OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

PERFORMANCE AND THERMAL ANALYSIS OF VARIOUS FUNCTIONAL GRADED MATERIALS (FGM) OF DISC BRAKE SYSTEM BY FEM

[1] Dr.C.NAGABHASKAR, [2]Dr.K.PRASADARAO [3]Mr.R.VIJAY KRISHNA, [4]Dr.VELIVELA LAKSHMIKANTH CHOWDARY, [5]D.RAMBABU

[1] Professor, Dept. of Mechanical Engineering, Principal of NRI Institute of Technology (Autonomous), Agiripalli(M), Vijayawada, Andhrapradesh .

[2] Professor, Head of the department, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous), Agiripalli (M), Vijayawada, Andhra pradesh .

[3] Associate Professor, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous), Agiripalli(M), Vijayawada, Andhrapradesh

[4] Associate Professor, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous), Agiripalli(M), Vijayawada, Andhra pradesh

[5]M.Tech Student, Dept. of Mechanical Engineering, NRI Institute of Technology (Autonomous) Agiripalli (M), Vijayawada, Andhra pradesh .

[1]cnbhaskar@gmail.com , [2]mehodnriit@gmail.com [3]vijaykrishnaclass@gmail.com [4]nrimtechthermal@gmail.com, [5]rambabudarshanala1@gmail.com

---

Abstract: The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc, usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and/or the axle. Functionally graded structures are those in which the volume fractions of two or more materials are varied continuously as a function of position along certain dimension(s) of the structure to achieve a required function. In this thesis, analytical investigation is to be done for functionally graded disc brake subjected to internal pressure. Different models of the disc brake are considered i.e disc brake with 40, 50, 60 holes.In this thesis, comparison is to be done by varying materials for disc brake, the materials are Cast Iron, FGM 1(Al2O3-Al) and FGM 2 (Zr-Al). FGM's will be considered for material variation profile through the thickness for k = 2, k = 4 and k = 6 .Theoretical calculations are to be done to calculate the material properties for each layer up to 10 layers for FGM'S. Structural analysis and thermal analysis are to be done on these three models by varying materials. 3D modeling is to be done in Pro/Engineer and analysis is to be done in Ansys.

I INTRODUCTION

Today technology is in need for speed, but at the same time, we need safety as well. For safety, we need deceleration to the maximum extent. These two things are moreover contradictory factors. For speed, we need engines of maximum efficiency and for keeping this speed in bounds, we need brakes of latest technology. For coping up with todays speed, new materials are introduced in the manufacture of disc brakes.The disc brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc is usually made of grey cast iron or ceramic composites (including carbon, Kevlar and silica). This is connected to the wheel and/or the axle.

Two types of brake discs are generally used, the solid type and the ventilated type. The ventilated type is more efficient since it provides better cooling.

Obviously, cast-iron disc is the heaviest part of a brake - about 8 kg each, or 32 kg per car. Though Aluminum alloy discs are light, they were less resistant to heat and fade, thus more powerful functionally graded materials are employed than conventional cast-iron for disc manufacturing.

Functionally graded materials:

The abrupt change in material properties across the interface between discrete layers in composites structures can result in large inter laminar stresses leading to de-lamination. One way to overcome these adverse effects is to use "functionally graded materials'' which are in homogenous materials with continuously varying material properties.

We consider a two- phase graded material with a power- law variation of the volume fractions of the constituents through the thickness. The effective material properties at a point are determined in terms of the local volume fractions.

Functionally graded materials are generally a mixture of ceramics and metals. The composition is varied from a ceramic-rich surface to a metal-rich surface, with a desired variation of the volume fractions of the two materials in between the two surfaces. The ceramic constituent of the material provides the high-temperature resistance due to its low thermal conductivity. The gradual change of material properties can be tailored to different applications and working environments. This makes functionally gradient materials preferable in many applications.

1.1 OBJECTIVES OF STUDY:

- The present objective of this thesis is to do analytical investigation of disc brake with 258 mm diameter, 10 mm thickness, and holes with 12 mm diameter.
- Here disc brake with three models are compared i.e., disc brake with 40, 50, 60 holes and also by varying materials of disc brake i.e., cast iron, FGM 1 (Al_2O_3-Al), FGM 2 (Zr-Al).
- A pressure of 1.2 N/mm^2 is considered in structural analysis and a temperature of 373 k is considered for thermal analysis.
- FGMs are assumed to be isotropic, and the grading is assumed to be only through the thickness.

1.2 THESIS OUTLINE

The remainder of this thesis is organized as follows:

The second chapter deals with previous work relevant to present investigations available in literature.

The third chapter includes the design and modeling of disc brake of three models

i.e., disc brake with 40, 50, 60 holes.

The fourth chapter presents the analysis of cast iron disc brake, FGM 1 (Al_2O_3-Al) disc brake, FGM 2 (Zr-Al) disc brake, including results of stress and thermal analysis.

