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TRANSIENT THERMAL AND STRUCTURAL ANALYSIS OF ROTOR DISC OF DISK BRAKE

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ABSTRACT

Transient Thermal and Structural Analysis of the Rotor Disc of Disk Brake is aimed at evaluating the performance of disc brake rotor of a car under severe braking conditions and there by assist in disc rotor design and analysis. In the present work, an attempt has been made to investigate the suitable hybrid composite material which is lighter than cast iron and has good Young's modulus, Yield strength and density properties. Aluminum base metal matrix composite and High Strength Glass Fiber composites have a promising friction and wear behavior as a Disk brake rotor. The transient thermo elastic analysis of Disc brakes in repeated brake applications has been performed and the results were compared. The suitable material for the braking operation is S2 glass fiber and all the values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria. By identifying the true design features, the extended service life and long term stability is assured..

KEYWORDS : Disc Brakes, Geometrical modelling,Finite element method,Results and disscussion of pad and rotor disc brakes

Brakes are often described according to several characteristics including: Peak force - The peak force is the maximum decelerating effect that can be obtained. The peak force is often greater than the traction limit of the tires, in which case the brake can cause a wheel skid.

- Continuous power dissipation - Brakes typically get hot in use, and fail when the temperature gets too high. The greatest amount of power (energy per unit time) that can be dissipated through the brake without failure is the continuous power dissipation. Continuous power dissipation often depends on e.g., the temperature and speed of ambient cooling air. Fade - As a brake heats, it may become less effective, called brake fade. Some designs are inherently prone to fade, while other designs are relatively immune. Further, use considerations, such as cooling, often have a big effect on fade.
- Smoothness - A brake that is grabby, pulses, has chatter, or otherwise exerts varying brake force may lead to skids. For example, railroad wheels have little traction, and friction brakes without an anti-skid mechanism often lead to skids, which increases maintenance costs and leads to a "thump thump" feeling for riders inside.
- Power - Brakes are often described as "powerful" when a small human application force leads to a braking force that is higher than typical for other brakes in the same class. This notion of "powerful" does not relate to continuous power dissipation, and may be confusing in that a brake may be "powerful" and brake strongly with a gentle brake application, yet have lower (worse) peak force than a less "powerful" brake.
- Durability - Friction brakes have wear surfaces that must be renewed periodically. Wear surfaces include the brake shoes or pads, and also the brake disc or drum. There may be tradeoffs, for example a wear surface that generates high peak force may also wear quickly.
- Weight - Brakes are often "added weight" in that they serve no other function. Further, brakes are often mounted on wheels, and unsprung weight can significantly hurt traction in some circumstances. "Weight" may mean the brake itself, or may include additional support structure.
- Noise - Brakes usually create some minor noise when applied, but often create squeal or grinding noises that are quite loud.

The present study was conducted to analyze which the geometry of vents in motorcycle disk brakes affects the surface of the disk.

In order to analyze the thermal characteristics of disk brakes, thermal deformation analysis and thermal stress analysis due to heat transfer was carried out through the finite element analysis for ventilated disk and solid disk. By comparing the maximum temperature in the braking process, the ventilated disk showed a lower temperature than the solid disk and effect of temperature increase and decrease, depending on the vent area generated in the flange part of the disk. The thermal deformation in ventilated disk type occurs in all directions by 0.1162 mm, thermal

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distribution in the circumferential direction showed large deviation, about 0.017 mm due to the vents.

Deformation, Von Mises stress and contact pressures at pad are investigated by coupled thermo-mechanical. These simulation results are satisfactorily verified by comparing with similar literature result. Thus, this study provides effective reference for design and engineering application of brake disc and brake pad.

Geometrical Modeling

The model is constructed by using CATIA V5R21, The explode view of the model as shown in Figure 4.

