DESIGN AND ANALYSIS OF DISC BRAKE USING FUNCTIONALLY GRADED MATERIALS WITH HOLES

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Abstract - *A brake disk rotor forms pan 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 without holes and with 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 fractions 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.

Key Words: **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 an isotropic 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. Çallıoglu (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. Çallıoglu (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 in-plane warm pressure and divergent worry in a turning plate without opening made out of FGMs with subjective warm and mechanical non homogeneities the outspread way. Liew et al(2003) have built up a diagnostic model for the thermo mechanical conduct of FG empty roundabout barrels 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).

DESIGN IN PRO-ENGINEER

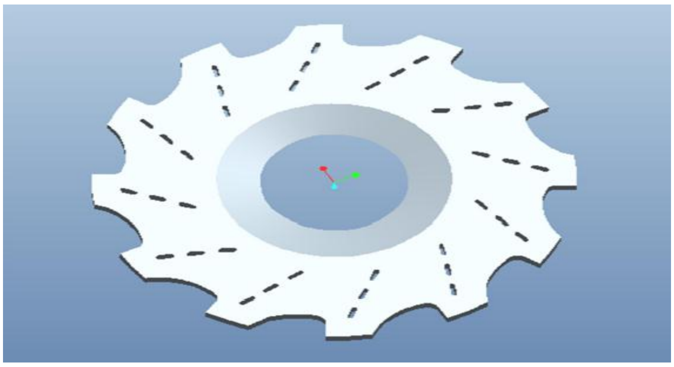
Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while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

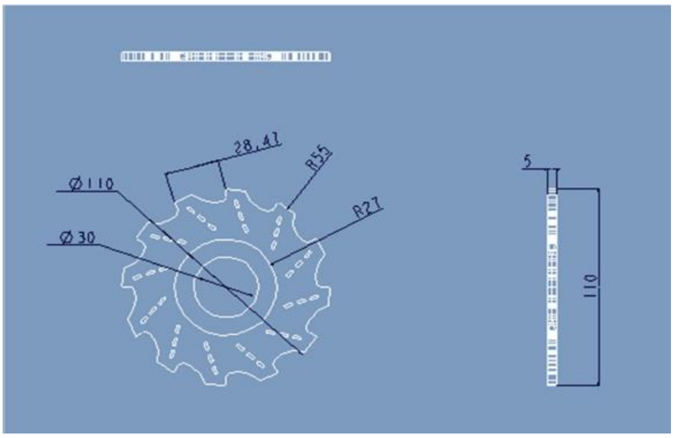
Different Modules in PRO/ENGINEER

- PART DESIGN
- ASSEMBLY
- DRAWING
- SHEETMETAL

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 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).

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.

Post processing 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) For k=2; z=1

$E(Z)=(Et-Eb)(z/h+1/2)^K+Eb$

$E(Z)=(380000-70000)(1/10+1/2)^2+70000$

$E(Z)=(310000)\ (0.36)+70000$

$E(Z)=181600$

2) For k=2; z=-1

$E(Z)=(Et-Eb)\ (z/h+1/2)^K+Eb$

$E(Z)=(380000-70000)(-1/10+1/2)^2+70000$

$E(Z)=310000\ (0.16)+70000$

$E(Z)=119600$

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

FOR DENSITIES:

Material Properties are

Ceramic (ρt=0.00000396)

Aluminium (ρb=0.0000027)

1) For k=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) For k=2; z= -1

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

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

$=0.0000029016$

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

FOR THERMAL CONDUCTIVITY:

Material properties:

Top material: ceramic (K=0.4498)

Bottom material: aluminium (K=0.18)

1) For k=2; z=1

$K\ (Z) = (Kt-Kb)\ (z/h+1/2)^K+Kb$

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

$K\ (Z) =0.2698\ (0.36) +0.18$

$K\ (Z) =0.27712$

2) For k=2; z=-1

$K\ (Z) = (Kt-Kb)\ (z/h+1/2)^K+Kb$

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

K (Z) =0.2698 (0.16) +0.18

K (Z) =0.22316

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

FOR SPECIFIC HEAT:

Material properties:

Top material: ceramic (C=920)

Bottom material: aluminium(C=896)

1) For k=2; z=1

C (Z) = (Ct-Cb) $(z/h+1/2)^{K}$+Cb

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

C (Z) = 904.64

2) For k=2; z= -1

C (Z) = (Ct-Cb)$(z/h+1/2)^{K}$+Cb

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

C (Z) =899.84

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

Structural Analysis OF Disc Brake

Used Materials

1. ALUMINUM 6061

Density=0.0000027kg/mm3

Thermal conductivity=18W/m-K

Young's modulus=68900MPa

Poisson's ratio=0.33

2. CAST IRON

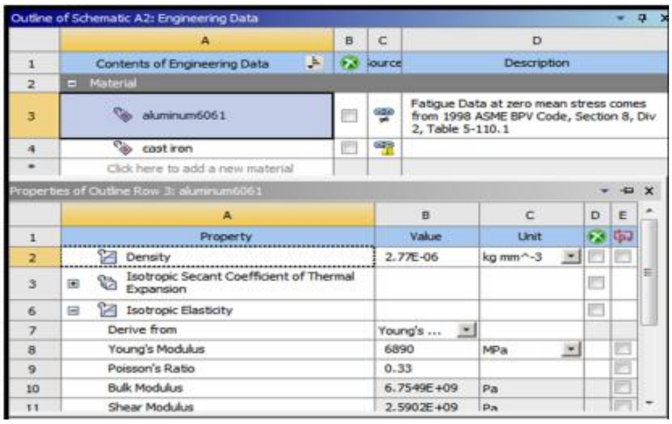
Density=0.0000071 kg/mm3

Thermal conductivity =50w/m-k

Young's modulus=103000N/mm2

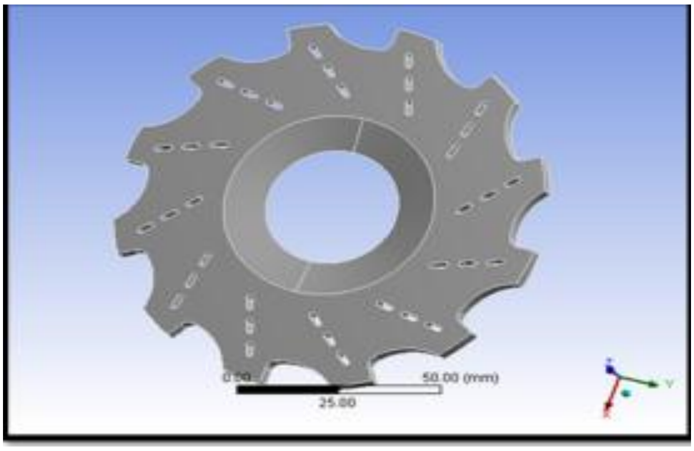
Poisson's ratio=: 0.211

Open ansys workbench 14.5>select engineering data>right click on it >select edit> enter material properties of required material



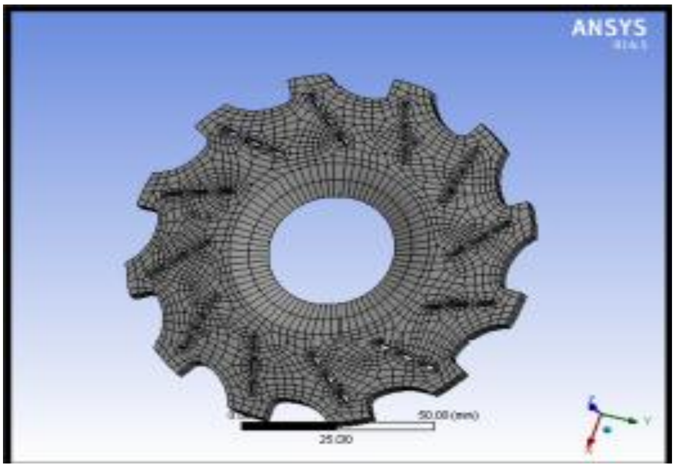
Select static structural >double click on it> select geometry> right click on it>select import geometry> select IGES file >open