The fifth chapter presents the results and discussions based on the graphs plotted by the data obtained from the analysis.

The sixth chapter includes the conclusions drawn by the findings of the investigation of the work.

II LITERATURE REVIEW AND BACK GROUND THEORY

J. N. Reddy [1], studied the Theoretical formulation, Navier's solutions of rectangular plates, and finite element models based on the third-order shear deformation plate theory are presented for the analysis of through-thickness functionally graded plates. The plates are assumed to have isotropic, two-constituent material distribution through the thickness, and the modulus of elasticity of the plate is assumed to vary according to a power-law distribution in terms of the volume fractions of the constituents. Numerical results of the linear third-order theory and non-linear first- order theory are presented to show the effect of the material distribution on the deflections and stresses.

J .Suresh Kumar [2], observed the analysis of functionally graded material (FGM) plates with material variation parameter (k), boundary conditions, aspect ratios and side to thickness ratios are investigated using higher order displacement model. The derivation of equations of motion for higher order displacement model is obtained using principle of virtual work. The nonlinear simultaneous equations are obtained by Navier's method considering certain parameters, loads and boundary conditions. The nonlinear algebraic equations are solved using Newton Rap son iterative method. The numerical results are obtained for various boundary conditions, material variation parameter, aspect ratio, side to thickness ratio and compared with the available solutions. The effect of shear deformation and nonlinearity response of functionally graded material plate.

Liu GR, Tani J, Ohyoshi T.Lamb (1990), investigated the dynamics of FGM plates; they also presented the concept of functionally graded piezoelectric materials for the first time and analyzed them using a hybrid numerical method.

Fukui Y, Yamanaka N (1992, investigated the effect of the gradation of the composition on the strength and deformation of the thick walled FGM tubes.

Obata Y, Nosa N (1992), conducted steady and transient thermal analysis and later on the optimal material design for FGM plates.

Tanigawa (1995), Compiled a comprehensive list of papers on the analytical models of thermo elastic behavior of functionally graded materials.

Praveen G N, Reddy JN (1998) [1], analyzed the nonlinear static and dynamic response of heated functionally graded ceramic-metal plates subjected to dynamic lateral loads by the finite element method.

Reddy J N (2000) [1], developed both theoretical and finite element formulations for thick FGM plates according to higher order shear deformation plate theory, and studied the nonlinear dynamic response of FGM plates subjected to sudden applied uniform pressure.

Fukui and Yamanaka, examined the effects of the gradation of components on the strength and deformation of thick-walled functionally gradient material tubes under internal pressure. Fukui et al. further extended their previous work by considering a thick-walled FGM tube under uniform thermal loading, and investigated the effect of graded components on residual stresses. They generated an optimum composition of the FGM tube by minimizing the compressive circumferential stress at the inner surface. Fuchiyama et al. used an eight-node quadrilateral axi symmetric element to study transient thermal stresses and stress intensity factors of functionally gradient materials with cracks. In their analysis, they concluded that temperature-dependent properties should be considered in order to obtain more realistic results.

Siti Nur Sakinah Jamaludin, studied the various fabrication techniques of FGMs composed by metallic and ceramic phases. Fabrication techniques in this field of work have incorporated many concepts from different background of gradation processes and consolidation or sintering processes. Each of these processes however has their own advantages and disadvantages. The best technique to be applied can be found by considering some critical issues highlighted in published literatures. He concluded the powder metallurgy (PM) as the most suitable technique certainly for mass production and up-scaling of the FGMs. The selection was strengthen after considering the advantages of the technique such as process cost-effectiveness, reliability of the practical implementation of the process and the high capability of the process to control the quality of the FGMs.

Present work is concerned with the analytical investigation of various disc brake models i.e., disc brake with 40,50,60 holes and also analytical investigation comparison is done for different materials i.e., cast iron, FGM 1 (Al_2O_3-Al), FGM 2 (Zr-Al) , by varying the material variation parameter through thickness (k) i.e., (for k = 2,k = 4,k = 6) for FGM's.

BACK GROUND:

2.1 Disc Brake:

The disc brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc (or *rotor*) 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 electro magnetically, 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 are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking.

The brake disc is the component against which the brake pads are applied. The material is typically grey iron form of cast iron. The design of the disc varies somewhat. Some are simply solid, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). The weight and power of the vehicle determines the need for ventilated discs. The "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily- loaded front discs.

Many higher-performance brakes have holes drilled through them. This is known as cross-drilling and was originally done in the 1960s on racing cars. For heat dissipation purposes, cross drilling is still used on some braking components, but is not favored for racing or other hard use as the holes are a source of stress cracks under severe conditions.

2.2 Disc brake damage modes:

Discs are usually damaged in one of four ways:

- Scarring
- Cracking
- Warping
- Excessive rusting.

2.2.1 Scarring:

Scarring can occur if brake pads are not changed promptly when they reach the end of their service life and are considered worn out. Once enough of the friction material has worn away, the pad's steel backing plate (for glued pads) or the pad retainer rivets (for riveted pads) will bear directly upon the disc's wear surface, reducing braking power and making scratches on the disc. To prevent scarring, it is prudent to periodically inspect the brake pads for wear.

2.2.2 Cracking:

Cracking is limited mostly to drilled discs, which may develop small cracks around edges of holes drilled near the edge of the disc due to the disc's uneven rate of expansion in severe duty environments.

No repair is possible for the cracks, and if cracking becomes severe, the disc must be replaced. These cracks occur due to the phenomenon of low cycle fatigue as a result of repeated hard braking.

2.2.3 Warping:

Warping is often caused by excessive heat. When the disc's friction area is at a substantially higher temperature than the inner portion (hat) the thermal expansion of the friction area is greater than the inner portion and warping occurs.

Another cause of warping is when the disc is overheated and the vehicle is stopped with the brakes continuously applied. In such a case, the area where the pads are in contact with the disc will cause uneven cooling and lead to warping.

Several methods can be used to avoid overheating brake discs. Use of a lower gear when descending steep grades to obtain engine braking will reduce the brake loading. Also, operating the brakes intermittently - braking to slower speed for a brief time then coasting will allow the brake material to cool between applications.

2.2.4 Rusting:

The discs are commonly made from cast iron and a certain amount of surface rust is normal. The disc contact area for the brake pads will be kept clean by regular use, but a vehicle that is stored for an extended period can develop significant rust in the contact area that may reduce braking power for a time until the rusted layer is worn off again. Over time, vented brake discs may develop severe rust corrosion inside the ventilation slots, compromising the strength of the structure and needing replacement.

Fig1:Disk brake without holes &disk brake with holes

2.3 FUNCTIONALLY GRADED MATERIALS:

Functionally graded structures are those in which the volume fractions of two or more materials are varied continuously as a function of position along certain dimension(s) of the structure to achieve a required function. For example, thermal barrier plate structures for high temperature applications may form from a mixture of ceramic and a metal. The composition is varied from a ceramic rich surface to a metal-rich surface, with a desired variation of the volume fractions of the two materials in between the two surfaces. The gradual change of material properties can be tailored to different applications and working environments. This makes functionally gradient materials preferable in many applications.

Functionally graded materials are composite materials, which are microscopically in homogeneous, and the mechanical properties vary smoothly or continuously from one surface to the other .It is this continuous change that results in gradient properties in functionally graded materials. Modern FGMs are constructed for complex requirements, such as the heat shield of a rocket or implants for humans. The gradual transition between the heat and corrosion resistant outer layer (often made of a ceramic material) and the tough metallic base material increases in most cases the life time of the component.

Typically these materials are made from a mixture of metals and ceramic, or a combination of different metals. Unlike fiber-matrix composites, which have a strong mismatch of mechanical properties across the interface of two discrete materials, bonded together and may result in de- bonding at high temperatures. Functionally graded materials have the advantage of being able to survive environment with high temperature gradient, while maintaining their structural integrity .The ceramic materials provides high temperature resistance due to its low thermal conductivity, while the ductile metal component prevents fracture due to thermal stresses.

Laminated composite materials provide the design flexibility to achieve desirable stiffness through the choice of lamination scheme, the anisotropic constitution of laminated composite structures often result in stress concentrations near material and geometric discontinuities that can lead to damage in the form of de-lamination, matrix cracking, and adhesive bond separation.

Functionally graded materials (FGMs) are a class of **composite materials** where the composition or the microstructures are locally varied so that a certain variation of the local material properties is achieved. The gradual variation results in properties of the material reduces thermal stresses, residual stresses, and stress concentration factors. These are manufactured from isotropic components such as metals and ceramics since they are mainly used as thermal barrier structures in environments with severe thermal gradients. In some applications the ceramic heat and corrosion resistance, mean while the metal provides the strength and toughness.

2.4 FIELDS UTILISING FGM's:

1. Aeronautics:

The concept of FGMs was originally devised for this field. FGMs were to provide two conflicting properties such as thermal conductivity and thermal barrier property in one material. At present, it enables to produce lightweight, strong and durable materials and is applicable to a broad range of fields such as structural material, energy conversion material and others. Especially, it will be a vital technology for rocket and space station construction. FGMs are also applicable to an outer wall of space plane and parts of rocket engine.

2. Industrial materials:

Many applications of FGMs have been recently carried out for industrial materials. One example is forming tools. Since recent products are getting stiffer because of increased strength and thermal resistance and tough to cut and form, demands for a new material for industrial tool are growing. In this field, it is required to have both wear resistance and toughness thus, we can say that FGM application is a solution. Besides, as need for dry cutting and not using cutting fluid increase in consideration of environment, development of a self-lubricant and high thermal resistant tool is expected. A trial production of industrial tool had been successfully conducted using diamond (outside) and steel (inside) and further development is now expected for a high-speed tool in any size or shape.

