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CALCULATION OF SEALING EFFICIENCY IN CYLINDRICAL PARTS

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Abstract- The load resistance and longevity of seals used in oilfield equipment are directly dependent on their structural design, material, and seating angles in their sockets. For extraction rod pump units and connecting of fountain fittings, equipment's validity depends on these nodes. The reliability of hydraulic cylinders used in oil mining depends on the reliability of its conditioners. For this reason, those conical layers are widely used in oilfield equipment. The main issue in this application is the placement and increasing of reliability as an urgent issue facing of modern science.

Keywords: Cylindrical Seals, Conical Seals, Buckling, Stresses, Deformation, Temperature Field.

1. INTRODUCTION

Conical stabilizers are damaged due to amplitude-frequency loads of the variable force arising from the vibrations. As a result of these loads, vibration modes appear. Under these modes, the structure cracks and fails due to fatigue. An increase in ambient temperature accelerates this degradation and causes equipment failure. Under different amplitudes of the circumferential stresses generated in the conical shapers, the propagation mechanism inside the shaper has not been deeply studied so far. With above-mentioned, measurement regarding vibration frequency about circumferential stress generated within cross-section concerning conical conditioners under dimensionless temperature parameters was proposed.

Cylindrical rubbers are used in various equipment to perform molding works. Mainly, they are widely used in connecting and regulating valves. Elements of different shapes are used to provide the effect of molding with rubber elements. These include rectangular, triangular, circular, conical and cylindrical shapes.

Among the mentioned forms, the issues of capacity of cylindrical and conical rubber molds have not been considered in depth. But they have a great role in creating a sloppy effect in special structural valves. From this point of view, the research work is devoted to the study of the functionality of conical and cylindrical fasteners used in connecting and regulating structures [1, 13, 14].

2. METHODS FOR SOLVING THE STATED PROBLEM

Consider conical seal loaded with internal pressure P at temperature T. We apply the coordinate system S, θ on the middle surface of the seal as shown in the Figure [4]. For identifying the impact of pressure and temperature along natural frequencies of oscillations of such a form of seal, we write differential equations of equilibrium, taking into account the change inside geometry appropriate to form regarding seal in consonance with the result of deformation. The equilibrium equations for an element of a deformed conical seal design have the form [1].

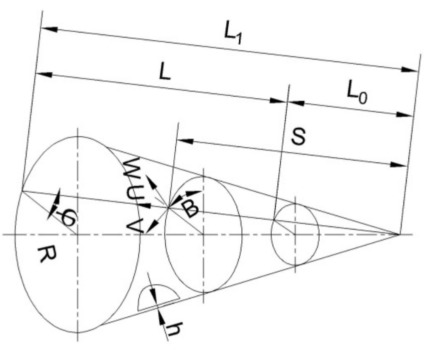


Figure 1. Calculation scheme for the stressed-deformed state

$$\frac{\partial(N_{11}H_2)}{\partial\alpha_1}+\frac{\partial(N_{21}H_1)}{\partial\alpha_2}+\frac{\partial(N_{12}H_2)}{\partial\alpha_1}t_1'+\frac{\partial(N_{22}H_1)}{\partial\alpha_2}-\left(r_1'N_{12}H_2+r_2'N_{22}H_1\right)\frac{-b\pm\sqrt{b^2-4ac}}{2a}+$$
$$+q_1'\frac{1}{H_1}\left[\frac{\partial(M_{11}H_2)}{\partial\alpha_1}+\frac{\partial(M_{22}H_1)}{\partial\alpha_2}-\frac{r_1'N_{12}H_2}{\partial\alpha_1}\cdot t_1'+\frac{\partial(M_{22}H_1)}{\partial\alpha_2}\cdot t_1'-\left(r_1''M_{12}H_2+r_2''M_{22}H_1\right)\right]+ \quad (1)$$
$$+q_2'\frac{1}{H_2}\left[\frac{\partial(M_{12}H_2)}{\partial\alpha_1}+\frac{\partial(M_{22}H_1)}{\partial\alpha_2}-\frac{\partial(M_{11}H_2)}{\partial\alpha_1}\cdot t_1'-\frac{\partial(M_{21}H_1)}{\partial\alpha_2}\cdot t_1'+(r_1'M_{11}H_2+r_2'M_{21}H_1)\right]=-H_1H_2q_1$$

$$\frac{\partial}{\partial\alpha_1}\left\{\frac{1}{H_1}\left[\frac{\partial(M_{11}H_2)}{\partial\alpha_1}+\frac{\partial(M_{21}H_1)}{\partial\alpha_2}-\frac{\partial(M_{12}H_2)}{\partial\alpha_1}\cdot t_1'+\frac{\partial(M_{21}H_1)}{\partial\alpha_2}\cdot t_1'-\left(r_1''M_{12}H_2+r_2''M_{22}H_1\right)\right]\right\}+$$
$$+\frac{\partial}{\partial\alpha_2}\left\{\frac{1}{H_2}\left[\frac{\partial(M_{12}H_2)}{\partial\alpha_1}+\frac{\partial(M_{22}H_1)}{\partial\alpha_2}-\frac{\partial(M_{11}H_2)}{\partial\alpha_1}t_1'-\frac{\partial(M_{21}H_1)}{\partial\alpha_2}\cdot t_1'+(r_1'M_{11}H_2+r_2'M_{21}H_1)\right]\right\}-$$
$$-\left(q_1'N_{11}H_2+q_2'N_{21}H_1\right)+p_1'N_{12}H_2+p_2'N_{22}H_1+H_1H_2P=-H_1H_2q_n$$

