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SOLUTION FOR ENERGY CONSUMPTION UNIFORMITY AT SINGLE BUCKET EXCAVATORS

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ABSTRACT

This paper presents a possible technical solution for energy consumption uniformity at single bucket excavators. The basics of this proposed solution consist of energy inertially stocked up and the proper way to implement this idea into the hydraulic driving system of the equipment. This kind of system was defined as a retrieval system because of the distinctive character comparative to other driving systems as follows: Load Sensing, adaptive, classical systems, etc.

KEYWORDS: energy consumption, single bucket excavator, hydraulic driving system, retrieval inertial system.

1. RETRIEVAL DRIVING SYSTEM

The working cycle of the single bucket excavators is composed by a sequence of interventions into the working space of specific components of the equipment: bucket, main arm, handle, and platform. A specific characteristic of the excavators is the rigorous sequence of the equipment components movements. The final phase of this sequence contains dislocation and carriage of the material into the working space. This characteristic operative sequence leads to the excavator framing into the cyclic working equipments group [1,2,3,4,5]. This main group of equipments is characterized by a very large variation of instantaneous power. The operation with great energy consumption is the proper excavation or the effective intervention of the equipment into the working space. The other operations have neglecting energy consumption rate. Aside from the proper excavation phase, on the other phases, the equipment acquires the movements both for preparing excavation, and for carryng the dislocated material from the working space. All ase phases are characterized by the adjustments of the equipment velocity which means the full control of the machine by the human operator. In Fig. 1 is depicted the instantaneous power variation on the working cycle for an excavator of 1.2 m^3 bucket capacity with classical hydrostatic driving system.

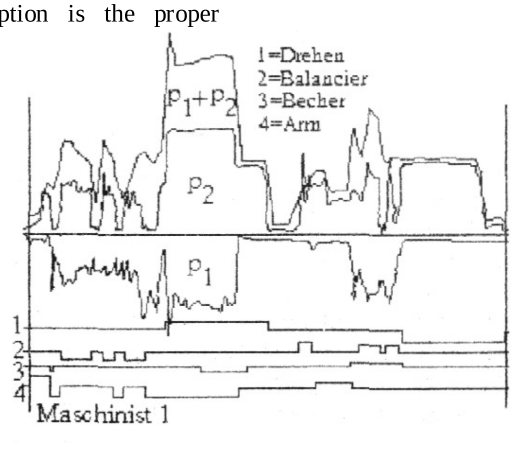


Fig. 1. Instantaneous power on the working cycle for an excavator of 1.2 m^3 bucket capacity

Back to the way of available energy utilization (disposable energy at the thermal engine output), it can justify the equipment energy consumption taking into account the next energy flows as follows:

- serviceable energy which is effectively used for the product or technology performied by the equipment; for the case of excavators this energy will be and into the dislocated and carried material from the working space;
- dissipated energy by friction which irreversible follows the serviceable energy and consists of the consummated energy for friction surmounted at the interaction between the machine (equipment) and the material, or surmounted by the internal friction between different components of the equipment having relative movements and taking part in the practical performing of the machine;
- irreversible dissipated energy into the working cycle, also named structural energy [2,6,7,12] which is consummed to supply the required kinematical or potential energy of the equipment. This energy part is taken into the constructive structure of the moving equipment as kinetic or potential way, and provides the basic support for flowing of the other kind of previously mentioned energy types. These de alt with kinds of energies the authors in different scientific works [1,2,3,6,7].

The serviceable and the friction dissipated energy will be recovered into the final product of the equipment or technology. The structural energy will be irreversiblely used into the working process for the motion with controlled kinetic regime of the equipment. With reducing the time duration of the working cycle of the equipment will be increased the energy global consumption for the machine parts movements.

If it is compared, the evolution of energy consumption of the cyclic working equipments class for the classical hydrostatic driving system and for the retrieval systems results a significant growing up of the equipment efficacy (see Fig. 2).

