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Analysis of the Load of a Transplanter PTO Shaft Based on the Planting Distance

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The purpose of this study was to analyze the load of a transplanter PTO shaft during transplanting operations with respect to planting distances. To measure the loads on the PTO shaft of a transplanter, a load measurement system was constructed using a torque sensor and an embedded system. Field experiments were conducted at planting distances of 26, 35, 43, and 80 cm in a field with similar soil conditions. The load measured was converted from the time domain to the frequency domain using the rain–flow counting and SWT methods. The damage level of the transplanter to the working load with respect to the planting distance was calculated using Miner's rule, and the damage level was represented by ratio of the damage sum to the smallest damage sum among the planting distances. The damage level was increased by 199, 493, and 708% when the planting distance gradually decreased from 80 to 43, 35, and 26 cm, respectively. The results show that a shorter planting distance has a stronger effect on the transplanter PTO shaft than a longer planting distance. Therefore, it is known that transplanter PTO shafts should be designed while considering working loads with respect to planting distance.

Key words: Transplanter, Transplanting operation, Planting distance, PTO, Load spectrum, Damage level

INTRODUCTION

Transplanting is planting seedlings grown on a seedbed in farmland. Until transplanter was developed, transplanting operations were mainly performed by manual labor. The working hours required for transplanting operations by farmers are 18.4 h per 10 acres, which accounts for 18.7% of the total working hours of farmers in Korea (Park *et al*., 2005). Recently, the number of transplanter has increased to improve the convenience and efficiency of transplanting operations in many countries. The transplanter is mainly used for the crop of cabbage, broccoli, corn, soybean, sesame and etc. The global market for transplanter in 2013 reached $10,650 million dollars, and it is expected to reach to $15,150 million dollars in 2018 (KAMICO and KSAM, 2015; Kim *et al*., 2016). Farmers are demanding transplanter that can fast transplanting for save time and money. Transplanting speed affects the load on the transplanter, fast transplanting affects the fatigue life of the machine, and reduces durability. Therefore, an analysis of the transplanter PTO shaft load with respect to planting distance should be performed.

Several studies have considered the planting device of transplanter. Min *et al*. (2015) analyzed transplanting devices according to the form of the transplanting device of vegetable transplanter to address transplanting devices for an onion transplanter. Park *et al*. (2005) developed a transplanting device that was the core technology for vegetable transplanter. The motion of the transplanting device was analyzed using a dynamic analysis program and verified using a high–speed camera. Lungkapin *et al*. (2009) developed a cassava planter suitable for use in local farms that was designed to plant stakes either on flat beds or in ridges and to apply fertilizer at the same time. However, no previous studies have focused on the fatigue of the transplanter PTO shaft.

Studies related to the PTO shafts of agricultural machines have largely been conducted in relation to agricultural tractors. Lee *et al*. (2016) simulated the PTO gear according to the change point of the engine power for the optimum design of the tractor powertrain. The results showed that if the tractor operation is performed at a lower point than the maximum output point of the engine, the life of the PTO gear is drastically reduced. Jang *et al*. (2016) simulated the safety factor of the PTO gear according to the change of the face width for the optimum design of the tractor PTO gear. The results showed that the tractor PTO gear was the larger the tooth width the higher the safety factor. Kim *et al*. (2011b) analyzed the power requirements of an agricultural tractor for major field operations using a power measurement system. Their results showed that among all operations, rotary tillage using PTO power requires the most power. Kim *et al*. (1998) measured transmission loads at the input shaft of a transmission gearbox during operations such as plow tillage, rotary tillage, and transportation operations. The time histories of the measured torque loads were converted into a load spectrum and analyzed with respect to the S–N curve of the shaft material to estimate the partial damage to the transmission. The results indicated that the load levels reached during rotary tillage using PTO power are approximately 59 times greater than those reached dur-

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ing plow tillage. Lee *et al*. (2015) analyzed the PTO load of an agricultural tractor during rotary tillage and baler operations. The results show that PTO damage levels increase as the ground or PTO rotational speed increase. Kim *et al*. (2011a) evaluated the severity of tractor PTO driving axles during rotary tillage operations using a torque measurement system and found that relative severe levels are greater at a higher PTO rotational speed under all soil conditions. The results of the above literature studies showed that most of the load was applied on the PTO shaft.