where,

$$t_1'=\frac{1}{H_1}\cdot\frac{\partial v}{\partial\alpha_1}-\frac{u}{H_1H_2}\cdot\frac{\partial H_1}{\partial\alpha_2}+\frac{1}{H_2}\cdot\frac{\partial u}{\partial\alpha_2}-\frac{v}{H_1H_2}\cdot\frac{\partial H_2}{\partial\alpha_1}$$
$$r_1'=\frac{1}{H_2}\times\frac{\partial H_1}{\partial\alpha_2}-\frac{\partial}{\partial\alpha_1}\left(\frac{1}{H_2}\times\frac{\partial u}{\partial\alpha_2}-\frac{v}{H_1H_2}\times\frac{\partial H_2}{\partial\alpha_1}\right)+\frac{H_1}{R_1}\left(\frac{v}{R_2}-\frac{1}{H_2}\times\frac{\partial W}{\partial\alpha_2}\right)$$
$$r_2'=\frac{1}{H_1}\cdot\frac{\partial H_2}{\partial\alpha_1}-\frac{\partial}{\partial\alpha_2}\left(\frac{1}{H_2}\cdot\frac{\partial u}{\partial\alpha_2}-\frac{v}{H_1H_2}\cdot\frac{\partial H_2}{\partial\alpha_1}\right)-\frac{H_2}{R_2}\left(\frac{u}{R_1}-\frac{1}{H_1}\cdot\frac{\partial W}{\partial\alpha_1}\right)$$
$$q_1'=\frac{H_1}{R_1}+\frac{1}{H_2}\cdot\frac{\partial H_1}{\partial\alpha_2}\left(\frac{v}{R_2}-\frac{1}{H_2}\cdot\frac{\partial W}{\partial\alpha_2}\right)+\frac{\partial}{\partial\alpha_1}\left(\frac{u}{R_2}-\frac{1}{H_2}\cdot\frac{\partial W}{\partial\alpha_2}\right)$$
$$q_2'=\frac{\partial}{\partial\alpha_1}\left(\frac{u}{R_2}-\frac{1}{H_2}\cdot\frac{\partial W}{\partial\alpha_2}\right)+\frac{H_2}{R_1}\left(\frac{1}{R_2}\cdot\frac{\partial v}{\partial\alpha_2}-\frac{u}{H_2H_1}\cdot\frac{\partial H_1}{\partial\alpha_2}\right)-$$
$$-\frac{1}{H_1}\cdot\frac{\partial H_2}{\partial\alpha_1}\cdot\left(\frac{v}{R_2}-\frac{1}{H_2}\cdot\frac{\partial W}{\partial\alpha_2}\right) \quad (2)$$
$$p_1'=\frac{1}{H_2}\cdot\frac{\partial W}{\partial\alpha_2}\left(\frac{H}{R_1}-\frac{1}{H_1}\cdot\frac{\partial W}{\partial\alpha_1}\right)-$$
$$-\frac{H_1}{R_1}\left(\frac{1}{R_2}\cdot\frac{\partial u}{\partial\alpha_2}-\frac{v}{H_1H_2}\cdot\frac{\partial H_2}{\partial\alpha_1}\right)-\frac{\partial}{\partial\alpha_1}\cdot\left(\frac{v}{R_2}-\frac{1}{R_2}\cdot\frac{\partial W}{\partial\alpha_2}\right)$$
$$p_2'=\frac{H_2}{R_2}-\frac{\partial}{\partial\alpha_2}\left(\frac{v}{R_2}-\frac{1}{R_2}\cdot\frac{\partial W}{\partial\alpha_2}\right)-\frac{1}{H_1}\cdot\frac{\partial H_2}{\partial\alpha_1}\left(\frac{u}{R_1}-\frac{1}{H_1}\cdot\frac{\partial W}{\partial\alpha_1}\right)$$
$$r_1''=\frac{\partial}{\partial\alpha_1}\left(\frac{1}{H_1}\times\frac{\partial v}{\partial\alpha_1}-\frac{u}{H_1H_2}\times\frac{\partial H_1}{\partial\alpha_2}\right)-\frac{1}{H_2}\times\frac{\partial H_2}{\partial\alpha_2}+\frac{H_1}{R_1}\left(\frac{v}{R_2}-\frac{u}{H_1H_2}\times\frac{\partial H_1}{\partial\alpha_2}\right)$$
$$r_2''=\frac{\partial}{\partial\alpha_2}\left(\frac{1}{H_1}\cdot\frac{\partial v}{\partial\alpha_1}-\frac{u}{H_1H_2}\cdot\frac{\partial H_1}{\partial\alpha_2}\right)+$$
$$+\frac{1}{H_1}\cdot\frac{\partial H_2}{\partial\alpha_1}+\frac{H_2}{R_2}\left(\frac{u}{R_1}-\frac{1}{R_1}\cdot\frac{\partial W}{\partial\alpha_1}\right)$$

where, in the Equation (1): $N_{11},N_{22},M_{11},M_{22},M_{12},M_{21}$ are normal and tangential forces, bending and torsional moments [6], respectively, α_1,α_2 are curvilinear coordinates of midsurface points, H_1,H_2 are Lame parameters, R_1,R_2 are Principal radii of curvature of the median surface, q_1,q_2,q_n are Components of the external load in the directions of the axes and α_1,α_2 are the external normal.

For natural vibrations and the seal design, instead of the external load components, inertia forces should be introduced into the equilibrium equations:

$$q_1=-\rho h\frac{\partial^2 u}{\partial t^2}\ ;\ q_2=-\rho h\frac{\partial^2 v}{\partial t^2}\ ;\ q_n=-\rho h\frac{\partial^2 W}{\partial t^2} \quad (3)$$

where, ρ is density and t are period.

For the conical part of the seal (Figure 1):

$$\alpha_1=S;\ \alpha_2=\theta;\ H_1=1;\ H_2=S\cos\varphi;\ R_1=\infty;\ R_2=\frac{S}{\text{tg}\varphi} \quad (4)$$

Let us represent the displacement and force factors included in the equilibrium equations as a sum of static and dynamic components:

$$u=u^0+W';\ v=v^2+v';\ W=W^0+W';N_{11}=N_{11}^0+N_{11}' \quad (5)$$

where, the index "0" denotes the components of the initia; stress-strain state of (thermoelastic) equilibrium and equilibrium under the action of static stress and the dashed line denotes the components of additional displacements and forces arising in the process of small oscillations near the position of static equilibrium [8]. Let us consider the oscillations of the axisymmetric temperature field and also the asymmetrically loaded conical form respecting seal about hydraulic cylinders characterized by system. If so, static deformation concerning seal's axisymmetric, so:

$$v^0=N_12^0=N_21^0=M_21^0=M_12^0=Q_2=0 \quad (6)$$

Using Equation (4), we obtain from general Equation (1) the equations for the conical shape of the seal. Considering the displacements and their derivatives as small quantities and taking into account that force factors are expressed in terms of displacements, we neglect in the equations the terms containing more than two factors depending on the displacements. Substituting Equation (5) into them, taking into account Equation (6) and excluding the terms, which include two factors with primes, we obtain a system of equations, which decomposes into a system of equations describing a static axisymmetric deformation.

$$\frac{dN_{11}^0}{dS}+\frac{N_{11}^0}{S}-\left(1+\mathrm{tg}\varphi\cdot\frac{dW^0}{dS}\right)\times\frac{dN_{22}^0}{S}-$$
$$-\frac{d^2W^0}{dS^2}\times\left(\frac{dW^0}{dS}+\frac{M_{11}^0-M_{22}^0}{S}\right)=0 \tag{7}$$
$$\frac{d^2M_{11}^0}{dS^2}+\frac{2}{3}\times\frac{dM_{11}^0}{dS}-\frac{1}{S}\times\frac{dM_{22}^0}{dS}\left(1+\mathrm{tg}\varphi\times\frac{dW^0}{dS}\right)-$$
$$-\frac{\mathrm{tg}\varphi}{S}\times M_{22}^0\times\frac{d^2W^0}{dS^2}\times N_{11}^0+\left(-\frac{\mathrm{tg}\varphi}{S}+\frac{1}{S}\times\frac{dW^0}{dS}\right)\times N_{22}^0+P=0$$

and a system of equations describing small oscillations around static equilibrium (perturbed motion equations),

$$\frac{\partial N_{11}'}{\partial S}+\frac{N_{11}'}{S}+\frac{1}{S\cos\varphi}\times\frac{\partial N_{21}'}{\partial\theta}-\frac{N_{22}'}{S}\times\left(1+tg\varphi\times\frac{dW^0}{dS}\right)-$$
$$-\left(-\frac{1}{S\cos\varphi}\times\frac{\partial^2W}{\partial\theta^2}+\frac{1}{S}\times\frac{\partial v'}{\partial\theta}+\cos\varphi\times tg\varphi\times\frac{\partial W'}{\partial S}\right)\times$$
$$\times\frac{1}{S\cos\varphi}\times N_{22}^0-\frac{\partial^2W}{\partial S^2}\times\left(\frac{dM_{11}^0}{dS}+\frac{M_{11}^0-M_{22}^0}{S}\right)-\frac{d^2W^0}{dS^2}\times$$
$$\times\left(\frac{\partial M_{11}'}{\partial S}+\frac{M_{11}'-M_{22}'}{S}+\frac{1}{S\cos\varphi}\times\frac{\partial M_{21}'}{\partial\theta}\right)=\rho h\times\frac{\partial^2u'}{\partial t^2}$$
$$\frac{\partial N_{12}'}{\partial S}+\frac{N_{12}'}{S}+\frac{1}{S\cos\varphi}+\left(\frac{dN_{11}^0}{dS}+\frac{N_{11}^0}{S}\right)\times\left(\frac{\partial v'}{\partial S}+\frac{1}{S\cos\varphi}\times\frac{\partial u'}{\partial\theta}-\frac{v'}{S}\right)+\frac{\partial^2v'}{\partial S^2}\times N_{11}^0+$$
$$+\frac{N_{21}'}{S}\times\left(1+\mathrm{tg}\varphi\cdot\frac{dW^0}{dS}\right)+$$
$$+\left(\frac{\mathrm{tg}\varphi}{S}-\frac{1}{S}\times\frac{dW^0}{dS}\right)\times\left(\frac{\partial M_{12}'}{\partial S}+\frac{M_{12}'}{S}+\frac{1}{S\cos\varphi}\times\frac{\partial M_{22}'}{\partial\theta}+\frac{M_{21}'}{S}\right)-$$
$$-\frac{\mathrm{tg}\varphi}{S}\left(\frac{dM_{11}^0}{dS}+\frac{M_{11}^0}{S}\right)\left(\frac{\partial v'}{\partial S}+\frac{1}{S\cos\varphi}\times\frac{\partial u'}{\partial\theta}-\frac{v'}{S}\right)-$$
$$-\left(\frac{\mathrm{tg}\varphi}{S^2\cos\varphi}\times\frac{\partial^2u'}{\partial S\partial\theta}-\frac{\mathrm{tg}\varphi}{S^2\cos\varphi}\times\frac{\partial u'}{\partial\theta}-\frac{\mathrm{tg}\varphi}{S^2}\times\frac{\partial v'}{\partial S}+\frac{\mathrm{tg}\varphi}{S^2}\times v'\right).$$
$$\cdot M_{11}^0+\frac{\mathrm{tg}^2\varphi}{S^2}\times\frac{dW^0}{dS}\times M_{21}'+$$
$$+\left(\frac{\mathrm{tg}\varphi}{S}\times\frac{\partial v'}{\partial S}-\frac{\mathrm{tg}\varphi}{S^2}\times v'-\frac{1}{S\cos\varphi}\times\frac{\partial^2W'}{\partial S\partial\theta}+\frac{1}{S^2\cos\varphi}\times\frac{\partial W'}{\partial\theta}\right).$$
$$\cdot\left(\frac{dM_{11}^0}{dS}+\frac{M_{11}^0-M_{22}^0}{S}\right)=\rho h\times\frac{\partial^2v'}{\partial t^2} \tag{8}$$
$$\frac{\partial^2M_{22}'}{\partial S^2}+\frac{1}{S}\times\frac{\partial M_{11}'}{\partial S}+\frac{1}{S\cos\varphi}\times\frac{\partial^2M_{21}'}{\partial S\times\partial\theta}-\frac{\partial M_{22}'}{\partial S}\left(\frac{1}{S}+\frac{\mathrm{tg}\varphi}{S}\times\frac{dW^0}{dS}\right)-$$
$$-\frac{dM_{22}^0}{dS}\left(\frac{1}{S\cos\varphi}\times\frac{\partial^2v'}{\partial S\times\partial\theta}+\frac{\mathrm{tg}\varphi}{S}\times\frac{\partial W^0}{\partial S}\right)-$$
$$-M_{22}^0\left(\frac{1}{S\cos\varphi}\times\frac{\partial^2v'}{\partial S\times\partial\theta}+\frac{\mathrm{tg}\varphi}{S}\times\frac{\partial^2W'}{\partial S^2}\right)-$$
$$-M_{22}'\times\frac{\mathrm{tg}\varphi}{S}\times\frac{d^2W^0}{dS^2}+\frac{1}{S^2\cos\varphi}\times\frac{\partial M_{12}'}{\partial\theta}+\frac{1}{S^2\cos^2\varphi}\times\frac{\partial^2M_{22}'}{\partial\theta^2}$$
$$-\left(\frac{dM_{11}^0}{dS}+\frac{M_{11}^0}{S}\right)\times\left(\frac{\partial^2v'}{\partial S\cdot\partial\theta}+\frac{1}{S\cos\varphi}\times\frac{\partial^2u'}{\partial\theta^2}-\frac{1}{S}\times\frac{\partial v'}{\partial\theta}\right)\times$$
$$\times\frac{1}{S\cos\varphi}-M_{11}^0$$
$$\left(\begin{array}{l}\dfrac{1}{S^2\cos^2\varphi}\times\dfrac{\partial^2u'}{\partial\theta^2\partial S}-\dfrac{1}{S^2\cos^2\varphi}\times\dfrac{\partial M_{21}'}{\partial\theta}\times\dfrac{\partial W^0}{\partial S}+\\ \dfrac{d^2W^0}{dS^2}\times N_{11}'+\dfrac{d^2W'}{dS^2}\times N_{11}^0\end{array}\right)+$$
$$+\left(-\frac{\mathrm{tg}\varphi}{S}+\frac{1}{S}\times\frac{dW^0}{dS}\right)\times N_{22}'+$$
$$+\left(\frac{\mathrm{tg}\varphi}{S^2\cos^2\varphi}\times\frac{\partial v'}{\partial\theta}+\frac{1}{S^2\cos^2\varphi}\times\frac{\partial^2W'}{\partial\theta^2}+\frac{1}{S}\times\frac{\partial W'}{\partial S}\right)\times$$
$$\times N_{22}^0=\rho h\frac{\partial^2W'}{\partial t^2}$$

Using the usual relation of the Linear theory of the conical shape of the seal between deformations and displacements, equations for force factors and thermoelectricity relations, we obtain equations in displacements for the forces and moments included in the equilibrium equations in the case of a linear change in temperature along the thickness:

