РОЗДІЛ «МЕХАНІКА ДЕФОРМОВАНОГО ТВЕРДОГО ТІЛА, МЕХАНІКА РІДИНИ, ГАЗУ ТА ПЛАЗМИ»

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THERMAL STRESS-STRAIN STATE OF THIN LAMINATED SHELLS OF REVOLUTION UNDER CONVECTIVE HEAT EXCHANGE WITH THE ENVIRONMENT

1 Formulation of the Problem

The thin stratified shells of rotation are examined. At the intensive heating in initial moments of time in these constructions there are large gradients temperatures that can cause the origin of flowages. For the estimation of durability of constructions it is necessary most exactly to determine arising up in them distribution of temperature in time.

Considered thin layered shell, for which the hypothesis of linear element for the entire package of layers [1]. As the governing equations used the ratio of non-isothermal deformation processes along the trajectories of small curvature. [2] Deviatoric strain components are represented as the sum of elastic and plastic components. The former are determined by Hooke's law. Components of plastic components are defined as the sum of increments for all stages of loading

$$e_{ij}^{n} = \sum_{k=1}^{m} \Delta_k e_{ij}^{n} \ ; \quad \Delta_k e_{ij}^{n} = \left\langle \frac{s_{ij}}{S} \right\rangle_k \Delta_k \Gamma_n \, ,$$

where S –intensity of tangential stresses; the angle brackets denote averaging over the second stage; $\Delta_k \Gamma_n$ – the increment of accumulated plastic component of the intensity of shear strain, which is determined by the instantaneous thermomechanical surface [2]. Problems thermoplasticity at each stage of loading is reduced to the integration of a system of ordinary differential equations.

In a lecture methodology of decision of axisymmetrical non-stationary task of heat conductivity is expounded for thin shells with the layers of variable thickness, thermophysical properties of that depend on a temperature. For the decision of task the method of eventual differences, allowing to get the values of temperature in the same system of coordinates and in the same knots of difference net, is used, what at the decision of task about the tensely-deformed state of shell.

As a test example we will define the temperature field of double-layer cylindrical shell with the layers of arcwise-variable thickness. Results we will confront with a decision on the method of eventual elements in the axisymmetrical spatial raising, got on the methodology expounded in-process [3, 4]. The geometrical sizes of shell following: radius of middle surface r=20 sm; length formative L=10 sm; thicknesses of layers $h_1(s_0) = h_2(s_0)$=1sm; $h_1(s_n) = h_2(s_n)$=0,5sm. Initial temperature T=20C. Coefficients of heat emission and temperature of washings a shell environments α_1=0,5 , α_2=0,3$\frac{\mathrm{cal}}{\mathrm{c{\cdot}sm^2{\cdot}C}}$, Θ_1=600C, Θ_2=200C. On the butt ends of shell a temperature and coefficients of heat emission on a thickness change on a linear law. The coefficients of heat conductivity and diffusivity arcwise depend on a temperature. At the decision of task on an offer methodology the amount of knots of breaking up along a meridian was accepted n=201, and on the thickness of every layer $k_1 = k_2$=11. At the use of method of eventual elements the meridional section of shell was approximated by quadrangles, each of that divided diagonals by four three-cornered eventual elements with linear distribution of temperature into each of them. In the total the meridional section of shell was covered by a net consisting of K_e=2000 eventual elements and K_u=1061 key points. As a result of decision tasks are set that the temperature field of shell is practically set to the moment of time t =30 s. In spite of the fact that the examined shell not thin, results of calculation on difference method and method of eventual elements coincided practically. It testifies to high exactness of the worked out methodology.

