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Study on performance test of orchard tractor power transmission systems

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Abstract : This study started to export an orchard tractor to Europe under the situations that R&D activities for orchard tractor were marginal and even it was not produced. The R&D for orchard tractor has been progressed and the most of it is accomplishing the goal. In this study, the durability of clutch friction part was tested for F/R clutch and moment of inertia of PTO clutch, and it was compared with the design criteria of transmission of tractor. According to the results of inertia test of F/R clutch, hydraulic pressures of clutch satisfied 1,961.33 ± 196.13 kPa of design criteria, and the variations of torque for forward and reverse operation were relatively constant. Therefore, it was found that the durability of clutch friction part was stable and reliable. Test results showed that the main hydraulic pressures were maintained 1,961.33 ± 196.13 kPa during the tests of moment of inertia of PTO clutch, and when it was operated, the hydraulic pressures were reached 1,961.33±196.13kPa. Therefore, it was found that the hydraulic pressures of PTO satisfied the design criteria. By the results that the time of the hydraulic pressures of PTO reaching main hydraulic pressure, and that of torque values restoring to the original was same as the time of the first gear of PTO reaching the maximum rotational speed, it was found that PTO could transfer power to attachments as it was designed.

Key words **:** Orchard tractor, Transmission, PTO, Hydraulic pressure, Clutch, Durability

I. Introduction

This study started to export an orchard tractor to Europe under the situations that R&D activities for orchard tractor were marginal and even it was not produced. By the principle of market economy, only general purpose tractors were exported. But, in order to secure additional market by an orchard tractor, and to substitute import of orchard tractors whereas domestic orchard mechanization has been progressing, we make an effort to enhance the brand image of domestic business and competitiveness. The R&D for orchard tractor has been progressed and the most of it is accomplishing the goal. Because its target is to export the orchard tractor developed to Europe market, the most suitable performance is being developing. Among the developments, a prototype of transmission was developed and tested for various performances.

In order to secure the reliability of transmission of orchard tractor, tests for efficiency, environment resistant, and durability are required. The clutch is a device of torque transmitting devices. It is not only connecting torque from engine to axles, but also reducing torque variations occurring inevitably from inertia resistant of reciprocating motion of engine components. Transmitting the power of engine, clutch has several problems such as performance degradation of power transmission caused by abrasion and fatigue from continuous use, and that by friction characteristic variation due to heat from severe usage conditions. Tests for performance and durability are necessary for clutches having such an important functions. In fact, the performance and durability of clutches are

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very important measures of technology and value of manufacturer.

The objectives of this study was to test the performance of a prototype transmission (T/M) developed for orchard tractor. In the tests, performance and durability of friction part against moment of inertia for the forward and reverse (F/R) clutch and the PTO clutch, should be tested, and compared with the manufacturer's design criteria of transmission of tractor.

II. Materials and Methods

1. Testing systems and methods (Test for inertia force of F/R clutch of transmission)

Study was conducted to test the durability of friction part against moment of inertia for the forward and reverse (F/R) clutch. Testing systems consisted of an engine, a prototype transmission, a test bench, two fly wheels, a pressure meter, two torque meters as shown in Fig. 1. Fig. 2. showed a picture of a prototype transmission combined with power measurement system. The power of engine used in the test was 52.2 kW. The capacity of the torque meter used (YDR-500KM) was 500 kgf-m, and its nonlinearity is 0.09% R.O. (Rated Output), and hysteresis is 0.08% R.O. The capacity of the pressure meter used (PH-200KB) was 20MPa, and its nonlinearity is 0.04% R.O., and hysteresis is 0.14% R.O. Rotational speeds of axle, pressures, and torques were recorded by a data recorder (EDX-1500A, 16CH, Kyowa). The specifications of sample transmission tested are shown as Table 1, and it was the first product.

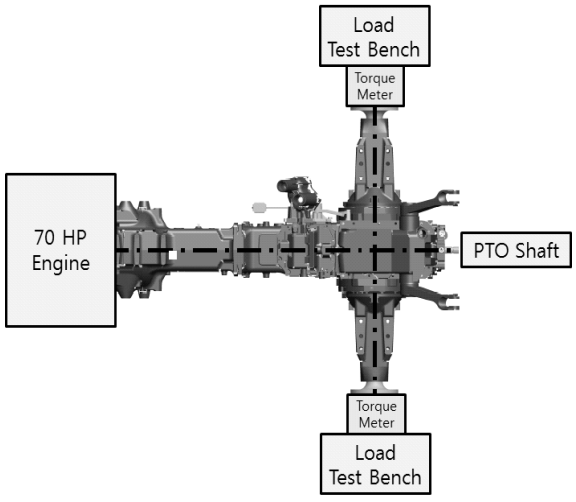

Fig. 1. The schematic of a transmission test.

