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PREDICTION OF THE TREAD PATTERN NOISE OF THE QUASI-STATIC STATE ROLLING TYRE

G.-J. Kim, S.-W. Cho, N.-J. Kim

R&D Center, Kumho Industrial Co., LTD, 555, Sochon-Dong, Kwangsan-Gu, 506-040, Kwangju, Republic Of Korea

Tel.: 062-940-2801 / Fax: 062-940-2850 / Email: gjkim@swan.kumho.co.kr

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ABSTRACT
Noise generated by rolling automobile tyres has influences on the ride comfort for passengers. The characteristics of the tyre pattern noise are mainly determined by the tread pattern geometry. It is assumed that tyre pattern noise is generated by the resultant force which is made up of a linear superposition of the force produced by each tread pattern element when it contacts with the road surface. For a more realistic modeling of the resultant force due to the tread pattern, an unevenly distributed contact pressure of a rolling tire is considered. The contact pressure is measured by using the flat bed machine. The simulated results are compared with test results. The predicted accuracy is greatly improved by considering the dynamic contact pressure of the tread element.

1 - TYRE NOISE REDUCTION METHOD
Tyre noise is generated by several mechanisms. With a modern tyre, tyre wall vibration is considered to be important at or below 1 kHz caused by collision between the tread blocks and the road. The general method to reduce tire pattern noise is categorized into two techniques. The first is the method to prevent tyre noise energy from concentrating in a narrow frequency range. This method can be achieved by using variable pitch and arrange them to around the tyre. The second method is to reduce exciting forces itself due to tread block discontinuity along the tyre rotating direction.

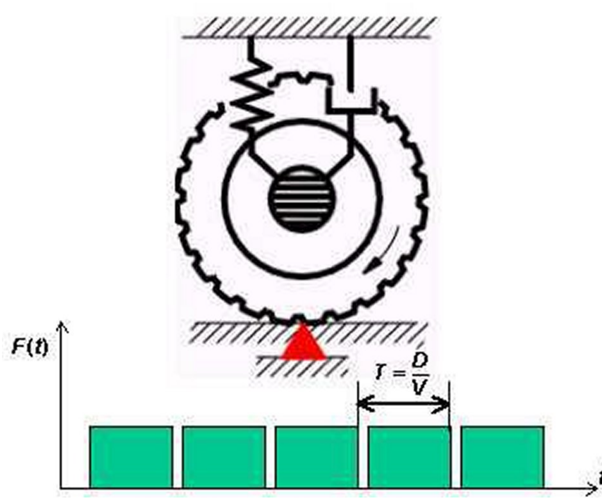

Figure 1: Impact force due to tread pattern profile.

2 - PREDICTION OF STATIC EXCITATION FORCE DUE TO TREAD PATTERN
To predict pattern noise, a proper mathematical model that can explain the tyre/road interaction at the contact area is required. The force acting between a tire and road surface will be the summation of

the vehicle weight and the excitation force due to the interactions. On the smooth road surface, time varying force mainly caused by tread pattern element. When tread blocks contact with road surface, the certain force is generated. On the contrary, when voids or groove contact with road surface, there is no force generated. For the tyre with the right angled groove pattern, the shape of excitation function can be represented as a periodic step function having the same shape of tire outer profile. In the case of more complicated shapes of tread pattern, the force can be obtained from a linear superposition of the force produced by each tread pattern element contacting with the road surface. If the tread pattern is divided into r by s elements for a unit pitch area. The excitation force can be modeled as follows:

$$f\left(t\right)=\sum_{i=1}^{s}\sum_{j=1}^{r}f_{ij}\left(t\right) \tag{1}$$

where f_{ij} is a force function of each element.

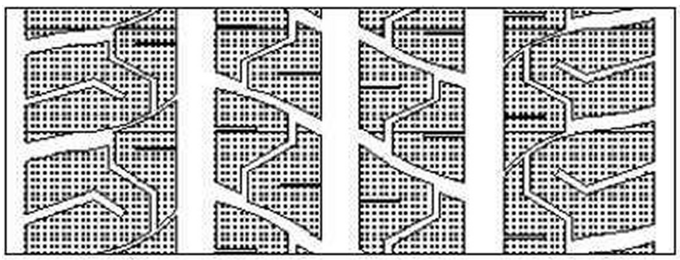

Figure 2: Tread pattern represented by small cells.

3 - DYNAMIC EXCITATION FORCE MODEL

The contact pressure distribution is not even within the contact area. The contact pressure in the edge portion is sometimes larger than that of center parts. Also, the stiffness at the edge of a rubber block is smaller than that of center of a block relatively. To predict tyre excitation force due to tread pattern, these uneven contact pressure distribution should be considered. Suppose that a magnitude of the excitation force for a unit element is proportional to the contact pressure in rolling tyre, then the excitation force can be estimated by following equation.

$$f\left(t\right)=\sum_{i=1}^{s}L_i\sum_{j=1}^{r}f_{ij}\left(t\right)P_{ij} \tag{2}$$

where, P_{ij} is a weighting factor of the pressure distribution along the axis direction and L_{ij} is a dynamic weighting factor for the tractive direction.

