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EFFECTIVENESS OF KINETIC ENERGY RECOVERY EXPLORED BY MEANS OF EXPERIMENTAL STAND

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Abstract: *The presented paper deals with efficiency determination of kinetic energy recovery explored by means of experimental stand installed in the Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology. Transfer of kinetic energy to pressure hydraulic energy was carried out by means of this stand and research was aimed to the use of results in transport, especially in heavy horse commercial vehicles operating in start-stop regime. The main purpose of stand experiments is to find conditions for the most economical operation of vehicles using two-way energy recovery.*

Keywords: Effectiveness, Energy, Recovery, Hydraulic, Stand.

1. Introduction

The basic idea of kinetic energy recovery is to use the kinetic energy of the braked vehicle which is commonly lost by braking and useless changed in heat. This can be done by the change of the kinetic energy to hydraulic energy that can be used at the following start of the vehicle. This system is especially suitable in vehicles working in frequent cycle braking-start as e. g. road rollers (Fig. 1), forklift trucks, garbage trucks, city busses etc. Value of efficiency serves as a criterion of optimum parameters settings and the recovery process effectiveness (Pourmovahed et al. (1992, 1992a)).

Fig. 1: The road roller.

Fig. 2: The experimental stand.

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2. Structure of the Experimental Stand

The main tasks for the new experimental stand were (Nevrlý, 2011, 2012):

- testing of operation states,
- measuring of the most important operation quantities for further analysis, mathematical modeling and computer simulation leading to size optimization of substantial parameters and elements and to optimization of valves control,
- finding suitable methods for efficiency determination as a measure of the system effectiveness.

The hydraulic motor drives the dynamometer that represents inertia of the real vehicle. The axial piston motor equipped with the electronic control is connected to the valve block. The electric motor of 22 kW is attached to the frame and drives the axial piston pump equipped with the proportional flow control. The pump block is connected to the valve block that contains six electromagnetic controlled valves. The valves of this block control a flow of oil into the corresponding branches of the hydraulic circuit according to the set operation regime (Nevrlý, 2012a, 2013a).

The stand for research of kinetic energy recovery is depicted in Fig. 2. The details can be seen in the hydraulic scheme in Fig. 3.

2.1. Operation regimes of the stand

- The regime STOP is the initial regime.
- The regime Set RPM serves for setting of output revolutions of hydraulic motor.
- The regime Decel causes a fly-wheel to brake.
- The regime Accel starts a fly-wheel to be driven by pressure of working liquid flowing from the high pressure accumulator.

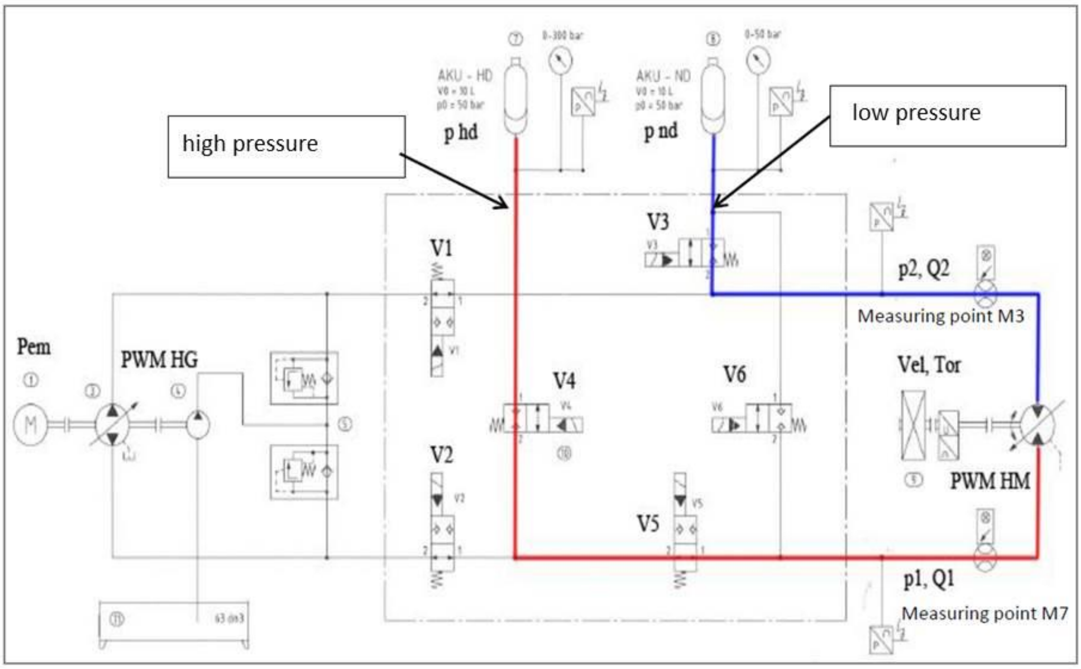

Fig. 3: Simplified scheme of the stand for operation regime Decel.

2.2. Example of efficiency determination

An example of measured high pressure and low pressure courses at regime Decel can be seen in Fig. 4 showing important trends during this operation mode.

