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Dynamics and Vibroacoustics of Machines

Pneumatic Valve's SealDynamic Load

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Abstract

This article presents the experimental study of the pneumatic valve's dynamic loading. The influence of structural and technological factors on the stress state of the sealing elements and their tightness are estimated.

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Keywords: Dynamic loading; sealing element; valve pair; pneumatic actuator.

1. Introduction

Nomenclature

P_{y1}, P_{y2}	pressure in the control chamber, MPa
P_P	work pressure, MPa
P_{BL}	blowing pressure, MPa
P_2	hydrotesting pressure, MPa
T	temperature, K
F_{OUT}	external vibration disturbance, kg/s
P_{NOM}	nominal pressure, MPa
V_0	initial speed, m/s

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Nowadays there are a number ofvalves designs. They are thoroughly discussed in papers [5, 6].There are a number of requirements for pneumatic valves such as fast-responding, impermeability as pneumatic valves largely determine the reliability of the whole mechanical system [1]. Conducted literature overview showed a number ofpapers devoted to valves reliability. They mostly focus on valve's sealing elements. Paper [2] shows the investigation of pneumatic aggregates failures and their reasons. The main conclusion of this work is that the main reasons of pneumatic valves failures are seals. Approximately 34 % of the total number of failures were caused by seals damages.

Valve seals performances are known to be mainly determined by behaviorof stress and deformations distributions over time. Paper [3] shows that valve units experience significant dynamic loadsduring operation. Paper [3] also describes the main reasons of dynamic loading of investigated valves. Paper [4] also proves that the main elements that determine the lifetime and reliability of valves are sealing elements.

Paper [7] notices that extremely high dynamic loads occur in seals in case of cyclic changes in a wide range of environment temperature as well as in case of influence of external overloads. Such dynamic loads lead to loss of impermeability. Main sources of external overloads are considered in paper [8].

Theoretical and experimental methods are widely used forinvestigation of valves dynamic loading.A theoretical model for study of pneumatic sealing elements loading state was proposed in paper [9]. This work indicates that the maximum dynamic load,occurring in case of collision of valves elements, at least in 2 times higher than static load. Therefore, limit value of the dynamic coefficient, used in calculations to avoid a rebound, should be significantly increased by introducing structural damping. The state-of-the-art of methods forvalve working processes calculation as well as principles for design the unloaded pneumatic valves with variable external load are described in paper [10]. Paper [11] formulates the design and technological recommendations for controlled valves developing.

However, a variety of structural, technological and operational factors influence on the operation of the valve seals of pneumatic valves. The complexity of the analytical description of these influences requires experimental investigations for studying valveloading state. Additionally, existing theoretical methods and approaches require a significant amount of experimental data about the parameters of the fluid system's working process. In fact,valve actuation leads to a number of phenomena that complicate mathematical calculations as they influence on the working processes in valves' seals: design features of the actuating drive, energy losses due to friction, vibration loading, depending on the valve installation location in the system and others. Usually, the following assumptions are made in theoretical simulations:

1. Heat exchangewith the environment is neglected.
2. Internal and external leakage of compressed gasare neglected.
3. Temperature of the compressed gas in the control chambers of the pneumatic system is assumed to be constant as the valve operates very short time.
4. Parameters distribution of a pneumatic system as well as local resistances are not taken into account.
5. Neglect the force of viscous friction during the deformation seal of the valve seal.

Such assumptions significantly reduce the accuracy of theoretical simulations. Therefore, to estimate the dynamic loading state of the valve seal, besides the seal, the whole pneumatic aggregate should be considered. Therefore,experiments are needed to investigate the dynamic loading state of the valve as theoretical data is not enough to do it.

2. Test object and bench

This paper presents the experimental results of the investigation of aviation valve loading state. Considered valve is presented in Figure 1. The valve represents the class of spring valves. It works with air drives both unilateral and bilateral actions. Due to the small volume of chambers of the pneumatic actuator, the valve provides a wide range of impact velocityof sealing elements. This is a reason why such valve was chosen for dynamic tests.Technical characteristics of the valve are shown in Table 1.