$$N_{11}=B\left[\frac{\partial u}{\partial S}+\frac{\mu}{S\cos\varphi}\times\frac{\partial v}{\partial\theta}+\mu\frac{u}{S}+\mu\frac{\mathrm{tg}\varphi}{S}W-\alpha(1+\mu)\times\left(T_0+\frac{.T}{12}\times\frac{h\mathrm{tg}\varphi}{S}\right)\right]$$
$$N_{22}=B\left[\frac{1}{S\cos\varphi}\times\frac{\partial v}{\partial\theta}+\frac{u}{S}+\frac{\mathrm{tg}\varphi}{S}\times W+\mu\frac{\partial u}{\partial S}-\alpha(1+\mu)T_0\right]$$
$$N_{12}=\frac{B}{2}(1+\mu)\left[\begin{array}{l}\dfrac{1}{S\cos\varphi}\times\dfrac{\partial u}{\partial\theta}+\dfrac{\partial v}{\partial S}-\dfrac{v}{S}+\dfrac{h^2}{6}\times\dfrac{\mathrm{tg}\varphi}{S}\\ \left(-\dfrac{1}{S\cos\varphi}\times\dfrac{\partial^2W}{\partial S\partial\theta}+\dfrac{1}{S^2\cos\varphi}\times\dfrac{\partial W}{\partial\theta}+\dfrac{\mathrm{tg}\varphi}{S}\times\dfrac{\partial v}{\partial S}-\dfrac{\mathrm{tg}\varphi}{S^2}v\right)\end{array}\right]$$
$$N_{21}=\frac{B}{2}(1-\mu)\left[\frac{1}{S\cos\varphi}\cdot\frac{\partial U}{\partial\theta}+\frac{\partial\vartheta}{\partial S}-\frac{\vartheta}{S}\right]$$
$$M_{11}=-D\left[\frac{\partial^2W}{\partial S^2}+\frac{\mu}{S^2\cos^2\varphi}\times\frac{\partial^2W}{\partial\theta^2}-\frac{\mu\cdot\mathrm{tg}\varphi}{S^2\cos\varphi}\times\frac{\partial\vartheta}{\partial\theta}+\frac{\mu}{S}\times\frac{\partial W}{\partial S}+\alpha(1+\mu)\left(\frac{T_0}{S}\mathrm{tg}\varphi+\frac{\cdot T}{h}\right)\right]$$
$$M_{22}=-D\left[\begin{array}{l}\dfrac{1}{S^2\cos^2\varphi}\times\dfrac{\partial^2W}{\partial\theta^2}-\dfrac{\mathrm{tg}\varphi}{S^2\cos^2\varphi}\times\dfrac{\partial\vartheta}{\partial\theta}+\dfrac{1}{S}\times\dfrac{\partial W}{\partial S}+\\ \mu\dfrac{\partial^2W}{\partial S^2}+\alpha(1+\mu)\dfrac{\cdot T}{h}\end{array}\right]$$
$$M_{12}=M_{21}=-D(1-\mu)\left[\begin{array}{l}\dfrac{1}{S\times\cos\varphi}\times\dfrac{\partial^2W}{\partial S\times\partial\theta}-\\ \dfrac{1}{S^2\cos\varphi}\times\dfrac{\partial W}{\partial\theta}-\dfrac{\mathrm{tg}\varphi}{S}\times\dfrac{\partial\vartheta}{\partial S}+\dfrac{\mathrm{tg}\varphi}{S^2}\vartheta\end{array}\right]$$
$$B=\frac{E\cdot h}{1-\mu^2}\ ;\ D=\frac{E\cdot h^3}{12\left(1-\mu^2\right)}$$

We also give an equation for the shear force Q_1 necessary for setting the boundary conditions:

$$Q_1=-D\left[\begin{array}{l}\frac{1}{S}\times\frac{\partial^2 W}{\partial S^2}+\frac{\partial^2 W}{\partial S^2}+\frac{1}{S^2\cos^2\varphi}\times\frac{\partial^2}{\partial S\cdot\partial\theta^2}-\frac{2}{S^2\cos^2\varphi}\times\frac{\partial^2 W}{\partial\theta^2}+\frac{2\text{tg}\varphi}{S^2\cos^2\varphi}\times\frac{\partial\vartheta}{\partial\theta}\\-\frac{\text{tg}\varphi}{S^2\cos^2\varphi}\times\frac{\partial^2\vartheta}{\partial S\partial\theta}-\frac{1}{S^2\cos^2\varphi}\times\frac{\partial^2 W}{\partial S}+\alpha(1+\mu)\times\left(\frac{\text{tg}\varphi}{S}\times\frac{\partial T}{\partial S}+\frac{1}{h}\times\frac{\partial(\cdot T)}{\partial S}\right)\end{array}\right] \tag{10}$$

In Equations (9) and (10)

$$T_0=(T_v+T_n)/2u\ ,\ \Delta T=T_v-T_n \tag{11}$$

where, $T_v(S)$, $T_n(S)$ are respectively, the temperature of the outer and inner surface; α is linear expansion coefficient [5]. Introducing dimensionless parameters:

$$\bar{U}^0=\frac{U^0}{h};\ \bar{W}^0=\frac{W^0}{h};\ \bar{U}'=\frac{U'}{h};\ \bar{\vartheta}=\frac{\vartheta}{h};\ \bar{W}'=\frac{W'}{h};\ \delta=\frac{h}{l_1}$$
$$\delta=\frac{l_0}{l_1};\ x=\frac{s'}{l_1},(\le x\le 1);\ l_x=\frac{1}{x};\ r_x=\frac{\tan\varphi}{x};\ r_x'=\frac{1}{x\cos\varphi} \tag{12}$$

Taking into account Equation (5) in Equation (9), we divide the force factors into static and dynamic. Substituting them into systems of Equations (7) and (8), respectively, neglecting nonlinear terms in Equation (7) and passing to a dimensionless form, we obtain two systems of equations in displacements:

- Axisymmetric strain equations:

$$(d^2\bar{U}^0)/(dx^2)+l_x(d^2\bar{U}^0)/dx-l_x^2\bar{U}^0+$$
$$\mu r_x(d^2\bar{W}^0)/dx-r_xl_x\bar{W}^0+\tilde{T}_1=0$$
$$\frac{\delta^2}{12}\left[\frac{d^4\bar{W}^0}{dx^4}+2l_x\frac{d^2\bar{W}^0}{dx^2}-l_x^2\times\frac{d^2\bar{W}^0}{dx^2}+l_x^3\frac{d\bar{W}^0}{dx}\right]$$
$$+\mu r_x\frac{d\bar{U}^0}{dx}+r_xl_x\bar{U}^0+r_x^2\bar{W}^0+\tilde{T}_3^0-\frac{1-\mu^2}{E\delta^2}P=0$$
$$\tilde{T}_1=-\alpha(1+\mu)\left[\frac{1}{\delta}\times\frac{dT_0}{dx}+\frac{1}{12}\times\frac{d(\cdot T)}{dx}\right]$$
$$\tilde{T}_3=\alpha(1+\mu)\left\{-r_x\frac{T_0}{\delta}+\frac{1}{12}\left[\delta r_x\times\frac{d^2T_0}{dx^2}+l_x\times\frac{d(\cdot T)}{dx}+\frac{d^2(\cdot T)}{dx^2}\right]\right\}$$

- Oscillation equation:

$$(A_{120}+A_{110}+A_{100}+A_{102})\bar{U}'+(B_{101}+B_{121})\bar{\vartheta}'+$$
$$+(C_{130}+C_{120}+C_{110}+C_{100}+C_{102}+C_{112})\bar{W}'= \tag{15}$$
$$=\frac{1-\mu^2}{E}\times\rho l_1^2\frac{\partial^2\bar{U}'}{\partial r^2}$$
$$(A_{310}+A_{300}+A_{302})\bar{U}'+(B_{303}+B_{301}+B_{321}+B_{311})\bar{\vartheta}'$$
$$+(C_{340}+C_{330}+C_{320}+C_{310}+C_{300}+C_{301}+C_{302}+C_{322}+C_{312})\times$$
$$\times\bar{W}'=\frac{1-\mu^2}{E}\times\rho l_1^2\frac{\partial^2\bar{W}'}{\partial t^2}$$

In differential Equation (15), the following operator notation is introduced to shorten the notation:

$$A_{ijk}=a_{ijk}\frac{\partial(j+k)}{\partial x^{(j)}\partial\theta^{(k)}};\ B_{ijk}=b_{ijk}\frac{\partial(j+k)}{\partial x^{(j)}\partial\theta^{(k)}}$$
$$C_{ijk}=c_{ijk}\frac{\partial(j+k)}{\partial x^{(j)}\partial\theta^{(k)}} \tag{16}$$

The sign index i corresponds to the parameters a_{ijk}, b_{ijk} and c_{ijk} are coefficients depending in the general case on the initial stress state.

