Analysis of normal and tangential forces on agricultural tire lug

Summary

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The objective of this study was to improve the performance of an agricultural tire by designing the shape of the tire lug.

Firstly, pressure sensors were mounted in the leading and the trailing lug sides, and tri-axial force transducers were mounted in the lug faces of a small agricultural drive tire to find out the function of each lug surface under positive and negative slippage. Secondly, result of agricultural drive tire experiment under positive slippage was verified with two types of transducers of wheel axis type and a three-surfaced lug type, respectively. Finally, two types of transducers also verified the result of agricultural drive tire experiment under negative slippage.

An important element in designing the shape of a tire lug is an understanding of how reaction forces on the surfaces of a lug influence wheel performance.

Chapter 2

In this chapter, a small agricultural drive tire which is often used in the Asian agriculture was used for experiment to determine the forces between the lug surfaces and the soil. Pressure sensors were mounted in the leading and the trailing lug sides, and tri-axial force transducers were mounted in the lug faces of a small agricultural drive tire to find out the function of each lug surface. Experiments were conducted under positive slippage when the tire was mounted on one tractor which was working with a plow, and under negative slippage when the tire was mounted on one tractor which was working with a rotary tiller. Experiments were conducted in an indoor soil bin (length 11000 mm, width 850 mm, depth 450 mm) that contains loam. Slippage were set to -10%, 10% and 20%. Inflation pressures were set to 0.4 kgf/cm^2, 0.8 kgf/cm^2 and 1.2 kgf/cm^2.

When slippage was 10%, the contact pressures were measured on only the lug face. Thus, the friction on a lug face is producing the net traction. When slippage was 20%, the contact forces were detected on the lug face and the leading lug side of the lug, but were not detected on trailing lug side. Thus, when the slippage is a relatively large positive value, the longitudinal force applied by the soil to the tire is in the forward direction, as would occur when a tractor is used for a plowing operation. When slippage was -10%, contact pressures were detected on a lug face and a trailing lug side, but were not detected on a leading lug side of the lug.

Thus, the longitudinal force applied by the soil to the tire is in the rearward direction, similar to a braking force, as would occur when a tractor is used with a rotary tiller of down cut operation. The motion resistance and the braking force of resultant forces were measured with the tri-axial force transducer at the center of a lug face. Results show the same tendency as what was measured with the axis transducer on tire axis of rotation.

Chapter 3

The purpose of this chapter is to clarify the relationships between the forces on lug surfaces and the soil reactions under positive slippage. Transducers of the three-surfaced lug type which can measure normal and tangential forces on each surface were used. The horizontal and vertical forces were calculated by the results of experiments. The basic structure of the transducers combination of cantilever, a fixed beam and an L-shape beam. The measuring principles of the devices using strain gauges were also discussed. The rigid model wheels which designed for five types of lug shape were used in this experiment. They were designed for the same vertical projection area but different by the angles of installation of the lug sides. Five types of lug were named the lug A ~ lug E. Lug A was designed symmetry for leading and trailing lug sides. The trailing lug side of lug B and lug C were designed perpendicular to the lug face. A lug face of lug B is longer than lug face of lug C. Lug D and lug E were obtained by using lug B and lug C in opposite directions, respectively. Experiments were conducted in the slip control system for changing the slippage of wheel. Slippage is adjusted by selecting the carriage speed by changing the gear ratio of the transmission. The travel speed of a tire at no load is set to 0.07 m/s. Slippage were set to 10% and 20%.

When the slippage was 10%, positive forces were measured on a lug face and a leading side of all types of lugs. The negative forces were measured on the trailing lug side of lug E and lug A. The negative forces was motion resistance, which prevents a tractor from running forward. There were no reactions on trailing lug sides of lug C and lug B.

Tractions were measured by wheel axis transducer. When the slippage was

10%, the maximum of traction was 320 N by lug C and the minimum of traction was 223 N by lug E. This shows that motion resistance may decrease if the angle of installation of the trailing lug side becomes small. The traction performance of wheel can be improved by using a lug designed as lug C shape.

Chapter 4

The purpose of this chapter is to clarify the relationships between the forces on lug surfaces and the soil reactions under negative slippage. The experimental device used in this chapter is the same as in chapter 3. Slippage is adjusted by selecting the carriage speed by changing the gear ratio of the transmission. The travel speed of a tire at no load is set to 0.07 m/s. Slippage were set to -10% and -5%.

When the slippage was -10%, negative forces were measured on a lug face and a trailing lug side of all types of lug. There was no reaction on leading lug side. The reaction on trailing lug side of lug B and lug C were smaller than lug A and lug E. The negative forces were braking forces and the maximum of braking force measured by wheel axis transducer was 400 N by lug E. The minimum of braking force measured was 328 N by lug B. This shows that braking force may increase if the angle of installation of the trailing lug side becomes large. The braking performance of wheel can be improved by using a lug designed as lug E shape.

Five types of trial lugs were used in the experiments to prove the theories for the installation angle of the trailing lug side. Lug B produced very little motion resistance and larger net traction, and Lug E produced larger barking force. This means that the design theories are proved to be reasonable.