

Design and Analysis of Disc Brake Using Functionally Graded Materials with Holes

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Abstract- A brake disk rotor forms a part of a foundation brake

and rotates with the wheel hub assembly. The main function of a foundation brake is to generate a retarding torque by converting mechanical energy to thermal energy by virtue of the frictional work done in relative sliding at the rotor-pad interface. Braking performance of a vehicle can be significantly affected by the temperature rise in the brake components.

A disc brake is analyzed for its strength and temperature distributions when subjected to internal pressure and temperature using functionally graded material. Two models of the disc brake are considered with and without holes. Comparison is done by varying materials with conventional materials and functionally graded materials, conventional materials are Cast Iron, Aluminum Alloy 6061. The Functionally Graded Material with metal Aluminum alloy 6061 using Ceramic as interface zone is taken for analysis. FGM's are considered for volume fraction of $K=2$. Theoretical calculations are done to calculate the material properties for each layer up to 10 layers. Structural and Thermal analysis are done on the model by varying materials. 3D modeling is to be done in Pro/Engineer and analysis is done in Ansys.

Keywords: Functionally graded materials; disc; Thermo elasticity; pressure; stress.

1. INTRODUCTION

The fortification in composites utilized as auxiliary materials in numerous aviation and vehicle applications is for the most part dispersed consistently. Practically reviewed materials

(FGMs) are being utilized as interfacial zone to enhance the holding quality of layered composites, to decrease the remaining and warm worries in fortified disparate materials and as wear safe layers in machine and motor segments. They have along these lines pulled in extensive consideration as of late.

One of the benefits of FGMs over overlays is that there is no pressure develops at sharp material limits because of consistent material property variety to dispose of potential basic uprightness, for example, delamination.

Analysis of a pivoting plate is an imperative subject because of the extensive variety of utilizations in mechanical designing. A logical arrangement to discover the worries in

anisotropic pivoting circle under mechanical or warm loads

can be found in writing (Timoshenko and Goodier 1951). A

few investigations that arrangement with fiber strengthened composite circles have additionally been found in the writing. Zenkour (2006) has introduced precise versatile answers for the pivoting variable thickness as well as uniform thickness orthotropic roundabout chambers. Çallıoğlu (2004, 2007) has explored the weights on pivoting rectilinearly or polar orthotropic circles subjected to different temperature circulations. Sayman and Arman (2006) have done an elastic–plastic pressure analysis in a thermoplastic composite plate fortified by steel strands curvilinear under unfaltering state temperature dissemination.

Albeit a great part of the work on FGMs has been done numerically, the mechanical and scientific displaying of FGMs is presently a dynamic research territory. Durodola and Attia (2000) have examined twisting and worries in practically reviewed turning plates by utilizing limited component technique and direct numerical coordination of

administering differential conditions. Chen et al (2007) have exhibited three dimensional systematic answers for a pivoting circle made of transversely isotropic practically reviewed materials. Mohammadi and Dryden (2008) have inspected the part of non homogeneous firmness on the thermo elastic stretch field. Tutuncu (2007) has acquired power arrangement answers for stresses and removals in practically reviewed barrel shaped vessels subjected to interior weight by utilizing the little twisting hypothesis. You et al (2007) have examined the weights on the FG pivoting roundabout circles under uniform temperature. Çallıoğlu (2008) has contemplated the pressure analysis of the pivoting empty plates made of capacity partner evaluated

materials under inner and outer weights. Bayat et al (2009) have introduced thermo elastic arrangements in a turning practically reviewed (FG) plate with variable thickness under a consistent temperature field. Kordkheili and Naghdabadi (2007) have researched a semi-scientific thermo elasticity answer for empty and strong pivoting axisymmetric circles made of FGMs. Sugano et al (2004) have introduced a strategy for material outline for the weight decrease, the high warm radiation and the unwinding of fin-
planewarm pressure and divergent worry in a turning plate without opening made out of FGMs with subjective warm and mechanical non homogeneity the outspread way. Liew

et al (2003) have built up a diagnostic model for the thermo mechanical conduct of FG empty roundabout barrel that are

subjected to the activity of a self-assertive unfaltering state or transient temperature field.

The objective of the examination is to explore the relative impacts of fundamental factors, for example, property degree, inner weight, outer weight, outward body stacking and warm stacking on stresses and relocation in a FG empty circle. Therefore, the balance conditions, which depend on the thermo elasticity hypothesis with microscopic misshapening, are determined, by utilizing power law capacities for variety of the material properties.

Introduction to CAD

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design documentation. Computer Aided Drafting describes the process of drafting with a computer.

CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes.

CADD output is often in the form of electronic files for print

or machining operations. The design of geometric models for object shapes, in particular, is often called computer-

aided geometric design (CAGD).

DESIGNINPRO-ENGINEER

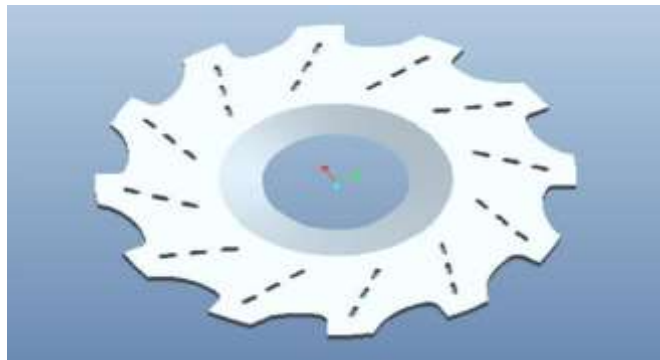
Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Customer requirements may change and time pressures may continue to mount, but your product design needs remain the same - regardless of your project's scope, you need the powerful easy-to-use, affordable solution that Pro/ENGINEER provides.

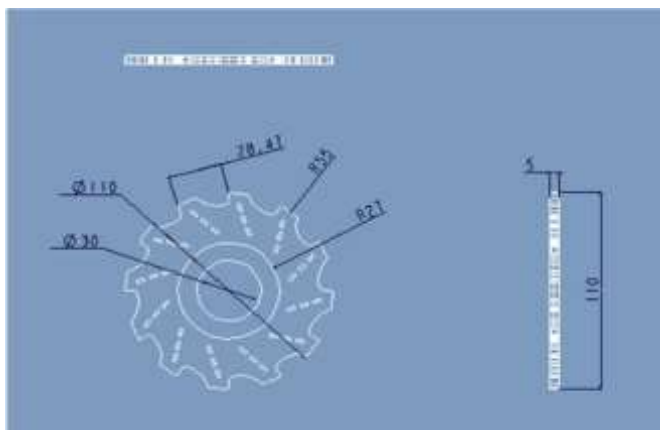
Different Modules in PRO/ENGINEER

- PART DESIGN
- ASSEMBLY
- DRAWING
- SHEET METAL

Model of Disc Brake



2D Drawing of Disc Brake



Structural Analysis:

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

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.

Steps involved in ANSYS:

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

Preprocessing module: Defining the problem

The major steps in preprocessing are given below

- defining keypoints/lines/areas/volumes
- define element type and material/geometric/properties
- mesh lines/areas/volumes as required

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

Solution process 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.

Postprocessing module: further processing and viewing of results in this stage we can see:

1. List of nodal displacement
2. Elements forces and moments Deflection plots, Stress contour diagrams

In addition to the above analysis types, several special-purpose features are available:

Fracture mechanics

- Composites
- Fatigue
- p-Method
- Beam Analyses

MATERIAL PROPERTY CALCULATIONS FOR FGM (K=2)

For structural analysis Material properties

Top material: ceramic (E=380000) Bottom material: aluminium (E=70000) For Young's Modulus:

1) Fork=2; z=1

$$E(Z) = (E_t - E_b)(z/h + 1/2)^K + E_b \quad E(Z) = (380000 - 70000)(1/10 + 1/2)^2 + 70000 \quad E(Z) = (310000)$$

$$(0.36) + 70000 \quad E(Z) = 181600$$

2) Fork=2; z=-1

$$E(Z) = (E_t - E_b)(z/h + 1/2)^K + E_b$$

$$E(Z) = (380000 - 70000)(-1/10 + 1/2)^2 + 70000 \quad E(Z) = 310000 (0.16) + 70000$$

$$E(Z) = 119600$$

Above Same Procedure Is Repeated Fork=2; and Z=2,3,4,5, -2, -3, -4, -5.

FORDENSITIES:

Material Properties are Ceramic ($\rho_t = 0.00000396$) Aluminium ($\rho_b = 0.0000027$)

1) Fork=2; z=1

$$\rho(Z) = (\rho_t - \rho_b)(z/h + 1/2)^K + \rho_b$$

$$= (0.00000396 - 0.0000027)(1/10 + 1/2)^2 + 0.0000027$$

$$= 0.00000315$$

2) Fork=2; z=-1

$$\rho(Z) = (\rho_t - \rho_b)(z/h + 1/2)^K + \rho_b$$

$$= (0.00000396 - 0.0000027)(-1/10 + 1/2)^2 + 0.0000027$$

$$= 0.0000029016$$

AboveSameProcedureIsRepeatedFork=2;andZ=2,3,4,5,- 2,-3,-4,-5.

