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THE ANALYSIS OF PNEUMO - HYDRAULIC ACCUMULATOR EFFICIENCY, APPLIED AS ELEMENT OF HYBRID DRIVING SYSTEM

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The paper presents simulating model investigations of hydraulic accumulator-working as a secondary source of energy in a multisource driving system. The simulation of the system for characteristic input functions was conducted by the use of real gas models: Benedict - Webb - Rubin (BWR) and Redlich - Kwong. The dependence of energetic efficiency of accumulator was analyzed in term of its time-constant, time of storage, number of cycles of load and it was compared to ideal gas thermodynamic processes.

1. Introduction

There are three levels of requirements which decide about energetic efficiency and ecological coefficients of hydrostatic multisource driving systems used in working machines and vehicles:

- energetic characteristic of components such as hydrostatic pumps and engines, as well as hydro accumulators and IC engines. In IC engines very essential are ecological characteristic e.g. share of harmful components in exhaust gases,
- suitable fitting of energetic characteristic of elements and units,
- suitable steering of the driving system, executing a given working cycles for optimum of chosen quality criteria [8].

It requires very good knowledge of energetic characteristics (energetic efficiencies or losses) in the whole working area of all components, realizing functions of trans-formation, transmission, distribution and accumulation of energy.

The last of these functions filled through secondary source of energy requires know-ledge of instantaneous surplus of energy of IC engine and recuperated energy (potential or kinetic) from a load.

Therefore good knowledge of energetic characteristic (static and dynamic) of a pneumo-hydraulic accumulator has principle significance for whole energetic balance of the system, and also for ecological characteristic of IC engine. Universally applied models of thermodynamics transformations of ideal gas are in such analyses useful only in limited cases. Therefore it is a reason to apply the real gas models which take into account the temperature of surroundings, kind of medium as well as accumulator construction.

2. Simulation research of pneumo - hydraulic accumulator

The flow Q_A, which corresponds to the charging intensity, storage and unloading phases of pneumo-hydraulic accumulator, is an input function. All phases of cycle are of equal duration and equals $t_l = t_r = t_{p1} = t_{p2} = 10$ s (***Fig. 1***).

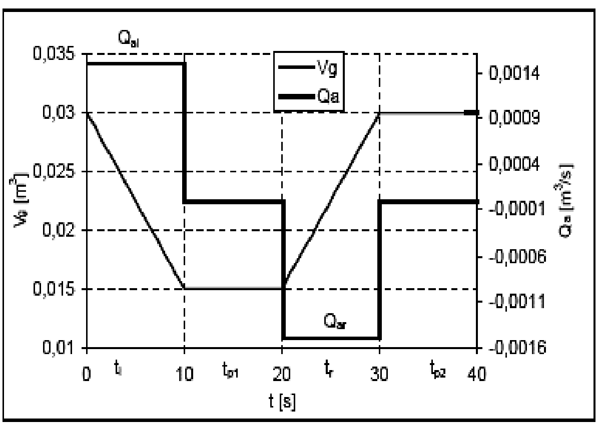

Fig. 1 *Input function set change of accumulator absorbency of (Qa) as well as the capacity of gas in accumulator (Vg)*

The studied accumulator is characterized by the following parameters: the initial pressure of gas in accumulator p_{g0} = 10 MPa, the maximum volume of gas in accumulator V_{gmax} = 0,03 m^3, temperature of surrounding T_{a1} = 300 K. As a result of simulation, for a set of the input function (***Fig. 1***), were pressure outputs functions p (***Fig. 2***) received, as well as the temperature of gas T (***Fig. 3***) in time of cycle for different models of thermodynamics transformations in studied pneumo-hydraulic accumulator.

Studying individual cycle of work of accumulator it is impossible to take into conside-ration an influence of the previous phase of cycle on its efficiency - the phase of storage under low pressure or expectation for a next charging.

The exchange of heat among accumulator and surroundings in this time also follows. For majority of cycles the temperature of end of unloading (***Fig. 3***) is lower from temperature of surroundings, the exchange of heat runs in direction from surroundings to accumulator.

