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# The Optimal Design of a Drum Friction Plate Using AnsysWorkbench

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## Abstract

In this paper Solid Works is used to establish the geometric model of drum brake. The solid model is imported into AnsysWorkbench, and analyzed for the friction plate stress distribution under different conditions. The results show that when the friction plate material is less metal, the thickness is between 3 mm and 5 mm, the starting angle is between 25 degrees and 27 degrees, the concentration degree of contact stress reduces and the volatility is relatively stable. This can provide good braking performance and increase the service life. The optimization parameters can provide data support for the development of new drum brake.

**Key words:** Drum friction plate; Finite element analysis; Stress distribution; Optimal design

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## INTRODUCTION

Brake is the most important component in a vehicle that affects the safety of motor vehicles. Brake has two commonly used types: disc brake and drum brake. Because the drum brake has good braking effect, more compact structure , and usually lower cost, it is widely used in automobiles, motorcycles, electric bicycles (Mao, Wang, & Hu, 2002). In the braking process, the friction plate and the inner surface of the brake drum contact each other, and realize the braking function by friction. In the actual production, the drum brake and the brake shoes have been improved greatly, however, very little has been done to improve the structure of the friction lining. The research of drum lining has very important significance and value (Yang, Gu, & Li, 2007).

From examining the failed friction linings that Jiangsu Goodfellow Technology Corp, provided, it can be seen that the middle part has serious wear and tear, both ends of the lining almost have no signs of wear. It is due to the small area of contact between the friction plate and the drum brake. It is difficult to dissipate large amount of heat in a very short period time that makes the surface changes. Therefore, how to optimize the design of the brake friction plate, enlarge the contact area , reduce wear, improve braking performance has become the main objectives of this research. This paper uses finite element simulation software AnsysWorkbench to analyze contact stress distribution between the drum brake and friction linings, optimize structural parameters of the friction plate. The analysis will provide theoretical supports for the improvement and development of the brake for its braking performance.

## 1. THE STRUCTURE PARAMETERS OF BRAKE

Drum brake structure is compact. It consists of drum, shoe block, friction plate, cam and other components, as shown in Figure 1. Its braking performance has a great relationship with the braking distance, velocity, thermal recession and the size of the operating force. Its structure parameters include the friction lining starting angle $\alpha$, the

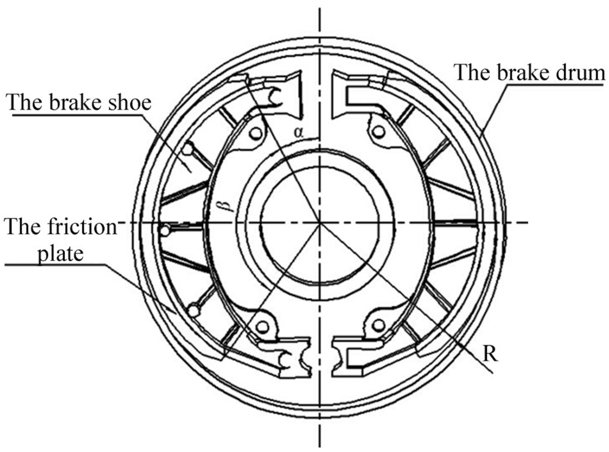



**Figure 1**
**Schematic of Brake Structure**

action line distance *e* from the brake center to the opening force *F*, the brake shoe point coordinates *a* and *c*, etc., as shown in Figure 2.

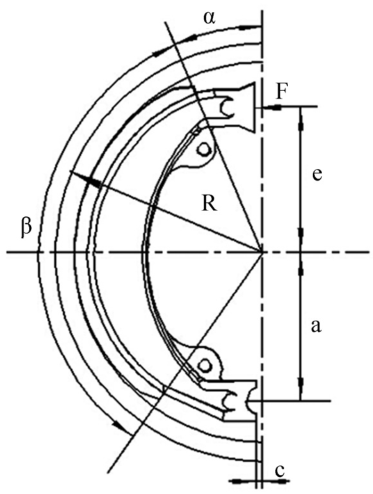



**Figure 2**
**Various Parameters of Drum Brake**

It is generally believed that the middle of the drum brake friction disc wear faster, and ends wear more slowly. This is because when the brake shoe open, the middle is always the first contact with the brake drum. When the contact area becomes larger, the wear amount is smaller, it is also associated with the structure parameters of brake shoe, such as: the radius of curvature, the friction plate thickness, the starting angle, etc.. They will have very important effect on the braking performance.