This paper presents useful information for the optimal design of a transplanter PTO shaft considering working loads. The purpose of this study was to analyze the load of a transplanter PTO shaft during transplanting operations with respect to planting distances. Our specific objectives were (1) to develop a load measurement system using a torque sensor and embedded system, (2) to measure the loads acting on the PTO shaft with respect to planting distance during transplanting operations, and (3) to analyze PTO shaft load with respect to planting distance through load spectrum and damage level calculations.

MATERIALS AND METHODS

Transplanter

Table 1 shows the specifications of the transplanter (PF2R, Yanmar, Japan) used in this study. The transplanter had a total mass of 615 kg and dimensions of 3,160 × 1,725 × 1,925 mm (length × width × height). The rated power of the transplanter was set at 7.1 kW at an engine revolution speed of 3,600 rpm. The transplanter was equipped with a hydro mechanical transmission (HMT) composed of two direction gears and two driving gears. The engine power of the transplanter is divided into a PTO shaft for the transplanting operation and a driving shaft for driving the wheels through the transmission, as shown in Fig. 1. The inputted power through the PTO shaft from the transmission is transferred to the lateral transfer shaft for seedbed interval control and the transplanting part of the transplanting operations. The transplanting part and lateral transfer shaft that use the power of the PTO shaft consume the most power due to the transplanting operations under high load.

Load measurement system

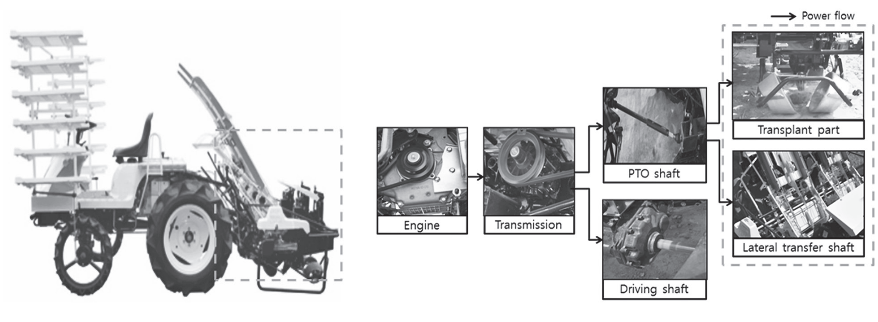
The transplanter load measurement system was constructed with torque sensors (TRS605, FUTEK, USA) to measure the torque of a PTO shaft, as shown in Fig. 2, and an embedded system to calculate the damage levels. A universal shaft is connected to a PTO driving shaft and planting part and the torque of the universal shaft is the same as the torque of the PTO driving shaft, as the universal shaft transmits PTO power to the planting part at the same rotational speed. A program based on LabVIEW (version 2010, National Instrument, USA) for measuring load signals was developed.

Field experiment

The load acting on a transplanter PTO shaft during

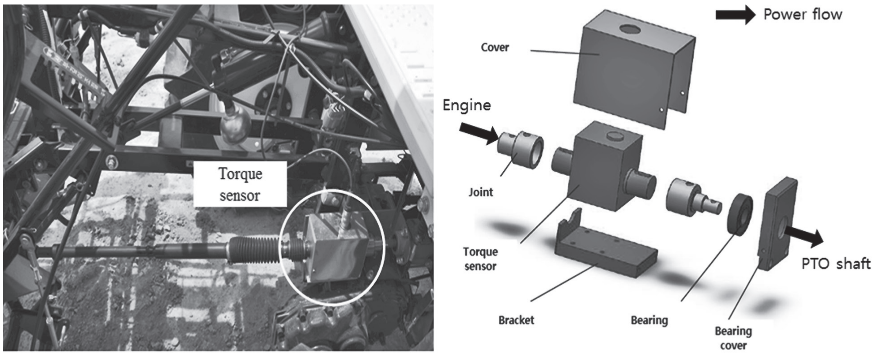
Table 1. Specifications of the transplanter used in the study

Parameter		Specifications	
Weight (kg)		615	
Length × Width × Height (mm)		3160 × 1725 × 1925	
Engine	Rated power (kW)	3.9 @ 1800 rpm	
	Rated torque (Nm)	18.8	
Transmission	HMT (Hydro mechanical transmission)	Direction gear	Forward, Backward
		Driving gear	1st, 2nd
Planting distance (cm)		26, 30, 35, 40, 43, 45, 50, 60, 70, 80	



(a) Transplanter used in this study (b) Schematic diagram of the power flow for the transplanter

Fig. 1. Photo and power flow for the transplanter used in this study.