- Equations for these coefficients:

$$a_{120}=1;$$
$$a_{110}=l_x-\mu r_x\delta\frac{d\bar{W}^0}{dx}$$
$$a_{100}=-l_x^2-r_xl_x\delta\frac{d\bar{W}^0}{dx}$$
$$a_{102}=(r_x')^2\times\left(\frac{1-\mu}{2}+\delta\bar{N}_{22}^0\right)$$
$$b_{101}=\frac{1-\mu}{2}l_xr_x'+\frac{\vartheta^3}{6}r_xr_x'l_x\frac{\partial^2\bar{W}^0}{dx^2}-\vartheta r_xr_x'\times\frac{d\bar{W}^0}{dx}-\vartheta r_x'l_x\bar{N}_{22}^0$$
$$b_{111}=\frac{1+\mu}{2}r_x'-\frac{1}{12}\delta^3r_xr_x'\times\frac{d\bar{W}^0}{dx^2}$$
$$c_{130}=\frac{1}{12}\delta^3\times\frac{d^2\bar{W}^0}{dx^2}$$
$$c_{120}=\frac{\delta^3}{12}\times l_x\frac{d^2\bar{W}^0}{dx^2}-\frac{\delta^3}{12}\left(\frac{d\bar{M}_{11}^0}{dx}+\bar{M}_{11}^0l_x-\bar{M}_{22}^0l_x\right)$$
$$c_{110}=\mu r_x-\frac{\delta^3}{12}\times l_x\frac{d^2\bar{W}^0}{dx^2}-\delta r_x\bar{N}_{22}^0$$
$$c_{100}=-r_xl_x-\delta r_x^2\frac{d\bar{W}^0}{dx}$$
$$c_{102}=-\frac{\delta^3}{6}(r_x')^2l_x\frac{d^2\bar{W}^0}{dx^2}$$
$$a_{112}=\frac{\delta^3}{12}(r_x')^2\times\frac{d^2\bar{W}^0}{dx^2}$$
$$a_{201}=\frac{1-\mu}{2}l_xr_x'+r_x'\delta\times$$
$$\times\left(\frac{d\bar{N}_{11}^0}{dx}+\bar{N}_{11}^0l_x-\frac{\delta^3}{12}r_x\frac{d\bar{M}_{11}^0}{dx}\right)+\frac{1-\mu}{2}r_xr_x'\delta\frac{d\bar{W}^0}{dx}$$
$$a_{211}=\frac{1+\mu}{2}r_x'-\frac{\delta^3}{12}r_xr_x'\bar{M}_{11}^0$$
$$b_{22}=\frac{1-\mu}{2}+\delta\bar{N}_{11}^0-\frac{1-\mu}{12}\delta^3l_xr_x\frac{d\bar{W}^0}{dx}$$
$$b_{210}=\frac{1-\mu}{2}l_x+\delta\frac{d\bar{N}_{11}^0}{dx}+\delta\bar{N}_{11}^0l_x+\frac{\delta^3}{12}r_xl_x\times$$
$$\times\left(\bar{M}_{11}^0-\bar{M}_{22}^0\right)+\delta r_x\frac{d\bar{W}^0}{dx}\left(\frac{1-\mu}{2}\right)\times\left(1+\frac{\delta^2}{6}r_x^2\right)$$

$$b_{200}=-\left(\frac{1-\mu}{2}\right)l_x^2-\delta l_x\frac{d\bar{N}_{11}^0}{dx}-\delta l_x^2\bar{N}_{11}^0-\frac{\delta^3}{12}r_xl_x^2$$

$$\left(\bar{M}_{11}^0-\bar{M}_{22}^0\right)-\delta r_xl_x\frac{d\bar{W}^0}{dx}\left(\frac{1-\mu}{2}\right)\times\left(1+\frac{\delta^2}{6}r_x^2\right)$$

$$b_{202}=\left(r_x'\right)^2-\frac{\delta^3}{12}\left(r_x'\right)^2r_xl_x\frac{d\bar{W}^0}{dx}$$

$$c_{203}=-\frac{\delta^2}{12}r_x\left(r_x'\right)^2+\frac{\delta^3}{12}l_x\left(r_x'\right)^2\frac{d\bar{W}^0}{dx}+$$

$$+l_xr_x'\left(\frac{d^2\bar{M}_{11}^0}{dx^2}+\bar{M}_{11}^0l_x-\bar{M}_{22}^0l_x\right)$$

$$c_{221}=-\frac{\delta^3}{12}r_x'\left[\left(1-\mu\right)r_x-\delta l_x\frac{d\bar{W}^0}{dx}\right]$$

$$c_{211}=\frac{\delta^3}{12}r_x'\left\{\left(1-2\mu\right)r_xl_x-\delta\begin{bmatrix}\left(\frac{d\bar{M}_{11}^0}{dx}+\bar{M}_{11}^0l_x-\bar{M}_{22}^0l_x\right)\\+\left(1-\mu\right)r_x^2\frac{d\bar{W}^0}{dx}-l_x^2\frac{d\bar{W}^0}{dx}\end{bmatrix}\right\}$$

$$a_{310}=\mu r_x-\delta\frac{d^2\bar{W}^0}{dx^2}-\mu\delta l_x\frac{d\bar{W}^0}{dx}$$

$$a_{300}=l_x\left(r_x-\mu\delta\frac{d^2\bar{W}^0}{dx^2}-\delta l_x\frac{d\bar{W}^0}{dx}\right)$$

$$a_{302}=-\frac{\delta^3}{12}\frac{d\bar{M}_{11}^0}{dx}\left(r_x'\right)^2 \tag{17}$$

$$a_{312}=\frac{\delta^3}{12}\left(r_x'\right)^2\bar{M}_{11}^0$$

$$b_{303}=-\frac{\delta^3}{12}r_x\left(r_x'\right)^2$$

$$b_{301}=r_x'\left\{r_x-\frac{\delta^3}{12}\begin{bmatrix}\left(1-\mu\right)r_x^2l_x\frac{d\bar{W}^0}{dx}-\\\left(r_x^2-\frac{\delta^3}{12}\right)\frac{d^2\bar{W}^0}{dx^2}-\frac{\delta^3}{12}r_x\bar{N}_{22}^0\end{bmatrix}-\delta l_x\frac{d\bar{W}^0}{dx}\right\}$$

$$b_{321}=-\frac{\delta^3}{12}r_x'\left[\left(1-\mu\right)r_x-\delta\bar{M}_{22}^0\right]$$

$$b_{321}=\frac{\delta^3}{12}r_x'\begin{bmatrix}3r_xl_x+\delta\\\left(\mu r_x^2\frac{d\bar{W}^0}{dx}+\frac{d\bar{M}_{22}^0}{dx}+\frac{d\bar{M}_{11}^0}{dx}\right)\end{bmatrix}$$

$$c_{310}=\frac{\delta^3}{12}\quad[7]$$

$$c_{330}=\frac{\delta^3}{12}\times\left[l_x^2+\delta r_x\begin{pmatrix}l_x\frac{d\bar{W}^0}{dx}+\\\mu\frac{d^2\bar{W}^0}{dx^2}+\bar{M}_{22}^0\end{pmatrix}\right]-\delta\bar{N}_{11}^0$$

