STRUCTURAL AND THERMAL ANALYSIS OF CAST IRON AND COMPOSITE BRAKE DRUMS

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ABSTRACT: The brake drum is a critical component that experiences high temperatures and develop thermal stresses during application of brakes. In addition, the application of shoe pressure gives rise to mechanical loads. So the analysis take into account both the thermal stresses and mechanical stresses together. Since the analytical solution is not possible due to combination of loads and varying of contour of the brake drum, it is necessary to carry out finite element approach in order to evaluate the exact stress distribution and make sure that the stress values are well below the allowable limits. Drum model here is, of the internal expanding type brake. The shoes of this kind of brake are contained within the drum and expand outwards when the brake is applied. Such kind of brakes is used in medium heavy-duty vehicles.

Key words: Brake drum,Transient thermal analysis, Temperature division

1.INTRODUCITON

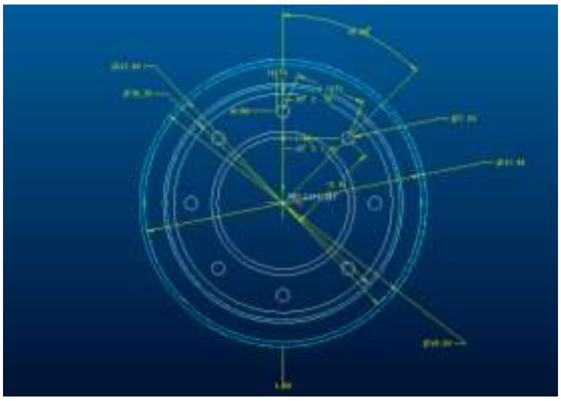
The commercial brake system uses disc brake for front wheels and drum brake for the rear wheels Grey cast iron is the conventional material used for making brake drums of light and heavy motor vehicle. The problems encountered in the cast iron material are described in the second chapter. An Al MMC brake drum has been designed to replace the heavy cast iron brake drum of a typical passenger vehicle .The design parameters such as inner radius, outer radius, and the width of drum, load and the allowable deformation are kept same for both cast iron and MMC brake drum. The theoretical formulation for the evaluation of stress, deformation and temperature rise has been described in this chapter. The finite element analysis of the cast iron and MMC brake drum has been also presented in the chapter. There has been interest in using aluminium based metal matrix composites (MMCs) for brake disc and drum materials in recent years. While much lighter than cast iron, they are not as resistant to high temperatures and are sometimes only used on the rear axles of automobiles because the energy dissipation requirements are not as severe compared with the front axle .While applying brake, the brakes convert the kinetic energy of the moving vehicle into thermal energy. This thermal energy diffuses through conduction within the brake drum and dissipates by convection and radiation from the outer surface of the brake drum. The material used for the brake drum should have the required physical, mechanical and thermal properties apart from being light weight. The failure of the brake drum is due to the high temperature generated inside the drum and also due to the high stresses applied on the drum .Matrix is a continuous phase in which the reinforcement is uniformly distributed.