3. Optoelectronics:

There are so many variations in the means of communication. Now, communication tools using optical fibers needs further advancement along with information increasing in volume. One idea is a light wavelength multiplex communication system using optical filters; especially, using a refractive index graded filter. It has a structure that refractive index for wave transmitting direction continuously varies along with wavelength frequency. With the filter, unnecessary refraction can be prevented to some extent. Application of FGMs to plastic optical fibers can provide high-speed transmission. Consequently, it will be able to spread optical communication system up to household level.

4. Energy materials:

Regarding environmental problems, there is a long list of causes. Some of them are CO_2, dioxin and ozone holes. Another problem is garbage we are producing in daily life. Thermoelectric power generation has attracted people's attention for effective utilization of garbage as energy. Thermoelectric materials are expected to be used in the power generation system. In the past, a single material used to be both high and low temperature regions. However, by grading function, an appropriate function will be applied to an appropriate temperature region; consequently it will make a high efficient system. It can be said that FGM is available in this field too. Energy material study aimed for efficient thermoelectric materials may be applied to other technologies such as opto electric conversion and sun energy-laser conversion.

5. Biomaterials:

Our body is supported by 206 bones, and some of them cover brain and organs. If we have a pain in a bone or a joint, we will have troubles in our lives. To solve such troubles, a new material that can substitute bones and joints and has a long life has been desired. Not only excellent hardness and corrosion resistance, but also biological compatibility and harmlessness are desired. Here again, FGM technology is applicable to artificial bones, joints and teeth. Structure grading technology is used in research for cancer prevention, too. One of them is, for instance, a study on collagen structure reinforcement using the grading technology.

6. Others:

Cellular phone is one of means of convenient communication tools. It is getting thinner and smaller. FGM technology is applicable in this field, too. For minimization of size and effective transmission, a permittivity-grading technology can be applied when producing substrates. Similarly, in other fields such as electronics field and chemistry field, FGMs are also applicable. Optical fibers made of completely fluorinated polymer have been developed. As well, further research may also develop new materials with novel functions by using nano-level grading technology

III DESIGN AND MODELLING

3.1 Design of Disc Brake in Pro/Engineer Software:

Pro/ENGINEER is a feature based, parametric solid modeling program. As such, its use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry. Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modeling, each feature is individually described then integrated into the part. The other significant aspect of conventional drafting is that the part geometry is defined by the drawing. If it is desired to change the size, shape, or location of a feature, the physical lines on the drawing must be changed (in each affected view) then associated dimensions are updated. When using parametric modeling, the features are driven by the dimensions parameters. To modify the diameter of a hole, the diameter parameter value is to be changed. This automatically modifies the feature wherever it occurs drawing views, assemblies, etc. Another unique attribute of Pro/ENGINEER is that it is a solid modeling program. The design procedure is to create a model, view it, assemble parts as required, then generate any drawings which are required. It should be noted that for many uses of Pro/E, complete drawings are never created.

Design of Disc Brake:

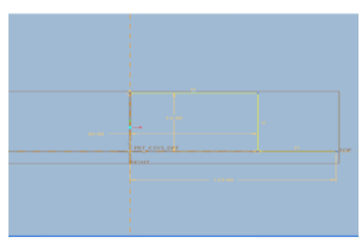


Fig 2 shows drawings in sketcher in Pro-E

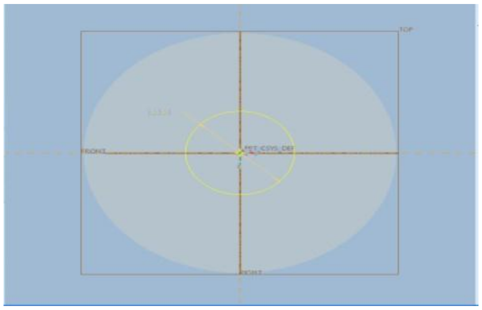


Fig3 :shows the drawing in sketcher in Pro–E

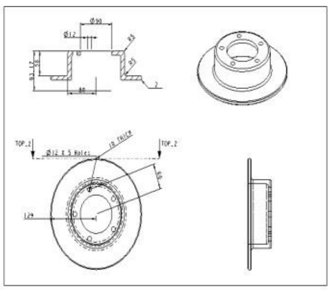


Fig 4 shows 2D drawing of disc brake

3.2 INTRODUCTION TO ANSYS:

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

3.3 Steps involved in ANSYS:

In general, a finite element solution can be broken into the following these categories.

1. Preprocessing module: Defining the problem The major steps in preprocessing are given below

- defining key points /lines/areas/volumes
- define element type and material /geometric /properties
- mesh lines/areas/volumes/are required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axis, symmetric)

2. Solution processor module: assigning the loads, constraints and solving. Here we specify the loads (point or pressure), constraints (translation, rotational) and finally solve the resulting set of equations.

