Finite Element Modelling and Analysis of Functionally Graded Disc

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ABSTRACT

The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor), usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attaches wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade.

The aim of the project is to model a disc brake used in Honda Civic. Structural is done on the disc brake. The materials used are Cast Iron, Aluminium Alloy 6061and Aluminium MMC. Analysis is also done by changing the design of disc brake. Actual disc brake has no holes, design is changed by giving holes in the disc brake for more heat dissipation. Modelling is done in CATIA, and analysis is done in ANSYS.

Keyword: *Stress, Strains, Composites material, Aluminium, Finite element analysis, Catia*

1. INTRODUCTION

A brake is a device what that exhibits motion. Its opposite component is a clutch. The rest of this article is dedicated to various types of vehicular brakes.

Most commonly brakes use friction to convert kinetic energy into heat, though other methods of energy conversion may be employed. For example, regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Still, other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel.

Disc Brakes

The disc brake or disk brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc (or rotor in U.S. English) is usually made of cast iron or ceramic composites (including carbon, Kevlar and silica). This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes (both disc and drum) convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade.

Disc brakes were most popular on sports cars when they were first introduced, since these vehicles are more demanding about brake performance. Discs have now become the more common form in most passenger vehicles, although many (particularly light weight vehicles) use drum brakes on the rear wheels to keep costs and weight down as well as to simplify the provisions for a parking brake. As the front brakes perform most of the braking effort, this can be a reasonable compromise.

Fig 1: Disc Brake being polished after scarring occurred

Fig 2: Disc brake caliper (twin-pot, floating) removed from brake pad for changing pad

1.1 Functionally Graded Materials (FGM)

The reinforcement in composites used as structural materials in many aerospace and automobile applications is generally distributed uniformly. Functionally graded materials (FGMs) are being used as interfacial zone to improve the bonding strength of layered composites, to reduce the residual and thermal stresses in bonded dissimilar materials and as wear resistant layers in machine and engine components. They have therefore attracted considerable attention in recent years. One of the advantages of FGMs over laminates is that there is no stress build-up at sharp material boundaries due to continuous material property variation to eliminate potential structural integrity such as delamination.

In materials science functionally graded material (FGM) may be characterized by the variation in composition and structure gradually over volume, resulting in corresponding changes in the properties of the material. The materials can be designed for specific function and applications. Various approaches based on the bulk (particulate processing), preform processing, layer processing and melt processing.

1.2 Literature Survey:

Belhocine, M. Bouchetara et.al.[1] was reported that **Thermal behaviour of full and ventilated disc brakes of vehicles by Braking is a process which converts a vehicle's kinetic energy into mechanical energy which must be dissipated in the form of heat**. During the braking phase, the frictional heat generated at the interface of the disc and pads can lead to high temperatures. This phenomenon is even more important than the tangential stress. The relative sliding speeds during contact are also important. The prediction of surface temperature for a brake rotor is regarded as an important step in studying brake system performance. The frictional heat generated on the rotor surface can influence excessive temperature rise which, in turn, leads to undesirable effects such as thermal elastic instability (TEI), premature wear, brake fluid vaporization (BFV) and thermally excited vibrations (TEV). The objective of this study is to analyse the thermal behaviour of the full and ventilated brake discs of the vehicles using computing code ANSYS. The modelling of the temperature distribution in the disc brake is used to identify all the factors and the entering parameters concerned at the time of the braking operation, such as the type of braking, the geometric design of the disc and the material used. The results obtained by the simulation are satisfactory compared to those of the specialized literature.

Jian, Xia Changgao et. al. [2] observed that the **Transient Temperature Field and Friction Properties on Disc Brakes** by Zhang according to the real dimension of the braking disc, the finite element modelling for three-dimensional transient cyclic symmetry during the long downhill braking is established. The distribution of the transient temperature field of the brake disc during the braking are analysed. The variation of the friction factor combined with the temperature characteristics of the friction factor during the braking are analysed. The analysis result show: During the braking, the temperature of the brake rises increasingly and reaches the top temperature of 316.04°C at the end of braking process, the high temperature section concentrates in the far area of the friction surface; The changes of the friction factor is relatively stable during the long downhill braking. There is no obvious thermal recession.

