Dynamic design and control of a high-speed pneumatic jet actuator

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Abstract. Mathematical model of an actuator, consisting of a pneumatic (gas) high-speed jet engine, transfer mechanism, and a control device used for switching the ball valve is worked out. The specific attention was paid to the transition (normalization) of the dynamic model into the dimensionless form. Its dynamic simulation criteria are determined, and dynamics study of an actuator was carried out. The simple control algorithm of relay action with a velocity feedback enabling the valve plug to be turned with a smooth nonstop and continuous approach to the final position is demonstrated.

1. Introduction

Besides the all others two factors complicate the analysis and optimization of the mechatronic system. These factors are the complexity of the basic mathematical model and the need to take into consideration the interaction of all subsystems. Gradually increasing of the model complexity together with its transition to the normalized form (that is to a dimensionless variables and similarity criterion, performing the function of the parameters and objectives) essentially facilitates the exploration process.

2. Actuator

For the model normalization the scales for the variables transition must be defined. The scales definition is an individual problem, especially when so called “multi-physics modeling and optimization multi-body system” [1,2] with the sub-systems of the different physical nature is executed. Such situation is typical for the majority of the mechatronic systems.

In the work noted, by reason of the complexity of the objects the optimization process considered is attached mainly to one of the subsystems, namely to the control subsystem. However the rest parts may have a significant influence upon the system behavior. That may be illustrated by the optimization of the point-to-point motion system [3-4, 8]. In such systems besides the positional accuracy a certain requirements to the motion mode of the output link is to be ensured. In [3] the general model of the system was transformed first to the lowest reduced form and normalized. That gives an opportunity to analyze all subsystems in there interaction and to find out the parameters of the actuator, transfer mechanism and control block to a first approximation. As a model complexity arises, the parameters correction is carrying out. The increase of the model complexity is carried out by taking into account actuators mechanical characteristic and stiffness, the control algorithm development, the time lag of the controller and the distributor.

It is of interest the similarity criteria set obtained as a result of the model normalization, in particular the inertial criterion. The latter as the main factor determines a motion mode of the output link, a travel...
time etc. In [4] the inertial criterion was employed in the optimization of the positioning system with a hydraulic drive and digital control subsystem.

The mechatronic system analyzed in this paper consists of the jet acting drive (jet engine), the composite transfer mechanism with variable transfer ratio and the control subsystem (Fig.1). Actuator with the jet pneumatic engine is intended for switching gas ball valves [5-8]. Compressed air (or gas) from the autonomous source or supply line comes through a distributing device to a hollow shaft of the engine rotor and then through a hollow arm of the rotor to nozzles located at the rotor periphery. Gas jets ejecting from the nozzles create reactive forces and driving torque on the rotor.

![Figure 1. Ball valve drive: 1 - engine, 2 - link mechanism, 3 - ball valve, 4 - stroke limiter, 5 - reducing gear, 6 - screw mechanism, 7 - damper.]

3. Conclusion

The offered normalized model of the ball valve actuator gives the opportunity to appreciate the actuator dynamics and to appoint its design parameters. It was established that the operating rate of the actuator output link is not too high but suffice for the employment of the actuator as the standby unit providing the safe pipe line shutdown in emergency situation in case of failure of the main drive.

Using the Painlevé test one can study the analytical properties as was suggested in reference [9,10]

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