TILLER HYDROSTATIC TRANSMISSION

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***Abstract**: The article relates to a hydrostatic transmission intended for the tillers equipped with internal combustion engines for continuous transmission of motion and power of the drive wheels or to a device for digging soil. The state of the art transmission tillers operated internal combustion engines using classical scheme consists of clutch, gearbox, control systems thereof etc. Chaining these elements presents disadvantages, on the one hand because they are complicated, bulky and heavy, requires a large number of control systems for drive and on the other hand that the transmission of the movement is done in steps. The hydrostatic transmission we propose simplify construction of tillers and control systems for its operation and will mount easily on the transmission instead of classical combustion engine. This transmission is made up of a variable displacement hydraulic pump which is connected to the internal combustion engine, an orbital hydraulic motor to drive the wheels of the driving or digging the ground equipment, on which is mounted a framework for the internal combustion engine, hydraulic pump and motor hydraulic pipes connecting the hydraulic motor and hydraulic pump.*

Keywords: tiller, hydrostatic transmission.

Introduction

A tiller is a self-propelled vehicle, usually having two drive wheels, internal combustion engine through a gearbox and clutch, operated by a handlebar of a leader who walk. The engines full power more than 15 kW and are powered by gasoline or diesel. The moving of tiller has different speeds, forward or backward, gears and moving purposes are changed using control systems located on the handlebars.

The tillers are used in horticulture and gardening soil processing using specific equipment attachments (plough, milling unit, ridge plough, cultivator, digging canals for irrigation equipment, digging pits equipment, equipment for crown shaped shrubs and trees, irrigation pump etc.). Also, the some tillers can pull a trailer on two wheels, the driver sitting in a chair.

The tiller to replace the mechanical transmission with a hydrostatic transmission is type produced by S.C. RURIS

Technical and functional characteristics of the tiller with mechanical transmission and hydrostatic transmission are presented in Table 1.

Technical and functional characteristics of the tiller

Table 1

Technical and functional characteristics	Values mechanical transmission	Values hydrostatic transmission
full power engine (net power)	5.5 kW (4.8 kW)	
maximum RPM engine	3600 rpm	
RPM drive wheels	40...125 rpm	
maximum resistant torque, m_{rmax}	30 daNm	
clutch	dry single disc clutch	-
gearbox	2 forward, 1back	-
reducer		-
geometric volume hydraulic pump	-	7,08 cm^3/rot

theoretical flow of hydraulic pump	-	25,5 l/min to 3600 rpm
operating pressure	-	210 bar
geometric volume hydraulic motor	-	125,7 cm^3 / rot
oil flow of the hydraulic motor	-	5,6 ÷ 17,4 l / min
metal wheels diameter	400 mm	
weight	65 kg	42 kg

The mechanical transmission, consists of clutch, gearbox and reducer, is replaced with hydrostatic transmission, consists of variable displacement hydraulic pump which is connected to the internal combustion engine, an orbital hydraulic motor to drive the wheels of the driving or digging the ground equipment, on which is mounted a framework for the internal combustion engine, hydraulic pump and motor hydraulic pipes connecting the hydraulic motor and hydraulic pump. In Figure 1 is presented the tiller with mechanical transmission.

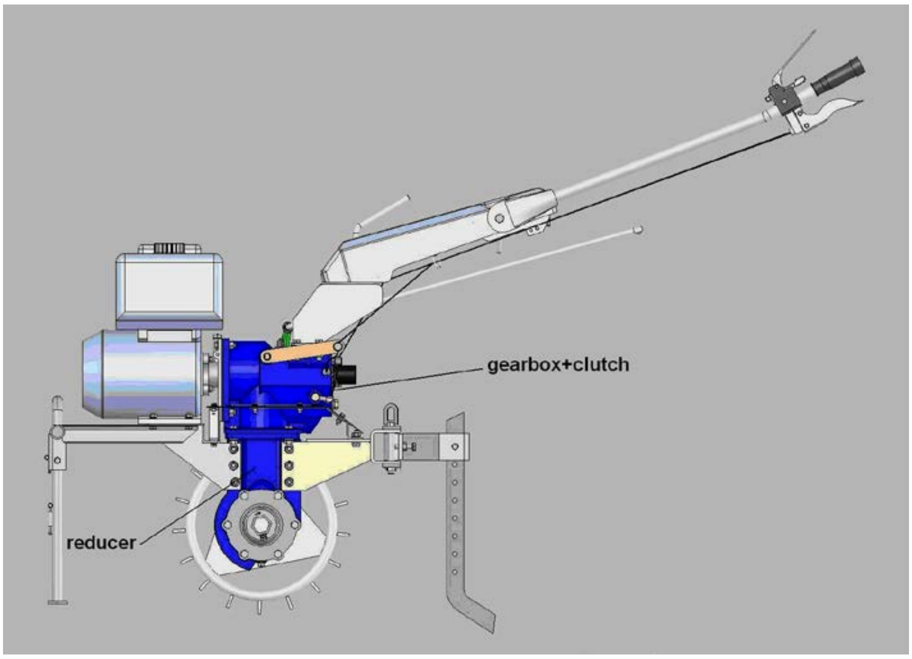

Fig.1 Tiller with mechanical transmission

1. TILLER WITH HYDROSTATIC TRANSMISSION

The tiller with hydrostatic transmission is mainly composed of an internal combustion engine, a flexible coupling, a variable hydraulic pump, two frames assembly, a hydraulic orbital motor with two axes, hoses and fittings and pump control system [Fig. 2].

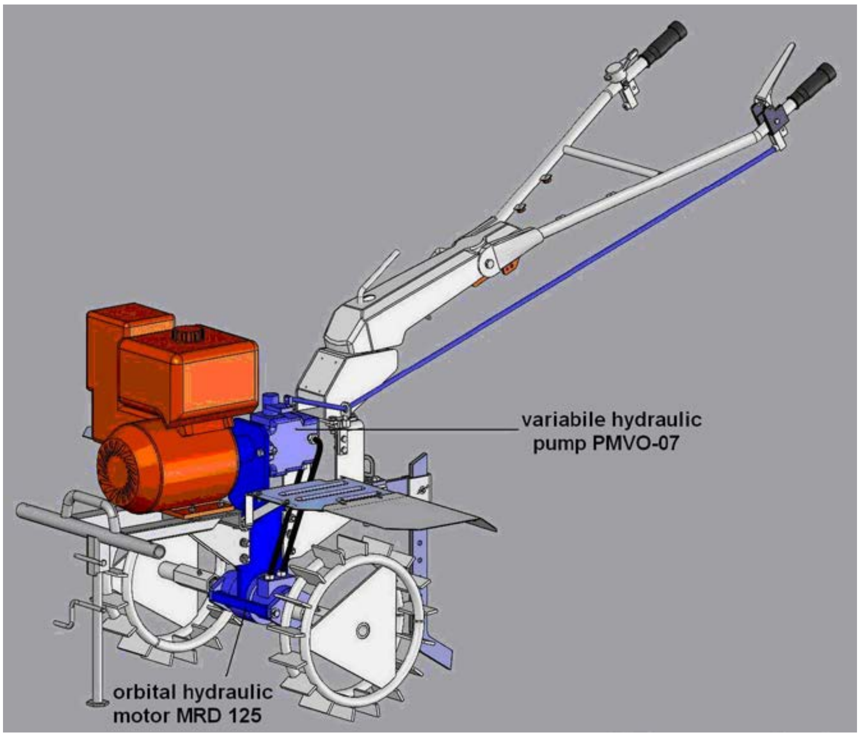

Fig.2 Tiller with hydrostatic transmission

Calculation of hydrostatic transmission

Internal combustion engine torque diagram is presented in Figure 3.

