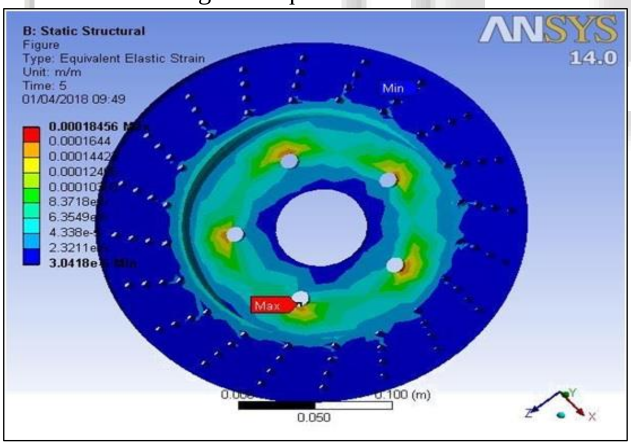
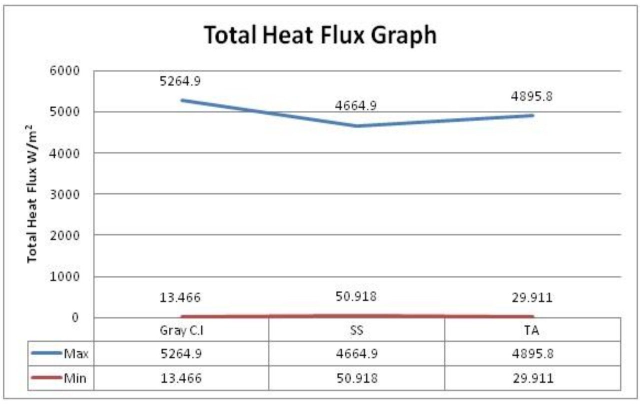
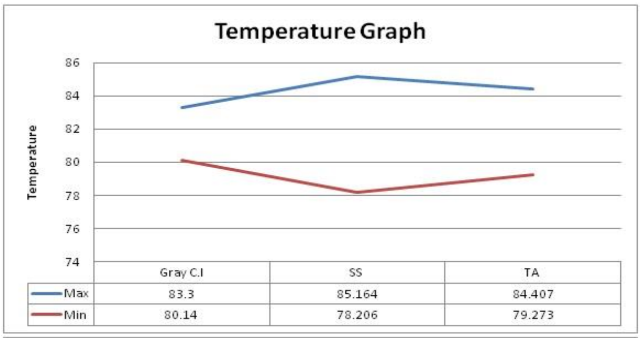
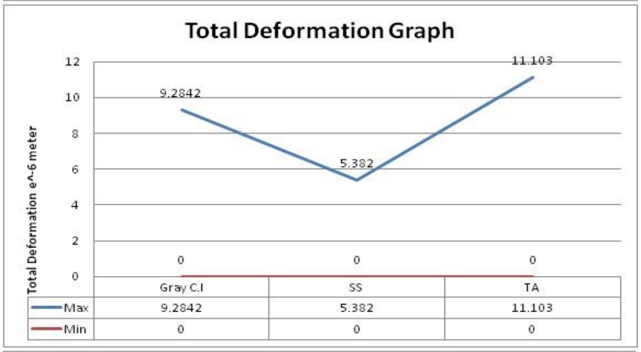


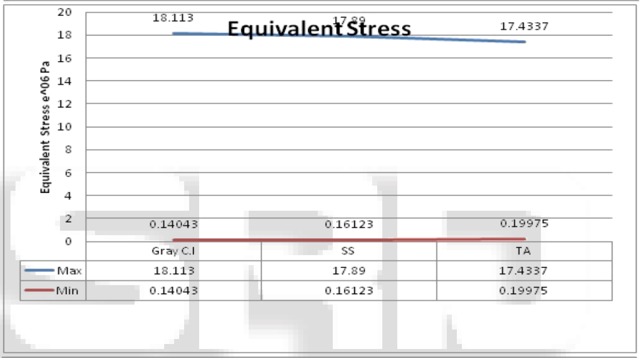
Fig. 17: Equivalent Strain

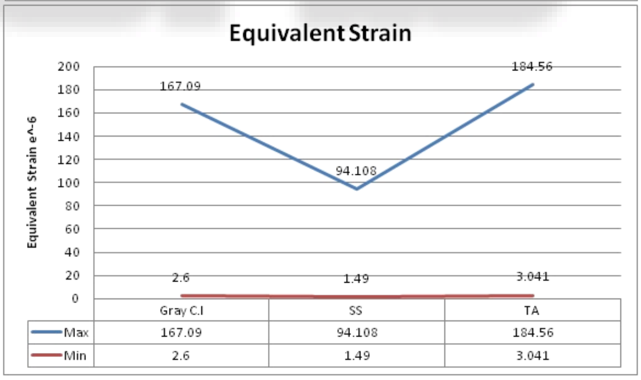
VII. GRAPHICAL FORMAT











VIII. CONCLUSION

Thus we have successfully compared three different materials, and best material is suggested with help of ansys software.

		Gray Cast Iron	Stainlees Steel	Titanium Alloy
Temperature	Max	83.3	85.164	84.407
	Min	80.14	78.206	79.273
Total Heat Flux	Max	5264.9	4664.9	4895.8

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	Min	13.446	50.918	29.911
Total Deformation	Max	9.28x10^{-06}	5.38x10^{-06}	11.1x10^{-06}
	Min	0	0	0
Equivalent Strain	Max	167.09x10^{-06}	94.108x10^{-06}	184.56x10^{-06}
	Min	2.6x10^{-06}	1.49x10^{-06}	3.041x10^{-06}
Equivalent Stress	Max	18.113x10^{06}	17.89x10^{06}	17.4337x10^{06}
	Min	0.14043x10^{06}	0.16123x10^{06}	0.199x10^{06}

IX. Future Scope

Stainless steel and titanium alloy can be made composite. Further improvement in design is possible.

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