(a) Installed torque sensor transplanter PTO shaft (b) Torque sensor assembly diagram

Fig. 2. Transplanter PTO load measurement system.

transplanting operations is dependent on many factors, including the soil conditions, driver skill, planting distance, and ground speed. Because it is difficult to consider all the factors, in this study, effects of these factors were minimized by focusing on the effects of plating distance on the PTO shaft load. The planting distance and ground speed were determined through a survey of transplanter users in Korea. Four planting distances (26, 35, 43, and 80 cm) were selected as representative planting distances from a total of ten planting distances. The ground speed was selected as driving gear levels 2 (0.9 m/s). Field experiments were conducted on a field with similar soil conditions and were repeated four times for each planting distance. The planting depth was selected as level 5 (105 mm) which is commonly used in Korea.

The field experiments were conducted in a field in Seobu–ro, Okcheon, Chungbuk Province in Korea. The area is located at 36°17′44.8″N and 127°33′41.4″E. The cone index (CI), depth, shearing force, moisture content, electric conductivity (EC), and temperature values were analyzed following the USDA standard for upland field sites (ASABE, 2011a; ASABE, 2011b). The environmental conditions of the test site were recorded as follows: average moisture content of 26.0%, average CI of 2,503 kPa, average EC of 2.7 dS/m, average soil shearing force of 20.6 Nm, average depth of 12 cm, and average temperature of 30.5°C. The measured load data were used to perform simple statistical analysis of maximum, mean, and standard deviation according to planting distance. One–Way ANOVA and Duncan's multiple range tests at a significance level of 0.05 were conducted with SAS (version 9.4, SAS Institute, Cary, NC, USA).

Load analysis

The load of the transplanter PTO shaft was analyzed by collecting load signals, analyses of load spectra, and calculations of damage ratios, as shown in Fig. 3 (Kim *et al.*, 2013). As the load of the transplanter PTO shaft was irregular (Xiong and Shenoi, 2005), the measured load data were converted from the time domain to the frequency domain using the rain–flow counting and Smith–Watson–Topper (SWT) methods. The rain–flow counting method is widely recognized as a good cyclic

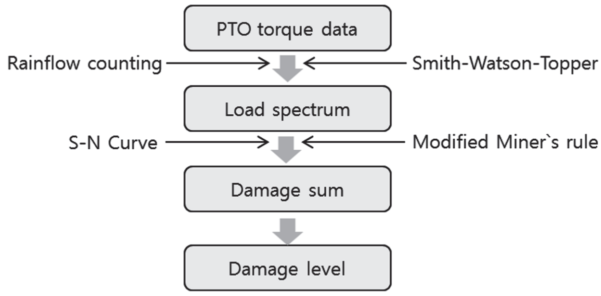


Fig. 3. Procedure used for the load analysis of the transplanter PTO shaft.

counting method for loads (Lee *et al.*, 2015; Hong, 1991). It decomposes a variable amplitude load history into simple events equivalent to individual cycles of constant load amplitudes (Kim *et al.*, 2013; Glinka and Kam, 1987). The SWT method, shown in Eq. (1), was used to calculate the spectrum magnitude and remove the effects of the mean torque.

$$T_e = \sqrt{(t_a + t_m)t_a} \quad (1)$$

where T_e is the equivalent torque (Nm), t_a is the torque amplitude (Nm), and t_m is the mean torque (Nm).

As the recorded time of the measured torque data was relatively short (25–30 second), the number of cycles had to be extended to the total transplanter usage time (Lee *et al.*, 2015). The total number of load cycles was calculated using Eq. (2).

$$N_T = 3600NLh \quad (2)$$

where N_T is the total number of load cycles (cycles), N is the number of calculated cycles of the measured torque (cycles/s), L is the lifespan of the transplanter used (year), and h is the annual transplanter usage time (h/year).

