Precision Agriculture Science and Technology

pISSN : 2672-0086
eISSN : 2713-5632

RESEARCH ARTICLE

Shifting performance of clutch pack for full powershift transmission of a tractor

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Abstract

The objective of this study is to simulate the shifting performance of a clutch pack for full power-shift transmission (PST) of a tractor. The shifting shock and shifting time were calculated based on the load profile of a tractor. Both shifting shock and shifting time were analyzed based on literature. It was found that the shifting shock and shifting time were satisfied with the simulation conditions. It was also found that shifting shocks were less than 9.8 m/s2 and the sifting times were maximum 1 s, which was less than 1.2 s. The limitation of the study is conducted by the only simulation. Finally, it can be said that this is the basic study on power-shift transmission. It is required to conduct the further study for enhancing the transmission performance.

Keywords: Tractor, power-shift transmission, clutch pack, shifting shock, shifting time

DOI: https://doi.org/10.12972/pastj.20200018

Received: July 1, 2020

Revised: August 21, 2020

Accepted: August 24, 2020

Introduction

Tractors are agricultural machines that are used for various purposes like agriculture, construction, forestry, and transportation (Kim et al., 2020). The Agricultural tractors are specially designed to perform at low speed for providing high tractor forces (Tanelli et al., 2011). A suitable power transmission system is essential to deliver continuous power to the driving axles during operations (Siddique et al., 2020). That is why several researchers and manufacturers have been developed various transmission systems considering continuous power supply, driver comfort, flexible, reliable, fuel-efficient, and high efficiency.

To ensure the high flexibility and available maximum power at all gear stages and all working conditions, agricultural tractors are equipped with advanced and popular technology, so-called power-shift transmission (PST). The PST allows us to change the vehicle speed on the run and under various load conditions. Liang et al., (2018) reported that the PST is the most popular power transmission system for being relatively easier and convenient to control and maintain on-farm for a driver.

PST technology is getting popular and also increasing the demand day by day. Yang et al., (2018) reported that the reason for getting popularity of the PST is the wide range of applications from low to high power vehicles. The PST can eliminate the clutch friction during transmission without losses of the vehicle performance (Tseng and Yu, 2015). Nievelstein (2005) reported that several factors influence fuel consumption such as weight, design, speed, and driver of the vehicle. He also observed that the PST can save effectively about 1.90 to 4.70% of fuel.

According to Li et al., (2018), the PST is one of the transmissions of a tractor which is applied by an electric control system to engage the clutch to improve the power, economy, and driving comfort. However, most of the tractors in Korea are commercialized using power shuttle and semi power-shift technology, which are not highly efficient and flexible for drivers.

This is the basic study, which is focused on the simulation model development of the clutch pack for power-shift transmission. Therefore, the objective of this study is to simulate the shifting performance of the clutch pack for full PST of an agricultural tractor and analyze the shifting performance.

Materials and Methods

Power flow of power-shift transmission

The power flow diagram of the power-shift transmission (PST) is shown in Fig. 1. Generally, the engine power is delivered through the main stages to the driving axle, followed by the high-low, range shift, and creep. The range shift has an available synchronous gears option that can be fast and comfortably shifted. The creep can gain precise vehicle speed in both the forward and reverse operating directions.

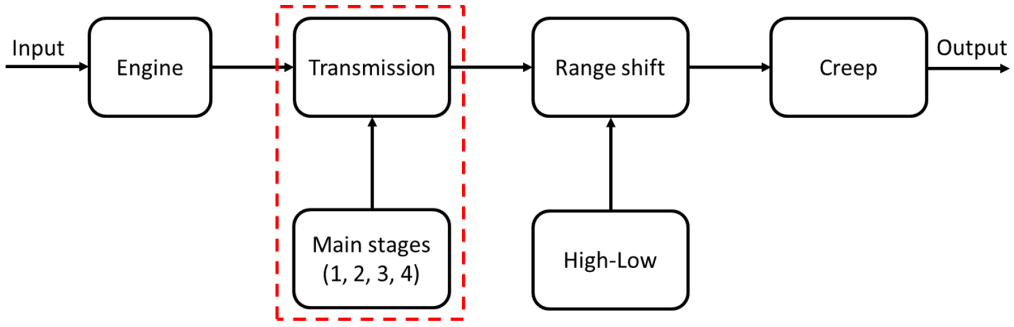

Fig. 1. The power flow diagram of power-shift transmission

Simulation model of the clutch pack for PST

The PST has 4 clutch packs (main gear stages), 2 high-lows, and 2 stages of range and creep (16×16) for forward speed. The clutch pack consists of several mechanical and power-train components, which are operated by the proportional valve performing the hydraulic pump. The proportional valve maintains the engage and disengage of the clutch pack. The specifications of the simulation model were considered based on 125 HP real full power-shift transmission, literature reviews, and recommended by several manufacturers of the power-shift transmission. The simulation model is shown in Fig. 2.

