ASIATRIB 2002International Conference
JEJU ISLAND, KOREA

Computer Modeling of Hot Spot Phenomena in Ventilated Disk Brake Rubbing Surface

Chung Kyun Kim[1], Seung Hyun Cho[1], Young Bae Ko[2]

[1]*Tribology Research Center, Hongik University*
72-1 Sangsu-Dong, Mapo-Gu, Seoul 121-791, KOREA
[2]*Bucheon Digital Dies & Molds Technology Center*
Bucheon Techno-Park 2BL, Bucheon City 420-831, Kyungki-Do, KOREA

This paper presents the hot spot behaviors on the rubbing surface of ventilated disk brake by using finite element method. The depth of asperities on the rubbing surface is usually 2-3 ㎛ so the real contact area is microscopically. Non-uniform contacts between the disk and the pads lead to high local temperatures, which may cause the material degradation, and develops hot spots, thermal cracking, and brake system failures at the end. High contact asperity flash temperatures in rubbing systems, which is strongly related to the hot spot. It was generally known that high temperature over about 700℃ may form martensite on the cast iron which is material for automotive disk brakes. In this paper, the contact stress, temperature distribution and strain have been presented for the specific asperities of real contact area microscopically by using coupled thermal-mechanical analysis technique.

Key words: Hot spot, Temperature, Contact pressure, Ventilated disk brake.

1. INTRODUCTION

The microscopic contact area is very important source for the analysis of hot spot demonstration on the rubbing surface. The hot spot may be caused by uneven temperature distribution that is produced by the roughness, thermal distortion, wear, and concentrated contact pressures.

When the contact flat surfaces slide over one another, the contact is occurred on the real contact area of the rubbing surfaces such as, junction growth, thermal expansion, wear, and a variety of physical phenomena. Thus non-uniform contacts between the disk and the pads lead to high local temperatures, which may cause the material degradation, and develop hot spots, thermal cracking, and brake system failures at the end[1-2]. Blok[3] described high contact asperity flash temperatures in rubbing systems, which is strongly related to the hot spot.

For the FEM analysis, it is very difficult to describe the real contact area on the contact surface microscopically. Thus, the previous analysis has applied to a simplified model of a single square or circle contact[4-5]. Vick and Furey presented the temperature distribution on the rubbing surface. But they did not explain multiple effects of neighbor asperities that are influenced by sliding velocity, load, material properties and others. The recent computer simulation for single asperity showed that the temperature distribution may be significantly overestimated because the surface roughness did not include in detail[6]. Even though many researchers have tried to explain hot spot phenomena on the rubbing surface using numerical method, nobody demonstrated hot phenomena clearly except experimental study. This cannot be explained with some assumptions such as uniformly machined surface and the same friction coefficient.

In this study, the contact stress, temperature distribution and strain have been presented for the specific asperities of real contact area microscopically. The microscopic distortion of the rubbing surface was presented for the specific bumps by using the nonlinear program.

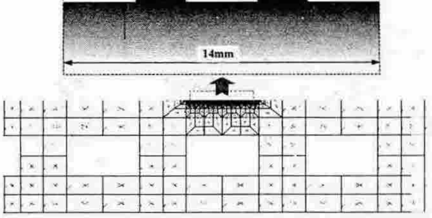
2. COMPUTER SIMULATION

2.1 FEM Models and Boundary Conditions

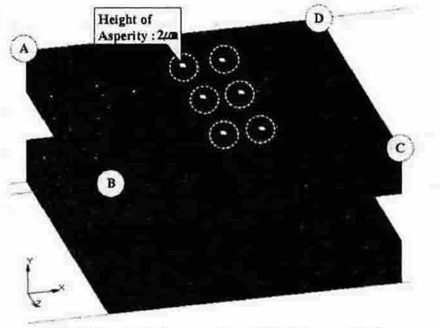
Several asperities in ventilated disk-pads contact model are shown in Fig. 1. The analysis have made for the speed of 10km/h to 97km/h and the friction coefficient is 0.3. The contact pressure between the disk and the pad is 15KN.

In two-dimensional disk model, the depth of two asperities is 2μm and the surface of ventilated disk brake may be deformed in any direction. This means that the disk is deformable body but the pad is rigid. The primary interest of this study is to demonstrate the hot spot phenomena on the rubbing surface of the disk. The disk is modeled for-noded, isoparametric, quadrilateral elements for axisymmetric applications.

In three-dimensional disk model, six asperities were considered as shown in Fig. 1(b). In this model, the element type is eight node, isoparametric, and arbitrary hexahedral.



(a) Two-dimensional disk model



(b) Three-dimensional disk model

Fig. 1 FE model of several asperities on the surface of ventilated disk brake.

3. RESULT AND DISCUSIONS

Fig. 2 shows the temperature distribution on the rubbing surface of a disk as a function of the speed of a car when the height of the bump area is 2 μm. The spike temperature on the bump area of the rubbing was produced with a speed range from 10km/h to 97km/h. At a low speed of 10km/s, the peak temperature on the real contact area as shown in Fig. 1 is 310°C, which is good temperature range in the disk-pad brake system. At a speed of 30km/s, the concentrated temperature on the bump area sharply increased up to 875°C at a speed of 60km/h and a friction coefficient of 0.3, which is very dangerous zone of the disk material. As to the increased speed of a brake, we cannot explain the real phenomena except the melting temperature of disk materials at the rubbing area. As a result, the local bump patch as shown in Fig. 1 may be removed by thermoelastic wear or melting wear.

