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Complex modal analysis model for frictional squeal of an automotive drum brake and its affect factors

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ABSTRACT

At present, for the relatively simple working principle, and low cost in the process, drum brakes are widely applied to automobile production. However, in the case of long-term use, its poorer heat dissipation, leads to corresponding problems, such as frictional squeal. Due to many squeal factors, this problem is difficult to break through. This study mainly performs corresponding analysis on complex modal analysis model for frictional squeal of an automotive drum brake and its affect factors. It performs corresponding verification analysis according to relevant principles and corresponding modal experiments, and analyzes the influence of brake pressure, friction coefficient and elastic modulus on corresponding frictional squeal[1]. It performs analysis through the experiment, to explore the corresponding influencing mechanism on the squeal.

KEYWORDS

Drum brakes; Frictional squeal; Complex modal analysis; Affect factor.

INTRODUCTION

The current influence factors of drum brake frictional squeal are relatively complex, so it is difficult to predict and control. The drum brakes are widely used in the current automobile industry, in the process of using, it will inevitably cause certain influence on the society. Therefore, it is necessary to strengthen corresponding measures and researches on it[1]. The mainly selected prediction method in current academic circle is finite element complex modal, the complex modal theory performs preliminary corresponding argument on instability factors in the frictional squeal, making scholars have further understanding on corresponding contact characteristics in friction. It strengthens corresponding correlation research, and on this basis, performs research on the distribution characteristics of the corresponding contact pressure, and performs corresponding analysis in order to determine the relationship existing between frictional squeal, providing a new idea for the research on influence factors of frictional squeal[2]. In this study, a certain type of drum brake is selected as a study object. A drum brake finite element model for its frictional squeal was established using ABAQUS. Using individual brake components to verify the correctness of the model. Then, effectively analyze the corresponding influence factors[3].

COMPLEX MODAL ANALYSIS MODEL OF FINITE ELEMENT

Modeling is divided into two stages: first, in order to establish the drum brake grid model effectively, it is necessary to perform CAD model related grid division through comprehensive use of the Hyper Mesh software, in the process of modeling. Second, based on grid model, use ABAQUS software to definite the contact connection relation, the loading, material properties, and so on, to get the corresponding finite element model.

(1) Basic assumptions. Assumption on the model has certain conditions. First of all, the material should be uniform, and density parameters should be conventional numerical. Second, friction coefficient should be recorded in constant value. In addition, in the assumption, the influence on thermal effect and wear should be ignored.

(2) Element division and geometry model. In the grid division through the Hyper Mesh software, the model has 52186 elements, and most of them are hexahedron elements, only 1023 pentahedron elements. As shown in Figure 1:

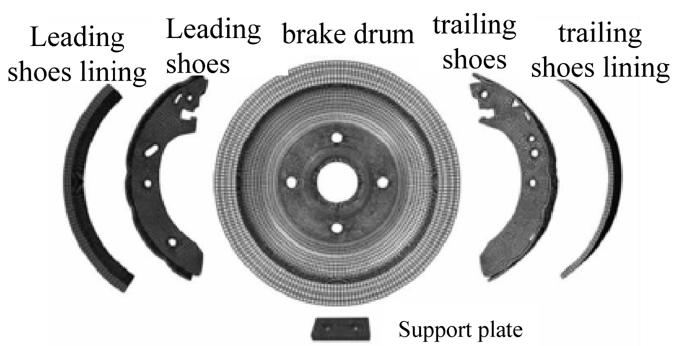


Figure 1 : Grid model of individual component

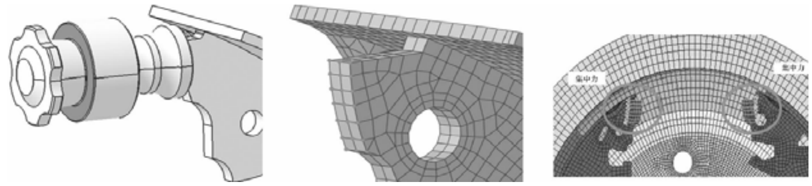
In drum brake, the corresponding finite element model is mainly formed by the brake drum, leading shoe, leading shoe lining, trailing shoe, trailing shoe lining, and the support board, through corresponding return spring. In the process of division, the affect factors on corresponding brake floor should be ignored, to perform better analysis on the model and corresponding grid.

(3) The definition and setting of material properties and boundary conditions. For setting boundary condition, the relevant objects are geometric constraint, loading setting, contact connection relation, etc. In addition, boundary conditions also contain the material attribute definition[4]. For the corresponding experimental research, it is necessary to strengthen the corresponding understanding and analysis, the details are shown below:

First of all, the contact connection setting. Between corresponding definition brake drum and friction lining, after corresponding surface contact on the brake shoe and support plate, perform separation and contacting, it will fix the friction lining and brake shoe, perform effectively connection through the contact surface, to avoid corresponding displacement.

Second, for the corresponding geometric constraint, in the process of implementation, it is necessary to adjust the limit brake shoe, which can undertake corresponding rotation, to achieve the corresponding automatic centering function, with brake shoe rotating around strong point[5]. In addition, it is also necessary to perform effective limiting on the corresponding degrees of freedom of support plate, and carry on the corresponding constraint, to achieve the node control and middle axis control. However, in this case, a node can only rotate along the axis.

Again, for the load step setting in complex model, if in assumption stage, corresponding brake pressure is constant, transverse concentrated force in this stage can reduce the corresponding error. And the realization of this approach is mainly to perform even distribution of brake pressure on the brake shoe, and load through each node. The corresponding dynamic loading is mainly performed through three phases. First, load small brake force, the main principle is applying force on the brake shoe and the clearance between drums. In the process of applying force, the shoe and drum will contact. Second, apply actual force in clearance between the drums, to calculate the corresponding pressure distribution. Last, control the force, for the relative concentration of corresponding force, to perform forward braking on brake drum. Achieve respective calculation on pressure under dynamic state, through corresponding actual braking simulation. As shown in Figure 2.



piston loading diagram braking force node braking force loading diagram in finite element model

Figure 2 : Load applying schematic diagram

Finally, in the material property setting, in the experiment on the free modal, it is necessary to confirm corresponding material properties, as the data shown in TABLE 1.

TABLE 1 : Material property parameters of drum brake components

	Brake drum	Leading/trailing shoes	Leading/trailing shoes friction lining	Sport plate
elasticity modulus/MPa	1.20E5	2.10E5	2.10E2	1.20E5
Poisson's ratio	0.24	0.27	0.23	0.24
Density/($t \cdot mm^{-3}$)	7.10E-9	7.86E-9	1.25E-9	7.10E-9

On this basis, it is also required to control the corresponding spring pressure within a certain range from top to bottom, and the corresponding upper and lower stiffness: 5.5 N/mm, 12 N/mm.

TEST VALIDATION ANALYSIS

For corresponding test validation on drum brake finite element model, it is mainly based on the effective validation on the material properties of finite element model. After the validation of properties, the experiment can be performed through the corresponding bench of brake, to predict squeal frequency accurately[6].

Modal experiment validation

In ABAQUS software, use corresponding LANCZOS for calculation on modal frequency and vibration model. On this basis, perform comprehensive comparison ton he calculated results and the corresponding experimental results, as shown in TABLE 2.

TABLE 2 : Free modal frequency of brake drum, comparison between vibration model calculation results and experimental results

	Modal analysis	Modal test	Frequency error %	Modal analysis	Modal test	Frequency error %
f/Hz	979	967	-1.28	2532	2487	-1.84
vibration model						
f/Hz	4534	4574	0.88	5070	5293	4.21
vibration model						
f/Hz	5807	5985	2.98	6842	6992	2.15
vibration model						

Due to brake size, there will be certain restriction in vibration model test. The test process is only for modal frequency. The comparison between leading and trailing shoes, is shown in TABLE 3 and TABLE 4.

TABLE 3 : Comparison between calculation results and experimental results on free modal frequency of leading shoes

Free modal test/Hz	2409	3489	4291	5167	5934
Free modal simulation/Hz	2404	3622	4510	5277	5833
Error/%	0.20	-3.81	-4.58	-2.14	1.70

TABLE 4 : Comparison between calculation results and experimental results on free modal frequency of trailing shoes

Free modal test/Hz	2719	3897	4907	5608
Free modal simulation/Hz	2718	3850	4996	5785
Error/%	-0.05	1.21	-1.83	-3.16

Therefore, the corresponding error is within 5%, conform to the requirements of the corresponding precision, and experimental results comply with the calculation results, which proves that the model in each component is accurate.

Brake bench test validation

In the process of the validation. For effective validation on finite element model in the experiment, It is necessary to extract the instability of the complex eigenvalues based on the complex model method, and measure the corresponding frequency in the bench experiment, and compare the unstable frequency, for effective validation of simulation modal[7]. And the process of relevant experiment, shall be carried out on the specified test bench, as shown in Figure 3.

