Design and Thermo Structural Analysis of Automotive Disc Brake

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Abstract— A brake is a device to stop the motion of a machine, by means of which artificial frictional resistance is applied to moving machine member. In the process of performing this operate; the brakes draw either kinetic energy of the moving member or the potential energy ceased by objects being brought down by hoists, elevators, etc. The energy sucked by the brakes is dissipated in the form of heat energy. Disc brake is a familiar automotive application where they are applied extensively for car and motorcycle wheels. In the past, surface roughness and wear at the pad interface have rarely been counted in studies of thermal analysis of a disc brake assembly using finite element method. The main purpose of this project is to Optimization of Automotive Brake Disc and analysis the thermal and structural conduct of the dry contact between the brake disc and pads during the braking phase. The thermal-structural analysis to determine the thermal flux and the Von Misses stresses built in the disc. The objective of the project is the design, analysis and optimization of solid and ventilated disc brake using Ansys. The ventilated brake disc assembly is built by a 3D model in Catia and imported to Ansys to evaluate the stress fields and thermal flux's which are established in the disc with the pressure on the pads and in the conditions of tightening of the disc.

Key words: Disc Brake; Catia; Finite Element Analysis; Deformation; Stress

I. The Problem

During primary operation, a disc brake system has been applied to the moving machine member, in order to reduce or stop the motion of machine member. Brakes govern over speed and provide emergency braking. The kinetic energy generated in terms of blade speed is converted in to heat energy due to the application of the brake system. The friction between the brake pad and the disc stop or reduce the motion of the system.

Manjunath T V et al… [1] He analyzed the thermo-mechanical behavior of the dry contact of the brake disc during the braking phase. The coupled thermal-structural analysis is used to determine the deformation and the Von Misses stress established in the disc for the both ventilated disc and modified ventilated with two different materials to enhance performance of the rotor disc.

Yathish K.O et al… [2]He study the functioning of disc brake for dissimilar materials (C.I & Al 6061-SiC-red mud composite) under like functioning conditions/parameters. The material effect on displacement, stress, contact pressure, contact status, contact sliding outdistance of disc and pad assembly are found using software's like ANSYS 14) and hyper mesh.

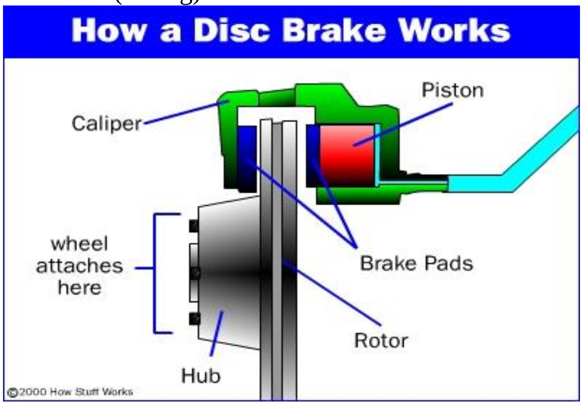
Ali BELHOCINE et al. [3] presented a paper on structural and contact analysis of 3D model disc brake to identify the thermal effects in the structure and contact behaviour of disc pad assembly.

Agnihotri and et al. [4] presented a paper on newly developed model to foresee the temperature rise and temperature behaviour of a ventilated and solid disc brake. They studied on heat and temperature distribution in a disc brake rotor. Thermostructural analysis has been performed using ansys. The materials used for disc brake in simulation are stainless steel and grey cast iron and results have been justified with better justification.

Parab et al. [5] carried thermomechanical analysis of disc brake using three materials, cast iron, stainless steel and carbon composites. Modeling was done using CATIA. Analysis was carried out to validate the strength and thermal properties of disc brake. The better material amongst the three was identified by comparing the results such as stresses, deformation, temperature distribution, etc.

Guru Murthy Nathi, et al. [6] has investigated the effect of stiffness, strength and variations of the disc brake rotor design and predicted temperature distribution and stress under severe braking conditions and thereby to assist the disc rotor design and analysis.