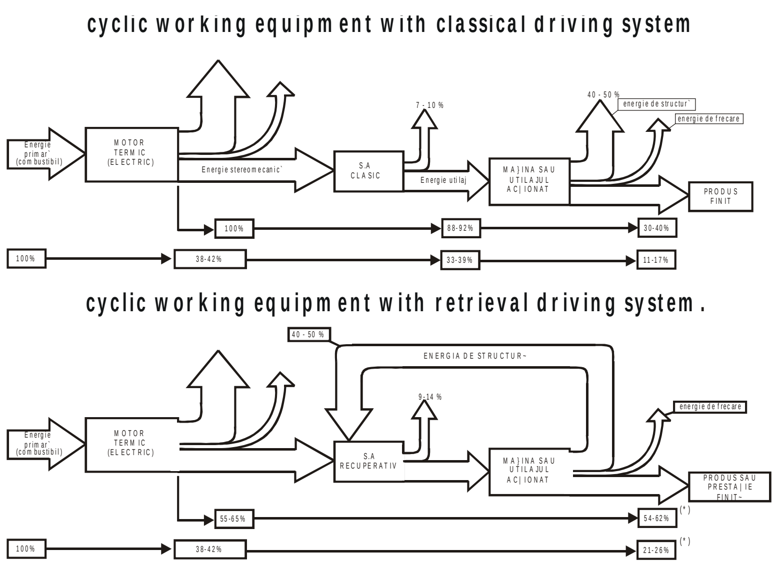


Fig. 2. The working flows of consumed energy for the cyclic working equipments

2. THE EVOLUTION OF DRIVING SYSTEMS FOR SINGLE BUCKET EXCAVATORS

Second generation of hydraulic driving excavators (1965 - 1970) is endowed with hydrostatic plants characterized by the fact that the majority of the velocity adjustments was realized with the help of dissipative devices such as hydraulic resistors (resistive adjustment). An example of such hydrostatic driving circuit is depicted in Fig. 3. This driving system still endows the Romanian excavators and not only.

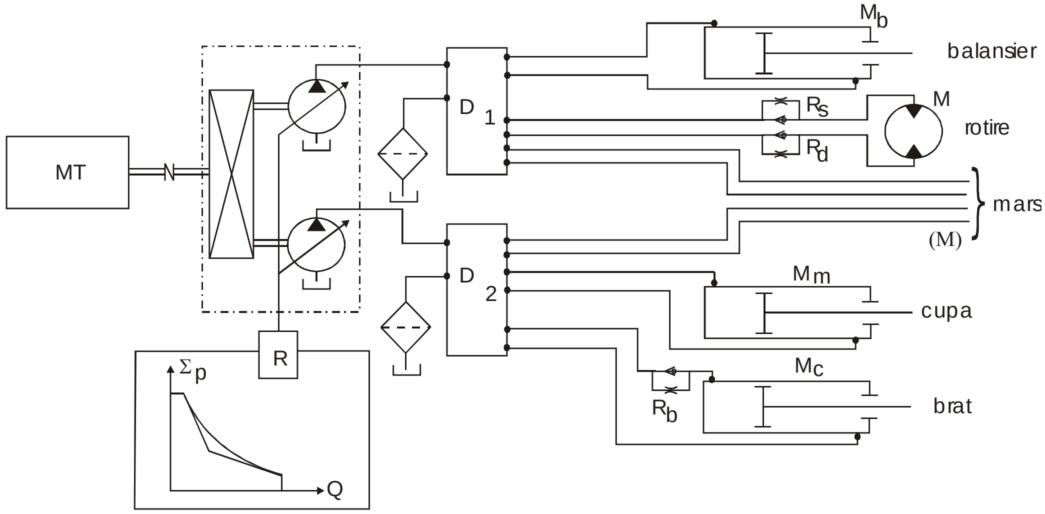


Fig.3. Second generation (classical) hydraulic driving system
MT - thermal engine; P_1, P_2 - double pump groups; D_1, D_2 - hydraulic distributors; R_bR_s,D_b - way resistors; M_b,M_m,M_c – hydraulic cylinders; M – rotative motors; R – pump with regulator power adjustment.

In the 80's were developed the excavators driving systems capable to detect the equipment loads. This kind of hydraulic driving systems are known as Load Sensing Systems. This case means tuning of driving system with instantaneous load value during the equipment exploitation, so that the energy consumption will have the necessary level for the equipment movement with imposed speed by the human operator.

