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NUMERICAL SIMULATION OF BELLOWS COMPENSATORS STRESS-STRAIN STATE IN AIR INTAKE SYSTEM

Ua У роботі представлено чисельне моделювання напружено-деформованого стану сильфонного компенсатора у системі забору повітря літака. Сильфонні компенсатори є невід'ємною частиною багатьох систем подачі повітря чи рідин у багатьох установках та транспортних засобах. Для розв'язання задачі про визначення напружено-деформованого стану сильфонного компенсатора у системі забору повітря літака аналітичні методи є неефективними внаслідок складної геометрії, тому доцільно застосовувати чисельні методи розрахунку. Для побудови скінчено вимірної моделі застосовувались тривимірні скінченні елементи у вигляді тетраедра. Було проведено аналіз напружено-деформованого стану сильфонного компенсатора та його основних складових: карданного кільця, хрестовини, внутрішнього кільця шарніра, зовнішнього кільця шарніра.

Ru В работе представлено численное моделирование напряженно-деформированного состояния сильфонного компенсатора в системе забора воздуха самолета. Сильфонные компенсаторы являются неотъемлемой частью многих систем подачи воздуха или жидкостей во многих установках и транспортных средствах. Для решения задачи определения напряженно-деформированного состояния сильфонного компенсатора в системе забора воздуха самолета аналитические методы являются неэффективными вследствие сложной геометрии, поэтому целесообразно применять численные методы расчета. Для построения конечномерных моделей применялись трехмерные конечные элементы в виде тетраэдра. Был проведен анализ напря-

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женно-деформированного состояния сильфона компенсатора и его основных составляющих: карданного кольца, крестовины, внутреннего кольца шарнира, внешнего кольца шарнира.

Introduction

The development of aircraft construction involves the creation of reliable structural elements in the air intake system of modern transport aircraft, so the urgent task is to determine the stress-strain state of the bellows compensation of the aircraft. Bellows expansion joints are an integral part of many air or fluid supply systems in many installations and vehicles. Due to the presence of compensators, the breakage from multi-cycle stresses is prevented. Bellows compensator is used to compensate for the thermal expansion of pipelines, as well as to compensate for the lack of coherence in pipeline systems appeared after installation work.

In a critical situation, when the auxiliary power plant (APP) is run, a rapid supply of air is produced, which causes the pipes to heat up. Temperature causes the pipes to lengthen, and it is at this time that the presence of a compensator in the system of the APP plays an important role. The bellows allow them to move without damage to the pipes.

An auxiliary power plant is an auxiliary source of mechanical energy on a vehicle that is not intended for propulsion of transport. In many cases, the purpose of the APP is to start the main engine and provide energy transport to the parking lots. The aircraft APP is typically a relatively small gas turbine engine that is used to generate electricity, to create pressure in the hydraulic system, and condition the air while the aircraft is locating on the ground, to start the main engines, to compress the air extracted from the supercharger.

Problem setting and problem solving

Analytical methods are ineffective due to complex geometry in solving the problem of determining the stress-strain state of the bellows compensator in the air intake system, so it is advisable to use numerical calculation methods [1, 2]. Three-dimensional finite elements in the form of a tetrahedron were used to construct a finite-dimensional model (Fig. 1), within which a linear field of displacements is specified:

$$u_x = f_1 + f_2 x + f_3 y + f_4 z;$$

$$u_y = f_5 + f_6 x + f_7 y + f_8 z;$$

$$u_z = f_9 + f_{10} x + f_{11} y + f_{12} z,$$

where $f_1 ... f_{12}$ are the arbitrary steels. By equating at nodal points u_x, u_y, u_z to the corresponding nodal displacements, it is possible to express constants through nodal displacements v^e and to obtain the dependence in the form $u = \alpha v^e$.

Using of the usual procedure allows us to find the stiffness matrix of such an element.

In the three-dimensional case, all six components of deformation are taken into account. We can write the matrix – column of deformations using geometric equations in the form:

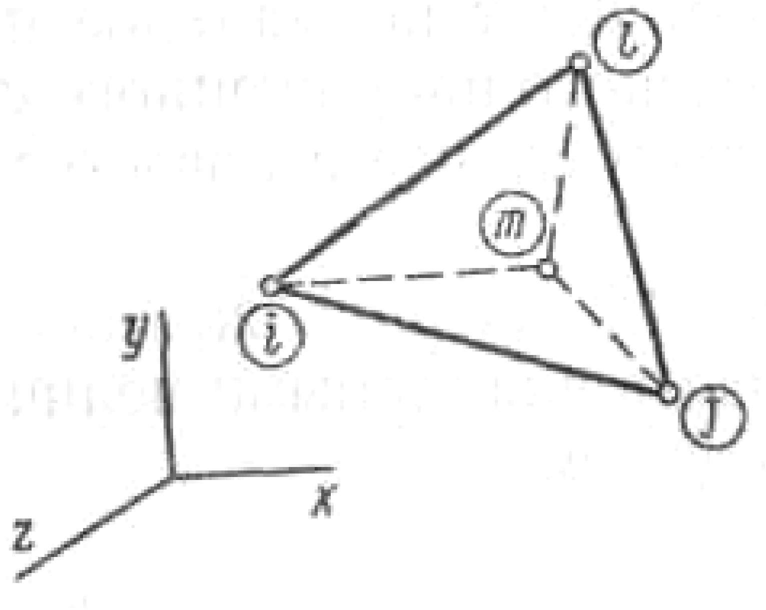

Fig. 1. Tetrahedral finite element

$$\{\varepsilon\} = \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix} = \begin{Bmatrix} \dfrac{\partial u}{\partial x} \\ \dfrac{\partial v}{\partial y} \\ \dfrac{\partial w}{\partial z} \\ \dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x} \\ \dfrac{\partial v}{\partial z} + \dfrac{\partial w}{\partial x} \\ \dfrac{\partial w}{\partial x} + \dfrac{\partial u}{\partial z} \end{Bmatrix}.$$

Stress matrix column is written as in the form in the general case:

$$\{\sigma\} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} = [D](\{\varepsilon\} - \{\varepsilon_0\}),$$

$\{\varepsilon_0\}$ – is the temperature deformation.

The elasticity matrix for the isotropic material has the form:

$$[D] = \frac{E(1-v)}{(1+v)(1-2v)} \begin{bmatrix} 1 & \frac{v}{1-v} & \frac{v}{1-v} & 0 & 0 & 0 \\ \frac{v}{1-v} & 1 & \frac{v}{1-v} & 0 & 0 & 0 \\ \frac{v}{1-v} & \frac{v}{1-v} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1-2v}{2(1-v)} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1-2v}{2(1-v)} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1-2v}{2(1-v)} \end{bmatrix}.$$

This paper deals with the bellows compensator in the air intake system of modern transport aircraft, and it determines its stress-strain state with a maximum design pressure of 4,8 MPa (Fig. 2).

The stress-strain state of the bellows compensator and its main components such as cardan ring, crosspiece, inner hingering, outer hingering were analyzed on the basis of modern numerical methods. The calculation was carried out by finite element in ANSYS software package [2].Tetrahedral linear elements were used. The number of elements was 98450. The finite element model is shown in Fig. 3.

Equivalent voltages were determined by Mises' criterion (Fig. 4).

