International Journal of Mechanical and Industrial Engineering

Volume 2 | Issue 2 Article 12

October 2012

Transient Analysis of Disk Brake By using Ansys Software

G. Babukanth
Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada, babukanthg@gmail.com

M. Vimal Teja
Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada, M.VimalTeja@gmail.com

Recommended Citation

Babukanth, G. and Teja, M. Vimal (2012) "Transient Analysis of Disk Brake By using Ansys Software," *International Journal of Mechanical and Industrial Engineering*: Vol. 2 : Iss. 2 , Article 12.
DOI: 10.47893/IJMIE.2012.1082
Available at: https://www.interscience.in/ijmie/vol2/iss2/12

Transient Analysis of Disk Brake By using Ansys Software

G. Babukanth & M. Vimal Teja
Department of Mechanical Engineering,
Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada
E-mail : babukanthg@gmail.com,

***Abstract* -** In this paper the thermo elastic phenomenon occurring in the disk brakes, the occupied heat conduction and elastic equations are solved with contact problems. The numerical simulation for the thermo elastic behavior of disk brake is obtained in the repeated brake condition.

The computational results are presented for the distribution of heat flux and temperature on each friction surface between the contacting bodies. Also, thermo elastic instability (TIE) phenomenon (the unstable growth of contact pressure and temperature) is investigated in the present study, and the influence of the material properties on the thermo elastic behaviors (the maximum temperature on the friction surfaces) is investigated to facilitate the conceptual design of the disk brake system. Based on these numerical results, the thermo elastic behaviors of the carbon-carbon composites with excellent mechanical properties are also discussed.

Keywords: *Disk Brake, Cast iron, Heat Flux, Thermal Conductivity, FEA, ANSYS*

I. INTRODUCTION

A disk brake consists of a cast iron disk bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disk there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. The passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston. A schematic diagram is shown in the figure 1.1.

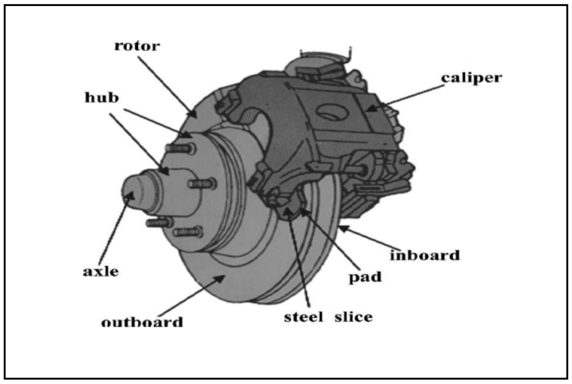


Figure 1 Disk Break Model

When the brakes are applied, hydraulically actuated pistons move the friction pads in to contact with the rotating disk, applying equal and opposite forces on the disk. Due to the friction in between disk and pad surfaces, the kinetic energy of the rotating wheel is converted into heat, by which vehicle is to stop after a certain distance. On releasing the brakes the brakes the rubber-sealing ring acts as return spring and retract the pistons and the friction pads away from the disk.

In the course of brake operation, frictional heat is dissipated mostly into pads and a disk, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disk.

The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. At other times, however, the stable evolution behavior of the sliding system crosses a threshold whereupon a sudden change of contact conditions occurs as the result of instability. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating as the result of the pressure increase. When this process leads to an accelerated change of contact pressure distribution, the unexpected hot roughness of thermal distortion may grow unstably under some conditions, resulting in local hot spots and leaving thermal cracks on the disk.

This is known as thermo elastic instability (TEI).The thermo elastic instability phenomenon occurs more easily as the rotating speed of the disk increases. This region where the contact load is concentrated reaches very high temperatures, which cause deterioration in braking performance. Moreover, in the course of their presence on the disk, the passage of thermally distorted hot spots moving under the brake pads causes low-frequency brake vibration.

The present investigation is aimed to study the given disk brake rotor of its stability and rigidity (for this Thermal analysis and coupled structural analysis is carried out on a given disk brake rotor and to investigate best combination of parameters of disk brake rotor like Flange width, Wall thickness and material there by a best combination is suggested.