The lifespan of the transplanter was estimated at 10 years. The annual usage time of transplanter is 25.5 h in Korea (KAMICO and KSAM, 2015; Lee, 2011). The load spectrum for the lifespan of the transplanter with respect to planting condition was denoted by the ratio of measured torques to the rated torque, which was 18.8 Nm. Ratios of load spectra exceeding 1 denote excessive load levels greater than the rated torque. The damage sum was calculated using measured torque data and the S–N curve to estimate the number of load cycles. The S–N curve was converted to a torque–cycle curve due to damage caused by the torque signal (Nguyen *et al.*, 2011). The S–N curve was obtained for the material of the PTO shaft, SCM 420 H, using the ASTM standard 2004 (ASTM, 2004) in Eq. (3). The ASTM standard is well known in the materials fatigue analysis field (Kim *et al.*, 2013).

$$N = 10^{(6-6.097\log(\frac{S}{223}))} \quad (3)$$

where N is the number of cycles and S is the shear stress (MPa).

To calculate the damage sum, the equivalent torque of the load spectrum was converted to stress, as shown in Eq. (4). The diameter of the transplanter PTO shaft was set to 14 mm.

$$S = \frac{16T}{\pi d^3} \quad (4)$$

where S is the stress (MPa), T is the equivalent torque (Nm), and d is the diameter of the shaft (mm).

The damage sum was calculated using Miner's rule (Miner, 1945) in Eq. (5). Miner's rule is a procedure used to estimate the number of loading cycles to failure (Miner, 1945; Renius, 1977). The number of cycles was obtained from an equivalent torque of the load spectrum. The fatigue life cycles were derived from the S–N curve of SCM 420 H. The damage sum was calculated by dividing the number of fatigue life cycles by the number of cycles.

$$D_t = \sum_{i=1}^{k} \frac{n_i}{N_i} \quad (5)$$

where D_t is the damage sum, n_i is the number of cycles, and N_i is the fatigue life (cycles).

RESULTS AND DISCUSSION

PTO shaft loads by planting distance

Fig. 4 shows the PTO shaft torques for four different planting distances. The transplanting operation consisted of a preparation period and planting period. The PTO shaft torque is not generated because the shaft does not rotate in the preparation period, and it is generated in the planting period as the shaft rotates to transmit the power. The measured torque on the PTO shaft shows regular fluctuations during transplanting operations. The PTO torque at the shortest planting distance (26 cm) occurred about three times more frequently than that at the widest planting distance (80 cm). The PTO torque was found to be inversely proportional to the planting distance. The PTO torque was measured frequently during the transplanting operation when the planting distance decreased. Table 2 shows the results of the load analysis on the transplanter PTO shaft by planting distance. The torque was calculated only for the planting period data. The average and maximum torques on the PTO shaft for the four different planting distances of 26, 35, 43, and 80 cm were 14.38 and 42.66, 13.88 and 43.24, 13.47 and 43.23, and 12.88 and 34.50 Nm, respectively. The PTO shaft load at difference planting distance showed a significant difference based on the planting distance ($p<0.05$). The PTO shaft load was slightly increased as planting distance was decreased.

