

# Study and Analysis of Energy Dissipation in Disc Brakes

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**Abstract** - In this paper, a study on the significant issues faced in the functioning of a motorcycle disc brake has been compiled and focuses on the problems pertaining to the thermo mechanical behavior of the motorcycle disc brake during dry contact of the brake disc in the braking phase. Structural performance of the disc-pad model such as Thermal stresses, Heat dissipation, deformation and Von-Mises stress are predicted using a coupled thermal-structural analysis on the same model with the includes of convection, heat flux elements and adiabatic are also studied. The results of temperature distribution, deformation, stress and contact pressure obtained from FDM is analyzed. Based on the results, changes are made on to the topology of the design and analyzed. Similarly changes in the material composition have also been made and analyzed. The relevant FDM results have been compared, this comparison may assist brake engineers to understand and analyze based on performance, strength, rigidity criteria and heat distribution to critically evaluate structural behavior of the disc brake assembly.

**Key Words:** Finite difference method, thermal analysis, structural analysis, ABAQUS, heat distribution

## 1. INTRODUCTION

Braking is probably the most important feature in an automobile. Once the vehicles starts moving, it gains speed and the kinetic energy of the vehicle increases, a vehicle can only stop when the kinetic energy is lowered down to zero. A braking system helps reduce the kinetic energy in the vehicle by converting kinetic energy into heat energy and dissipating it to the atmosphere. The heat energy is generated by the friction force acting between the disc brakes and the disc pads, study is made to find the best possible material for the disc as well as pads. Also study is carried out on the design of the disc rotors and the pads, structural and thermal properties are considered.

## 2. PROBLEM STATEMENT

The literature review of the phenomena of braking shows that the sharp variation in temperature due to the friction causes various stresses and load acting on the disc. During braking cycle the temperature increases and it must be dissipated to the atmosphere as fast as possible before the next braking cycle occurs to retain proper braking. If the temperature is not dissipated the thermal stresses acting on the disc increases along with the normal stresses. Thermal

load is due to the temperature rise while braking, leading to slope of temperature, and thermal cycles because of conduction, convection or radiation. The temperature can vary from 20°C to more than 700°C in a few seconds only. These abrupt temperature variations do not make it possible to be homogenized. So the disc experiences very high temperature slopes in the thickness of the friction tracks, but also in the circumferential direction. These last gradients are explained by the fact that the heat flux which enters the disc is localized under the brake pads. Sometimes, it appears what is called of the hot-spots; they are circular zones regularly spaced on the tracks where the temperature is locally higher. These increases the chances of the brakes to fail. Our objective here is to reduce the thermal stresses acting on the disc by creating a CADD model of a stock set up, analyzing with the various parameters and obtain the results. Next step is to make changes in the topology as well as material and execute two separate simulations for each of them. The same parameters and deck preparation is considered as of the stock set up and the results are obtained and a comparison has been made.

## 3. METHODOLOGY

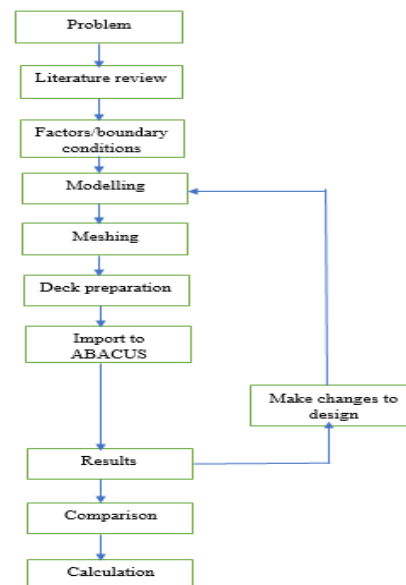


Fig-1: Methodology flow chart

#### 4. MODELING OF THE DISC BRAKES

Modeling is a process of creating/re-creating the design of an actual working model using computer software. It involves creation, modification, analysis and optimization of a design. The computer software can be used to draw various shapes and designs which are complex in two-dimensional space or in three-dimensional space.

The OEM front disc and pad of a Bajaj Pulsar 150(2005) has been used as a reference for our CADD model to help us in our study.