FORTH THERMAL CONDUCTIVITY:

Material properties:

Top material: ceramic (K=0.4498) Bottom material: aluminium (K=0.18)

1) Fork=2; z=1

$$K(Z) = (K_t - K_b)(z/h + 1/2)^K + K_b$$

$$K(Z) = (0.4498 - 0.18)(1/10 + 1/2)^2 + 0.18 \quad K(Z) = 0.2698 (0.36) + 0.18$$

$$K(Z) = 0.27712$$

2) Fork=2; z=-1

$$K(Z) = (K_t - K_b)(z/h + 1/2)^K + K_b$$

$$K(Z) = (0.4498 - 0.18)(-1/10 + 1/2)^2 + 0.18$$

$$K(Z) = 0.2698 (0.16) + 0.18$$

$$K(Z) = 0.22316$$

AboveSameProcedureIsRepeatedFork=2;andZ=2,3,4,5,- 2,-3,-4,-5.

FORSPECIFIC HEAT:

Material properties:

Top material: ceramic (C=920) Bottom material: aluminium (C=896)

1) Fork=2; z=1

$$C(Z) = (C_t - C_b)(z/h + 1/2)^K + C_b$$

$$C(Z) = (920 - 896)(1/10 + 1/2)^2 + 896 \quad C(Z) = 904.64$$

2) Fork=2; z=-1

$$C(Z) = (C_t - C_b)(z/h + 1/2)^K + C_b$$

$$C(Z) = (920 - 896)(-1/10 + 1/2)^2 + 896 \quad C(Z) = 899.84$$

AboveSameProcedureIsRepeatedFork=2;andZ=2,3,4,5,- 2,-3,-4,-5.

Structural Analysis OF Disc Brake Used Materials

1. ALUMINUM 6061

Density=0.0000027 kg/mm³ Thermal conductivity=18 W/m-K Young's modulus=68900 MPa

Poisson's ratio=0.33

2. CAST IRON

Density=0.0000071 kg/mm³ Thermal conductivity =50 W/m-k Young's modulus=103000 N/mm²

Poisson's ratio=: 0.211

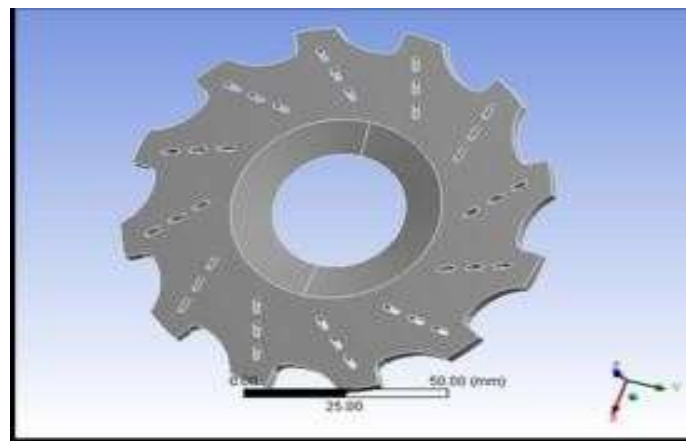
Openansys workbench 14.5 > select engineering data > right

click on it > select edit > enter material properties of required material

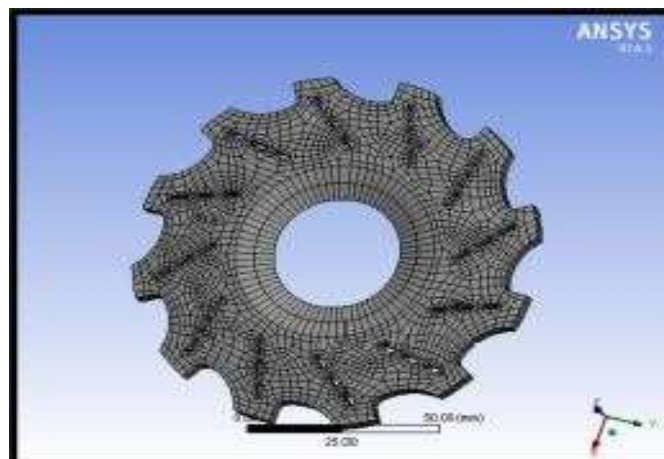
Outline of Schematic A2: Engineering Data				
	A	B	C	D
1	Contents of Engineering Data		source	Description
2	Material			
3	aluminum6061			Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
4	cast iron			
*	Click here to add a new material			

