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Application of numerical methods for calculation of working processes in pneudraulic devices

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Abstract

This article is devoted to the development of a combined method for working processes calculation in pneudraulic devices. The method is based on execution of interrelation between the mathematical models of the work processes in approximation of lumped and distributed medium thermodynamic state parameters and makes it possible to take into account irregularity of the pressure distribution inside a vessel. In the article this method is implemented on the basis of the low-end gas pressure regulator and the basic results of the computation and their concise analysis are presented.

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Keywords: pneudraulic systems; pressure regulator; valve; lift force coefficient; distributed thermodynamic state parameters; lumped thermodynamic state parameters

1. Introduction

At present the computational and theoretical methods [4, 6, 7] find ever-growing use for investigating the work processes in pneudraulic devices (PHD) [2]. These methods are more effective than performance of full-scale testing as far as the time and resources consumed are concerned, while qualitatively the picture obtained by calculation processes coincides with the real processes revealed as a result of the tests.

There are two basic approaches to mathematical models development for conducting the computational and theoretical studies of the work processes: describing the work processes through approximation of lumped medium (liquid or gas) thermodynamic state parameters and describing the work processes through approximation of distributed medium thermodynamic state parameters. In the former case, it is assumed that the state parameters are measured similarly within the whole testing volume and do not depend on the coordinates of the considered point

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inside this volume, while in the other case the gas state parameters depend on the coordinates of the considered point within the testing volume. Most frequently in case of mathematical simulation of the work processes in the pneudraulic device a gas or liquid chamber of the device acts as a test volume. Each of the approaches has its own advantages and disadvantages. Thus, the description of the work processes through approximation of lumped thermodynamic state parameters is easily implemented and does not require great expenditure of computing capacities. Implementation of such an approach presents general ideas of the work processes occurring in the device, but does not allow to take into account inhomogeneity of the operating medium parameters within the considered volume, which actually takes place in the PHD chambers. The description of the work processes through approximation of distributed thermodynamic state parameters makes it possible to take into account the inhomogeneity of the operating medium parameters within the considered volume, but requires considerable processing power. This approach cannot be practically implemented for sophisticated pneudraulic systems.

Thus it is important to develop the new methods of work processes computation in the pneudraulic devices that combine simplicity of implementation like in the use of lumped thermodynamic state parameters modeling method and at the same time completeness of description of the work processes ensured by the use of distributed parameters modeling method.

2. The study subject

Such a method was developed by the article authors and tested on the example of the low-end gas pressure regulator (hereinafter referred to as the PR). PR design circuit is shown in Fig. 1. The PR is divided into five gas chambers, while the controlled member (CM) appears to be the sixth chamber. The physical processes equal in their volumes take place in these chambers. The structural elements are loaded with gas forces, elastic forces, and friction forces. The operating medium flow processes in the internal channels are replaced with the losses of fluid through conventional metering valves.

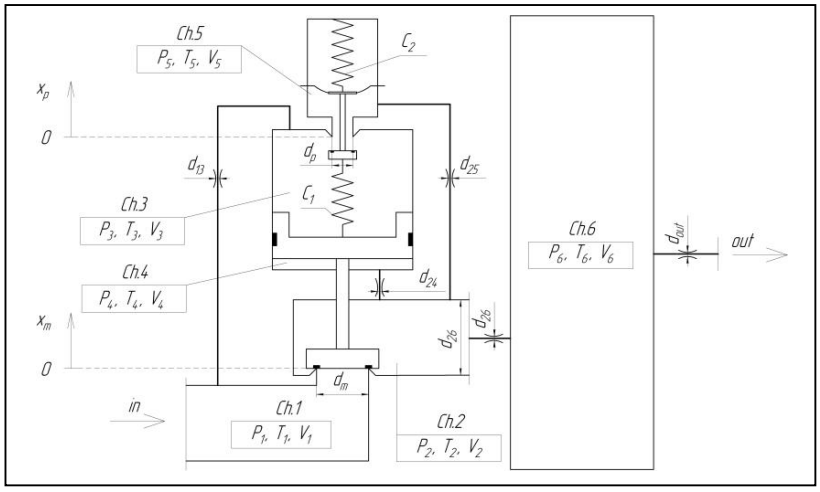

Fig. 1. Design circuit of pressure regulator with allowance for attached elements of the pneumatic system. *P* – pressure; *T* – temperature; *V* – volume; *d* – diameter; *x*–valve plate displacement; C - spring constant. Indexes *1…5* means number of the gas chamber. Indexes *m* and *p* means main and pulse valve accordingly.

The regulating element of the PR is made in the form of a valve plate. The technical literature concerned with the study of work processes in pneumatic valves shows that the inhomogeneity of pressure distribution in the device's flow part substantially influences on the load acting on the regulating element and the flow of work processes. This should be taken into account in making preliminary computations in the course of designing and studying the device work. It is assumed that the difference between the effective gas force distributed over the whole valve plate area