Trans. Korean Soc. Mech. Eng. C, Vol. 3, No. 2, pp. 125~130, 2015

<응용기술논문> DOI http://dx.doi.org/10.3795/KSME-C.2015.3.2.125 ISSN 2288-3991(Online)

Simulation Analysis on Flexible Multibody Dynamics of Drum Brake System of a Vehicle

Liu Yi* and Hu Wen-Zhuan**

* Jiangsu University School of Automotive and Traffic Engineering, Zhenjiang, 212013, Jiangsu Province, P. R. China
** Jiangsu Nanfang Bearing Co., Ltd,Wunjin ,213161, Jiangsu Province P.R.China

(Received February 16, 2015 ; Revised March 31 2015 ; Accepted April 10, 2015)

Key Words: Flexible Body, Brake Drum, Friction, Dynamic Simulation

Abstract: Using flexible multibody system dynamic method, the rigid-flexible coupling multibody dynamic analysis model of the drum brake system was developed, and the kinematic and dynamic simulation of the system was processed as its object of study. Simulations show that the friction will increase with the dynamic friction coefficient, but high dynamic friction coefficient will cause the abnormal vibration and worsen the stability of the brake system, even the stability of the whole automobile.The modeling of flexible multi-body can effectively analyze and solve complex three-dimensional dynamic subjects of brake system and evaluate brake capability. Further research and study on this basis will result in a convenient and effective solution that can be much helpful to study, design and development of the brake system.

1. Introduction

Modern cars can travel very fast, so good brakes are essential for safety.(1) Practically most modern vehicles have disc brakes on the front wheels, and drum brakes on the rear wheels. The disc brake is a lot like the brakes on a bicycle. Bicycle brakes have a caliper, which squeezes the brake pads against the wheel. In a disc brake, the brake pads squeeze the rotor instead of the wheel, and the force is transmitted hydraulically instead of through a cable. Friction between the pads and the disc slows the disc down. Drum brakes work on the same principle as disc brakes: shoes press against a spinning surface. In this system, that surface is called a drum. In the drum-and-shoe type, there is a wheel brake cylinder with two pistons. When brake pedal is pushed by the driver, brake fluid is forced into the brake cylinder by the action at the master cylinder, and the two pistons are forced outward. This causes the curved brake shoes to move into contact with the brake drum. The brake shoes apply friction to the brake drum, forcing it and wheel to slow or stop.

Two kinds of brake system in braking both can produce noise.According to the mechanism of generation, brake noise can be classified into three types.(1~3) The first type is called creep-groan, which is caused by the stick-slip motion . The second type of noise is often called hot judder or rumble, which is caused by periodic features on the rotor surface that result in cyclic brake torques between the friction material and the rotor surface. The third type of noise is usually called squeal. Noise with a dominant frequency over 1 kHz generally belongs to this category.

Prediction of vehicle drum brake roughness noise is a meaningful work.In fact, neither the source mechanisms, nor the transfer paths are so far well understood. Traditionally, drum brake noise problems are studied as part of the friction-induced noise field, where the source is considered to be a more or less local phenomenon related to the brake drum and brake shoes. However, for the roughness noise of interest here this viewpoint is not adequate when attempting to solve the interior noise problem since the transfer of vibro-energy from the brake into the vehicle body is a crucial aspect and plays an important role in the understanding and solution to the problem.(4,5) The vibro-acoustic energy transfer associated with the brake roughness noise is a problem where geometrical complexity and material combinations, including rubber bushings, pose anintricate modelling problem. Additionally, system altering effects from moving parts and loadings are important, e.g. due to the steering or brake systems. In addition,the source mechanisms themselves must also be understood to be able to solve

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† Corresponding Author, liuyixbjd@163.com, Tel.: +8618306122636

the problem. The current work constitutes a combined experimental and theoretical inves-tigation, aiming at an increased understanding of the source, the transfer paths and how they are effected by change in the operational state.

