The Control of the Rotational Speed of Hydraulic Engine in Hydrostatic Transmission by Use the Module DSP

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Annotation

In spite that hydrostatic transmission is well-known object since a long time and practical universally to it new solutions in continuation were sought was, which was it been possible to apply in arrangements of adjustment. Such drives must have great precision in set problem, the most important is the exact realization of set speed. With regard on kind of running executed through hydrostatic drives as well as on variation of conditions in what this running she be executed, the sequence of problems appears in track the projections and the construction of for hydrostatic transmissions the arrangements of adjustment in working machine engines. The rotational speed of hydraulic engine the two-stage controller, controllers of type PID to control the most often be practical in classic figure at present or noise modified at an angle of immunity.

Rotational speed method using absolute value DSP in article be circumscribed to control. The practical gender of hydrostatical transmission about closed circulation of liquid to investigations was put-upon the most often. She be built from multi-piston axial pump about variable of efficiency as well as engine about solid working absorbency. The change of rotational speed of hydraulic engine be realized across control volumetric on road of change of efficiency hydraulic pump. The output of pump control be realized with the help of the electrohydraulic of aggregate master, which hydraulic coupling cylinder is from deflection executive unit the rotor of pump. Unit servovalve is master. Angular deflection of rotor of pump and this the dislocation the piston rod of cylinder be exchanged on dislocation it causes change of her output as well as direction of expression then it in turn causes the change of rotational speed as well as sense of rotation of hydraulic engine. Incriminating aggregate the weight of transmission be realized electrohydraulic, connect from hydraulic engine, which similarly how transmission works in closed circulation of liquid.

The mathematical model of transmission in first unit of article was introduced. It model on his basis was built was to simulating investigations in packet MATLAB/SIMULINK.

It in more far unit was described was prepare the realization of controller of type PID near utilization modules SPAC20, which is quick coprocessor (DSP) for programmers Mitsubishi. He is provided for to intensive calculations numeric as well as to folded processes .It to it was control the rotational speed of hydraulic engine was proposed the cascade algorithm. Dislocation hydraulic servo-motor the parameters of controller were well-chosen to control first and the parameters of controller were chosen stabilizing the rotational speed of hydraulic engine then. The computer of PC to registration of measuring data was used. It processed measuring signals were passed was on analog input of measurement card Advantech.

Received unit of article the state the composition and comparison of results on road of simulation with coming from with laboratory investigations of object results. The results of investigations of controller be introduced for different points of working as well as near regard the disturbances also.

1. Mathematical model of the transmission

A hydrostatic transmission is a very complex object. Having in mind huge knowledge accumulated on this subject and the constructed model's target application, certain simplicative assumptions were adopted. These assumptions aim at writing a model in possibly simplest form, at the same time preserving the significant features of a real object.

Accordingly, it has been assumed that: a hydrostatic transmission is a system with lumped constants, static and dynamic features of a transmission do not depend upon the direction of hydraulic engine's rotation – mathematical model was developed for one rotation direction only; a transmission is in thermal balance state, module of volume elasticity is constant, angular velocity of the main pump shaft is constant, pressure drop in hydraulic cables is negligible, leaks in pump and engine can be summed, a pump's efficiency does not depend upon its shaft's rotation angle, absorptivity of hydraulic engine does not depend upon its shaft's rotation angle, safety valve is closed all the time.

The calculation scheme presented in Figure 1 was adopted for developing mathematical model of a hydrostatic transmission.

