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# DYNAMIC MODELS FOR THE TRACTION SYSTEMS OF THE SELF-PROPELLED MACHINES

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## ABSTRACT

*The work presents a classification of traction systems as a function of structure, the systems being classified into: integrally mechanical-tractional systems–STIM, mechanical-hydrostatical tractional -STMH and integrally tractional hydrostatical systems STIH. Each structural model contains the main components from dynamic points of view: the thermical engine as the source of energy, the system of transmission of the traction, the system of movement formed of wheels with tyres or the of self-propelled equipment. For each structural model is the dynamic model to which dynamic analyses should be done by excitation accomplished by the road (the run away). The models allowed the author to analyse the dynamic behaviour produced by dislevels of the road, consistence of the road, adherence of the road, etc. The necessity of these models has been due to the study models of dynamic behavior and of traction systems comparison of different structures, mechanic, mechanic and hydraulic.*

## 1. The classification of traction systems.

The traction systems of the technological equipments are complex systems formed of a large number of constitutive hydrostatical mechanic, or combinations of these components which reciprocally interacts in the aim of equipment movement in different conditions of movement. Dynamic modelling for all the exploitation situations is unaccomplished, at least with the conditions and available modelling methods this moment, the study of dynamic behavior used dynamic simple models with one or two degrees of freedom, when the traction system is substituted by one, two or three concentrated masses connected between them with elements of transmission being considered elastic systems by a certain rigidity.

A category of the models for the study of dynamic behavior of traction systems is given by the models with more degrees of freedom special in modeling of the mechanical systems, to which the mechanical components of the system are modeled as elastic elements being featured by a certain rigidity. These model permit as the influence to be studied in dynamic behaviour of certain components of the transmission (couplings, gearbox, cardan drive, differential, the wheel, the tire), etc.

The disadvantage of these models consists in the fact that is too complicated, it has too many variables and perturbation sizes which makes difficult its usage especially to the mechanical-hydraulic traction models to which besides the variables of the mechanical system (the angles and the angular speeds of rotation) also interfere the variables of the waterworks (pressures, angular speeds, flows, etc.)

A step towards the generalization of dynamic models for the traction systems constitutes the models with a finite number of freedom degrees, which are to be considered the factors of amortization entered by the components of the system in the model besides the rigidity of the mechanical components which compose the traction system structure . \
The physical sizes which characterizes these systems are the rigidities of structural elements written with $k_{ij}$ and the amortizations of the same elements written with $c_{ij}$.

In order to accomplish the mathematical models upon which to be studied the behavior of the system excitations produced by the dislevels of the run away it is necessary the realization of a classification of the characteristic types of traction systems presented, taking count of the dynamic characteristics.
These types contain the basic elements of coupled transmission between they so that to accomplish the traction features specific to a certain self-propelled equipment. The models directed must answer to the following requirements:

- To take account of dynamic features produced by the components of the mechanic transmission and the way of coupling of these (gearings, arbors, planetary cardans, couplings, etc.)
- To take account of dynamic features produced by the components of the hydrostatical transmission and the way of coupling of these (pumps and hydraulic motive rotative printing press, hydraulic meshes, the hydraulic used-up environment as the agent of thing, etc.)
- To take account of rigidities and the linear and angular amortization being introduced by the organ of movement (tire or caterpillar) to excitation produced by the run away;
- To take account of characteristics viscous-elastic of environment from which is composed the run away and the degree of its deformability;
- To considers the kinematic excitation produced by the dislevels of the run away, through the resistant moments of the equipment wheels;
- To take account of the touch moment of the equipment adherence, and therefore of the skids of the moment organ in report with the way;
- To take account of the moment angular-speed feature, from the external feature the source (thermic engine) and the reglation laws of waterworks;
- To accomplish a dynamic simple model but conclusive to estimate by numerical modeling , influence of the road to dynamic behavior of traction system;
- To achieve models for typical traction systems which permit to compare to miscellaneous solicitations inducted by the run away.