4 - MEASUREMENT OF DYNAMIC WEIGHTING FACTOR P_{ij} AND L_{ij}

The pressure distribution along the axial direction can be approximated as the static pressure distribution in case of straight driving condition. The contact pressure of a tire is measured using contact load cells of size 5 by 5(mm). Fig. 3 shows measured result of the 175/70R13 passenger tyre. While, for the tractive direction, contact pressure changes from the leading edge to trailing edge during a tyre rotation. To estimated dynamic contact pressure, the flat bed machine of which moving speed of 1 m/sec is used (Fig. 5). For a sample block, dynamic contact pressure histories of 63 point are measured. The measured results are curve-fitted to get the reference dynamics weighting factor. Fig. 6 is the dynamic pressure distribution along the tractive direction.

5 - ESTIMATION OF DYNAMIC EXCITATION FORCE

The dynamic excitation force wave due to tread pattern can be expressed as a periodic function as follows

$$f\left(t\right)=f\left(t+T\right) \tag{3}$$

where, T is period of tyre rotation. This period function was transform to frequency domain by FFT algorithm for 1024 data points. Fig. 6 shows a resultant spectrum from the equation (1) and Fig. 7 represents a resultant spectrum using the equation (2) which consider dynamic contact pressure. In the Fig. 6, spectrum has the shape of even distribution of excitation energy in first and second harmony

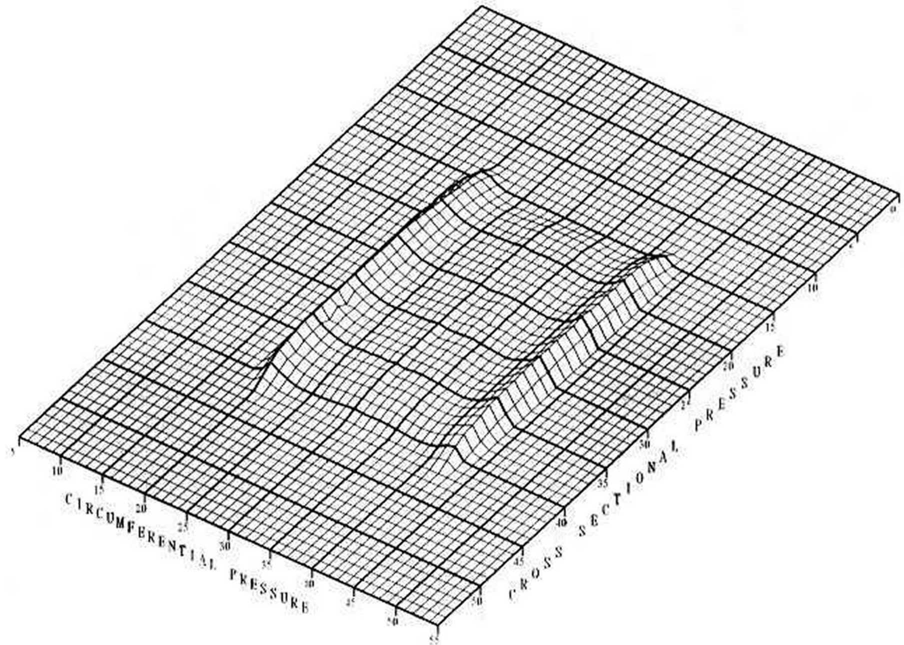

Figure 3: Contact pressure of a passenger tyre.

of tyre rotation, while in Fig. 7 the excitation energy in the first harmony is much larger then second harmony. Fig. 8, the measured noise spectrum in the Lab, shows the same trend with the spectrum of the dynamic excitation estimation.

6 - CONCLUSION

To predict tyre pattern noise, the excitation force is estimated by the linear superposition of the force produced by each tread pattern element when it contacts with the road surface. For a more realistic modeling of the resultant force due to the tread pattern, dynamic contact pressure of a rolling tire is considered. The simulated results are compared with measured result. They show that the prediction accuracy is greatly improved by considering the dynamic contact pressure of the tread element

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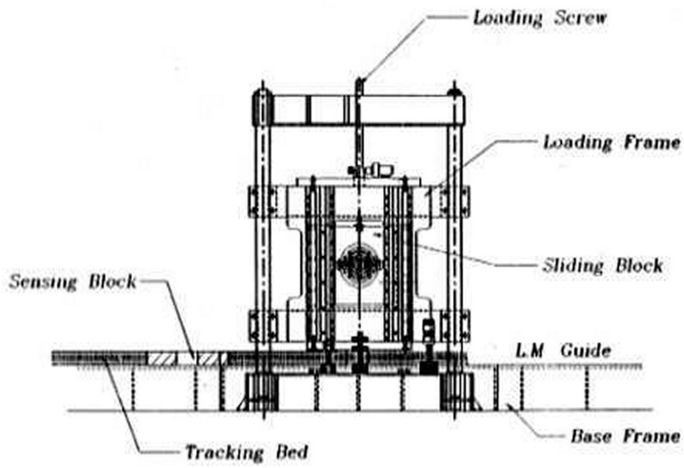

Figure 4: Flat bed machine.

