MEASUREMENT OF FIELD PERFORMANCE FOR TRACTOR

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ABSTRACT

This study was performed to develop a measurement system of tractor field performance for plow and rotary operations. Measurement system for tractor consisted of torque sensors to measure torque of drive axles and PTO axle, speed sensors to measure rotational speed of drive axles and engine, microcomputer to control data logger, and data logger as I/O interface system. The measurement system was installed on four-wheel-drive tractor. Four-element full-bridge type strain gages were used for torque measurement of drive axles and optical encoders were used to measure speeds of drive axles and engine. Slip rings were mounted on the rotational axles. Signals from sensors were inputted to data logger that was controlled by microcomputer with parallel communication. Sensors were calibrated before the field tests. Regression equations were found on completion of the calibrations.

The field experiment was performed at paddy fields and uplands. Rotary and plow were used when the tractor was operated in the field. Travelling speeds of the tractor were 1.9 km/h, 2.7 km/h, 3.7 km/h, 5.5 km/h, 8.2 km/h, and 11.8 km/h. Operating depths of implements were maintained approximately 20cm during the tests. Torque data of drive axles were different at each location during plow and rotary operations. Results showed that torque of rear axles were greater than those of front axles. Total torque were 6860 ~ 11064 Nm at the upland and 7360 ~ 14190 Nm at the paddy field for plow operations. It was found that torque at the paddy field were about 20% greater than those at the upland for plow operations. Torque data showed that rotary operations required less power than plow operation at the paddy field and the upland. Torque measurements at each axle for rotary operations were only 8 ~ 16% of plow operations in the upland and 15 ~ 20% in the paddy field.

Key Word : Filed Performance, Data Acquisition System, Torque, Speed.

INTRODUCTION

Load data of field performance is necessary to design the various types of agricultural machinery. Data acquisition systems have been studied and developed to measure field performance of agricultural machinery. As the operation conditions of agricultural machinery were different in the field, various techniques have been studied to measure load data of agricultural machinery. There were lots of problems to measure torque in the field operations.

With appropriate sensors and system interface, data acquisition systems based on microcomputer were developed and evaluated in the field. The sensors are important in collecting the field performance data. Various types of torque sensors were designed and tested in the field to measure the power requirement of agricultural machines.

Drawbar pull, axle torque, engine speed, slip, rotational speeds of wheels, ground speed, and fuel consumption were measured to evaluate the field performance of agricultural machinery. Microprocessors, microcomputers (one-chip, single board, and personal), and data loggers were used to control the data acquisition systems. Floppy disk (Reynolds et al., 1982), magnetic tape (Grevis et al., 1982), digital cassette tape (Choi et el., 1983), computer memory were used to record the data in the field. Siyami et al. (1986) developed data acquisition system that measured impact accelerations along three orthogonal axles. Alimardani (1987) developed a data analysis system to evaluate various field performance data of farm tractors. Sakai et al. (1989) were measured the PTO torque in the field to improve the field performance of tractors. The power, torque, specific fuel consumption, and etc were measured with a data logging system. It was found that much improvement has been done for these tractors.

The purpose of this study was to develop measurement system of field performance for four-wheel-drive tractor. This system could measure toques and rotational speed of axles, and engine speed in the field.

MATERIALS AND METHODS

Measurement system for tractor consisted of torque sensors to measure torque of drive axles and PTO axle, speed sensors to measure rotational speed of drive axles and engine, microcomputer to control data logger, and data logger as I/O interface system as shown in Figure 1. The measurement system was installed on four-wheel-drive tractor (Model LT470DC, LG, Korea). The tractor had a total mass of 2395 kg, dimensions of 3620 x 1655 x 2410 mm (length x width x height), and engine power of 47 ps.

Torque sensors were designed to measure torque of front and rear axles, and PTO axle. Four-element full-bridge type strain gages (CEA-06-250US-350, Micro Measurement Co., USA) were attached on front-right, front-left, rear-right, rear-left, and PTO axles. These strain gages were designed to install easily on the center of the axles and the effects of bending stress could be minimized. Optical encoders were used to measure speeds of drive axles and engine. Pulse signals from encoders were converted to voltage signals by F/V (frequency and voltage) converters. Rotational speed of PTO axle was calculated from the engine speed.