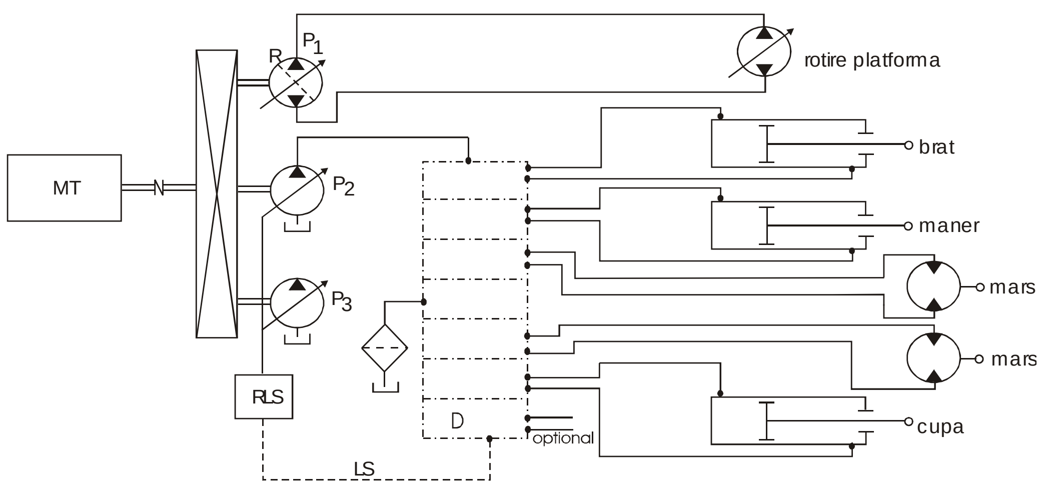


Fig. 4. Load Sensing Hydraulic Driving System
MT- thermal engine; P_1 - reversible pump, closed circuit; P_2P_3 – equipment pumps with LS regulator (LSR); D - LS distributor; M - equipments; LS - Load Sensing command signal.

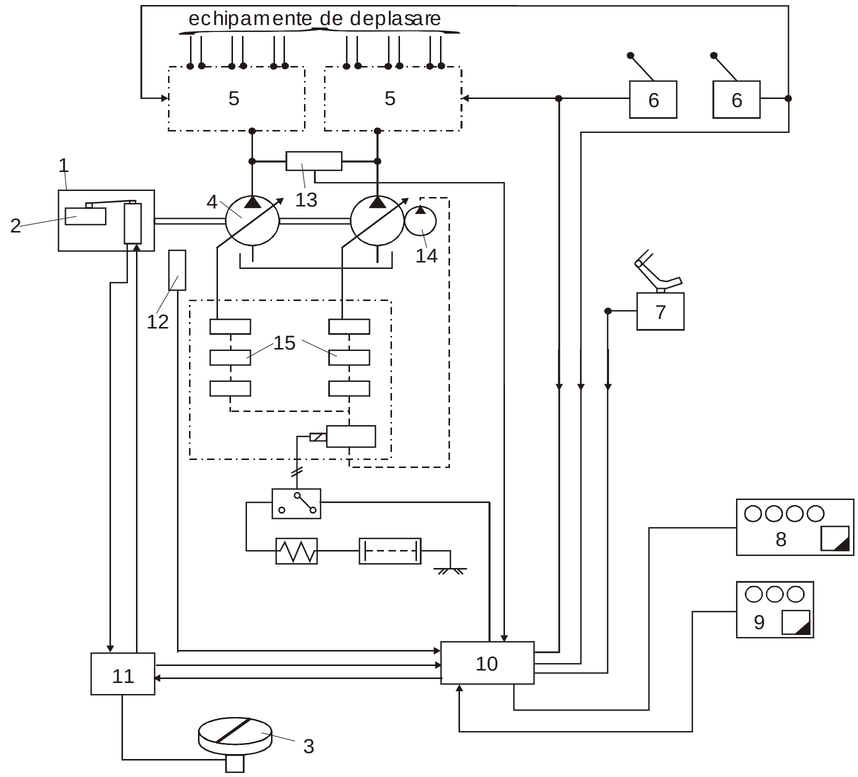


Fig. 5. LS Hydraulic Driving System - EOLSS type - 1mc bucket excavator
1 – thermal engine, 2 – injection pump and command electronic system, 3 – the command for the thermal engine working regime, 4 – the driving system pump for the equipment and the displacement, 5 – LS distributors with electrical command, 6 – equipment electrical command, 7 – equipment displacement command, 8,9 – electronic display for parameters, 10,11 – main system computer, 12 – speed transducer, 13 – pressure transducer, 14 - command circuit pump, 15 - LS regulator for main pumps.

This brief presentation of the driving system evolution of the excavators pointed out the concern of the international scientific research regarding the energy efficiency increasing for the main components and systems used into the excavators hydraulic driving.