Finite Element Method

Import the IGS file to hypermesh and clean up the geometry. In meshing Rtria mesh was done on whole outer surface of the model and then tetra mesh (4 noded triangular elements) is obtained. hexa (8 noded) solid meshing is made to bush and metal sleeve.

Results and Discussion of PAD with Different Rotor Materials

Thermal and structural analysis is performed in order to know the maximum nodal temperature, displacement, contact pressure and Frictional shear stress developed on a pad for different rotor material on a disc brake.

Pad Rotor

Aluminum Metal Matrix Composites (ALMMC)

Results obtained the above figures and table, by changing rotor material of the disc brake there is a considerably affects the pad surface. Hence from the above table, it's concluded that S2 glass has less frictional shear

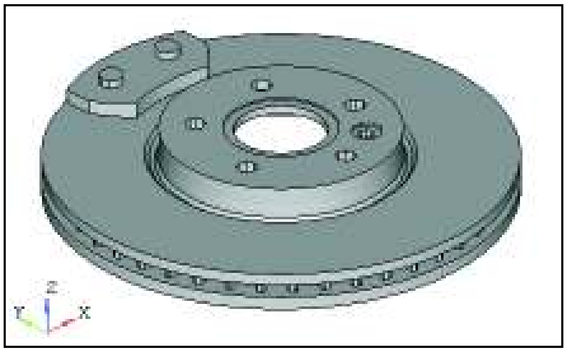


Figure 2.1 : 3D Modeling

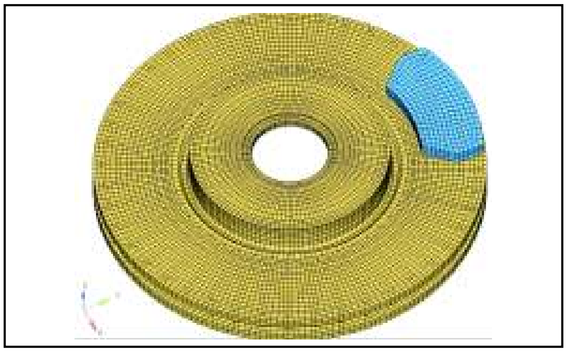


Figure 3.1 : Meshed Model

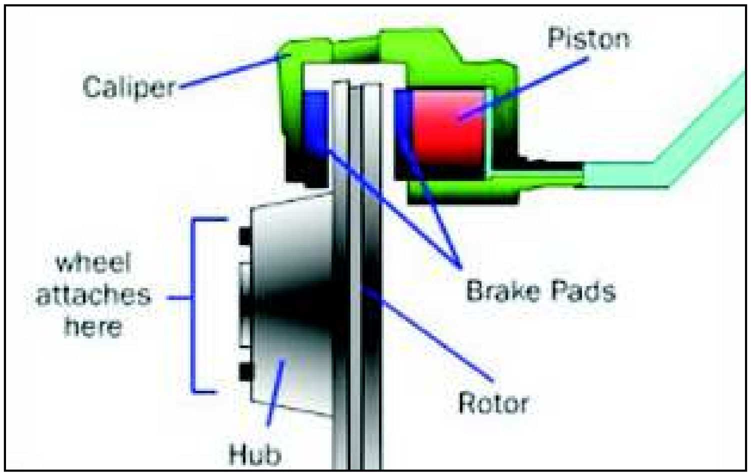


Figure 1.1 :Disc Brake

Table 2.1: The Material Property of the Pad

Material Properties	Pad
Thermal conductivity, k (w/m. C)	5
Density, (kg/m^3)	1400
Specific Heat, c (J/Kg. C)	1000
Possion's ratio,	0.25
Thermal expansion, (10^{-6}/ C)	10
Elastic modulus, E (GPa)	1