Properties of Outline Row 3: aluminum6061				
	A	B	C	D
1	Property	Value	Unit	
2	Density	2.77E-06	kg mm ⁻³	
3	Isotropic Secant Coefficient of Thermal Expansion			
6	Isotropic Elasticity			
7	Derive from	Young's ...		
8	Young's Modulus	6890	MPa	
9	Poisson's Ratio	0.33		
10	Bulk Modulus	6.7549E+09	Pa	
11	Shear Modulus	2.5902E+09	Pa	

Selectstaticstructural>doubleclickonit>selectgeometry>rightclickonit>selectimportgeometry>selectIGESfile
>openImportedmodel



Selectmodel>rightclickonit>selectedit>selectmesh>right click on it > select generate mesh
Meshedmodel



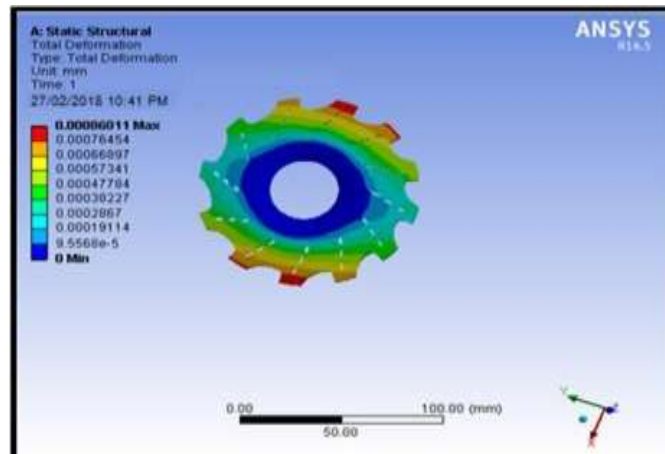
Selectstaticstructural>rightclickonit>selectinsert>select displacement>selectrequiredareaonthe component>ok,

selectforce>selectdirectionofforce>enterforcevalue (1000N) ok.

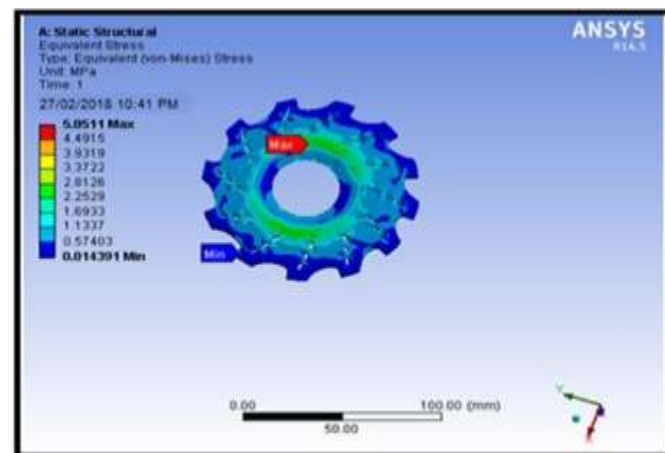
Selectsolution>rightclick>selectinsert>selecttotal deformation, equivalent stress & strain.