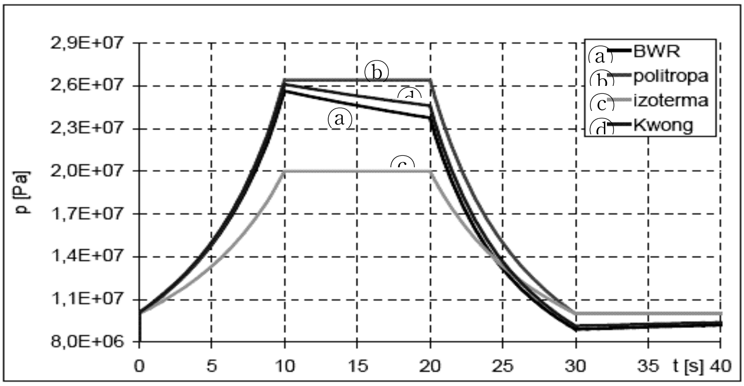

Fig. 2 *Changes of gas pressure in pneumo- hydraulic accumulator for four models of thermodynamics transformations real patternel Benedict - Webb - Rubina (BWR), Redlicha - Kwonga (Kwong); as well as ideal: polytropic curve (politropa) as well as isotherm (izoterma)*

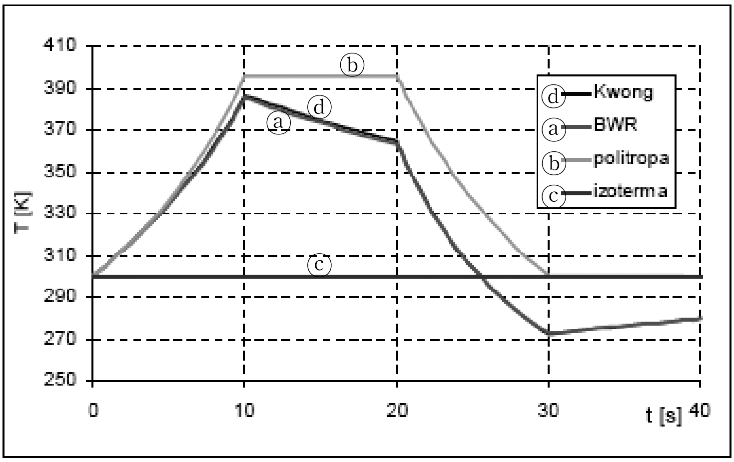

Fig. 3 *Changes of temperature gas in pneumo - hydraulic accumulator for four models of thermodynamics transformations real: Benedict - Webb Rubin (BWR) model, Redlich - Kwong model (Kwong); as well as ideal: polytropic curve (politropa) as well as isotherm (izoterma)*

In this time follows partial energy lost recovery during storage under high pressure. It has essential influence on second cycle and next after him following, so long, until dynamic settled condition will not reach, in which the temperature of end of unloading cycle will not level with temperature of surroundings. In dependence from capacity of accumulator, condition of such equilibrium follows after several, a dozen or so or even tens cycles.

The changes of efficiency of accumulation for repeated cycles were considered for two models of thermodynamics transformations in accumulator: BWR and Redlich - Kwong (***Fig. 4***).

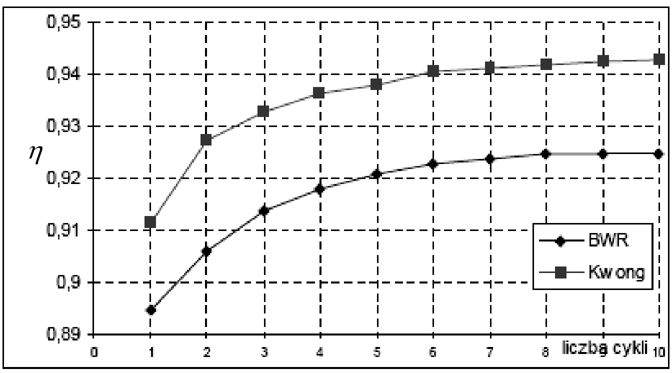

Fig. 4 *Efficiency of accumulation for repeated cycles (the temporal heat constant τ = 30)*

Analysing received results, it was affirm that thermal equilibrium set in sixth cycle. Difference among results from both real models of thermodynamics transformations is insignificant (max 2,6 %).

Simulation investigations results shows, that principle influence on efficiency of cycle has time of his duration, and particularly the phase of energy storage under high pressure. ***Fig. 5*** shows the influence of liquid storage time on efficiency of cycle under high pressure. The efficiency was marked in place of connection of accumulator with hydraulic installation. The thermodynamical phenomena were considered as well as connected with flow of liquid to and from accumulator. Graph results shows, that efficiency, very high near small times storage, it falls clearly, when time is lengthen.

However if the time of duration of cycle lengthens, then the fall of efficiency becomes less intensive, which agrees from earlier observations that the process of cooling accumulator runs according to opposite exponential curve.

