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HYDRAULIC PLANT WITH ENERGY INERTIA RECUPERATOR FOR SINGLE BUCKET EXCAVATOR

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ABSTRACT

This paper analyse the driving solutions for hydraulic single bucket excavators, by the point of view of the energy consumptionon the technological working cycle. It is presented a solution of accumulation and re-circulate of the energy flow, using the inertia accumulation system, applied on the hydraulic excavator of 0.8 mc bucket, which allow the nominal power reduction.

1. Hydraulic Drive System for Single Bucket Excavators. Classical Diagram. Retrieval Diagram

The running of the excavators with single bucket it is characterised by the fact that the working cycle composition contain a intercessions sequence of the equipments (bucket, main arm, handle, foothold gyration). In this complex working process appear the repetitive modifications of the equipment dynamic parameters. The characteristic of the excavators working cycle is the fact that the technological sequence is very strictly, and it is finalized with the material dislocate and transportation from the working sector. This technological sequence situate the excavator into the group of the cyclic working equipments [1], [2], [3], [4], [5], that are characterised by the very large limits of the instant power variation. The technological operation with large energy consumption is the properly excavation or the effective intercession of the equipment into the working sector. The other phases have small energy consumption. With properly excavation phase exception, in the other technological phases, the equipment movements have the scope of the excavation prepareing or the evacuation of the digging material from the working sector. In these last mentioned phases, in the classical drive systems, it is realised the equipment speed controls with the scope of checked up by the machine operator. In the Fig. 1 it is presented the instant power variation, in the working cycle, for a single bucket excavator with hydraulic drive system, by 1.2 mc bucket.

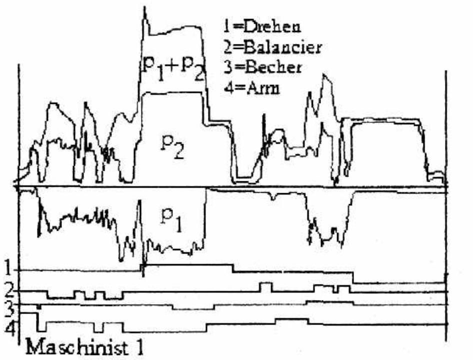


Figure 1. The instant power in the working cycle for 1.2 mc excavator

Keeping to the available energy using mode (the energy produced by the thermic engine), it could be account for energetical consumption of the equipment by considering the next energy inputs:

- helpful energy, effective consumed for realise the product or the final performing of the equipment; for the excavators, this energy are recovered in the excavated and deplaced material volume from the working sector (soil, rocks, sand, a.s.o.).
- friction dissipated energy, that follow the helpful energy, in the irreversible way, and consist from the energy consumed for surmount the friction both on the machine - terrain interaction, and between the components which have the relative

movement and interfere for realised the helpful performing of the machine (equipment).

- disipated energy, in the irreversible way, into the technological process, structural energy named in some papers [2], [6], [7], [12], and are consumed to cover the kinetic or potential energy of the equipment. This energy type are taked in the moving equipment structure under the kinetical or potential energy shape, and constitute the saucer for deplacement of the others energy types, previous presented. About these types of energy the author was conceived in the sundries papers [1], [2], [3], [6], [7].

The helpful and the friction dissipated energy will be recover into the final product of the equipment. Teh structiral energy are irreversible consumed into the technological process, through the moving on the controled kinetic state for the machine. With diminished the working cycle of the equipment, the global energy consumption are growing up (e.g. for excavators with 0.6 - 3.2 mc and working cycle time of 14...42 sec., the needlees energy consumption, for a single working cycle, are about 97 - 1100 kJ). This paper, like [4], [5], [6], [13], [14], proved the fact that exist the possibility of stocking up the structural energy, for each equipment working cycle, and giving this energy on the other phases of the cycle that are large energy input (e.g. for the excavators, the properly excavation phase).