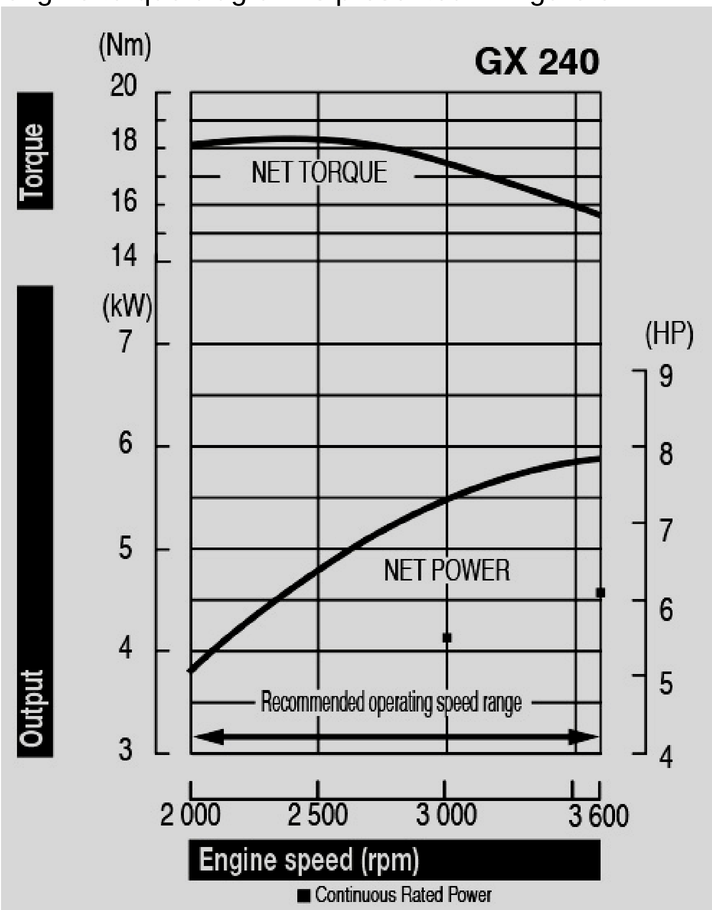

Fig.3 Internal combustion engine torque diagram

The tiller hydrostatic system will have variable flow hydraulic pump PMV0-07, driven by the combustion engine at speed of n_p = 3000 rpm and an orbital hydraulic motor with two-axis output MRB 125, to drive the wheels of the driving or digging the ground equipment.

Hydrostatic installation diagram is presented in Figure 4.

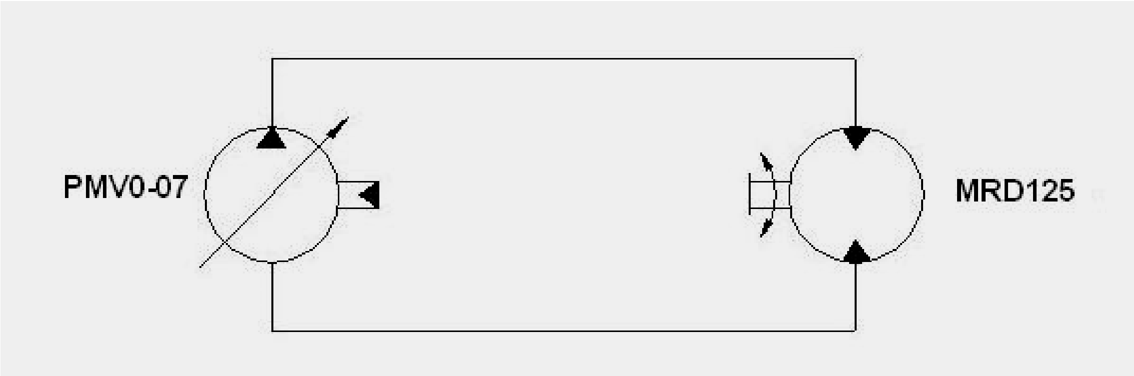

Fig.4 Hydrostatic installation diagram

The total efficiency of the hydraulic motor is calculated with relation 1 [1]:

$$\eta_{tm} = \eta_{vm}\ \eta_{mm} \qquad (1)$$

where η_{tm} is total efficiency of the hydraulic motor;
η_{vm} – volumetric efficiency of the hydraulic motor, η_{vm}=0,9 ÷ 0,95; it is choose $\boldsymbol{\eta_{vm}}$**= 0,9;**
η_{mm} – mechanical efficiency of the hydraulic motor; $\boldsymbol{\eta_{mm}}$**= 0,9.**

Resulting: η_{tm} = 0,81…0,85. For the calculation it is chosen**:** $\boldsymbol{\eta_{tm}}$ **= 0,81.**

Geometrical calculation of the hydraulic motor is calculated with relation 2 [1]:

$$V_{gm} = \frac{2\pi\ M_{r\,max}}{(p_n - p_r)\,\eta_{mm}} 10^2 \qquad (2)$$

where V_{gm} is geometric volume of the hydraulic motor, in cm^3/rot;
$M_{r\,max}$ - maximum resisting moment, $\boldsymbol{M_{r\,max}}$ **= 30 daNm;**
p_n – nominal pressure of the hydraulic motor, $\boldsymbol{p_n}$ **= 210 bar;**
p_r – the pressure in the return line; $\boldsymbol{p_r}$**=4÷5bar**;
η_{mm} - mechanical efficiency of the hydraulic motor, $\boldsymbol{\eta_{mm}}$**=0,9.**

Resulting: $\boldsymbol{V_{gm}}$ **=102,16 cm^3/rot.**

It is choose hydraulic motor **MRB 125** from Motors Catalog [2], with the following characteristics:
- geometric volume: 125,7 cm^3/rot;
- maximum speed: n_{max}= 475 rpm;
- maximum torque: M_{max} = 30 daNm;
- torque on the shaft A: M_A = 20 daNm;
- torque on the shaft B: M_B = 20 daNm;
- pressure drop: Δp = 175 bar;
- maximum flow: $Q_{m\,max}$ = 60 l/min.

