LOAD CHARACTERISTICS OF ROTARY OPERATION BY TRACTOR IN WET PADDY FIELDS

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ABSTRACT

The torque loads were measured at the input shaft of the transmission and driving shaft of the tractor having a cage wheel attached to the driving tires as a traction aid during a rotavating operation in wet paddy fields with deep hardpan. Their load spectra were also calculated. Effects of design parameters of the cage wheel on the load characteristics were analyzed. The torque load exerted on the input shaft decreased as diameter of the cage wheel increased and increased as the rotating speed of the rotavator increased. The torque load exerted on the driving shaft increased as the working speed of the tractor increased and decreased as the PTO speed increased. Both the torque loads with the cage wheel were greater than those without the cage wheel. The cage wheel was developed for this study

Key Word : Work loads, Rotary operation, Tractor, Wet paddy field.

INTRODUCTION

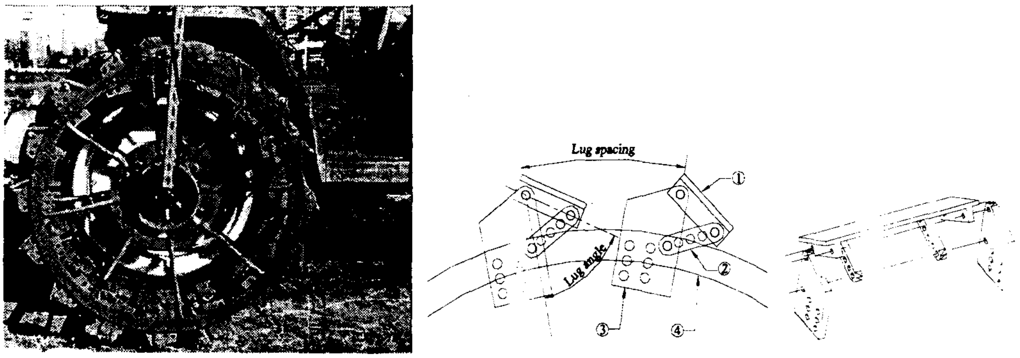
The load characteristics of tractor operations must be considered when designing a transmission of tractors and conducting reliability tests or evaluation of fatigue life of tractors. Therefore, understanding of the load characteristics of tractor operations is very important. One of the previous works dealt with the measurement and analysis of work loads of agricultural tractors was made by Kim et. al[4]. He intended to develop the load spectra of the transmission and final drive shaft for plowing operations. The work loads were measured respectively at the input shaft of the transmission and at the final drive shaft of the tractor under five field conditions. The torque loads acting on the input shaft of the transmission during plowing, rotavating and transporting operations were also measured and analyzed by Kim et. al[3]. He also surveyed the operational speeds and transmission gears most frequently used for each operation. Han[2] measured the work loads acting on the transmission during rotavating operation in poorly drained paddy fields and compared its severeness with that measured in different field conditions.

This study was conducted to investigate the load characteristics of rotavating operations in wet paddy field condition by a tractor with cage wheels attached to driving tires as a traction aid. Soil of the paddy field was soft sandy clay loam and depth of its hardpan was 30-40 cm, about twice deeper than the normal condition. Such field conditions caused deep sinkage, high rolling resistance and large slippage of the diriving tires, resulting in a heavy work load. The cage wheel affected positively the work performance of rotavating operation by increasing the width of driving wheels and reducing their sinkages.

Kim et. al[3] reported that the severeness of work loads in rotavating operations was greater than those in the other operations. In this study, the torque loads acting on the input shaft of the transmission and the final drive shaft of the tractor were measured during the rotavating operations in wet paddy field conditions and analyzed to determine the load characteristics. The effects of the cage wheel on the load characteristics were also investigated.