2. LITERATURE REVIEW

In basic working operation, a disc or drum brake system has to reduce wheel speed when a driver desires vehicle deceleration. The kinetic energy generated by a vehicle in terms of wheel speed is converted into heat energy due to the application of the brake system. The friction force between disc/drum and brake pad/brake shoe applies friction torque to the wheel in the opposite direction of the car’s movement. This result in the reduction of vehicle speed and heat energy occurring in the brake disc/drum causes a temperature increment in the disc/drum swept area during the brake application. This physical action of the brake disc/drum causes heat conduction to the adjacent braking system components [1]. Lee [2] stated that inconsistent dissipation of heat inside the brake disc could cause deformation of the disc. Even worst, the disc deformation could also cause friction loss and consequently led to brake fade [3]. Furthermore, high temperatures of the brake disc could cause cracking in the brake disc material due to high thermal stresses .On top of that these factors also cause vibration [4, 5]. It is become common in the brake research . et al., Tribology in Industry Vol. 36, No. 4 (2014) 406-418 407 community to fully utilize finite element approach in order to identify and predict disc/drum brake structural performance. For instance, [6] performed temperature analysis on brake discs under heavy operating conditions. He found that the physical shape of vehicle brake discs play a significant role in determining the temperature characteristics including the overall brake efficiency tong et al. [7]attempted to link the interaction between mechanical and thermal effects with disc movements and heat caused by frictions. They concluded that, from finite element analysis, temperatures on the disc surface changed at each point over the period, which indicates inconsistent dissipation and temperature differences in each side of the disc. Hence, inconsistent contact between disc and pad could affect material deformation. Be cine et al. [8] used the finite element Software ANSYS to study the thermal behaviour of the dry contact between the discs of brake pads at the time of braking phase. Temperature distribution obtained by the transient thermal analysis was used in the calculations of the stresses on disc surface .Abdullah and [9] used finite element method to calculate the heat generated on the surfaces of friction clutch and temperature distribution for case of bands contact between flywheel and clutch disc, and between the clutch disc and pressure plate (one bad central and two bands) and compared with case of full contact between surfaces for single engagement and repeated engagements. In other work, Abdullah etal. [10] used the finite element method used to study the contact pressure and stresses during the full engagement period of the clutches using different contact algorithms. Moreover, sensitivity study for the contact pressure was presented to indicate the importance of the contact stiffness between contact surfaces.

3.ANALYSIS DIAGRAM

3.1TWO DIMENSIONAL OF THE BRAKE DRUM



BRAKE DRUM DIMENSIONS

Outer diameter	=	0.47m
Inner diameter	=	0.395m
Depth	=	0.187m
Depth of rib	=	0.048m
Rib diameter	=	0.486m
Hole diameter	=	0.022m
Hub diameter	=	0.223m
Outer edge chamber	=	45 x 0.005m
Inner edge chamber	=	45 x 0.01m
Eight holes with center		

SELECTION OF MMC

There has been interest in using aluminium based metal matrix composites (MMCs) for brake disc and drum materials in recent years. While much lighter than cast iron, they are not as resistant thigh temperatures and are sometimes only used on the rear axles of automobiles because the energy dissipation requirements are not as severe compared with the front axle .While applying brake, the brakes convert the kinetic energy of the moving vehicle into thermal energy. This thermal energy diffuses through conduction within the brake drum and dissipates by convection and radiation from the outer surface of the brake drum. The material used for the brake drum should have the required physical, mechanical and thermal properties apart from being light weight. The failure of the brake drum is due to the high temperature generated inside the drum and also due to the high stresses applied on the drum. Linear motion is motion in a straight line: an apple falling from a tree or a sliding door closing is an example of linear motion. We can represent linear motion by arrows like the ones below

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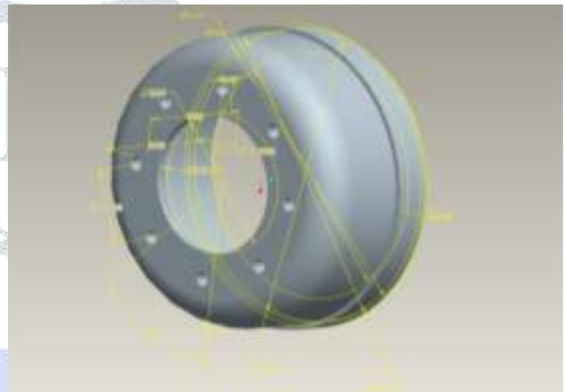
SELECTION OF REINFORCEMENT

Reinforcement increases strength, stiffness and temperature resistance capacities of MMCs. The reinforcement has different sizes, shape sand volume fractions in the composite. The reinforcement may be continuous fibers, whiskers or particles. The continuous fiber reinforcement has superior properties than the discontinuous reinforcements, but suffers from the disadvantage of anisotropic properties added to the need of adopting near net shape forming techniques. The discontinuous reinforcement offers isotropicproperties and amenability to be processed by conventional secondary metal forming techniques. Particulates are most common and least costlyreinforcement materials. The SiC particulate reinforced Al MMCs have good potential for use as wear resistance materials. Actually particulates lead to a favourable effect on properties such as hardness, wear resistance and compressive strength. Selection criteria for the ceramic reinforcement include factors like elastic modulus, tensile strength ,density, melting temperature, thermal stability, compatibility with matrix material and cost effectiveness.