Table 2.2 : The Material Property of The Brake Assembly

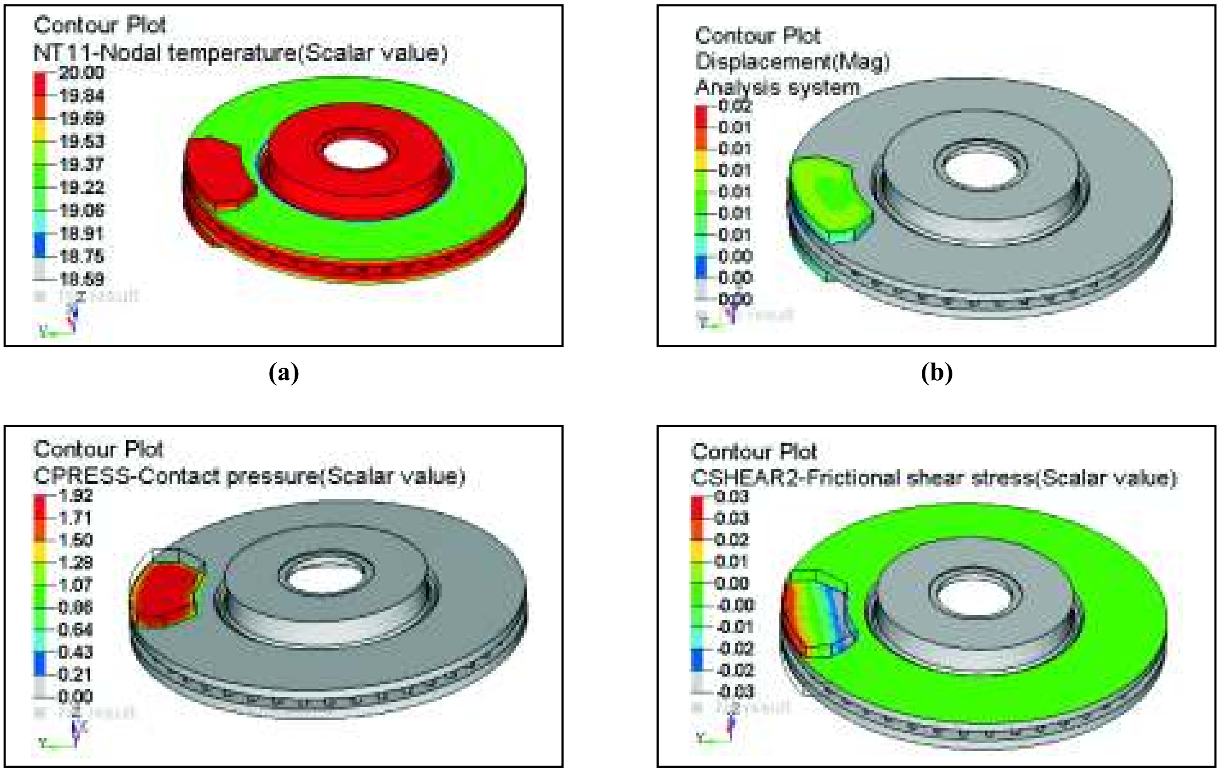
Table3.1: Mesh Details

Nodes	36745
Elements	32787

The type of element used for structural analysis is C3D8 & for Thermal analysis is DCC3D8.

Table 2.2 : The Material Property of The Brake Assembly

Properties	Cast iron	AIMMC	S2 glass	E glass
Density, ρ	7100 kg/m^3	2765.2 kg/m^3	2460 kg/m^3	2580 kg/m^3
Youngs modulus, E	125 GPa	98.5 GPa	86.9 GPa	72.3 GPa
Thermal conductivity, k	54 W/m.K	181.65 W/m.K	1.45 W/m.K	1.3 W/m.K
Specific Heat C_p	586 J/Kg .K	826.8 J/Kg.K	737 J/Kg.K	810 J/Kg.K
Possion's ratio, υ	0.25	0.33	0.28	0.22
Coefficient of expansion, α	8.1*10 ^{6}/ K	17.5*10 ^{6}/ K	0.9*10 ^{6}/ K	5.4*10 ^{6}/ K



(a) (b)

(c) (d)

Figure 4.1: a, b, c and d Shows the Maximum Pad Nodal Temperature, Displacement, Contact Pressure and Frictional Shear Stress for Pad with Rotor Material ALMMC.