The shifting performance was conducted based on axle load conditions. The load profile was shown in Fig. 3.

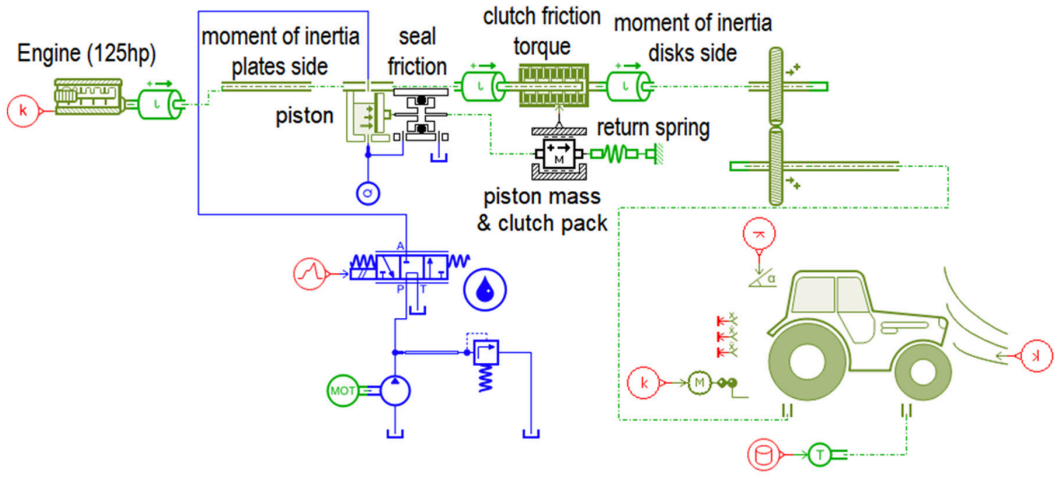

Fig. 2. The simulation model of the clutch pack for full power-shift transmission.

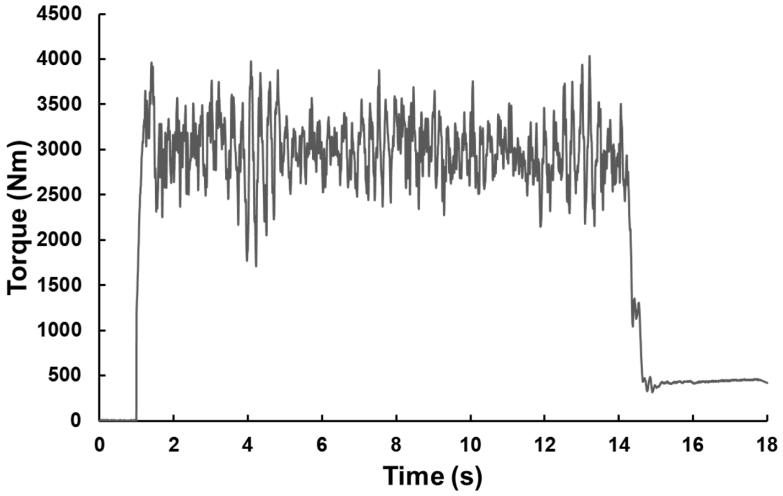

Fig. 3. The load profile to measure the shifting performance.

Experimental method

The simulation was conducted for a step input profile and applied to the proportional valve as a clutch profile. The simulation results such as vehicle shifting shock and shifting time were analyzed by the simulation conditions for automatic transmission from the literature on the PST (Eom and Lee, 2018), and the simulation conditions were listed in Table 1.

Table 1. The simulation conditions with reference

Items	Target	Eom and Lee, 2018
Shifting shock (m/s^2)	9.8	9.8
Shifting time (s)	1	1.2

Results and Discussion

The shifting shock and shifting time are the key factors for PST performance because shifting time is inversely proportional to the shifting shock. Both factors were analyzed at the maximum rotational speed, 2350 rpm.

Shifting shock

The performance of the PST depends on the shifting shock of the vehicle. The peak to peak shifting shock was calculated using the subtraction of the maximum and minimum peak of the shifting shock at 2350 RPM. The shifting shocks were shown in Fig. 4. It was found that the shifting shock was 4.965 m/s^2. The shifting shock was listed in Table 2.