In the second example we will define the temperature field of double-layer shell the co-ordinate meridian of that is represented on a fig. 1. Geometrical sizes of shell : R =14sm, r=4sm. Thickness of internal layer h_1=0,4 sm, outward h_2=0,2 sm. A shell consists of cylindrical link with length formative and two lines as a torus, each of that has length of arc L . Links mark on a figure the Roman numerals $I-III$ and fluently united between itself without the break of derivative. Ambient temperatures Θ_1=350C, Θ_2=20C. Initial temperature T_0=20C.

The coefficient of heat emission arcwise changes along the meridian of shell, taking on the borders of links next values: α_1=0,01; 0,01; 0,009; 0,008. Coefficient α_2 =0,0001(the same system of units is here accepted, what in a previous example). Butt ends are heat-insulated $(\alpha_3 = \alpha_4 = 0)$.

Material of internal layer is steel of 12X1MФ [5], coefficient of diffusivity of that for the values of temperature $T = 0$; 200; 400C takes on values a_1= 0,1225; 0,1233; 0,1131.

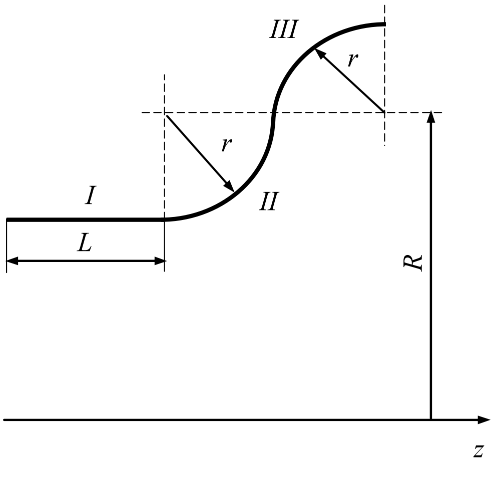

Figure 1 – Meridian of double-layer shell

The coefficient of heat conductivity is accepted by независящим from a temperature λ_1 =0,1051. Material of periblast – Izolat -4 [6], thermophysical descriptions of that are determined by values a_2=0,0812; $\lambda_2 = 4{,}78 \cdot 10^{-6}$.

At the decision of task the amount of knots of breaking up along the meridian of every link was accepted n_l=201, and on the thickness of layers k_1=11, $k_2 = 6$.

As a result of decision tasks are set that in every layer of shell distribution of temperature on a thickness is near to linear and in time this character does not change. A temperature is set to the moment of time t =300 s.

On a fig. 2 the charts of change of temperature are shown along a coordinate $\varsigma^* = \varsigma + h_1$ in a section $s = s_n$. Increasing lines on a picture correspond to the moments of time t =1; 5; 10; 30; 60; 120; 300 s. On a fig. 3 for the same moments of time the charts of change of temperature are represented along the meridian of shell at $\varsigma^* = 0$. From a picture evidently, that at t = 300s temperature practically does not change along a meridian.