From these viewpoints can be achieved the following features of the traction systems:

## 1. 1. The complet integral mechanical system –STIM

This traction system is characterized as a matter of fact of the achieved ensemble between the thermic engine, as source of energy and the organ of movement of the equipment, formed of tires or caterpillars, is exclusively composed from constitutive mechanic in the shape of systems of denticulate wheels, axe and organized arbors in specific components (gearboxes, planetary reductors, differentials, transmissions cardanics, couplings, etc). These components achieves functional scheme of the equipment through miscellaneous methods of coupling, of the order of entering the system and the place of placing of the component in the functional scheme. This organization of the scheme causes the touch of functional parameters for systems but and a certain dynamic behavior of this caused by the dynamic parameters of the system (moments of inertia, features of rigidity and amortization, etc). The typology of the systems is rendered in fig. 1 what comprise most the completed systems of used-up mechanics for the actuation of technological equipments.[1]; [3]; [4].

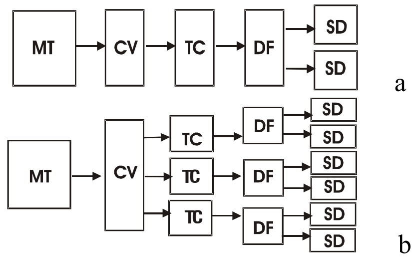


Fig. 1. The model of mechanical integral traction systems . STIM.
a) system with a power line; b) system with the many power-lines.
M.T- thermic engine; Cv- mechanic transmission with denticulate wheels of speeds; Tc- card transmission; Df- differential; OD/SD organs/ systems of movement.

## 1.2. The mechanical-hydrostatical traction system STMH

This is characterized as the fact the accomplished system between the thermic engine as the source of energy and the organ of movement of the equipment, formed of wheels or caterpillars, is formed of mechanical as those presented before to which are added hydrostatical components as pumps, engine, apparatus of casting and protection, hydraulic meshes, etc. These by dint of average used-up liquid as the hydraulic agent conduces to the conduction of the energy of the system to the desirable parameters, but through own dynamical characteristics influences the dynamic behavior of draft system of the equipment. Elastic characteristics and the amortization of hydraulic agent and of hydraulic apparatus is added to the characteristics of the used-up components, causing the dynamic behavior to the whole traction system. The tipology of these systems is rendered as in fig. 2 which includes the most mechanical systems used-up for the action of technological equipments. [1]; [3]; [4].

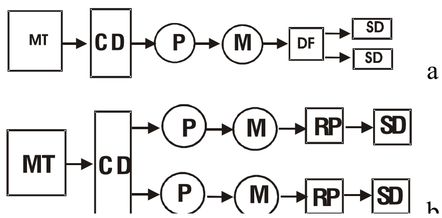


Fig. 2. The model of mechanical traction systems . STMH.
a) equipments on tire; b) equipments on caterpillars.
MT- thermic engine; CD, DF, RP- mechanic transmission with denticulate wheels (cable box, differential, planetary reductor); P, M- hydrostatics transmission; OD/SD organ/system of movement.

## 1.3. The complet hydrostatical traction system STIH

It is characterized as a matter of fact by the action realised between the thermic engine as the source of energy and the organ of movement of the equipment, formed of wheels or caterpillars, it is composed by exclusively from hydrostatical coupled round open or closed components. Dynamical characteristics of the system are influnced by the dynamical features of hydrostatical used-up components, by the command way and regulation of these components and of the way of coupling in system. The typology of this system is rendered as in fig. 3. which includes the most of integral hydrostatical used-up systems for the action of technological equipments. [1]; [2]; [3].

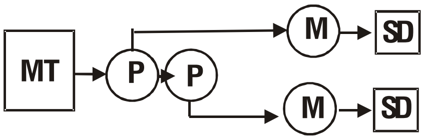


Fig. 3. The model of hydrostatical systems traction. STIH.
M.T-thermic engine; P, M- hydrostatics transmission; OD/SD organ/system of movement.

In the case of this system, the thermic motor acts directly the pump or the volumic pumps (mount the tandem), and the volumic engines, acts directly the organ of movement of the equipment.

The dynamic behavior of draft system is to influence the dynamic behavior of hydrostatical link (pump hydraulics).