II. RELATED WORK

S. V. Tsinopoulos et al [4] an advanced boundary element method was appropriately combined with the fast Fourier transform (FFT) to analyze general axis-symmetric problems in frequency domain elastodynamics. The problems were characterized by axis-symmetric geometry and non-axis-symmetric boundary conditions. Boundary quantities were expanded in complex Fourier series in the circumferential direction and the problem was efficiently decomposed into a series of problems, which were solved by the BEM for the Fourier boundary quantities, discretizing only the surface generator of the axis-symmetric body. Quadratic boundary elements were used and BEM integrations were done by FFT algorithm in the circumferential direction and by Gauss quadrature in the generator direction. Singular integrals were evaluated directly in a highly accurate way. The Fourier transformed solution was then numerically inverted by the FFT, provided the final solution. The method combines high accuracy and efficiency and this was demonstrated by illustrative numerical examples.

A. Floquet et al [6] determined of temperature distribution and comparison of simulation results and experimental results in the disc by 2D thermal analysis using axis-symmetric model.

The disc brake used in the automobile is divided into two parts; a rotating axis-symmetrical disc, and the stationary pads. The friction heat, which is generated on the interface of the disc and pads, can cause high temperature during the braking process. The influence of initial velocity and deceleration on cooling of the brake disc was also investigated. The thermal simulation is used to characterize the temperature field of the disc with appropriate boundary conditions.

A Finite-element method was developed for determining the critical sliding speed for thermo elastic instability of an axis-symmetric clutch or brake. Linear perturbations on the constant-speed solution were sought that vary sinusoidally in the circumferential direction and grow exponentially in time.

These factors cancel in the governing thermo elastic and heat-conduction equations, leading to a linear Eigen value problem on the two-dimensional cross-sectional domain for the exponential growth rate for each Fourier wave number. The imaginary part of this growth rate corresponds to a migration of the perturbation in the circumferential direction.

The algorithm was tested against an analytical solution for a layer sliding between two half-planes and provided excellent agreement, for both the critical speed and the ,migration speed. Criteria were developed to determine the mesh re-finement required to give an adequate discrete description of the thermal boundary layer adjacent to the sliding interface.

The method was then used to determine the unstable mode and critical speed in geometries approximating current multi-disc clutch practice.

A. E. Enderson et al [8] investigated the hot spotting in automotive friction system. When sliding occurs with significant frictional heating, thermo elastic deformation may lead to a transition from smoothly distributed asperity contact to a condition where the surfaces are supported by a few thermal asperities. This circumstance may be associated with a transition to a condition of severe wear because of the elevated contact pressure and temperature, and also because of production of tensile stresses. This second stress component may lead to heat checking whereupon the rough checked surface acts to abrade the mating material.

III. AXIS-SYMMETRIC ANALYSIS

Due to the application of brakes on the car disk brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disk rotor cross section. The condition of braking is very much severe and thus the thermal analysis has to be carried out.

The thermal loading as well as structure is axis-symmetric. Hence axis-symmetric analysis can be performed, but in this study we performed 3-D analysis, which is an exact representation for this thermal analysis. Thermal analysis is carried out and with the above load structural analysis is also performed for analyzing the stability of the structure.

The dimensions of brake disk used for transient thermal and static structural analysis are shown in Fig.2