Thus, methodology of determination is worked out in the real lecture

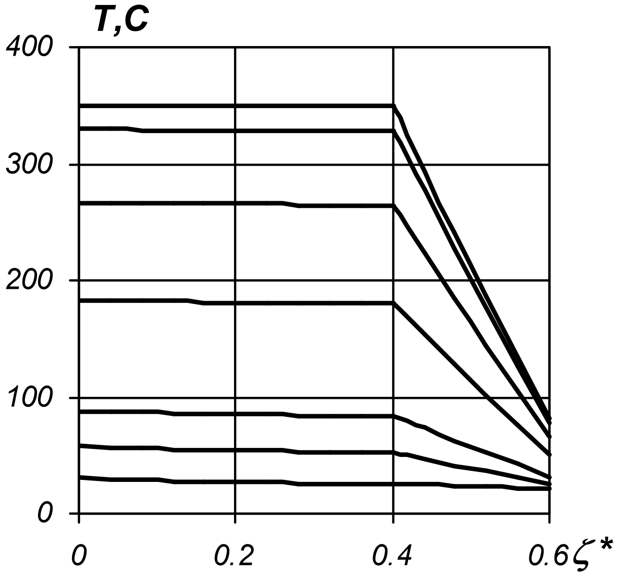

Figure 2 – Variation of temperature along the coordinates ς^*

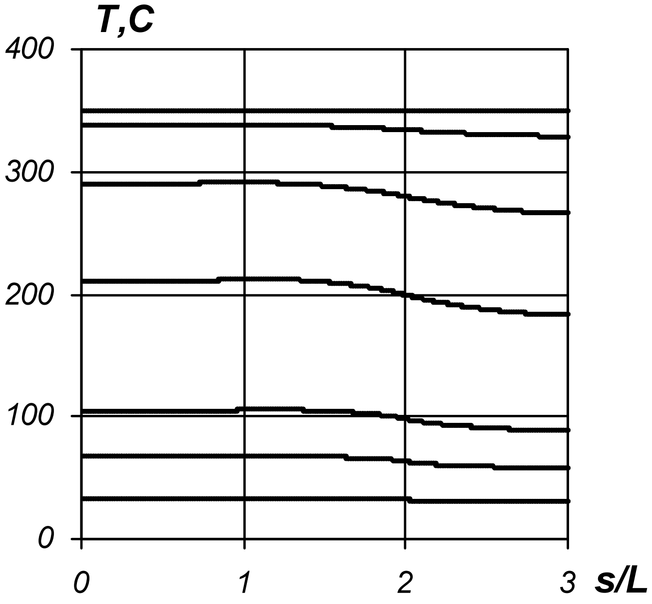

Figure 3 – Variation of temperature along the meridian of shell

In basis of methodology the method of eventual differences, and obvious разностная chart, is fixed at times. Efficiency of methodology is confirmed by the decision of test example.

2 Stress State

As an example we will define temperature tense state of double-layer shell the co-ordinate meridian of that is represented on a fig. 1.

A shell consists of cylindrical and two links, each of that has length of arc L. Geometrical sizes have next values: R=0.14 m, r=0.04 m. A thickness of internal layer h_1=0.004 m, external h_2=0.002 m. As a co-ordinate surface the interphase of layers is chosen.

Initial temperature of shell T_0=293 K. of Temperature of environments Θ_1=673 K, Θ_2=293 K; coefficients of heat emission α_1=1000, α_2=100 $\frac{\mathrm{Vt}}{\mathrm{m}^2 \cdot \mathrm{K}}$. Butt ends s_0, s_n are heat-insulated $(\alpha_3 = \alpha_4 = 0)$. A shell is subject to the action of intrinsic pressure, the axial squeezing and moving efforts operating at $s = s_0$. Intrinsic pressure in time changed by law $q_\varsigma = 0.02 f(t)$, where $f(t) = 1 - \exp(-100t)$. Border terms on butt ends: at $s = s_0$ $N_s = -0.002 f(t)$, $N_{\varphi s} = -0.001 f(t)$, $M_s = Q_s = \psi_{\varphi s} = 0$; at $s = s_n$ $Q_s = u = v = \psi_s = \psi_\varphi = 0$.

Material of internal layer is steel of EI437, physical and mechanical descriptions of that are accepted by the following: ν=0.28, $\alpha_T = 12 \cdot 10^{-6}\ K^{-1}$, a_1=0.0158 $\frac{\mathrm{m}^2}{\mathrm{h}}$, $\lambda_2 = 19.5 \frac{\mathrm{Vt}}{\mathrm{m} \cdot \mathrm{K}}$. A external layer is made from the carbide of tantalum, possessing next properties: ν=0.17, $\alpha_T = 12 \cdot 10^{-6}\ K^{-1}$, a_2=0.031 $\frac{\mathrm{m}^2}{\mathrm{h}}$, $\lambda_2 = 22.2 \frac{\mathrm{Vt}}{\mathrm{m} \cdot \mathrm{K}}$.