MATERIALS AND METHODS

A cage wheel was developed and attached to the driving tires of the tractor as shown in Figure 1. The cage wheel was designed so that its lug angle, lug pitch, diameter and width could be easily changed to investigate their effects on the load characteristics. The tractor used for the load measurement was mid-sized 41 ps. The torque acting on the input shaft was measured by using a strain-gauged torque meter and a radio-telemetry system, and



① Lug plate ② Lug angle adjusting linkage ③ Lug frame ④ Wheel rim

Fig. 1 A view of cage wheel attached to driving tire of test tractor.

the torque acting on the final drive shaft by a strain-gauged wheel torque meter. The actual travel speed of the tractor was measured using a radar speed sensor. The rear wheel speed was measured using a rotary encoder. The measured signals from each pick-up were transmitted to and stored in a data logger (Wu, 2000).

The soil characteristics of the wet paddy field are given in Figure 2 and Table 1. The soil type was determined according to the USDA classification. The cone index was measured using a cone penetrometer with a base area of 323 ㎟ and an apex angle of 30°. The soil cohesion, internal friction angle, adhesion and soil-metal friction angle were measured using a SR-2 soil penetrometer.

Table 1 Soil properties of wet paddy field

Soil type	Sandy clay loam	Moisture content (% d.b.)	40.7
Cohesion (kpa)	11.9	Liquid limit (%)	56.6
Internal friction angle, (deg)	17.5	Plastic limit (%)	40.7
Adhesion (kpa)	4.8	Specific weight	2.6
Soil metal friction angle, (deg)	10.4		

Table 2 shows the variations of design parameters of the cage wheel made for the load measurements. The load measurement was conducted under two different wheel conditions; one with the cage wheel attached to the driving tires and one with driving tires only without the cage wheel. For rotovating operations, the PTO gear was set to P1 and P2 to match with tractor gears M1 and M2, respectively. The PTO speeds at the P1 and P2 gears were respectively 588 and 704 rpm, and the forward speeds of the tractor at the M1 and M2 gears were respectively 2.93 and 4.12 km/h at the rated engine speed of 2600 rpm. During the load measurements, rotavating width and depth were kept constant as 165 and 20 cm respectively. The load measurements were performed three times for each operational condition. The sampling rate of the torque signals was set to 333.3 samples per second.

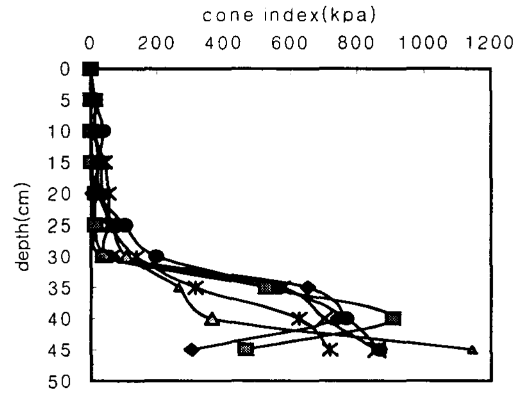


Fig. 2 Cone index measured at test field.

Table 2 Variations of design parameters of cage wheel

Diameter (mm)	Width (mm)	Lug pitch (mm)	Lug angle (°)
1182	300	232	45
1182	300	310	45
1222	300	240	45

The time history of the measured torque signals was digitized, and its cycle components and associated amplitudes were analyzed using the rain-flow cycle counting method. Since the measured torque load is not completely reversed one, the effect of mean torque load must be taken into consideration when calculating the spectrum magnitudes. To do this, the magnitudes of every torque cycles were modified using the Smith-Waston-Topper equation [1] after the rain-flow counting was performed.

The levels of the torque loads were determined by dividing the range of the modified torque magnitudes by 64 equal intervals. To eliminate the effect of differences in the measuring time the working hours for the rotavating operation were assumed as 300 hours. The statistical analysis on the torque magnitude and mean torque was done by using the average value of it.

RESULTS AND DISCUSSION

Figures 3-6 show the load spectra of the input shaft with different values of cage wheel parameters under four operational conditions. The vertical axis of the load spectra represents the ratio of the measured torque load to the rated engine torque that was estimated to be 110.8 N.m. The horizontal axis represents the total number of cycles in the logarithm scale. To get the load spectrum, the entire torque range was divided by a number of equal intervals and the number of load cycles in each interval was counted.

