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Numerical Investigation Of Helical Indented Disc Brake With Various Extent Of Perforations

Md. Sadiq Mohiuddin[1], Dr. M. Anwarullah[2]

[1]Research Scholar, Mechanical Engineering Department, Mewar University, Rajasthan, India.

[2]Research Supervisor, Mechanical Engineering Department, Mewar University, Rajasthan, India & Senior Professor, Mechanical Engineering Department, LIET (A), Hyderabad, Telangana, India.

ABSTRACT:

Increasing road accidents are a source of concern for everyone these days, and the road and safety department of the Indian government, as well as state governments, are working hard to control them using various means. Braking system must assure to the customer that this is the safest equipment provided to the vehicle for avoiding accidents. Brakes must fulfil and capable to meet all the required parameters of modern vehicles such as speed power and comfort. The friction pad and disk cause the wheels to slow down during braking. The present work is aimed to study the behaviour of the disc brake with various sizes of perforation on the disc brake rotor by means of various parameters. The parameters considered in the work are diameter of holes 8mm, 10mm, 12mm; circular patterns holes 32, 26, 20 on the disc brake and the distance between the holes 8mm, 9mm and 10mm. Materials consider during the analysis are AISI 1020, AISI 1040, AISI 1113, AISI 1213. From the findings it is observed that AISI 1020 material has performed better than other materials in terms of their strength and attained lower deformation in comparison with other materials.

Keywords: AISI Steel, Diameter of Hole, Circular Pattern, Disc Brake Rotor

I. INTRODUCTION

The shape of a disc is a key component in determining its thermal and mechanical qualities. When the brake system needs to cool down more quickly, like in racing cars and motorbikes, the author recommends employing discs with holes and air foil vents. On the basis of geometric design, this paper investigated various types of discs. According to the author, disc rotor 1 has a temperature rise of 12.32 % more than disc 3, and it weighs 15.18 % more than the rotor. However, this research suggests that disc flange rotors should only be utilised in a small number of heavy braking situations where a stronger braking power is needed [1]. The thermal analysis of these braking discs under cyclic thermal load circumstances are discussed. An uneven distribution of rotor temperature results from heat generated at the disc-pad interface during abrupt braking. Between 300 and 800 degrees Celsius is the range of the heat energy released [2].

The effect of thermal stresses induced in brake pad and disc during repeated breaking. Experimental obtained temperature field has been used for the study of thermal stresses in disc. With the application of FEM network thermal stresses effect has been calculated and found that heat dissipation is the essential factor in disc braking [3]. Asserted helpful design and support for enhancing disc brake systems' mechanical, thermal, and structural performance. The aforementioned analysis can help improve the brake performance of the disc brake system and provide a useful design. It has been noted that the modified (new disc 5) disc has the lowest temperature distribution when compared to the real standard Bajaj Pulsar 2-Wheeler and other new discs. The optimum material for disc brakes has been found to be gray cast iron. The new disc number five is superior to the original disc from the Bajaj Pulsar or any other new disc in terms of heat dissipation. New disc number five is capable of delivering strong braking force while operating without cracking or buckling [4].

Parameter temperature distribution was seen on a variety of disc types, including vented and complete brake discs. According to the author, radial ventilation is essential for brake disc cooling while braking. However, the author does not conduct experimental validations to evaluate the precision of the numerical model produced [5]. When conducting a study on the repeated braking criterion, the author of this paper took into consideration variables such as temperature, operating speed, and coefficient of friction. According to the author, the simulation and the laboratory experimental study that were used to anticipate the field results are equally accurate. However, experimental testing is limited to two-wheeler brake systems and does not account for vehicle speed variations [6]. When deformation is observed and pressure rises, the author advises that the calliper be subjected to structural analysis. The convection film coefficient was applied to the whole surface of the disk because convection occurs on the pad's periphery. However, the study is limited to braking components that are currently on the market, aside from the panic braking criterion. The factors that must be taken into account while constructing new braking components are not the author's primary concern [7]. the structural and thermal investigation of the disc brake are discussed considering the overall strain, heat dispersion, and stress equivalent. While cast iron outperforms other materials in terms of stress, and stainless steel performs better in terms of deformation. However, the author only looked into three materials [8].