Load spectrum

Fig. 5(a) shows the load spectrum on the trans-

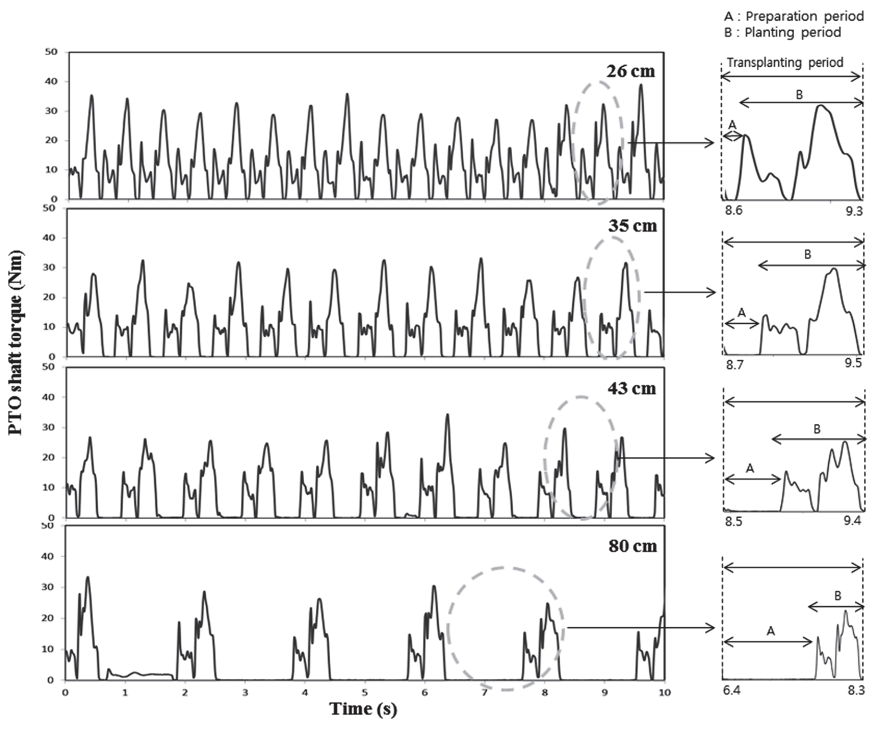
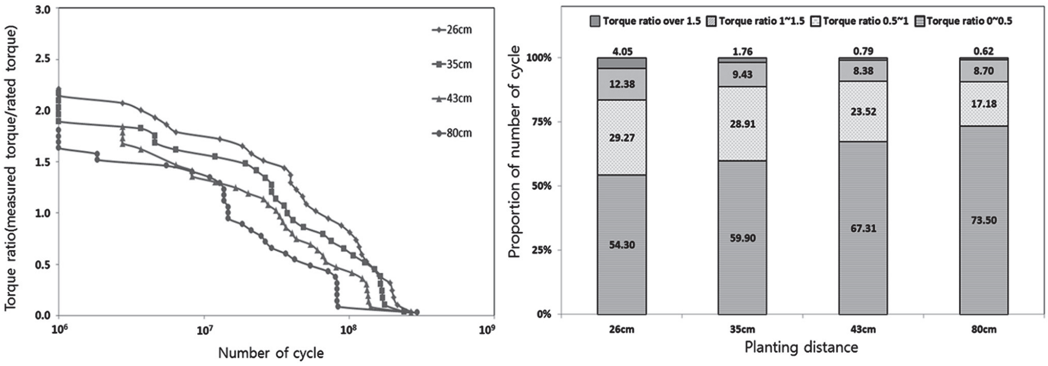


Fig. 4. Transplanter PTO shaft torque with respect to planting distance.

Table 2. Result of the load analysis with respect to planting distance (N=4)

Parameter	Planting distance (cm)			
	26	35	43	80
Max (Nm)	42.66	43.24	43.23	34.50
Avg. ± Std. Dev. (Nm)	14.38 ± 8.34[a]	13.88 ± 7.26[ab]	13.47 ± 6.92[bc]	12.88 ± 6.86[c]

[1] Means with different superscripts (a, b, c,d) in each column are significantly different at $p < 0.05$ by Duncan's multiple range



(a) Load spectrum (b) Proportion of number of cycle

Fig. 5. Load spectrum and number of cycle ratio for the transplanter PTO shaft with respect to planting distance.

planter PTO shaft for the lifespan of the transplanter (10 years) during transplanting operations. The maximum torque on the transplanter PTO shaft at planting distances of 26, 35, 43, and 80 cm was measured as 2.21, 2.17, 1.85, and 1.81 times of the rated torque, respectively. When the planting distance decreased, the torque ratio on the transplanter PTO shaft increased. The proportion of the number of cycles under a torque ratio over 1.5 and a torque ratio of 1–1.5 at planting distances of 26, 35, 43, and 80 cm were 4.05 and 12.38, 1.76 and 9.43, 0.79 and 8.38, and 0.62 and 8.70%, respectively, as shown in Fig. 5(b). In addition, the proportion of number of cycles under a torque ratio of 0.5–1 and a torque ratio of 0–0.5 at planting distances of 26, 35, 43, and 80 cm were 29.27 and 54.30, 28.91 and 59.90, 23.52 and 67.31, and 17.18 and 73.50%, respectively. The ratios of the torque level greater than rated torque at planting distances of 26, 35, 43, and 80 cm were 16.43, 11.19, 9.17, and 9.32%, respectively. The proportion of the number of cycles with a torque ratio over 0.5 decreased, when planting distance increased. These results show that as the planting distance increases, the proportion of high loads for the transplanter PTO shaft with a torque ratio over 0.5 decreased and the proportion of relatively low loads with a torque ratio under 0.5 increased.