$$c_{310}=\frac{\delta^3}{12}\times\begin{bmatrix}l_x^3+\delta r_x\\\left(l_x^2\frac{d\bar{W}^0}{dx}+l_x\frac{d^2\bar{W}^0}{dx^2}+\frac{d\bar{M}_{22}^0}{dx}\right)\end{bmatrix}-\delta l_x\bar{N}_{22}^0$$

$$c_{300}=r_x\left(r_x-\mu\delta\frac{d^2\bar{W}^0}{dx^2}-l_x\delta\frac{d\bar{W}^0}{dx}\right)$$

$$c_{304}=\frac{\delta^3}{12}\left(r_x'\right)^4$$

$$c_{302}=\left(r_x'\right)^2\begin{Bmatrix}\frac{\delta^3}{12}l_x^2+\frac{\delta^3}{12}r_x\left[\left(1+\mu\right)l_x\frac{d\bar{W}^0}{dx}-\frac{d^2\bar{W}^0}{dx^2}\right]\\-\delta\bar{N}_{22}^0\end{Bmatrix}$$

$$c_{322}=\frac{\delta^2}{6}\left(r_x'\right)^2$$

$$c_{322}=-\frac{\delta^2}{6}\left(r_x'\right)^2$$

$$c_{312}=-\frac{\delta^3}{12}\left(r_x'\right)^2\left(2l_x+\mu\delta r_x\frac{d\bar{W}^0}{dx}\right)$$

$$\bar{N}_{ji}^0=\frac{1-\mu^2}{Eh\delta}N_{ji}^0;\ \bar{M}_{ji}^0=\frac{12\left(1-\mu^2\right)}{Eh^2\delta^2}M_{ji}^0;\ (j=1,2) \tag{18}$$

Let us consider problem related to natural oscillations, considering static forces and deformation to be known. [7] Using expansions:

$$\bar{u}'\left(x,\theta,t\right)=\sum_{n=0}^{\infty}\bar{u}_n'\left(x\right)\times\cos\left(n\theta e^{i\omega_nt}\right) \tag{19}$$

For achieving ordinary different equations, we minimize system regarding partial differential equations (we will omit subscript n for simplicity of notation)

$$\begin{aligned}&\frac{d^2\bar{u}'}{dx^2}a_{120}+\frac{d\bar{u}'}{dx}a_{120}+\bar{u}'\left(a_{100}-n^2a_{102}+K^2\right)+\frac{d\bar{v}'}{dx}\left(nb_{111}\right)+\\&+\bar{v}'\left(nb_{101}\right)+\frac{d^2\bar{W}'}{dx^2}c_{130}+\frac{d^2\bar{W}'}{dx^2}c_{120}+\frac{d\bar{W}'}{dx}\left(c_{110}-n^2c_{112}\right)+\\&+\bar{W}'(c_{100}-n^2c_{102})=0\\&\frac{d\bar{u}'}{dx}(-na_{211})+\bar{u}'(-na_{201})+\frac{d^2\bar{v}'}{dx^2}b_{220}+\frac{d\bar{v}'}{dx}b_{210}+\\&+\bar{v}'\left(b_{200}-n^2b_{202}+K^2\right)+\frac{d^2\bar{W}'}{dx^2}(-nc_{221})+\frac{d\bar{W}'}{dx}(-nc_{211})+[11]\\&+\bar{W}'\left(n^3c_{203}-nc_{201}\right)=0\\&\frac{d\bar{u}'}{dx}\left(a_{310}-n^2a_{312}\right)+\bar{u}'\left(a_{300}-n^2a_{302}\right)+\frac{d^2\bar{v}'\mathbb{F}}{dx^2}\left(nb_{321}\right)+\\&+\frac{d\bar{v}'}{dx}\left(nb_{321}\right)+\bar{v}'\left(-n^3b_{303}+nb_{301}\right)+\frac{d^4\bar{W}}{dx^4}c_{310}+\\&+\frac{d^3\bar{W}r'}{dx^3}c_{310}+\frac{d^2\bar{W}'}{dx^2}\left(c_{320}-n^2c_{322}\right)+\frac{d\bar{W}'}{dx}\left(c_{310}-n^2c_{312}\right)+\\&+\bar{W}'\left(c_{310}-n^4c_{304}-n^2c_{302}-K^2\right)=0\end{aligned} \tag{20}$$

In Equations (19) and (20) n is the number of waves in the circumferential stress; angular natural frequency; K is dimensionless frequency related to the frequency ω by Equation (21):

$$K^2 = \frac{1-\mu^2}{E} \times \rho l_1^2 \omega^2 \tag{21}$$

The solution of system (20) must satisfy the boundary conditions. At the circular end, a conical seal in most practically important cases, they are determined with the help regarding four equations:

$$N_{11} = 0\,;\ \frac{\partial W}{\partial S} = 0 \text{ or } M_{11} = 0$$

$$W = 0 \text{ or } Q_1^* = Q_1 + \frac{1}{S \times \cos\varphi} \times \frac{\partial M_{12}}{\partial \theta}$$

$$v = 0 \text{ or } N_{12}^* = N_{12} + \frac{\text{tg}\varphi}{S} \times M_{12} \tag{22}$$

Using conditions (19), Equations (9) and (10), relation (5), (12) and stand (19), it is easy to obtain boundary conditions for any variant of fixing the ends of the conical seal [2]. Let us write down in terms of displacements the most typical boundary conditions for the vibration problem (20):

A) Hard pinched edge $u = v = W = \frac{\partial W}{\partial S} = 0$;

$$\bar{u}' = \bar{v}' = \bar{W}' = \frac{d\bar{W}'}{dx} = 0 \tag{23}$$

B) Hinged edge movable along the generatrix (Navier condition)

$(v = W = N_{11} = M_{11} = 0)$

$$\bar{v}' = \bar{W}' = 0$$

$$\frac{d^2\bar{W}'}{dx^2} + \mu l_x \frac{d\bar{W}'}{dx} = 0$$

$$\frac{d\bar{u}'}{dx} + \mu l_x \bar{u}' = 0 \tag{24}$$

V) Free edge ($N_{11} = M_{11} = N_{12}' = Q^*$)

$$\frac{d\bar{u}'}{dx} + \mu r_x n \bar{v}' + \mu l_x \bar{u}' + \mu r_x \bar{W}' = 0 \quad [12]$$

$$\frac{d^2\bar{W}'}{dx^2} - \mu\left(r_x' n\right)^2 \bar{W}' - \mu r_x n \bar{v}' + \mu l_x \frac{d\bar{W}'}{dx} = 0$$

$$-n r_x' \bar{u}' + \frac{d\bar{v}'}{dx} - \bar{v}' l_x + \frac{\delta^2}{3} n r_x r_x' \left(\frac{d\bar{W}'}{dx} - l_x \bar{W}'\right) = 0$$

$$\frac{d^2\bar{W}'}{dx^2} + \left[(1-\mu)\left(r_x' n\right)^2 - (1+\mu) l_x^2\right]\frac{d\bar{W}'}{dx} + 3\left(r_x'\right)^2$$

$$l_x n^2 \bar{W}' + n r_x r_x' \left[3 l_x \bar{v}' - 2(1-\mu)\frac{d\bar{v}'}{dx}\right] = 0 \tag{25}$$

