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DETERMINING OPTIMAL PARAMETER RATIOS IN THE STUDY OF LONGITUDINAL VIBRATIONS OF THREADS IN WEAVING PROCESS USING A MODEL

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Abstract: During the formation of the fabric, various dynamic processes took place, including fluctuations in the threads. The article covers the technology of computer modeling of technological processes on example of the research of transverse oscillations of the thread in weaving process. As an example, the longitudinal oscillations and tension of the threads in the process of surf on a loom are considered.

Keywords: Model, mechanical system, thread vibrations, longitudinal vibrations, transverse vibrations, result, speed, process.

Introduction. Physical model of the object is any other object, individual properties of which completely or partially coincide with properties of the source. The model is created for research, which is either impossible, or expensive, or inconvenient to carry out on the real object. The main purposes of the creation of the models are the following:

- to identify the interdependence of variables, the nature of their change over time and to find existing regularities. At the same time, those dependencies that are directly related to its functioning are determined in the source object;
- to learn how to predict the behavior of object and control it by testing various control options on the model;
- to use models to find the optimal ratios of parameters and to research special operating modes [1].

Computer model is the software implementation of mathematical model, supplemented by various utility programs. Computer model displays the properties of the physical model when a computer interprets its abstract components, i.e. programs [2]. In addition, computer model as a physical device can be part of test benches and virtual laboratories. Computer modeling allows without significant difficulties modifying mathematical models, which is the basis for obtaining results with a high degree of accuracy [3].

Methodology & empirical analysis. Let us consider a mechanical system consisting of threads and parts of a loom. In this case, during the formation of the fabric, various dynamic processes occur, including vibrations of the threads, in particular, longitudinal and transverse vibrations. Longitudinal vibrations are described by a second-order differential equation, and transverse vibrations are described by a fourth-order differential equation, respectively:

$$A_1 \frac{\partial^2 u}{\partial x^2} + A_2 \frac{\partial u^2}{\partial t^2} + A_3 u = F_1(x,t) \text{, (1)}$$

$$B_1 \frac{\partial^4 w}{\partial x^4} + B_2 \frac{\partial^2 w}{\partial x^2} + B_3 w = F_2(x,t) \text{ (2)}$$

After applying the method of separation of variables, equation (1) is reduced to ordinary differential equation with respect to time:

$$\frac{d^2 y}{dx^2} + k^2 y = f(t) \qquad (3)$$

With a number of assumptions (linearity of the restoring force, absence of a disturbing force, a certain relationship between the m, a, k parameters), a simplified mathematical model can be used [4]

$$x(t) = A\sin(kt + \alpha) \text{ (4)}$$

Using (4), the solution of a less complicated differential equation (4) is written in explicit form. For the mathematical models (4), (3), a computer model can be created. Figure 1 shows a model created using the «Mathcad».

Mathematical model 1;

$$m\frac{d^2 y}{dt^2} + k^2 y = f(x,t)$$

Mathematical model 2;

$$y = A\sin(kt + \alpha)$$

Physical model;

$$y = \begin{bmatrix} 0 \\ 0 \end{bmatrix};$$

$$D(t,x) = \begin{bmatrix} y \\ -k^2 \cdot y + 50 \cdot \sin(0{,}05t) \end{bmatrix};$$

$$z = rkfixed(y, 0.100, 400, D);$$

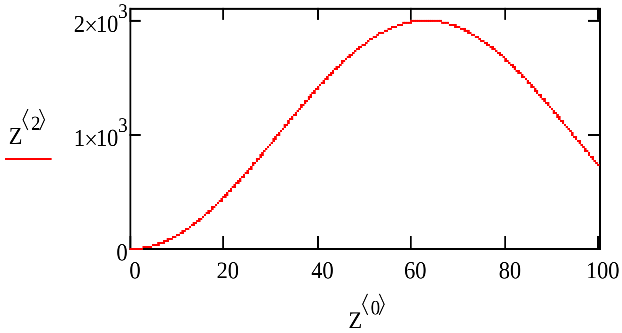


Figure 1. Computer modeling.