The structural and thermal examination of the disc brake revealed the following strength and heat dissipation values. Despite aluminum's higher heat dissipation over steel, the author believes that disc brake rotors cannot employ aluminum due to its poor strength. But just three materials were examined by the author [9]. Critical value that must be added to the efficient distribution of braking force in today's and future scenarios. This thesis deals with the development of anti-locking controlled brake systems, the thorough analysis of the design principles and the variables concerning them, the typical distribution of the brake force, influenced by the wheel brakes, as well as their dispersion due to differences in the friction coefficient. A brief survey of hydraulic pressure valve systems guided by the concept of efficient brake force distribution was recorded in this research. This study has provided a discussion of the control ranges of the anti-locking devices, based on the real distribution of brake power [10].

The aim of the present work is to design and develop the disc brake system for Electric Two Wheelers using thermal analysis system approach, and study the performance of disc brake by opting the various geometry of rotor and to optimize the performance of disc brake.

II. NUMERICAL ANALYSIS OF DISC BRAKE ROTAR

The Design of Experimentation (DOE) refers to the planning process that takes place throughout a research project in order to achieve certain goals. The optimal design of an simulation is a very crucial aspect in order to meet the study goals in a clear and efficient manner with the relevant kind of data and the suitable sample size. The majority of simulation work related to equipment errors and random causes are corrected by repeating the tests. The modelling of the disc brake performed in ProE are shown in fig. 1-2, meshed model in Ansys in fig. 3, and the simulation results in fig. 4-7.

Table 1: Factor considered in present work

Circular Patterns	Hole Diameter (mm)	Distance between Holes (mm)	Weight (N)	Temperature (°C)	Stresses (N/mm^2)	Deformation (mm)
32	8	8	26	204	128.6	0.215
32	10	9	26.4	203	127.8	0.219
32	12	10	27.2	203.5	142.1	0.221
26	8	9	26.8	205	122.6	0.226
26	10	10	27.1	204.5	153.1	0.224
26	12	8	28	204.7	149.3	0.234
20	8	10	27	205	120.9	0.224
20	10	8	27.4	205.5	141.4	0.223
20	12	9	28	205.3	158.9	0.235

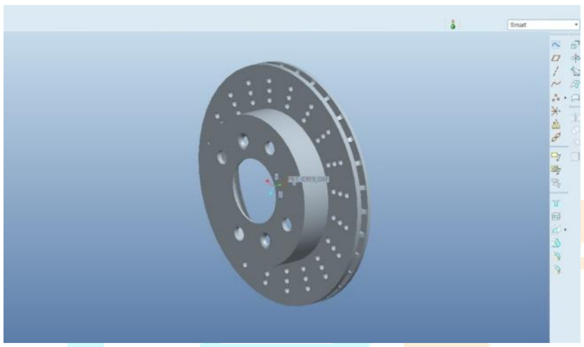
Figure 1: 3D model of disc brake made in ProE

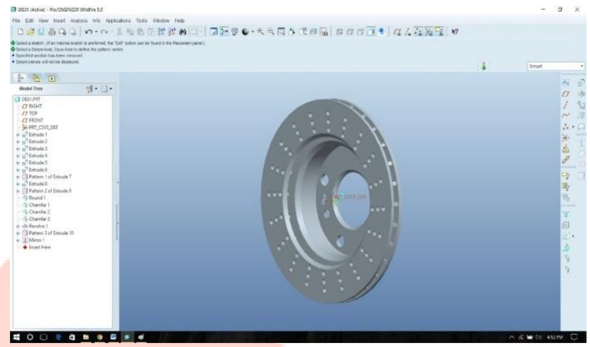
Figure 2: solid model of disc brake with hole

