

Vibration Behavior Analysis of Tire Bending Mode Exciting Lateral Axial Forces

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ABSTRACT

The demand to reduce noise in the passenger cars is increasing. Tire vibration characteristics must be considered when studying road noise because of the strong interaction between tire vibration characteristics and interior car noise. Car manufacturers are keenly interested in studies on the prediction of NVH (Noise, Vibration and Harshness) performance, including viewing tires as substructure. Recently, studies have illustrated the effect that tire lateral bending mode have has on road noise, while most past studies of tire vibration focused on the circumference mode, which excited the vertical spindle force. Therefore, further study of tire lateral bending mode is necessary.

Modeling of the tire lateral bending mode is described in this paper. First, lateral spindle force is measured under tire rolling conditions. Second, experimental modal analysis is performed to grasp tire lateral bending mode. Finally, a tire vibration model is built using the cylindrical shell theory.

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INTRODUCTION

To tackle noise reduction, it is necessary to counter each noise and vibration sources. Road noise, which occurs in the low frequency range, is one of the main interior noises of passenger cars. Reducing the noise level of road noise is a high priority. Road noise is excited by tire vibration due to road roughness. Therefore, there is a high correlation between tire vibration characteristics and the interior noise of passenger cars. Studying tire vibration characteristics is essential for the reduction of interior noise.

Early research on tire vibration characteristics for road noise focused primarily on the circumference mode because this mode is dominant in vertical spindle force [1]. However, recent study of NVH (Noise, Vibration and Harshness) prediction, including tires as car substructure, found that not only the circumference mode, but also the lateral bending mode affect interior noise [2]. Vibration characteristics of the lateral bending mode have not been clarified. Therefore, understanding the effect of the lateral bending mode is essential to noise reduction.

This paper describes the effect of the lateral bending mode on spindle force and modeling of the lateral bending mode. First, lateral spindle force was measured under tire

rolling conditions, which clarifies the characteristics of lateral spindle force. Second, an experimental modal analysis was performed to grasp the lateral bending mode. We also analyzed mode shape for modeling. Finally, a tire model for the lateral bending mode was built based on the thin cylindrical shell theory. Since the lateral bending mode considers tread deformation to be an un-extensional deformation assumption, the modeling is simplified and solution of the vibration motion formula is written as a harmonic function. We compared the experimental result, the mode shape, and natural frequency.

VIBRATION CHARACTERISTICS OF LATERAL SPINDLE FORCE

Experimental Outline

The purpose of our experiment is to clarify the interaction of lateral spindle force and the lateral bending mode. In this experiment, lateral spindle force was measured when a rolling tire ran over a projection implanted in the surface of a drum test machine, as shown in [Figure 1](#). This test assumes that input due to the projection is impulse input and the half power point method is applied to the response spectrum for



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identification of natural frequency. The two projection positions are the shoulder and the mediate (the area between the center and the shoulder. See Figure 1). These projections are in the shape of a cylinder with a 10 mm diameter, and were mounted at a height of 1.5, 3.0, and 4.5 mm at the drum surface. The rolling speed was 30km/h and constant.

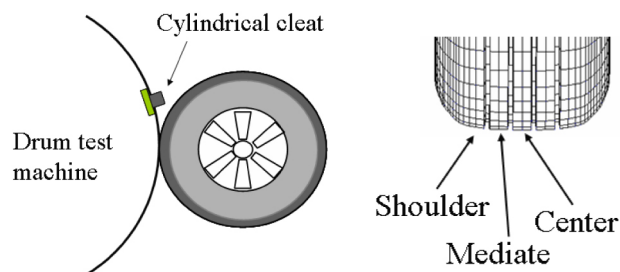


Figure 1. Measuring and test schematic for spindle force

Comparison of Lateral Spindle Force with Various Input Conditions

Spindle forces were measured for cleat positions at each shoulder and mediate. The cleat height was 3.0 mm. Figure 2(a) shows the spindle forces and Figure 2(b) shows the power spectrum density (PSD) of the spindle forces. The blue and red lines show the spindle force from each shoulder and mediate input. The wave shapes are the same and the output amplitude of the shoulder was larger than that of the mediate.