3. Post processing module: further processing and viewing of results

In this stage we can see:

List of nodal displacement

Elements forces and moments

Deflection plots

Stress contour diagrams.

Table 1: Material Input Values of FGM 1 (Al_2O_3-Al):

1) For k = 2

Z	Young's modulus E (N/mm^2)	Density (Kg/mm^3)
+5	380000	3.96×10^{-6}
+4	321100	3.7206×10^{-6}
+3	268400	3.5064×10^{-6}
+2	221900	3.3174×10^{-6}
+1	181600	3.1536×10^{-6}
-1	119600	2.9016×10^{-6}
-2	97900	2.8134×10^{-6}
-3	82400	2.7504×10^{-6}
-4	73100	2.7126×10^{-6}
-5	70000	2.7×10^{-6}

Table 2, For k = 4

Z	Young's modulus E (N/mm^2)	Density (Kg/mm^3)
+5	380000	3.96×10^{-6}
+4	273391	3.526×10^{-6}
+3	196976	3.216×10^{-6}
+2	144431	3.0025×10^{-6}
+1	110176	2.863×10^{-6}
-1	77936	2.732×10^{-6}
-2	72511	2.710×10^{-6}
-3	70496	2.7020×10^{-6}
-4	70031	2.7012×10^{-6}
-5	70000	2.7×10^{-6}

Table 3, For k = 6

Z	Young's modulus E (N/mm²)	Density (Kg/mm³)
+5	380000	3.96×10^{-6}
+4	234746	3.3696×10^{-6}
+3	151251	3.0302×10^{-6}
+2	106456	2.8481×10^{-6}
+1	84446	2.7587×10^{-6}
-1	71269.76	2.70516×10^{-6}
-2	70225.99	2.70091×10^{-6}
-3	70019.84	2.70008×10^{-6}
-4	70000.31	2.700001×10^{-6}
-5	70000	2.7×10^{-6}

Table 4: Material Input Values of FGM 2 (Zr-Al): For k = 2

Z	Young's modulus E (N/mm²)	Density (Kg/mm³)
+5	151000	3×10^{-6}
+4	135610	2.943×10^{-6}
+3	121840	2.892×10^{-6}
+2	109690	2.847×10^{-6}
+1	99160	2.808×10^{-6}
-1	82960	2.748×10^{-6}
-2	77290	2.727×10^{-6}
-3	73240	2.712×10^{-6}
-4	70810	2.703×10^{-6}
-5	70000	2.7×10^{-6}

TABLE 5: For k = 4

Z	Young's modulus E (N/mm²)	Density (Kg/mm³)
+5	151000	3×10^{-6}
+4	123144	2.8968×10^{-6}
+3	103177	2.822×10^{-6}
+2	89448.1	2.772×10^{-6}
+1	80497.6	2.738×10^{-6}
-1	72073	2.7076×10^{-6}
-2	70656	2.7024×10^{-6}
-3	70129.6	2.70048×10^{-6}
-4	70008	2.7003×10^{-6}
-5	70000	2.7×10^{-6}

Table 6: For k = 6

Z	Young's modulus E (N/mm²)	Density (Kg/mm³)
+5	151000	3×10^{-6}
+4	113046.64	2.8594×10^{-6}
+3	91230.1	2.7786×10^{-6}
+2	79525.6	2.7352×10^{-6}
+1	73774.6	2.713×10^{-6}
-1	70331.776	2.7012×10^{-6}
-2	70059.049	2.70021×10^{-6}
-3	70005.184	2.70001×10^{-6}
-4	70000.081	2.7000×10^{-6}
-5	70000	2.7×10^{-6}

3.3 THERMAL ANALYSIS:

Table 7: Thermal Properties of FGM 1(Al_2O_3-Al):1) For k = 2

Z	Thermal Conductivity K (W/mm k)	Specific Heat C (J/Kg k)
+5	0.03	920
+4	0.0642	916.2
+3	0.0948	912.8
+2	0.1218	909.8
+1	0.1452	907.2
-1	0.1812	903.2
-2	0.1938	901.8
-3	0.2028	900.8
-4	0.2082	900.2
-5	0.21	900

Table 8: For k = 4

Z	Thermal Conductivity K (W/mm k)	Specific Heat C (J/Kg k)
+5	0.03	920
+4	0.091902	913.122
+3	0.1362	908.192
+2	0.16678	904.802
+1	0.186672	902.592
-1	0.2053	900.512
-2	0.20854	900.162
-3	0.209712	900.032
-4	0.209982	900.002
-5	0.21	900

