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Thermal Analysis of Disc Brake System

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Abstract: Brakes are one of the most significant safety systems in an automobile. In the braking process, the rotor will be exposed to large stresses which result in surface cracking, overheating of brake fluid, seals and other components. Therefore one of the main tasks of the braking system is to reduce the surface temperature of the brake rotor. This can be achieved by choosing the right material which will undergo the least thermal stresses. In this project, thermal analysis for vented disc brake rotor of Mahindra Bolero's done, for providing an efficient material for disc brake rotor and brake pads which can dissipate heat generated during braking at faster rate and also being structurally safe.
Keywords: Braking system, Disc Brake Rotor, Thermal, Structural Analysis, CATIA V5, ANSYS WORKBENCH

I. INTRODUCTION

The disc brake is a wheel brake which slows the rotation of the wheel by the friction caused by the pushing brake pads against a brake disc with a set of calipers. The brake rotor is connected to the wheel and axle. To stop the wheel, the friction material mounted on a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and wheel to slow down. The function of brakes is based on the law of conservation of energy. In this process, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators, etc. The energy absorbed by brakes is dissipated in the form of heat to the surrounding atmosphere. The brakes efficiency decreases with an increase in temperature which is a phenomenon known as brake fade.

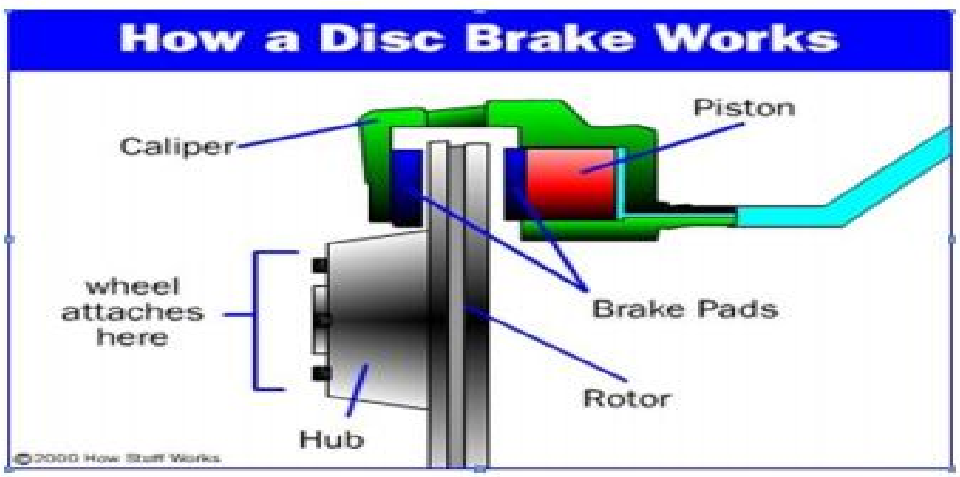

Figure 1: Working principle of disc brake

II. DESIGN PARAMETERS

Product	Brake disc
Product name	Mahindra Utility, Bolero
Material	Cast Iron
Type	Plain
Dimensions	Outer Diameter: 272.5mm Total Height : 40mm Inner Diameter : 152mm Plate Thickness: 21mm

