RESEARCH OF TRACTION FORCE DURING THE TRACTORS POWER SHIFTING

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Abstract

Because of the agricultural requirements, the tractors need a lot of gears in order to reach the ideal hyperbole of traction power. The tractors must excent huge forces inside a narrow velocity range.The large number of gears in transmission also can be explained by the narrow r.p.m. interval of the engine. Nowadays to perform the general requirements such as increasing the engine power and efficiency, or making a modern electronic control system are not enough. In order to optimize the engine parameters the traction force hyperbole must be traced out as accurate as possible. The change of load during the work explains the continuous or periodic change of the gear ratio. In this study the change in time of traction force was examined during power shifting.

1. Introduction

The transmissions of agricultural power machines must be suitable to fulfill the special and different requirements of the soil-wheel connection. The tractor powertrains achieve it in different ways nowaday. For the efficient work, it is not enough to have a modern diesel engine, but the engine power must be transmitted to the wheels with the minimum loss. It's important for the optimal engine load and consumption. It is worth to follow the traction force hyperbole at constant power in order to get the optimal relation between the tractor and the towed machine. The conventional gearboxes contain many overlapped gears for this purpose that make possible shifting under loaded conditions (DeVincent and Roethler, 2006) The most ideal solution is the Continuously Variable Transmissions (CVT). The energetically optimal working point was kept inside a narrow velocity range in the field works.

The new tractor transmissions are combined: they contain both mechanical and hydrostatic elements that can make possible the chosen working speed in a part or the whole velocity range. The continuous variability available in each speed ranges. The hydrostatic unit has poor efficiency at the margins of the interval: in very low speed and near maximum speed (Kugi et al., 2000) The efficiency can be increased by using mechanical elements, for example planetary gear.

To improve the efficiency, Power Shift transmission should be used. This unit uses hydraulic power to actuate the multi-disc clutches to shift under load. The shifting process can be controlled by the actuating pressure. During the shifting procedure the slip of the multi-disc clutches is controlled (Laib and Vas, 1998), while the transferred torque decreases (Szente, 1999). The analysis of the shifting process is important in order to determine the energy loss of the machine, and the working quality as well. If energy loss occurs during the shifting process, it is necessary to accelerate after shifting (Kim and Kim, 2000). By using heavy duty agricultural tractors the more you accelerate the more specific consumption increasing. The objective of our research activity is to analyse the power transfer during shifting. The changes of traction force related to the time also can be determined.

2. Research method

The examination was carried out under field condition, with a John Deere 8300 tractor in Balkány, and with a Case IH MXM 155 tractor in Nagyecsed. The same size mid-weight disc harrow was used as a load both of the places. The traction force was measured in an indirect way, a hydraulic cylinder was applied between the tractor and the attached machine and the changes of the generated hydraulic pressure in relation of time were measured. The used hydraulic cylinder attached in the circuit can be seen in the fig. 1.

Figure 1. Hydraulic cylinder application for traction force measurement

The wheel velocity has been measured by an opto-electronical r.p.m.– signaler. The reflection labels were fixed in different places on the tractors. AS for the Jonh Dere 8300 we hadn't got enough place for placing stickers, because the JD transmission is rather close to the cab, therefore 4 labels were placed on the inner side of rear tyre. As for the Case-IH tractor stickers were fixed on the front axle (this is the place where the velocity sign is the most exact) This unit can be sense only wheel r.p.m., without slip.

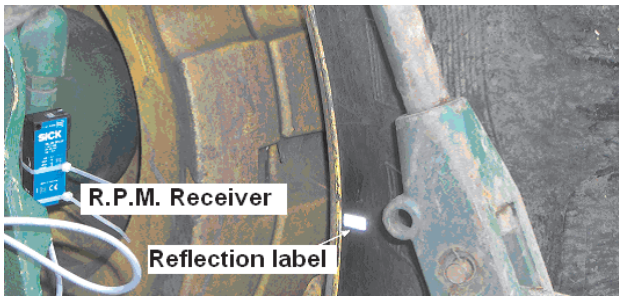

Figure 2. Velocity sensing solution

We used the pressure and r.p.m. converters of HYDAC hydraulic research kit, and the HMG 2020 data collector.

This data collector can be received 4 analog (pressure sign 4-20 mA) and 1 digital (r.p.m.) sign every 10 milliseconds, and the built in memory has half million data capacity.

The slip between the wheel and the soil hasn't been measured, because it isn't effect for the traction force exertion. Both of the tractors has multiplier system powershift transmission.

The John Deere has four gear groups, A, B, C and D, inside the groups has four gears (1.,2.,3.,4.) , therefore the transmission has 16 gears altogether. Shifting under load is possible in numbered gears and between the gear groups also.

The Case -IH has three gear groups, A, B, and C, inside the groups has six gears (1.,2.,3.,4.,5.,6.) , therefore the transmission has 18 gears altogether. Shifting under load is possible in numbered gears and between the gear groups also.

3. Results of measurement

Both of the tractors were tested in working condition, at constant engine r.p.m (1500 r/min) during acceleration and deceleration. Testing the John Deere during acceleration started from gear B1, shifting up through B2→B3→B4 to C1 gear continuously. When shifting from B4 to C1 it is necessary to change gear group as well. The traction force-time curve can be seen in fig. 3.