IV STRESS AND THERMAL ANALYSIS FOR CAST IRON, FGM 1, FGM 2

4.1 STRUCTURAL ANALYSIS FOR CAST IRON: CAST IRON DISK BRAKE WITH 40 HOLES:

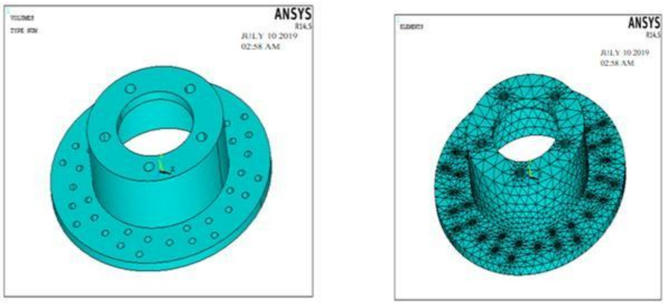


FIG5:CAST IRON DISK BRAKE & MESH OF CAST IRON DISK BRAKE WITH 40HOLES WITH 40 HOLES

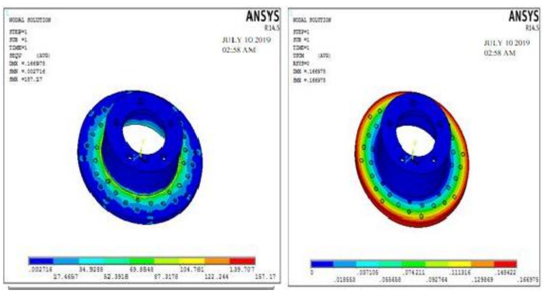


fig6: Displacement vector sum of cast iron& Vonmises stress of Cast Iron disc brake with 40 holes

4.2 Structural Analysis of FGM (Al_2O_3Al) Disk Brake with 40 holes for material variation parameter 'k'=2:

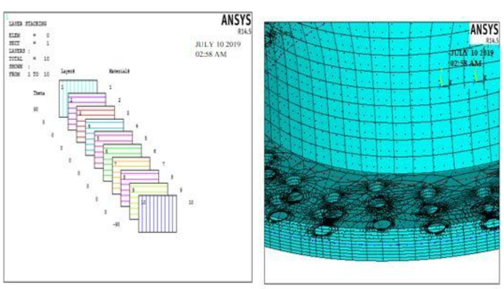
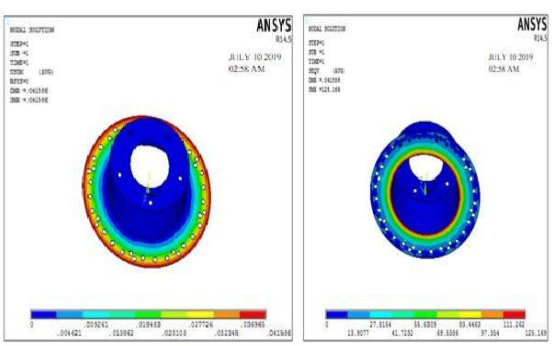


Fig 7:FGM 1 (Al_2O_3-Al) & showing the 10 layers of the FGM



e 9:

Fig 8:Displacement vector sum for FGM 1(Al_2O_3-Al) & Vonmises

Stress for FGM 1

4.3 STRUCTURAL ANALYSIS FOR FGM 2(Zr-Al):

Analysis of FGM 2 (Zr-Al) Disk Brake with 40 holes for material variation parameter 'k'=2:

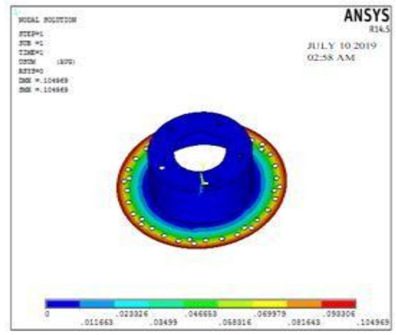


Fig 9: Displacement vector sum for FGM 2(Zr-Al)

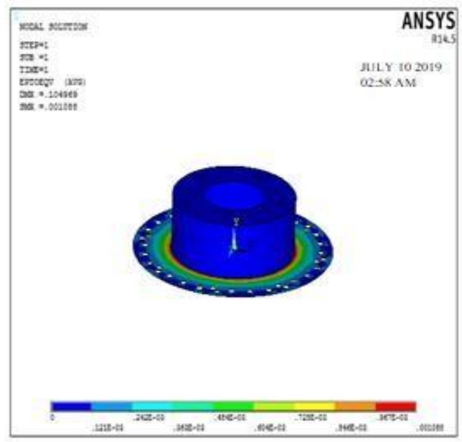


Fig 10 :Strain for FGM 2(Zr-Al)

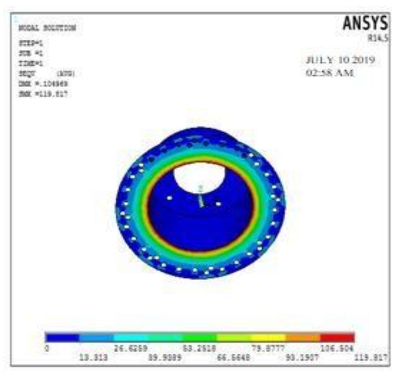


Fig 11:Vonmises stress for FGM 2 (Zr-Al)

