A Study on the Tire Noise

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Abstract

Noise emitted by driving cars affects our daily life, penetrating wherever man lives or works. There are three types of possible sound emitting processes that are aerodynamic sources, air pumping and tire vibration. In this paper, a theoretical model has been studied to describe the sound radiation by the surface vibration of running tires and experimental verification has been conducted to evaluate sound radiation characteristic due to tire vibration.

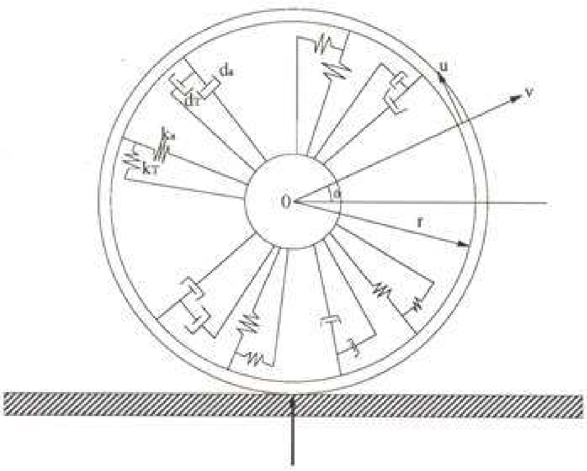
1. Theoretical Background

On analyzing tire, tire has been modeled as a curved beam or ring with distributed springs and damper that represent the radial, tangential stiffness and damping of tire, respectively. For the modeled tire with beam, sound radiation from beams under the action of harmonic moving forces is studied. The reaction due to fluid loading on the vibratory response of the beam is considered. It is assumed that the beam occupies the plane z=0 and is axially infinite. Also, it is assumed that the beam material and elastic foundation is ideal Bernoulli-Euler beam theory including a tensile force, damping coefficient and stiffness of foundation will be employed.

The expression for sound power is integrated numerically and the results examined as a function of Mach number, wave-number ratio and stiffness factor. And in case of the modeled tire with circular ring, through numerical integration of the sound pressure, the radiated sound power is calculated as a function of normalized frequency and structural loss factor. The basic sound radiation mechanism is shown to be the damped progressive wave field on the structure in the vicinity of the applied force. The results indicate that the potential sound reduction could be obtained if optimum values of normalized frequency and structural loss factor are investigated. The vibration characteristics of radial tire are studied. In order to obtain theoretical natural frequency and mode shape, the plane vibration of a tire is modeled to that of circular beam. Modal parameters varying the tire air pressure are determined experimentally by using the transfer function method. In addition, an investigation of the influence of a variety of load on tire and various driving velocities on the vibration characteristics of the radial tire was made. Results show that material properties and wear are parameters for shifting of natural frequency and damping and the increase of side wall stiffness caused by the load on a tire results in the increase of natural frequency of the tire, and the driving velocity of the tire has no influence on the natural frequency.

2. Numerical Analysis

While tire is supported by elastic-damping foundation, tension acts on it and tire is excited by random line forces that move at constant speed, relative sound power due to tire vibration characteristic factor's change is analyzed. Because sound power equation that is derived from theoretical analysis is consist of non-dimensional basic stiffness coefficient, wave number ratio of non-dimensional frequency function, non-dimensional damping coefficient, non-dimensional Mach number and non-dimensional tensile coefficient, relative sound power due to change of these factors is examined. Effect of line forces length that excite tire from road surface is examined.



[Fig. 1] Model for a pneumatic tire

Table 1, 2 is showing material properties of tire used on numerical analysis and excitation power spectrum density due to various road surfaces

[Table 1] Physical properties of tire(P195/65R14)