Previous studies of brake noise using multibody dynamics simulation have replicated the fundamental characteristics of brake and provided a means for countermeasure development. A key to simulation of a sustained signal was noted to be the flexible characteristics of suspension components such as the axle tube and shaft.(6,7) These were accounted for in crude fashion using beam elements within the multibody dynamic model. In order to achieve a higher degree of correlation between simulated and experimental brake moan on a brake with a more complex suspension, many studies have developed an approach combining flexible bodies from some finite element analysis software(For instance,NASTRAN and ANSYS) with some dynamics simulation software(For instance,ADAMS and RecurDyn) model and applied it to a selected brake system which exhibited noise.

The goal of this effort was to create a multibody dynamic model of the drum brake system which accurately simulated brake noise. In the future, this model can be used to further study this phenomenon, to test and design potential countermeasures, and can serve as a template for quickly developing models of future designs for predictive analysis.

2. Multi-body Modeling

A model configuration consisting of certain left-rear brake and rotor mounted on a rear suspension was chosen based on prior experimental work((Fig. 1)). It had been determined experimentally that the noise vibration could be significantly reduced with certain modifications, including changing the properties of the suspension tie blade – also commonly referred to as the “trailing arm.” A stiffening rib stamped into this member significantly decreased the noise vibration. Furthermore, noise was only observed on an actual vehicle, not in any simplified test bench configurations without chassis components. This suggested that modeling the suspension, specifically the tie blade, would be needed to replicate the moan behavior in the multibody dynamic model.

A coupling dynamic model was developed through combining rigid dynamic with flexible dynamic theories. Considering the high flexibility of the friction lining and wheel drum,it was modeled as a multi-flexible-body subsystem. whereas the drum brake as a muiti-rigid body system .the modeling procedure includes three steps: fristly, a muit-rigid body dynamic model for the drum brake is formed with Lagrange method; secondly, a multi-flexible body dynamics model of is built; thirdly, the multi-rigid body model drum brake model and the multi-flexible body model of the system are coupled through grasping boundary coupling or roiling contact coupling condition.

All parts in the brake and suspension system were modeled as rigid bodies, with the exception of the tie blade. As mentioned above, the bending characteristics of the tie blade were previously known to play a key role in the noise vibration; therefore, it was represented as a flexible body.

RecurDyn is Computer Aided Engineering (CAE) software that is focused on Multibody Dynamics (MBD), while offering multiphysics solutions. The technology behind RecurDyn has superior calculation efficiency because it is based on recursive formulation. Because of this, RecurDyn gives the best performance in large-scale multibody problems (systems with a large number of bodies), including mechanical systems that experience a lot of contact. Solid model(which were built

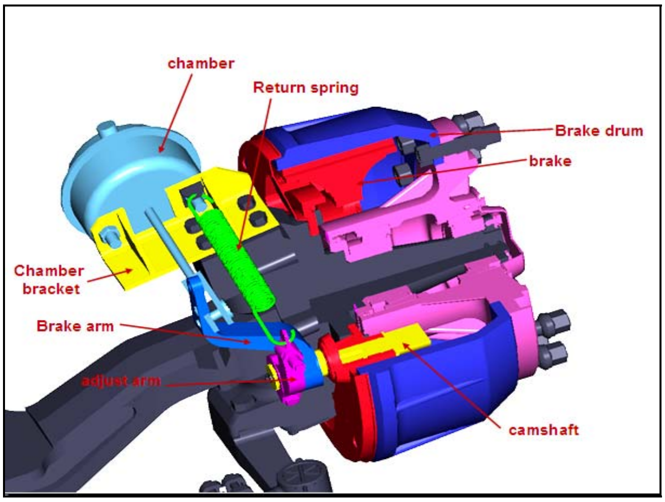

Fig. 1 The component of brake system

3D CAD design software SolidWorks) of the drum brake components was the source of much of the input data to the multi-body dynamic model, as it provided accurate geometric and mass properties. It included the anchor plate, caliper, inner and outer shoes, locking pin, and the rotor. This model was imported to RecurDyn via the interface, which creates RecurDyn parts for each of the components contained in the solid model. In the multi-body dynamic model, initially each part is floating freely in space. These parts were then constrained in the model, first by kinematic joints, and then by compliant elements such as forces, bushings, and springs(Fig. 2).