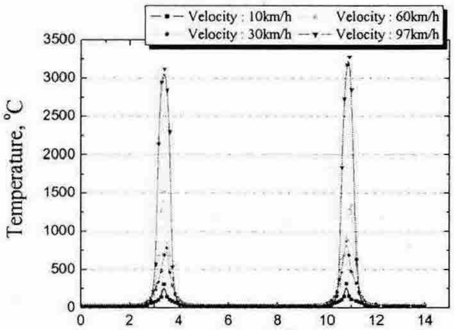


Fig. 2 Temperature spikes due to a bump on the rubbing surface of a ventilated disk brake. Speed of a car: 50km/h; Friction coefficient: 0.3.

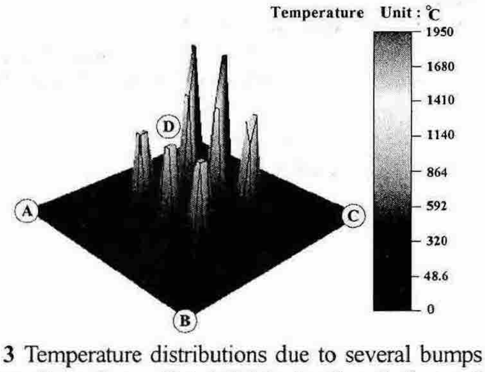


Fig. 3 Temperature distributions due to several bumps on the rubbing surface of a ventilated disk brake. Speed of a car: 60km/h; Friction coefficient: 0.3.

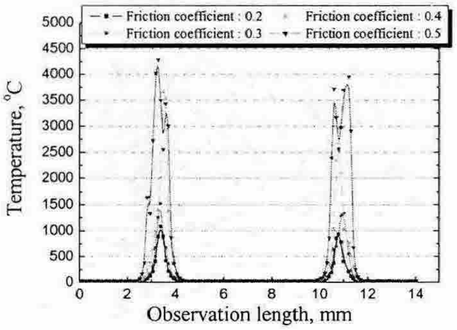


Fig. 4 Temperature spikes due to a bump on the rubbing surface of a ventilated disk brake. Speed of a car: 60km/h; Friction coefficient: 0.3.

In Fig. 3, three-dimensional temperature distribution has been presented at a speed of 60km/h and a friction coefficient of 0.3. The peak temperature on the rubbing patch of Fig. 1(b) is 1900°C. This result is 400 °C high compared to the two-dimensional analysis model. This means that the micro-patch may influence to the neighbor bump because this model describes 6 micro-bumps as shown in Fig. 1(b).

Fig. 4 shows the temperature distribution on the rubbing surface of a disk as function of the friction coefficient between a disk and pads at a speed of 60km/h. when the friction coefficient are 0.2 and 0.3, the peak temperature on the rubbing surface of disk is about 1,000°C and 1,500°C.

It is rapidly increasing up to 3,500°C with the friction coefficient of 0.4, and it increased up to 4,300°C with the friction coefficient of 0.5. Specially increment of the peak temperature is conspicuous when the friction coefficient over 0.4.

As a result, we know that the friction coefficient is more critical factor than the speed of automotive on the peak temperature generation.

4. CONCLUSIONS

The calculated results show that the roughness on the rubbing surface of a disk is a critical factor affecting the temperature distributions and the automotive moving velocity. In addition, a friction coefficient between a disk and a pad is also important.

The peak temperature rapidly increased when a velocity is over 60km/h and a friction coefficient over 0.4.

From the computed results, the micro-contact on the rubbing surface of the disk has important meaning. This means that the micro-contact may produce the thermoelastic wear and melting one because of the hot spot phenomena. Conclusively, the roughness on the disk surface and the thermal distortion sharply reduce the life of the disk surface.

5. REFERENCES

[1] Kwangjin Lee and J. R. Barber, "An Experimental investigation of Frictionally-Excited Thermoelastic Instability in Automotive Disk Brakes Under a Drag Brake Application," J. of Tribology, Vol. 116 (1994) 409-414.

[2] Azarkhin, A. and Barber, J.B., "Thermoelastic Instability for the Transient Contact Problem of Two Sliding Half-Planes," Transactions of the ASME, J. of Tribology, Vol. 107 (1985) 565-572.

[3] Block, H., "Theoretical Study of Temperature Rise at Surfaces of Actual Contact Under Oiliness Conditions," Proc. Inst. of Mechanical Engineers General Discussion of Lubrication, Vol. 2 (1937) 222-235.

[4] Furey MJ,Vick B,Foo SJ, Weick BL., "A theoretical and experimental study of surface temperatures generated during fretting" Proceedings of the Japan International Tribology Conference,Nagoya 1990:809-14

[5] Vick B,Furey MJ, Iskandar K., "Surface temperatures and tribological behavior of pure metallic elements", Proceedings of the Fifth International Tribology Conference-Austirb'98, Brisbane(Australia), 1998, pp.491-496.

[6] Vick B,Furey MJ., "A basic theoretical study of the temperature rise in sliding contact with muliple contacts" , Tribology International, 2001, pp.823-829.