Three types of slip rings were mounted on front wheel axles, rear wheel axles, and PTO propeller shaft. Slip rings (K6, HBM, Germany) were mounted and sealed at the middle of the front wheel axles. The other types of slip rings (SR-10M/E60, MI-Scientific, USA) mounted at the end of the rear wheel axles as shown in Figure 2. The slip ring included encoder, amplifier (AMP-SG-U2, MI-Scientific, USA) and power supply (PS-DC-1.0 V2, MI-Scientific, USA). Another slip ring (B6-2, MI-Scientific, USA) was installed on PTO propeller shaft.

The data logger (Model MGC, HBM, Germany) had 14 analog channels. Input signal of each channel can be changed by change the module. Ten channels were used as four for drive axle torque, one for PTO axle torque, four for drive axle speeds, and one for engine speed. The data logger was controlled by microcomputer with parallel communication. The software was provided by HBM to control the data logger.

Torque sensors were calibrated before the field tests. The tires were removed and a 1-m cantilever was attached at the end of the axle. The strains and voltages were recorded as the weights at the cantilever were changed. The weights were increased or decreased up to 100 kg with 5 kg intervals. PTO dynamometer (GS-130, Schenk, Germany) was used for the calibration of PTO torque sensor. A tachometer (Multi 5000, Hydro Tech Co., Germany) was used for the calibration of speed sensors. Regression equations were found on completion of the calibrations. Calibration results showed that the sensors had good performance to measure torque and speed with o.99 of coefficient of determination (R^2).

The field experiment was performed at paddy field and upland at Suwon (3 paddy filed and 5 upland) and Ichon (8 paddy filed and 6 upland), Kyunggi-Do, Korea in spring of 1998. Rotary and plow were used when the tractor was operated in the field. Travelling speeds of the tractor were 1.9 km/h, 2.7 km/h, 3.7 km/h, 5.5 km/h, 8.2 km/h and 11.8 km/h. Operating depths of implements were maintained approximately 20 cm during the tests.

An inverter (M700, Sam Sung Co., Korea) was used to supply electricity to measurement system and microcomputer in the field. The inverter converted 12V DC voltage from tractor battery to 110V AC voltage, and the capacity was 700 W.

RESULTS AND DISCUSSION

Plow operations

Torque of each axle was measured more than 50 seconds per each replication at each area. Torque data of drive axles were different at each area during plow operation. Figure 3 shows torque measurements for plow operations at the upland with 5.5 km/h of travelling speed. The figure shows that torque of rear axles were greater than those of front axles. Torque of left axle and right axle were not different at front axles. However, there were big difference torque of left axle and right axle at rear axles.

Table 1 and Table 2 show torque measurements for plow operations when the tractor traveled at 5.5 km/h. Torque data shown for each axle were averaged values for 10-second operations at static conditions. Total torque, summation of four axles, were 6860 ~ 11064 Nm at upland and 7360 ~ 14190 Nm at paddy field for plow operations. Test results showed that torque at the paddy field were about 20% greater than those at the upland for plow operations. Soil density of the paddy field was also greater than that of the upland.

Rotary operations

Figure 4 shows torque measurements for rotary operations at the upland with 5.5 km/h of travelling speed. The figure also shows that torque of rear axles were greater than those of front axles. It was found that left axle and right axle had similar torque at front and rear axles.

Table 3 and Table 4 show torque measurements for rotary operations when the tractor traveled at 5.5 km/h. Results showed that torque at the paddy field were greater than those at the upland for rotary operations. Torque data showed that rotary operations required less power than plow operation at the paddy field and the upland. Torque measurements at each axle for rotary operations were only 8 ~ 16% of plow operations in the upland and 15 ~ 20% in the paddy field.

CONCLUSIONS

Field data are important to design agricultural machinery. Data measurement in the agricultural filed and data analysis will be required to develop new version of farm tractor. The purpose of this study was to develop measurement system of field performance for four-wheel-drive tractor. The system could measure toques and rotational speed of axles, and engine speed in the field.