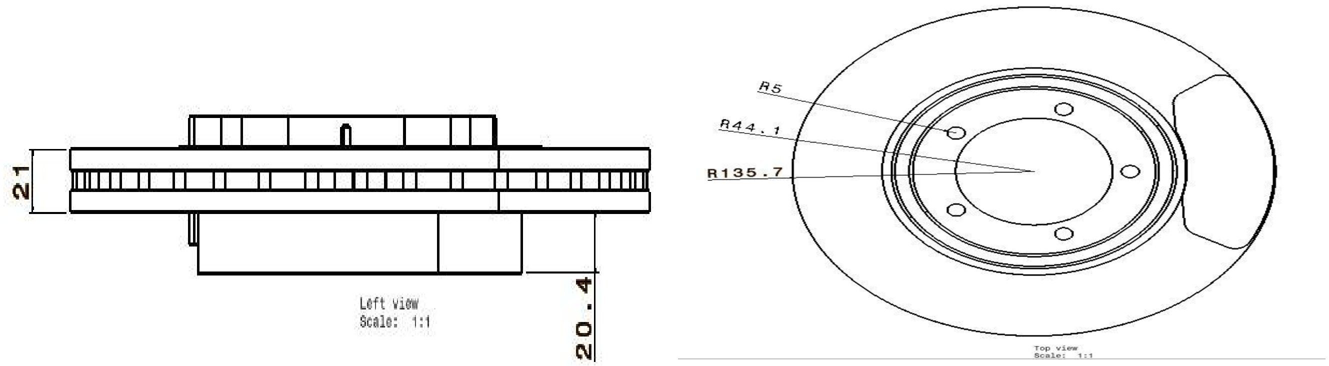

Figure 2: Drafted View of Disk Brake

III. DIFFERENT PAD MATERIALS

Table 3: Pad materials

Material Properties	Material 1	Material 2	Material 3	Material 4
Density (gm/cc)	2.29m/cc	2.25gm/cc	2.30gm/cc	2.34gm/cc
Thermal Conductivity (W/mk)	0.93	1.06	1.258	1.35
Coefficient of Friction	0.33	0.34	0.36	0.42
Percent Of Steel powder	0%	4%	8%	12%

IV. HEAT FLUX CALCULATION

A. *For Pad Material 1*

For Velocity $=10\frac{km}{hr}$

1) Kinetic Energy of Vehicle

$$K.E = \frac{mv^2}{2} = \frac{1725 \times 2.77}{2}$$

$$\therefore K.E = 6617.876 Joule$$

Where, K. E − kinetic Energy (J)

M − Mass of vehicle (Kg)

V − Linear velocity of vehicle $\left(\frac{m}{s}\right)$

2) *Stopping Distance of Vehicle*

Braking distance of vehicle refers to the distance a vehicle will travel from the point when its brakes are fully applied to when it comes to a complete stop.

3) The maximum friction force, = $0.330 \times 1725 \times 9.81$

$\therefore$ F = 5584.342N

4) Hence deceleration of the vehicle,

$$a = \frac{F}{m} = \frac{5584.342}{1725}$$

$\therefore$ a = 3.23 $\frac{m}{s^2}$

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5) Time taken to stop the vehicle,

$$t = \frac{v}{a} \quad - 0.857$$

$$\therefore t \cong 1\text{sec}$$

So distance covered by vehicle in 1 second is = 2.77 × 1
Stopping distance (SD) =2.77m

1. Heat Flux = $\dfrac{\frac{\text{Heat generated}}{\text{time}}}{\text{Contact area}}$

Where, Contact area = 2×contact area of piston of caliper

$=2\times\frac{\pi}{4}\times$ [(diameter of rotor)^2 - (diameter of rotor - diameter of piston)^2]

$=2\times\frac{\pi}{4}\times[(0.2725)^2 - (0.2725- 0.057)^2]$

$= 0.04369\ m^2$

$$\therefore \text{Heat Flux} = \frac{\frac{6617.876}{1}}{0.04369}$$

$$\therefore \text{Heat Flux} = 1.5147e^5 \frac{W}{m^2}$$

Similarly, Heat Flux for different velocities and different pad materials is calculated. All the calculated vales are shown below in table.

Table 5: Values for Heat Flux at different velocities

Velocity (Km/hr)	KineticEnergy (Joule)	Time (Seconds)	Heat Flux $(\frac{W}{m^2})$
$10\frac{km}{hr}$	6617.876J	1sec	$1.5147e^5\frac{W}{m^2}$
$20\frac{km}{hr}$	26567.156 J	2sec	$3.04e^5\frac{W}{m^2}$
$30\frac{km}{hr}$	59847.926 J	3sec	$4.566e^5\frac{W}{m^2}$
$40\frac{km}{hr}$	106460.186 J	4sec	$6.09e^5\frac{W}{m^2}$