Efficiency of the regime Decel is defined as relation of energy coming in the process and energy going out of him. Efficiency has been determined by computation and by measuring of electric power input (Němec, 2013, 2013a).

$$\eta = \frac{E_1}{E_2} = \frac{E_{phd} - E_{pnd}}{E_k + E_{em}} = \frac{\int Q_2 \cdot p_{hd} \cdot dt - \int Q_1 \cdot p_{nd} \cdot dt}{\int P_{E_k} \cdot dt + \int P_{em} \cdot dt}$$

$$P_{E_k} = \frac{d\left(\frac{I \cdot \omega^2}{2}\right)}{dt}$$

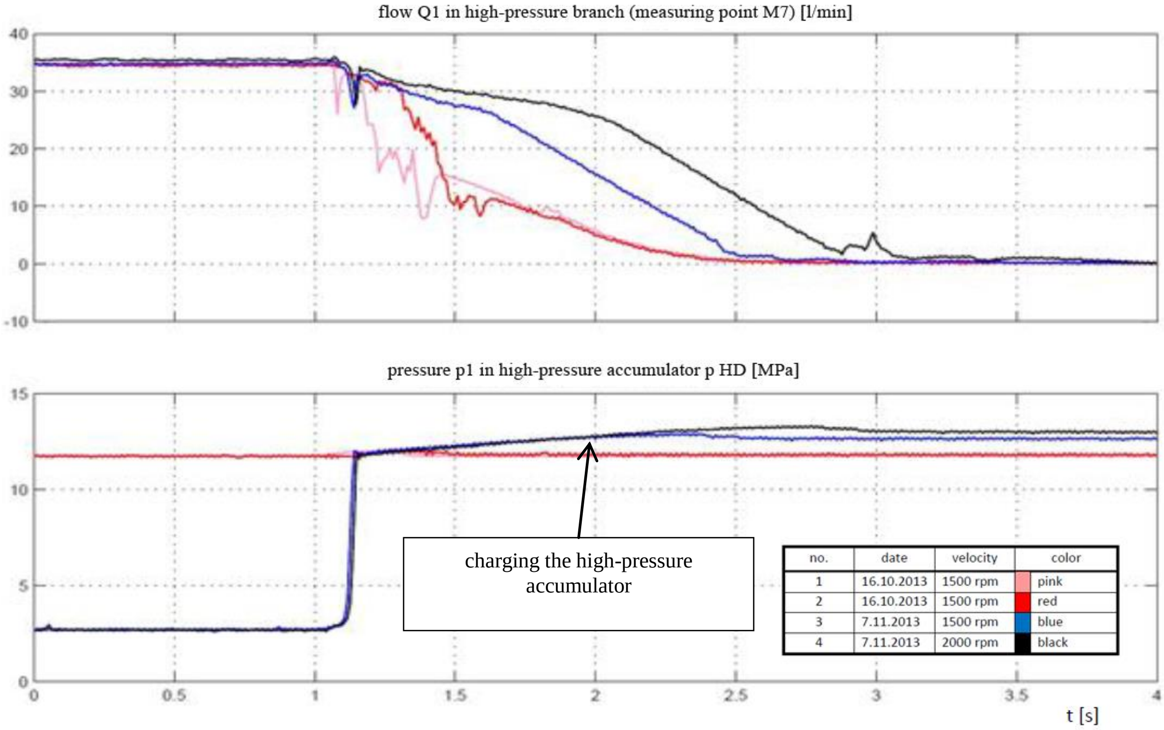

Fig. 4: Example of measured high pressure and low pressure courses at regime Decel.

Tab. 1: Determination of energy recovery effectiveness in cyclic regime by means of electric power input measuring.

	recovery start	recovery end	recovery difference	standard start	standard end	standard difference	saving	saving
velocity	el.energy consump.	el.energy consump.	el.energy consump.	el.energy consump.	el.energy consump.	el. energy consump.		
min^{-1}	Wh	Wh	Wh	Wh	Wh	Wh	Wh	%
1500	49.90	132.62	82.72	46.40	138.45	92.04	**9.32**	**10.12**
2000	84.53	177.61	93.07	20.03	125.86	105.82	**12.75**	**12.04**

3. Conclusions

Measuring of energy recovery effectiveness during cyclic operation by means of electric power input measuring (Tab. 1) proved the following positive results (Nevrlý, 2013b):

1) Saving of **10 % till 12 %** shows maximum energy saving in stand till **18 %** at 3500 rpm.
2) Prospect of real energy saving in road roller AP 240 H is about **15 %.**

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References

Němec, Z. (2013) Models and simulation for recovery stand equipped by hydrostatic drive (in Czech). Chapter 4.4 in (Nevrlý, 2013b).

Němec, Z. (2013a) Valves timing of in recovery stand of FME. Partial research report. FME BUT, (in Czech).

Nevrlý, J. (2011) Kinetic Energy Recovery at Heavy Cycle-rate Operating Commercial Motor Vehicles. Research report. Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, (in Czech).

Nevrlý, J. (2012) Hydraulic Energy Recovery Stands for Vehicles. In: Proc. 53rd International Conference of Machine Design Departments. Conference Proceedings, ISBN 978-80-214-4533-8. Brno University of Technology, Faculty of Mechanical Engineering, Institute of Machine and Industrial Design. Mikulov, pp. 199-206.

Nevrlý, J. (2012a) Recovery hydrostatic module for utility vehicles. Periodical report 2012 of the project LF12029. Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, Brno, (in Czech).

Nevrlý, J. (2013a) Experimental Hydrostatic Stand to Energy Recovery Research for Vehicles. In: Proc. 54th International Conference of Machine Design Departments. ICMD 2013, Liberec, Czech Republic. pp. 137-142.

Nevrlý, J. (2013b) Recovery hydrostatic module for utility vehicles (in Czech). Periodical report 2013 of the project LF12029. Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, Brno.

Pourmovahed, A., Beachley, N. H., Fronczak, F. J. (1992) Modeling of Hydraulic Energy Regeneration System – Part I: Analytical Treatment. Journal of Dynamic Systems, Measurement, and Control. Vol. 114, pp. 155-159.

Pourmovahed, A., Beachley, N. H., Fronczak, F. J. (1992a) Modeling of Hydraulic Energy Regeneration System – Part II: Experimental Program. Journal of Dynamic Systems, Measurement, and Control. Vol. 114, pp. 160-165.