Transmission tests were conducted for more than 5,000 Cycles (over 150 hours) with the unit cycle (2 minutes) of transfer from forward to reverse, and from reverse to forward. During the tests, The gear of engine (E/G) was maintained 2,300 rpm constantly unit cycle (2 minutes) of transfer from forward to reverse, and from reverse to forward. During the tests, The gear of engine (E/G) was maintained 2,300 rpm constantly.

Maintaining the rpm of engine same as the rated rpm of input shaft of tractor, discs were attached on the axles in order to substitute the load of axle to an equivalent inertia force. The torque and hydraulic pressure of axles exerted by the forward and the reverse rotation of axles, were measured by the

Fig. 2. A picture of general view of transmission test (F/R)

Table 1. Specification of tested transmission.

Power	70HP = 52.2kW
Imput speed (rpm)	2,300
Shift range	12 (Range C, L, H × Main 1, 2, 3, 4)

torque meters attached on the shaft of output power. Transmission gear was selected as the maximum torque could be loaded on axle, and rotations of power transfer were conducted forward and reverse continuously. During tests, H1 gear applying maximum traction load was selected as a transmission gear, and the torque and hydraulic pressure were measured in 100Hz interval. For the tests, temperature of T/M should be maintained as 80~90℃, temperature measured at outlet of cooling water should not be over 105℃, oil temperature of E/G should be lower than 130℃. Furthermore, temperature of exhaust gas should not be over 660℃, and if hydraulic pressure of F/R reached more than 1,961.33 ± 196.13 kPa, tests should be stopped because of abnormal of testing machineries.

2. Test of inertia force of PTO clutch of transmission

Discs were attached on the PTO axles in order to substitute the load of PTO axle to an equivalent inertia force. Transmission gear was selected as the maximum torque could be loaded on axle, and on/off of PTO was conducted continuously. During the tests, the gear of engine (E/G) was maintained 2,300 rpm constantly and accordingly with the first gear of PTO. Transmission tests were conducted for more than 2,000 Cycles (over 100 hours) with the unit cycle (3 minutes) of on (one minute) and off (two minutes) of clutch. Fig. 3. shows a picture of transmission test bench (PTO) used in the test. Testing systems was same as the one used F/R clutch test. Measuring variables were main hydraulic pressure, hydraulic pressure of PTO, rotating speed of PTO, and torque of PTO.

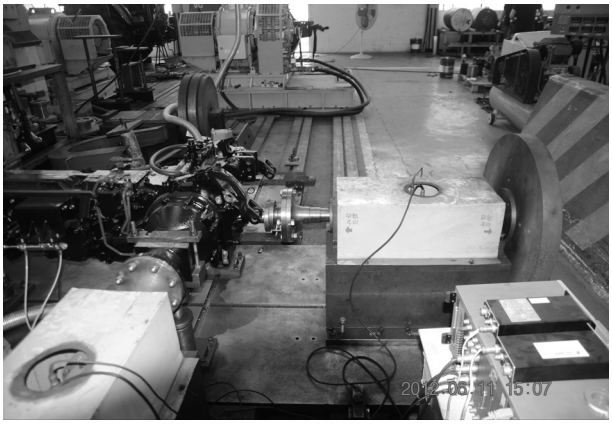

Fig. 3. A picture of transmission test bench (PTO) used in the test.

III. Results and Discussion

Fig. 4. shows the graph of the variation of hydraulic pressure and torque of F/R clutch. It was found that the

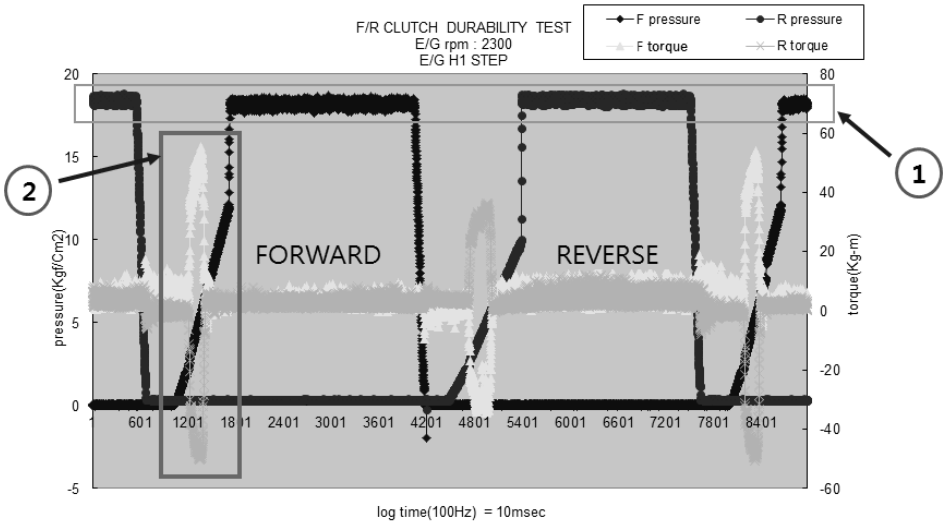

Fig. 4. F/R clutch durability test graph.

variation of hydraulic pressure and torque were constant for the forward and the reverse of clutch such as ① of Fig. 4.

