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MATHEMATICAL MODEL FOR THE FEIGNING OF THE DYNAMICAL BEHAVIOR OF THE MECHANIC – HYDROSTATIC OF MOVEMENT SYSTEMS AT THE AUTOPROPULSIVE EQUIPMENT ON SHAMS

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ABSTRACT

In the paper it is presented a mathematical model of the movement transmission for an autopropulsive equipment on shams. The elaborated model and presented in the paper contains all the influences produced on the ensemble of mechanical and hydrostatic components: Thermal engine, cable box, pumps, hydraulic circuit, hydrostatic engines, reduction gear, planetaries, shams. They are considered: the specific features of the thermal engine, the feature of the adjustment of the pumps, the elastic features and the damping features introduced by the toothed forecarriage of the mechanical components and the feature of the working body. The model can serve to analyzing the dynamic behavior of the movement transmission by numerical simulation for the concrete cases of equipment using programs as: VMAPLE or MATCAB.

1.Introduction

In the 2 latest centuries the mechanic-hydrostatic systems were imposed on the majority of the technological mobile autopropulsive equipment as efficient solutions of the constructions of the movement systems.
Those solutions combine the advantages of the mechanical acting with those of the hydrostatic acting.
To a first view it is found that the majority of the equipment of mobile constructions are using systems alike from those which we can remind the steam navvies, heavy mobile cranes, power blade graders, motor scrapers, compaction rollers, frontal charges, etc.
This thing justifies the enhancement in the scope of the analyze of behavior in different conditions of exploitation such as: the movement on flabby roads (marsh, sand, damp soil, etc.), the movement on frozen soil, the simulation of starting and braking, etc.
A first stage in the theoretical research previously specified is constituted of by the elaboration of the mathematical model of the movement system, model which continues the dynamic comportamental influences of the system's components from the power source (thermal engine) to the working body (the sham of the wheel).
The present paper has as object the equipment of mathematical model for the transmission of movement of an autopropulsive equipment on shams (steam navvy, bulldozer, excavator machine, mathered loader on shams, autopropulsive crane on shams, etc.).
In a first stage of the research the model is achieved in the following assumption:
- The moment applied to the working body (the sham) (Me) is constant and contains resistance at rolling and on slope, given by the expression:

$$M_E = f \cdot G + M_p = \text{const.} \tag{1}$$

where:
f – coefficient of resistance at rolling on different soils;

G – the total weight of the equipment; M_p – reduced moment of resistance at the axle of the motor wheel of the sham induced by the equipment movement on slope.- The movement of adherence of the working body at the rolling way (MA) is constant, given by the relation:

$$M_A = \varphi G \quad (2)$$

where:

φ – adherence coefficient at the rolling way;

G – the total weight of the equipment.

- The 2 energetic lines of the movement are considered one energetic line at which pumps and the engines are equally charged and they have double cylinders, given by the relations:

$$V_{op} = V_{op_1} + V_{op_2}\,;\, M_{om} = V_{om_1} + V_{om_2} \quad (3)$$

where:

$V_{op_1};V_{op_2}$; $V_{om_1};V_{om_2}$ represent the maxim cylinders of the pumps, respectively of the specific engines of the 2 energetic lines of the movement.

2.The actions scheme of the equipment

For an hydraulic engine made at PROMEX Braila, the action scheme of the movement system is presented in the first figure.

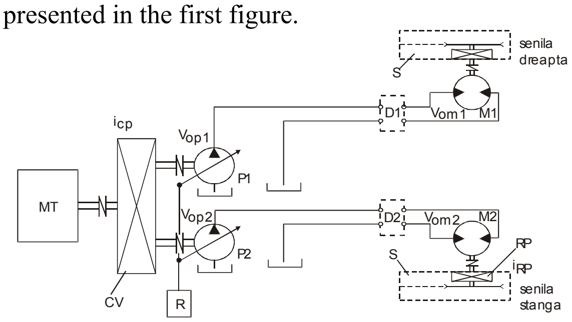


Fig 1. The action scheme of the steam navvy S1203, made in 1999.

MT–thermal engine; CV – cable box with reduction report i_{CP}; P_1; P_2 – pomps with variable cylinders equipped with regulator of power (R);

D_1; D_2 – hydraulic distributors; M_1; M_2 – hydraulic rotational engines with axle pistons;

SD; SS – the right sham respectively the left sham;

RP – planetary regulator of movement with reduction report i_{RP}.

3.Dynamic model of the movement system

The scheme of the model realized on the assumptions from the first paragraph is restored in the figure no.2.