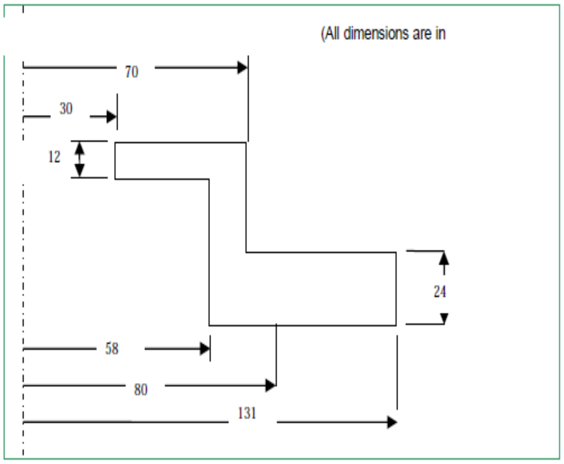


Figure 2 Dimensions of 24mm Disk Brake

According to given specifications the element type chosen is solid 90.Solid 90 is higher order version of the 3-D eight node thermal element (Solid 70). The element has 20 nodes with single degree of freedom, temperature, at each node. The 20-node elements have compatible temperature shape and are well suited to model curved boundaries. The 20-node thermal element is applicable to a 3-D, steady state or transient thermal analysis.

If the model containing this element is also to be analyzed structurally, the element should be replaced by the equivalent structural element (Solid 95).

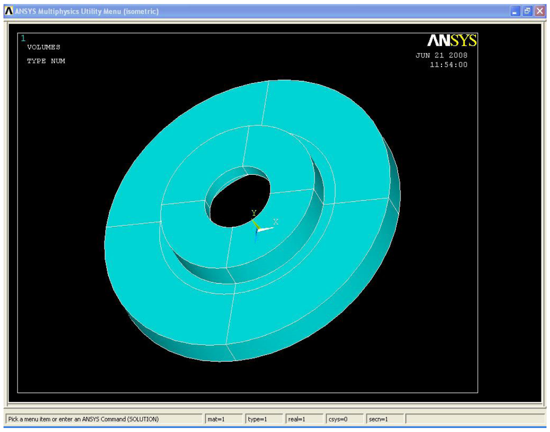


Figure 3 Model of 24mm Disk brake

As shown in Fig. 4 a model presents a three dimensional solid disk squeezed by two finite-width friction material called pads. The entire surface, S, of the disk has three different regions including S1 and S2. On S1 heat flux is specified due to the frictional heating between the pads and disk, and S2 is defined for the convection boundary. The rest of the region, except S1 U S2, is either temperature specified or assumed to be insulated: the inner and outer rim area of disk.

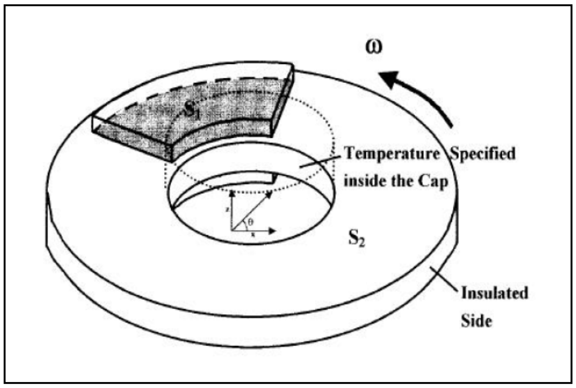


Figure 4 Thermal model

In the contact region S1, the local shear traction cause frictional heating that flows into the disk and pads. Heat flux q on a contact area is updated per the pressure distribution at every simulation step

$$q = \mu * V * p = \mu * \omega * r * P$$

Where μ is the coefficient of friction, V the sliding speed, P the contact pressure, and ù is used for angular velocity.

In the solution procedure, frontal solver is used. It involves two steps. After the individual element matrices are calculated, the solver reads in the degree of freedom (DOF) for the first element.

The program eliminates any degrees of freedom that can be expressed in terms of the other DOF by writing an equation to the .TRI file. This process repeats for all the elements until all the degree of freedom have been eliminated and a complete triangular zed matrix is left on the .TRI file.

The term frequently used is the frontal solver is wave front. The wave front is the number of degrees of freedom retained by the solver while triangularization of the matrix.The nodal solution plots of temperature distribution in thermal analysis. Graph of the temperature variation with respect to the radial distance from the point of application of the heat flux. Graph of the temperature variation with respect to the time. The nodal solution plot of Stress distribution in structural analysis.