For Different Materials for Pad the Same Procedure Has Been Followed and the results are Tabulated.

Table 4.1: Comparison for a Pad Having Different Rotor Disc Brake Materials

Materials	Pad with Rotor Different Material			
	Nodal Temperature	Displacement	Contact pressure	Frictional shear stress
ALMMC	20	0.02	1.92	0.03
CI	20	0.009	1.917	0.034
E-glass	20	0.01	1.944	0.035
S2 - glass	20	0.01	1.93	0.03
Steel	20	0.015	1.908	0.041

stress when comparing with respect to the different rotor materials.

And also from the above table, it's concluded that by changing rotor material of the disc brake won't have much effect on the performance of the pad surface.

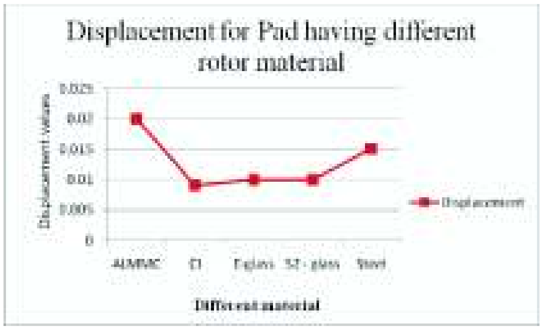


Figure 4.2 (a) : Displacement for Pad Having Different Rotor Material

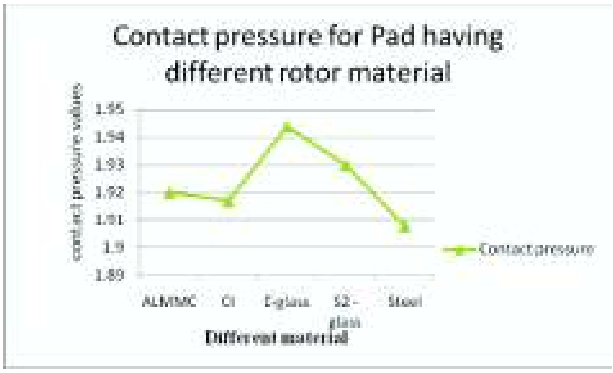


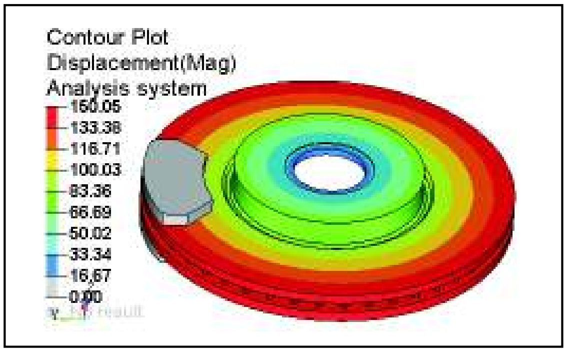
Figure 4.2 (b): Contact Pressure for Pad Having Different Rotor Material

Figure 4.2(c): Friction Al Shear Stress For Pad Having Different Rotor Material Theabove Three Graphs Shows The Comparision of Different Tests For Different Materials

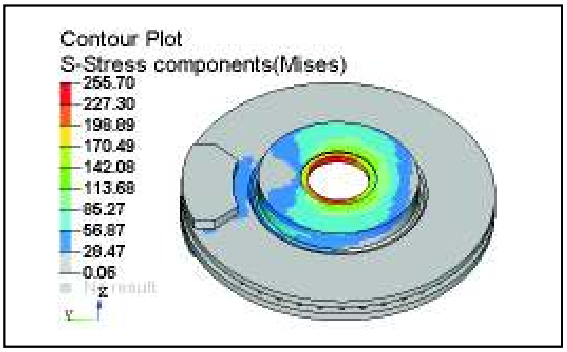
Parametric Studies on Rotor Disc for Different Materials

Thermal and structural analysis is performed in order to know the displacement, rotor stress component, contact pressure and Frictional shear stress developed on a rotor disc brake for different materials as shown in figures below.