The width of the drum brake friction plate is *b* and the wrap angle is *β*. The plate has a great influence on the wear life. If the width of the friction plate is relatively small, it can accelerate the speed of the wear and tear, and shorten the life of the friction plate. If the width of the friction plate increases, its breaking effect will increase, associate with the cost increases. Therefore, it is reasonable to consider the width parameter of the friction plate as a design variable. The friction plate wrap angle generally is in the range of 90°-100°, then the wear is small and braking efficiency is high. But if the wrap angle is small, the pressure per unit area will increase, the wear will speed up; if the wrap angle is too large, it will make the braking action not stable and may result in self-locking. The starting angle *α* is not symmetrical in the actual situation, namely $\alpha \neq 90° - \beta/2$.To make the friction plate pressure uniform, the friction plate must be placed in the middle of the brake shoe, it can improve the wear performance (Yoon, Shin, & Lee, 2013; Zhao, 2013).

Within the constraint of structure, the length *e* should increase as much as possible to improve the braking effect. In addition, the brake shoe position coordinates *a* and *c* should increase its value under the constraint of fixed end face without interference, it was recommended that the value: $a=0.8R$ (Ma & Xie, 2011). By measuring the analysis of drum brake, its various parameters are shown as Table 1.

**Table 1**
**The Various Parameter Values of Drum Brake**

| Brake parameter names | Symbol | The values |
|---|---|---|
| The radius of the brake drum | $R$ | 60 mm |
| The width of the friction plate | $b$ | 24 mm |
| Wrap angle of friction plate | $\beta$ | 126° |
| Starting angle of friction plate | $\alpha$ | 21° |
| The thickness of friction plate | $h$ | 4 mm |

The brake efficiency factor *K* is the ratio friction force due to the interaction and input force. It is also an important target to evaluate the brake performance.

When the rotation direction of the brake shoe linings fits with the brake drum, we call it the leading shoe. If they are in the opposite direction, call it secondary shoe. When the brake contains them above, we call it leading trailing shoe brake, it has simple structure and lower cost.

In addition, according to the efficiency factor, it is possible to calculate the driving forces of leading shoe and secondary shoe.

$$T=K_1P_1r_1+K_2P_2r_2\ . \qquad (1)$$

Among them: $T$— The braking torque; $K_1$, $K_2$— Brake efficiency factors;

$P_1$, $P_2$—The driving forces; $r_1$, $r_2$— Effective brake radius.

Through the calculation formula above, we can obtain the braking efficiency factors and the magnitude of the driving force. Because we mainly optimize the contact force distribution of the friction plate and structure, the size is not special requirements for its value. Therefore we don't calculate the value of the driving force.

## 2. THE ESTABLISHMENT OF FINITE ELEMENT MODEL

### 2.1 The Geometric Model of Brake

It is more difficult to build complex surface model in finite element software, and the efficiency is very low, but there is a great advantage in the three-dimensional modeling software. So we often build in three-dimensional software, then import analysis software.

After measurement, the geometric model of parts is created using three-dimensional software Solidworks, then assembled. The drum brake contains many parts, when it is imported the finite element software to analyze, the complexity of the model also affects the accuracy and efficiency of the grid, and the use of algorithm will be restricted. Therefore, in order to simplify the geometric model established above, such as: ignore the stiffener and cylinder structure of the brake shoe. The simplified model is shown in Figure 3.