FORMULATION

The objective of this optimization is to minimize the temperature rise inside the drum surface without sacrificing the strength and rigidity of thebrake drum. The objective function is arrived by substituting the value of heat flux from Equation (3.25) in the Equation (3.29). The objective function is expressed as

3.2 THREE DIMENSIONAL BRAKE DRUM



TEMPERATURE RISE IN BRAKE DRUM

For the lining material, high temperature results in reduced coefficient of friction, increased wear rate and burning (Eyre 1992). The high braking forces at elevated temperatures results in bell mouth effect on the brake drum resulting in a reduced braking effect (Rohatgi 1992). In addition ,because of the unequal coefficient of thermal expansion of lining and drum material, the drum/shoe contact area is reduced resulting in reduced braking force. Thermal shock is induced in the drum because of rapid and frequent application of the brake (Kwok 1999). High temperature also increases the rate of wear of drum resulting in reduced drum life. As the maximum operating temperature of aluminium MMC brake drum is less, a reduction of the temperature rise is essential to retain the braking effect at high deceleration levels and also the to reduce wear of drum and lining materials

TEMPERATURE RISE IN BRAKE DRUM

With a high deceleration level, resulting high heat generation in a single stop, the braking time may be less than the time required for the heat to penetrate through the drum and shoe which will lead to temperature rise at the interface. The maximum surface temperature rise T max in a single stop without ambient cooling may be expressed as (Limpert 1999).

REQUIREMENTS OF MMC

The current investigation is aimed at the development of MMC brake drum to replace the heavy cast iron brake drum used in the light passenger vehicles. The dimensional parameters of the brake drum which are used for the analysis is listed in the Table 3.1. Hence, the MMC brake drum has to satisfy the braking and thermal requirements of the conventional brake drum.

PROPERTIES OF A356/ SiC_P MMC

Aluminium alloy reinforced with SiC particles exhibit increased strength and stiffness as compared to non-reinforced aluminium alloy. In contrast to the base metal, the composite retains its room temperature tensile strength at higher temperatures. Discontinuous silicon carbide/aluminium MMCs are being developed by the aerospace industry for use in airplane skins, inter coastal ribs, and electrical equipment. In the liquid metal processing technique, the molten aluminium has the tendency to react with the reinforcing materials. The severity of the reaction is based on the kinetics and the prevailing thermodynamic conditions. The presence of alloying elements in the matrix has the influence on viscosity, contact angle and reaction rate with the dispersed particles. In the case of SiC, the following reaction is observed with the molten aluminium alloy (Pai 2001).3SiC + 2Al → Al2 C3 + 3Si ΔG = -51.3KJ

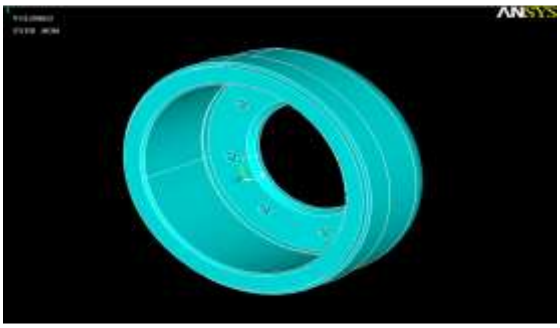
1However, the above reaction can be prevented by the presence of about 8%