Measurement system for tractor consisted of torque sensors to measure torque of drive axles and PTO axle, speed sensors to measure rotational speed of drive axles and engine, microcomputer to control data logger, and data logger as I/O interface system. The measurement system was installed on four-wheel-drive tractor. Four-element full-bridge type strain gages were used for torque measurement and attached on front-right, front-left, rear-right, rear-left, and PTO axles. Optical encoders were used to measure speeds of drive axles and engine. Pulse signals from encoders were converted to voltage signals by F/V converters. Rotational speed of PTO axle was calculated from the engine speed. Slip rings were mounted on the rotational axles. Signals from sensors were inputted to data logger that was controlled by microcomputer with parallel communication. Sensors were calibrated before the field tests. A 1-m cantilever with weights and PTO were used for calibration of torque sensor. A tachometer was used for speed sensors. Regression equations were found on completion of the calibrations. Calibration results showed that the sensors had good performance to measure torque and speed with o.99 of coefficient of determination.

The field experiment was performed at eleven paddy fields and eleven uplands in spring of 1998. Rotary and plow were used when the tractor was operated in the field. Travelling speeds of the tractor were 1.9 km/h, 2.7 km/h, 3.7 km/h, 5.5 km/h, 8.2 km/h, and 11.8 km/h. Operating depths of implements were maintained approximately 20cm during the tests. Torque of each axle was measured more than 50 seconds per each replication at each area. Torque data of drive axles were different at each location during plow and rotary operations. Results showed that torque of rear axles were greater than those of front axles. Total torque, summation of four axles, were 6860 ~ 11064 Nm at the upland and 7360 ~ 14190 Nm at the paddy field for plow operations. Test results showed that torque at the paddy field were about 20% greater than those at the upland for plow operations. Torque data showed that rotary operations required less power than plow operation at the paddy field and the upland. Torque measurements at each axle for rotary operations were only 8 ~ 16% of plow operations in the upland and 15 ~ 20% in the paddy field.

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Table 1. Torque for plow operation at paddy field.

Torq. / Area	AXLE TORQUE(Nm)			
	F/LH	F/RH	R/LH	R/RH
1	1196	1284	4508	5684
2	1313	1441	2724	3900
3	1088	1107	2695	3734
4	1519	1264	4136	4145
5	1029	1156	2832	3263
6	1127	1107	2930	2989
7	1098	1205	2166	2381
8	1303	1343	3205	3851
9	882	892	1568	1607
10	1107	1107	2332	3048
11	862	892	1490	1950

Table 2. Torque for plow operation at upland

Torq. / Area	AXLE TORQUE(Nm)			
	F/LH	F/RH	R/LH	R/RH
1	1382	1401	2421	3195
2	1137	1303	6429	5321
3	1323	1284	3979	4234
4	1196	1107	3234	3332
5	1000	1147	2675	3244
6	1352	1441	4361	4361
7	1009	951	4028	3861
8	1205	1205	3420	3842
9	696	696	3949	4194
10	1078	1068	5272	4635
11	676	686	2832	3165

Table 3. Torque for rotary operation at paddy field.

Torq. / Area	AXLE TORQUE(Nm)				
	F/LH	F/RH	R/LH	R/RH	PTO
1	294	294	392	392	392
2	676	637	980	1000	235
3	314	353	353	363	294
4	559	568	147	206	412
5	568	686	323	510	284
6	794	745	657	902	245
7	470	500	833	588	284
8	431	451	510	568	431
9	715	735	902	1058	235
10	843	853	1039	1147	353
11	274	304	1117	1196	461

Table 4. Torque for rotary operation at upland

Torq. / Area	AXLE TORQUE(Nm)				
	F/LH	F/RH	R/LH	R/RH	PTO
1	333	412	598	343	284
2	274	274	647	725	470
3	255	235	588	617	441
4	265	343	647	764	480
5	559	627	1137	1450	176
6	588	510	882	1039	245
7	627	676	1039	862	255
8	608	696	1313	1460	274
9	725	725	872	1058	225
10	627	862	441	451	314
11	578	706	853	804	255