When the brakes are applied, hydraulically actuated pistons move the friction pads in to contact with the disc, applying equal and opposite forces on the later. On releasing the brakes the brakes the rubber-sealing ring acts as a return spring and retract the pistons and the friction pads away from the disc (see fig)



II. Disc brake problems

During the course of brake operation, the heat energy generated due to friction is dissipated mostly in to pads. Sporadic temperature distribution on the components can provoke severe thermo elastic distortion of the disc. Due to this thermal distortion on a flat surface of a rotor disc, deformation takes place which leads to thermo elastic transition. On the other hand due to the advancement behaviour of the sliding system crosses limits as a result of which sudden changes in contact conditions occur as the result of instability. This invoke,

- Localized bulging due to frictional heating.
- Contact pressure increases due to localized bulging.
- Local hot spots due to frictional heating.

A. *Material properties:*

PROPERTIES	ALUMINIUM ALLOY 6061	CAST IRON
DENSITY (Kg/M^3)	2810	7100
YOUNG'S MODULUS (GPa)	72	125
POISSON RATIO	0.33	0.25
THERMAL BEHAVIOURIVITY (W/M-K)	130	54.5
SPECIFIC HEAT (J/Kg-K)	960	586
COEFFICIENT OF FRICTION	0.3	0.2

III. MODELING OF DISC BRAKE

A. *MODEL OF DISC BRAKE SKETCH*

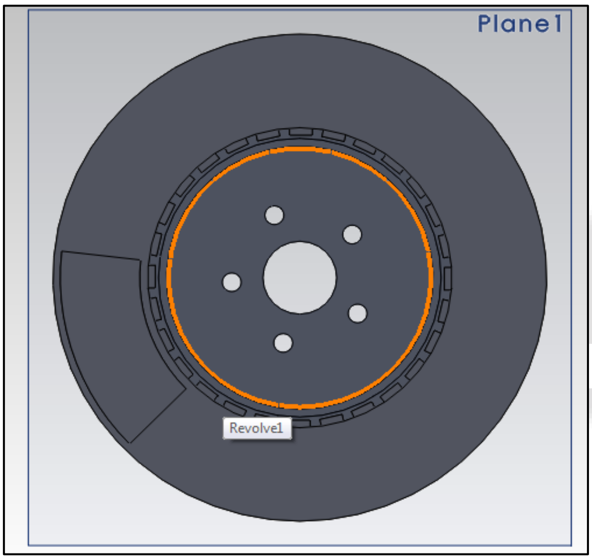


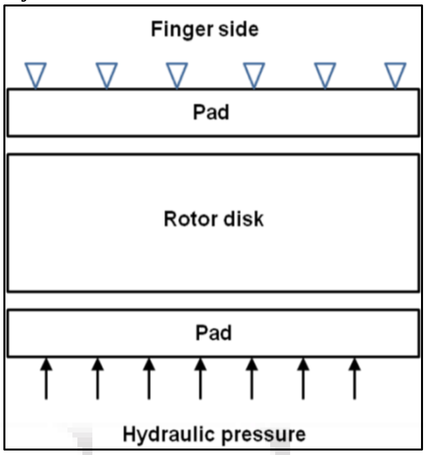
Fig. 1: Existing model for disc brake

Fig. 2: Modified Model of disc brake

IV. FINITE ELEMENT ANALYSIS

A. *Finite element (FE) model:*

Figure shows the finite element model of disc brake. The outer radius, inner radius, and thickness of a disc are as 0.300, 0.050and 0.025m, respectively. The thickness of pad is 0.010m. Hydraulic pressure is applied along the piston side pad and the immobility condition in the axial direction is applied to the boundary along the radius of the finger side one. In this paper, static thermal analysis is carried out to examine the thermal variations across the disc by applying heat flux value for repeated brake application using ANSYS. Further static structural analysis is carried away by coupling thermal analysis.