IV. MATERIAL INTRODUCTION

Comparison of transient results with the steady state solution of thermo elastic behaviors was performed for the operation condition of the constant hydraulic pressure P =1Mpa and angular velocity ù = 50 rad/s (drag brake application) during 10 seconds. If the transient solution for this operation condition converges to the steady solution as time elapse, it can be regarded as validation of the applied transient scheme. The thermal boundary conditions used are adiabatic on the boundary of the inner and outer radius and the prescribed temperature condition T = 20°C on the both boundaries along the radius of the lower and upper pad by assumption of the cooling state. The material properties and operation conditions used for the validation of the transient thermo elastic scheme are given in Table below. The time step Δt =0005 sec. was used.

Material Properties	**Pad and Disk**
Thermal conductivity, K (w/m k)	50
Density, ρ (kg/m3)	1800
Specific heat , c (J/Kg k)	1.88
Poisson's ratio, v	0.3
Thermal expansion , α $(10^{-6}/k)$	0.3
Elastic modulus, *E* (GPa)	50.2
Coefficient of friction, μ	0.2
Operation Conditions	
Angular velocity, ω (rad/s)	50
Hydraulic pressure, *P* (Mpa)	1

The heat flux distribution on the friction surfaces for the steady and transient (at t=10 sec) solution. Actually, after time t=3 sec, a change of heat flux distribution does scarcely occur, and then the steady state is reached. Also, this result indicates that the heat flux distribution on each friction surface occur dissimilarly as time elapse. The major cause of these phenomena is that the contact condition on the friction surfaces is changed to satisfy the new equilibrium state due to the rise in temperature.

V. THERMO ELASTIC BEHAVIOR

To investigate the transient thermo elastic analysis behavior of disk brake, the ANSYS simulation is obtained in 10 repeated brake applications. In actually, variation of the rotating speed during braking must be determined through vehicle dynamics. However, in this study, the rotating speed of disk was considered to be a known value. The time history of hydraulic pressure h P and angular speed ù assumed for brake cycle is shown in Fig.5. One cycle is composed of braking (4.5 sec), acceleration (10.5), and constant speed driving (5 sec). In each process, the hydraulic pressure h P was assumed to linearly increase to 1 MPa by 1.5 sec and then kept constant until 4.5 sec. Also, the angular velocity ù was assumed to linearly decay and finally became zero at 4.5 sec. The time step Δt =0.001 sec was used in the computations. The material properties adopted in the computations are shown in Table below.

Material Properties	**Pad**	**Disk**
Thermal conductivity, K (w/m k)	5	57
Density, ρ (kg/m3)	1400	7100
Specific heat , c (J/Kg k)	1000	452
Poisson's ratio, v	0.25	0.25
Thermal expansion , α $(10^{-6}/k)$	10	11
Elastic modulus, *E* (GPa)	1	106
Coefficient of friction, μ	0.0667	
Operation Conditions		
Angular velocity, ω (rad/s)		150
Hydraulic pressure, *P* (Mpa)		1

The heat convection coefficient is considered

$$h = 100(w/m^2k)$$

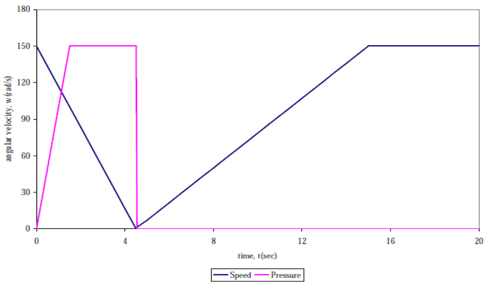


Figure 5 Load Curve

Fig.6 shows the heat flux distribution on the friction surfaces for the steady and transient (at t=10 sec) solution. Actually, after time t=3 sec, a change of heat flux distribution does scarcely occur, and then the steady state is reached. Also, this result indicates that the heat flux distribution on each friction surface occur dissimilarly as time elapse.

The major cause of these phenomena is that the contact condition on the friction surfaces is changed to satisfy the new equilibrium state due to the rise in temperature.

