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Finite element analysis of discharge antivibrational pipe stress state of the piping system flexible joint

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Abstract

The paper studied the stress-strain state of the discharge antivibration pipe of the flexible joint of piping systems from the effects of overpressure. The estimation of the distribution of contact forces and stresses in the fastening elements of the pipe shell and contact areas with metal flanges has been carried out. Newmark method was used in solving problems with geometric nonlinearity.

Keywords: antivibration pipe, stress-strain state, finite element, Newmark method, composite shell, strain, stress, contact pressure, metal flanges, pipelines.

1. Introduction

Antivibration pipes based on the reinforced composite shells are designed to be installed in piping systems as a flexible joint to compensate deformations occurring in the pipes and to reduce the level of vibration transmitted through them. Depending on the acting loads the antivibration pipes are divided into pressure-suction (suction and discharge of working liquids - operation under vacuum and excess pressure in the shank bore of the pipe) and discharge (to pump the working fluids - operation under excessive pressure).

The aim of this work is to study and analyze the discharge pipe stress-deformed state of the piping system antivibration flexible joint from the excessive pressure effects.

The purpose of the study is:

- to determine the stress-strain state of the composite shell and the metal flanges of the pipe;
- to assess the distribution of contact forces and stresses in the fastening elements of the pipe shell and contact areas with metal flanges.

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2. Study subject

The object of this study is a discharge antivibration pipe (Fig.1) with fastening elements (colors denote areas with different properties of the materials used).

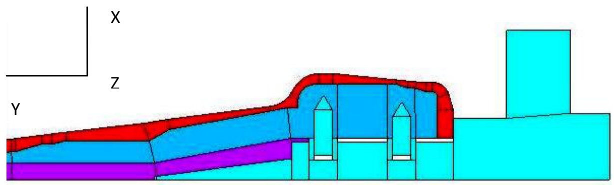

Fig.1. The scheme of a discharge anivibration pipe with fastening elements (colors denote areas with different properties of the material used).

The initial data of the examined design of the discharge antivibration pipe as follows:
Metal flanges steel: E=2.1E5 MPa; μ=0.3
A sealing layer rubber: E=5.0 MPa; μ=0.4999
A coat layer rubber: E=5.0 MPa; μ=0.4999
Rubber cord layer E_x=1.123E9; $E_{y,z}$=1.44E8
$\mu_{xy,xz}$=0.048; μ_{yz}=0.586
$G_{xy,xz}$=7.0E7; G_{yz}=4.54E7
The pressure of the working environment 1.0 MPa
Nominal diameter of the pipe 100 mm

3. Methods

Nowadays to solve the problems in mechanics numerical methods are used more often as they allow extending the scope of solved problems largely. These methods are effective in the study of structures with complex geometry and made from materials having nonlinear physical properties. Among these structures anti-vibration discharge pipes are investigated.

The problem of stress-strain state calculation of antivibration discharge pipes is achieved in axisymmetric setting using finite elements that support this option.

The study includes an option of large deformation consideration, as well as considering nonlinear geometry that is necessary in connection with the use of hyper elastic properties of rubber. The load is linearly increased from zero to a maximum value at each step of solving the problem.

The use of a numerical method leads to obtaining a system of equations. At the same time, if some displacements are considered as unknown, the system of equations describing the structure equilibrium can be written as [1]:

$$[K]\{u\}-\{F^a\}=0 \tag{1}$$

To solve the problems with large geometric nonlinearity considering the boundary conditions of a special kind there can be applied a method, according to which the static equation of form (1) is replaced with the dynamic equations, where system (2) is included as a term corresponding to unbalanced load. The obtained system of differential equations takes the form [1]: