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Analysis of the Main Factor of Wheel Loader Torque via Wireless Measurements

Byung-Ik Kang*,#, Hong-Il Dong*, Byung-Ki Kim*, Yong-Hun Choi*
*Korea Gas Safety Corporation (KGS)

무선계측을 이용한 휠로더 구동토크의 주요인 분석

강병익*,#, 동홍일*, 김병기*, 최용훈*
*한국가스안전공사

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ABSTRACT

Measuring the torque of the wheel loader of a driving device is a preemptive task to ensure its performance. In this study, wireless torque measurements were successfully conducted. Moreover, based on the experimental results and the adopted design method, the key factor of torque generation, which is the main load in driving devices, was analyzed. Other data not analyzed in this paper will be the basis for the logical design of wheel loader-based driving devices.

Keywords : Wheel Loader Driving Device(휠로더 구동토크), Wireless Torque Measurement(무선 토크 계측), Analysis of Main Factor(주요인 분석)

1. Introduction

Wheel loaders are a typical construction equipment used to move materials such as mines in working environments such as mining areas[1]. In particular, the work format represented by the V-phase is an optimized way to move a movable object from a previous location to a desired location[2]. The driving performance of the wheel loader is supported by the above operation. Therefore, it is essential to secure the durability performance of the driving device for reliable use of the wheel loader. It is necessary to accurately grasp the torque acting on the driving device. However, the task of accurately grasping the torque acting on the driving device is a task requiring many know-how and ideas, and data can not be easily acquired. Therefore, this study analyzes the main factors of torque generation, which is a representative load of the wheel loader driving system, and identifies improvement points in the design of the wheel loader driving system and suggests correct operating conditions to the users. The results of this study will also provide a quantitative design basis for the related parts, clearly demonstrating the operating torque of the driving power train connected to the drive shaft.

Corresponding Author : byoungik5@gmail.com
Tel: +82-10-9331-6097, Fax: +82-43-750-1948

2. Preliminary Backgrounds for Driving Torque Measurement

For the conventional torque measurement, a strain-based method was used. However, torque was required to be able to accurately measure the torsional strain rate rather than the strain measured by general tension and compression. Therefore, full - bridge type torque gauge is used in this study. In general, the difference between the quarter bridges which are used for tensile and compressive strain measurements and the full bridges is differentiated by the number of variable resistances in the Wheatstone bridge, as shown in Fig. 1. In the case of a quarter bridges, it consists of three fixed resistances and a variable resistance, and in the case of full bridges, there are four variable resistances and no fixed resistance. Therefore, it is possible to measure the tensile and compression generated when the twist occurs in each variable resistance of the full bridge, and it is possible to measure the twist more accurately than the quarter bridge.

Even if the torque calculation is determined through the twist measurement, it is necessary to select the twist measurement position. For this purpose, the process of transferring the power of the wheel loader was investigated. The power transmission process of the wheel loader driving device is shown in Fig. 2. The torque(y-axis) generated by the engine reaches the drive shaft through the transmission to achieve the desired power through the converter with a constant transmission ratio(x-axis) as shown in Fig. 3. Among them, the drive shaft which is exposed to the outside of the wheel loader was selected in order to easily attach and detach at the time of preparation of measurement, and to cope with an unexpected problem during measurement(Fig. 4).

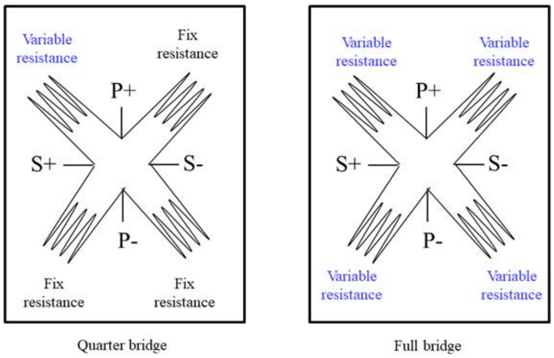

Fig. 1 Comparison of quarter bridge and full bridge

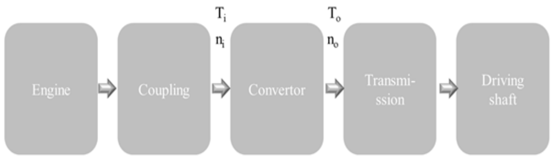

Fig. 2 Process of power transfer

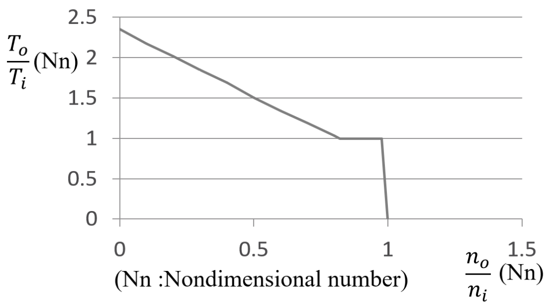

Fig. 3 Mechanism of convertor for torque transfer

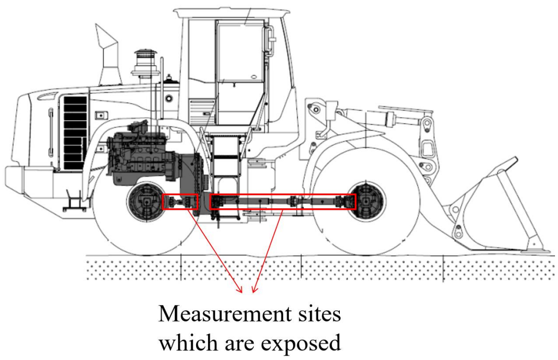

Fig. 4 Wheel Loader schematic and measurement site

Even if the measurement method and the measurement position are selected, it is necessary to select the data collection method to secure the reliability of the data. In the case of torsion measured in this study, it is aimed at the rotating axis. Therefore, if the wired measurement used in general is used, the measurement line may be twisted and broken. To prevent this problem, data collection using wireless measurement can be considered. In this study, we use the T24 product line, which is capable of wireless measurement, in order to avoid the above questions. The T24 product line is a highly reliable product of data processing, transmission and power delivery methods for wireless measurement (Fig. 5). This makes it possible to secure the reliability of data transmission and reception, and focus on the measured data analysis[3].

Fig. 5 T24 system and use example

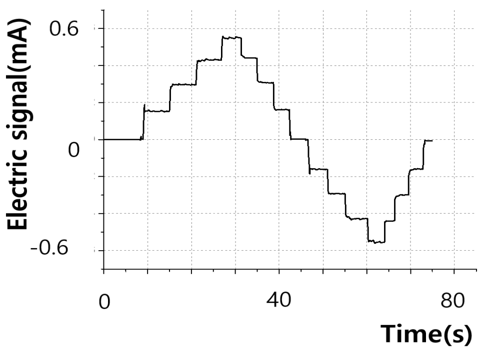

Fig. 6 Calibration loading

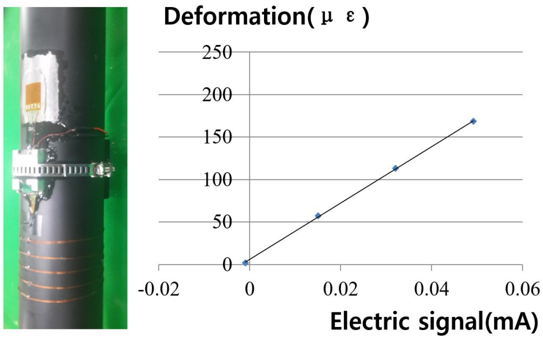

Fig. 7 Results of calibration

After that, calibration was performed to reduce the uncertain error[4] in the measurement process of converting the physical signal into the electrical signal, and the result was used (Fig. 6 for relating with load according to time_x-axis and electric current_y-axis). The relationship between the amount of deformation_y-axis, which is the desired physical quantity, and the electrical signal_x-axis, which is the measurement physical quantity, can be derived as shown in Fig. 7

3. Material and Experiment procedure

In order to analyze the main factors of the wheel loader driving torque, the test procedure as shown in Fig. 8 was derived. First, the torque measurement scenario of the driving device is set. Second, the designed measuring device is mounted on the wheel loader. Third, the basic operation is compared with the measurement data to confirm suitability of the measurement data. Fourth, data is acquired (Fig. 8).