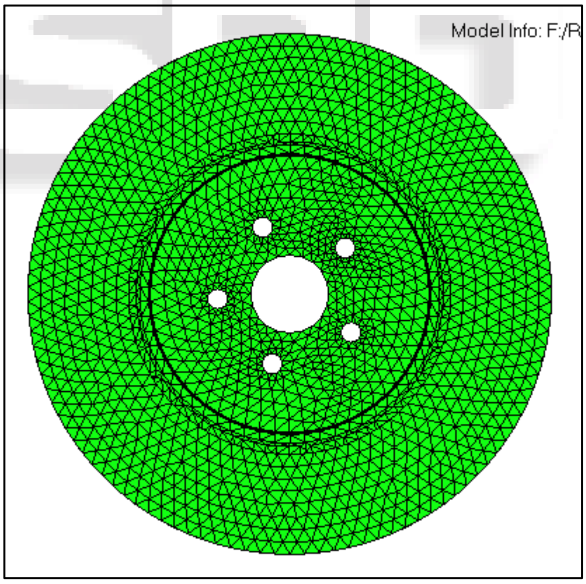


Fig. 3: Straight vented Disc Meshed Model

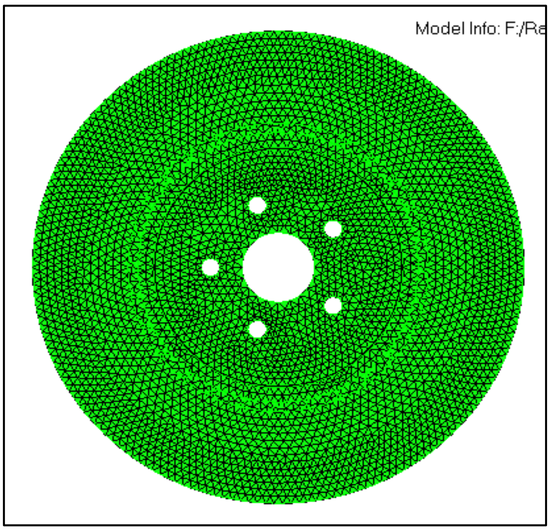


Fig. 4: Curved vented Disc Meshed Model

In transient thermal analysis a time varying thermal load (temperature load) is applied and its behavior is analyzed. Both convection and heat flux parameters are considered for evaluation of results. Although the convection coefficient varies with velocity and surface a general convection coefficient of 5 W/(m2.°C) is taken for both internal and external convection

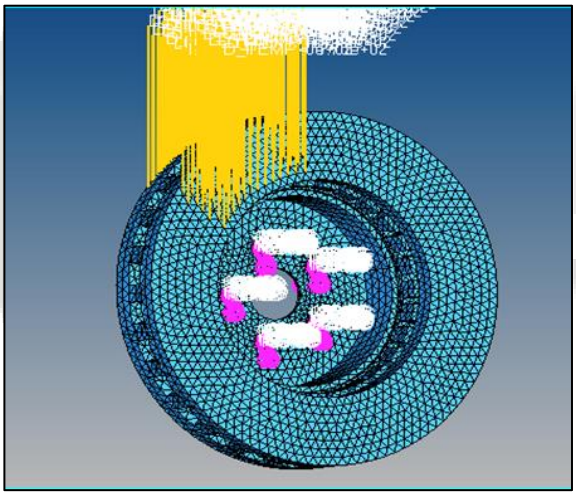


Fig. 5: Conditioned Straight Vented Disc Brake Meshed Model

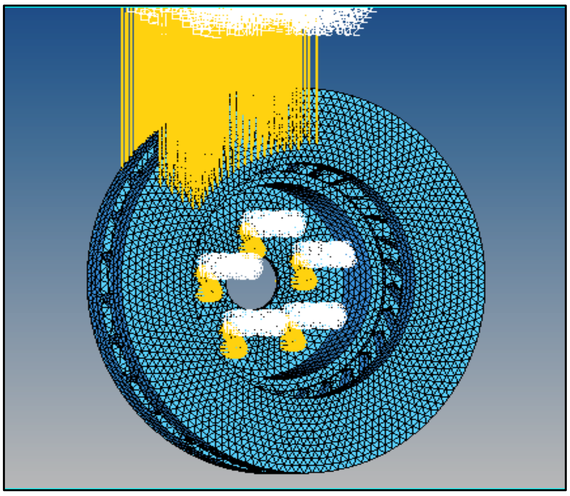


Fig. 6: Conditioned Curved Vented Disc Brake Meshed Model

V. RESULTS & DISCUSSION

Coupled static thermal and structural analysis was performed using ansys which allows us to establish the thermal distribution and the structural deformation of the disc due to sliding friction between the brake pad and disc. Analysis was carried out for model with two different materials. The best material amongst them was identified by comparing the results obtained.