The load exerted by the cage wheel with a diameter of 1222 mm and a lug spacing of 240 mm was relatively low when compared with that by the cage wheels with other values of their parameters. However, there were no distinctive differences in the magnitudes of the loads due to the differences in the values of the cage wheel parameters. Therefore, the design parameters of the cage wheel were known to have little effect on the load spectra. The magnitude of the load spectrum increased in the order of M1P1, M2P1, M1P2 and M2P2 gear combinations. It was noticed that the load spectrum of the transmission input shaft was significantly influenced by both the velocity of the tractor and the rotational speed of the rotavator.

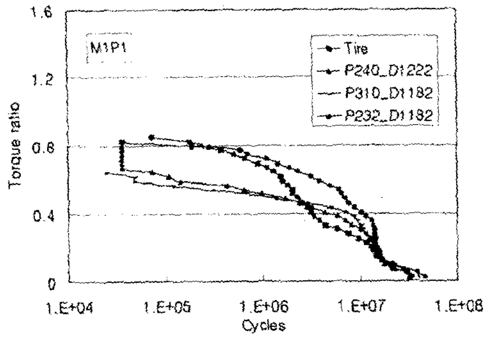


Fig. 3 Load spectra of input shaft with M1P1 gear.

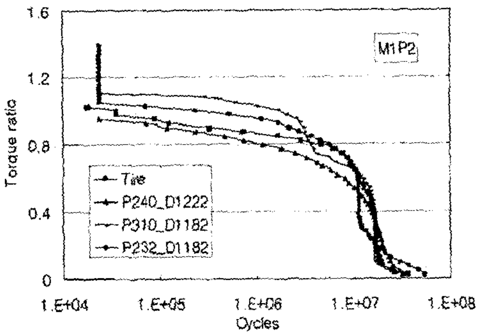


Fig. 4 Load spectra of input shaft with M1P2 gear.

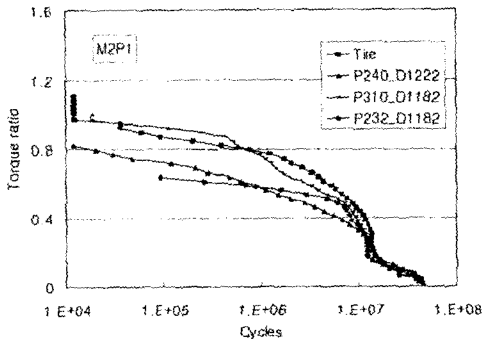


Fig. 5 Load spectra of input shaft with M2P1 gear.

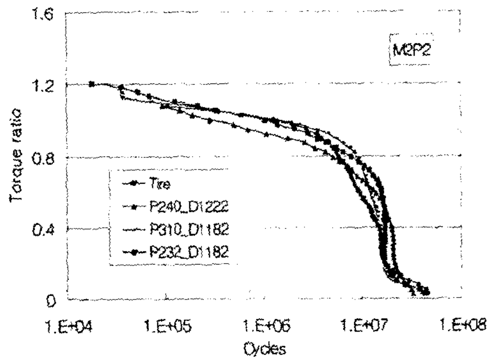


Fig. 6 Load spectra of input shaft with M2P2 gear.

The magnitudes of the torque loads acting on the input shaft with M1P1 and M2P1 gear combinations differed significantly from those with M1P2 and M2P2 as shown in Figure 7. By the LSD method they were said to be statistically different at the significance level of 95%. The rotating speed of the rotavator had significant effects on the torque load acting on the input shaft. The mean torque load acting on the input shaft was greater when the cage wheel was attached to the driving tires as shown in Figure 8. The increase in the mean torque load was attributable to the increased rolling resistance due to the increased wheel width by attaching the cage wheels.