Spindle forces were measured under cleat heights of 1.5, 3.0, and 4.5 mm. The cleat position was at the shoulder. Figure 3(a) shows the spindle forces and Figure 3(b) shows the PSD of the spindle force. The blue and red and black lines show the spindle force due to 1.5, 3.0, and 4.5 mm cleat heights. Output amplitude increases depending on the cleat height. Figure 3(b) has some sharp peaks in range of 40 - 170 Hz range.

In this paper, some modes generating lateral spindle force are defined as the lateral bending mode, as described below:

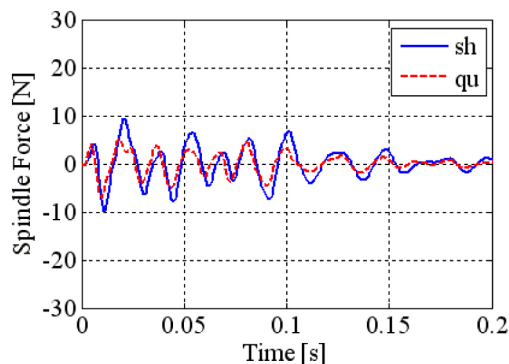


Figure 2(a). Comparison of lateral spindle force between shoulder input and mediate input

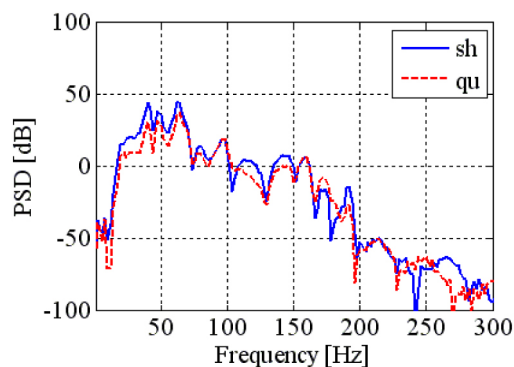


Figure 2(b). Comparison of PSD between shoulder input and mediate input

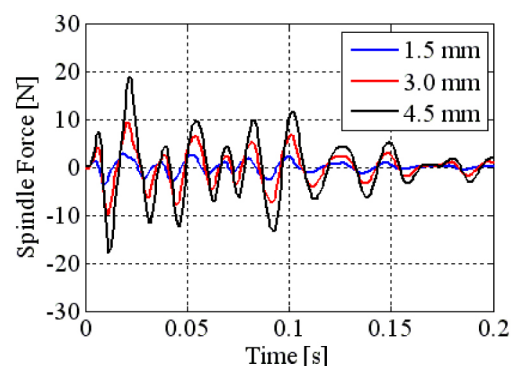


Figure 3(a). Comparison of lateral spindle force between 1.5, 3.0, and 4.5 mm cleat heights

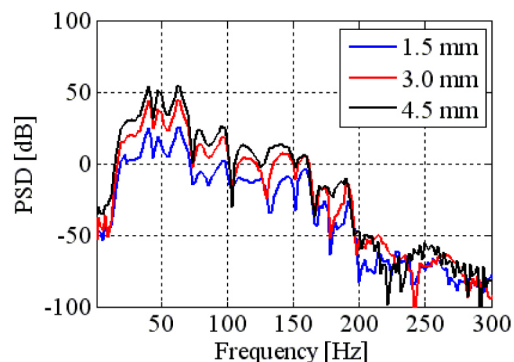


Figure 3(b). Comparison of PSD between 1.5, 3.0, and 4.5 mm cleat heights

VIBRATION CHARACTERISTICS OF LATERAL BENDING MODE

Experimental Outline

Experimental modal analysis was performed under unrolling and unload conditions. Figure 4 shows the test schematic. The response points in the tire radial direction were set on the tread center, both shoulders, and the sidewall in the circumferential direction at every 30 degrees, and the