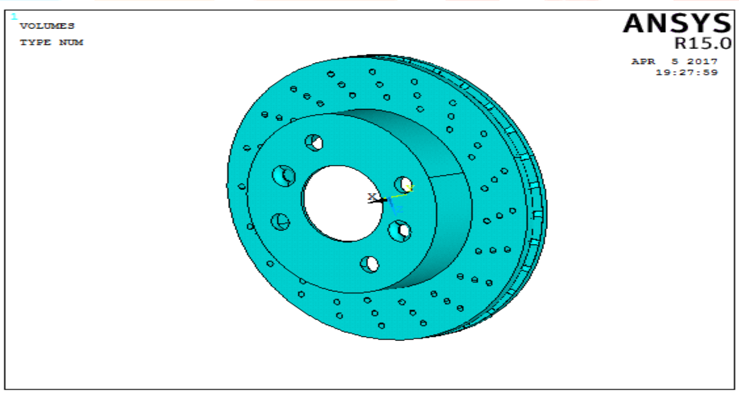

Figure 3: IGES file of disk brake isometric view by Ansys software

Figure 4: Tetrahedral mesh disc brake

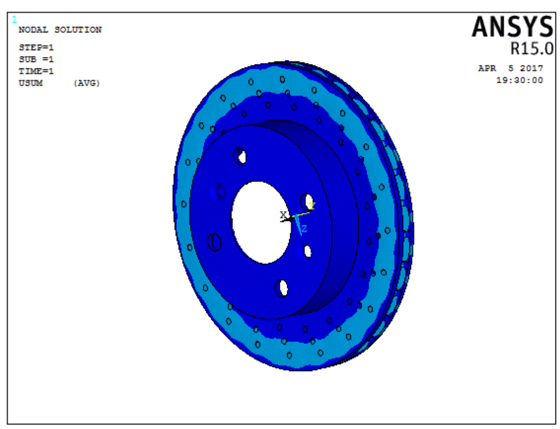

Figure 5: Displacement vector sum

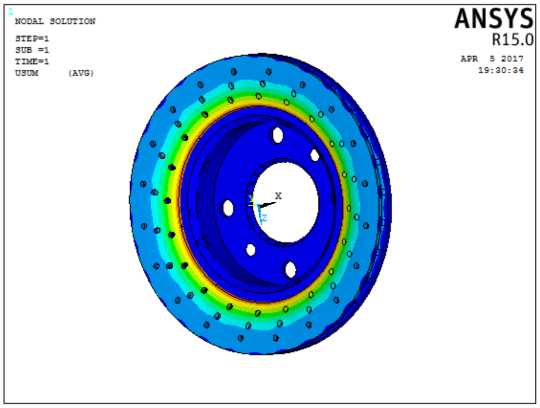

Figure 6: Displacement vector sum occurs at mid rear side

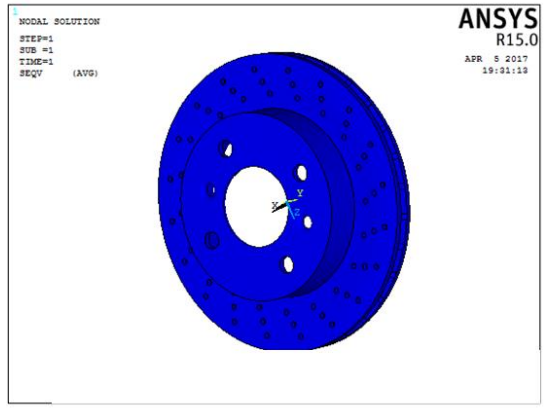

Figure 7: Von Misses stress on Disk brake

III. RESULTS AND DISCUSSIONS

In order to assess the disc brake's thermal and structural response and maximize its performance on disc brake, the following attributes and their levels are considered for the experiments: diameter of hole, circular pattern and distance between the holes are considered. From this parameter optimum parameter is considered for fabricating the disc brake and to test the same at various speeds. In this connect as a first step numerical analysis is performed on the disc brake rotor modelled in ProE and using IGES format the file is imported in Ansys and angular velocity is applied to study the behaviour of the disc. Materials considered in the work are AISI 1020, AISI 1040, AISI 1113, AISI 1213.