Through this, either the global power of the equipment are reduced, for the same dynamic characteristics, or the global power are keeped, but dynamic characteristics are intensified.

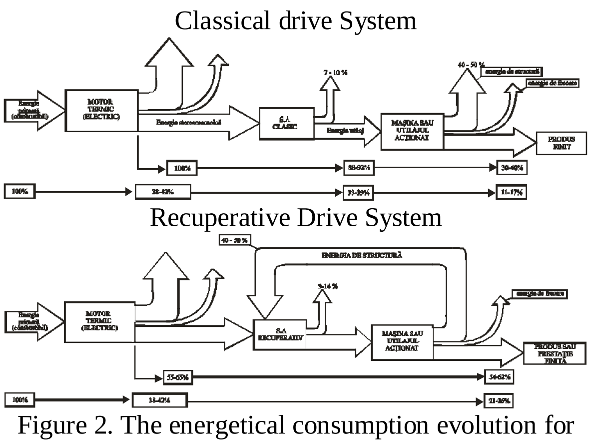


Figure 2. The energetical consumption evolution for cyclic equipments

If it is compared, with informing character, the energetical consumption evolution for the group of the cycling working equipments, drive both with classical hydraulic systems, and with recuperative systems, it is observed an increasing of the equipment efficacy (Fig. 2).

This paper constitute a synthesis of the collective research activity from PROMEX - Romania [2], [3], [15], [16], [17], to realise the phisical model for an 0.8 mc excavator, with recuperative hydrostatic drive system. The author was the chief of the research collective.

2. The Evolution of Drive System for Single Bucket Excavator

The hydraulic drive excavators, from second generation, of 1965 - 1970 years, are endowed with hydraulic plants, characterised by the fact that the majority of the speed regulators was realised with the help of dissipative components, like hydraulic resistances. This type of drive system is presented in the Fig. 3. This hydraulic drive system outfit the majority of the Romanian excavators, are not alone.

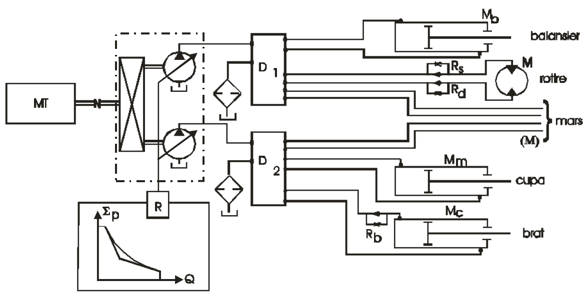


Figure 3. The second generation excavators hydraulic drive system (classical drive)

MT - thermic engine; P_1, P_2 - double pumps group; D_1, D_2 - hydraulic distributors; R_b, R_s, D_b - way resistances; M_b, M_m, M_c - hydraulic cilinders; M - rotative motors; R - pump power regulator.

In the 80's was developed the drive systems for excavators that was capable to detectthe loading on the working equipment, named and knowed under the "LOAD SENSING".

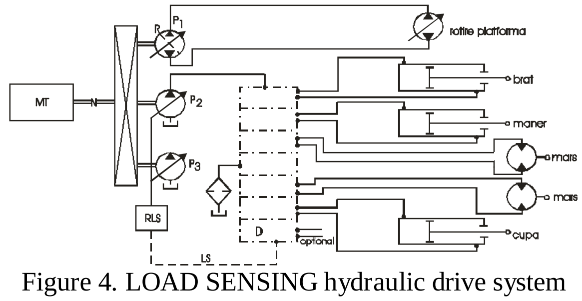


Figure 4. LOAD SENSING hydraulic drive system

MT - thermic engine; P_1 - reversible pump for closed circuit; P_2, P_3 - equipment pumps, equiped with LS (RLS) regulator; D - LS distributor; M - equipments; LS - LOAD SENSING control signal.