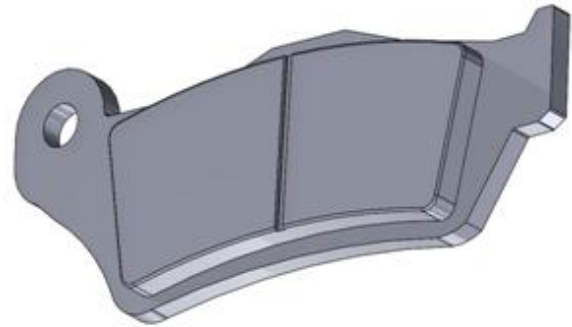


Fig -4: Isometric view of the right-side of the Pad



Fig -2: Side View of the Disc

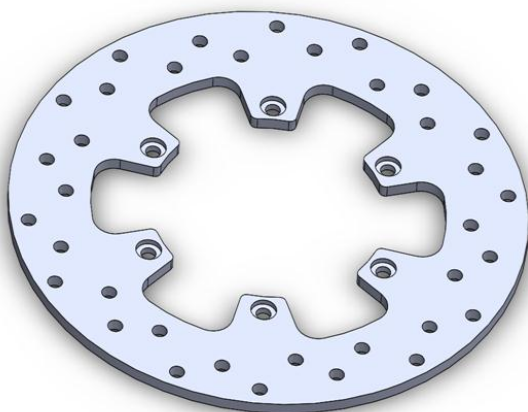


Fig -3: Isometric View of the Disc

#### Meshing

Meshing/discretization is the process of converting a physical entity with an infinite degree of freedom to a mathematical equivalent having finite degree of freedom. Here we are going with coupled thermal analysis using explicit method. The type of mesh used is tetrahedral mesh on a 3D model as we are going with a coupled thermal analysis.

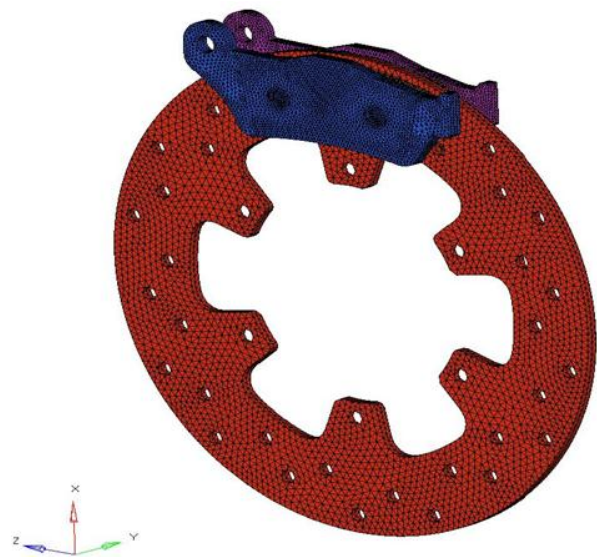


Fig 5: Meshing of the Disc and Pads Assembled



Fig -6: Cut Section View of the Tetrahedral Mesh

geometry	nodes=	2 9 6 7 3
FE entities	elems=	1 1 6 7 8 4

Fig-7: Number of node and elements in the Disc-Pad Model

### Material selection

The standard disc material generally used is Cast iron and Steel Grade 321, we are considering Steel because it is the most commonly used material in motorcycle discs. The disc pads are basically made of three different parts which is friction material, adhesive and back plate. Usually three different materials are used for the different parts but we are considering one friction material which Al SiC but in two different blends and the backing plate as Cast iron. We are neglecting the adhesive as it increases the complexity of the solver.

### Testing standards considered

For our tests we have considered the NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA) laboratory test procedures for motorcycles brake systems (TP-122-03). According to these standards the initial temperature to be considered should be between 55 to 100<sup>o</sup> C. The initial speed is 60 kmph and the vehicle deceleration rate should be around 1.5 to 2 m/s<sup>2</sup>. Brake actuation force to be considered is 200 newtons at the brake lever. We are considering a multiplication factor of 1.5 for the actuation force to the piston.

### Deck Preparations

Deck preparation is done to provide the details and forces considered for the material to conduct the simulation/calculations. It is to be noted that the output of the system is directly related to the inputs provided during deck preparations and there are no error systems.