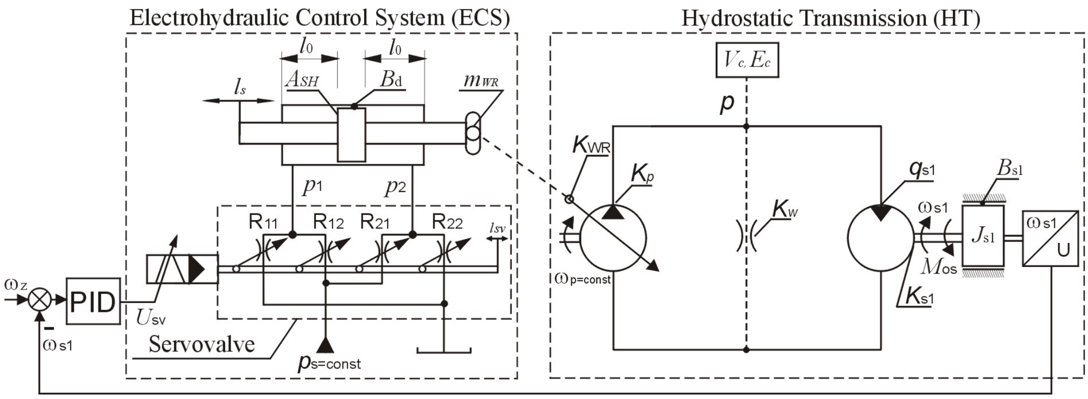

Figure 1. Hydrostatic transmission calculation scheme

The mathematical model of the transmission presented in Figure 1 is described by the following equations:

$$\dot{p} = \frac{E_c}{V_c}\left(K_p l_s - K_w p - q_{s1}\omega_{s1}\right) \tag{1}$$

$$\dot{\omega}_{s1} = \frac{1}{J_{s1}}\left(K_{s1} p - B_{s1}\omega_{s1} - M_{os}\right) \tag{2}$$

$$\ddot{l}_s = \frac{1}{m_{WR}}\left(A_{SH}(p_1 - p_2) - B_d \dot{l}_s - K_{WR} p\right) \tag{3}$$

$$\dot{p}_1 = \frac{E_c}{A_{SH}(l_0 + l_s)}\left(RSV(l_{sv}, p_s - p_1) - A_{SH}\dot{l}_s - RSV(-l_{sv}, p_1)\right) \tag{4}$$

$$\dot{p}_2 = \frac{E_c}{A_{SH}(l_0 - l_s)}\left(RSV(-l_{sv}, p_s - p_2) + A_{SH}\dot{l}_s - RSV(l_{sv}, p_2)\right) \tag{5}$$

$$RSV(l_{sv}, p_{sv}) = K_{sv} SAT(l_{sv}) \operatorname{sgn}(p_{sv})\sqrt{|p_{sv}|} \tag{6}$$

$$SAT(l_{sv}) = \max\{\min\{l_{sv\max}, l_{sv0} + l_{sv}\}, 0\} \tag{7}$$

Notation: K_{sv} – coefficient of the reinforcement servovalve, m_{WR} – mass reduced on the cylinder piston rod, l_{sv} – servovalve's spool position, l_{sv0} – overlap position, p_{sv} – pressure drop in servovalve's spool, E_c – fluid bulk modulus, V_c – fluid volume, B_{s1}, B_d – resistance coefficient of viscous friction, K_w – volumetric leakape coefficient of the hydrostatic system, K_p – pump delivery coefficient, K_{s1} –motor's torque coefficient, q_{s1} – hydrostatic motor displacement, J_{s1} – total moment of inertia reduced on the shaft of motor.

2. Laboratory tests

The measuring and control system was built to research. It consists of: servovalve, sensors, transducers, amplifiers and elements of computer system. The software of control system for hydrostatic transmission was built by using MATLAB/SIMULINK. Measurement's signals are converted and give in the analog input of the measurement card. PC computer is used for registration of data. The PID controller was built by using signal coprocessor SPAC 20 and the program was written in IRD Bloc program.

The research started from prepare object's static characteristic. First was dependence between pressure and voltage. On Figure 2 is shown result of test. Characteristic have a hysteresis form. It means that object is nonlinear.