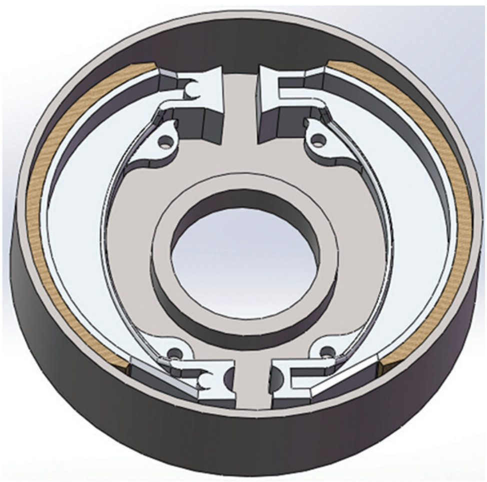


**Figure 3**
**Simplified Model of the Brake**

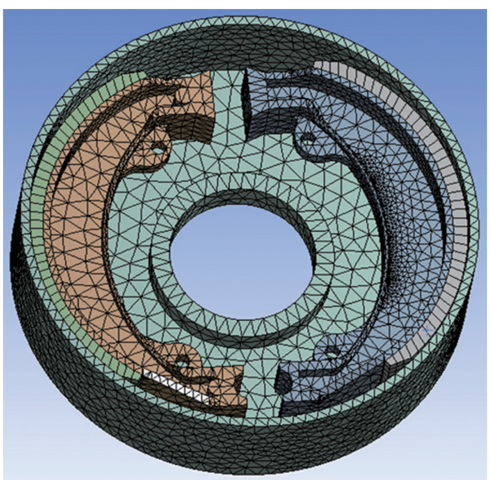


**Figure 4**
**Finite Element Model of Drum Brake**

The model is saved as *.*x_t* format, and imported into the AnsysWorkbench to be analyzed. It can enter DM module firstly that can make certain changes to the model, then choose the Static Structural module and share the geometry model (Yuan, Xu, & Zhang, 2014). In the Engineering Data module, it defines the properties of brake shoe, brake drum and friction plate, as shown in Table 2.

**Table 2**
**Material Properties of Drum Brake Parts**

| Part names | Materials | Density /(kg/m$^3$) | Modulus of elasticity /Gpa | Poisson's ratio |
|---|---|---|---|---|
| Brake drum | HT200 | 7,100 | 150 | 0.25 |
| Brake shoe | YL112 | 2,740 | 72 | 0.3 |
| Friction plate | Less metal | 3,300 | 7.8 | 0.27 |
| Friction plate | Half metal | 5,300 | 8.3 | 0.28 |
| Friction plate | Ceramic | 2,300 | 765 | 0.32 |

### 2.2 Mesh and Contact Conditions

Mesh generation could be automatic, in which the correlation value is 50, and the associated center is Medium. It can be divided into 70,673 nodes, 36,182 units, as shown in Figure 4.

The commonly used contact types in AnsysWorkbench are: Bonded, No Separation, Frictionless, Rough, Frictional. If it is non symmetric behavior, the selection of contact surface and target surface

needs the following matters: (a) If convex surface and concave surface contacts, we should select the concave surface as the target surface; (b) If you have rough surface and fine grid mesh surface, then select the rough surface as target surface; (c) If a surface is larger than the other, then choose the larger surface as target surface. The Mechanical also provides a variety of contact algorithms, such as: Pure Penalty, Normal Lagrange, Augmented Lagrange, MPC, etc.. In practice, the penalty function method and the extended Lagrange algorithms are supporting symmetrical behavior.

Then we set the contact pairs, including: firstly select inner surface of the brake drum as the target surface, the outer surface of the friction plate as the contact surface, the contact state is frictional contact, the friction coefficient is 0.3, the algorithm is the penalty function method; secondly select the inner surface of the friction plate as the target surface, the outer surface of the brake shoe as contact surface, the state is bonded contact and the same algorithm.

Among them, the penalty function equations as follows: setting drum friction stress minimum as objective function, the allowable stress value as constraint function, solving the analysis.

That is: $$\min f(x) \tag{2}$$

$$s.t \quad f_1 \leq [\sigma_1]; f_2 \leq [\sigma_2]; f_3 \leq [\sigma_3];$$
$$[\sigma_1],[\sigma_2] \leq 192\text{Mpa}$$
$$[\sigma_3] \leq 128\text{Mpa}$$

Among them: $f_1, f_2, f_3$—The stress analysis of different materials;
$[\sigma_1]$, $[\sigma_2]$, $[\sigma_3]$—The allowable stress of different materials.

### 2.3 Impose Boundary Conditions

According to the actual braking effect, the drum brake is applied the following boundary conditions: (a) Set The bottom surface of the brake drum as fixed constraint goal; (b) Set the degree of *Z*-axis direction as free which is based on two contact round faces of pins; (c) The load is applied on surface of the brake shoe and the cam, the size is 600N and the direction is opposite. In addition, there is a certain gap between the brake drum and the friction plate, it will affect the precision of calculation. Therefore, a small corner is applying on the brake shoes to eliminate their gap before solving. Finally, analyzes the results.