The oil flow of the hydraulic motor is calculated with relation 3 [1]:

$$Q_m = \frac{V_{gm} n_{mh}}{\eta_{vm}} 10^{-3} \qquad (3)$$

where Q_m is oil flow of hydraulic motor, in l/min;

n_{mh} - RPM motor hydraulic, $\mathbf{n_{mh} = 40 \div 125}$ **rpm**;
η_{vm} – volumetric efficiency of the hydraulic motor, $\mathbf{\eta_{vm} = 0,9}$**.**

Resulting: $\mathbf{Q_m = 5,6 \div 17,4}$ **l/min.**

Total efficiency of hydraulic pump is calculated with the relation 4 [1]:

$$\eta_{tp} = \eta_{vp}\ \eta_{mp} \tag{4}$$

where η_{tp} is total efficiency of the hydraulic pump;
η_{vp} – volumetric efficiency of hydraulic pump, $\eta_{vm}=0,9\div0,95$; it is choose $\mathbf{\eta_{vp}= 0,9}$**;**
η_{mp} – mecanichal efficiency of hydraulic pump; $\mathbf{\eta_{mp}=0,9}$**.**

Resulting: η_{tp} = 0,81…0,85. For the calculation is chosen $\mathbf{\eta_{tp} = 0,81}$**.**

Geometric volume calculation of the hydraulic pump is calculated with the relation 5 [1].

$$V_{gp} = \frac{1000 Q_p}{n_p \eta_{vp}} \tag{5}$$

where V_{gp} is the geometric volume of the hydraulic pump, in cm^3/rot;
Q_p - assured flow of hydraulic pump $\mathbf{Q_p = Q_m = 17,4}$ **l/min.**
n_p – RPM driving pump, $\mathbf{n_p = 3000}$ **rpm;**
η_{vp} – volumetric efficiency of hydraulic pump, $\mathbf{\eta_{vp}= 0,9}$**.**

Resulting: $\mathbf{V_{gp} = 6,44\ cm^3}$**/rot**

Is chosen hydraulic pump **PMV0 - 07 C1 M 00 A0 00 R** from Poclain Hydraulic Catalog [3], with the following characteristics:

- geometric volume of the hydraulic pump: V_{gp} = 7,08 cm^3/rot;
- RPM driving: $n_p = 700\div3600$ rpm;
- theoretical flow: 25,5 l/min, to 3600 rpm;
- operating pressure: 210 bar;
- maximum pressure: 300 bar;
- inlet pressure: 0,8 bar;
- mounting flange: SAE A;
- setting: mechanical;
- weight:7,5 kg (for setting mechanical).

The calculation of necessary power the hydraulic pump is made with relation 6 [1]

$$P_p = \frac{Q_p\ p_{max}}{600\,\eta_{tp}} \tag{6}$$

Resulting: $\mathbf{P_P = 4,37}$ **kW**

The calculation of the torque consumed by the pump is made with relation 7:

$$M_p = 973,8 \frac{P_p}{n_p} \tag{7}$$

where M_p is the consumed torque by the pump, in daNm.

Resulting: $\mathbf{M_p=1,42}$ **daNm**.

3. CONCLUSIONS

Lately it tends to develop technical solutions to achieve tiller that allow much more control over it safely and effectively, given that it is run and handled directly by the operator. More specifically, it is the ability to control the speed, so the movement no load, but especially in the work, knowing that a tiller can work with a very wide range of equipment.

From this point of view it required a much wider range of gear adapted to the work carried out and the nature and state of the ground work, which is not possible with current versions of tillers, they generally having only two working speeds, seldom three. To meet these requests, otherwise justifiable, it was realized a tiller with hydrostatic transmission.

The hydrostatic transmission, with variable displacement hydraulic pump and an orbital hydraulic motor, replace the mechanical transmission (clutch, gearbox and reducer), thus enabling a very wide speed range.

An other advantages of the hydrostatic transmission we propose, simplify construction of the tiller and for the control systems for its operation and will mount easily on the transmission instead of classical combustion engine.

The disadvantage of the hydrostatic transmission is lower efficiency and higher costs.

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