## 2. The dynamic fashions

### 2. 1. Structure of dynamic suggested model for - STIM

The integral mechanical traction system - STIM, having the same mechanical components, is reduced down to a dynamic equivalent to model two degrees of freedom, one represents the thermic engine of the equipment, as source of autonomous energy, and the other of the organ of movement of the equipment, respectively the wheel with its tyres or caterpillars. Between these two ascertainable components is interposed the transmission mechanical of the equipment to characterize the equivalent rigidity $K_{tr}$ of the factor of equivalent amortization of the transmission $C_{tr}$. The system achieved is reduced to the motive thermic axle, characterized of the angle of rotation. The moment of inertia mechanic $J_s$ is similar reduced to the motive thermic axle and contains the own moment of engine but and the moments of components of components of the mechanical transmission. The moment $M_s$ represents the active moment applied to the transmission and results from external characteristic thermic engine definite to a formal law $M_s$=f ($\dot{\varphi}_s$). The moment of inertia mechanic $J_R$ represents the moment of inertia of the organ from the same axis of the equipment( the wheels with tyres from the caterpillars). To this moment of inertia is added the moment of reduced inertia of the equipment as far as $J_u$ the touch of the moment of adhesive $M_A$ (Fig. 4). In the same way proceed to equipments with many axe assets. (Fig. 4. B). In the case of the gearboxes with many stairs of brave the features of rigidity, amortization, the moment of inertia reduced mechanical and the active moment shall be evaluate for each step and enter accordingly in the dynamic model.

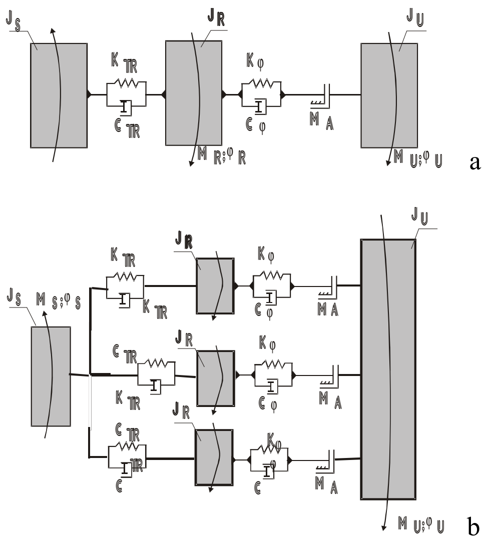


Fig. 4. The dynamic model for the complet mechanical systems -STIM.
a) system with a power line; b) system with many power lines.

**$J_S$,$M_S$,$\varphi_S$** -dynamic parameters of thermic motor h; **$J_R$,$M_R$,$\varphi_R$** - dynamic parameters of the organ of movement( wheels or caterpillars); **$J_U$, $M_U$, $\varphi_U$** - dynamic parameters of the equipment; $K_{TR}$, $k_\varphi$ - the transmission of the mechanic and the active element of the system of movement ( tyres ); **$c_{TR}$**, $c_\varphi$ - the factors of proper amortization of the transmission and systems of movement; **$M_A$** of adherence to the organ of movement of the equipment.

In the situations presented topmost the aspect of accomplishing of the dynamic model is adverted to the determination rigidities and the factors of equivalent amortization have the components of used-up mechanical in the transmission mechanic. Shaping the traction system is considered for the case presented the in fig. nr. 4. of a equipment with an only motor deck and four wheels with tyres.

### 2.2. The structure of dynamic model suggested for STMH

The mechanical –hydraulic traction system- STMH, is reduced to a dynamic equivalent model formed of two or many systems with two or three degrees of freedom, which models the dynamic behavior of the mechanical components (gearboxes, reductors, etc), bound between them through hydrostatical components (pump), fig. 5.

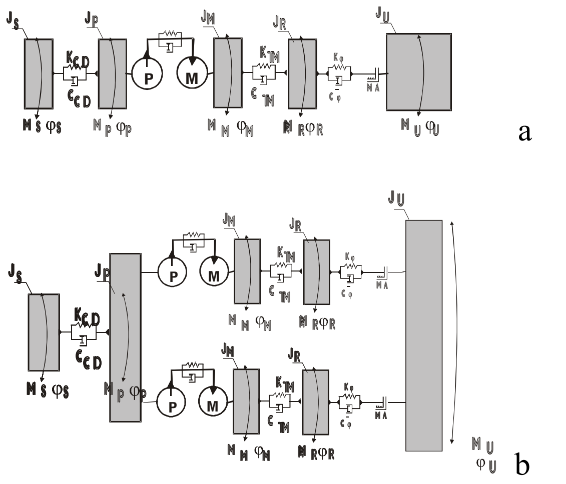


Fig. 5. The dynamic model for the mechanical – hydraulic system-STMH.
a) models with one power line; b) model with two power lines.