The torque measurement scenarios of the driving devices consisted of 14 tasks that are the basis for using the wheel loader. The measurement scenarios are configured to represent all usage environments as shown in Fig. 9 through changing the usage rate of each basic task. The main goal of this measurement is torque. The reason for this is that the torque increases exponentially with the exponential value of

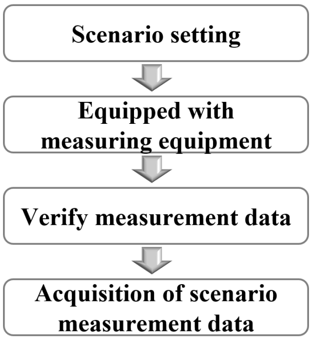

Fig. 8 Test procedure

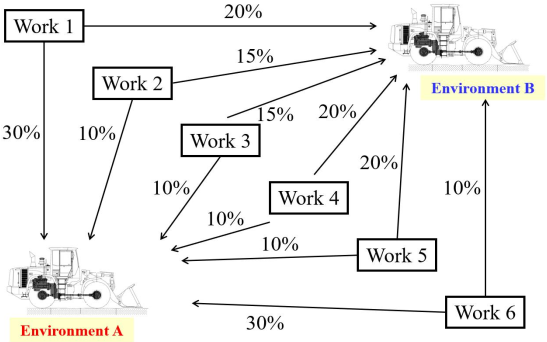

Fig. 9 Representation of environment through change of usage rate

the mechanical device when calculating the load of the traveling device (see Equation 1)[5] and is used as the main load in the dynamic analysis of the structure.

$$N \cdot S^{X} = C \tag{1}$$

The following is the installation of the wheel loader of the designed measuring device. In the measurement area, the driving shaft of the wheel loader driving device was selected in order to cope with unexpected problems and easy attachment and detachment. In order to further confirm the difference between the torque transmitted to the front wheels and the rear wheels, the torque measurement of the front and rear drive shafts was prepared (Fig. 10).

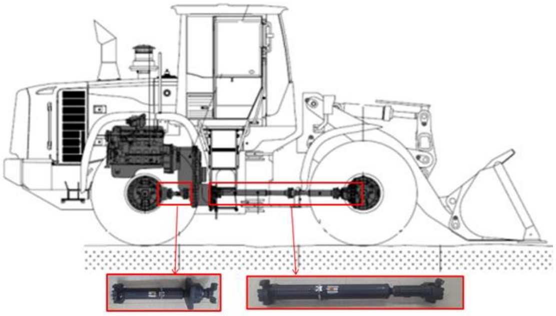

Fig. 10 Measuring equipment on front and rear drive shaft

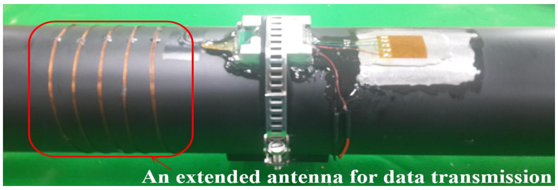

Fig. 11 An extended antenna for data transmission

The measurement equipment of the front and rear drive axes prepared was attached to the wheel loader and the measurement data was checked. As a result, no data appeared in the driven part, and a phenomenon appearing rarely occurred. In order to get rid of the problem, it was determined that there was a problem in data transmission and reception, and the data transmission / reception area was widened (Fig. 11). As a result, the data showed a clear change in data during operation, and the reliability of the data could be secured.

After securing the reliability of the transmission / reception data, the working torque of the wheel loader driving device was measured. In order to solve the problem caused by the lack of representativeness due to single measurement at the time of measurement, the measurement was repeatedly performed at each measurement 5 times (Fig. 12 for relating with load according to time_x-axis and electric current_y-axis). This analysis was performed to present the analysis results of the data obtained by

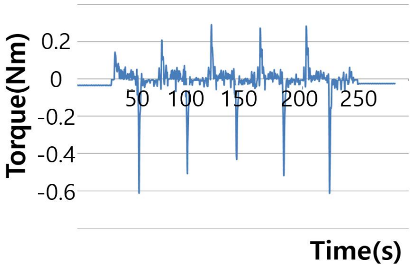

Fig. 12 Measure 5 to ensure representation

the measurement excluding the maximum and minimum values in the analysis as numerical values representative of the basic work.

4. Results and Discussions

The main factor of torque generation of the wheel loader driving device was examined using the measurement data. In this study, we used the results of eight scenarios (Table 1). Here, the torque generation magnitude is calculated based on the difference between the maximum torque and the minimum torque. The reason for this is that the fluctuating load resulting from the difference between the maximum torque and the minimum torque has the greatest effect on the durability of the structure[6].

