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# Simulation of an Auxiliary Drive for an Agricultural and Forestry Transportation Aggregate

*A hydraulic auxiliary drive is presented here for agricultural and forestry transportation aggregates. The system model was developed and tested at the University of Agriculture in Hanoi. The concept is based on the kinematic calculations of two parallel drive lines from the tractor engine to the driven axles, so that the auxiliary system can be activated and deactivated automatically depending on tractor slip. The simulation indicates that the transportation aggregate with the auxiliary drive can easily drive over local obstacles on agricultural and forestry roads, because the auxiliary system immediately reacts to changes in tractor slip.*

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**Keywords**

Tractor, auxiliary drive, transportation aggregate

In agro-forestry transportation, tractor and trailer frequently have to go across the poor stretches of roads, such as local obstacles, slopes or local skidding. Those working conditions lead to decreasing transportation capacity and increasing fuel consumption. To improve agro-forestry transportation, a one axle trailer with hydraulic auxiliary transmission has been designed and manufactured at Hanoi Agricultural University. The trailer is connected to a four wheel tractor (30 kW) Shibaura 3000. Research on designing and testing has been introduced in [1, 2]. Due to the preeminent properties of hydraulic transmission, such as active connection between tractor and trailer, automatic coupling and uncoupling of hydraulic transmission with high safety that can significantly improve transportation capacity on the poor road conditions in agro-forestry. This article analyzes operation properties of a tractor trailer aggregate with a hydraulic auxiliary drive.

The diagram of the aggregate with hydraulic assistance as shown in *Figure 1* is used for agro-forestry transportation. This aggregate operates as a two axle's self-propelled machine. The second axle is driven from engine through PTO and a hydrostatic gear-box. Trailer is automatically connected or disconnected, depending on the slip of the tractor's driving wheel and the corresponding ratio of two driving axles, that means depending on the balance between velocities created from moving lines of tractor and trailer.

To get an effective auxiliary transmission and fast adaptation, it is necessary to calculate the general transmission ratio of the system exactly.

In *Figure 1* there is: 1. Tractor engine; 2. Tractor Clutch; 3. Tractor gear-box; 4. PTO transmission; 5., 6. Hydraulic pump and motor; 7.Auxiliary gear-box; 8. Cardan-joint; 9. Differential; 10. Tractor wheel; 11. Trailer wheel; 12. Transportation TA.

The ratio of auxiliary transmission is calculated from kinetic balance between two driving axles:

$$V_{TA,T} = V_{TA,A} \tag{1}$$

Where: $V_{TA,T}$ and $V_{TA,A}$ are velocities created from moving lines of tractor and trailer, therefore:

$$\frac{\omega_m}{i_T} R_B (1 - S_H) = \frac{\omega_m R_R \eta_V}{i_S i_P i_{vs}} \tag{2}$$

In the above formula, the figures of system, such as transmission ratio $i_T$, radius of tractor wheel $R_R$, transmission ratio $i_{vs}$, hydraulic efficiency $\eta_V$, are known or determined. There are only two changeable factors including transmission ratio of auxiliary gear-