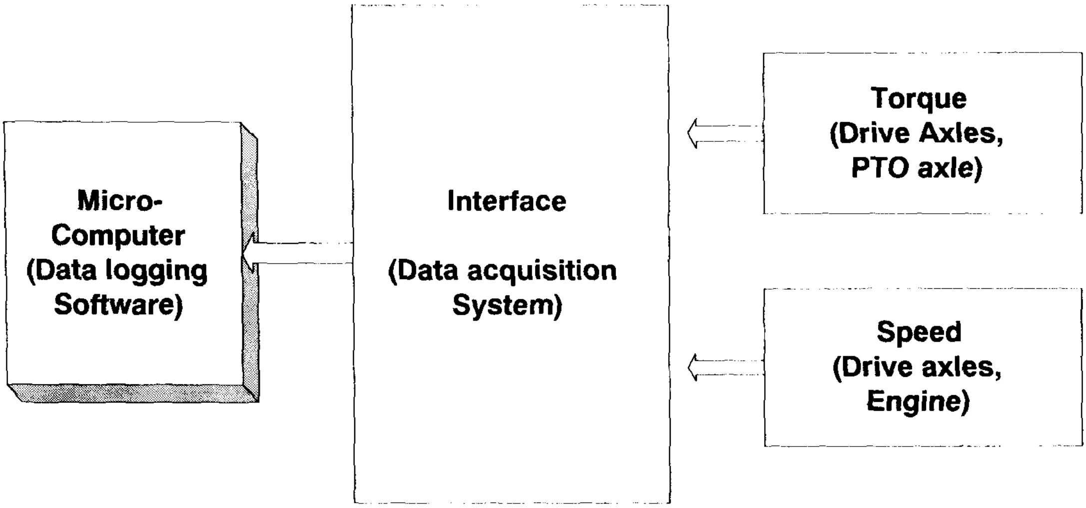

Figure 1. Configuration of the measurement system for tractor field performance.

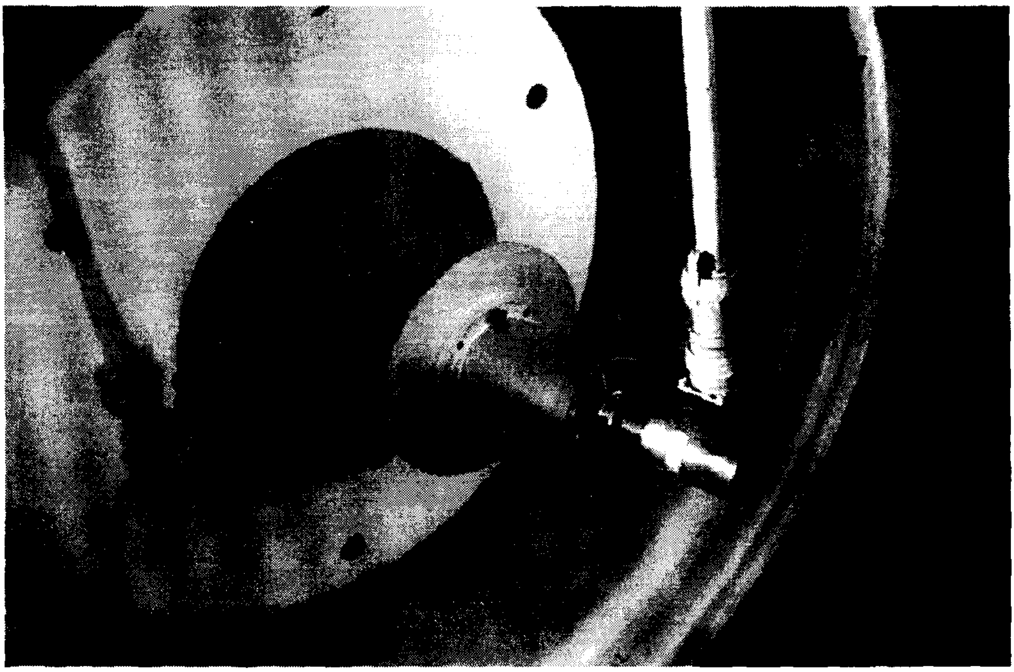

Figure 2. Slip ring attached on the rear wheel.