In this case it was realised the modulate of the drive system with the instant load size of the equipment, thus the energetical consumption

will be at the necessary level for machine moving with the operator controled speed.
At this equipments, the foothold rotate and machine deplacement are realised in closed circuit, with direct command of the pump specific capacity. This type of driving is presented in the Fig. 4, and outfit the 3rd and 4th generation excavators.
Although in the 1980 - 1985 years it was believed that the electronics will not entering into the construction equipment domain, the 5th generation drive systems quash this fact. In the Fig. 5 it is presented the drive system for KOMATSU 1 mc excavator, realised in EOLSS variant (LOAD SENSING system with closed centre).

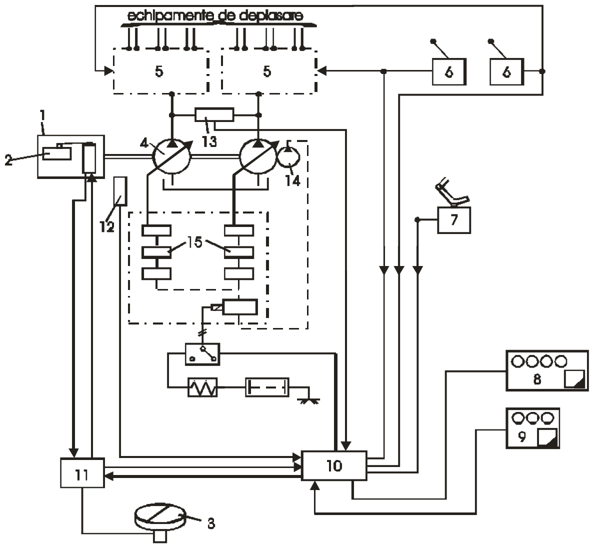


Figure 5. LS drive system - EOLSS variant - 1 mc excavator

1- thermic engine; 2 - injection pump and the auxiliar electronic command system; 3 - working state command for the thermic engine; 4 - the pumps of the drive system for equipment and deplacement; 5 - LS distributors with electrical command; 6 - electrical commands for the equipment; 7 - equipment moving command; 8, 9 - electronic display for parameters values; 10, 11 - the system computer; 12 - angular speed traducer; 13 - pressure traducer; 14 - command circuit pump; 15 - the LS regulator for the main pumps.

The succint presentation of the excavators drive systems underlined the international scientifical community concerning for energetical efficacy of the components and systems used for excavators driving.
However, the excavator composition remain in the same way, without the essential structural modifications. In consequence, regardless of the used drive system, the structural energy remain the same, i.e. the energy necessary for equipment deplacement into the gravitational field, and acceleration and deceleration of the equipment masses, in the working cycle process. For re-circulating of these energy, in the working cycle process, in this paper is presented a practically solution that are realised at PROMEX SA - Romania.

3. Recuperative Drive Sistem - Inertial Variant

With the main scope to uniform the energetical consumption on the working cycle of the single bucket excavators, it was realised the prototype of the 0.8 mc caterpillar excavator, with inertial recuperative system. This prototype was realised at PROMEX SA - Braila, Romania, with code name ARE-0800-I, and with drive system diagram presented in the Fig 6.