Selectstaticstructural>rightclickonit>selectsolve MATERIAL- ALUMINUM6061

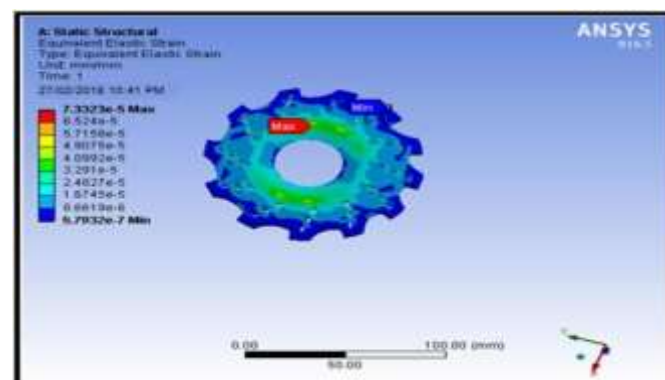
TotalDeformation



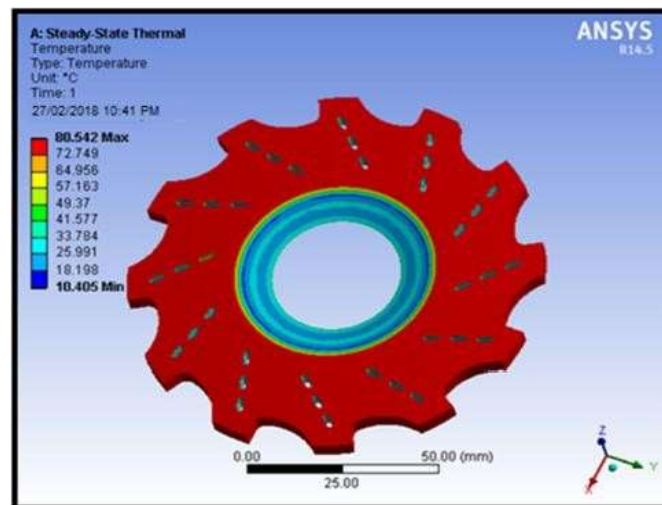
EquivalentStress



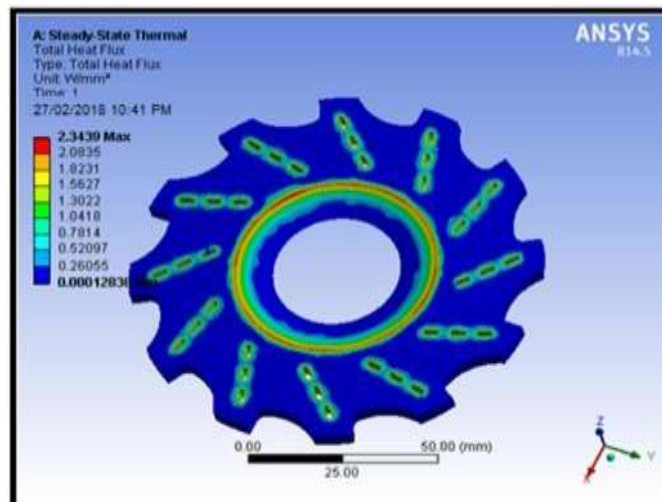
Strain



Temperature



Heatflux



Definition of Results obtained

Displacement-A vector quantity which refers to the distance which an object has moved in a given direction. It is measured as the length of a straight line between the initial and final positions of a body.

Von Mises Stress-The Von Mises criteria is a formula for combining these 3 stresses into an equivalent stress, which is then compared to the tensile stress of the material.

Nodal Temperature-A temperature can be applied to nodes, surfaces, or parts in a model. A surface temperature applies nodal temperature to each node on the surface, and a part temperature applies nodal temperature to each node in the part.

Thermal Gradient - A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location.

Thermal flux - Heat flux or thermal flux is the rate of heat energy transfer through a given surface.

RESULTS:

Table-1:StructuralResult

MATERIAL	DISPLACEMENT (mm)	STRESS (N/mm ²)	STRAIN
AL-6061	0.017289	104.821	0.153E-03
CASTIRON	0.068932	106.061	0.598E-03

Table-2:Structurallinearlayeranalysisresults

	RESULTS		
	DISPLACEMENT(mm)	STRESS (N/mm ²)	STRAIN
K=2	0.1598258	150.074	0.001091

Table-3:ThermalResults(AtTemperatureof393K)

MATERIAL	NODAL TEMPERATURE(K)	THERMAL FLUX (W/mm ²)
AL-6061	393	55.2384
CASTIRON	393	21.0567

Table-4:ResultsofFGMwithholes

MATERIAL	TEMPERATURES(K)	RESULTS	
		NODAL TEMPERATURE(K)	HEAT FLUX (W/mm ²)
K=2	393K	392.688	14.953

CONCLUSION

In this thesis, a disc brake is designed in 3D modeling software Pro/Engineer. The design is changed by specifying holes on the disc brake. In this thesis, comparison is done by varying materials for disc brake, the materials are Cast Iron, Aluminum Alloy 6061, Composite material Kevlar fiber and the Functionally Graded Material with metal Aluminum alloy 6061 using Ceramic as interface zone is also taken for analysis.

By observing the structural analysis results, the stresses and displacements are less for Functionally Graded Material, so it is safe to use FGM and the stresses are less for the disc brake without hole at volume fraction $K=4$.

By observing the thermal analysis results, the heat transfer rate is more for disc brake with holes than without holes since thermal flux is more. Using FGM with volume fraction of $K=2$ is better since heat transfer rate is more.

So it can be concluded that using FGM with volume fraction of $K=2$ for disc brake is better with holes since the stresses are within the permissible limit and more heat transfer rate.

FUTURE SCOPE:

Analytically using FGM is better, but investigations are to be done experimentally for better use of FGM for disc brake.

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