SELECTION OF MATRIX

Matrix is a continuous phase in which the reinforcement is uniformly distributed. The advantages of metallic matrices as compared topolymer matrices are their higher tensile strength, and shear modulus, high melting point, low coefficient of thermal expansion, resistance to moisture, dimensional stability, high ductility and toughness characteristics such as density, strength, high temperature strength, ductility and toughness are to be considered. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag ,Zn have been used as the matrix material. The main focus is given to aluminium matrix because of its unique combination of good corrosion resistance and excellent mechanical properties. The combination of lightweight, high thermal conductivity, and low cost makes the aluminium matrix well suited for use as a matrix metal. The melting point of aluminium is highenough to satisfy the application requirements. Also aluminium can accommodate a variety of reinforcing agents including continuous boron, aluminium oxide, SiC, and graphite fibers and various particles, short fibers and whiskers

3.3 BRAKE DRUM ANALYSIS

The commercial brake system uses disc brake for front wheels and drum brake for the rear wheels. Grey cast iron is the conventional material used for making brake drums of light and heavy motor vehicle. The problems encountered in the cast iron material are described in the second chapter. An Al MMC brake drum has been designed to replace the heavy cast iron brake drum of a typical passenger vehicle. The design parameters such as inner radius, outer radius, and the width of drum, load and the allowable deformation are kept same for both cast iron and MMC brake drum. The theoretical formulation for the evaluation of stress, deformation and temperature rise has been described in this chapter. The finite element analysis of the cast iron and MMC brake drum has been also presented in this chapter.



A brake drum assembly of a light passenger vehicle which is used for the analysis is shown in Figure 3.1. The drum brake consists of backing plate, brake shoes, brake drum, wheel cylinder, return springs and a self adjusting system. Brake shoes consist of a steel shoe with the friction material lining riveted or bonded to it.

Metal Matrix Composites (MMCs) have emerged as a class of advanced materials capable of advanced structural, aerospace and automotive applications. MMCs have matured during the last two decades and are currently used as structural components subjected to cyclic load The temperature rise is optimized for cast iron and MMC brake drum of a passenger car by having the same design variables. The input parameters are given in the Table 3.3. The outer radius and drum width are also kept same for both the drums. The input parameters for the GA are given in Table 3.4.The variation of inner radius with number of generations for cast iron brake drum is shown in Figure 3.10. More fluctuation energy following are observedupto200generations then it reaches the optimum value with smaller fluctuations. The variation of the width with the number of generations for cast iron drum

4.CONCLUSION

The inner radius and the width of cast iron and MMC brake drums are optimized using Genetic Algorithm, an on traditional optimization technique. The temperature rise in cast iron brake drum before optimization is observed as 356.6 °C. After optimization, the temperature rise is reduced to 101.97 °C. So, a net reduction in temperature rise of 255 °C is achieved. The temperature rise in MMC brake drum before optimization is observed as 208.5°C. After optimization, the temperature rise is reduced to 21.3°C. So, a net reduction in temperature rise of 187.5 °C is achieved.57 The mass of the cast iron brake drum before optimization is4.3 kg. After optimization, the mass of the drum is 3.2 kg .So, a weight reduction of 24% is achieved for the cast iron brake drum. The mass of the MMC brake drum before optimization is1.68 kg. After optimization, the mass of the brake drum is1.38 kg. So, a weight reduction of 20% is achieved for the MMC brake drum

If the conventional cast iron brake drum brake drum is replaced by the MMC brake drum the temperature rise is reduced to 208.5°C. If Genetic algorithm is applied, the temperature rise is still reduced to 21.3°C.. It is observed that the GA leads to larger reduction in temperature rise due to its search for global optimum as against the local optimum in traditional search methods. Since these results are encouraging, the GA can be effectively used for other complex and realistic designs often encountered in engineering applications

The temperature rise in cast iron brake drum before optimization is observed as 356.6°C.After optimization, the temperature rise is reduced to 101.97 °C. So, a net reduction in temperature rise of 255 °C is achieved.

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