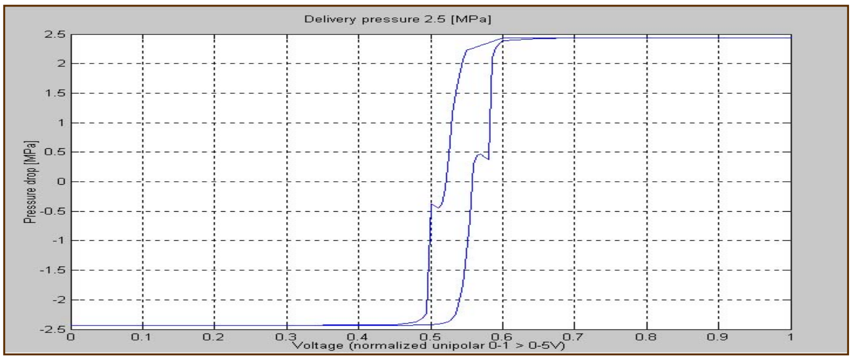

Figure 2. Dependence between pressure and voltage

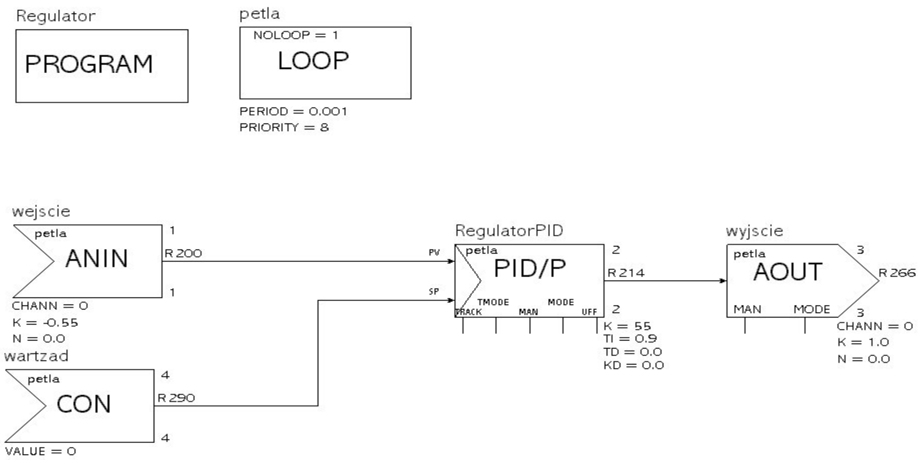

Figure 3. Program which realise PID controller for cylinder position

First the controller for servo-cylinder position was investigated. Position of cylinder is from –5 to +5 [V] which correspond –27.5 to +27.5 [mm]. To control was chosen controller PI with parameters: k_R = 55 [%], T_i = 0.9 [s]. The tests were done for three values: 10, 20 and 25 [mm] in 30 [°C] temperature.

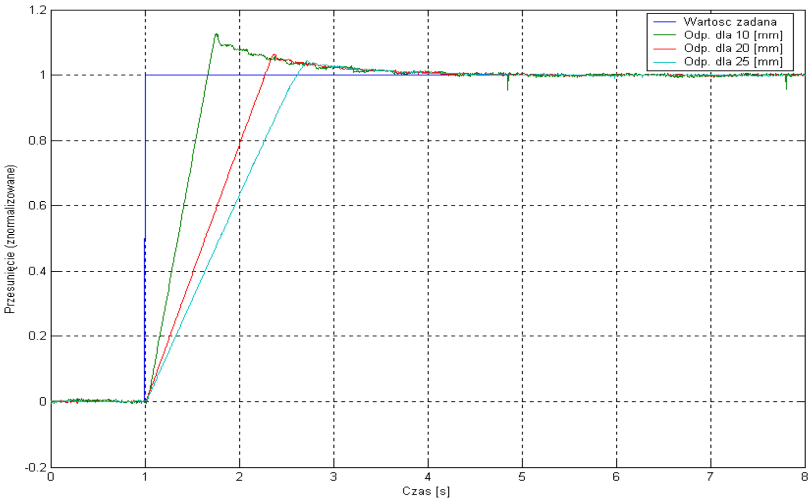

Figure. 4. Comparison step responses for three different values for position

Table 1. Performance indices

Performance indices	Set value 10 [mm]	Set value20 [mm]	Set value 25 [mm]
Settlement time 2% [s]	2.205	2.28	2.245
Over -regulation [%]	12.66	6.347	4.468
Offset [mm]	0	-0.028	-0.018
Integral of absolute error: IAE Integral of squared error: ISE	0.4585 0.2458	0.6955 0.4309	0.8328 0.534

In the next stage was built cascade controller. First PID internal loop (I step) realise control of position cylinder and the second external loop (II step) realise control of rotational speed of hydraulic engine.

