*The work examines the various dimensions of the anatomical elements in several tropical tree species.*

*Measured are the dimensions of the cells and rays, ensuring their variation. A comparison is made between the anatomical characteristics of the individual species.*

***Wood, tropical wood species, trachea, rays, fibers.***

*The main characteristic of tropical timber - a constant diameter and the average density of the trachea within the ring. The border between the rings in them or vыdsutnya or barely noticeable. Many species similar in appearance and location of anatomical elements difficult to distinguish, but can be differentiated by quantitative anatomical characteristics of indicators.*

*This study examined differences in the size of anatomical elements in several tropical tree species.*

*The measured rozmirovyd ray cells and tracking their variation. Made comparison between anatomical characteristics of individual species.*

***Wood, tropical wood species, trachea, serdtsevynni rays fibers.***

UDC 684.4.04

## Nonlinear dynamical model deformation and fracture of composite materials based on wood

***SM Kuhlman, Ph.D.***
***PE "Company InterDesign"***

*Cross-impact effect of thermal expansion and thermoelastic effect in the field of external heat and power*



*stress, leads to self-oscillation dynamical system. Orthogonality functions of local internal stresses and local deformations internal, cause an increase in amplitude of oscillation. That in turn leads to a doubling of the oscillation frequency of the local temperature. Bifurcation dynamic system due to doubling, puts the system in the region of stable limit cycle, attractor.*

***Composite materials, nonlinear dynamics, kinetics of deformation and fracture, durability, oscillator, attractor, self-oscillation***

**Problem.** Efficacy of new composite materials depends on a lot of strength and stiffness for a given operating conditions, throughout life. Therefore, understanding the process of deformation and fracture, is one of the most important tasks of Materials and important part of the task of designing products from these materials. To make progress in this area, you need to understand the mechanism of internal stresses and strains and their interaction in the system, which is under certain environmental conditions [1].

**Analog recent research.** In [2, 3] kinetics, namely the impact of nonlinear interaction effects of internal factors on long-term durability. It was found that it was the presence of crosstalk effects during deformation leads to the accumulation of local destruction, eventually the global destruction. Given that changes deformation depend not only on changes in stress, but also from changes in temperature, Hooke's law should be represented as equations Duhamel-Neumann [1] (for simplicity, leave only one coordinate):

$$\varepsilon_x = \varepsilon_{\sigma_x} + \varepsilon_{T_x} = (1)\frac{1}{E}\left(\sigma_x - \nu\left(\sigma_y + \sigma_z\right)\right) + \alpha(T - T_0)$$

Solving equation (1) on $\sigma_x$And excluding, for simplicity, consider the effect of Poisson get:

$$\sigma_x = E\varepsilon_x + \alpha(T - T_0)E. \quad (2)$$

Equation (2) takes into account the amount of stress from external loads (surface forces) and the volume of internal forces related to the thermal expansion of the body.

Elastic load is not only reversible changes in body shape and size, but also change the internal characteristics of atomic-molecular dynamics. It appears thermoelastic effect (Joule effect) - change in temperature elastic bodies that have adiabatic load. In uniaxial load, temperature change ΔT body that is at a temperature T, is given by the Kelvin:

$$\Delta T = -\frac{\alpha T}{C}\sigma(3)$$

where σ - uniaxial tension during positive and negative stretching during compression; α - coefficient of linear thermal expansion along the axis of the load; C - heat capacity per unit volume of the body.

In uniaxial, elastic laden specific work and, therefore, increase the proportion of internal energy of the body is approximately (the effect of Poisson) will be:

$$\Delta W(\sigma) = \int_0^\sigma \sigma(\varepsilon)d\varepsilon, \quad (4)$$

where ε - relative elastic deformation of the body.

It follows from (3) that the change in the specific heat of the body during exercise will be:

$$\Delta Q(\sigma) = C\Delta T = -\alpha T\sigma. \quad (5)$$

Study of the dynamics of interaction between temperature and internal pressure during deformation and fracture of composite materials based on wood have shown [3] that it was lag changes in local temperature in the zone of destruction of local internal stress changes in this area, leading to periodic entropy production, and eventually to fracture.

So naturally assume that the rate of change of the parameters that determine the state of the body at the moment, just depend on these parameters. Phenomenological model the impact of cross-effects during deformation hot body, under constant external load, considered as a thermodynamic oscillator [3]:

$$\frac{d_i s}{dt} = \sigma J_1 + T J_2; \quad J_1 = L_{1_1}\sigma + L_{1_2}T; \quad J_2 = L_{2_1}\sigma + L_{2_2}T;$$

$$\frac{dT}{dt} = \sin\sigma; \qquad \frac{d\sigma}{dt} = \cos T. \tag{6}$$

It is shown that the cross effects inside the heated body that is under constant load are sources of phase shift between the internal local temperature and local internal stresses. Moreover lag changes in local temperature zone local stress state changes from local internal stress in the area, leading to periodic entropy production, and therefore to the cost of internal energy.

**The purpose of research.** Detail model the deformation process of composite materials based on thermodynamic oscillator system dynamics methods.

*Materials and methods research.* Phenomenological model (6) describes the general, thermodynamic picture of deformation and fracture. Therefore, in order to get a more accurate model of deformation of laminated chipboard, consider the heated body under external mechanical load in the form of autonomous non-conservative dynamical system.