Note that similarly, we can achieve equations related to cylindrical section concerning seal (cylindrical conical seal). If dimensionless quantities are introduced for the cylindrical section of a composite seal,

$$\delta = \frac{h}{R};\ x = \frac{s}{R}\ \left(0 \le x \le \frac{l_c}{r}\right)$$

Then the equations for the cylinder coincide with those for the conical shell, in which it is assumed $l_x = 0,\ r_x = r_x' = 1$ and l_1 noticeable on R, where l_c is the length, R is radius pertained to cylindrical segment. [3]

Natural frequencies can be evaluated considering vibration modes by the thermal action of the conical seal structure, described by structure respecting Equations (20) by border states (23)-(25), was solved numerically by reducing border rate issue to superposition respecting Cauchy problem [4]. To solve the latter, the standart procedure of the Runge-Kutta method was used. Previously differential equations were reduced to normal form:

$$\frac{dy_i}{dx} = \sum_{j=1}^{8} a_{ij}(x) y_i\ ;\quad (i = 1,2,\ldots,8) \tag{26}$$

Using the following notation for the desired functions and their derivatives:

$$y_1 = \frac{d^3\bar{W}'}{dx^3};\ y_2 = \frac{d^2\bar{W}'}{dx^2};\ y_3 = \frac{d\bar{W}'}{dx};\ y_4 = \bar{W}'$$

$$y_5 = \frac{d\bar{u}'}{dx};\ y_6 = \bar{u}';\ y_7 = \frac{d\bar{v}'}{dx};\ y_8 = \bar{v}' \tag{27}$$

In this case, border states within interval $\lambda \le x \le 1$ presented in the form:

$$x = \lambda;\ \sum_{j=1}^{8} d_{ij}^{(0)} y_j = 0\,;$$

$$x = 1;\ \sum_{j=1}^{8} d_{ij}^{(0)} y_j = 0\,;$$

$$x = 1;\ \sum_{j=1}^{8} d_{ij} y_j = 0;\quad (i = 1,2,3,4) \tag{28}$$

Looking for a singular result $y(x)$ concerning border rate issue of Equations (26) and (28) in the form:

$$z(y) = \sum_{j=1}^{4} L_j \times z_j(x) \tag{29}$$

where, $z_j(x)(j = 1,2,3,4)$ are direct unconventional results related to four auxiliary Cauchy problems considering homogeneous equation structure (26), initial conditions which must satisfy the four left boundary states specified for $x=\lambda$.

The direct evaluation related to the issue in this form as is well known, unstable. Achieving fixed numerical solution, the method by S.K. Godunov [1] was used. In this case, the solution interval $\lambda<x<1$ was divided by points $x=x_s$ into the required number of smaller intervals. After numerical integration on the next section $x_{s-1} \le x \le x_s$ at points x_s the resulting vector functions were normalized,

$$z_k\ (k = 1,2,3,4),\ \omega_{11} = \sqrt{(z_1, z_1)}\,;\ z_1 = \frac{z_1}{\omega_{11}}$$

$$\omega_{kj} = \left(z_k, z_j\right);\ k=2,\ 3,\ 4$$

$$\omega_{kk} = \sqrt{\left(z_k, z_k - \sum_{j=1}^{k-1} \omega_{kj}^2\right)};\ k = 2,3,4$$

$$z_k = \frac{1}{\omega_{kk}}\left(z_k - \sum_{j=1}^{k=1}\omega_{kj} z_j\right); k = 2,3,4 \quad (30)$$

The solution obtained at the first end of the interval (x=1):

$$y(1) = \sum_{j=1}^{4} C_j^{(N)} Z_j^{(N)} \quad (31)$$

must satisfy the boundary conditions (28) at x=1, which lead to $C_j^{(N)}$:

$$\sum_{j=1}^{4} \alpha_{ik} C_k^{(N)} = 0 \ , \ i = 1,2,3,4 \quad (32)$$

Where indicated:

$$\alpha_{ik} = \sum_{j=1}^{8} d_{ij}^{(1)} z_{ki}(1) \quad (33)$$

For z_{ki} the first index corresponds to vector-functions according to auxiliary Cauchy problem z_k, and the second-vector component. Finding such values appropriate to parameter ω=ω_*, for which the determinant of system (32) is equal to zero:

$$\Delta(\omega) = \det \alpha_{ik}(\omega) = 0 \quad (34)$$

Value ω=ω_* is the natural frequencies of the conical shape of the hydraulic cylinder seal under consideration. In practice, the search procedureω_* reduces to multiple for different. To calculate the waveforms corresponding to the found value ω=ω_*, from the system of Equation (32) up to an arbitrary constant C_0 define a constant C_j. Assuming, for example C_4=C_0 and discarding the fourth equation:

$$\sum_{j=1}^{3} \alpha_{ik} C_k^{(N)} = -C_0 \alpha_{i4} \ , \ i = 1,2,3 \quad (35)$$

After defining C_j at the right end of the interval (at x=1) value $C_j^{(s)}$ at all points $x = x_s$ can be determined in the backtracking process from the recurrence relations:

$$\Omega^{(s+1)} C^s = C^{(s+1)} \quad (36)$$

where, Ω is triangular matrix, composed of orthogonalizing coefficients ω_{ik} (30). The solution of the problem at points $x = x_s$ we build according to (29):

$$y(x_s) = \sum_{j=1}^{4} C_j^{(s)} Z_j(x_s) \quad (37)$$

The numerical result regarding issue proposed method was done on a computer, while the number of orthogonalization points N in the considered examples was taken 20-40. In this case, the solution time required to obtain $\Delta(\omega)$ for one arbitrary value of ω (one step along ω) is 5-15 seconds. If the task was to determine only natural frequencies, then there was no need to store information for intermediate orthogonalization points. When determining the modes of oscillations corresponding to the found values ω_*, into machine memory matrices were written $\Omega^{(s)}$ and vectors $Z_j^{(S)}$ $(j = 1,2,3,4)$ in each of N orthogonalization points (s= 0, 1, 2, …., N). In the reverse course, these values were used for calculations by Equations (36) and (37). The initial stress state was previously calculated from the solution of the thermoelectricity problem using a separate program. Results of this solution, specified as vectors $y_{st}^{(s)}$, written to external memory (s=0, 1, 2, …, M) [9].

When solving this problem, the values $y_{st}^{(s)}$ entered into Random Access Memory as an array with dimensions $6 \times M$. To get values $y_{st}(x)$ at an arbitrary point x, the linear interpolation procedure was used. In the considered problems, the number of points M was 40 [7].

3. ANALYSIS OF RESULTS

3.1. Calculation Results

Using the described algorithm, a computer technique was developed that allows calculating the natural frequencies and vibration modes of ring seals, cylindrical and conical seals with various Navier boundary conditions for oscillation frequencies $\omega_0 = \omega R\left(\frac{P}{G}\right)^{\frac{1}{2}}$ closed to supported circular seal $(\mu = 0.3;\ l_c / R = 2)$ oscillation equations which were calculated, and completely coincided with the forms obtained by exact analytical methods.

For an O-ring pinched at the edges, the proposed method also gave good agreement with the exact result [2]. The influence of the axisymmetric initial stress-strain state on the natural vibration frequencies of a circular conical seal was studied using the example of a truncated conical seal with pinched edges, which is under uniform temperature conditions. Calculation results for summarization with parameters $\delta = 0.005$; $\lambda = 0.2$; $\varphi = 60°$; $\mu = 0.3$ as shown in Figure 2.