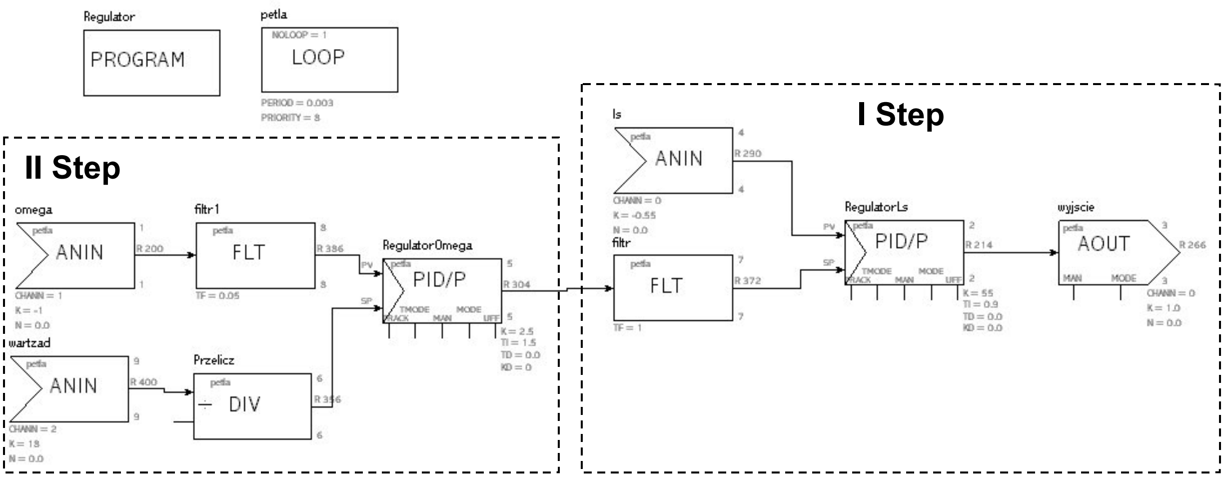

Figure 5. Program which realise PID controller for rotational speed of hydraulic engine

To control was chosen controller PI with parameters: $k_R = 2.5$ [%], $T_i = 1.5$ [s]. The tests were done for three set values of rotational speed: 300, 600 and 900 [mm] in 30 [°C] temperature of oil.

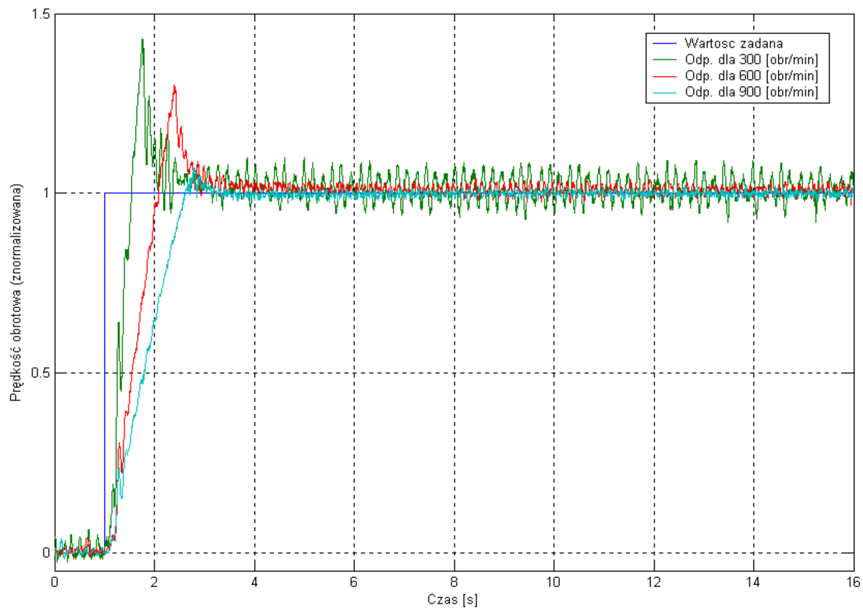

Figure 6. Comparison step responses for three different values for rotational speed