Imported model



Select model> right click on it>select edit>select mesh >right click on it > select generate mesh

Meshed model



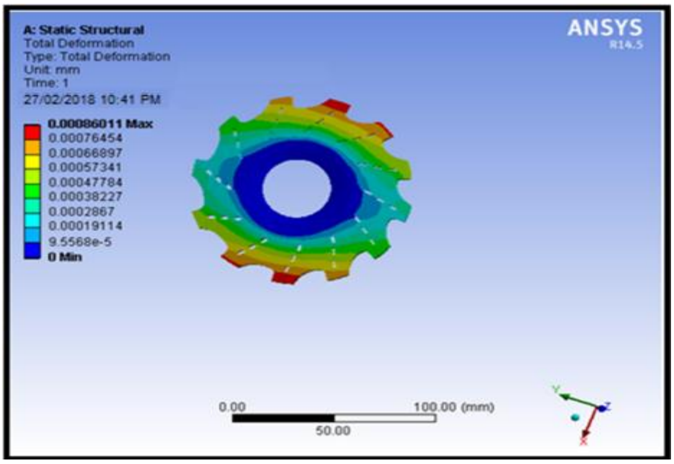
Select static structural >right click on it >select insert> select displacement> select required area on the component>ok, select force >select direction of force > enter force value (1000N) ok.

Select solution> right click>select insert > select total deformation, equivalent stress & strain.

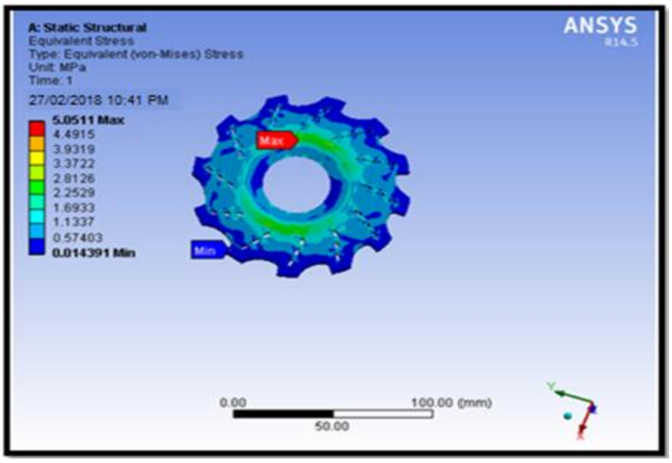
Select static structural> right click on it >select solve