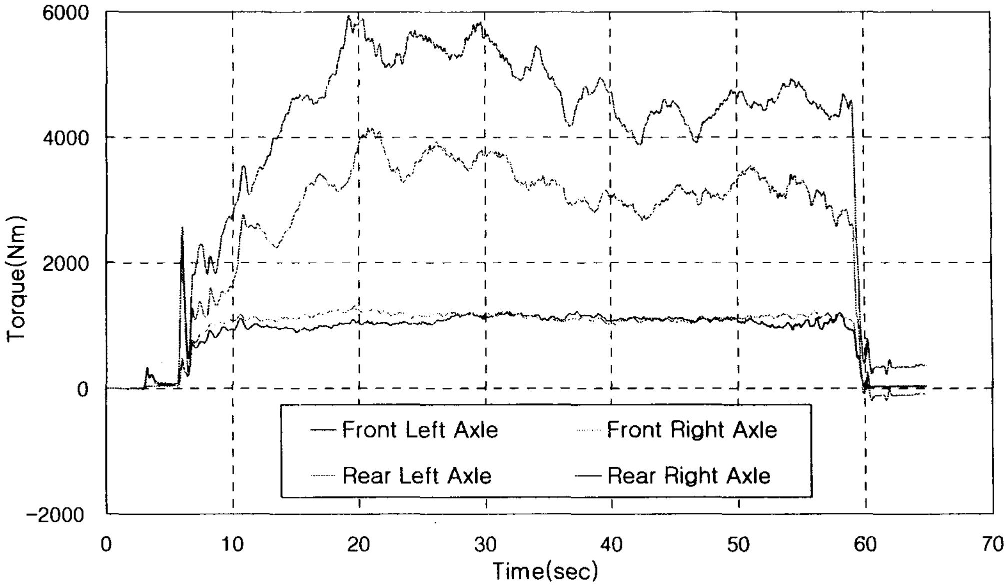

Figure 3. Torque data for plow operation at upland.

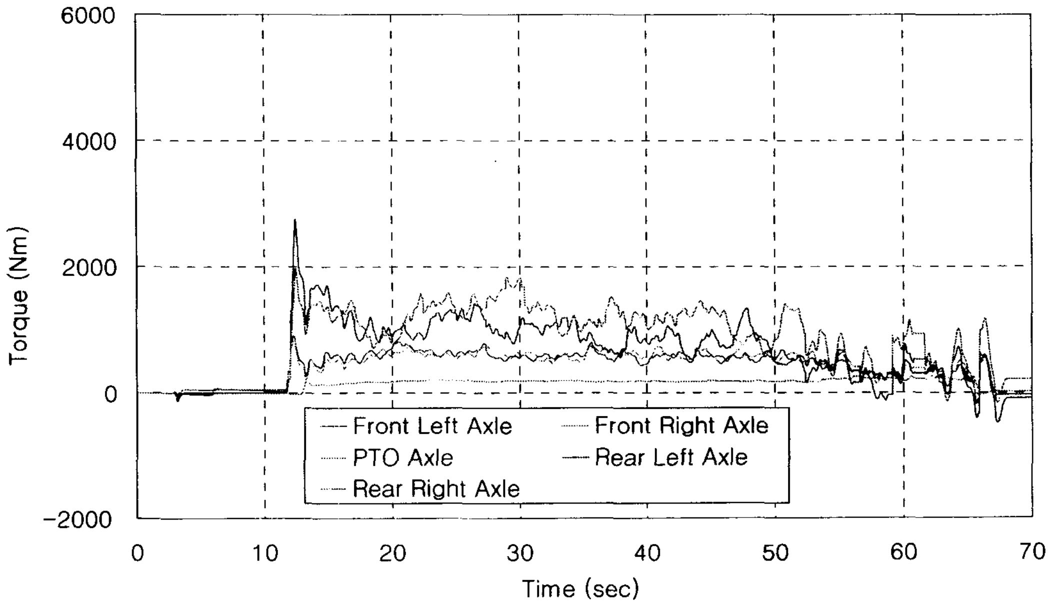

Figure 4. Torque data for rotary operation at upland.