However, the excavator structure remains the same without being adopted essential structural changes. As a consequence, regardless the driving system, the structural energy of the equipment remains the same, which is necessary to move the equipment into the gravitational field, and to accelerate and decelerate the machine during the cyclic working process.

For the effectiveness of this energy flowing during the excavator exploitation time, this paper presents o practical solution developed at Promex SA Company Braila Romania.

3. THE INERTIAL RETRIEVING DRIVING SYSTEM

To equalize the energy consumption during the working cycle of single bucket excavators was developed the functional model of a 0.8mc bucket capacity excavator with caterpillar displacement system and with inertial retrieval driving system. The prototype was realized at Promex SA Company Braila Romania. The code name of this machine is ARE-0800-I and the basic schematic diagram is depicted in Fig. 6.

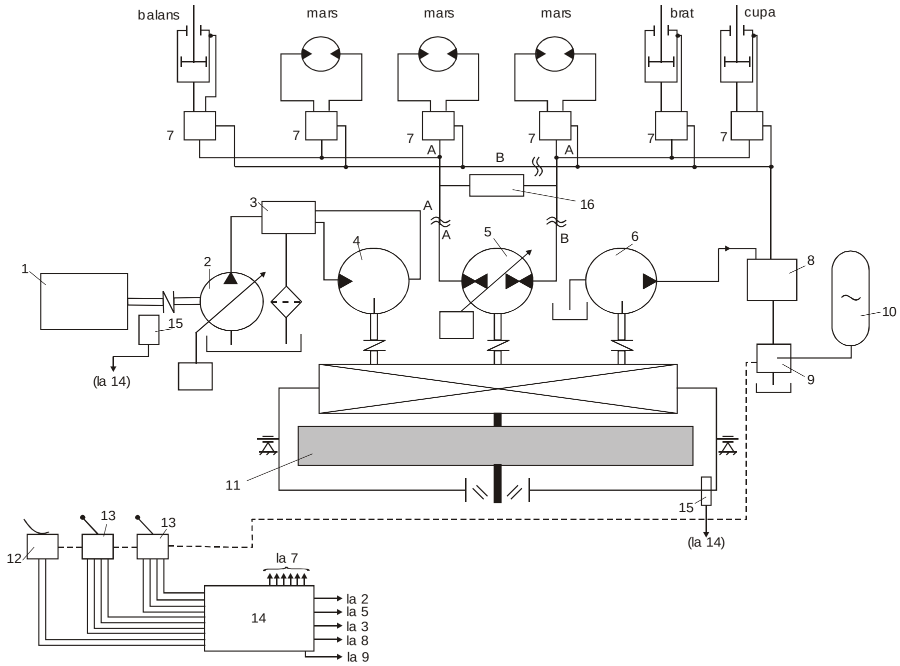


Fig. 6. The schematic diagram of the ARE-0800-I plant for the 0.8mc bucket capacity excavator
1- thermal engine; 2 - secondary circuit pump; 3,7,8,9 - hydraulic gates with electrical command; 4 - hydraulic motor for secondary circuit; 5 - primary circuit reversible pumps; 6 - the pump of supplying, refreshment and command circuit; 10 - hydro-pneumatic accumulator; 11 - inertial accumulator (gyro system); 12,13,14 - electro-hydraulic command for equipment and motion; 14 - main computer; 15 - speed transducers; 16 - pressure transducers.

Retrieval hydrostatic system ARE-0800-I from the caterpillar excavator S802 uses two reversible hydraulic units (5) with proportional electrical command with successive working regime as pump or motor. The hydrostatic units are coupled through the gates (7) with electrical command to the equipment components. The gates (7) mean distribution blocks based on hydro-logistic units which allow the electrical command of the main parts of the excavators equipment such as swinger, whirl, movement, main arm, bucket, to connect them to the primary circuit pumps. The pumps (5) are driven through the distribution block by the fly wheel (11) which is rotated through a secondary circuit framed by a hydraulic motor (4) and a hydraulic pump (2). The pump (2) is connected to the thermal engine (1) of the equipment. The fly wheel (11) drives also the pump (6) which serves the supplying, refreshment and command circuit. The command process is electronically supervised by the computer (14). This computer analyzes the operator commands, opens the suiting gates (7), makes the proportional command of the pumps (5) and (2) capacities, and opens/closes the supplying and refreshment circuit by the gates (8) and (9). In this way any command for equipment drooping into gravitational field leads to the pump (5) switching on the motor regime and to the structural energy transfer to the fly wheel (II) parallel with the energy given by the thermal engine (1) through the secondary circuit. The energy transfer between the two circuits of the pumps (5) is made automatically through a distributive box of inertial system. For the proper excavation phase when the bucket and the swinger are driven, the necessary energy is provided both by the inertial system, and by the thermal engine. In case of the deceleration phase for equipment in motion, the driving process supposes a kinetic energy transfer from the equipment structure to the inertial system. The supplying and refreshment circuit handles permanently the compensation both of volumetric differences of hydraulic agent into the hydraulic cylinders, and of the losses into the rotative hydraulic motors.