### Material data inputs for disk

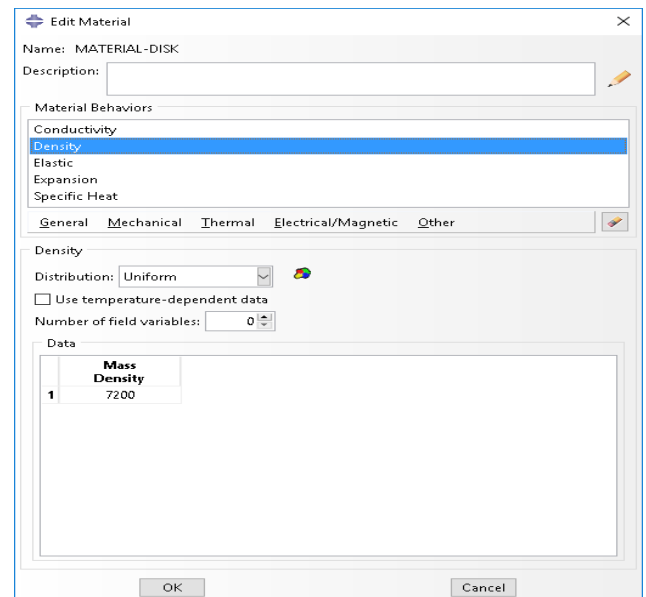


Fig-8: Density considerations of the Disc

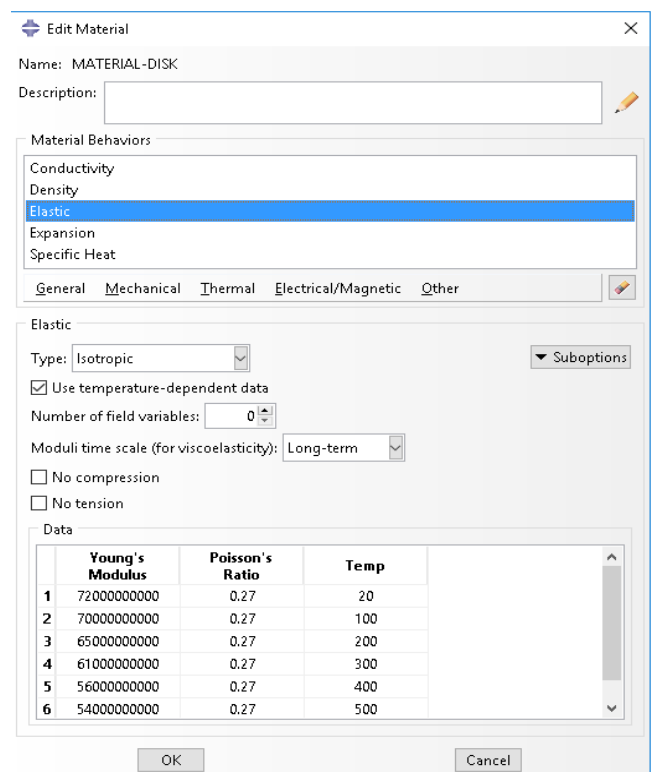


Fig-9: Thermal Expansion Co-efficient of the Disc

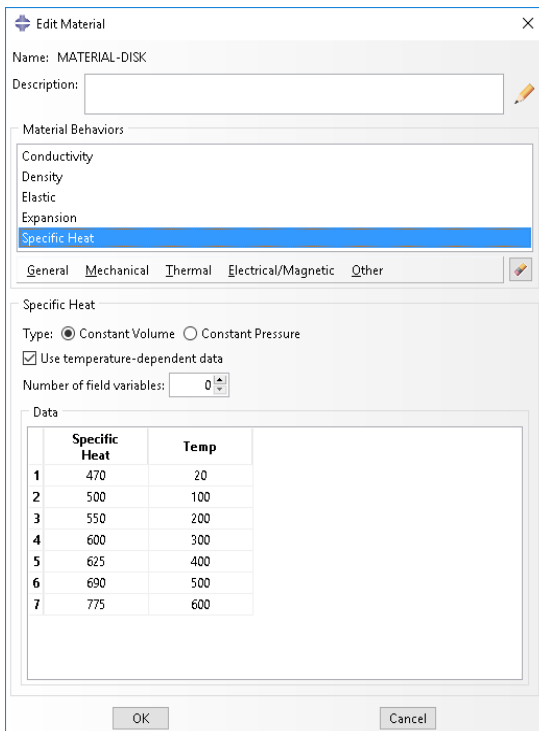


Fig-10: Specific Heat at different Temperatures (Temperature dependent values)

**Brake Pads Deck Preparation**

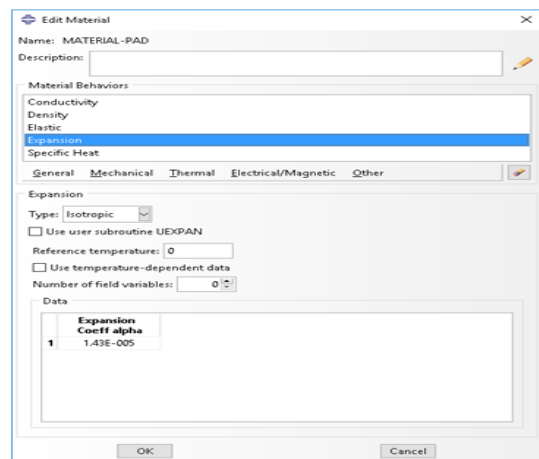


Fig-12: Thermal Expansion Co-efficient of the Pads

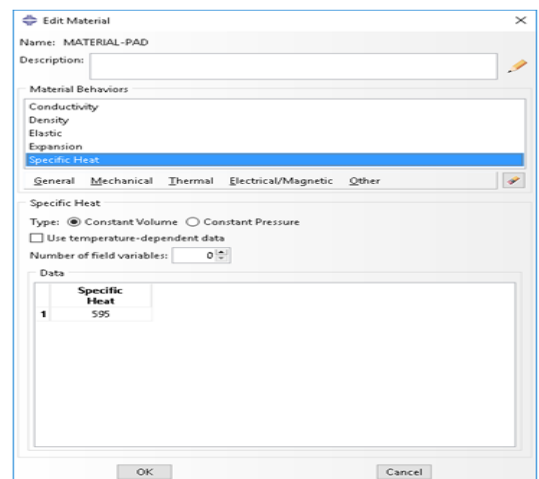


Fig-12: Specific heat of the Pads

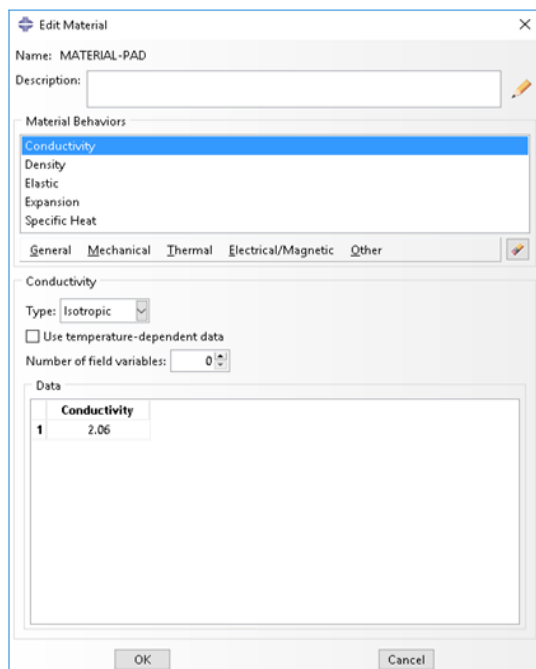


Fig-11: Heat Conductivity of the Pads

**5. RESULT AND DISCUSSION**

**Results of Stock Set up**

The results of the stock set up got by considering the process parameters and deck preparation given above. The figure shown below indicates temperature distribution in a disk of stock material for increment of 12278 & step time = 0.001

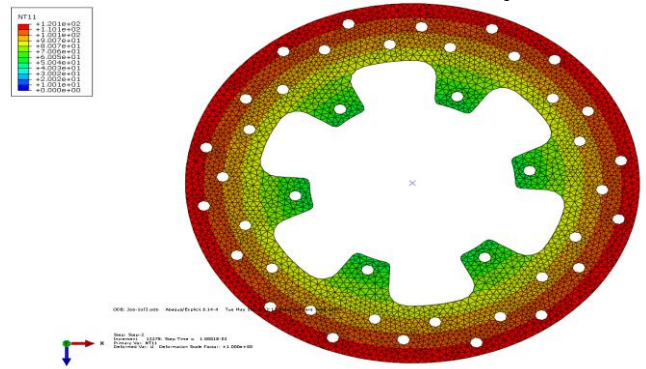


Fig-13: Temperature distribution of stock set-up



The below figure shows the stress distribution in the disk for stock material with same increment and step time as mentioned above.

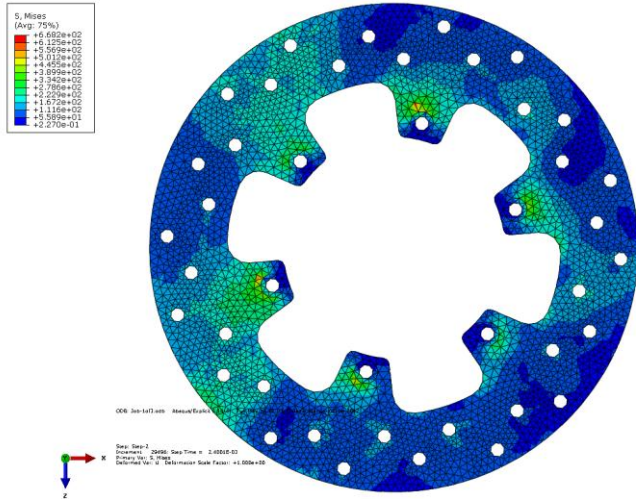


Fig-14: Stress distribution of stock set-up

**Results of set up with material changes**

The figure shown below indicates the result for a same disk with material Al-Sicof increment 49181 & step time 0.004

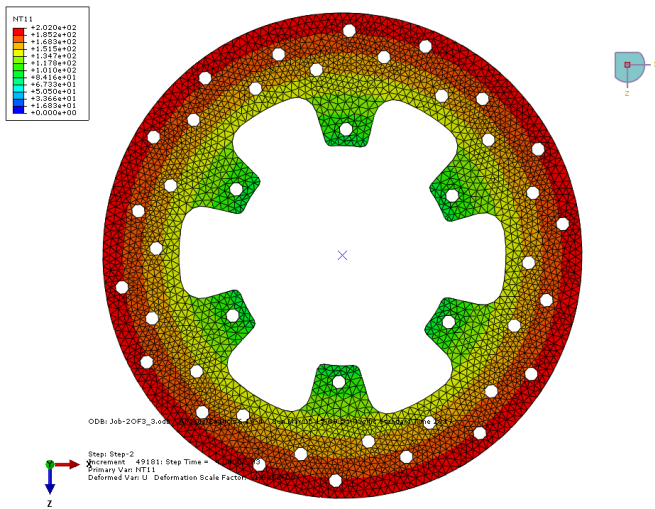


Fig-15: Temperature distribution in Al-Sic disc

The below figure shows the stress distribution in the disk for material Al-Sic with same increment and step time as mentioned above.

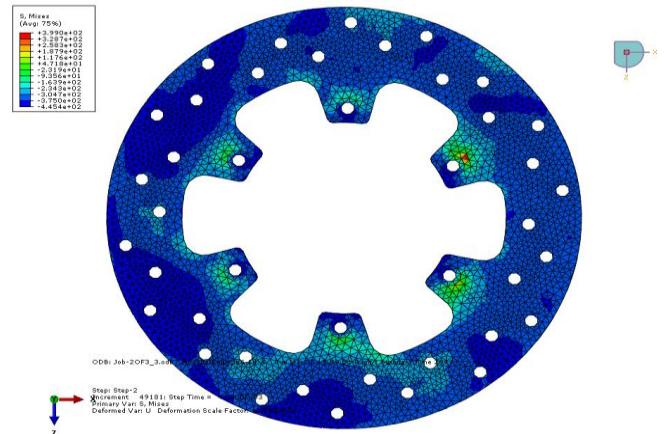


Fig -16: STRESS DISTRIBUTION IN Al-Sic DISC

**Comparison between Stock material and Al-Sic**

As discussed above the results shows that changing the material of the disk lead to the better Temperature distribution and also Stress distribution in the disk.

This change in result is majorly because of change in disk material i.e. from stock material to Al-Sic which is a nonlinear material. Hence this shows that material nonlinearity effects on the Temperature distribution and Stress distribution. The table shown below helps to compare the results of the disk plate with different material. In material non linearity even when computing displacement gradients to first order, only the higher order material relationship introduces higher order effects in the differential equation hence the results of nonlinearity material is better compared to linear material.