Based on the above results, a main factor analysis using Minitab's complete factoring method (2 ^ 3 = 8) was performed[7]. We can confirm that the break method and object movement have a great effect even considering both the normal probability distribution of the result effect (Fig. 13) and the Pareto chart (Fig. 14). In order to quantitatively confirm the above results, the main effects and interactions of Minitab are shown in Fig. 15 and 16. There was almost no difference in the case of lockup. But, in the case of the type of brake and load, the effect was quantitatively significant. In the case of braking, a large torque was generated when the engine brake was used, and when the object was shipped, a large torque was generated when the object was. The interaction of each factor is shown in Fig 16. Fig 16 shows that there is no significant effect between the factors, but the effect of brake use and object shipment is relatively large. However, this is less than the effect of brake type and object shipment due to the following effect at the level of significance can be confirmed again in Fig 13 and Fig 14.

Table 1 Scenario for analysis of main factor

Scenario	Lock up	Brake	Load	Torque
1	Use	Foot	Apply	23
2	Use	Engine	Apply	51
3	Not use	Foot	Apply	26
4	Not use	Engine	Apply	53
5	Use	Foot	Not	36
6	Use	Engine	Not	94
7	Not use	Foot	Not	51
8	Not use	Engine	Not	100

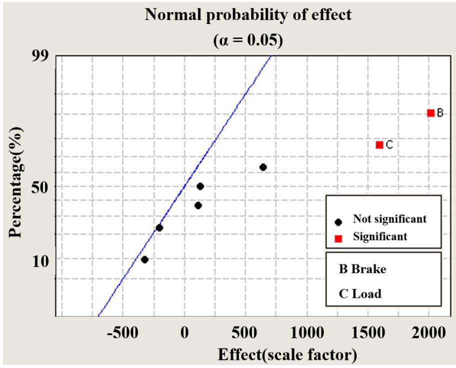

Fig. 13 Normal probability of effect for torque

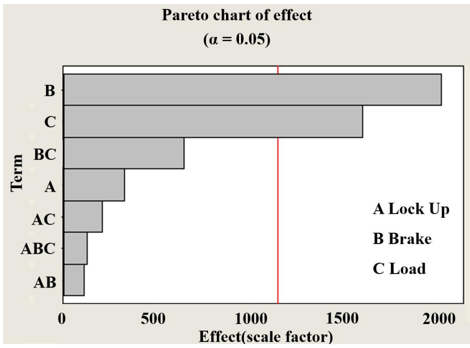

Fig. 14 Pareto chart of effect for torque

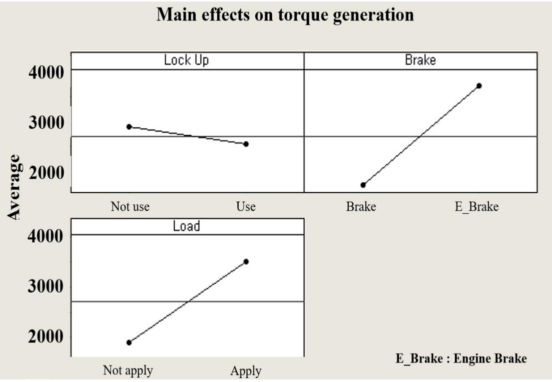

Fig. 15 Main effects on torque generation

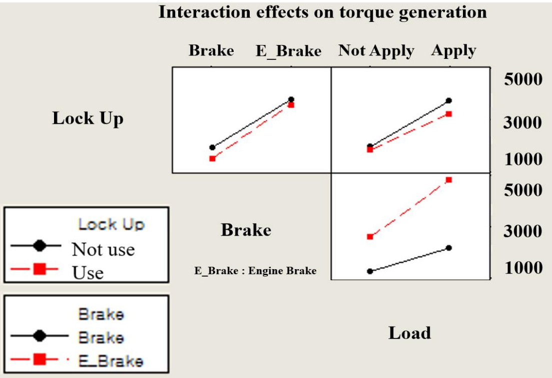

Fig. 16 Interaction effects on torque generation

5. Conclusion

In this study, the transmission torque setting which should be preceded for securing the reliability of the wheel loader driving system is secured through measurement. Among these, a full factorial design method was constructed for three factors considered as main factors of torque generation, and quantitative main factors of torque generation were secured by using this. The main factor of ensured torque generation was the type of brake used and whether or not the wheel loader was shipped. It can be seen that the torque acting on the wheel loader driving device is larger according to the driving habit of the driver rather than the lock-up problem which is pointed out in the design as the main cause of the torque generation. Therefore, it is confirmed that the driver's driving habit is more important than the lock-up function, for safe and trouble-free use of the wheel loader driving device. Also, the torque data of the basic work in the above-mentioned study will present a quantitative and logical design load to many mechanical parts constituting the wheel loader device having no definite design load according to the usage environment.

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