Figure 3 : Experimental bench

Therefore, it is necessary to fix the brake drum, and brake plate. Perform corresponding rotation under driving force. Again, the corresponding translational inertia on corresponding simulation vehicle, provide certain brake pressure under the control of the hydraulic system, and perform specific detection on noise.

The main process of the test is the brake pressure application on the brake in the experiment. The entire process should have corresponding sustainability, and the specific pressure should be 1MPa. Then in the experimental hysteresis process, the 300 s should be subdivided, mainly divided into three stages, namely: acceleration, constant and deceleration. The corresponding speed is shown in Figure 4:

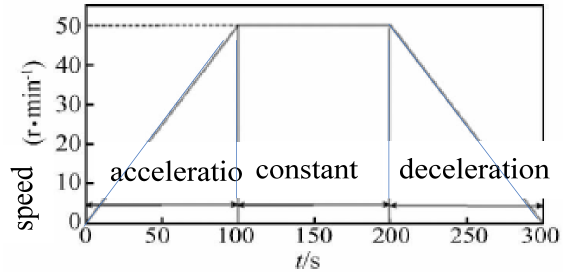


Figure 4 : Speed over time

At the same time, in the process of operation, temperature subjects to the corresponding room temperature. And on this basis, control the corresponding noise, which should be not more than 50 50dB. And the humidity should be 20% ~ 90%, taking102400Hz as sampling frequency in the experiment. Figure 5 is the statistical conclusion after many experiments.

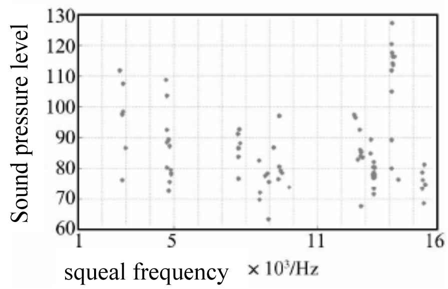


Figure 5 : Squeal frequency and acoustic pressure level statistics in bench experiment

The squeal frequency in the Figure focuses on nine setting squeal frequency. Complex eigenvalue under the simulation experiment mainly in seven modal frequencies in a state of flux. As shown in Figure 6.

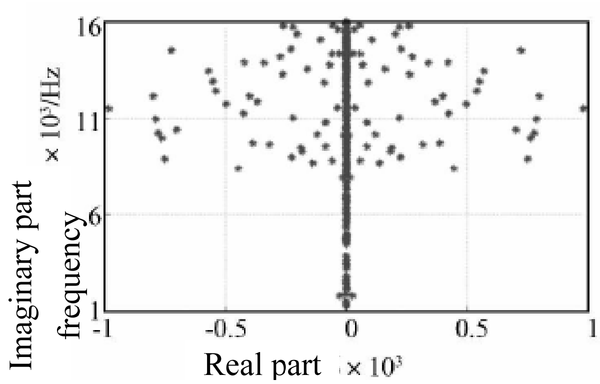


Figure 6 : Complex eigenvalue distribution of complex modal calculation

From Figure 5 and Figure 6, the complex modal analysis used by the experts has two problems, namely: less prediction and over prediction. However, the corresponding model calculation on this basis, has relatively small error, which is in the range of accuracy control standard. It also means that the analysis method is acceptable.

AFFECT FACTOR ANALYSIS

At present, The main analysis on corresponding influence factors of drum brake frictional squeal involves material properties, working conditions and friction characteristics. And on this basis, auxiliary analysis involves friction lining, brake pressure and corresponding parameters[8].

First of all, working condition setting analysis. In the process of corresponding working condition setting analysis, the setting steps are mainly divided into the following:

(1) Simulation working condition transfer speed to 50 r/min, to match the corresponding working condition in experiment.

(2) Take 210、525、1050MPa as corresponding level affect analysis.

(3) For the brake pressure, according to the experimental results, take 0.33、0.66、1MPa for analysis.

(4) In the setting process, the friction coefficient is specially calculated, and take three levels in the experimental results for calculation analysis, i.e., 0.3, 0.4, 0.5.