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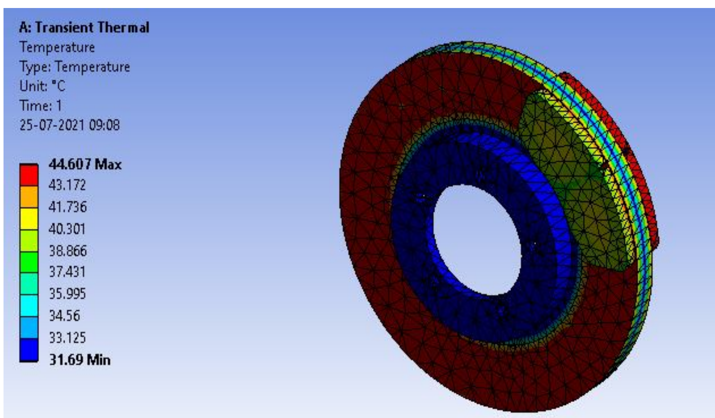
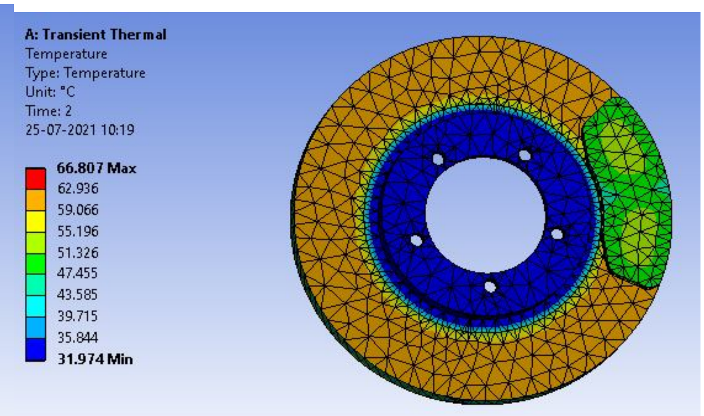
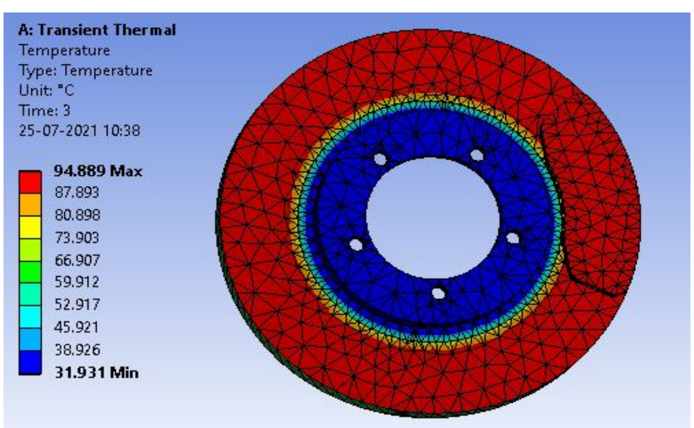
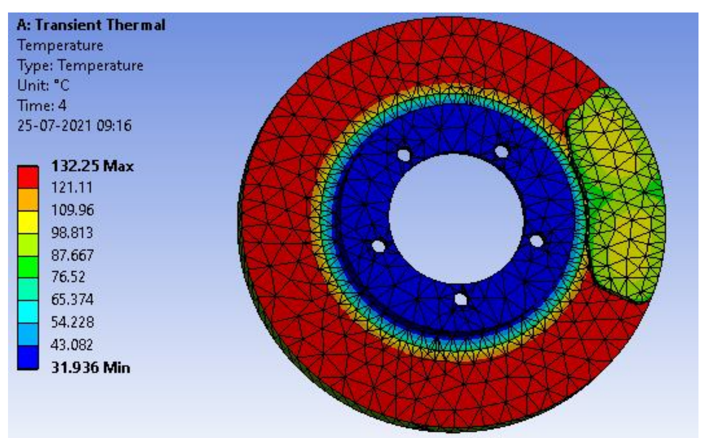
V. ANALYSIS RESULTS FOR PAD MATERIAL 1