Damage level

Fig. 6 shows the damage level with respect to planting distance. The damage level for each planting distance was represented by ratio of the damage sum to the smallest damage sum among the planting distance of 26, 35, 43, and 80 cm. Generally, when the planting distance decreases, the transplanter PTO shaft load is assumed to increase by the same ratio. However, the results of load analysis in this study reveal different results. The damage level was increased by 199, 493, and 708% when the planting distance gradually decreased from 80 to 43, 35, and 26 cm, respectively. These results show that a shorter planting distance results in higher damage level effects on a transplanter PTO shaft.

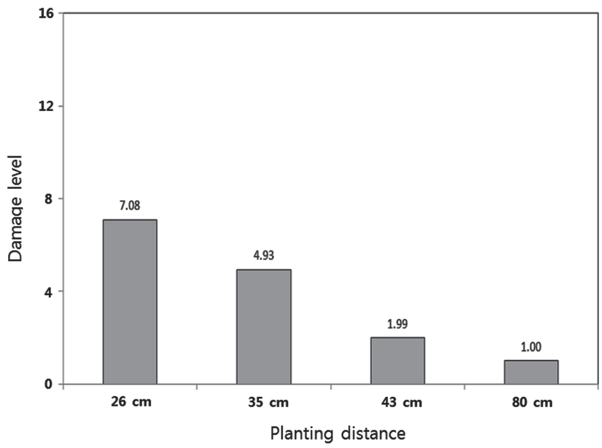


Fig. 6. Damage level on the transplanter PTO shaft with respect to planting distance.

SUMMARY AND CONCLUSIONS

This study was conducted to analyze the loads acting on a transplanter PTO shaft with respect to planting distance during transplanting operations. First, the loads acting on a PTO shaft were measured using a load measurement system with respect to planting distances. The system was constructed using torque sensors to measure the torque of a PTO shaft and an embedded system to calculate the damage levels. Second, field operations were performed over four planting distances (26, 35, 43, and 80 cm) on a field with similar soil conditions. Third, the load of the transplanter PTO shaft was analyzed through load signal measurements, load spectrum analysis, and damage sum calculations. The damage sum was calculated using measured torque data and S–N curves to estimate the number of load cycles. The S–N curve was obtained for the material of the PTO shaft, SCM 420 H, using the ASTM standard 2004. Finally, a load analysis of the transplanter with respect to the planting distance was conducted. The damage level was increased by 199, 493, and 708% when the planting distance gradually decreased from 80 to 43, 35, and 26 cm, respectively. These results show that a shorter planting distance has a stronger effect on a transplanter PTO shaft than a longer planting distance. Especially, the higher the proportion of number of cycles with a torque ratio exceeding 0.5, the higher the level of damage.

Farmers tend to conduct transplanting operations at shorter planting distances for greater field efficiency. However, shorter planting distances cause greater loads and a shorter fatigue life of the PTO shafts. Therefore, transplanter PTO shafts should be designed while considering working loads with respect to planting distance. The results of this study provide useful information for the optimal design of transplanter PTO shaft considering working loads. Futures studies are still required to provide data for the design of a transplanter PTO shaft under variations in other work conditions, such as the ground speed and planting depth.

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REFERENCES

ASABE 2011a Soil cone penetrometer. In: ASABE Standards S313.3 St. Joseph, Mich: ASABE publication

ASABE 2011b Procedures for Using and Reporting Data Obtained with the Soil Cone Penetrometer. In: ASABE Standards EP542. St. Joseph, Mich: ASABE publication

ASTM 2004 Statistical analysis of linear or linearized stress–life (S–N) and strain–life (e–N) fatigue data. In: ASTM Standard E739–91. Pittsburgh: ASTM publication

Glinka, G. and J. C. P. Kam 1987 Rainflow counting algorithm for very long stress histories. *Int. J. Fatigue*, **9**(4): 223–228

Hong, N 1991 A modified rainflow counting method. *Int. J. Fatigue*, **13**(6): 465–469