Table 2. Performance indices

Performance indices	Set value 300 [rpm]	Set value 600 [rpm]	Set value 900 [rpm]
Settlement time 5% [s]	-	2.38	1.9050
Over -regulation [%]	42.82	30.127	7.0638
Integral of absolute error: IAE Integral of squared error: ISE	0.8866 0.2813	0.851 0.4328	0.8889 0.5498

The next tests rely on giving a disturbance as a step function. First the rotational speed was changed: 300, 500, 700 and 900 [rpm] but the disturbance was constant. Second the rotational speed was constant but the disturbance was changed: 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7.

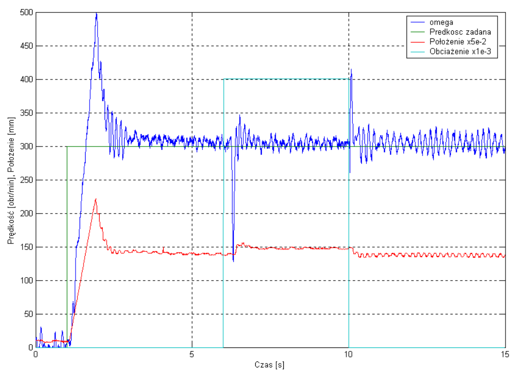

Figure 7. Rotational speed (300[rpm]) and cylinder displacement with disturbance

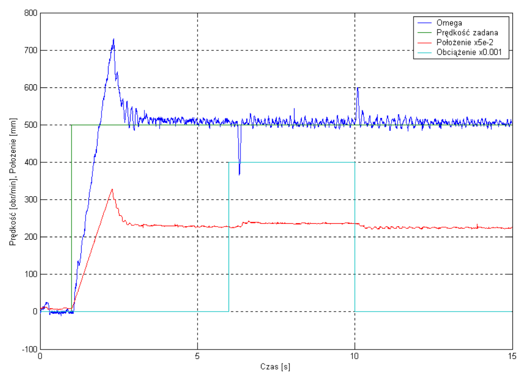

Figure 8. .Rotational speed(500[rpm]) and cylinder displacement with disturbance

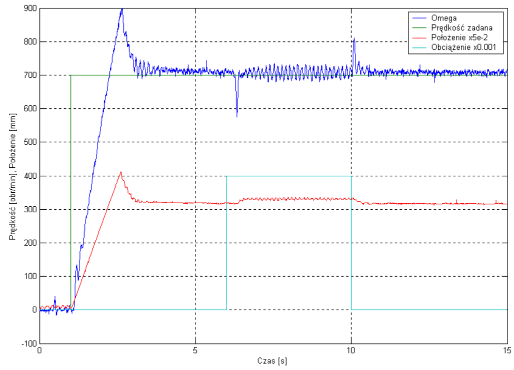

Figure 9. Rotational speed (700[rpm]) and cylinder displacement with disturbance

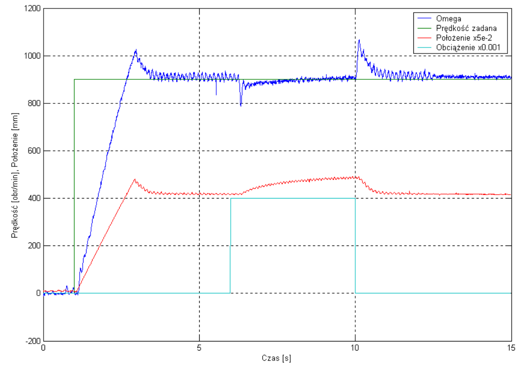

Figure 10. .Rotational speed (900[rpm]) and cylinder displacement with disturbance