P. Hosseini Tehrani, M. Talebi et. al. [3], studied that **Stress and Temperature Distribution Study in a Functionally Graded Brake Disk**. The simulation results show that the material properties of the disk brake exert an essential influence on the surface temperature, Von- Mises stress distribution and vertical displacement of the disk. It is shown that the temperature variation and vertical displacement in FGM disk is much lower than steel disk. Besides von misses stress distribution in radial direction grows gradually and has not shown a maximum value in FGM disk. As a result, the FGMs disk restrains the growth of thermal perturbation and delay the contact separation. Furthermore, it is shown that localized contact is not as prevalent in FGM brake disk as steel disk and use of FGM brake disk may eliminate thermal cracking and wear in localized contact point or hot spots.

Leszek Wawrzonek et. al. [4], experimented and stated that the Temperature in a disk brake simulation and experimental verification. The novelty of the paper is in the simplified and robust simulation model of the brake, the concept of the experimental rig and the methodology of uncertainty assessment. The developed methodology can be useful to researchers and industry involved in safety investigations and determining safety standards, specifically in explosive atmospheres. It may also be of interest to the automotive industry.
Modelling and Analysis of Functionally Graded Materials and Structures by Victor Birman and Larry W. Byrd, this paper presents a review of the principal developments in functionally graded materials (FGMs) with an emphasis on the recent work published since 2000. Diverse areas relevant to various aspects of theory and applications of FGM are reflected in this paper. They include homogenization of particulate FGM, heat transfer issues, stress, stability and dynamic analyses, testing, manufacturing and design, applications, and fracture.

2. Modeling and Analysis:

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used. Its use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.
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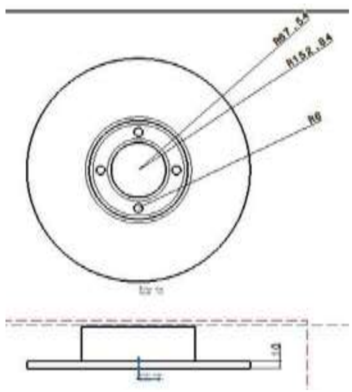

Fig: 3 Model of disc without holes

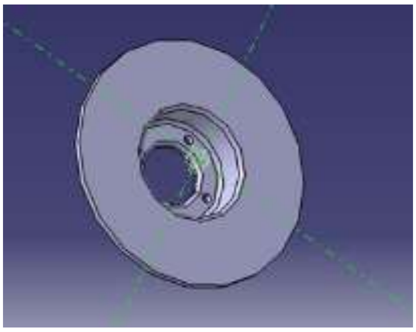

Fig: 4 Dimensions of disc

2.1 Finite Element Modelling

Introduction Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

Many comprehensive general-purpose computer packages are now available that can deal with a wide range of phenomena, together with more specialized packages for applications, for example, for the study of dynamic phenomena or large-scale plastic flow. Depending on the type and complexity of the analysis, such packages may run on a microcomputer or, at the other extreme, on a supercomputer. FEA is essentially a piece-wise process. It can be applied to one-dimensional problems, but more usually there is an area or volume within which the solution is required. This is split up into several smaller areas or volumes, which are called finite elements. Figure 1 shows a two-dimensional model of a spanner that has been so divided: the process is called discretization, and the assembly of elements is called a mesh.

2.2 Load Types

Displacements (UX, UY, UZ, ROTX, ROTY, ROTZ)

These are DOF constraints usually specified at model boundaries to define rigid support points. They can also indicate symmetry boundary conditions and points of known motion. The directions implied by the labels are in the nodal coordinate system.

Forces (FX, FY, FZ) and moments (MX, MY, MZ)

These are concentrated loads usually specified on the model exterior. The directions implied by the labels are in the nodal coordinate system.

Pressures (PRES)

These are surface loads, also usually applied on the model exterior. Positive values of pressure act towards the element face (resulting in a compressive effect).

2.3 Structural Analysis of Disc Rotor

Case 1: - Structural Analysis of Disc Rotor Without holes with material Cast Iron

