Effects of tire lug excitation on dynamic wheel load and vibration of farm tractor

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1. Introduction
The analysis of wheel load and vibration of a moving vehicle is importance for the investigation of tire characteristics as well as for validation of vehicle dynamic simulations. Experiments were conducted to derive wheel loads by strain gage-based transducers arranged on the rear axle of a 2WD tractor driven on asphalt road. In addition, the measurements of accelerations were made at the center rear axle using accelerometers. The experimental results were analyzed to investigate the effects of tire lug excitation on the fluctuations of dynamic wheel loads and tractor vibration.

2. Materials and Methods
The left and right rear wheel load of the tractor are calculated from axle torque and two bending moments of tire vertical reaction and longitudinal forces acting on rear axle measured by two sets of three strain gage-based transducers which are mounted on rear axle between case and flange. A triaxial accelerometer was used to measure the bounce, roll and pitch accelerations of rear axle center under driver’s seat. Tractor velocity, tire slip and drawbar pull were measured by two photo switches and reflective tapes attached on the rim of front and rear wheels, and a load cell. The experiments were conducted on asphalt road at steady straightforward condition at tractor speed range of 0.5-0.7m/s with different tractor operations (pulled, self-propel and pulling), two combinations of tire pressure. The measured data were sampled at rate of 200Hz with a 30Hz low-pass filter by a data acquisition system and analyzed in frequency and time domain by discrete Fourier transform and Wavelet coefficients selection.

3. Results and Discussions
The experimental result indicated that the dynamic wheel load and accelerations fluctuated in different magnitudes depending on tractor operation, and tire parameters (Fig.1). The dynamic load transfer between left and right rear wheel has been clearly seen. The frequency compositions of force and acceleration revealed that high spectral amplitudes occurred at the basis frequencies such as the first order frequency of the wheel, the first and second order frequencies \( f_1 \) and \( f_2 \) of tire lug, which are produced respectively by mutual and successive lugs, lug phase difference frequency between left and right tire, and engine firing frequencies. For dynamic wheel load, the predominant excitation frequencies are caused by tire lug and tire non-uniformity, while tractor vibration are mainly excited by engine firing frequencies.

From the spectral analysis, the dominant excitation of wheel load is the \( f_1 \) for high inflation pressure tire, and is the \( f_2 \) for low pressure tire during the pulled tests. Inversely, the significant excitation frequencies of wheel load are \( f_2 \) and \( f_1 \) respectively, for high and low pressure tire during self-propel and pulling tests. This is because of different tire contact area with ground as well tire slip. Furthermore, the lug frequencies slightly excited the pitch acceleration of the center of front and rear axle, but caused resonances in bounce and roll accelerations of rear axle center.

The multiresolution of measured signals was conducted by Wavelet coefficients selection method. The original signals were decomposed into 5 levels using db4 wavelet. The time histories of measured data were reconstructed from wavelet coefficients of each level in order to investigate the effects of tire characteristics on dynamic wheel load and tractor vibration in time domain. The synthesized data provided intuitive vision of periodic fluctuation of wheel load and tractor vibration due to tire lug excitation.

4. Conclusions
The tire lugs cause considerable excitation of dynamic wheel load and tractor vibration. Data analysis shows two significant frequency ranges caused by mutual lugs and successive lugs in the ground contact area. The excitation level depends on tractor operation, tire inflation pressure as well as tire slip.

Fig.1. Time and frequency histories of measured wheel load and accelerations in one rotation during pulled test at 0.7m/s with 330kPa tire inflation pressure