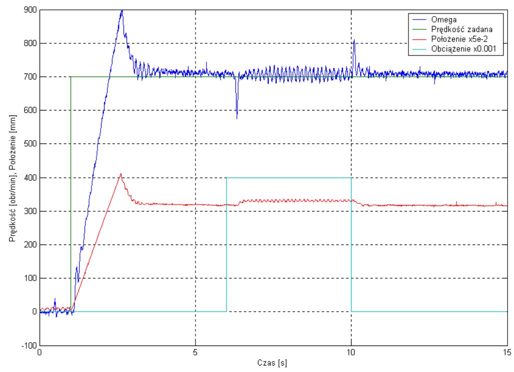

Figure 11. Rotational speed (700[rpm]) and cylinder displacement with disturbance 0.2

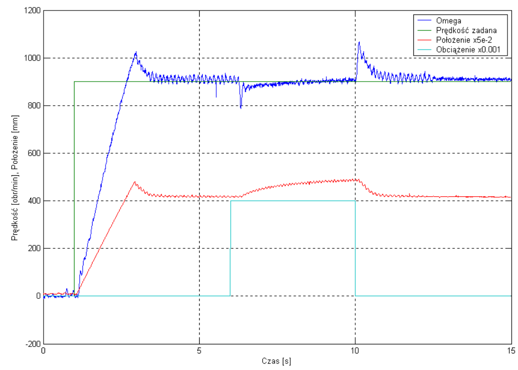

Figure 12. .Rotational speed (700[rpm]) and cylinder displacement with disturbance 0.7

Next effect of temperature of oil was checked. First the tests was done in temperature 30 [°C] than in 40 [°C]. After comparison of tests may conclude that better results are in higher temperature. Settlement time is shorter and over-regulation is smaller.

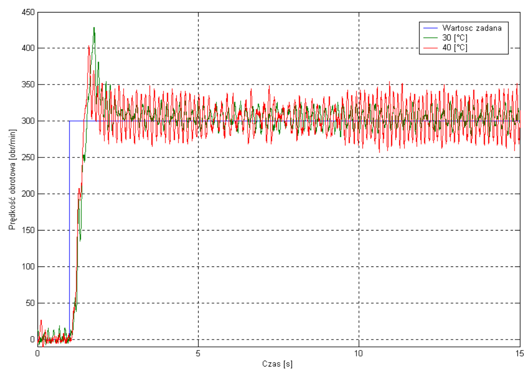

Figure 13. Rotational speed 300 [rpm] in 30 [°C] and 40 [°C] temperature oil

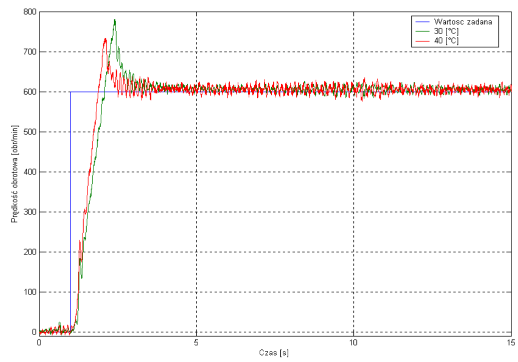

Figure 14. Rotational speed 600 [rpm] in 30 [°C] and 40 [°C] temperature oil

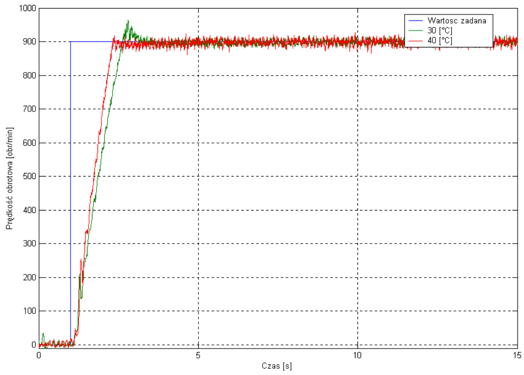

Figure 14. Rotational speed 900 [rpm] in 30 [°C] and 40 [°C] temperature oil

3. Conclusion

The research shown that object is very nonlinear. Object's static characteristic has a hysteresis. More tests with controller confirm those results. The controller is good only in one working point and propriety of working depends on temperature of oil. Because of nonlinearity next part of research will be with fuzzy controller.

References

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