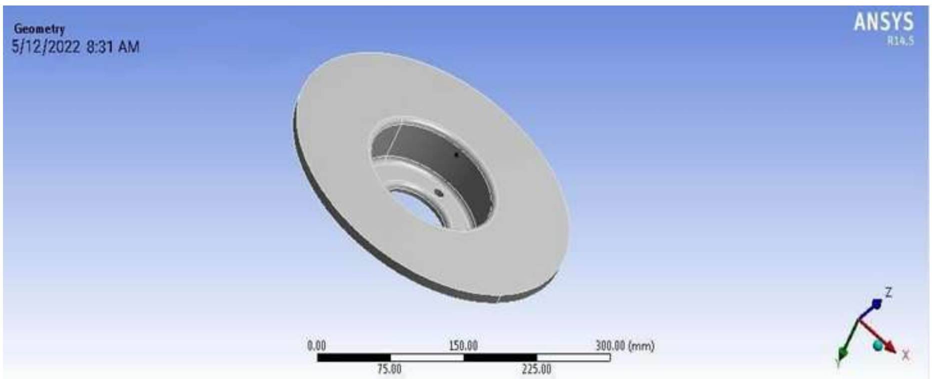

Fig: 5 Imported disc model into Ansys

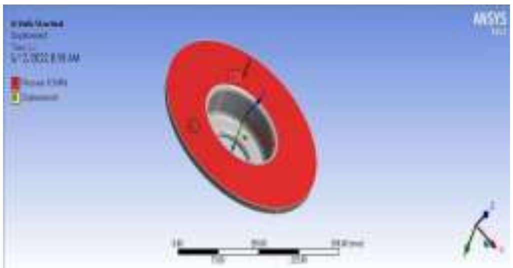

Fig: 6 Generation of mesh in Ansys

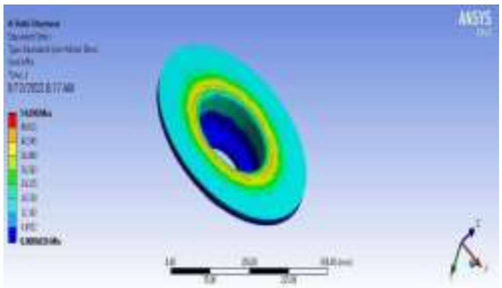

Fig :7 Total deformation in cast iron disc without holes VON – MISES STRESS

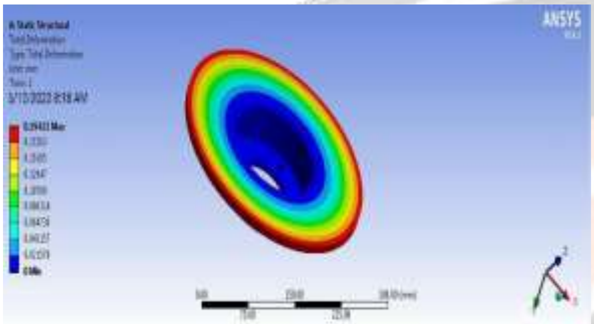

Fig 8 Von-mises stress in cast iron disc without holes VON – MISES STRAIN

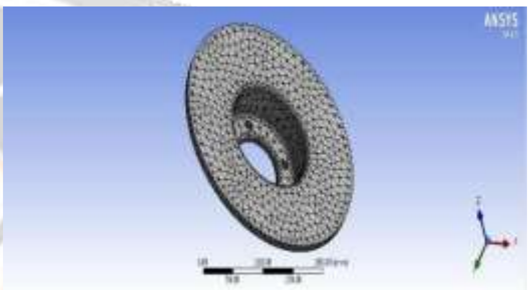

Fig 9 Von-mises strain in cast iron disc with holes VON – MISES STRAIN

Total Deformation for Aluminum 6061

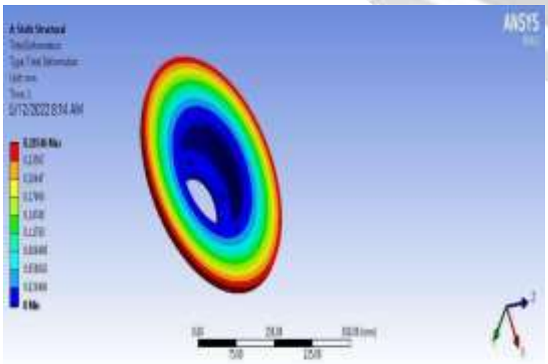