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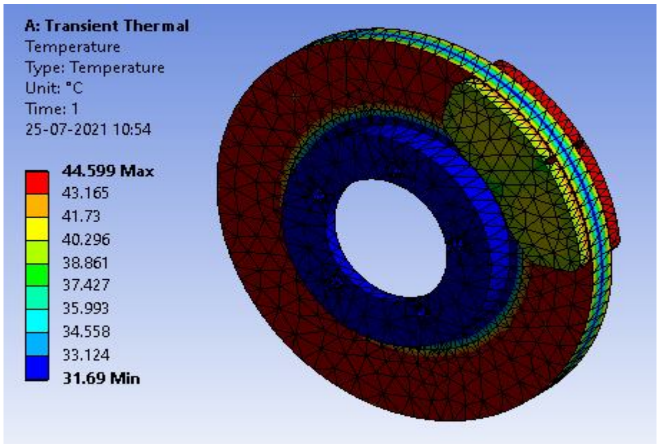
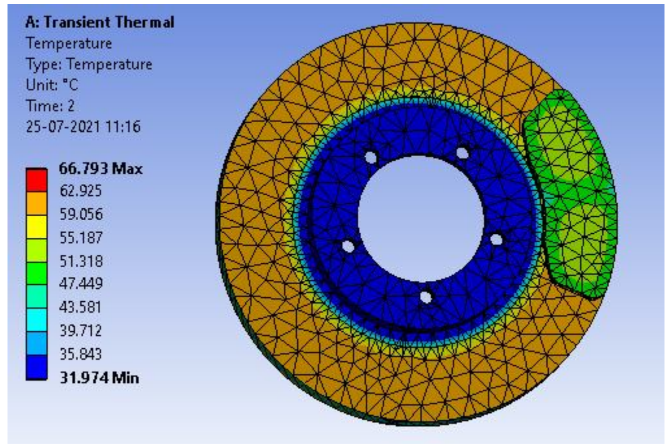
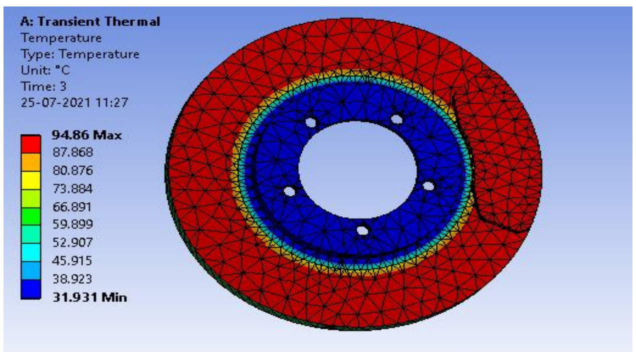
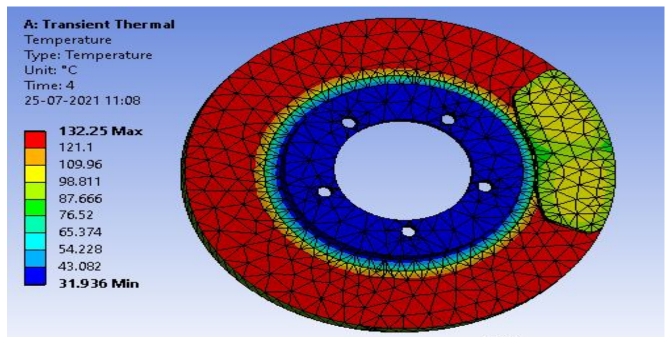
VI. ANALYSIS RESULTS FOR PAD MATERIAL 2