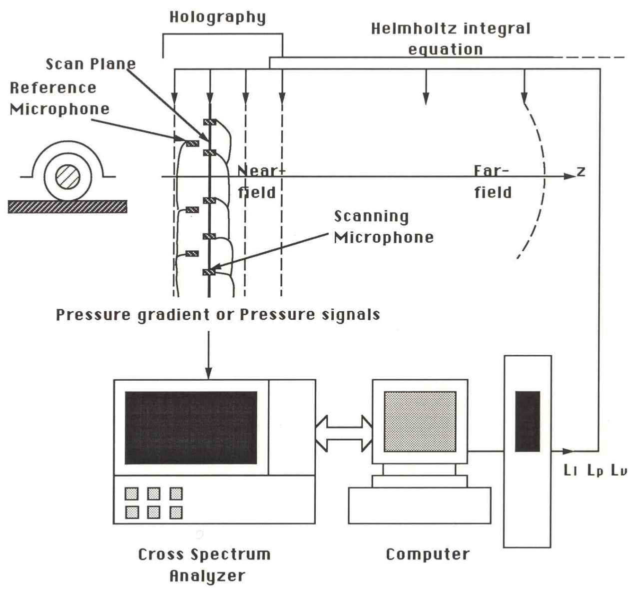
Loss Factor(η)	0.2	
Bending stiffness of the tire(EI)	0.582	N/m^2
Radial stiffness(K)	1.134E5	N/m^2
Radial damping coefficient(C)	20	N/s^2
Tension(T)	368.8	N
Mass of unit length($\sigma_s A$)	1.412	Kg/m

[Table 2] Power of spectral density function for road surface

Description	Power
Smooth runway	3.8
Rough runway	2.1
Smooth highway	2.1
Highway with gravel	2.1
Pasture	1.6
Plowed field	1.6

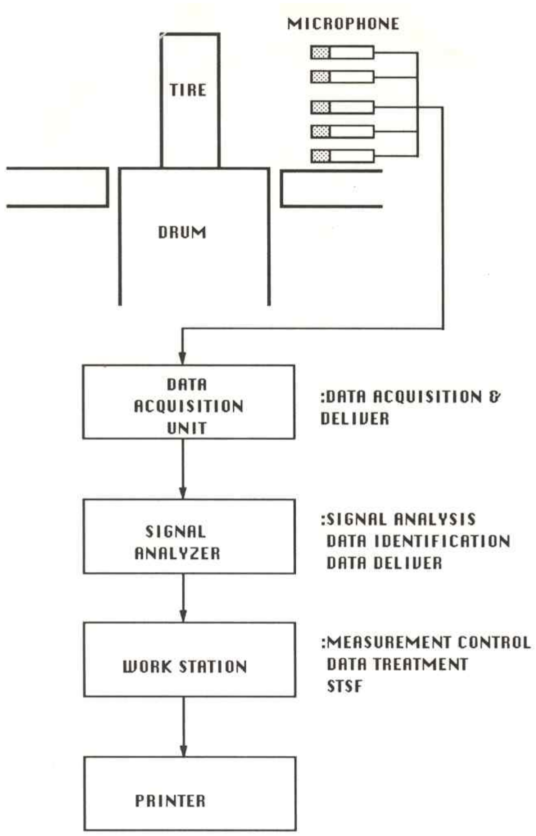
3. Experimental Method and Result

The experimental investigation for the sound radiation of a radial tire has been made. Based on the sound intensity and spatial transformation of sound field techniques, the sound pressure and the sound radiation are measured. It turns out that operation condition in tire, material properties, and design factors of the tire govern the sound radiation characteristics.



[Fig. 2] Principle of STSF

The comparison of numerically analyzed results to experimental results was made separately for the tire both in rotating and static status. In the case of the tire in static status, relative sound power was compared both by the various tensile factors through the fluctuation of tire air pressure and by the various damping factors through the fluctuation of tread material. And in the case of the tire in rotating status, relative sound power caused by the variation of driving velocity and bending stiffness of tread was compared. As a result of this study, a simulation program is intended for being developed fcor the prediction of the tire vibration sound radiation, and that enables a tire designer to foresee the influence of the various design factors on the tire vibration sound radiation



[Fig. 3] Schematic diagram of a tire structural vibration noise test

4. Conclusions

The following conclusion can be made from study of structure-borne noise control of tire that is forced by random move line forces and sound radiation analysis for low noise tire design.

(1) If non-dimensional tension factor that is related to air inflation pressure of tire increases, relative sound power decreased a little bit, and if critical acoustic length that is connected with force that act on tire, relative sound power decreases, also, if wave-number ratio increases in low frequency range, relative sound power increases.

(2) In wave-number ratio zone where exciting frequency connected with running speed of tire is equal to natural frequency of tire, relative sound power increases a lot, and if wave-number ratio increases due to increasing of wave-number ratio, wave-number ratio that generates resonance changes.

(3) Relative sound power decreased as non-dimension damping coefficient connected with physical properties of tire increases, and bending strength and mass of tire tread have effect on relative sound power.

Acknowledgements

This work was supported by grant No.(2010-0023299) from the Basic Research Program of National Research Foundation of Korea

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