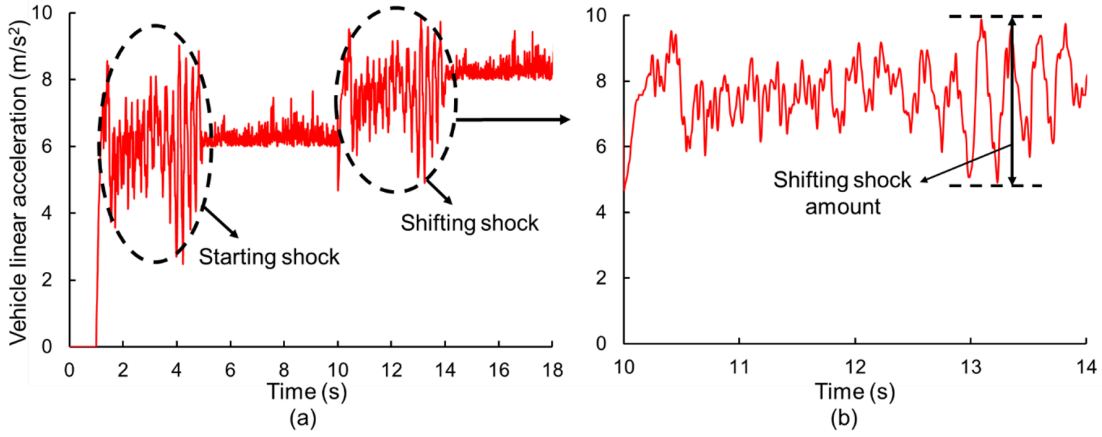

Fig. 4. The shifting shock of vehicle at 2350 RPM: (a) The fulltime simulation; (b) The enlarged of the shifting shock.

Table 2. The shifting shock of the clutch actuator

Parameters	Maximum	Minimum	Peak to peak
Shifting shock (m/s^2)	9.870	4.905	4.965
Shifting time (s)	11.5	10.5	1

Shifting time

The shifting times were calculated by the duration of time to change the vehicle speed from one stage to another stage. The shifting time was also calculated at 2350, which is listed in Table 2. The vehicle speeds were displayed in Fig. 5. It was observed that the vehicle speed was started to increase at 10.5 s and become stable at 11.5 s. It indicates that the vehicle took 1 s to shift the clutch from 1st stage to 2nd stage.

Conclusion

This study was conducted to simulate the shifting performance of the clutch pack for full power-shift transmission (PST) of a tractor. The shifting shock and shifting time were calculated at the maximum speed of 2350 RPM for load profile. Both shifting

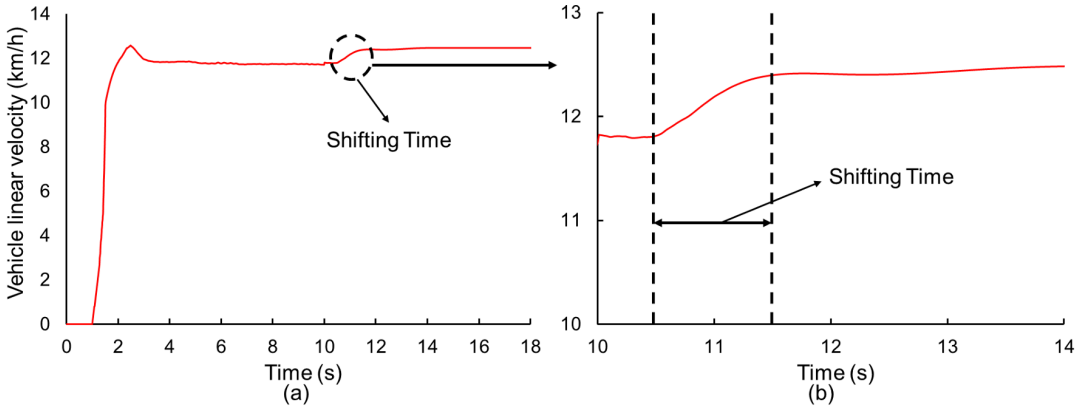

Fig. 5. The shifting time of PST clutch pack: (a) The fulltime simulation; (b) The enlarged of the shifting time.

shock and shifting time were analyzed based on literature. It was found that shifting shock was 4.965 m/s^2, which was less than 9.8 m/s^2 and the shifting time was 1 s, which was also less than 1.2 s. The results indicate that the shifting performances of the vehicle were satisfied with the simulation conditions, which could be applied to the PST model of a tractor. The limitation of the study is conducted by the only simulation. In the future, the validation test is important for the simulation model by performing the field operation or using the prototype PST model. Finally, it can be said that this is the basic study on power-shift transmission. It is required to conduct the further study for enhancing the transmission performance by minimizing the shifting shock.

Acknowledgments

This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Project No. PJ014981022020)" Rural Development Administration, Republic of Korea.

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