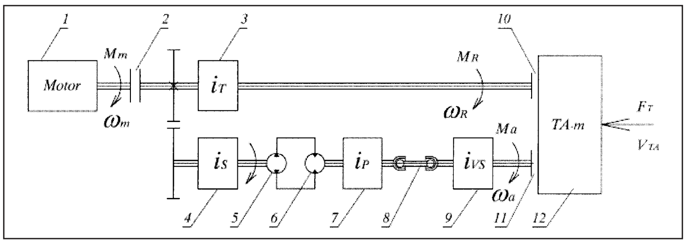


*Fig. 1: Drive pattern of the TA with the hydraulic propelled trailer axle*

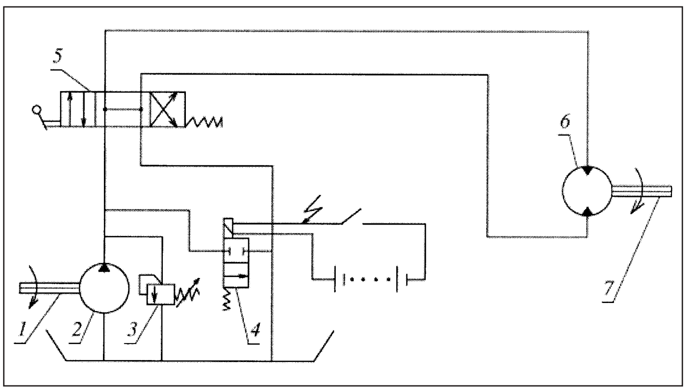


*Fig. 2: The hydraulic circuit for the trailer drive*

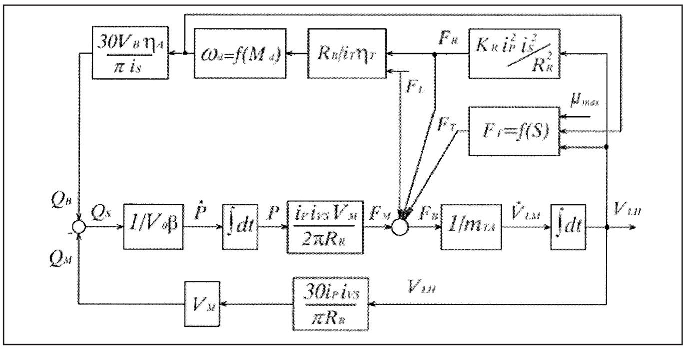

Fig. 3: Block diagram for controlling the auxiliary drive

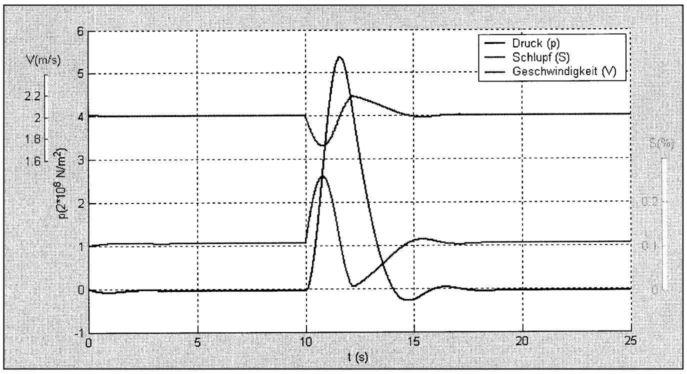


Fig. 4: Result of a simulation calculation: jump from $\mu_{max}$= 0.8 to $\mu_{max}$ = 0.5

box and skidding degree of tractor wheel for obtaining automatic connection and disconnection to trailer exactly. After simply converting, ratio of auxiliary gear-box can be calculated as following:

$$i_P(1-S_H)=\frac{\eta_h i_T R_R}{i_S i_P R_B} \quad (3)$$

The wheel slip of the tractor, which starts connecting the auxiliary transmission is chosen when 8% to 10%. The other figures are chosen depending on technical characteristics of the tractor Shibaura 3000, the manufactured trailer and the selected hydrostatic gear-box.

### Diagram of hydraulic circuit for the auxiliary transmission

Auxiliary transmission of the aggregate is implemented by a hydraulic system (*Fig. 2*). There is: 1. PTO; 2. Hydraulic pump; 3. Safety valve; 4. Valve 2/2; 5. Valve 4/3; 6. Hydraulic motor; 7. Output shaft to trailer axle.

Main component of the hydraulic system is a hydrostatic gear-box. Its driving shaft is connected to the PTO of tractor, which means hydraulic pump is driven from tractor engine through PTO. Output shaft of the hydrostatic gear-box is connected to differential box of the trailer through cardan-joint and auxiliary gear-box (*Fig. 1*). The engine and hydraulic pump are selected to ensure that the aggregate can work, even when the wheel slip of the tractor reaches 100%. The auxiliary transmission is controlled by using one manual distribution valve 4/3 and one restricted pressure valve as a safety valve. Besides, there is one distribution valve 2/2 for cutting transmission, when braking the aggregate.

### Analyzing operation properties of the transportation aggregate

*Model development*

To analyze operation properties of the transportation aggregate with hydraulic auxiliary transmission, one simulation model has been developed. The model is developed basing on technical data of the transportation aggregate, which is tractor Shibaura 3000 one axle trailer with hydraulic transmission. Based on drive pattern (*Fig. 1*) and hydraulic circuit diagram (*Fig. 2*), one block diagram has been sketched out for automatically controlling the auxiliary transmission. (*Fig. 3*).