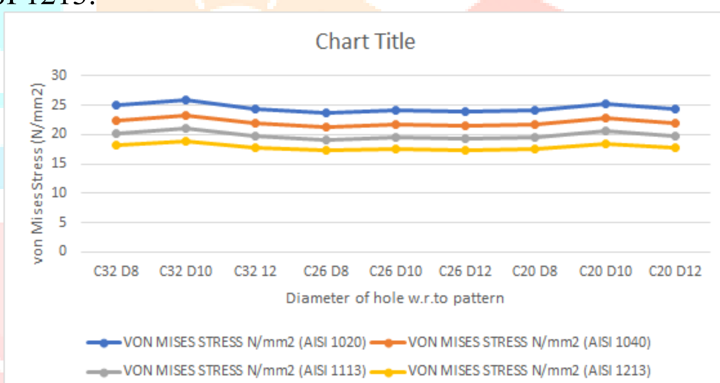

Figure 8: von Mises stress of disc brake rotor with different material

The stress behaviour of a disc brake rotor with different materials (AISI 1020, 1040, 1113, and 1213) under varying hole diameters arranged in a circular pattern. The x-axis represents the diameter of the holes (in mm), while the y-axis shows the corresponding stresses (in N/mm^2). As the hole diameter increases from 8mm to 12mm, stresses increased from 8mm to 10mm and again decrease from 10mm to 12mm, generally rises for all materials. Fig. 8 indicates that the von Mises stress of the disc brake rotor fluctuates considerably based on the selected material. AISI 1020 steel has the greatest stress under applied loads, signifying its somewhat inferior resistance to deformation. Conversely, AISI 1213 exhibits the lowest stress values, rendering it a more advantageous option for applications necessitating superior strength and durability. This stress behaviour can be ascribed to the disparities in mechanical properties, including tensile strength and yield strength, among the materials.

The results further emphasise the influence of hole designs and diameters on the rotor's performance. Upon comparing circular patterns across diverse configurations, it is evident that all ranges exhibit comparable performance, indicating that the distribution of stress is consistent irrespective of the specific pattern arrangement. The diameter of the perforations significantly influences load distribution. A 10mm diameter hole exhibits optimal performance among the investigated sizes, possibly due to its ideal equilibrium between material removal and structural integrity. This dimension probably promotes efficient heat dissipation while preserving enough mechanical strength, hence minimising stress concentrations. These findings offer significant insights for the design optimisation of disc brake rotors to improve their operational efficiency and longevity.

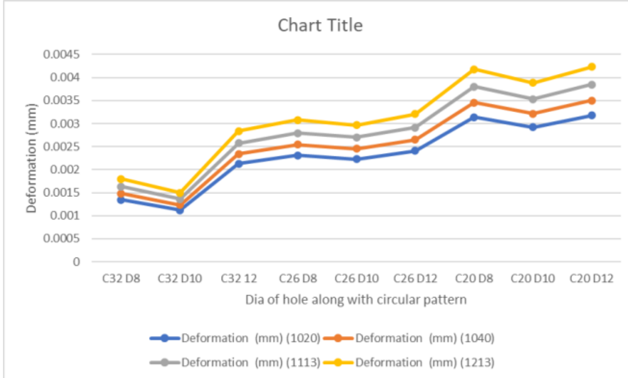

Figure 9: deformation of disc brake rotor with different material

The graph illustrates in figure 9, the deformation behaviour of a disc brake rotor with different materials (AISI 1020, 1040, 1113, and 1213) under varying hole diameters arranged in a circular pattern. The x-axis represents the diameter of the holes (in mm), while the y-axis shows the corresponding deformation (in mm). As the hole diameter increases from 8mm to 12mm, deformation generally rises for all materials. AISI 1020 material, represented by the blue line, exhibits the lowest deformation among the tested materials, indicating its relatively lower stiffness and resistance to deformation under load. Across all materials, the deformation remains comparatively low for smaller hole diameters, such as 8mm and 10mm, but significantly increases at 12mm. This trend suggests that larger holes compromise the structural integrity of the rotor, leading to greater deformation. Despite variations in material properties, a circular hole diameter of 10mm demonstrates a balanced performance, offering reduced deformation while maintaining structural efficiency. Overall, AISI 1040 is identified as the lowest deformation-resistant material, and a 10mm hole diameter emerges as an optimal design choice for improved performance and durability of the rotor.

IV. CONCLUSION

Based on the aforementioned results and discussions about the structural and thermal analysis of the disc brake rotor, both numerically and experimentally, the following conclusions are formed.

- The mechanical characteristics of AISI 1020, AISI 1040, AISI 1113, AISI 1213, and AISI 1020 exhibit notable differences. AISI 1020 exhibits the minimal deformation (0.02451 mm), demonstrating it to be the most unyielding material.
- AISI 1020 demonstrates the maximum Von Mises stress (541 MPa), indicating its ability to endure elevated loads prior to yielding. AISI 1040 exhibits a yield strength of 507 MPa, whereas AISI 1113 demonstrates the lowest yield strength at 188 MPa.
- The difference in absorption between materials AISI 1020 and 1040 is 6.281%. AISI 1020 is the most appropriate material for high-stress applications requiring rigidity and strength, whereas AISI 1213 is ideal for high-temperature conditions but allows for greater deformation. AISI 1113, owing to its diminished strength and thermal resistance, is more appropriate for applications involving minimal stress and heat exposure.

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