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Synthesis of Hydrostatic Mechanical Transmission of Wheeled Tractors for Agricultural Purposes

Key words: *hydrostatic mechanical transmission, planetary gear, tractor industry.*

Annotation: *In the given work, according to the results of the complex static analysis there were revealed and presented the kinematic schemes of prospective hydrostatic mechanical transmissions, identified their main design parameters, the dimension-type of hydraulic units of the hydrostatic drive, specified the kinematic, power and energy transmission parameters, analyzed the schemes of hydrostatic mechanical transmissions with two differentials: input and output.*

Introduction

Recently, they started to serially install entirely new tractor hydrostatic mechanical transmissions (HSMT) on wheeled tractors for agricultural purposes of different power, which provide stepless adjustment of torque over a wide range and its smooth transfer to the drive wheels, stable operation of the engine in the optimum regime zone, the opportunity to reverse the course of the tractor movement, etc.

Currently, in present day HSMT design by reducing the share of power, flowing through the hydraulic branch, and increase of the proportion that passes through the mechanical branch, as well as the use of modern hydraulic units of volume type, which have a rather high overall coefficient of performance (COP), they achieved a significant increase in HSMT efficiency, and thus eliminated one of the major drawbacks of the HSMT design: a significant difference in efficiency between the stepped ratio gear transmission and HSMT.

Analysis of publications

The authors (1-6) identified the trends and prospects for application of stepless HSMT in automotive and tractor industry, conducted a comparative analysis of stepless two-engine hydro-mechanical transmissions.

In papers (7–9) there are given the diagrams of HSMT that are most commonly used and operate according to the scheme "input differential" and "output differential", compiled their simplified kinematic and structure schemes, offered the mathematical description of kinematic, power and energy parameters change, determined the main parameters of the above considered transmissions with equal and different volumes of hydraulic machines (hydro-pumps and hydraulic motor), identified the influence of hydraulic motor volume on the kinematic, power and energy parameters of HSMT, analyzed the distribution of power flows in HSMT.

However, in (6–9) there were not specified the most promising HSMT, and there were not considered the diagrams with two differentials: input and output.

The purpose of research and goal setting

The purpose of this paper is to identify and research the prospective HSMT of wheeled tractors for agricultural purposes.

To achieve this goal it is necessary to solve the following problems, based on the results of studies (6–9): give the kinematic diagrams of prospective HSMT, identify their main design parameters, the dimension-type of hydraulic machines of the hydrostatic transmission (HST), determine their kinematic, power and energy parameters, analyze the HSMT diagrams with two differentials: the input and output.

Synthesis of HSMT of wheeled tractors for agricultural purposes

According to the results of a comprehensive static analysis of HSMT operating according to the diagram “input differential” and “output differential” (as the initial data there were chosen the following parameters: maximum angular velocity of the crankshaft of the engine - 2250 r/min, 0.85 m - radius of the wheels, tractor weight - 9000 kg, speed implemented within the draw ratio in the range of motion resistance of 0.5 – from 0.02 to 10 km/h, hydro-pump working volume - 130 cm^3, cylinder capacity of hydraulic motor - 130-250 cm^3); there was identified a number of kinematic diagrams of prospective transmissions (Fig. 1), made known their main design parameters, the dimension-type of hydraulic units of HST, highlighted their kinematic, power and energy parameters (Fig. 2, 3, Table 1).

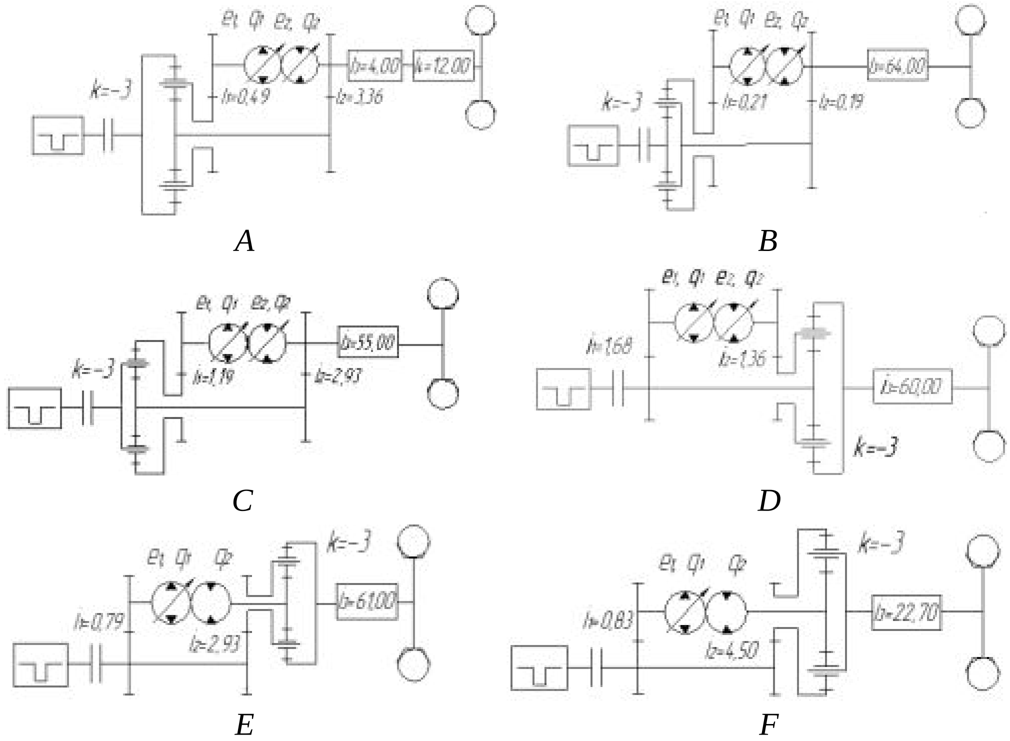
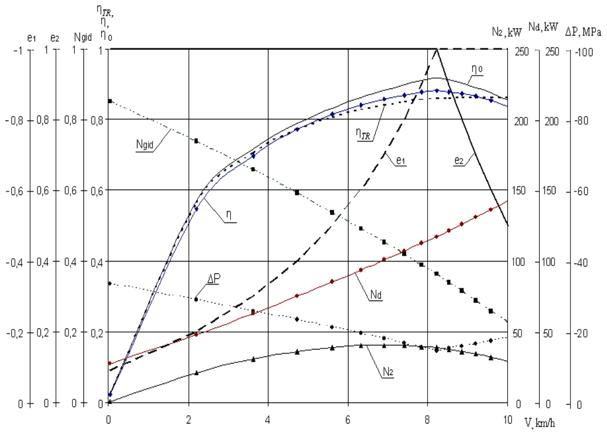
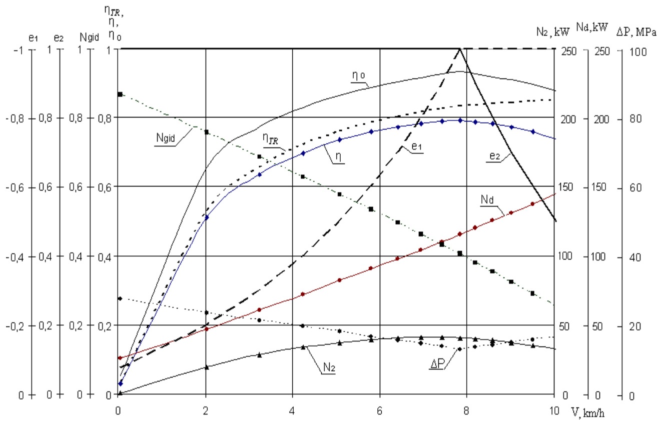


Fig.1. Kinematic diagrams of prospective HSMT (working volume of hydraulic motor of transmissions, *A*, *B*, *C* , *D* - 130 cm^3, *E* , *F* - 250 cm^3): i_j - gear box ratio; e_1, e_2 - relative parameter of HST adjustment; q_1, q_2 - maximum performance of hydraulic machines; *k* -