Analysis results of Cast Iron Disk Brake:

Number of Holes	Displacement (mm)	Stress (N/mm^2)	Strain
40 Holes	0.521	157.17	0.675×10^{-3}
50 Holes	0.75	174.56	0.845×10^{-3}
60 Holes	0.88	182.56	0.902×10^{-3}

Table 10:

Analysis results of FGM 1 (Al_2O_3-Al):

i) For Material Variation Parameter k = 2

Number of Holes	Displacement (mm)	Stress (N/mm^2)	Strain
40	0.415	125.16	0.39×10^{-3}
50	0.734	162.24	0.83×10^{-3}
60	0.765	169.76	0.89×10^{-3}

Table 11:

ii) For Material Variation Parameter k = 4

Number of Holes	Displacement (mm)	Stress (N/mm^2)	Strain
40	0.77	169.59	0.92×10^{-3}
50	0.817	171.86	0.93×10^{-3}
60	0.835	174.45	0.95×10^{-3}

V RESULTS AND DISCUSSIONS

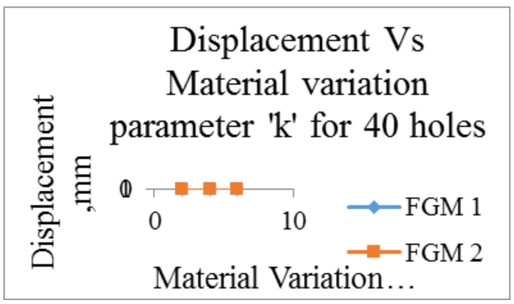


Fig 11 shows displacement Vs material variation parameter 'k' for 40 holes

5.1 Discussion for Displacement Vs material variation parameter 'k' for 40 holes:

- shows the variation of displacement with respect to material variation parameter 'k' for FGM 1 (Al O -

  Al) and FGM 2 (Zr-Al) with number of holes 40 for disc brake.
- It can be observed with increase in material variation parameter 'k', displacement increases largely for FGM 1 and nominally for FGM 2.
- As material variation parameter 'k' increases, the volume fraction of ceramic decreases leading to an increase in the volume fraction of metal. So the material brittleness decreases leading to an increase in the deflection.
- FGM's attain full metallic property with variation of 'k' from zero to infinity. Minimum to maximum k variations results in pure metallic behaviors there the above trend is justified when k =2 the displacement is low where as it is high when k =6.
- From the above graph it is observed that FGM 1 (Al_2O_3-Al) has shown higher displacement variations as compared to FGM 2 (Zr-Al). It can be predicted that FGM 1 (Al_2O_3-Al) has high modulus values as compared to FGM 2 (Zr-Al). Hence FGM 1 with high material variation parameter has shown higher displacement as compared to FGM 2 for the same value of k = 6.

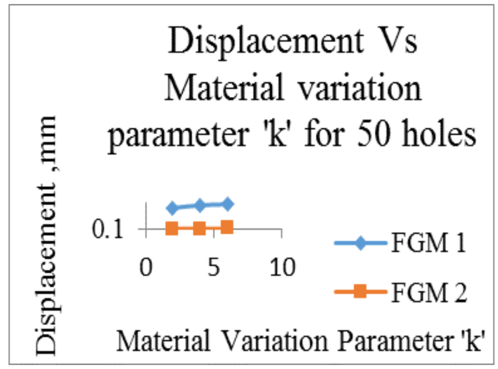


Fig 12 shows displacement Vs material variation parameter 'k' for 50 holes

5.2 Discussion for Displacement Vs material variation parameter 'k' for 50 holes:

- shows the variation of displacement with respect to material variation parameter 'k' for FGM 1 (Al_2O_3- Al) and FGM 2 (Zr-Al) with number of holes 50 for disc brake.
- It can be observed with increase in material variation parameter 'k', displacement increases largely for FGM 1 and nominally for FGM 2.
- As seen above the same trend is seen for disc brake with 50 holes. As explained earlier same discussion is applicable.

5.3 Discussion for Displacement Vs material variation parameter 'k' for 60 holes:

- shows the variation of displacement with respect to material variation parameter 'k' for FGM 1 (Al_2O_3- Al) and FGM 2 (Zr-Al) with number of holes 60 for disc brake.
- It can be observed with increase in material variation parameter 'k', displacement increases largely for FGM 1 and nominally for FGM 2.s explained earlier, same discussion is applicable for disk brake with 60 holes.

5.4 Discussion for Displacement Vs cast iron, FGM 1, FGM2:

• Fig 5.4 shows the comparison of displacement for 40, 50, 60 holes with respect to cast iron, FGM 1 (Al2O3-Al), FGM 2 (Zr-Al).

• It can be observed that higher number of holes resulted in higher displacement.

• As the number of holes increases the disk may become weak due to reduction in load bearing area hence resulted in higher displacement. This is true for all cases of materials.

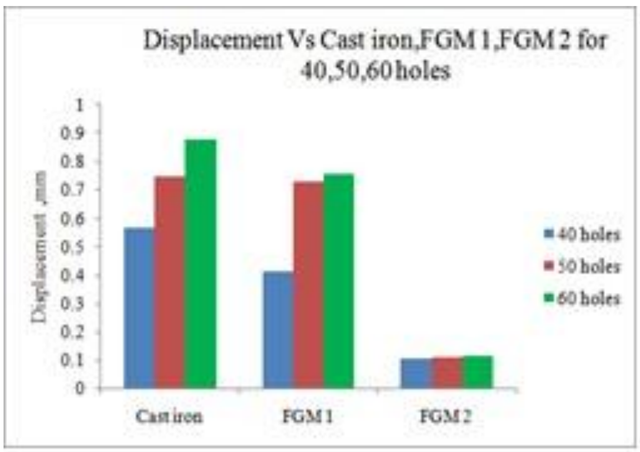


Fig 14 shows displacement Vs cast iron, FGM 1, FGM 2

5.5 Discussion for thermal flux Vs material variation parameter 'k' for 60 holes:

• shows the variation of thermal flux with respect to material variation parameter 'k' for disk brake with 60 holes.

• It is observed that with increase in material variation parameter 'k', thermal flux values are found to be increasing.

• It is true because as 'k' increases, the FGM'S attain near metallic properties, there by their behavior becomes more conductive. Hence, higher flux values have been observed for higher 'k' values.

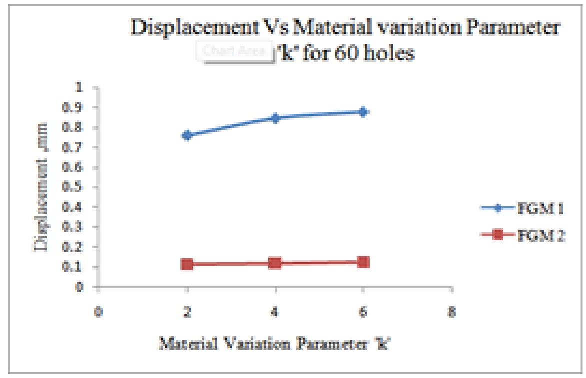


Fig 15: shows thermal flux Vs number of holes for cast iron,

VI CONCLUSIONS

- The proposed FGM 1 (Al_2O_3-Al) and FGM 2 (Zr-Al) are found to be superior as compared to cast iron from generated stress point of view.
- FGM 2 can be preferred over FGM 1 because of less stress generation.
- Increment in stress values has been observed with increasing material variation parameter 'k'.
- Higher is the number of holes, higher is the stress produced irrespective of materials i.e. Cast Iron, FGM 1, FGM 2.
- Higher displacement values and variation in displacement with increasing 'k' is superior for FGM 1(Al_2O_3-Al) as compared to FGM 2(Zr-Al).
- The proposed FGM 2 (Zr-Al) exhibited higher thermal flux values compared to FGM 1(Al_2O_3-Al), which is very much essential from heat dissipation point of view.

6.2 Scope For Future Work:

Analytically studies show that FGMs are better, but investigations are to be done experimentally for practical use of FGM as a material for disc brake.

REFERENCES:

[1] Reddy, J.N. ''Analysis of functionally graded plates'', International Journal for Numerical Methods in Engineering, 47, pp. 663–684 (2000).

[2] J.suresh kumar, ''Geometrically non linear analysis of functionally graded material plates using higher order theory'' Vol. 3, No. 1, 2011, pp. 279-288.

[3] Timoshenko, S.P. and Woinowsky-Krieger, S., Theory of Plates and Shells, McGraw-Hill, New York (1959).

[4] Koizumi, M. ''The concept of FGM'', Ceramic Transactions, Functionally Gradient Materials, 34, pp. 3–10 (1993).

[5] Birman V., Byrd L.W.. 2007. Modeling and analysis of functionally graded materials and structures, Applied Mechanics Reviews, Vol. 60, No. 5, pp.195-216.

[6] Matsunaga, H. 2009. Stress analysis of functionally graded plates subjected to thermal and mechanical loadings, Internatioal Journal of Composite Structures, Vol. 87, pp.344-357.

[7] Hirai, T. and Chen, L. ''Recent and prospective development of functionally graded materials in Japan'', Materials Science Forum, pp. 308–311 (1999).

[8] Şimşek, M. ''Fundamental frequency analysis of functionally graded beams by using different higher-order beam theories'', Nuclear Engineering and Design, 240, pp. 697–705 (2010).

[9] Thermal behavior of full and ventilated disc brakes of vehicles by A. Belhocine, M. Bouchetara.

[10] Modeling and Analysis of Functionally Graded Materials and Structures by Victor Birman and Larry W. Byrd.

[11] Stress and Temperature Distribution Study in a Functionally Graded Brake Disk by P. Hosseini Tehrani, M.Talebi.