The model is developed based on:

- Flow balance: $Q_B - Q_M = Q_S$
- Force balance: $F_B = F_T + F_M - F_L - F_R$

Where: $Q_B$ - flow to pump; $Q_M$ - flow through motor; $Q_S$ - compressing flow; $F_B$ - inertia force, $F_T$ - tangent force on drive wheel of tractor; $F_M$ - tangent force on trailer wheel; $F_L$ - loading force of aggregate; $F_R$ - friction force of motor converted equivalently to trailer wheel.

*Simulation*

This is an example of simulation for the aggregate going across a stretch of local skidding road. Performance condition for this state is:

$\mu_{max} = \mu_{max1}$, if $t < t_1$; $t_1 > t_2$

$\mu_{max} = \mu_{max2}$, if $t < t_1 < t_2$

MATLAB/SIMULINK software is used for calculating. The simulation results are shown in *Figure 4* and *Figure 5*.

The reaction of the auxiliary transmission can be recognized. The change of μ in step shape from $\mu_{max}$ = 0.8 to $\mu_{max}$ = 0.5 (*Fig. 4*) and then to $\mu_{max}$ = 0.3 lead to correlative sudden change of oil pressure in hydraulic pump and produce a correlative rotation moment in axle of trailer.

This auxiliary moment helps the aggregate easily go across the stretch of skidding road. Wheel slip of the tractor wheel is 10% at the moment the auxiliary transmission starts working. Depend on jump step measure of grip coefficient $\mu_{max}$, hydraulic pressure will increase to a value that can create an auxiliary moment to the trailer wheel, which helps the machine to go across the stretch of skidding road.

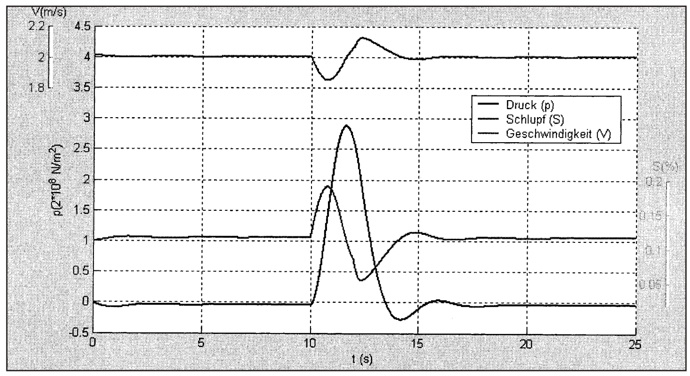


Fig. 5: Result of a simulation calculation: jump of $\mu_{max}$ = 0.8 to $\mu_{max}$ = 0.3

### Summary

With the hydraulic auxiliary transmission to the trailer axle, the transportation on poor condition roads can be improved significantly. Since the transportation aggregate can easily go across local obstacles, consequently transportation capacity can be increased and fuel consumption can be reduced. Simulation result show that the auxiliary system can automatically operate and react in time to changes of whell slip of the tractor. With the operational properties mentioned above, this auxiliary system can be broadly applied in agriculture and forestry.

## Literature


[1] *Bui Hai Trieu*: Hydraulic Assistant Transmission in transportation combine machine. Science & technology journal of agriculture & rural development 67 (2005), no. 9, Hanoi /Vietnam

[2] *Bui Hai Trieu*: Extract analysis to operate of hydraulic transmission system on the trailer combined with tractor transporting in the farm and forestry. Science & technology journal of agriculture & rural development 67 (2005), no. 9, Hanoi/Vietnam

[3] *Bui Hai Trieu and Han Trung Dung*: Determining power performance of the diesel engine by acceleration testing method. Proceedings of the 20th scientific conference in Hanoi University of technology, Hanoi, October 2006

[4] *Nong Van Vin and Han Trung Dung*: Theory – experimental method for investigating the drawbar performance of the farm tractor. Science & technology journal of agriculture & rural development ISSN – 1859-0004

[5] *Nong Van Vin*: Reseach on improving Farm tractor for working on the Forestry sloping road. Scientific Report belongs with National Science and Technology Programme code KD-07-26, Hanoi, November 2006