**Table.1.** Temperature distribution and Stress distribution in the disk.

Material Name	stock		Al-Sic Composite	
	Min	Max	Min	Max
Temperature Distribution	+0.000e+00	+1.201e+02	+0.000e+00	+2.020e+02
Stress Distribution	+2.270e-01	+6.682e+02	-4.454e+02	+3.990e+02

**Meshing of the Disc with Topological Changes**

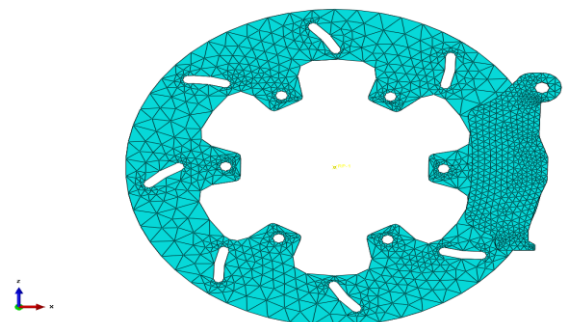
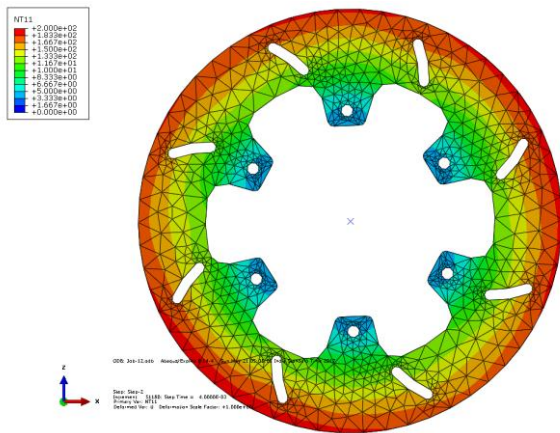
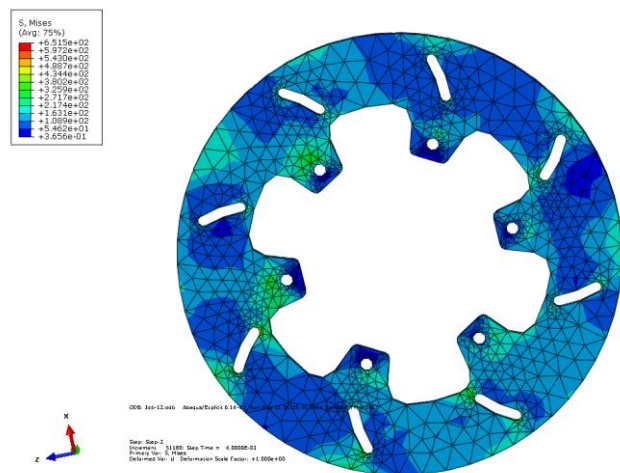


Fig-17: Tetrahedral mesh of the Disc-Pad system with topological changes

## Results of the Setup with Topological Changes



**Fig-18:** Temperature distribution of the set-up with topological changes



**Fig-19:** Stress distribution of the set-up with topological changes

## 6. CONCLUSION

From the results obtained and studies conducted we observe the influence of temperature on the structure and contact behavior of the disc brake assembly. Considering these factors the use of steel grade 321 as disc material shows resistance to significantly higher stresses. Another method that can be used to dissipate stresses is the use of slots on the high stress regions (contact surface) which also help in heat dissipation and cooling. This insight may help design engineers understand the necessary considerations and visualize the forces experienced and its prominent effects on the disc brake assembly that effect the work efficiency and safety. As this isn't a very accurate depiction of the forces experienced engineers and designers may use experimental data from XRD tests, friction tests and vehicular tests to improve the accuracy of the calculation/simulation conducted.

## 7. SCOPE OF FUTURE WORK

Further studies on the prediction of the wear rate can be conducted by considering accurate material data, and surface interaction data can be done. Similarly studies have been conducted on brake squeal and vibrations occurred in the disc brake assembly. The use of a smooth mesh gives a more precise result on the contact surface and the rest of the geometry, but is limited by the computational capabilities of the computer and the software used. Studies on the use of various materials such as carbon reinforced steel or a fully carbon based discs and the use of bio-sintered or organic materials in pads can be conducted with the help of relevant data. Simulation of the heat dissipated to the atmosphere with the help of CFD analysis can be conducted as cooling by air also plays an important role. And in future considerations the use of multi body dynamics considering the weight of the driver/rider, forces absorbed by the flex in chassis and dive in suspension, friction force on tires can be used in predicting an accurate idea of the brake force experienced by the assembly

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