Jang, J. H., S. O. Chung, C. H. Choi, Y. J. Park, W. K. Chun, S. I. Kim, O. W. Kwon, C. W. Kim, S. J. Hong, and Y. J. Kim 2016 Effects of PTO gear face width on safety factors. *Korean J of Agric Sci*, **43**(4): 650–655

KAMICO and KSAM 2015. Agricultural Machinery Yearbook in Republic of Korea. Suwon: Korea Agricultural Machinery Industry Cooperative and Korean Society for Agricultural Machinery

Kim, J. H, K. U. Kim, C. W. Choi, and Y. G. Wu 1998 Severeness of transmission loads of agricultural tractors. *J Biosystem Eng*, **23**(5): 417–426

Kim, W. S., S. O. Chung, C. H. Choi, J. S. Cho, D. S. Choi, Y. S. Lee, S. D. Lee, S. J. Hong, S. M. Koo, S.M, and Y. J. Kim 2016 Analysis of the PTO torque of a transplanter by planting condition. *J Biosystem Eng*, **41**(4): 313–318

Kim, Y. J., S. O. Chung, and C. H. Choi 2013 Effect of gear selection of an agricultural tractor on transmission and PTO load during rotary tillage. *Soil Till. Res*, **134**: 90–96

Kim, Y. J., S. O. Chung, C. H. Choi, and D. H. Lee 2011a Evaluation of Tractor PTO Severeness during Rotary Tillage Operation. *J Biosystem Eng*, **36**(3): 163–170

Kim, Y. J., S. O. Chung, S. J. Park, and C. H. Choi 2011b Analysis of power requirement of agricultural tractor by major field operation. *J Biosystem Eng*, **36**(2): 79–88

Lee, D. H 2011 Analysis of Power Requirements of Tractor for Field Operations (M. S. thesis). Suwon, Korea: Sungkyunkwan University

Lee, D. H., Y. J. Kim, S. O. Chung, C. H. Choi, K. H. Lee, and B. S. Shin 2015 Analysis of the PTO load of a 75 kW agricultural tractor during rotary tillage and baler operation in Korean upland fields. *J. Terramech*, **60**: 75–83

Lee, P.U., S. O. Chung, C. H. Choi, Y. J. Park, and Y. J. Kim 2016 Analysis of the effects of operating point of tractor engine on fatigue life of PTO gear using simulation. *Korean J of Agric Sci*, **43**(3): 441–449

Lungkapin, J., V. M. Salokhe, R. Kalsirisilp, and H. Nakashima 2009 Design and development of a cassava planter. *Trans. ASABE*, **52**(2): 393–399

Miner, M. A. 1945 Cumulative damage in fatigue. *J. Appl. Mech*. **12**(3), 159–164

Min, Y. B., J. K. Kang, and C. S. Ryu 2015 Development Onion Transplanter: Analysis a Transplanting Locus on The Type of Transplanting Devices for a Vegetable Transplanter. *J of Agric & Life Sci*, **49**(6): 289–294

Nguyen, N. T., Q. T. Chu, and S. E. Kim 2011 Fatigue analysis of a prefabricated orthotropic steel deck for light–weight vehicles. *J. Constr. Steel Res*, **67**(4): 647–655

Park, S. H., Y. J. Kim, D. K. Choi, C. K. Kim, T. Y. Kwak, and S. C. Cho 2005 Development of Walking Type Chiness Cabbage Transplanter. *J Biosystem Eng*, **30**(2): 81–88

Renius, K. T. 1977 Application of cumulative damage theory to agricultural tractor design elements. Konstrucktion, **29**(3): 85–93

Xiong, J. J., and R. A. Shenoi, R. A 2005 A reliability–based data treatment system for actual load history. *Fatigue Fract. Eng. Mater*, **28**(10): 875–889

Author Contributions: Wan-Soo Kim designed the study, analyzed the data and wrote the paper, and performed the field experiments. Yeon-Soo Kim constructed load measurement system of the transplanter PTO and developed operating and measuring software. Yong-Joo Kim supervised the work, wrote the paper, and provided facilities and resources. Chang-Hyun Choi constructed the load spectrum and calculated damage sum of the transplant PTO shaft by planting distance. E. Inoue and T. Okayasu participated in the design of the study and verified the suitability of the method and result of the statistical analysis of transplanter PTO shaft load. Also, suggested the possibility of using this study in transplanter design. All authors assisted in editing of the manuscript and approved the final version.