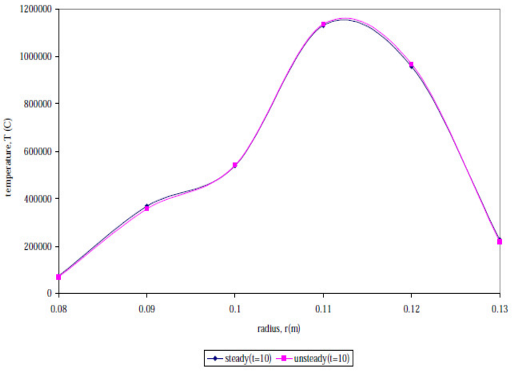


Figure 6 Heat Flux distribitution

Fig.7 presents the temperature distributions on the friction surfaces for the steady and transient (at t=10 sec) results. As the preceding results, the trend is for the temperature distribution to converge towards the steady state.

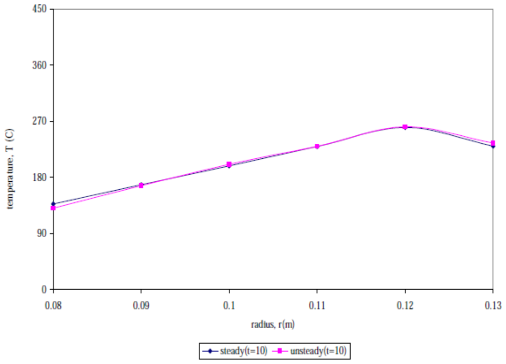
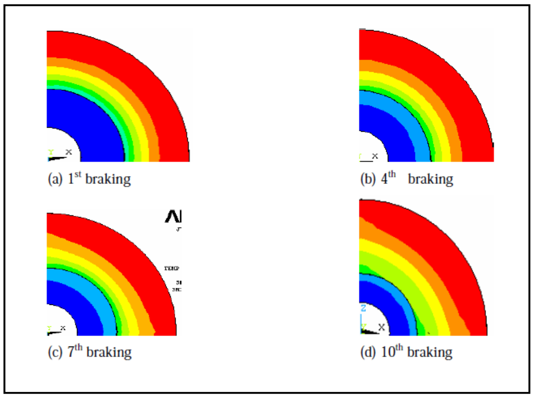


Figure 7 Temperature Distribution



(a) 1st braking

(b) 4th braking

(c) 7th braking

(d) 10th braking

Figure 8 Temperature contours of cast iron disk

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their comments which were very helpful in improving the quality and presentation of this paper.

REFERENCES:

1. BARBER, J. R. Stability of Thermo elastic Contact, Proc. International Conference on Tribology, p Institute of Mechanical Engineers, page. 981-986, (1987).
2. LEE, K. AND BARBER, J. R. An Experimental Investigation of Frictionallyexcited Thermo elastic Instability in Automotive Disk Brakes under a Drag Brake Application, ASME J. Tribology, vol. 116,page 409-414, (1994).
3. KENNEDY, F. E., COLIN, F. FLOQUET, A. AND GLOVSKY, R. Improved Techniques for Finite Element Analysis of Sliding Surface Temperatures. Westbury House page 138-150, (1984).
4. TSINOPOULOS, S. V, AGNANTIARIS, J. P. AND POLYZOS, D. An Advanced Boundary Element/Fast Fourier Transform Axis symmetric Formulation for Acoustic Radiation and Wave Scattering Problems, J.ACOUST. SOC. AMER., vol 105, page 1517-1526, (1999).
5. COMNINOU, M. AND DUNDURS, J. On the Barber Boundary Conditions for Thermo elastic Contact, ASME J, vol. 46, page 849-853, (1979).
6. FLOQUET, A. AND DUBOURG, M.-C. Non axis symmetric effects for three dimensional Analyses of a Brake, ASME J. Tribology, vol. 116, page 401-407, (1994).
7. DOW, T. A. AND BURTON, R. A. Thermo elastic Instability of Sliding Contact in the absence of Wear, Wear, vol. 19, page 315-328, (1972).

◆◆◆