3. Simulation Results and Analysis

Fig. 3 shows that the deformation of the drum wheel in time 0.162s from the multi-body dynamics simulation; Fig. 4 shows that the stress distribution of the drum wheel in time 0.09s from the multi-body dynamics simulation.

The friction coefficient is one of the most critical parameters that have significant influence on squeal generation. As predicted in the complex eigenvalue analysis, higher friction coefficients always tend to facilitate two modes merging to form an unstable complex mode. As the friction coefficient further increases, real parts of eigenvalues, the values that can be used to gauge the degree of instability of a complex mode, increase further, as well, and more unstable modes may emerge.

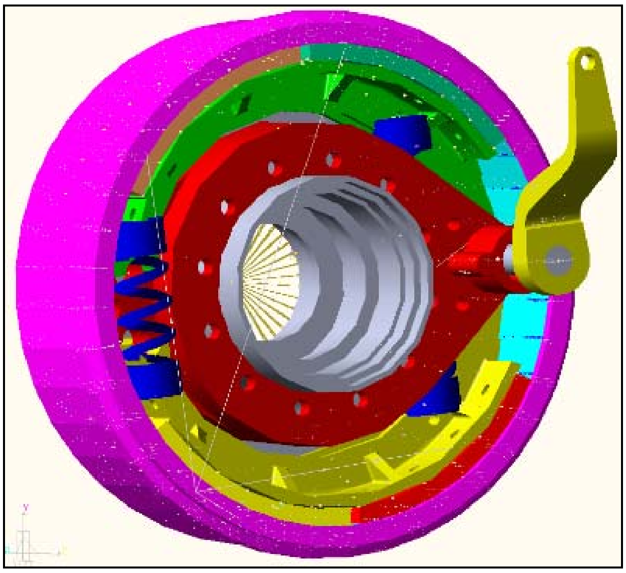

Fig. 2 Virtual prototyping of the brake system

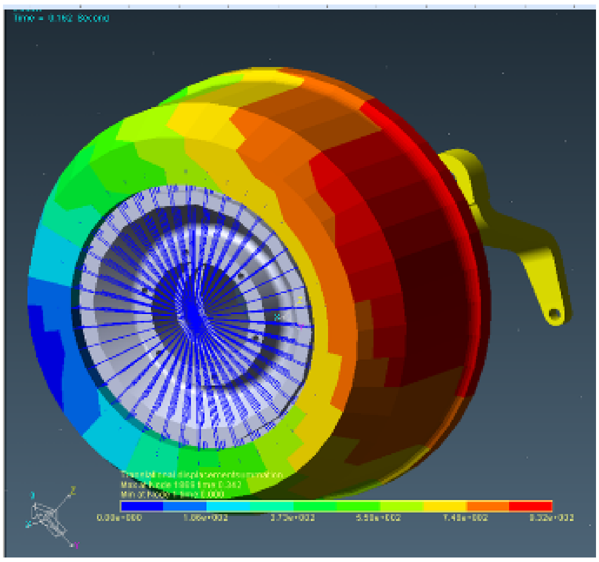

Fig. 3 The deformation of the drum

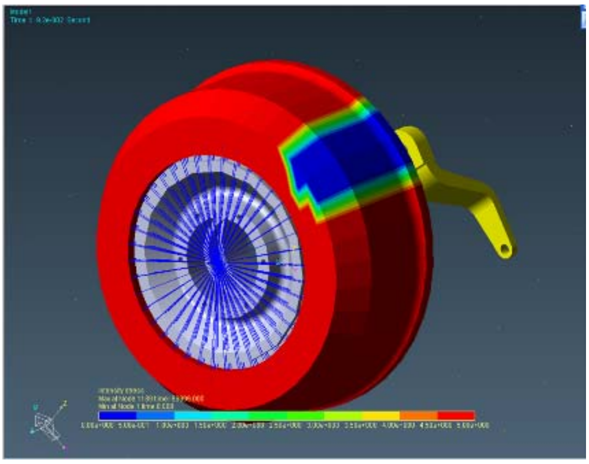

Fig. 4 The stress distribution of the drum

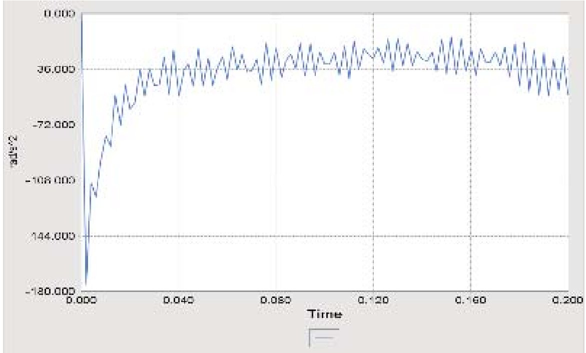

Fig.5 Angle acceleration of the wheel

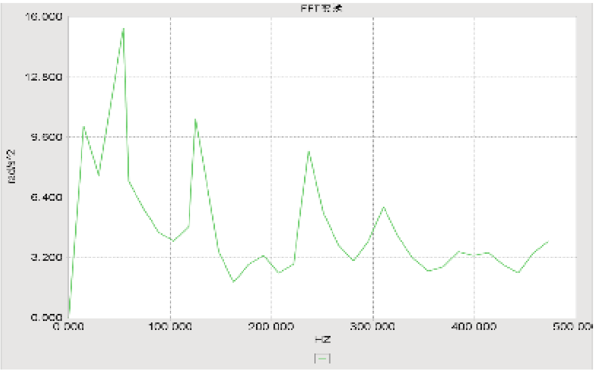

Fig.6 Frequency-domain angle acceleration

Fig. 5 and 6 shows a time history(0.4s) and corresponding frequency-domain plot angle acceleration of the wheel from the multi-body dynamics simulation(friction coefficient is 0.34).