Thermal Analysis of Disc Brake using cast iron and Aluminium alloy 6061:

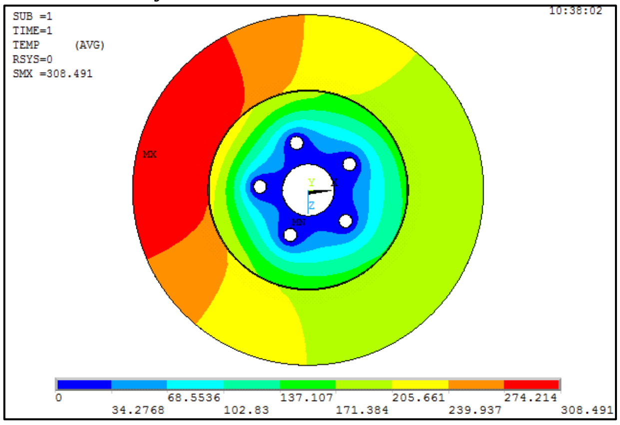


Fig. 7: Temperature distribution for cast iron staright vent disc brake

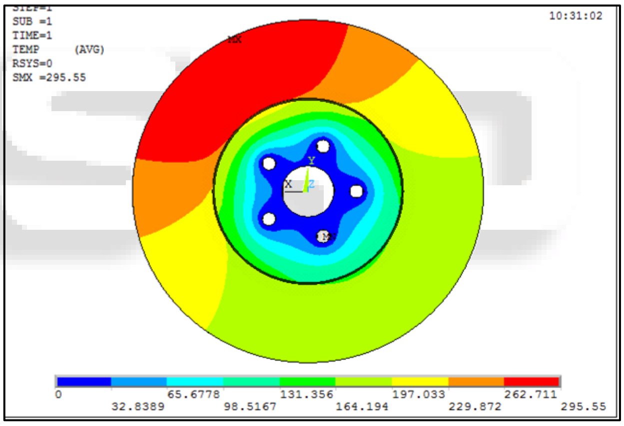


Fig. 8: Temperature distribution for cast iron curved vent disc brake

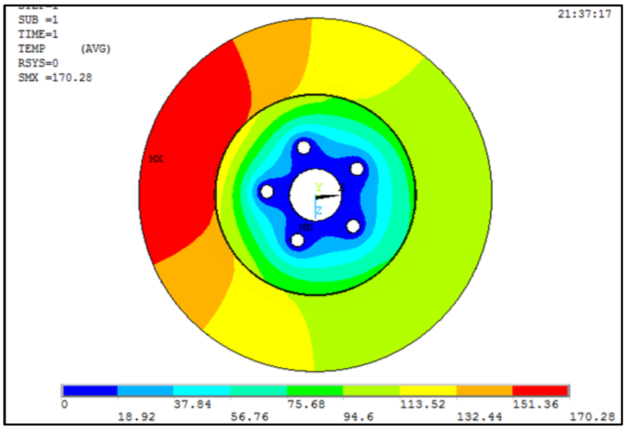


Fig. 9: Temperature distribution for aluminium alloy straight vent disc brake

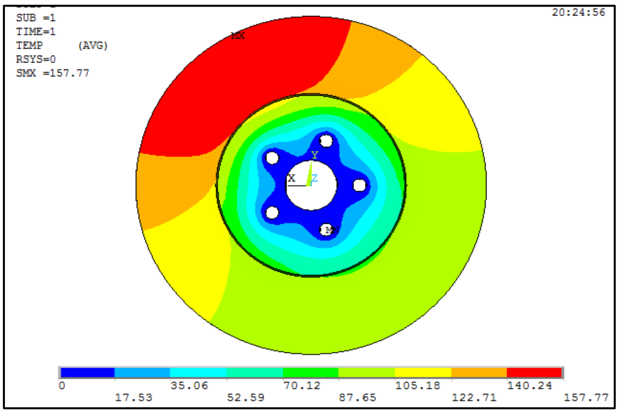


Fig. 10: Temperature distribution for aluminium alloy curved vent disc brake

Material	Nodal Temperature(^{0}c)		Thermal gradient vector sum(k/m)		Thermal flux vector sum(*10^3 w/m^2)	
	Straight	curved	Straight	curved	Straight	curved
Aluminium Alloy 6061	170.28	157.77	11.394	10.8961	1481.49	1416.28
Cast Iron	308.491	295.55	20.6424	20.4116	1135.31	1122.64

