Modal Coupling Analysis of Brake Discs

Hung-Tse Chiang¹, Han-Ming Chen¹, Yung-Tai Lin¹ and Chang-Sheng Lin¹*

¹ Department of Vehicle Engineering, National Pingtung University of Science and Technology, Pingtung, Taiwan
*changsheng@mail.npust.edu.tw

Abstract. The topic of this paper is to investigate the causes of squeal under the operation of brake systems. We firstly confirm the validity of the finite element model through experimental modal analysis (EMA) for actual a brake disc and linings, and also verify the agreement with value of modal assurance criterion (MAC) between the mode shapes obtained from finite element analysis and EMA. Furthermore, we evaluate the possibility of squeal for various parameters of brake system, and also estimate the frequency and stability of modal coupling to the brake disc under consideration.

Introduction. The disc brake system uses hydraulic pressure to push the piston, and the linings can then be clamped to the discs. The friction material of linings is rubbed against the disc to reduce the speed of the vehicle, noise and vibration may be, however, generated during the operation. The relatively high frequency noise (Squeal) generated under braking operation occurs in the range of about 1,000 to 20,000 Hz. Du and Wang [1] demonstrated that the mode-merging induced by the friction coupling is the major mechanism for brake squeal when treating the modal coupling analysis as a self-excited vibration issue. Kang et al. [2] described the mode-coupling-type squeal mechanism in a disc brake system. The mode shapes of a disc and a brake pad can be obtained respectively by using the component eigenvalue analysis and the Rayleigh–Ritz method. In addition, Yuan [3] presented noise indices versus frequencies because the system eigenvalues with positive real parts obtained from the numerical analysis indicate possible squeal frequencies in practice.

Metrology. In this paper, we investigate the causes of squeal under the operation of brake systems. It has been shown in a previous study that the squeal is usually caused by unstable oscillation modes from a system. Based on the finite element analysis (FEA), through the Workbench function in the procedure of ANSYS for an automotive brake disc and linings, the modal parameters of a disc brake can be determined by using the modal and harmonic analysis. In addition, through ME'Scope commercial software, modal estimation of the brake disc can be carried out in EMA. We also verify the agreement with value of MAC between the mode shapes obtained from FEA and EMA. Furthermore, we evaluate the possibility of squeal for various parameters of brake system, including the thickness of brake lining, piston pressure, and friction coefficient, and also estimate the frequency and stability of modal coupling to the brake disc under consideration.

Result. Thought the simulation results of modal coupling, we observe that some modal coupling frequencies are separated after coupling, which may be due to material damping and friction force of linings, as shown in Fig.1. In addition, for various lining thickness and piston pressure, noise index [3] is more sensitive to the variety of piston pressure than lining thickness, as shown in Fig.2.

Conclusion. Through the simulation verification, some conclusions drawn from the results as follows:

[1] From simulation results, we could observe that some modal coupling frequencies would be separated after coupling, which may be because of material damping and friction coefficient between lining pads and disc.

[2] For the various parameters of a brake system, including the thickness of lining pad and piston pressure, it can be observed that the noise index is more sensitive to the variety of piston pressure than lining thickness.

Reference.

[1] Y. C. Du, and Y. J. Wang, "Squeal Analysis of a Model-Parameter-Based Rotating Disc Brake Model," International Journal of Mechanical Sciences, Vol.131-132, pp.1049-1060, 2017.

[2] J. Y. Kang, C. M. Krousgrill, and F. Sadeghis, "Analytical Formulation of Mode-Coupling Instability in Disc-Pad Coupled System," International Journal of Mechanical Sciences, Vol.51, pp. 52-63, 2009.

[3] Y. Yuan, “A study of the Effect of Negative Friction Speed Slope on Brake Squeal,” Proceedings of the ASME Design Engineering Technical Conference, vol. 3, part A, pp. 1135-1162, 1995.