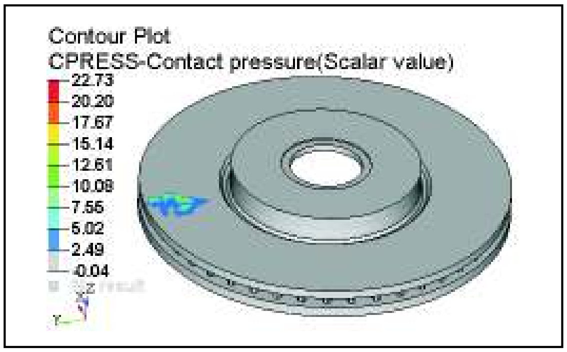
Rotor Disc Brake - Aluminum Metal Matrix Composites (ALMMC)



(a)



(b)



(c)

(d)

Figure 5.1: a, b, c and d Shows the Maximum Displacement, Stress Component, Contact Pressure and Frictional Shear Stress for ALMMC Rotor Disc Brake.

For different materials for Rotor disc brake the same procedure has been followed and the results are tabulated.

Observing all the above figures, the rotor having different material on a disc brake in order to obtain the Maximum displacement, stress component, contact pressure and Frictional shear stress. Hence one can declare that from the above figures that E glass having less frictional shear stress than the other materials.

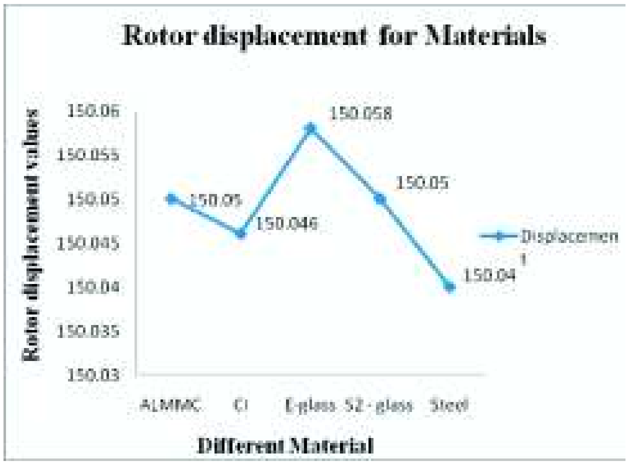


Figure 5.2 (a): Rotor Displacement for Different Material

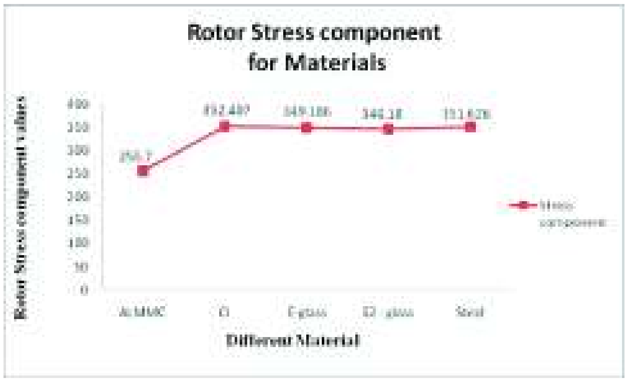


Figure 5.2 (b): Rotor Stress Component for Different Material

Table 5.1: Comparison for a Different Rotor Disc Brake Material

Materials	Pad with Rotor Different Material			
	Displacement	Stress Component	Contact pressure	Frictional shear stress
ALMMC	150.05	255.7	22.73	2.7
CI	150.046	352.407	25.987	3.074
E-glass	150.058	349.186	16.354	2.239
S2 - glass	150.05	346.18	18.05	2.45
Steel	15.04	351.626	16.684	2.269