## 3. PARAMETERS OPTIMIZATION OF BRAKE

### 3.1 Material Optimization

At present, there are three commonly used materials in the friction plate: Less metal, semi-metal, ceramic, and others are using the default value. According to the above steps and requirements, we analyze the stress of friction plates of different materials, view their surface contact stress situation after solving, as shown in Figure 5.

(a) Less metal (b) Half metal (c) Ceramic

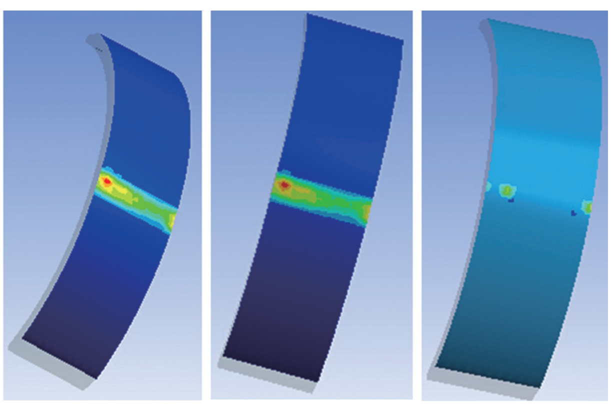


**Figure 5**
**Friction Plates of Different Materials Stress Distribution**

From the figure we can observe that these types of friction plates are not penetrating each other, namely it meets security requirements. The stress of ceramic is minimum, and the distribution is uniform. The state of stress distribution of half metal and less metal is similar, the edge stress is larger and relatively easy to wear the edges.

In order to improve the performance of friction plate, we take eight points to measure stress from the arc surface of the friction plate, draw the curve as shown in Figure 6. From the trend of the curve, we determine contact stress fluctuations and stability of the surface. This can provide the support to choose friction plate intuitively.

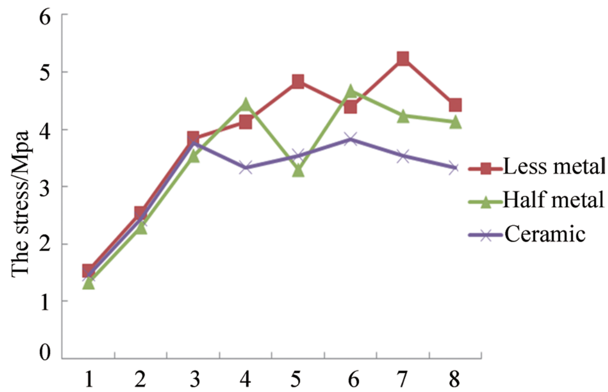



**Figure 6**
**The Friction Plate Stress Curve of Different Materials**

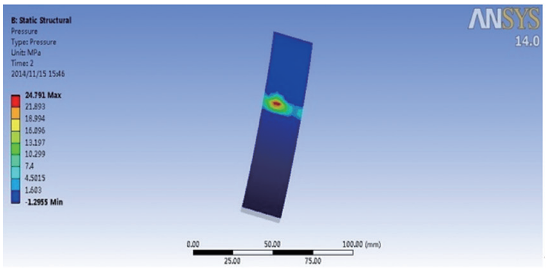
From the graph we can see, the less metal stress changes are relatively stable, the semi-metal stress fluctuation is large and easy to produce big noise and corrosion (Spelsberg-Korspeter, 2012). The ceramic stress change is the most stable, the curve is gentle and very suitable for brakes, it is a good option for brake pads, but the cost is too high and the promotion is not very good. Therefore, less metal friction plate metal is the best choice for industrial applications.

### 3.2 The Starting Angle Optimization

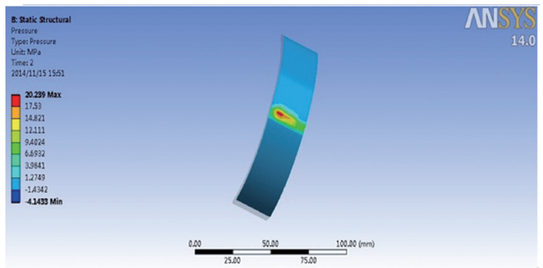
When the drum is in braking action, the drum friction plate and brake drum are not completely in the contact, the pressure per unit area is relatively large and some others do not contact, these are associated with the starting angle of drum brake (Hua, Li, & Liu, 2012). The starting angle of drum friction plate to be studied is 21°, the wrap angle is 126°. It can be seen that the friction plate is not the symmetrical distribution in the brake shoe. In order to research the influence of starting angle on the braking performance, now we change the size of the starting angle. When the distribution of the friction plate on the drum brake is symmetrical, the size of the starting angle is 27°. We select angle values from 21° to 27° for the simulation analysis, then set the starting angle for 24°, 25°, 27° and solve the stress distribution of the friction plate. According to the analysis of less metals friction plate above, other constraints are the same as above, then solve it and analyze the results.

(a) Starting angle is 24°



(b) Starting angle is 25°



(c) Starting angle is 27°

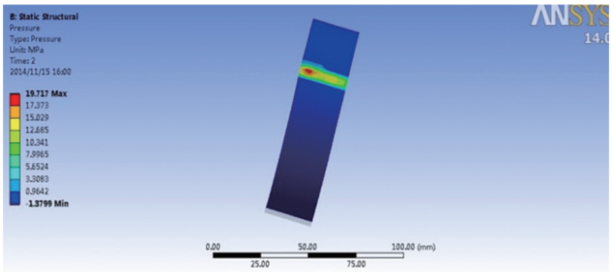


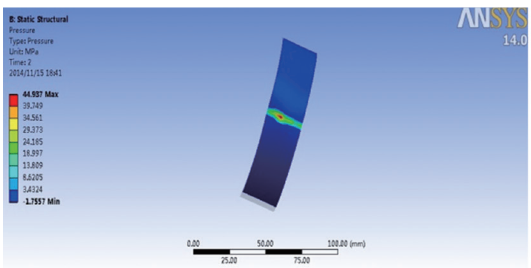
**Figure 7**
**Friction Plate Stress Distribution of Different Starting Angles**

When the starting angle is 24°, the maximum contact stress is 24.8 Mpa, and increases 3.0 Mpa compared with the original values; When the starting angle is 25°, the maximum contact stress is 20.2 Mpa, and reduces 1.6 Mpa compared with the original model; When the starting angle is 27°, the maximum contact stress value is 19.7 Mpa, and decreases 2.1 Mpa compared with the original model values. When the drum brake structure is under the same circumstances and the friction plate is symmetrical in brake shoe, the contact stress is minimal. If the starting angle of friction plate is too small, it will lead to increase stress and partial overload phenomenon; if the stress is too large, will affect the efficiency factor, the friction plate design must be reasonable on the bonding position of the brake shoe (Park, da Luz, & Suleman, 2008). The starting angle of friction plate in this model chooses between 25°-27°.

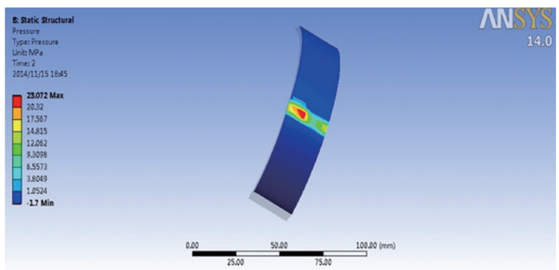
### 3.3 The Thickness Optimization

In order to better study the impact of different parameters on the braking performance, we analyze the contact stress on the thickness of the friction plate, then respectively take drum friction plate thickness as 2 mm, 3 mm, 5 mm, the others are same as above and then solve it. Finally, we view the contact stress of the surface, and draw the corresponding conclusions.