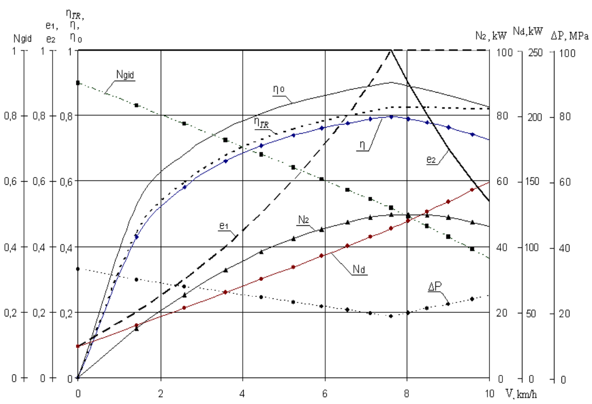
internal gear ratio of the planetary series; *A*, *B*, *C* – diagrams of HSMT with inlet differential; *D*, *E*, *F* – diagrams of HSMT with output differential.

Despite the fact that the diagram *C* (Fig.1) of the HSMT with inlet differential is inferior in performance efficiency to other diagrams, at present on its basis there was developed the Fendt Vario transmission, which is the most original, effective and simple of all stepless HSMT in use. Moreover, the diagram is characterized by the minimum value of the angular velocity of the hydro-pump shaft compared with diagrams *A* and *B* (Fig. 1).





A *B*



C

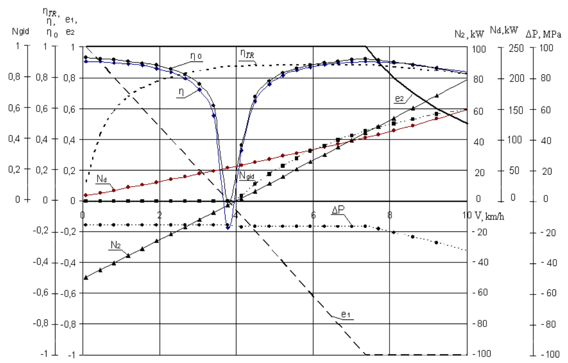
Fig.2. Results of the static analysis of HSMT with input differential: *A*- corresponds to the kinematic diagram *A* of Fig. 1; *B* - corresponds to the kinematic diagram *B* of Fig. 1; *C* - corresponds to the kinematic diagram *C* in Fig. 1; η_o - volumetric efficiency of the HST; η - the overall efficiency of the HST; η_{TR} - efficiency of transmission; N_d - engine power, kW

(kilowatts); N_2 - output power of HST, kW; N_{gid} - capacity ratio in percent transmitted through the hydraulic branch to the output of a closed loop; ΔP - difference of working pressure in the HST, MPa (Mega Pascal); e_1, e_2 - relative parameter of the HST adjustment; V - speed of the tractor.

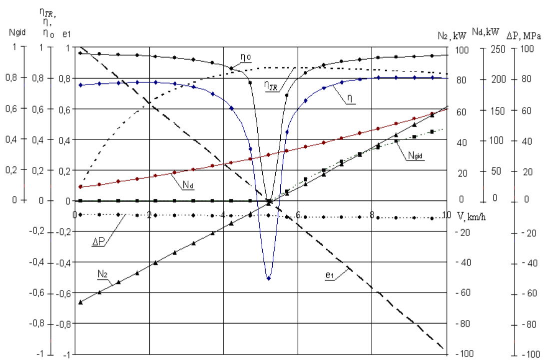
As a result of HSMT analysis that operate according to diagrams "input differential" and "output differential" it was established:

- the best of the considered HSMT with inlet differential for the given initial data is *A* diagram (Fig.1) with a maximum transmission efficiency of 0.862 at speed of 8.5 - 10.0 km/h, in second place is *B* diagram (Fig.1) with maximum transmission efficiency of 0.850 at speed 10.0 km/h, in third place is *C* diagram (Fig. 1) with a maximum transmission efficiency of 0.823 at speed of 7.5 - 8.5 km/h (all equipped with an adjustable hydraulic engine with a working volume of 130 cm^3);