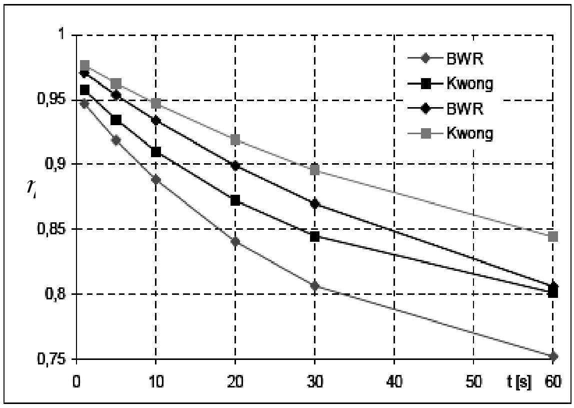

***Fig. 5** An influence of storage time on accumulator efficiency*

Temporal heat constant τ has major influence on efficiency of accumulator. It depends from his parameters mainly. However it is possible to shape the efficiency in determined borders e.g. enlarging the surface of heat exchange, enlarging the intensity of cooling or just the opposite - isolating accumulator.

The influence of temporal heat constant τ on efficiency of accumulation of energy for two real models of thermodynamics transformations was introduced on ***Fig. 6***. In both models the curve of efficiency possesses clear minimum for similar values of τ - in this case for temporal heat constant τ = 6 [s].

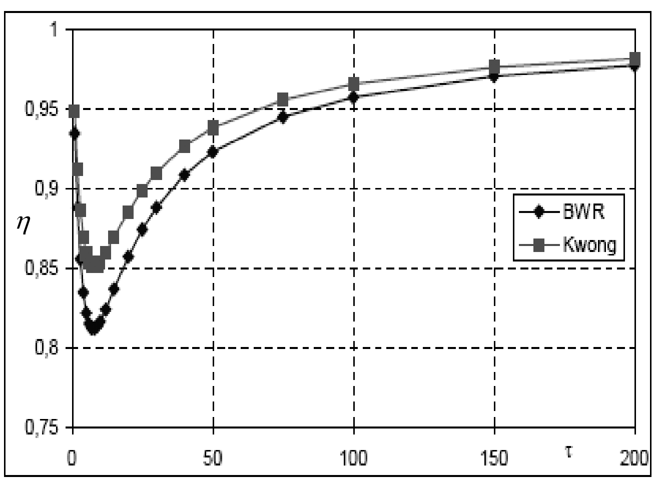

***Fig. 6** An influence of temporal heat constant τ on efficiency of working cycle*

However temporal heat constant τ = 0 and τ t = ∞ represent two ideal, impossible to technical realization thermodynamic transformations - isothermal and adiabatic. Such cycles when upper transformations step out, characterize ideal energetic efficiency

η = 1. Regard on this, would belong to aim to obtainment of such temporal heat constant values to bring nearer to ideal transformation in track of loading and unloading phases of the accumulator.

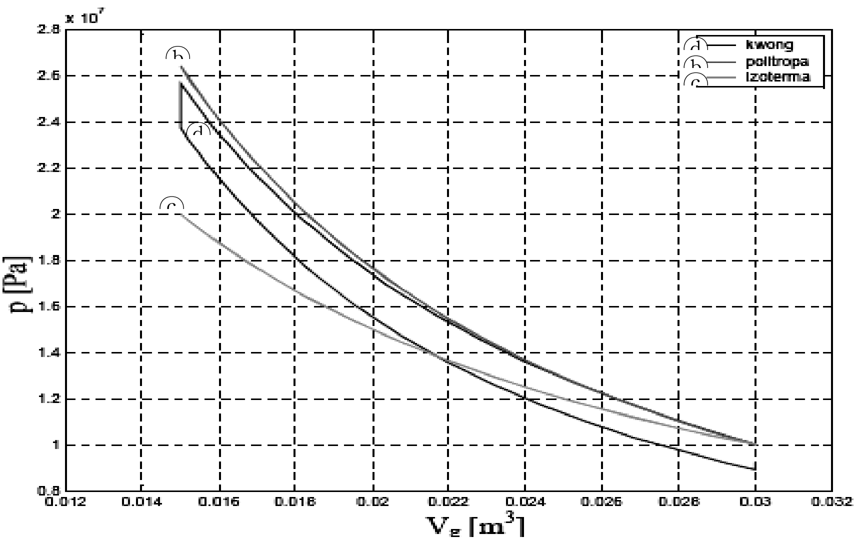

***Fig. 7** Working cycle of gas accumulator in co-ordinates p-v*

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Summary

THE ANALYSIS OF PNEUMO - HYDRAULIC ACCUMULATOR EFFICIENCY, APPLIED AS ELEMENT OF HYBRID DRIVING SYSTEM

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Phenomenon's drawings ahead in pneumo-hydraulic accumulator have essential meaning for efficiency of hydrostatic multisource driving system. Their knowledge and suitable mathematical descriptions way make possible:

- rational selection of accumulator and his exploration parameters to multisource driving systems,
- the expectation with help of modeling, possible energetic and ecological parameters of˙the multisource driving systems of machine working in determinate cycle of load,
- in dependence from suitable closeness (the complexity of simulation model) and the way of modeling, the premises to steering the hybrid system in real time (Control Rapid Prototyping) exist.