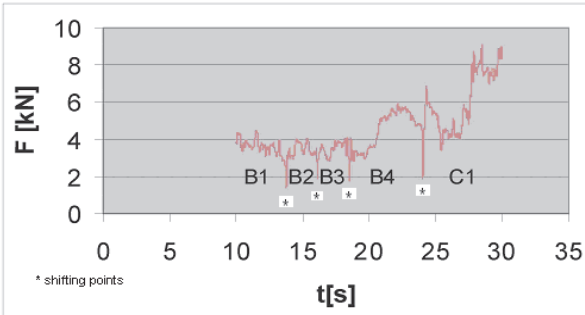

Figure 3. Traction force changes during acceleration at John Deere 8300

Testing the Case-IH during acceleration started from gear B3, shifting up through B4→B5→B6 to C1 gear continuously. When shifting from B6 to C1 changing gear group is needed also. The traction force and wheel velocity curve can be seen in fig. 4.

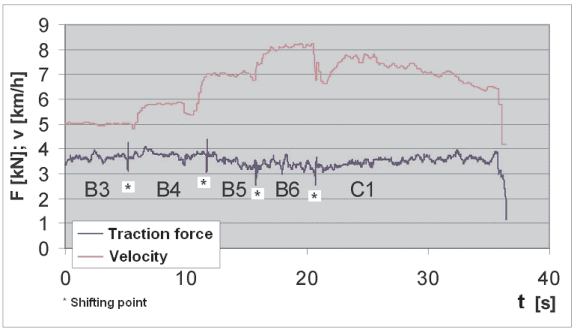

Figure 4 . Traction force and velocity changes during acceleration at Case-IH MXM-155

It can be stated that traction force decreasing significantly at gear-group shifting. (B6-C1). The fluctuation of traction force was more than 20% in the shifting moments. The reason of this fluctuation is the construction of the equipments. The hydraulically actuated multi-disc clutches slip right before and after the shifting, until the working pressure reaches its nominal value.

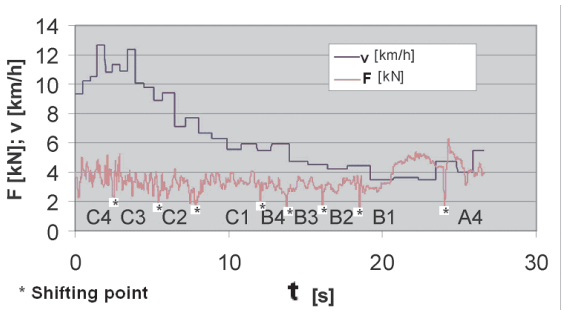

Figure 5. Traction force changes during deceleration at John Deere 8300

The heat generated by the friction during shifting means energy loss. In the first case the quantity of generated heat is proportional the shifting time and the transmitted torque. In the second case the length of shifting time is important for the machine kinetic energy. The momentum of the machine decreases until the end of the shifting, and if this time is too long the machine stops. This is also refers to deceleration during work also. The momentum of machine effects on the opposite direction when shifting to lower gear. The deceleration curve can be seen on the fig.5. and Fig.6.

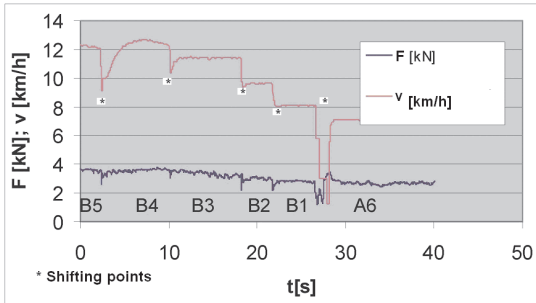

Figure 6 . Traction force and velocity changes during deceleration at Case-IH MXM-155

In order to analyse the shifting moment, the relevant part of the traction force-time curve must be enlarged.

Thanks to the particular data collecting, the changes can be followed. This can be seen in the diagrams of fig. 7 and fig.8. As for the gear group change it needs longer time than a „simply" shift between the gears. The Case- IH need almost 1second time to accomplish this operation. In spite of the bigger size and power the John Deere needs only 0,4 second to do this.

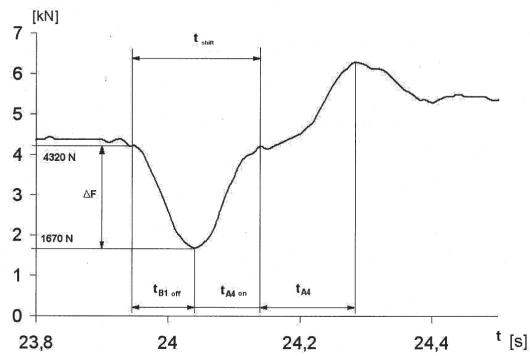

Figure 7. Traction force changes during deceleration gear group shifting at John Deere 8300

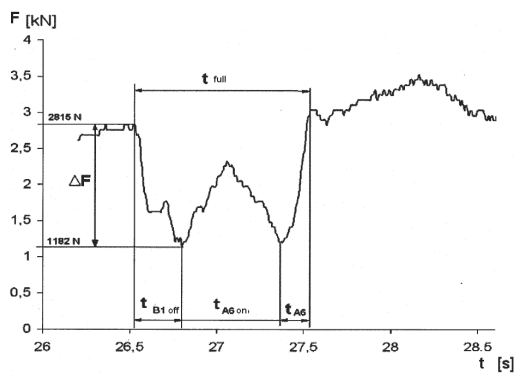

Figure 8. Traction force changes during gear group shifting at Case-IH MXM-155

4. Conclusions

It can be concluded from the data presented above that the shifting time and the changes of traction power are very important for using tractors or other constant loaded machines. Significant momentum loss can be experienced in shifting time, that can cause the stop of the machine train, or can make the shifting impossibly. This conclusion is especially for the simply, mechanical shiftable transmssions.

Tractor transmission development and construction process are effected by these factors. The more and more spreading powershift and CVT transmissions can help to have the optimal range.

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