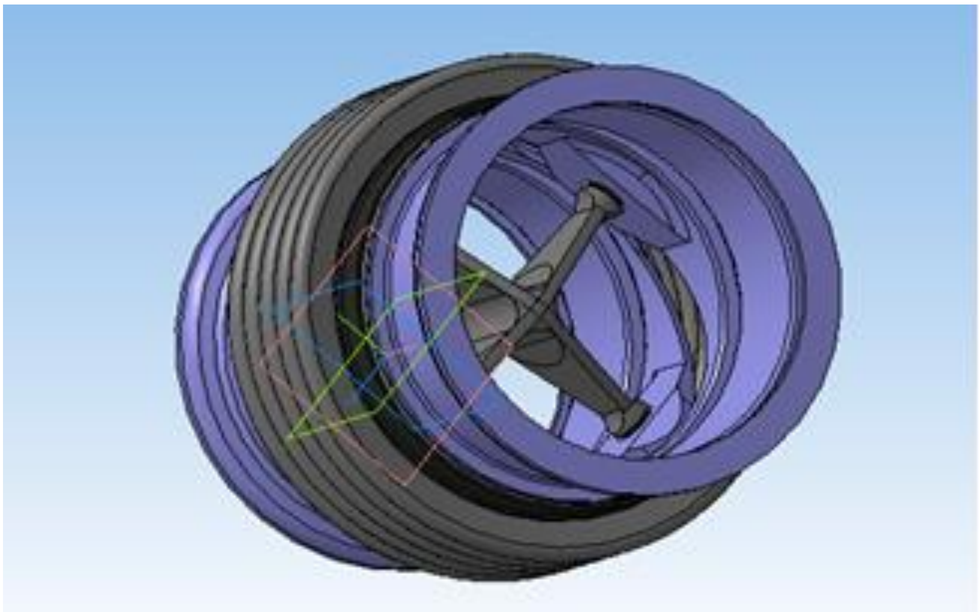

Fig. 2. 3D model of bellows compensator

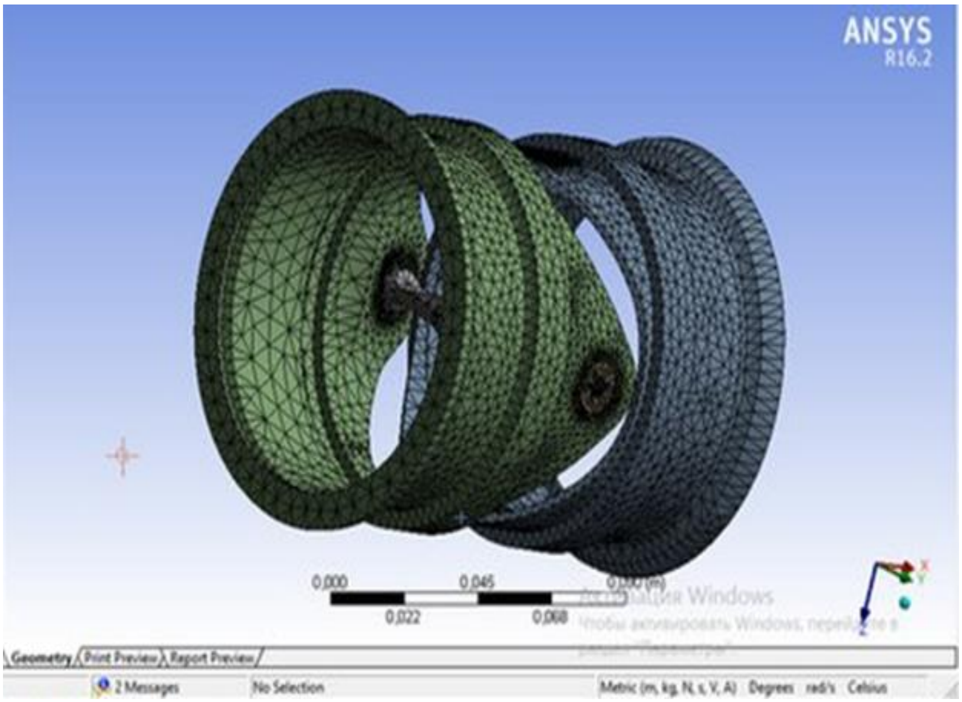

Fig. 3. Finite element model of bellows compensator

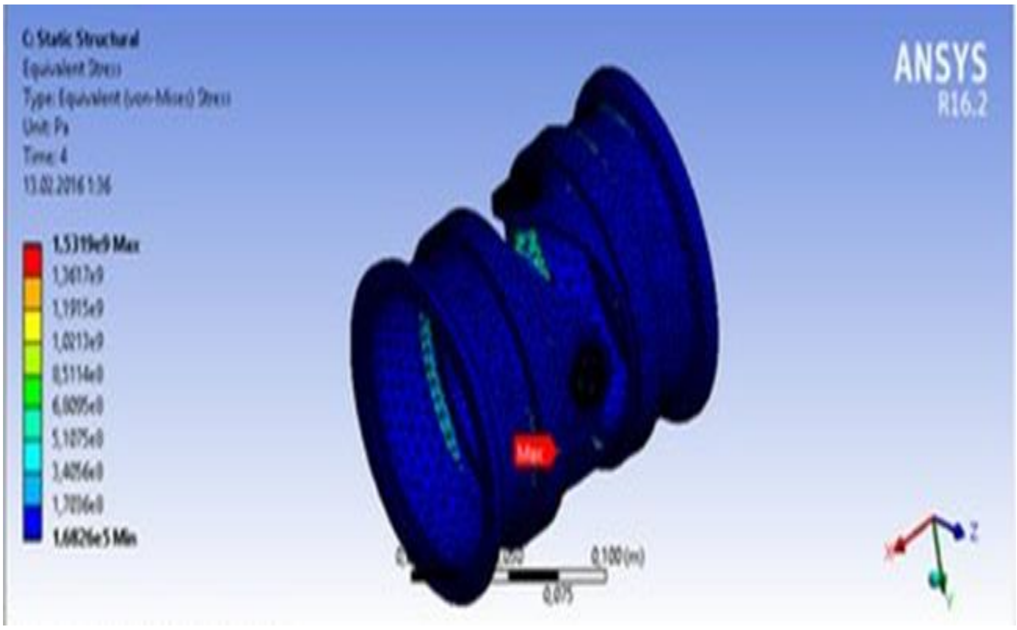

Fig. 4. Distribution of equivalent stresses

Conclusion

This approach allows to determine the location of possible destruction of the structure, and to optimize the geometry, which should increase the life of the bellows compensator.

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