For the one-track energetical systems, as are the equipments on tire with only one motor deck (4x2) or the equipments on tire with two or many motor decks (4x4; 6x4; 6x6), to which hydrostatical link (P-M) is interposed between source of energy (MT) and the draft system achieved wholely mechanic, the suggested model is one from fig. 5. The thermic engine and the inclusive cable box are modelled as the a system with two degrees of freedom, characterized of rigidity and the factor of equivalent amortization, which acts primary constitutive the hydrostatical system volumic pumps-p. The draft system, inclusively the system of movement are modeled as a system with three degrees of freedom, set secondary constitutive the hydrostatical motor volumic engine-M system. The mechanical components of the transmission are modeled as viscous-elastic elements to characterize the equivalent rigidity and the factor of equivalent amortization $c_{tm}$. By dint of these is set the organ of movement ( tyre or caterpillars) to characterize elements sequence of the rigidity and the factor of amortization -$k_\varphi ; c_\varphi$ , by dint is set g the equipment ($J_u$). In the case of draft systems with two power lines, which is the case of fitting-out of the equipments on caterpillars (bulldozers, chargers, dredgers, tractors, special equipments, etc), the equipments on tires with direction through side-slip (chargers, multipurpose machines, etc) or the equipments with tractional axle (active trailers, transport platforms, etc), the model described previously is reprographic with the number of power lines, in the case from fig. 5. B, with two shipments two power lines are enforced to the solicitation inducted of the run away of the two organs of equipment run (deck with tires or caterpillar). And in the case of the loss state analysis of adhesive the equipment is to consider through the touch boundary value of adhesion -MA.

## 2.3. Structure of dynamic model suggested for STIH

The draft complet system hidrostatic-stih, is modeled as a dynamic system with two degrees of freedom, to which the connections to the dynamic inertial components of thermic engine and of the system of run (tires or caterpillars) are realized of hydrostatical components, without pure mechanic components (denticulate wheels, couplings, etc).

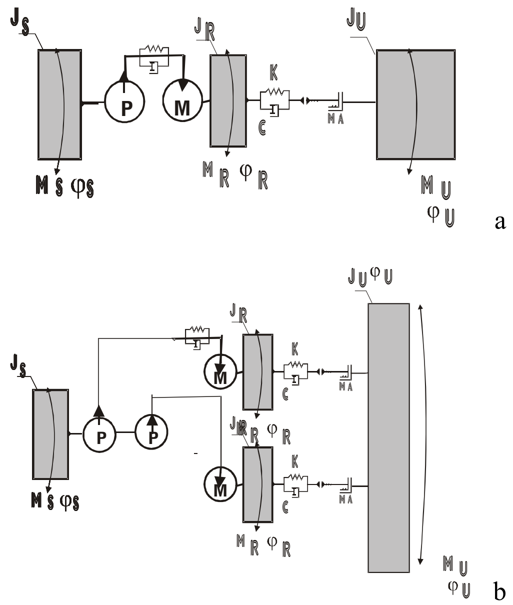


Fig. 6. The dynamic model for the complet hydraulics-stih systems.
a) models with a single power line; b) model with two power lines.

In the dynamic model is considered only one viscous-elastic connection, or except elastic one realized by the movement organ of the equipment (wheels with tires or caterpillars). This connection is interposed between the run away and the equipment, being the components of the model through with is inducted the draft force produced by the system of action

## 3. Conclusions

As it has been presented the analysis of the work results as the draft systems of technological self-propelled equipments to are characterized through three types of structural which models cover most of the practical situations. The discrepancies which characterizes the dynamic models of STIM, STMH, STIH are put in obvious. For each of ascertainable models achieved numerical and experimental analyses and their results are presented in another scientific papers of main author. The principal conclusion is detached from paper is that for process modelling take place in a draft systems of self-propelled equipments it was necessity of the conclusions model which to contain the elemental structures of the equipment: thermic engine of the draft system formed of transmission and the system of movement ( the wheel, caterpillar) run away. The run away constitutes the factor of excitation of draft system to miscellaneous disturbances produced by the dislevels, the states, the humidity, consistence, etc, run away.

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