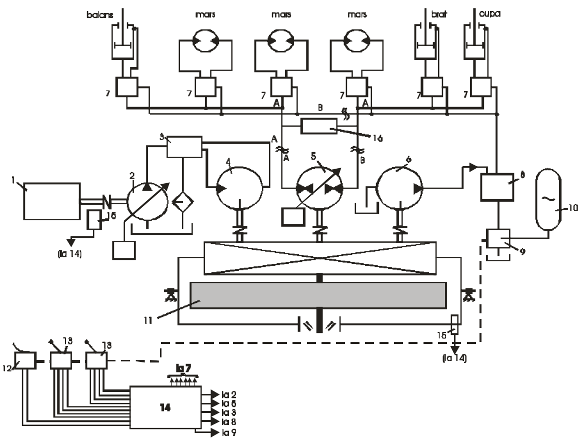


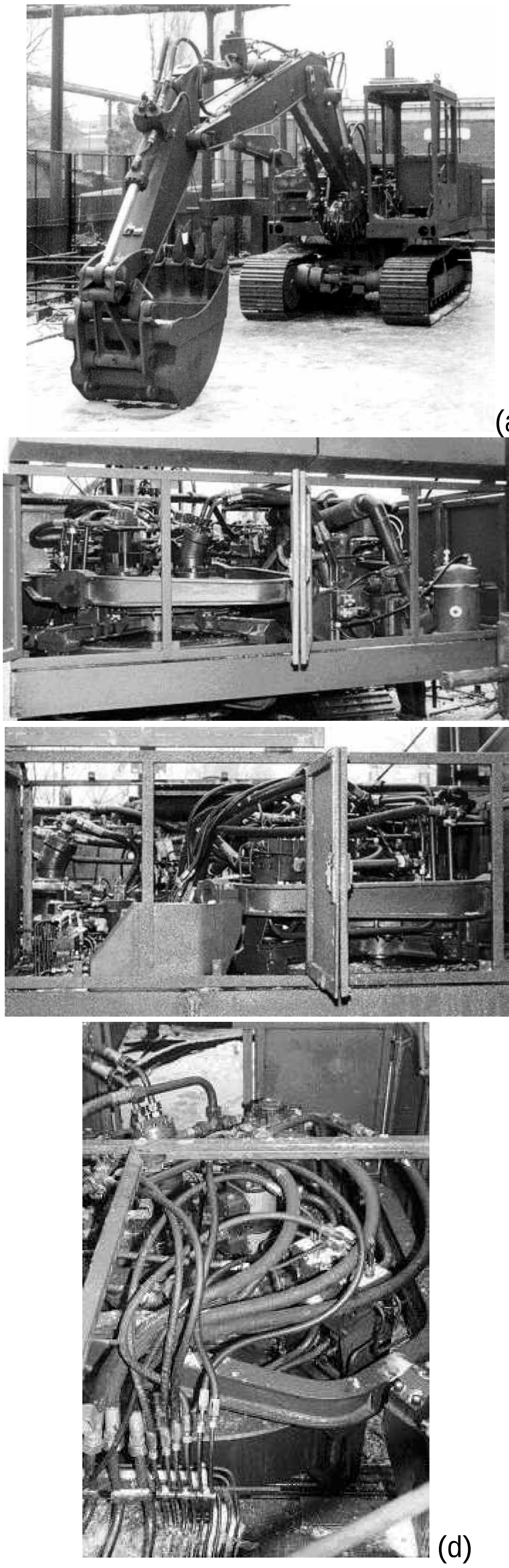
Figure 6. Principled diagram of the ARE-0800-I plant for 0.8 mc caterpillar hydraulic excavator

1 - thermic engine; 2 - secondary circuit pump; 3, 7, 8, 9 - hydraulic gates, with electrical commands; 4 - hydraulic motor, secondary circuit; 5 - reversible pumps of the primary circuit; 6 - the pump of the supplying, freshing, and command circuit; 10 - hydro-pneumatic accumulator; 11 - inertial accumulator (gyroscopic system); 12, 13, 14 - electro-hydraulic commands, for equipament and deplacement; 14 - process computer; 15 - angular movement traducers; 16 - pressure traducer.