Figure 5.2 (c) : Rotor Contact Pressure for Different Material

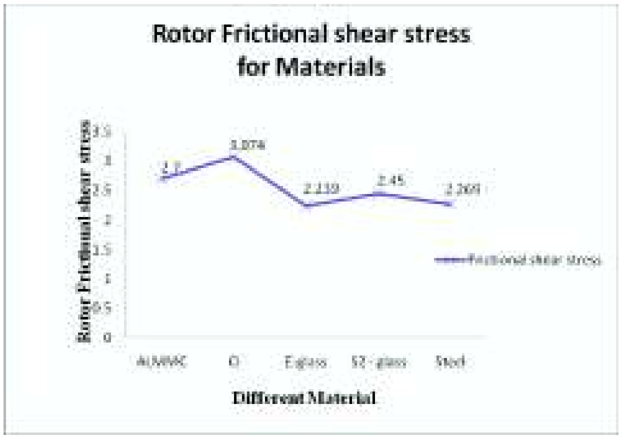


Figure 5.2 (d): Rotor Frictional Shear Stress For Different Material.

The above graphs are different tests for different materials.

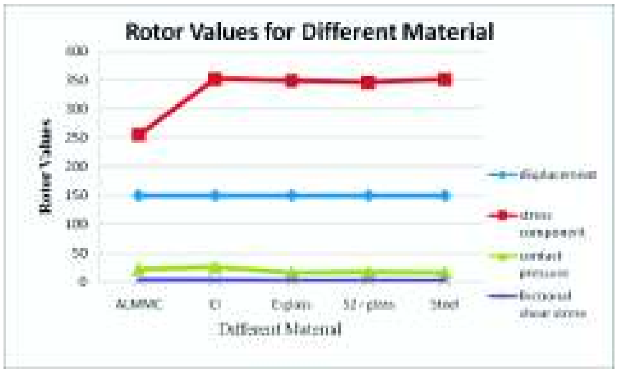


Figure 5.3: Rotor Values for Different Materials.

The above graph shows the rotor values for different materials.

CONCLUSION

In order to improve the braking efficiency and provide greater stability to vehicle An investigation was carried out and the suitable hybrid composite material which is lighter than cast iron and has good Young's modulus, Yield strength and density properties. The low weight, the hardness, the stable characteristics also in case of high pressure and temperature and resistance to thermal shock.

The transient thermo elastic analysis of Disc brakes in repeated brake applications has been performed. Abaqus software is applied to the thermo elastic contact problem with frictional heat generation. To obtain the simulation of thermo elastic behavior appearing in Disc brakes, the coupled heat conduction and elastic equations are solved with contact problems. The effects of the friction material properties on the contact ratio of friction surfaces are examined and the larger influential properties are found to be the thermal expansion coefficient and the elastic modulus.

It is observed that the orthotropic Disc brake scan provide better brake performance than the isotropic ones because of uniform and mild pressure distributions. The present study can provide a useful design tool and improve the brake performance of Disc brake system. From calculation we can conclude that that E glass fibre is the suitable material for the braking operation and all the values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria.

REFERENCES

ABAQUS Manual Version 6.4., 2003. Rhode Island, USA: Hibbitt, Karlsson & Sorensen, Inc.

Abu-Bakar, A. R., Sharif, A., Rashid, M. Z. A., & Ouyang, H., 2007. Brake squeal: Complex eigenvalue versus dynamic transient analysis. SAE Technical Paper 2007-01- 3964.

Anderson A., 1992. Friction and wear of automotive brakes (Metals Handbook: Friction, Lubrication and Wear Technology, vol. 18, pp. 569577.

