The bending and torsion coil spring dynamics problem was resolved. The stress-strain state of springs for different boundary conditions are shown in the figures.

![Figure 3](image)

Figure 3 – Movements, bending and torsional deformation of the spring coils (A and B). Two positions of the spring in non-deformable and strain state for B

References

IDENTIFICATION OF THE ELASTIC MODULUS OF POLYMERIC MATERIALS BASED ON COMPRESSION OF THIN-WALLED CYLINDRICAL SPECIMENS

Gluhih S. A., Kovalovs A. O., Chate A.
Riga Technical University, Institute of Materials and Structures
1 Kalku str., LV-1658, Riga, Latvia
s_gluhih@inbox.lv

The technique suggested in the present study regarded as an alternative for determining the elastic modulus of polymeric materials. It is based on the solution of a geometrically nonlinear problem of transverse deformation of thin-walled circular cylindrical shells. The account of nonlinear effects makes it possible to use a considerably wider range of the loading curve in the elastic area of deformation, thus increasing the accuracy of results. In addition, we employ the «principle of a unified specimen» i. e., the possibility of measuring the elastic modulus as a function of the processes proceeding in a specimen and affecting the structure of a polymeric material (aging, sorption, and desorption of liquid media and vapors by the material, temperature variations, etc.).
In the first case let us consider one layer cylindrical shell under the action of a force that is transmitted through the undeformed upper plane, when the lower plane is immobile. The dependence of the force $P$ on the displacement $\Delta$ is now called the loading diagram. According to [1], we introduce the dimensionless parameters of displacement $\alpha$ and load $\beta$

$$\alpha = \Delta/(2R), \beta = PR^2/(EJ).$$

where: $E$ – elastic modulus of the material, $J$ – moment of inertia, $R$ – radius of the cylinder, $l$ – width of the sample, $b$ – thickness of the sample, $P$ – force, $\Delta$ – displacement. The unified loading diagram in the $\alpha-\beta$ coordinates allows us to solve the inverse problem on identification of the elastic modulus. In this case the numerical method was used.

The numerical method proposed in the present investigation consists of the numerical model and material identification procedure.

In the first stage, the finite element model of thin circular shells has been used to model the unified loading diagram with the initial guess values of parameters. The initial guess values of parameters have been determined by using the method of planning of experiments. In the second stage, these numerical data are taken to determine simple functions.

The plan of the experiment was formulated for four design parameters $(E, l, R, \Delta)$ and 60 experiments. Then, in the points of the plan of the experiments, finite element analysis was carried out to determine the forces and displacements.

Let us consider a criterion for the elaboration of the plans of the experiment. This criterion is to be independent of the mathematical model of the designed object [2]. The initial information for development of the plan is the number of factors $n$ and the number of experiments $k$. The points of experiments in the domain of factors are distributed as regularly as possible. For this reason the following criterion is used:

$$\Phi = \sum_{i=1}^{k} \sum_{j=i+1}^{k} \frac{1}{l_{ij}^2} \Rightarrow \min,$$

where $l_{ij}$ is a distance between the points having numbers $i$ and $j$ ($i\neq1$). Physically it is equal to the minimum of potential energy of repulsive forces for the points with unity mass if the magnitude of these repulsive forces is inversely proportional to the distance between the points.

The finite-element models constructed by using the ANSYS program, due to symmetry, had the form of quarter of a circular ring. The boundary conditions reproduced the conditions of symmetry. Since we considered thin-walled shells allowing large displacements and rotations, as a finite element, we employed a SHELL181 element corresponding to the given requirements. In solving the contact problem, a CONTA174 contact element was used. The elastic properties of the material were modeled by Hooke’s relations. The problems were solved with account of friction in the contact zone. The solution of geometrically nonlinear problems was based on a stepwise procedure in displacements or in force, with an iterative
correction at each step. For all the problems, macros with a menu for entering initial data were written.

The algorithm of determination of the elastic modulus from unified loading diagram can be described as follows. Seven or eight points of the loading diagram are measured in the range of relative displacements \( \alpha = 0.2 - 0.8 \) on the test bench. The relation between forces and displacements is recalculated in the dimensionless \( \alpha - \beta \) coordinates. By comparing the resulting data with the unified loading diagram, we find the modulus for each point of the particular loading diagram. Over all measurement points, the average value of \( E \) is determined; then the deviation of the modulus from its average value is calculated at each point, and the average value of error \( |\delta| \) is found. An error \( |\delta| \) not exceeding 5% points to a satisfactory accuracy of the result obtained.