Fig 10 Total deformation in aluminium 6061 disc without holes

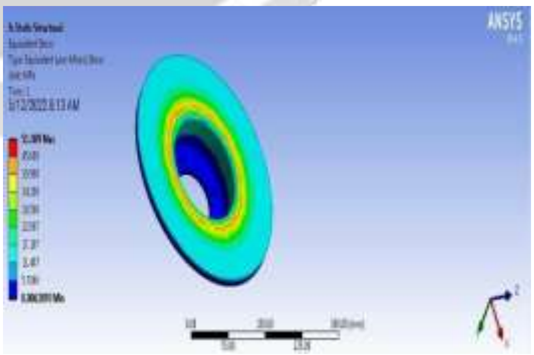

Fig 11: Von-mises stress in aluminium 6061 disc without holes

Material-Aluminum MMC (Al With Sic) Material Properties of Al with Sic

Total Deformation

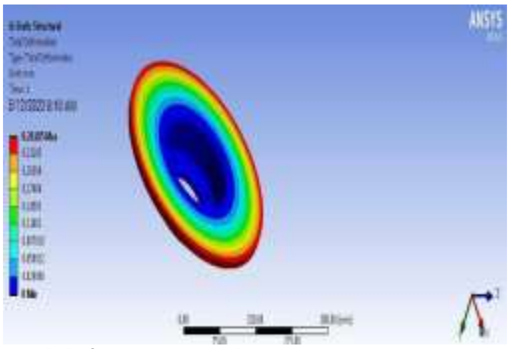

Fig 12: Total deformation in aluminium MMC disc without holes

Material – Cast Iron (Imported Model)

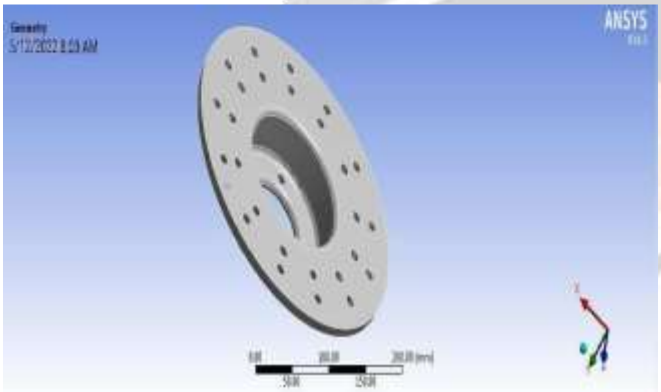

Fig 13: imported model of cast iron disc with holes.

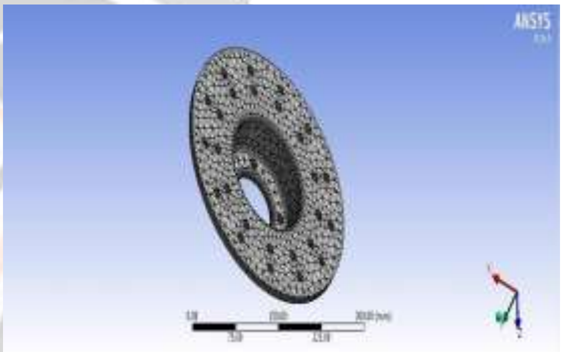

Fig 14: meshed model of cast iron disc with holes.