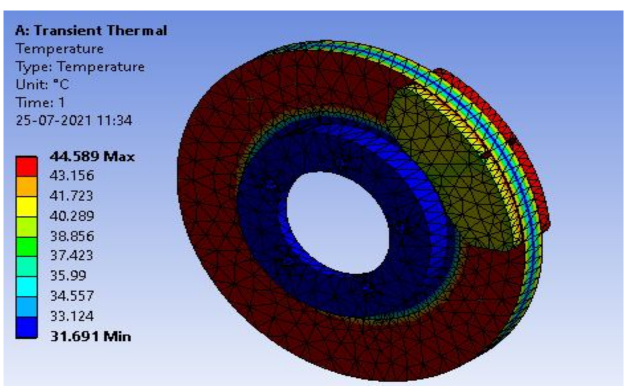


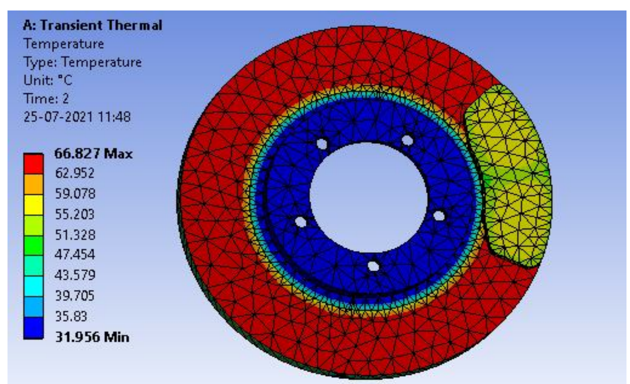


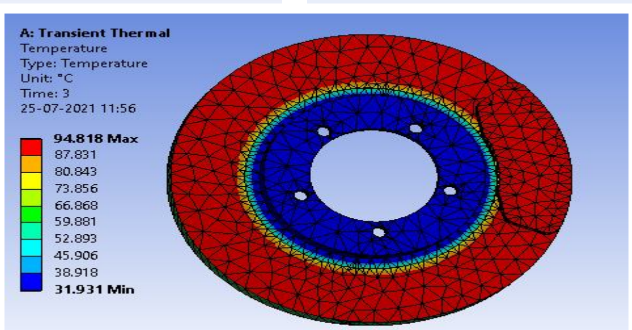




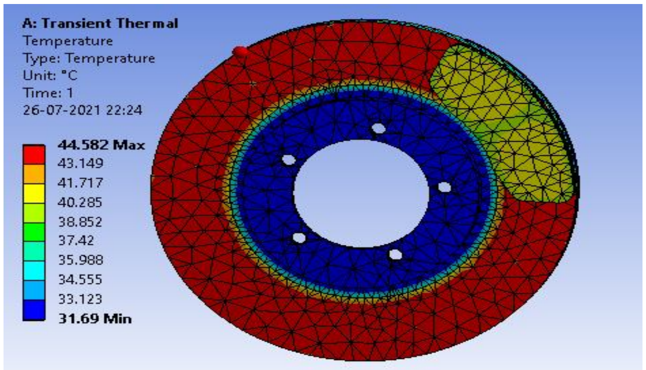
VII. ANALYSIS RESULTS FOR PAD MATERIAL 3