Bae J. And wicket J., 2000. Freee vibration of coupled disc-hat structures. J. Sound and vibr. 235, 117-132.

Bolt B., 1989. 'Computation of a thermally stressed brake disc'. SAE technical paper series: 890086.

Brooks, P. C., Barton, D., Crolla, D. A., Lang A. M., & Schafer, D. R., 1994. A new approach to disc brake judder using thermo-mechanical finite element model. Proceedings of I.Mech.E. Paper No. C462/31/064.

Fieldhouse, J. D., Ashraf, N., & Talbot, C., 2008. The measurement and analysis of the disc/pad interface dynamic centre of pressure and its influence on brake noise. SAE Technical Paper 2008-01-0826.

Fukano A. Nad Matsui H., 1986. 'Development of disc brake design method using computersimulation of heat phenomena', SAE technical paper series: 860634.

Grieve, D.G., Barton, D.C., Crolla, D. A. And Buckingham, J,T., 1998. 'design of a light weight automotive brake disc using finite element and taguchi techniques', Proc. Instn. Mech. Engrs, 212, Part D.

Hassan, M. Z., Brooks, P. C., & Barton, D. C., 2008. Fully coupled thermal-mechanical analysis of automotive disc brake squeal. Automotive Research Conference 2008, Paper No. 05AARC.

Kinkaid, N. M., O'Reilly, O. M., & Papadopolous, P., 2003. Review of automotive disc brake squeal. Journal of Sound and Vibration, Vol. 267, 105-166.

Lee Y. S., Brooks, P. C., Barton, D. C., and Crolla, D. A., 2003. “A predictive tool to evaluate disc brake squeal propensity Part 1: The model philosophy and the contact problem,” International Journal of Vehicle Design, Vol. 31, No. 289-308.

Liles, G. D., 1989. Analysis of disc brake squeal using finite element methods. SAE Technical Paper 891150.

Limpert, R., , 1975. 'The Thermal Performance of Automotive Disc Brake', SAE Technical paper series: 720447.

Newcomb and Spurr, 1967. R. T. A theory of brake sueal. Proc. Instn Mech. Engrs, Auto Div., (1), 33-40.

Ouyang, H., Nack, W. V., Yuan, Y., & Chen, F., 2005. Numerical analysis of automotive disc brake squeal: a review. International Journal Vehicle Noise and Vibrations, Vol. 1, Nos. 3-4, 207-230.

Papinniemi, J.C.S. Lai, J. Zhao, L. Loader, 2002. Brake squeal: a literature review, Applied Acoustics 63:391-400.

R. Limpert, 1999. Brake Design and Safety. 2nd Edition, Warrendale,Pennsylvania: Society of Automotive Engineering Inc., pp. 137-144.

S. Koetniyom., 2000. Thermal stress analysis of automotive disc brakes, PhD thesis, university of leeds, leeds.

Sheridan, D. C., 1988. Kutchey, J.A.and Samie, F., 'approaches to the thermal modelling of disc brakers', SAE Technical paper series: 880256.

Sun Chung, Sung Pil Jung, 2006. “Numerical analysis method to estimate thermal deformation of a ventilated disc for automotives”.pp-40 49.

T. Valvano and K. Lee, 2000. An Analytical Method to Predict Thermal Distortion of a Brake Rotor. Society of Automotive Engineers, Inc 2000-01-0445.

Thuresson D., 2000. Influence of material properties on slid-ing contact braking applications. Wear, 257 (56), 451-460.

Timtner K. H., 1979. 'Calculation of disc brakers components using the finite element method with emphasis on weight deduction', SAE technical paper series: 790396.

Yi, B. Y., Barber, J. R. and Zagrodzki, P., 2001. "Eigenvalue Solution of Thermoelastic Instability Problems using Fourier Reduction," Proc. of the Royal Society of London A, Vol. 456 : 2799-2821.