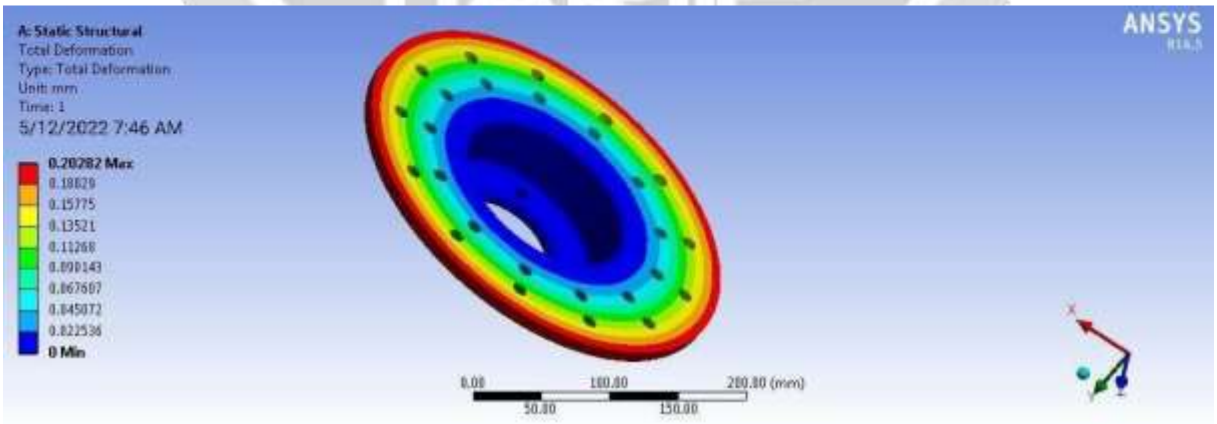

Figure – 15: Total deformation in cast iron disc with holes VON-MISES STRESS

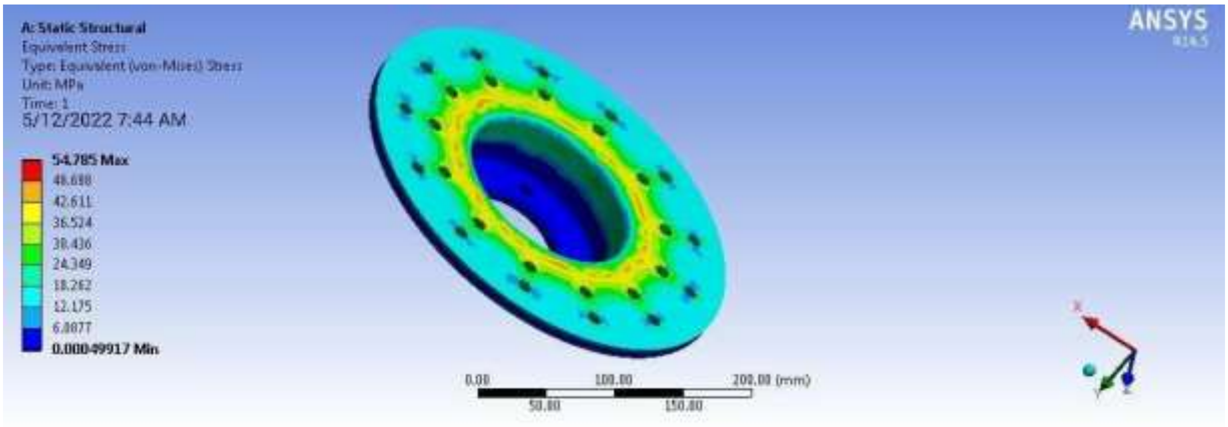

Figure 16: Von – mises stress in cast iron disc with holes VON-MISES STRAIN

Layers stacking

Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
10	5	1	90
9	4	1	0
8	3	1	0
7	2	1	0
6	1	1	0
5	-1	1	0
4	-2	1	0
3	-3	1	0
2	-4	1	0
1	-5	1	-90
(-Z)			