Fig. 7. and 8 shows a time history(0.4s) and corresponding frequency-domain plot angle acceleration of the wheel from the multi-body dynamics simulation(friction coefficient is 0.42).

As a result of dynamical simulation and analysis of the flexible multibody models, we have some conclusions: The friction increase along with the dynamic friction coefficient. But there will be great instantaneous amplitude that would cause vibration of brake system and worsen the stability. On the contrary, with a lower dynamic friction coefficient, the vibration will be restrained but the capacity of brake system will be too low. When selecting brake shoe, the dynamic friction coefficient must fulfill the request of both brake capability and stability.

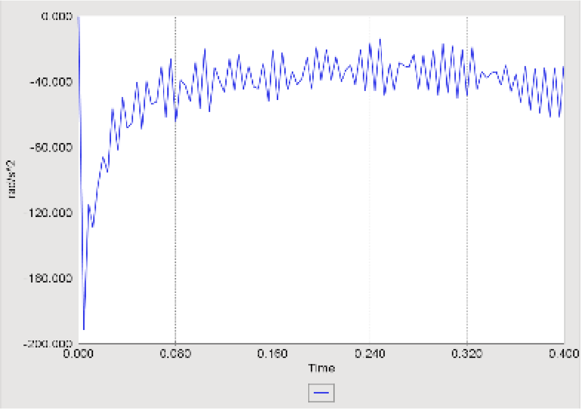

Fig.7 Angle acceleration of the wheel

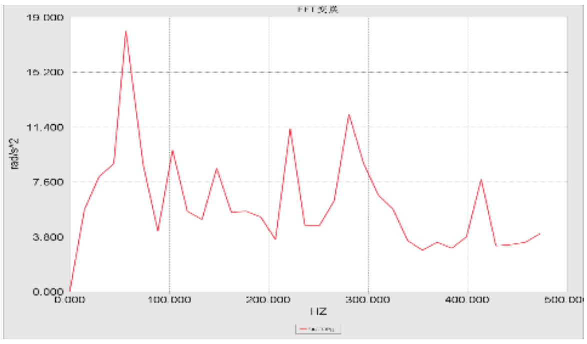

Fig.8 Frequency-domain angle acceleration

For further analysis we can get conclusion: to increase self-lock angle of the brake shoe or decrease the cover angle will lower the brake capability and the selection also should fulfill the request of both brake capability and stability. At the same time, it should pay attention on precision of production and assemble.