On a fig. 4-11 for two values of temperature stroke lines are show the diagrams of deformation of material of internal layer, and continuous - loading.

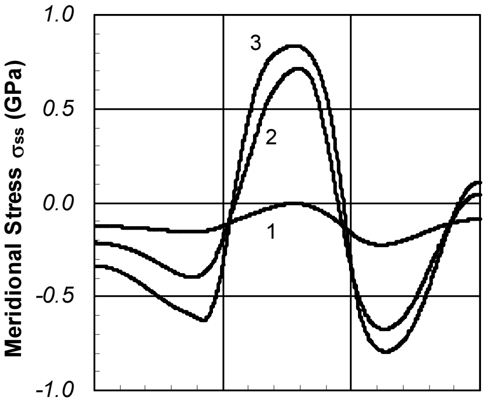

Figure 4 – Inner Surface

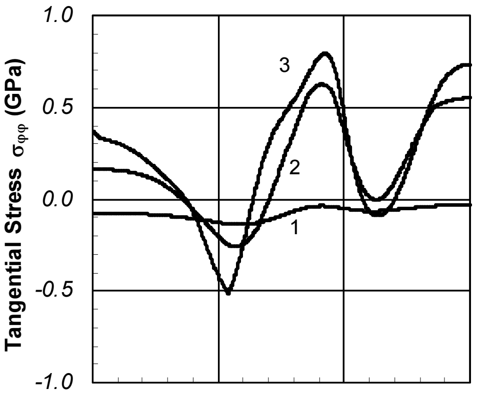

Figure 5 – Outer Surface

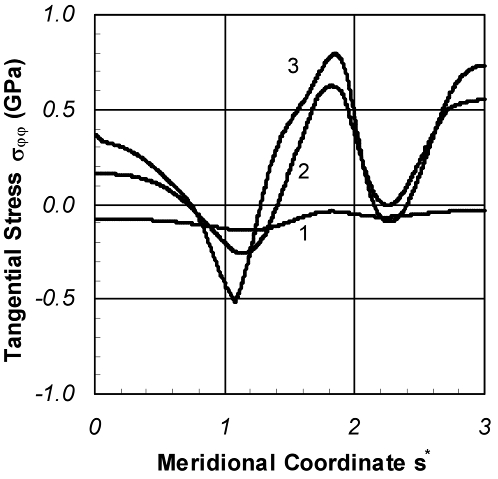

Figure 6 – Inner Surface

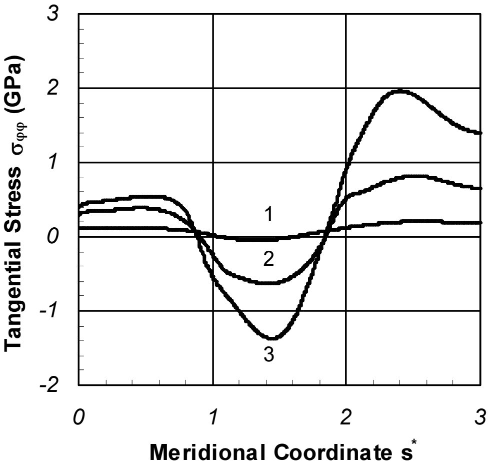

Figure 7 – Outer Surface

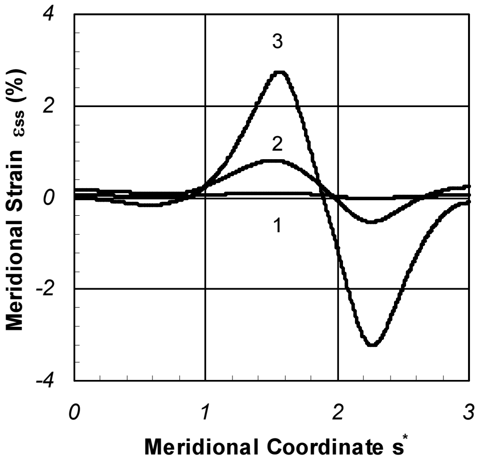

Figure 8 – Inner Surface

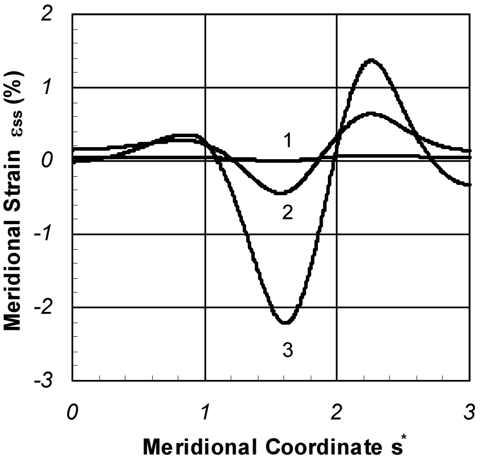

Figure 9 – Outer Surface

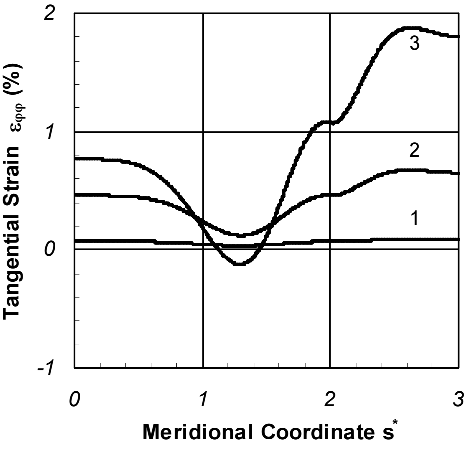

Figure 10 – Inner Surface

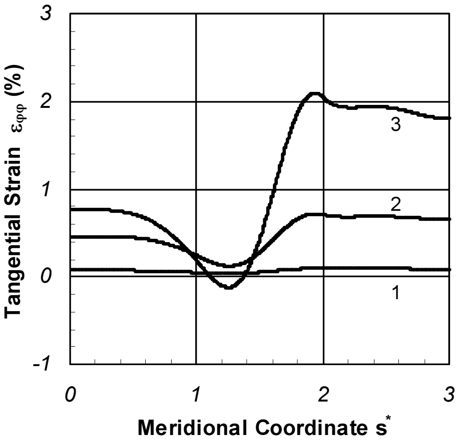

Figure 11 – Outer Surface

The amount of knots of breaking up along the meridian of every link was accepted n_l=201, and on the thickness of layers k_1=11, $k_2 = 9$.

As a result of decision tasks are set that the prospected process of ladening an active ladening will be realized in every point of shell.

Conclusions

Thus, in the real lecture the methodology for determination of the axisymmetrical non-stationary temperature fields and thermoelastoplastic stress-strain state in the thin laminated shells of revolution with the layers of variable thickness is worked out. Dependence on a temperature of thermophysical properties of material is taken into account.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ТЕМПЕРАТУРЫ ОТЖИГА ЛИСТОВОЙ СТАЛИ 25ХГСА НА ПРОЧНОСТЬ СОСУДОВ ВЫСОКОГО ДАВЛЕНИЯ

Введение. Наиболее часто тонкостенные сосуды высокого давления являются конструктивными элементами транспортных установок как емкости для топлива, используются в тормозных системах автомобильного и железнодорожного транспорта в качестве резервуаров для сжатого воздуха. В летательных аппаратах с ЖРД тонкостенными сосудами являются баки с окислителем и горючим, а с ТРД - корпуса двигателей, заполненные твердым топливом. Назначение сосуда и условия его работы определяют требования к материалу, конструктивному оформлению и технологии изготовления. Прочность емкостей, работающих в условиях высокого давления, зависит от многих факторов, в частности, от геометрии, свойств материала, режима