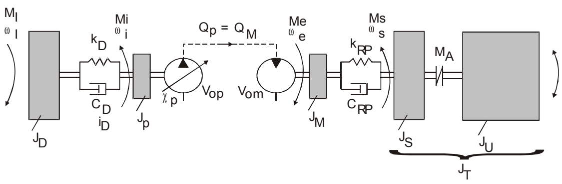


Fig 2. The dynamic model of the movement system

J_D – inertness moment of the thermal engine; K_D; C_D; i_D – the elastic features of the amortization and cinematic features of the cable box; J_P – inertness moment of the pomps; V_{op} – total cylinders of the pomps; Q_p=Q_m – volumic debits of the hydrostatic system; V_{om} – the total cylindrics of the hydrostatic engines; J_M - the inertness moment of the hydrostatic engine; K_{RP}; C_{RP}; i_{RP} – the elastic, cinematic and of amortization features of the planetary regulator; J_S – inertness moment of the steams; M_A – the adherence moment; J_U – the inertness moment of the equipment reduced at the sham's axle; J_T – the total inertness moment (equipment + shams); M_E – the rezistent moment at the working body (the sham); M_J(J=I, i, e, s) – moments at the component's axle ω_J (J=I, i, e, s) – angular velocity at the axle of the component. Mathematical expresions which determins the movement phenomenon of the equipment are presented in the following paragraph:

4. The mathematical expressions of the movement system

The equations which describe the dynamic process of the system are given by the relations:

$$\begin{cases} J_D\ddot{\varphi}_I = M_I - r^2 k^l{}_D(\varphi_I - i_D\varphi_i) - \\ - r^2 C^l{}_D(\dot{\varphi}_I - i_D\dot{\varphi}_i) \\ J_P\ddot{\varphi}_I = i_D[r^2 k^l{}_D(\varphi_I - i_D\varphi_i) + \\ + r^2 C^l{}_D(\dot{\varphi}_I - i_D\dot{\varphi}_i)] - \gamma_p\dot{\varphi}_i - \delta_p p \\ Q_p = \chi_p \dfrac{V_{op}}{2\pi}\dot{\varphi}_i - \alpha_p p - \beta_p \dot{p} \\ Q_M = \dfrac{V_{op}}{2\pi}\dot{\varphi}_e + \alpha_m p + \beta_m \dot{p} \\ J_M\ddot{\varphi}_e = \gamma_p\dot{\varphi}_e - \delta_M p + r^2 k^l{}_{RP}(\varphi_e - i_{RP}\varphi_S) + \\ + r^2 C^l{}_{RP}(\dot{\varphi}_e - i_{RP}\dot{\varphi}_s) = \dfrac{V_{om}}{2\pi} p \\ J_T\ddot{\varphi}_s = i_{RP}[r^2 k^l{}_{RP}(\varphi_e - i_{RP}\varphi_S) + \\ + r^2 C^l{}_{RP}(\dot{\varphi}_e - i_{RP}\dot{\varphi}_s)] - M_E \end{cases} \quad (4)$$

where:

M_I – represents the motor moment of the energy source;

$k^1{}_D;C^1{}_D$ - the elastic features and the amortization of the cable box;

i_D – the ratio of transmission of the cable box;

χ_p - the adjustment feature of the pomp (pomps);

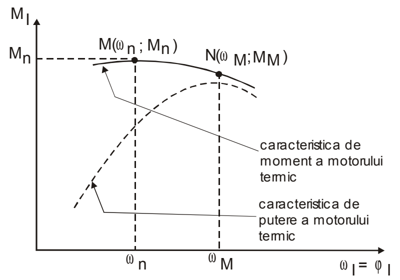
$\alpha_p;\alpha_m$ - linear coefficient of losses in the pomps/engines of the system;

$\beta_p;\beta_m$ - compactibility coefficients of the hydraulic medium from the hydrostatic medium;

$V_{op}\,;V_{om}$ - the total cylinders of the hydrostatic pomps/engines of the system;
δ_M - coefficient of load loss in the hydraulic engines, proportional to the pression;
$k^1{}_{RP};C^1{}_{RP}$ - the elastic and amortization features of the planetary regulator;
i_{RP} - the support of reduction of the planetary regulator of the movement system;
Q_p – the differential debit of the pomp; Q_M – the absorbed debit by the engine;
φ_J (J=I, i, e, s) – the rotation angle of the system's component;
$\dot{\varphi}_J;\ddot{\varphi}_J$ - the angular velocity respectively the angular velocity acceleration of the component;
r – the equivalent ray of the component's system
γ_m - couple losses proportional to the angular velocity.
The loaded characteristic of the thermal engine, is obtained by the linear of the external characteristic of the thermal engine and have the expression (5).