In the second case the cylindrical shell consisting of two layers with different elastic modulus is considered. The inner layer (bandage) of the cylindrical shell is made from a rigid polymeric material with relatively high elastic modulus. The outer layer is made from a softer polymer. Poisson’s ratios of both layers are 0.35.

The average radius \( R \), the length \( L \), the elastic modulus of the inner layer \( E_1 \) and the thickness of both layers \( t_1 \) and \( t_2 \) of the cylindrical shell are assumed to be known. The parameter to be identified is the elastic modulus of the outer layer \( E_2 \).

For the identification of the elastic modulus of the outer layer \( E_2 \) the method is based on the solution of the problem of compression of a thin-walled cylindrical tube by two parallel planes.

According to the above mentioned method at first the so-called reduced elastic modulus \( E_{\text{priv}} \) (modulus of inelastic buckling) is determined from the compression experiment of a cylindrical shell. The cylindrical shell is assumed to be single-layered with thickness \( t = t_1 + t_2 \). Then the step-down ratio for the elastic modulus \( K = E_1 / E_{\text{priv}} \) is introduced. Further a Finite Element model for the problem of compression of a two-layer cylindrical shell is built by using software package ANSYS. The Finite Element model is built by using SHELL181 element which allows multi-layer properties.

The plan of the experiment was formulated for four design parameters \( (E_2, t_2, R, \Delta) \) and 60 experiments. Then, in the points of the plan of the experiments, finite element analysis was carried out to determine the forces and displacements.

Further the series of calculations of the cylindrical shell with different elastic modulus of the outer layer are carried out. Obtained results are tabulated and then on the basis of theses tables the graph of the dependence of the relative elastic modulus \( E_i / E_{\text{priv}} \) from the logarithm of the ratio of the elastic modulus of layers \( \log(E_i / E_2) \) is constructed.

The technique suggested for identifying the elastic modulus of a polymeric material is characterized by simplicity of experiments and a low consumption of materials. The use of a wide range of the loading diagram in the elastic region of
deformation makes it possible to obtain more initial data, which increases the accuracy of identification of the elastic modulus.

References

COUPLED BEM AND FEM IN DYNAMIC ANALYSIS OF TANKS FILLED WITH A LIQUID

Ogorodnyk U. E., Gnitko V. I.
The A. N. Podgorny Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine
2/10 Dm. Pozharsky St., Kharkiv, Ukraine
uliyanka@ya.ru, basil@ipmach.kharkov.ua

Thin-walled shells are widely used in many industries including aerospace, civil, marine, petrochemical and nuclear engineering, power machine building, wind power engineering and transport. In many circumstances these shells are subjected not only to static loads but also to dynamic disturbances and filled with internal fluid. Usually they are filled with oil, flammable or toxic liquids. Such facilities are fuel tanks, liquid storage tanks, oil and propellant storage containers. The influences of both media on each other must not be neglected in stress-strength analysis of these structural elements. So the interaction between the sloshing liquid and the shell structure has been the challenging field of research in many engineering applications. In most cases, discrete techniques, such as the Finite Element Method (FEM) and the Boundary Element Method (BEM) have been employed and continuously further developed with respect to accuracy and efficiency. In fact, it did not take long until some researchers started to combine the FEM and the BEM in order to profit from their respective advantages by trying to evade their disadvantages. A detailed review on different numerical models for fluid-structure interaction can be found, e.g., in [1]. Several studies have been carried out in the different fields of sloshing liquids. Evaluation of the natural frequencies and corresponding mode shapes of liquid sloshing in a tank, linear and non-linear characters of the liquid flow, sloshing analysis in low and zero gravity, optimization and control of sloshing characteristics are some of researcher’s favorite fields. Such research is needed to better understand the processes and help reduce the probability and aftermath of these tanks destruction due seismic actions or shockwaves that can lead to environmental catastrophe.

The dynamic analysis of shell structures is often performed by use the finite element programs. But such 3-D finite element analysis, including the contained fluid is complex and extremely time consuming. In [2–4] authors offer the approach based on using the boundary element method to the problem of natural vibrations of the fluid-filled elastic shells of revolution, as well as to the problem of natural liquid vibrations in the rigid vessels. The research findings are summarized in [5].