4. Summary and Conclusions

The objective of this paper is to build the drum brake model of a commercial vehicle and examine its dynamic behavior by using MBS methods becoming important steps of virtual prototyping adapted in the automotive industry. The usage of multi-body dynamics simulation afforded the possibility to expedite parametric case studies by using flexible bodies only where needed.

The flexible multi-body model of the brake system not only concerns the flexibility deformation of the components of the brake system, but also concerns the influence of moment of inertia of the rotating components of the automobile. Add the equivalent moment inertia to the brake disc, if not the simulation will be badly distorted.

The comprehensive validation procedure previously discussed created confidence in the model’s ability to represent the noise phenomenon. The model reasonably replicated the moan signal. Furthermore, it responded similarly to physical test experience when subjected to known countermeasures and system input variation.

The successfully validated model has already been used to explore the independent effects of certain system parameters on the noise signal. It will serve as a useful tool for continuing investigation of brake noise on this particular platform. Specifically, parameters and combinations of parameters that most directly influence the phenomenon and appropriate countermeasures will be studied. This technology will be used hand-in-hand with work in physical test labs. Often, discoveries or insight gained through one method can be expanded upon or validated in the other. Furthermore, experience in modeling flexibility with finite element analysis is vast and proven. It is extremely useful to have a tool that allows the engineer to quickly combine these methods with multi-body dynamic models.

Acknowledgment

The authors gratefully acknowledge the China Postdoctoral Science Foundation funded project (No. 2012M521003) and the National Basic Research Program of China (973 Program) (No. 2014CB049401) for financial support of this research work.

References

(1) Abdelhamid, M.K., 2001, :An overview of Brake Noise and Vibration Problems, Proc. of IMAC-XIX, pp. 57-61,Kissimee, Florida, Feb. 5-8.

(2) Gugino, A., Janevic, J. and Fecske, L., 2000, Brake Moan Simulation Using Flexible Methods in Multibody Dynamics, Proc. SAE Brake Colloqium 2000, SAE Paper 2000-01-2769, 99-104.

(3) Ouyang, H., Cao, Q., Mottershead, J.E. and Treyde, T., 2004, "Predicting Disc Brake Squeal Frequencies Using Two Distinct Approaches," *Proceedings of the 22nd Int. Modal Analysis Conference (CD-ROM*), Society for Experimental Mechanics.

(4) Glocker, C. and Studer, C., 2005, "Formulation and Preparation for Numerical Evaluation of Linear Complementarity Ssystems in dynamics," Multibody System Dynamics 13, pp. 447~463.

(5) Harsha, S. P., Sandeep, K. and Prakash, R.,"Nonlinear Dynamic Response of a Rotor Bearing system due to surface waviness," *Nonlinear Dynamics* 37(2), 2004, 91~114.

(6) Schell, J., Johansmann, M., Schussler, M. and Oliver, D., Three Dimensional Vibration Testing in Automotive Applications Utilizing a New Non-Contact Scanning Method, SAE Paper, No. 2006-01-1095.

(7) Krupka, R. and Ettemeyer, A., 2001, "Brake Vibration Analysis with Three-Dimensional Pulsed ESPI, Experimental Techniques, Vol. 25, No. 2, pp.38~41.

Liu Yi, Graduated from the Northwestern Polytechnical University (NPU) of the school of mechanical engineering, China in 2011 and earned a Doctor's degree in mechanical design and theory. The main research direction is modern mechanical design method.