MATERIAL- ALUMINUM6061

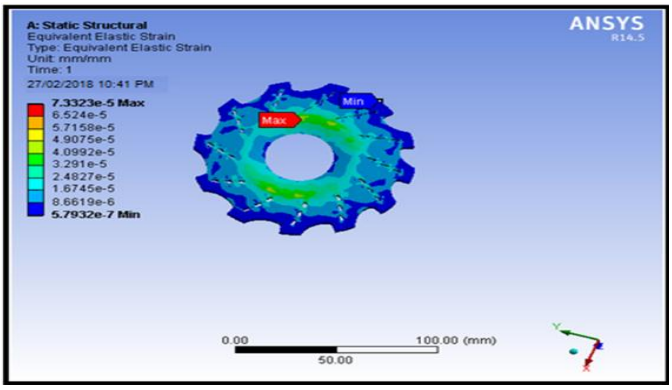
Total Deformation



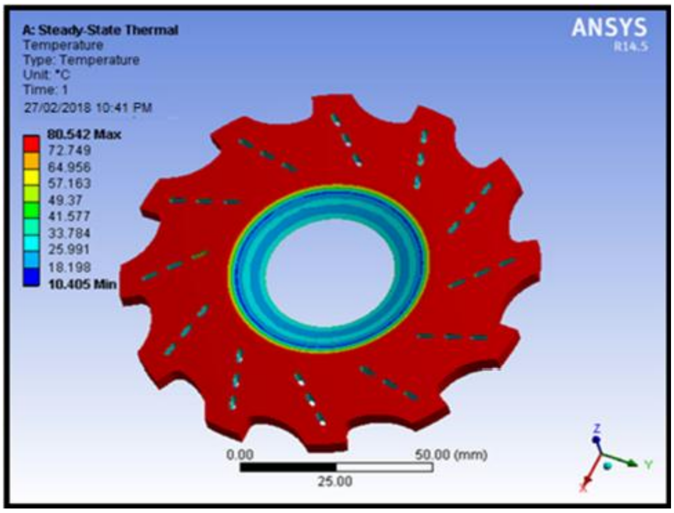
Equivalent Stress



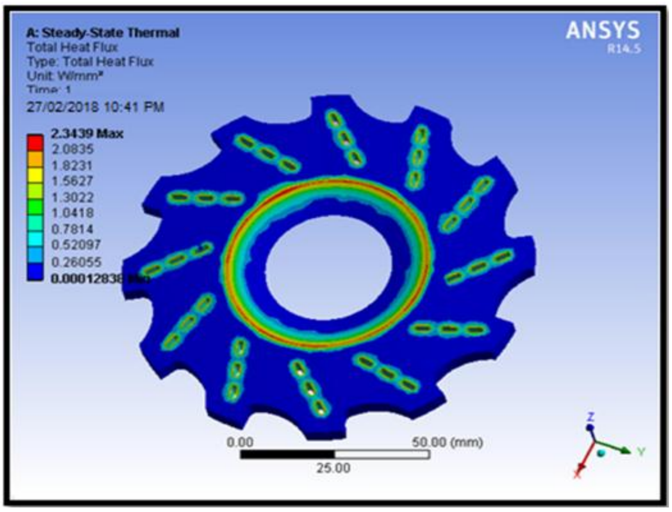
Strain



Temperature



Heat flux



Definitions 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 Misses Stress - The Von Misses 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 temperatures to each node on the surface, and a part temperature applies nodal temperatures 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: Structural Results

MATERIAL	DISPLACEMENT (mm)	STRESS (N/mm2)	STRAIN
AL-6061	0.017289	104.821	0.153E-03
CAST IRON	0.068932	106.061	0.598E-03

Table -2: Structural linear layer analysis results

	RESULTS		
	DISPLACEMENT (mm)	STRESS (N/mm2)	STRAIN
K=2	0.1598258	150.074	0.001091

Table -3: Thermal Results (At Temperature of 393K)

MATERIAL	NODAL TEMPERATURE (K)	THERMAL FLUX (W/mm2)
AL-6061	393	55.2384
CAST IRON	393	21.0567

Table -4: Results of FGM with holes

MATERIAL	TEMPERATURES(K)	RESULTS	
		NODAL TEMPERATURE (K)	HEAT FLUX (W/mm2)
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.

REFERENCES

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

2. Research of the Transient Temperature Field and Friction Properties on Disc Brakes by Zhang Jian, Xia Changgao

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

4. Temperature in a disk brake, simulation and xperimental verification by Leszek Wawrzonek,

5. Modeling and Analysis of Functionally Graded Materials and Structures by Victor Birman and Larry W. Byrd

6. Finite Element Analysis of Themalelastic Instability of Disc Brakes by S.P. Jung, T. W. Park, J H Lee, W H Kim, W. S. Chung

7. Hosseini Kordkheili, S. A. and R. Naghdabadi. " Thermoelastic analysis of a functionally graded rotating disk," .

8. Zagrodzki P., "Thermoelastic instability in friction clutches and brakes modal analysis revealing mechanisms of excitation of unstable modes. "

9. Zhu ZC, Peng UX, Shi ZY, Chen GA. "Three-dimensional transient temperature field of brake shoe during hoist's emergency braking."

10. Voldrich J.," Frictionally excited thermoelastic instability in disc breaks—transient problem in the full contact regime."