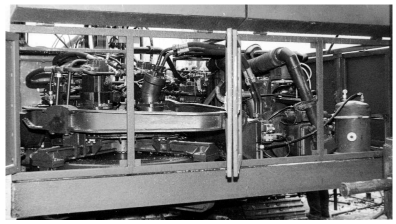
The main characteristics of the real model are presented as follows: nominal power 40.5 kW compared to 59 kW for the classical excavator (CE); bucket capacity 0.82 m^3; average time length of standard working cycle 16.9 s compared to 17.2 s for CE; hourly productivity 174.6 m^3/h compared to 171 m^3/h for CE; equipment weight 108 % compared to the classical excavator (100%).

The main characteristics for hydraulic driving system were adopted as follows:
- pump capacity - primary circuit 2x90 cm^3/rot compared to 2x63 cm^3/rot, secondary circuit 1x63

cm^3/rot, and supplying/refreshment circuit 2x32 cm^3/rot;
- pressure - primary circuit 35 MPa, secondary circuit 28 MPa and supplying circuit 4Mpa (comparative with 32 MPa for CE);
- fly wheel mass 3500 kg;
- fly wheel moment of inertia 985 kgm^2;
- fly wheel nominal speed 1800 rpm;
- maximum energy stocked into the 17.5 MJ;
- energy variation during working cycle 1.5 MJ (8.5 %);
- fly wheel speed variation of 80 rpm;
- time length for fly wheel transitory regime 7.2...8.1 min from start.

Figure 7 shows the images of the real excavator model equipped with retrieval hydrostatic system ARE-0800-I.

a



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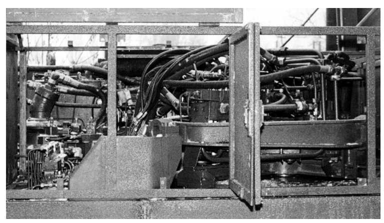

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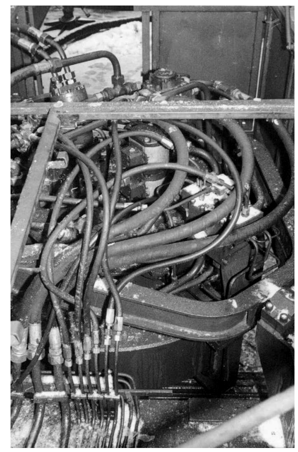

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Fig. 7. S802 excavator model with ARE-0800-I system
a) general view; b,c,d) excavator platform views with inertial accumulator montage details.

4. CONCLUSIONS

Experimental researches developed on caterpillar excavator S802 with 0.8 mc bucket capacity and retrieval system ARE-0800-I lead to the folloving concluding remarks:

- In the frame of power consumption uniform by theworking cycle for the single bucket excavators, the inertial retrieval systems represent an interesting solution which allows also for an equipment nominal power decreasing. For the presented case the nominal power was diminished from 80 HP (58.8 kW) to 55 HP (40.4 kW) which means 31 %, with the same dynamic characteristics for the equipment.
- The inertial system especially designed and used in this case is a medium speed system with a great moment of inertia which increases the total equipment mass with 8% in the same time with the balance weight elimination from the equipment platform.
- The model development supposed a total change of the hydraulic driving system and the command system conception. This fact meant were of course that the components and apparatus change which led to a 21% increase of expenses.
- An increasing of the global performances of the driving circuit can be made with the next approach as follows: the secondary circuit elimination, the fly wheel direct driving by the equipment thermal engine or by a separate turbine and the fly wheel speed increasing to 3000...5000 rpm with a direct effect in its mass decreasing.

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