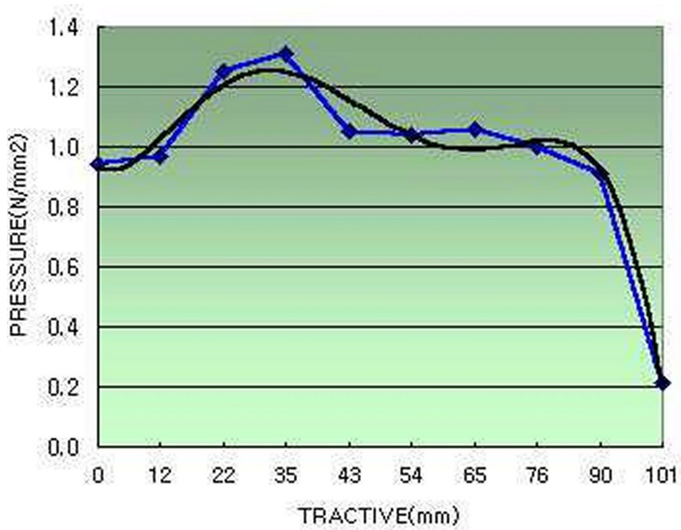

Figure 5: Dynamic contact pressure history in the tractive direction.

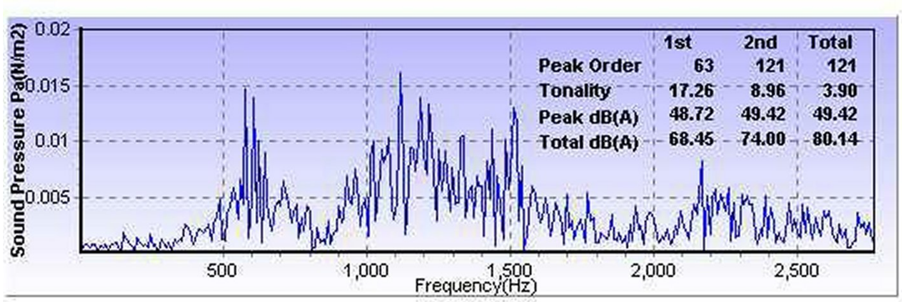

Figure 6: Excitation spectrum with static contact pressure.

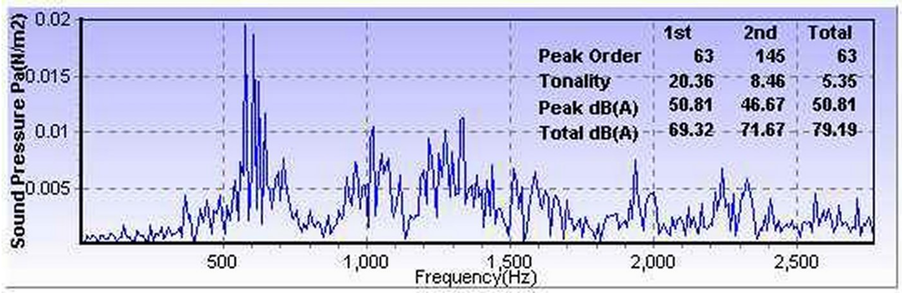

Figure 7: Excitation spectrum taking account into dynamic contact pressure.

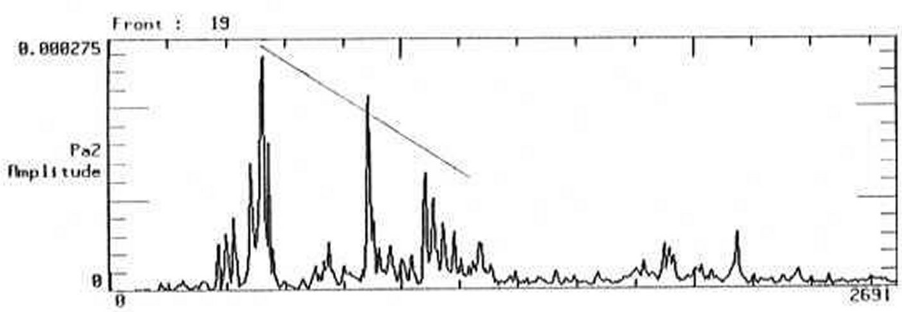

Figure 8: The measurement noise spectrum.