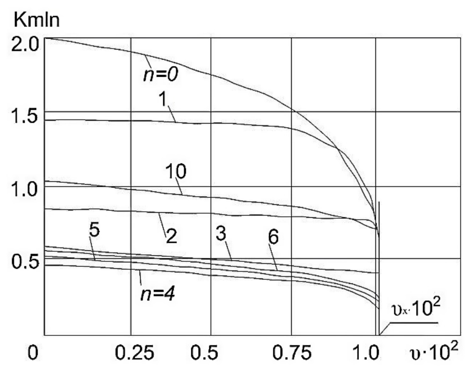


Figure 2. The above graphics reflect the dependence of the dimensionless frequency

The $K_{\min} = \omega_{\min} l_1 \left[\frac{\rho(1-\mu^2)}{E}\right]^{\frac{1}{2}}$ on the dimensionless temperature parameter is used in θ=αT for a different number of waves n in the circumferential direction.

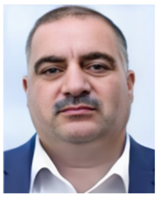
4. CONCLUSIONS

1. As a general result of the conducted research, it should be noted that the use of cylindrical and conical rubber seals in the connecting and regulating valves is one of the important signs in increasing the sealing effect.
2. For ring seals, cylindrical and conical seals, the proposed analytical method that allows you to calculate natural frequencies and vibration modes with different boundary conditions.
3. Given the relevant information about numerical solution regarding evaluations, dependence of the dimensionless temperature parameter E at a different number of waves in the circumferential voltage is obtained, which shows the lower frequencies correspond to the vibration forms at n=4 and n=5. High temperature can reduce the natural frequencies at a high rate. At $\theta=\theta_*$ the lowest frequency becomes zero, which corresponds to the loss of stability.

REFERENCES

[1] K.S. Mammadov, J.N. Aslanov, "Frictional Wear of Improved Valve Hermetic Elements Caused by Heat Transfer", Journal Tribology, Vol. 35, pp. 134-149, 2022.
[2] V.T. Mammadov, C.R. Damirova, J.N. Aslanov, "Research of the Unstable Movement Adjustment of Sucker Rod Pump", International Journal of Engineering Studies Inventions (IJEI), Taylor and Francis, Issue 3, No. 2, Vol. 9, pp. 592-600, 2017.
[3] J.N. Aslanov, A.B. Sultanova, Z.S. Huseynli, F.F. Mustafayev, "Determination of Radial Strains in Sealing Elements with Rubber Matrix Based on Fuzzy Sets", Lecture Notes in Networks and Systems, No. 362, pp. 765-773, 2022.
[4] J.N. Aslanov, A.S. Ahmadov, Z.E. Eyvazova, G.A. Hamidova, L.R. Ibayeva, "Harmonic Analysis of Loading Characteristics Research of Pump Jack", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 54, Vol. 15, No. 1, pp. 110-115, March 2023.
[5] M.B. Babanli, R.K. Mekhtiyev, N.A. Gurbanov, J.N. Aslanov, Y.S. Tanriverdiev, "Cracks in Hybrid Fiber Metal Laminated Nanocomposites under Uniaxial Tension", Journal of Applied Mechanics and Technical Physicsthis Link is Disabled, Vol. 63, No. 5, pp. 837-876, 2022.
[6] S.D. Mustafaev, Z.E. Eyvazova, "Spherical-Radial Stationary Incompressible Filtration", Scientific-Technical Journal of Eko-Energetics Academy, No. 2, pp. 59-63, 2017.
[7] J.N. Aslanov, K.S. Mammadov, "Design and Performance Analysis of Improved Valve Construction Being Used in Oil and Gas Industry", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 51, Vol. 14, No. 2, pp. 98-103, June 2022.
[8] V.T. Mammadov, T.U. Khankishiyeva, "Study of the Mechanism of Friction and Wear in the Wellhead Joint of the Rod Well Pump Unit, Applied and Practical Mechanics", Scientific and Technical Journal between Universities, No. 1-2, pp. 24-51, Baku, Azerbaijan, 2017.
[9] V.T. Mammedov, S.R. Rasulov, K.G. Akperova, "Stability of the Elastoplastic Stress State of Field Pipelines During Oxidation", Scientific and Technical Journal, Equipment and Technologies for the Oil and Gas Complex, OJSC VNIIOENG, pp. 51-54, Moscow, Russia, February 2017.
[10] V.T. Mamedov, F.F. Mustafaev, "Influence of the Geometry of Sealing Elements of a Downhole Packer on their Characteristics", Scientific and Technical Journal, Equipment and Technologies for the Oil and Gas Complex, OJSC VNIIOENG, pp. 13-15, Moscow, Russia, February 2017.
[11] V.T. Mammadov, T.A. Aghadiyeva, "Calculation for Regulation of Packers and Putting them into Action", News of Azerbaijan Engineering Academy, Vol. 9, No. 1, pp. 41-45, January - March 2017.
[12] J.N. Aslanov, Z.S. Huseynli, N.M. Abbasov, A.V. Sharifova, "Durability Study of Specialized Sealing Elements", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 52, Vol. 14, No. 3, pp. 8-13, September 2022.
[13] J.N. Aslanov, T.U. Khankishiyeva, L.T. Huseynova, "Study of Physical Processes Created by Sand Grains in the Working Nodes of Adjustable Throttle", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 54, Vol. 15, No. 1, pp. 171-177, March 2023.
[14] V.I. Aliyev, J.N Aslanov, N.I. Nabiev, M.S. Rahimova, "Influence of the Non-Equilibrium State of Real Gases on their Properties", Oil and Gas Institute - National Research Institute, Vol. 79, No. 2, pp. 84-95, Poland, 2023.

BIOGRAPHIES



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Research Interests: Pumps, Pumpjacks, Friction and Wear
Scientific Publications: 48 Papers, 5 Textbook, 4 Educational Supplies, 1 Methodological Resource

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Scientific Publications: 88 Papers, 3 Monograph, 3 Textbook, 3 Educational Supplies, 59 Theses, 30 Patents

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Doctorate: Mechanical Engineering. Faculty of Oil Mechanical Engineering, Azerbaijan State Oil Academy, Baku, Azerbaijan, 2015
The Last Scientific Position: Assoc. Prof., Azerbaijan State Oil and Industry Univ., Baku, Azerbaijan, Since 2020
Research Interests: Packers, Seals, Increase Friction and Wear Resistance of Units in Oil and Gas Fields Machinery and Equipment
Scientific Publications: 62 Papers, 1 Monograph, 2 Textbook, 3 Educational Supplies, 1 Methodological Resource

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Master: Technical Machines and Equipment, Faculty of Oil Mechanical Engineering, Azerbaijan State Oil Academy, Baku, Azerbaijan, 2021
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Research Interests: Valves, Choke Valves, Ball Valves, Wear and Friction
Scientific Publications: 2 Papers

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Master: Technological Machine and Equipments Engineering, Faculty of Oil Mechanical Engineering, Azerbaijan State Oil and Industry University, Baku, Azerbaijan, 2021
The Last Scientific Position: Assist. lecturer, Azerbaijan State Oil and Industry Univ., Baku, Azerbaijan, Since 2021
Research Interests: Valves, Tribological Research, Increase Friction and Wear Resistance of Units in Oil and Gas Fields Machinery and Equipment
Scientific Publications: 4 Papers