(a) Thickness is 2 mm



(b) Thickness is 3 mm



(c) The thickness is 5 mm

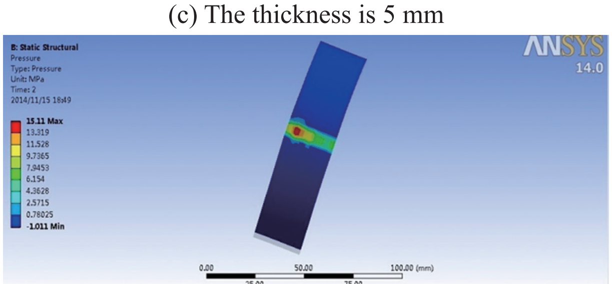


**Figure 8**
**Friction Plate Stress Distribution of Different Thicknesses**

From Figure 8, we can see that the thickness is increasing, the maximum friction stress value is 44.9 Mpa, 23.1 Mpa, 15.1 Mpa respectively, and the stress distribution extends from the edge of the middle position to the center position of friction plate. According to the analysis of the friction plate, when the thickness of friction plate is 4 mm, the contact stress is 21.8 Mpa, and the maximum stress value of the friction plate is less than it too when the thickness is 5 mm.

When the thickness is 2 mm, it can be seen the friction plate has been deformed, and the stress concentration is in the middle position, it is prone to accidents; When the thickness is 3 mm, the maximum stress is gradually dispersed to the edge position. It is easy to tear (Chen, 2011; Matějka et al., 2008; Bian, Zhao, & Bai, 2012); When the thickness is 5mm, the stress value is minimum and not very concentrated, but the increase of the thickness will affect the structure of brake design. According to the requirements of security and the analysis results, friction plate thickness should be 3 -5 mm.

## CONCLUSION

By establishing the three dimensional model of drum brake, we imported its solid model into the finite element software AnsysWorkbench and made the simulation analysis. The stress distribution of drum friction plate surface was obtained from the analysis, and then the starting angle, material, thickness were optimally chosen. According to the above analysis, we draw the following conclusions:

(a) Using the finite element method to optimize different structural parameters, it provides an effective approach to design and to improve the product, at the same time the optimized brake parameters provide data support for the development of the drum brake.

(b) When the material is less metal, friction plate stress is relatively stable, and the cost performance is high; when the starting angle is 25°-27°, the maximum stress value reduces and it no longer appear in the middle part of the friction plate; when the thickness in 3-5 mm, the friction stress reduces, the maximum value begins to transfer the edge and concentration decreases.

## REFERENCES

Bian, X. L., Zhao, W. D., & Bai, Y. N. (2012). Contact pressure analysis and optimization of shoe brake based on ANSYS/ Workbench. *Construction Machinery and Equipment, 43*(7), 27-30.

Chen, H. (2011). *Motorcycle drum brake structure optimization and simulation*. Tianjin University.

Hua, B., Li, H., & Liu, X. L. (2012). Finite element simulation for drum brake of electric bicycle. *Computer Engineering and Applications, 48*(3), 212-215.

Ma, X., & Xie, C. (2011). Finite element simulation and contact analysis of drum brakes. *Machinery Design & Manufacture,* (8), 16-18.

Mao, Z. D., Wang, X. L., & Hu, Y. J., et al. (2002). Contact analysis of drum brakes. *Journal of Hua Zhong University of Science and Technology(Nature Science), 30*(7), 71-73.

Matějka, V., Lu, Y. F., & Fan, Y. L., et al. (2008). Effects of silicon carbide in semi-metallic brake materials on friction performance and friction layer formation. *Wear, 17,* 1121-1128.

Park, E. J., da Luz, L. F., & Suleman, A. (2008). Multidisciplinary design optimization of an automotive magneto rheological brake design. *Computers and Structures, 17,* 207-216.

Spelsberg-Korspeter, G. (2012). Eigenvalue optimization against brake squeal: Symmetry, mathematical background and experiments. *Journal of Sound and Vibration, 331,* 4259-4268.

Yang, G.-J., Gu, Z.-Q., Li, & W.-P. (2007). Finite analysis on drum brake. *Machinery Design & Manufacture,* (4), 14-15.

Yoon, S. W., Shin, M. W., & Lee, W. G., et al. (2012). Effect of surface contact conditions on the stick–slip behavior of brake friction material. *Wear, 294,* 305-312.

Yuan, Y. J., Xu, Y. Y., & Zhang, Y. H. (2014). *AnsysWorkbench 14 modeling and simulation technology and detailed examples*. Beijing, China: Chemical Industry Press.

Zhao, W. D. (2012). *Braking performance analysis and optimization research of shoe brake*. Hebei University of Technology.