The process of building and research the computer models is called a computational experiment. For this, the following steps are needed:

– Highlight the essential properties of the objects under consideration;

– Debugging a computer model;

– Assessment of the adequacy of model constructed;

– Research the model;

– Analysis of obtained results.

As an example, we consider the longitudinal oscillations and tension of the threads during the surf on a loom [5]. We consider that one end of the thread is fixed on a rock, and impact is made on the other end. Let the end of the main thread at the edging be connected with the reed, so the speed of this end during the surf is equal to the speed of the reed, and this speed can be considered linear $v = v_0 - \beta t$, where $\beta = v_0 / t_{\ddot{\imath}\eth}$; $t_{\ddot{\imath}\eth}$ is surf time. In contrast to, we will consider the thread to be viscoelastic [6]. Then the integral-differential equation of motion of the thread will be written as follows:

$$\frac{1}{a^2}\frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} + \frac{1}{a^2}\int_0^t F(t-\tau)\frac{\partial^2 u}{\partial x^2}d\tau, \quad \frac{\partial u}{\partial x} = 1 + \alpha[T - \int_0^t G(t-s)u(s)ds]$$

Boundary and initial conditions must be added to this system of equations:

$u(0,t) = 0$, $u(l,t) = v_0 t - 0.5\beta t^2$, $u(x,0) = 0$, $\dot{u}(x,0) = 0$ at $0 \le x < l$ and $\dot{u}(x,0) = v_0$ at $x = l$.

Therefore, the mathematical model of the task has been built, and now we need to write a program that implements it.

The program and calculation results are shown in Figure 2. In this case, the software package "Mathcad" has been used.

$$v_0 = 2;\ b = 3;\ a = 3;\ l = 12;\ \omega_s = 25;\ \varepsilon = 0{,}5;\ \alpha = 2;\ k = 1{,}2,\dots,10;$$

$$x = 2;\ t = 2;$$

$$b(k) = \sqrt{\alpha \cdot \mu} \cdot \beta \cdot \frac{l}{k \cdot \pi};$$

$$p(k) = \pi \cdot \frac{k}{l \cdot \sqrt{\alpha \cdot \mu}};$$

$$a(k) = \frac{(-1)^k}{k^2};$$

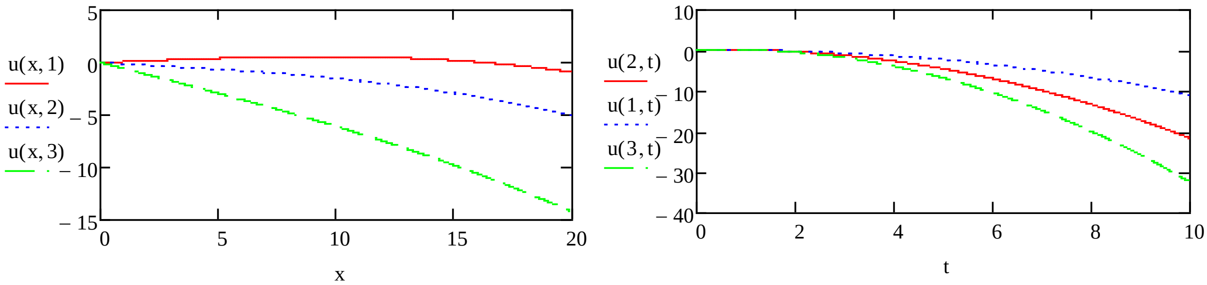
$$u_1(x,t) = 2 \cdot \sqrt{\alpha \cdot \mu} \cdot \frac{l}{\pi^2};$$

$$u_2(x;t) = \exp(-0{,}5 \cdot \varepsilon \cdot \omega_s \cdot \lambda n \cdot t;$$

$$u_3(x;t) = (-1)^n \cdot 2 \cdot b \cdot l^2 \cdot (\cos(l - 0{,}5 \cdot \varepsilon \cdot \omega_s) \cdot \lambda n \cdot t) \cdot (a^2 \cdot \pi \cdot n)^{-3};$$

$$u_4(x;t) = (-1)^n \cdot 2 \cdot v_0 \cdot b \cdot l^2 \cdot (\cos(l - 0{,}5 \cdot \varepsilon \cdot \omega_s) \cdot \lambda n \cdot t) \cdot (a^2 \cdot \pi \cdot n)^{-3};$$

$$u(x,t) = u_1(x,t) + \sum_{n=1}^{100} [(u_2(x,t) \cdot (u_3(x,t) - u_4(x,t)) \cdot \sin(\lambda n \cdot a^{-1} \cdot x)];$$



a) *b)*

Figure 2. Changes in displacement components.
a) changes in displacement depending on x;
b) changes in displacement depending on t;