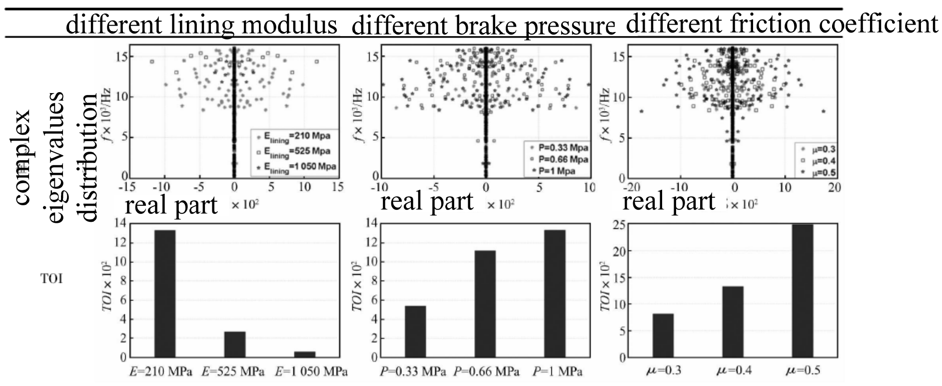
In the calculation of complex modal, level numerical calculation on corresponding affect factors is required. With the correspondingcomplex eigenvalues, perform corresponding calculation on Tendency of Instability, namely Instability Tendency coefficient, the formula is shown below:

$$TOI = \sum_{J} \left(\frac{A_j}{B_j} \times 1000\right), \mathrm{Re}\,al(A_j) > 0 \quad (j = 1, 2, 3, \cdots)$$

In TOI formula calculation, the damping coefficient related concept is shown in the formula. That is to say when the system is in a state of flux, the resulting value is relatively large, and the corresponding squeal tendency will increase, this means that the damping coefficient can assess the possibility of squeal[9].

TOI summary and complex eigenvalues respectively affected by liner modulus, brake pressure and friction coefficient. As shown in TABLE 5.

TABLE 5 : Complex eigenvalue distribution under various levels of affect factors and TOI



(1) As the corresponding numeric in the table, with the young's modulus in the rising stage, the corresponding instable modal numeric will drop precipitously, quantity will be affected thereby, and the real part of unstable complex eigenvalue will decrease, thus reducing the squeal tendency.

(2) For brake pressure, as the pressure rising, the modal number will increase its instability, and under the influence of instability, squeal numeric will rise, increasing the corresponding real part, thus increasing the squeal tendency.

(3) The corresponding friction coefficient in the table has direct effect on modal number. It will change with the numeric. And when the coefficient rises, the corresponding squeal number will increase, making the real part increase accordingly, thereby increasing the TOI, thus increasing the squeal tendency.

INFLUENCE MECHANISM ANALYSIS ON THE SQUEAL

For the influence mechanism, it is almost free from the affect factors. This study is based on contact pressure distribution. It arrange corresponding influence mechanism, unifying it into corresponding pressure distribution.

Therefore, the max affect of friction lining on the corresponding contact pressure appears on the peak. It will increase with the increasing of elastic modulus, and the corresponding contact area will decrease. Under the basis, it has small affect on the center position, which is basically unchanged.

In the process of brake pressure increasing, it will affect the pressure peak on the corresponding leading and trailing shoes linings. In the process of increasing, it will increase the peak of the corresponding contact pressure. Of course, the contact center position is quite stable.

In this process, the friction coefficient can has certain influence on corresponding lining, which will produce certain reinforcing effect, making the peak higher, and the contact center will has a certain degree of displacement. At the same time, the friction lining is affected by the own force reduction, leading to minute change on corresponding peak. On this basis pressure peak will be slightly smaller and the pressure distribution center will move in the direction of the force. However, in the process, the contact area will not has obvious change.

In working condition of changing brake pressure, when brake pressure increases, the corresponding peak and contact area of leading and trailing shoes will increase, and the corresponding non-uniform degree of contact pressure will be greatly affected by the increasing of peak, making it increase in the process, thus increasing the corresponding system stability, thus the squeal tendency is relatively small. When contact area increases, non-uniform degree of contact pressure will constantly decrease, and the system will be relatively stable, thus increasing the squeal tendency. Eventually, making non-uniform degree decrease when contact area is increasing. The corresponding TOI change constantly, thus increasing, the corresponding slope is reducing in the process, because of unstable system, increasing the corresponding squeal tendency[10].

In the corresponding working condition with changing friction coefficient, the coefficient increasing leads to the decreasing of pressure distribution and area change. under the condition of steady non-uniform degree, TOI change is mainly due to the corresponding friction coefficient increasing on the integral elements in area of asymmetry in the process.

CONCLUSION

From above, in the process of the analysis on corresponding affect factors and influence mechanism, this study performs detailed analysis on squeal tendency of corresponding drum brake, and performs comprehensive analysis on the corresponding calculation method, and subtle analysis on the corresponding experiment in this paper. From which, it can be found that at present the study on squeal affect factors and complex modal in China has certain defects. Therefore, in order to promote the industry development, it is necessary to strengthen the corresponding treatment measures and certain research, in order to promote the progress of the society development.

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