Figures 9-12 show the load spectra of the final drive shaft with different values of the cage wheel parameters under four operational conditions. The vertical axis of the load spectra represents the ratio of the measured torque load to the maximum torque capable of transmitting to the drive shaft that was estimated to be 4.053 kN.m. The horizontal axis

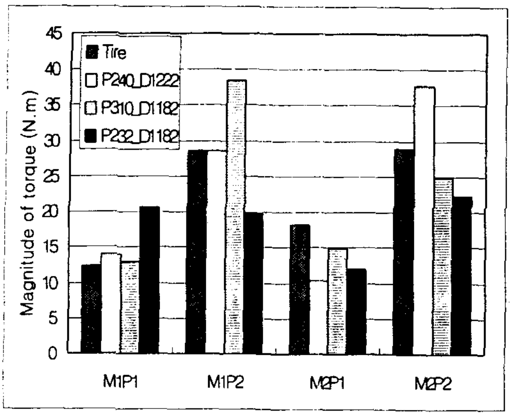


Fig. 7 Comparison of magnitude of torque load acting on input shaft of tractor equipped with four different wheels at four gears.

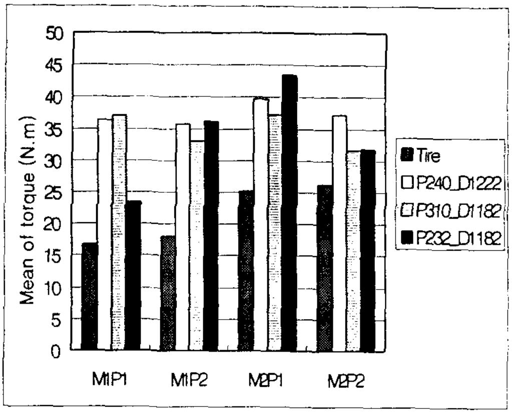


Fig. 8 Comparison of mean torque load acting on input shaft of tractor equipped with four different wheels at four gears.

represents the total number of cycles in the logarithm scale. The magnitudes of the load spectrum of the drive shaft with M1P2 gear were greater than those with M1P1 gear. Those with M2P2 gear were also greater than those with M2P1 gear. This indicates that the torque load of the drive shaft varies with the rotational speed of the rotavaror. As the speed of the rotavator increased the thrust force generated by the rotavator increased and the torque load of the drive shaft decreased. The torque load of the drive shaft with M2 gear was greater than that with M1 gear. This was because the rolling resistance increased due to the increase in operational speed. The torque load of the drive shaft was also greater when the cage wheel was attached to the driving tires

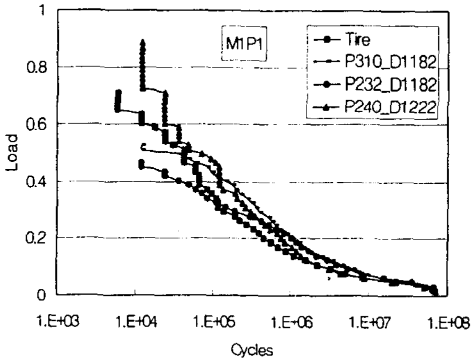


Fig. 9 Load spectra of drive shafts with four different types of wheels at M1P1 gear.

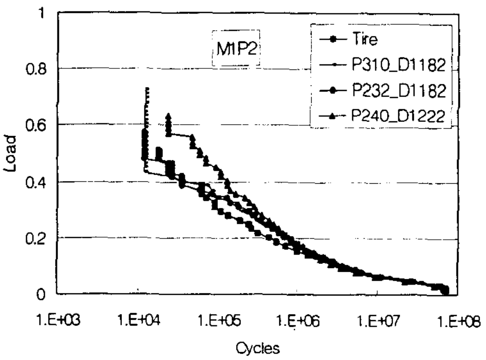


Fig. 10 Load spectra of drive shafts with four different types of wheels at M1P2 gear.

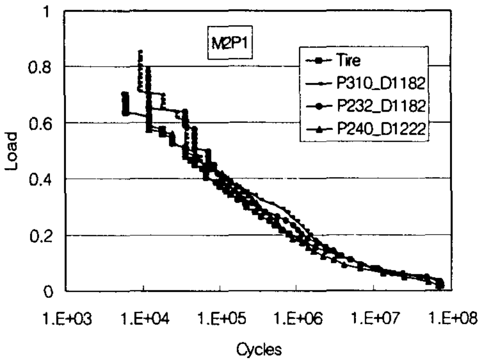


Fig. 11 Load spectra of drive shafts with four different types of wheels at M2P1 gear.