The F/R clutch of transmission satisfied design criteria of 1,961.33 ± 196.13 kPa for hydraulic pressure, and it worked well and stably. When clutch was operated forward and reversely, the hydraulic pressures were lower than 1,961.33 kPa. This condition may be occurred by the friction of valve and foreign materials. There were overshoots of torque for the forward and the reverse of clutch as ② of Fig. 4. showed. This was the time that rotating direction of axle changed direction reversely, overshoot would be caused by the control valve action. In other words, since the dynamic energy was changed to pressure energy, a sudden pressure variation occurred and it caused surge pressure. Even though such a surge pressure did not much affected transmission in our tests, the high surge pressure meant that damages on component might be serious. The surge pressure is used to occur in the hydraulic circuit, when there are delayed works of relief valve or control of electronic change-over valves, and if these caused sudden change of oil flow. And in some other cases such as if there are mixture of air to oil or variation of oil viscosity, surge pressure might be occur, and mitigation measures are needed surge pressure, respectively.

Fig. 5. showed the results of durability test of PTO clutch. Using the loads applied to PTO axle of transmission, durability was compared with the design criteria. The main hydraulic pressure was 1,961.33 ± 196.13 kPa, an overshoot was occurred as indicated by ① of Fig. 5. and it was a result of a surge pressure caused by the opening of PTO valve. As indicated by ② of Fig. 5. at the time of PTO operation, variation of torque was occurred and restored to the original levels of torque. This showed that torques were produced during power transmitting to PTO discs, then after finishing power transmitting, PTO axle and discs became one united body and produced no more torques. There was a procedure of reaching certain rotating speed of PTO from its quiescence condition by the first gear of PTO as ③ of Figure 5 indicating. From that procedure, waveform such as ④ of Fig. 5. could be produced. This situation explained that clutch burning or mechanical damage might be occurred by the quick connecting of F/R clutch. This result suggests us that, in order to prevent such problems, clutch should be connected

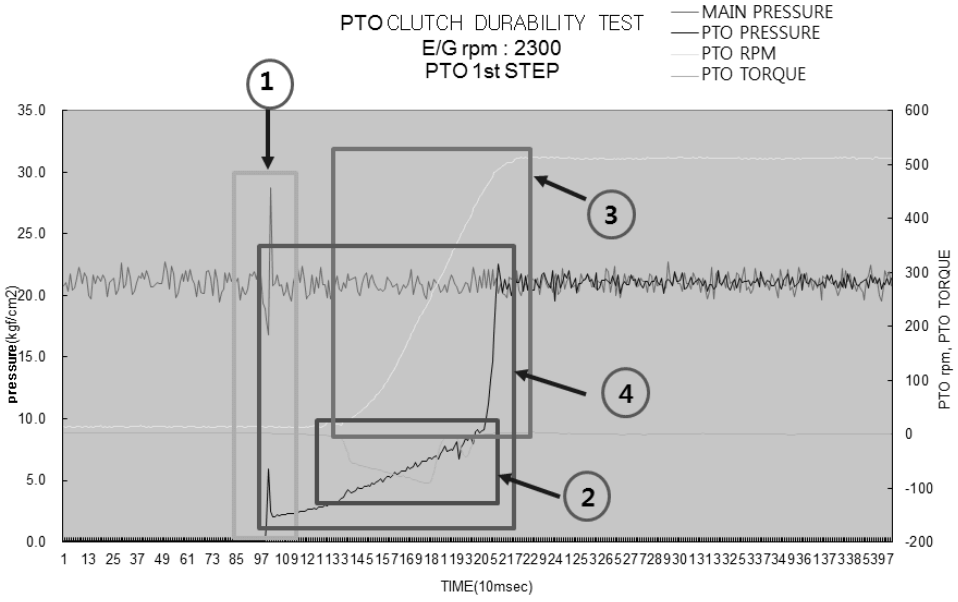

Fig. 5. PTO clutch durability test graph.

smoothly by controlling hydraulic pressure of PTO.

IV. Conclusions

In this study, the durability of clutch friction part was tested for F/R clutch and moment of inertia of PTO clutch, and it was compared with the design criteria of transmission of tractor. According to the results of inertia test of F/R clutch, hydraulic pressures of clutch satisfied 1,961.33 ± 196.13 kPa of design criteria, and the variations of torque for forward and reverse operation were relatively constant. Therefore, it was found that the durability of clutch friction part was stable and reliable. Test results showed that the main hydraulic pressures were maintained 1,961.33 ± 196.13 kPa during the tests of moment of inertia of PTO clutch, and when it was operated, the hydraulic pressures were reached 1,961.33 ± 196.13 kPa. Therefore, it was found that the hydraulic pressures of PTO satisfied the design criteria. By the results that the time of the hydraulic pressures of PTO reaching main hydraulic pressure, and that of torque values restoring to the original was same as the time of the first gear of PTO reaching the maximum rotational speed, it was found that PTO could transfer power to attachments as it was designed.

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