$$M_I = A - B\dot{\varphi}_I \tag{5}$$

A,B – constants on the engine's characteristic which have the form:



$$A = \frac{M_n\omega_M - M_M\omega_n}{\omega_M - \omega_n}$$
$$B = \frac{M_n - M_M}{\omega_M - \omega_n} \tag{6}$$

Adjustment characteristic of the pomps is described by the relations:

$$\chi_p \begin{cases} \chi_p = 1 \text{ ptr } \Sigma_p \in [0,\Sigma_{p\,basc}] \\ \chi_p = a - b\Sigma_p \in \Sigma_p \in \left[\Sigma_{p\ basc};\Sigma_p{'}\right] \\ \chi_p = c - d\Sigma_p \in \Sigma_p \in \left[\Sigma_p{'};\Sigma_{p\,max}\right] \end{cases} \tag{7}$$

The semnification of the terms from (7) is described in the figure no.3.

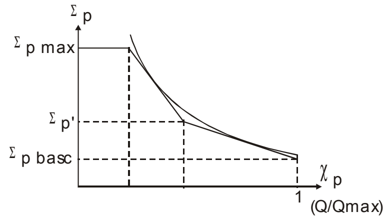


Fig. 3 Adjustment characteristic of the pomps (with regulator of total resistance).

After the manufacture of the equations (4) and the variables ordering we obtain the system of the differential equations (8) which represents the dynamic model of the considered movement system.

$$\begin{cases} \ddot{\varphi}_I + \dfrac{(B+C_D)}{J_D}\dot{\varphi}_I + \dfrac{k_D}{J_D}\varphi_I = \dfrac{i_D k_D}{J_D}\varphi_i + \dfrac{i_D C_D}{J_D}\dot{\varphi}_i + \dfrac{A}{J_D} \\ \ddot{\varphi}_i + \dfrac{(\gamma_p + i_D{}^2 C_D)}{J_p}\dot{\varphi}_i + \dfrac{i_D{}^2 k_D}{J_p}\varphi_i = \dfrac{i_D k_D}{J_p}\varphi_i + \dfrac{i_D C_D}{J_p}\dot{\varphi}_i - \dfrac{\delta_p}{J_p}p \\ \left(\chi_p\dot{\varphi}_i - \dfrac{V_{OM}}{V_{op}}\dot{\varphi}_e\right) = \dfrac{2\pi}{V_{op}}(\alpha_p + \alpha_m)p + \dfrac{2\pi}{V_{op}}(\beta_p + \beta_M)\dot{p} \\ \ddot{\varphi}_e + \dfrac{\gamma_M + C_{RP}}{J_M}\dot{\varphi}_e + \dfrac{k_{RP}}{J_M}\varphi_e = \dfrac{1}{J_M}\left(\dfrac{V_{OM}}{2\pi} - \delta_M\right)p + \dfrac{i_{RP}k_{RP}}{J_M}\varphi_S + \dfrac{i_{RP}C_{RP}}{J_M}\dot{\varphi}_S \\ \ddot{\varphi}_S + \dfrac{i_{RP}{}^2 C_{RP}}{J_T}\dot{\varphi}_S + \dfrac{i_{RP}k_{RP}}{J_T}\varphi_S = \dfrac{i_{RP}k_{RP}}{J_T}\varphi_e + \dfrac{i_{RP}{}^2 C_{RP}}{J_T}\dot{\varphi}_e - \dfrac{M_E}{J_T} \end{cases} \tag{8}$$

The unknown values of the model are: $\varphi_I;\varphi_i;p;\varphi_e;\varphi_S$ - which depend on the load at the sham introduced by M_E;
The model is variable in the condition:
$M_E < M_A$
When we reach the adheration limit of the contact: sham – rooling track.

5.Conclusions

The model of the movement system described by (8), permits the analysis of the dynamic comportment in different situations of exploitation and for different equipment on sham. For the concrete analysis we need to specify the concrete data of the specific system of a certain equipment. The moulding is realized according to known programs (MATLAB, VMAPLE, etc.), which permit to point out certain comportamental aspects specific to the movement in certain conditions. Those aspects will be pointed out in subsequent papers published by the author. At the first attempt of the model in VMAPLE program, it was found that the model covers enough the comportamental aspects specific to the analyzing stage specified in the first paragraph.

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