The ARE-0800-I recuperative hydrostatic system, which equiped the S802 caterpillar excavator, use two reversible hydraulic units (5), with proportional electrical command, with pump or motor successive working state; these hydraulic units are coupled through the gates (7) which have electrical command at the excavator equipments. The gates (7) are, in fact, distribution - blocks with hydro-logistors, which allowed the electrical command connections of the equipments (swinger, angular movement, deplacement, arm, bucket) at the primary circuit pumps. The pumps (5) are drived through the distribution - box by an gyroscope (11), which are rotated by a secondary circuit composed from hydraulic motor (4) and hydraulic pump (2), drived by thermical engine (1). Also, the gyroscope drive the pump (6), which are part of the supplying (compensation), freshing and command circuit. The command process are supervising by the process computer (14), which analyse the equipment operator commands, open the coressponding gates (7), proportional drive the specific capacity of the pumps (5) and of the pump (2), open or close the supplying and freshing circuit from the blocks (8) and (9). In this way, every command for lifting down the equipment into the gravitational field are followed by the switching of the pumps (5) in the motor state and structure energy transfering to the gyroscope (II), in parallel with the energy supplying by the thermic engine (1) through the secondary circuit. The energy transfer between the two circuits of the pumps (5) are self-acting maded through the distribution - box of the inertial system. In the properly excavation phase, when are drived only the bucket and the swinger, the necessary energy are supplying both from the inertial system, and the thermic engine. In the case of moving equipment part decelerate, the process also acting by the transfer of the kinetical energy acumulated into the equipment structure, to the inertial system. The supplying and freshing circuit realise the compensation of the hydraulic agent volumes differences from the equipment cilinders, and the compensation of the losses from the rotational motors of the equipment.

Mainly characteristics of the proposed model are presented in the next: installed power 40.5 kW, compared with 59 kW wich equip the classical excavator; bucket capacity 0.82 mc; medium time interval of working cycle 16.9 sec., compared with 17.2 sec. for classical excavator; hour productivity 174.6 mc/h compared with 171 mc/h for classical excavator; equipment weight 108% compare with 100% for classical excavator.

Drive system characteristics are: pumps specific capacity: primary circuit 2x90 cmc/rot, compared with 2x63 cmc/rot for classical excavator, secondary circuit 1x63 cmc/rot; supplying and freshing circuit 2x32 cmc/rot; pressures: primary circuit 35 MPa, secondary circuit 28 MPa; supplying and freshing circuit 4MPa, compared with 32 MPa for classical excavator; gyroscope mass 3500 kg; inertia moment of gyroscope 985 kgmp; operating



(a) (b) (c) (d)

Figure 7. S 802 excavator model, equiped with ARE-0800-I system

a) excavator general wiew;

b), c), d) excavator foothold wiews, with inertial accumulator positioning modes.

turation of the gyroscope 1800 rot/min; maximum energy accumulated into the inertial system 17.5 MJ; energy variation on the working cycle 1.5 MJ/8.5%; the variation of the gyroscope turation 80 rot/min; gyroscope recall time to the operation turation 7.2 - 8.1 min (from pause state).

In the Fig.7 are presented the images of the excavator model equiped with ARE- 0800-I recuperative hydrostatic system.

4. Conclusions

Experimental researches realised with S 802 caterpillar excavator, with 0.8 mc, equiped with ARE-0800-I recuperative system, imposed the next conclusions:

- to uniformisation of the power consumption on the working cycle, for a simple bucket excavators, the inertial recuperators constitutes an interesting solution which allow the equipment instaled power diminishing. For the presented case, the instaled power was diminished from 80 HP (58.8 kW) to 55 HP (40.4 kW), respectively 31%, with keeping the initial equipment dynamic caracteristics.

- the used inertial system, special designed for this application, is the system of medium speeds, with great inertia moment, which was imposed the growing up of the equipment total weight with 8%, with elimination of the contra-weight from the equipment foothold.
- the realisation of the model was supossed the total change of the command and drive plant conception, and implicitly, the drive components changing, which was imposed the 21% quipment expensives costs.
- it appears the possibility of the entire drive system performances growing up, through the secondary circuit elimination, directly gyroscope drived from the thermic engine or gases turbine, and growing up the gyroscope speed at 3000-5000 rot/min, with direct effect at his mass reduction.

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