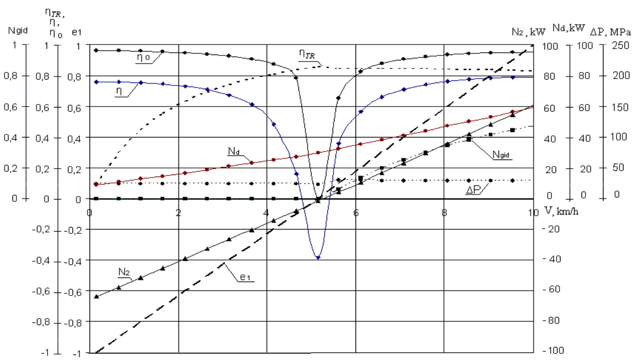
- the best of the considered HSMT with output differential for the given initial data is *D* diagram (Fig. 1) (when using a hydro-pump with a working volume of 130 cm^3, an adjustable hydraulic motor with working volume of 250 cm^3) with maximum efficiency of transmission at speed of 0.883 5 8 - 7,2 km/h, in second place is *E* diagram (Fig. 1) (when using a hydro-pump with a working volume of 130 cm^3, an unregulated hydraulic motor with a working volume of 130 cm^3) with maximum efficiency of transmission at speed of 0,866 5.2 - 7,2 km/h, in third place is *F* diagram (Fig.1) (when using a hydro-pump with a working volume of 130 cm^3, an unregulated hydraulic motor with a working volume of 250 cm^3) with maximum transmission efficiency of 0.856 at speed of 5.2 km/h.



A



B



C

Fig.3. Results of the static analysis of HSMT with output differential (references of HSMT parameters are the same as for the HSMT with input differential): *A*- corresponds to the

kinematic diagram *D* of Fig. 1; *B* - corresponds to the kinematic diagram *E* of Fig. 1; *C* - corresponds to the kinematic diagram *F* of Fig. 1.

Table 1

Generalization of static analysis results of prospective HSMT

Diagram (Fig.1)	$\lvert\Delta P\rvert_{max}$, MPa	$\eta_{TP\,max}$	Angular velocity of satellite gear $\lvert\omega_s\rvert_{max}$, radian per second	$N_{d\,max}$, kW	Angular velocity of hydraulic pump shaft $\lvert\omega_1\rvert_{max}$, rad/s	Angular velocity of hydraulic motor shaft $\lvert\omega_2\rvert_{max}$, rad/s
A	33,57	0,862	572,1	142,5	359,2	157,1
B	27,47	0,850	235,4	144,9	375,0	209,9
C	33,02	0,823	304,5	153,5	264,7	184,1
D	32,67	0,883	323,8	149,0	140,0	120,1
E	11,60	0,866	363,4	150,4	298,9	311,7
F	12,13	0,856	153,5	148,4	282,6	152,3

In the course of investigations of kinematic diagrams of HSMT with two differentials: input and output, it was revealed that the presence of kinematic, power and energy parameters of given transmissions is not possible without:

- blocking one of the links of the input differential or one of the links of the output differential, which leads to the transformation into a complex diagram with an inlet differential or separately with an output differential;
- rigid connection of links of the input differential with the links of the output differential, which leads to significant complications of design.

Application of HSMT with two differentials: input and output results in the need for additional elements that are switched, and it causes complications of design.

Conclusion

As a result of investigating there was specified a number of prospective HSMT diagrams (Fig. 1) and set the optimum diagram for tractors with full weight of 9000 kg – diagram of HSMT with output differential (Fig. 1, D) equipped with a hydraulic pump with working volume of 130 cm^3, an adjustable hydraulic motor with working volume of 250 cm^3. The given HSMT has maximum transmission efficiency of 0.883 at speed of 5.8 - 7.2 km/hour.

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