Table 1: Thermal Analysis Results Comparison

Structural Analysis of Disc Brake using cast iron and Aluminium alloy 6061:

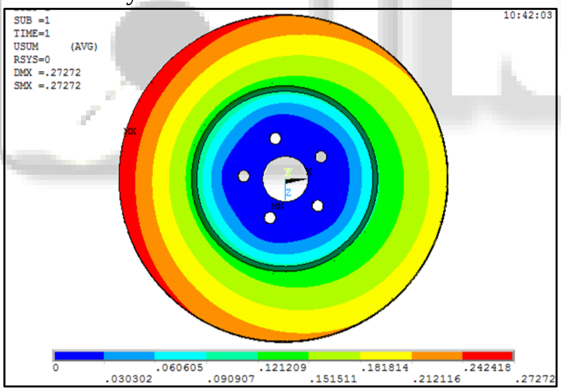


Fig. 11: Straight Vented Disc Brake Using Cast Iron Displacement

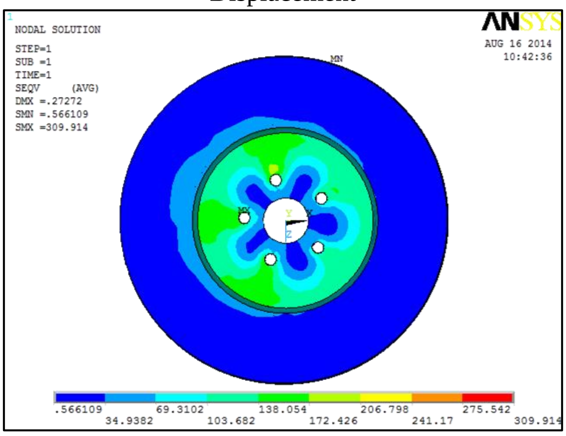


Fig. 12: Straight Vented Disc Brake Using Cast Iron Vonmises Stress

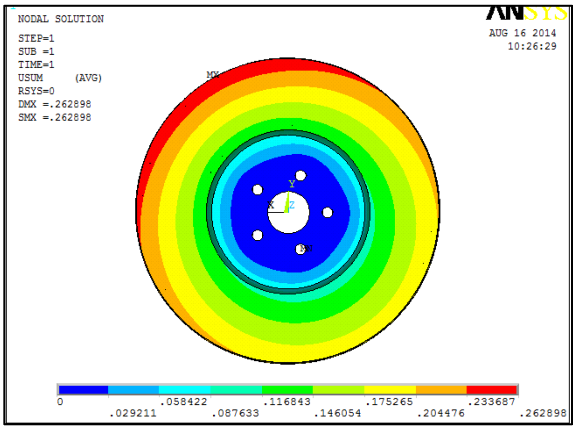


Fig. 13: Curved Vented Disc Brake Using Cast Iron Displacement

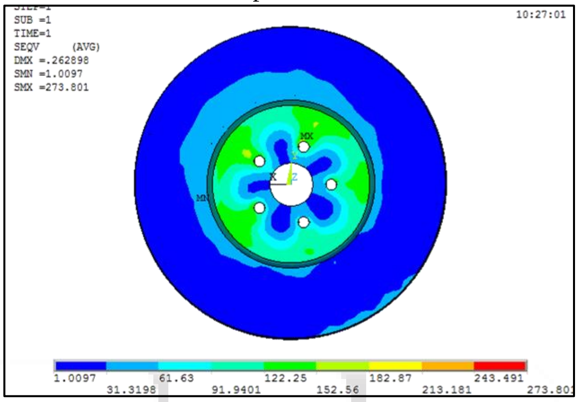


Fig. 14: Straight Vented Disc Brake Using Cast Iron Vonmises Stress

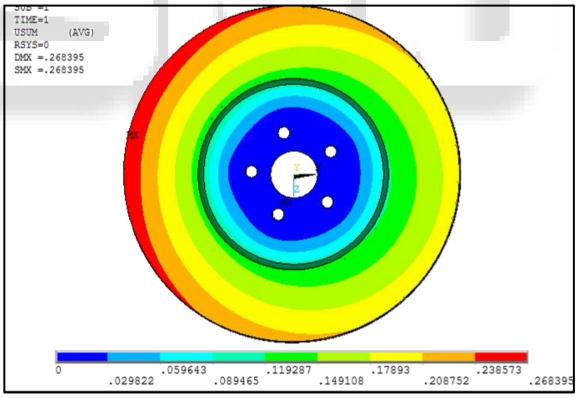


Fig. 15: Straight Vented Disc Brake Using aluminium alloy Displacement

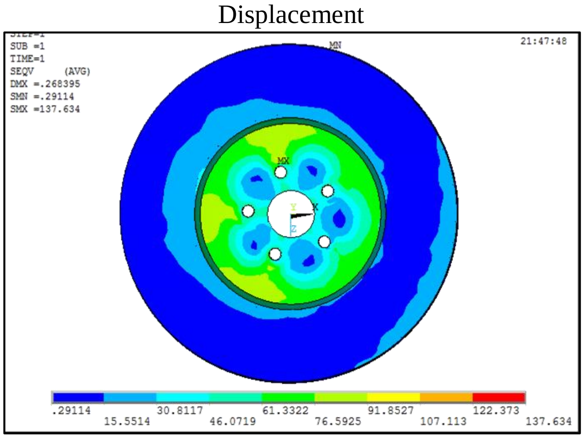


Fig. 16: Straight Vented Disc Brake Using aluminium alloy Vonmises Stress

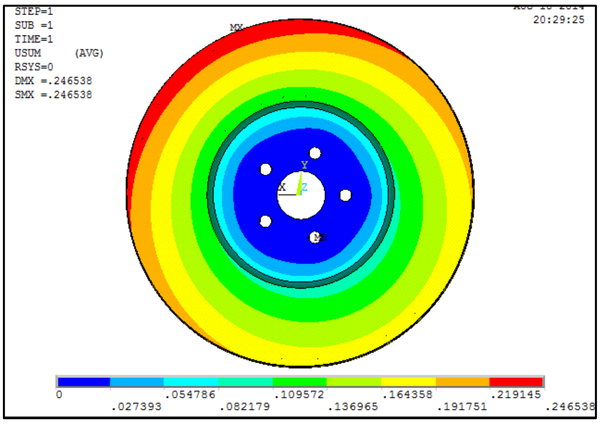


Fig. 17: Curved Vented Disc Brake Using aluminium alloy Displacement

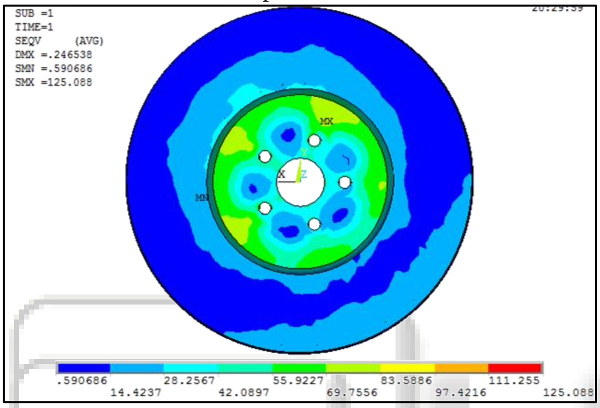


Fig. 18: Curved Vented Disc Brake Using aluminium alloy Vonmises Stress

Material	Displacement (mm)		Von Mises Stress (N/m^2)	
	Straight	curved	Straight	Curved
Aluminium Alloy 6061	0.268395	0.246538	137.634	125.088
Cast Iron	0.27272	0.262898	309.912	273.801

Table 2: Structural Analysis Comparison of results

VI. Conclusion

The following conclusions can be drawn from the above analysis.

- Structural and Thermal analysis of disc brake has been carried out using 20 node Solid 95 and 20 node Solid 90 through ANSYS (F.E.A) software.
- The maximum temperature obtained in the brake disc for the Materials Cast iron and Aluminium Alloy 6061were295.55 and 157.77 respectively at the contact surface.
- Static structural analysis is carried out by coupling the Thermal solution to the structural analysis and the maximum Displacements was observed to be0.246538 for Aluminium Alloy 6061and 0.262898 for cast iron.
- The Brake disc design is safe based on the Strength and Rigidity Criteria.
- Thermal and Structural Analysis for two different materials were carried out separately and the results were compared.
- Comparing the different results obtained from the analysis, it is concluded that Aluminium Alloy 6061is the Best possible combination for the present application.

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