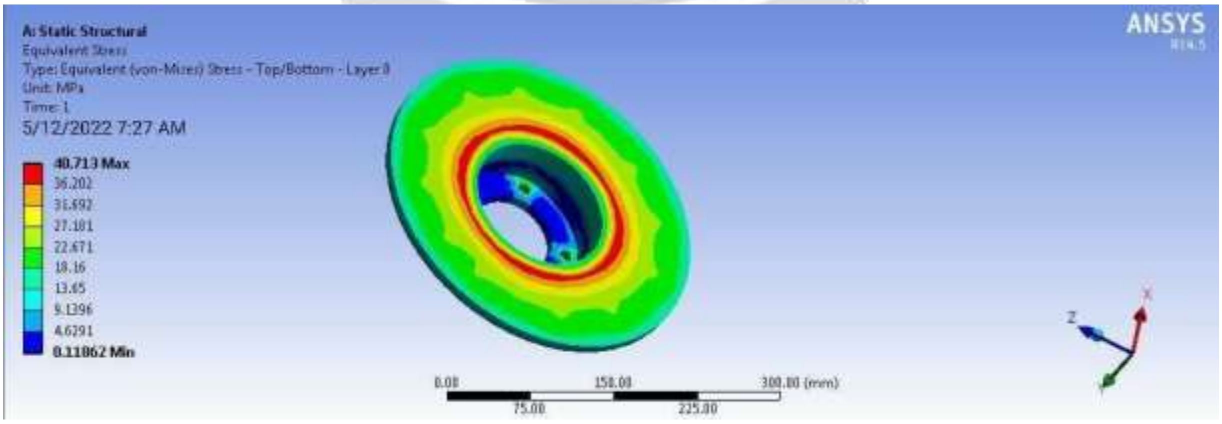

Figure – 4.27: Von – mises stress in FGM disc without holes

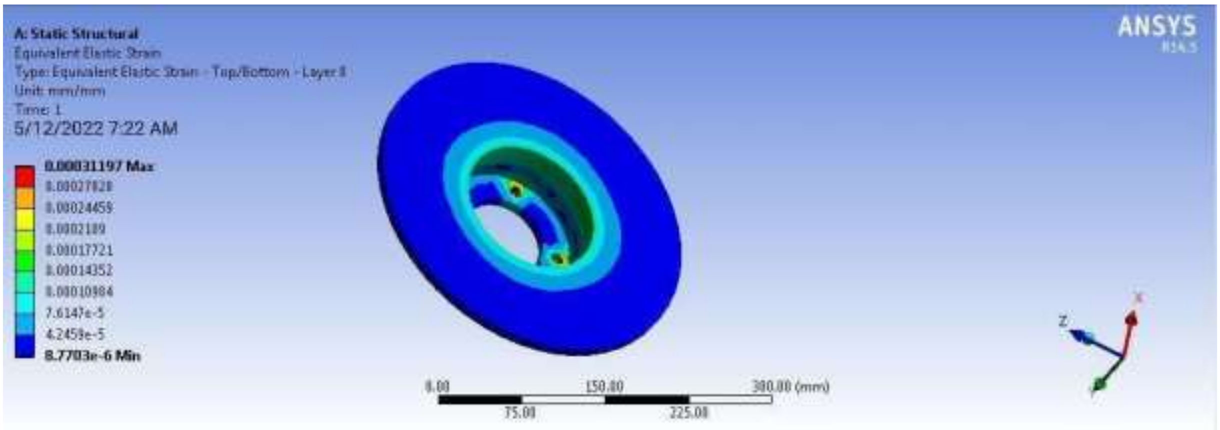

Figure – 4.28: Von – mises strain in FGM disc without holes

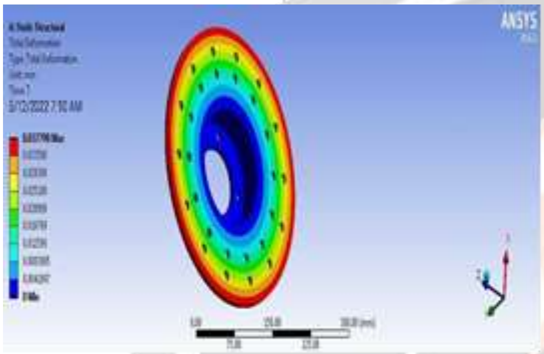

Figure – 4.31: Total deformation in FGM disc with holes VON-MISES STRESS

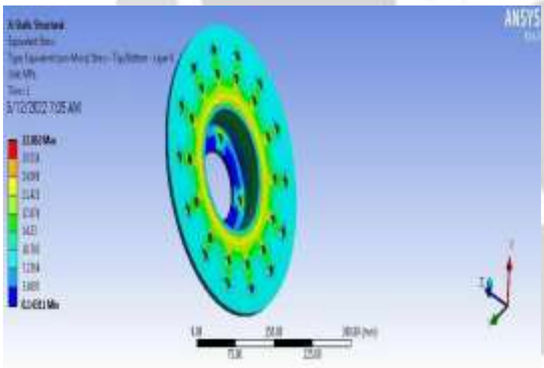

Figure – 4.32: Von – mises stress in FGM disc with holes

3. Results and Discussions

Table: 5.1 Static Analysis Results

CASES	MATERIALS	DEFORMATION (mm)	STRESS (N/mm^2)	Strain
Without holes	Cast iron	0.19421	54.698	0.0005065
	Aluminium 6061	0.2654	51.309	0.0007271
	Aluminium MMC	0.26105	49.412	0.0007075
With holes	Cast iron	0.20282	54.785	0.0005055
	Aluminium 6061	0.2785	51.472	0.0007276
	Aluminium MMC	0.27362	49.551	0.0007075

Table: 5.2 Linear Layer Analysis Results (FGM)

CASES	DEFORMATION (mm)	STRESS (N/mm^2)	STRAIN
Without holes	0.084068	40.713	0.00031197
With holes	0.037798	32.063	0.0000996

4. CONCLUSIONS

In this project a disc brake used in two-wheeler is designed and modelled in 3D modelling software CATIA. Two models one with holes and the other one without holes are modelled. Structural analysis is done on the disc brake using materials Cast iron, Aluminium MMC, functionally graded material and Aluminium alloy 6061.

By observing the structural analysis results, the stress values are more disc brake with holes than that of disc brake without holes. So as per structural analysis, using disc brake without holes is better. By comparing the materials, using functionally graded material is better as the stresses are less than the allowable stress and weight of the disc brake is less than that of Cast Iron since its density is less. So, it can be concluded that disc brake with holes and using functionally graded material is better.

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