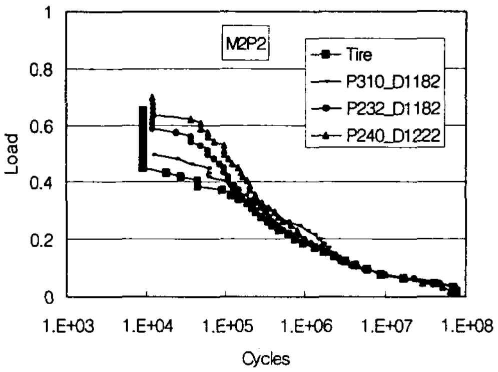


Fig. 12 Load spectra of drive shafts with four different types of wheels at M2P2 gear.

As shown in Figure 13, the magnitude of the torque load of the drive shaft increased as the diameter of the cage wheel and its lug pitch increased. The mean torque load of the drive shaft was greater when the cage wheel was attached as shown in Figure 14. This was because the rolling resistance increased due to the increased wheel width.

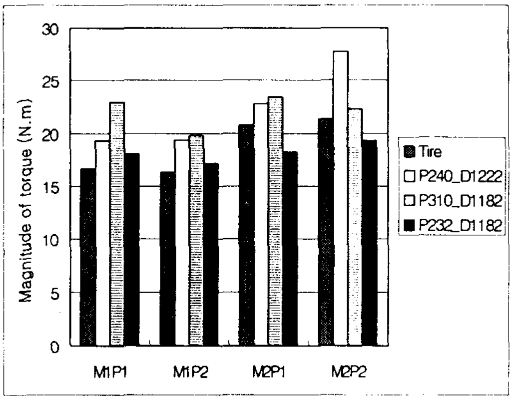


Fig. 13 Comparison of magnitude of drive shaft torque load of tractor equipped with four different types of wheels at four gears.

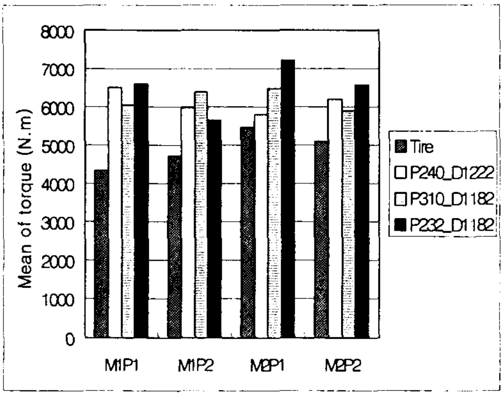


Fig. 14 Comparison of mean torque load acting on drive shafts of tractor equipped with four different types of wheels at four gears.

SUMMARY AND CONCLUSION

This study was conducted to investigate the load characteristics of rotavating operations by tractor with cage wheel attached to the driving tires as a traction aid under the wet paddy field conditions. Followings are the results of the study.

The lowest load spectrum of the input shaft of the transmission was obtained with the cage wheel of 1222 mm diameter and 240 mm lug pitch under 4 different gear conditions. The load of the input shaft decreased as the diameter of the cage wheel increased. It also increased proportionally as the rotational speed of the rotavator increased regardless of the wheel dimensions. The mean torque acting on the input shaft was greater when the cage wheel was attached. The increase in the mean torque was attributable to the increased wheel width that develops more rolling resistance

The load spectrum of the driving shaft decreased as the PTO speed increased. This was due to the increased thrust by the rotavator blades when rotavating operation. The torque load of the driving shaft was greater when the cage wheel was attached. This was because the rolling resistance increased due to the increased wheel width by attaching the cage wheels to the driving tires. The magnitude of the torque load of drive shaft increased as both the diameter of the cage wheel and the lug space increased. The mean load of the driving shaft decreased as the PTO speed increased.

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