In most cases, one experiment or a single run of the model will not be enough to achieve the desired result. For example, our task is the parametric optimization of the initial data. When solving this problem, a separate run of the model is used. The optimization algorithm sets some values included in the equations of motion of the parameters [7]. By setting different values of these parameters, because of numerical experiments, the most rational values of the input parameters are determined [8].

Results. At the same time, a separate task is to find special values of the model coefficients that qualitatively change the nature of its behavior [9]. To this end, let us consider the analysis of numerical results (Figure 2-4). Figure 2 shows the tension variations curves depending time for various values of the initial tension. In this case, the lower curve corresponds to the initial tension value T0 = 2, the middle one corresponds to T0 = 4 and the upper one T0 = 6. Similar curves are shown in Figure 4.

In this case, the values of the initial speed varied from 0.2 to 1.2 m/s. The results show that the value of the initial speed of the thread should not exceed 1.2 m/s.

The nature of the change in tension depending on the x coordinate is shown in Figure 4. In this case, as in the previous example, the curves are plotted for different values of the initial speed, and the time is fixed [10].

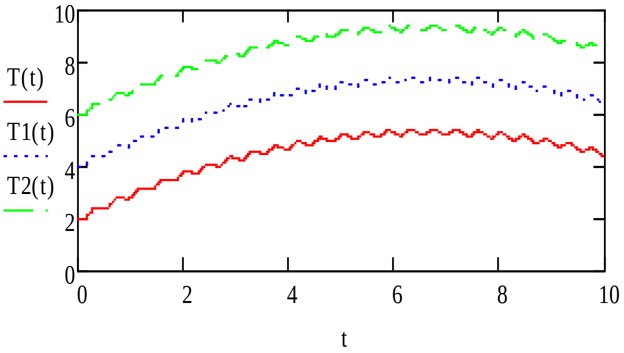


Figure 3. Changes in thread tension depending on time for different values of the initial tension.

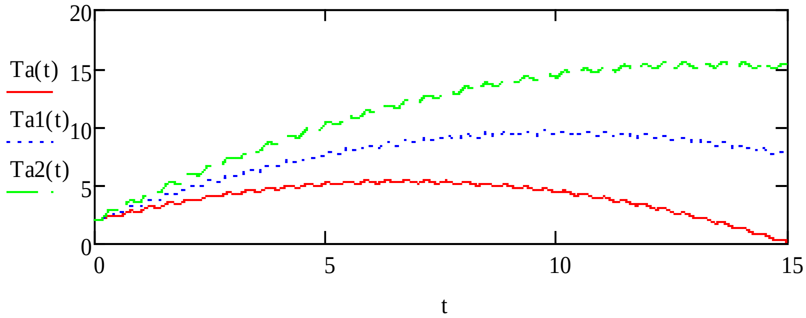


Figure 4. Changes in tension as a function of x for different values of initial tension at a fixed value of time.

For this example, the determination of rational values of the characteristic quantities is not difficult. In the general case of applying numerical procedures for searching for rational values, input parameters that qualitatively change the nature of the behavior of the problem under consideration, it is necessary to know that they exist and be able to estimate the range of parameters where they should be searched [11].

Conclusions. Figure 3 shows the change in tension depending on x for different values of the initial tension at a fixed value of time. In our case, the most rational values of the parameters included in the resolving equations are as follows:

$$T0 = 6;\ v0 = 1.2;\ \alpha = 0.2;\ \beta = 0.4;\ A = 0.125.$$

Methods of technology of computer modelling the dynamic processes on the example of the transverse vibration of the thread during the weaving process has been proposed, and the rational values of the input parameters have been determined.

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