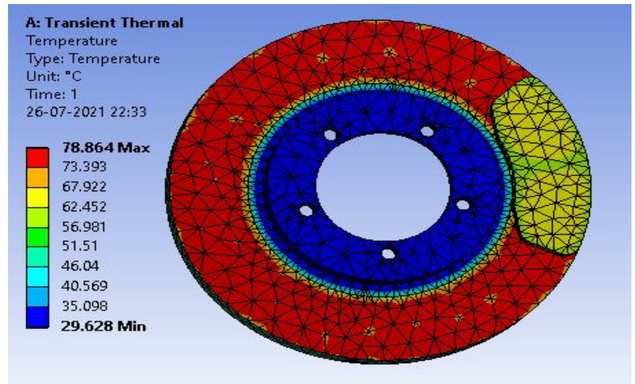


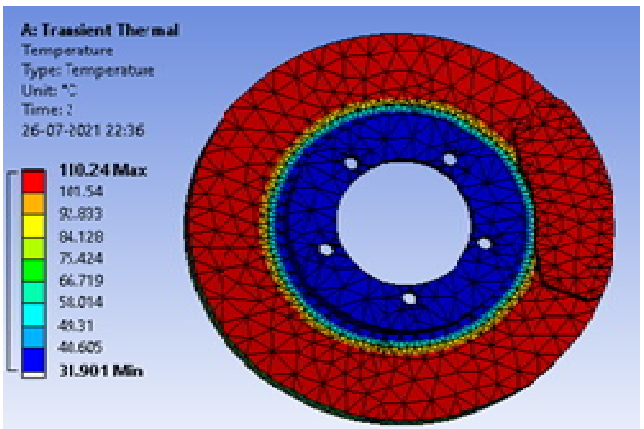


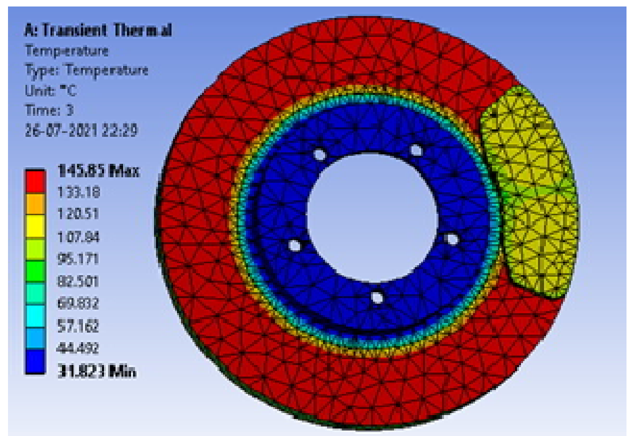


VIII. ANALYSIS RESULT FOR PAD MATERIAL 4









IX. ANSYS RESULTS

A. Ansys Result for pad Material 1

Velocity	Static Structural Analysis				Transient Thermal Analysis			
	Total Deformation(m)		Equivalent Stress (Pa)		Temperature (°C)		Total Heat flux (W/m^2)	
	Mini	Max	Mini	Max	Mini	Max	Mini	Max
10km/hr	0.m	2.3082e-003 m	737.39 Pa	2.1601e+06 Pa	31.69 °C	44.607 °C	1.5818e-003 W/m²	1.8362e+005 W/m²
20km/hr	0.m	2.3162e-003 m	4381.9 Pa	2.1373e+06 Pa	31.974 °C	66.807 °C	3.2051e-003 W/m²	4.0423e+005 W/m²
30km/hr	0.m	2.3491e-003 m	22677 Pa	2.706e+006 Pa	31.931 °C	94.889 °C	1.6166e-002 W/m²	7.6648e+005 W/m²
40k/hr	0.m	2.349e-003 m	22675 Pa	2.706e+006 Pa	32.076 °C	132.25 °C	8.4451e-002 W/m²	8.8363e+005 W/m²

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B. Ansys Result for Pad Material 2

Velocity	Static Structural Analysis				Transient Thermal Analysis			
	Total Deformation(m)		Equivalent Stress (Pa)		Temperature (°C)		Total Heat flux(W/m^2)	
	Mini	Max	Mini	Max	Mini	Max	Mini	Max
10km/hr	0.m	2.3076e-003 m	427.8 Pa	2.1617e+006 Pa	31.69 °C	44.599 °C	2.6934e-003 W/m²	1.8362e+005 W/m²
20km/hr	0.m	2.3139e-003 m	7096.6 Pa	2.1437e+006 Pa	31.974 °C	66.793 °C	3.4235e-003 W/m²	4.0423e+005 W/m²
30km/hr	0.m	2.3401e-003 m	29551 Pa	2.3503e+006 Pa	31.931 °C	94.86 °C	2.1112e-002 W/m²	7.6648e+005 W/m²
40k/hr	0.m	2.3394e-003 m	29559 Pa	2.3503e+006 Pa	31.936 °C	132.25 °C	7.1614e-002 W/m²	8.8363e+005 W/m²

C. Ansys Result for Pad Material 3

Velocity	Static Structural Analysis				Transient Thermal Analysis			
	Total Deformation(m)		Equivalent Stress (Pa)		Temperature (°C)		Total Heat flux(W/m^2)	
	Mini	Max	Mini	Max	Mini	Max	Mini	Max
10km/hr	0.m	2.3076e-003 m	438.02 Pa	2.1616e+006 Pa	31.691 °C	44.589 °C	1.262e-003 W/m²	1.8363e+005 W/m²
20km/hr	0.m	2.3141e-003 m	7061.3 Pa	2.1432e+006 Pa	31.974 °C	66.774 °C	2.4058e-003 W/m²	4.0423e+005 W/m²
30km/hr	0.m	2.3408e-003 m	28053 Pa	2.3776e+006 Pa	31.931 °C	94.818 °C	2.1487e-002 W/m²	7.6648e+005 W/m²
40k/hr	0.m	2.3401e-003 m	28061 Pa	2.3776e+006 Pa	31.936 °C	132.25 °C	7.6048e-002 W/m²	8.8363e+005 W/m²

D. Ansys Result for Pad Material 4

Velocity	Static Structural Analysis				Transient Thermal Analysis			
	Total Deformation(m)		Equivalent Stress (Pa)		Temperature (°C)		Total Heat flux (W/m^2)	
	Mini	Max	Mini	Max	Mini	Max	Mini	Max
10 km/hr	0.m	2.3076e-003 m	449.2 Pa	2.1615e +006 Pa	31.69 °C	44.582 °C	2.1357e-003 W/m²	1.8362e+005 W/m²
20 km/hr	0.m	2.3142e-003 m	6905. Pa	2.1428e +006 Pa	29.628 °C	78.864 °C	1.9322e-003 W/m²	7.1907e+005 W/m²
30 km/hr	0.m	2.3252e-003 m	15302 Pa	2.1188e+006 Pa	31.901 °C	110.24 °C	6.1243e-003 W/m²	9.0992e+005 W/m²
40 km/hr	0.m	2.3407e-003 m	26933 Pa	2.3994e +006 Pa	31.823 °C	145.85 °C	3.4331e-002 W/m²	1.1379e+006 W/m²

X. CONCLUSION

A. From the results obtained we can conclude that pad material with the least coefficient of friction will help to reduce the temperature rise in the disc rotor.

B. From analysis maximum temperature for pad material 4 is observed as 145.85 °C.

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