As you know, the mathematical model of a dynamical system is considered to be given if the entered parameters (coordinates) system that uniquely determine its condition, and the Act of the evolution of its condition at the time. In the first approximation we take into account only the elastic properties of the material under study. Further details of the model takes into account the dissipative properties. The object under study allows to describe his condition following variables X1, X2, ..., XN (In this case T, σ, ε) at some time t =*t0*. The values of Xi can take arbitrary values, with two different sets of values $X_{ii}$ и $X_i'$ correspond to two different states. In this case, the law of evolution of a dynamical system in time we write the system of ordinary differential equations:

$$\frac{dX_i}{dt} = f_i(X_1, X_2, \dots, X_N), \; i = 1,2,\dots,N. \tag{7}$$

**Research results**. Dynamic system that studied can be considered either as an object in a heated body, under the influence of external forces, or as a process of deformation of the body under constant external load time. Dynamic system presented in the form of differential equations:

$$(8)\begin{cases} \frac{dT}{dt} = \alpha(T - T_0)\sigma - \frac{1}{2}(\sigma - \sigma_0)\varepsilon \\ \frac{d\sigma}{dt} = (\varepsilon - \varepsilon_0)E - \alpha(T - T_0)E - \delta \\ \frac{d\varepsilon}{dt} = \alpha(T - T_0) - (\sigma - \sigma_0)/E. \end{cases}$$

We take as the object of research laminated JV, | manufactured by "Krono-Ukraine". Plant material properties: modulus of elasticity E = 2600 MPa, flexural strength | bend | [σ] = 14 MPa, density 700 kg / m3, α = 0,00005 K-1. When initial conditions: t = t0; T0 = 300 K; *σ0* = 1 MPa; ε0 = σ0 / E. Deviations from the initial conditions at the time of system startup allows for microscopic fluctuation correction $\delta = \sigma_0/1000000$.

The solution of the system (8) by the Runge-Kutta fourth order shown in Fig. 1 in the form of phase trajectories mode continuous time that can trace the evolution of the system.

Analysis of the results of computer simulation shown in Fig. 1 - 6, can provide a number of features of its behavior. In particular, dynamic system (8) describes the process fluctuations and frequency changes of internal stress, strain and temperature.

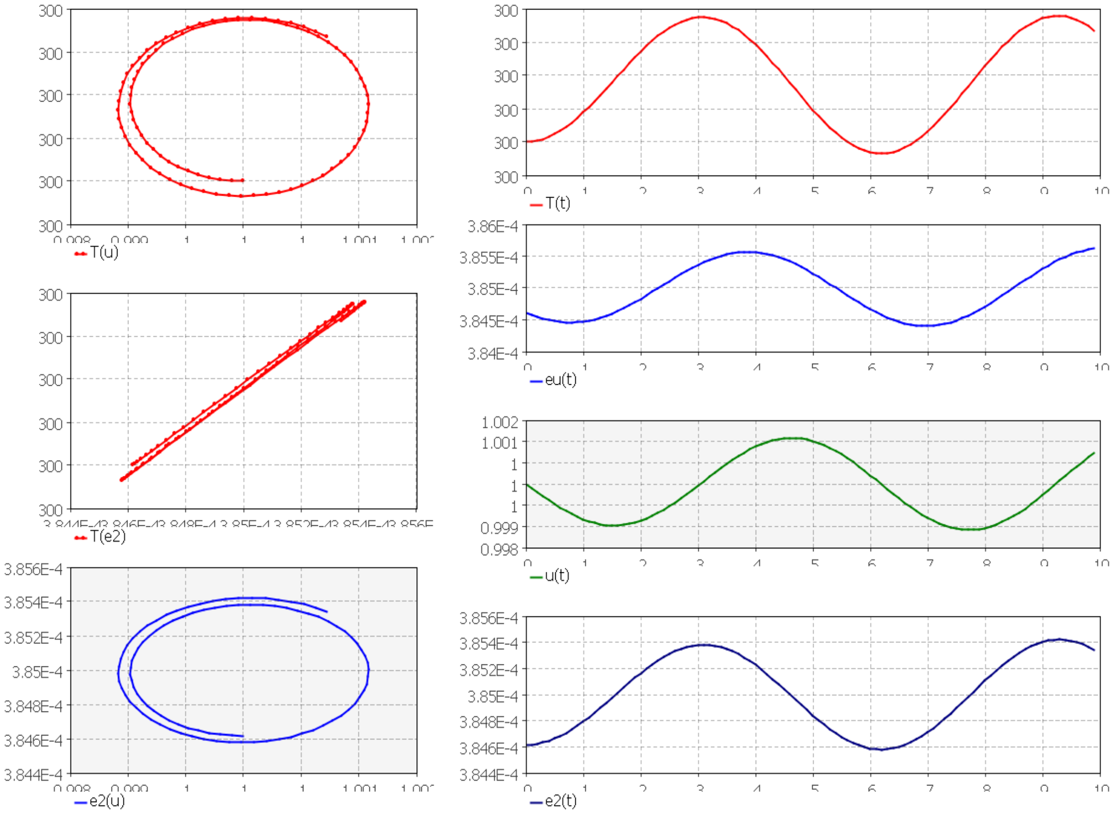


Fig. 1. Graphs internal stress (σ ≡ u); strain (e2 ≡ ε); of deformation (εσ ≡ e2u); internal temperature T (u) in the first ten conventional units of

time, and depending on the phase diagram of deformation (e2 ≡ ε) and local temperature T (e2) deformation in the area of internal stress (σ ≡ u) in the first ten conventional units of time.

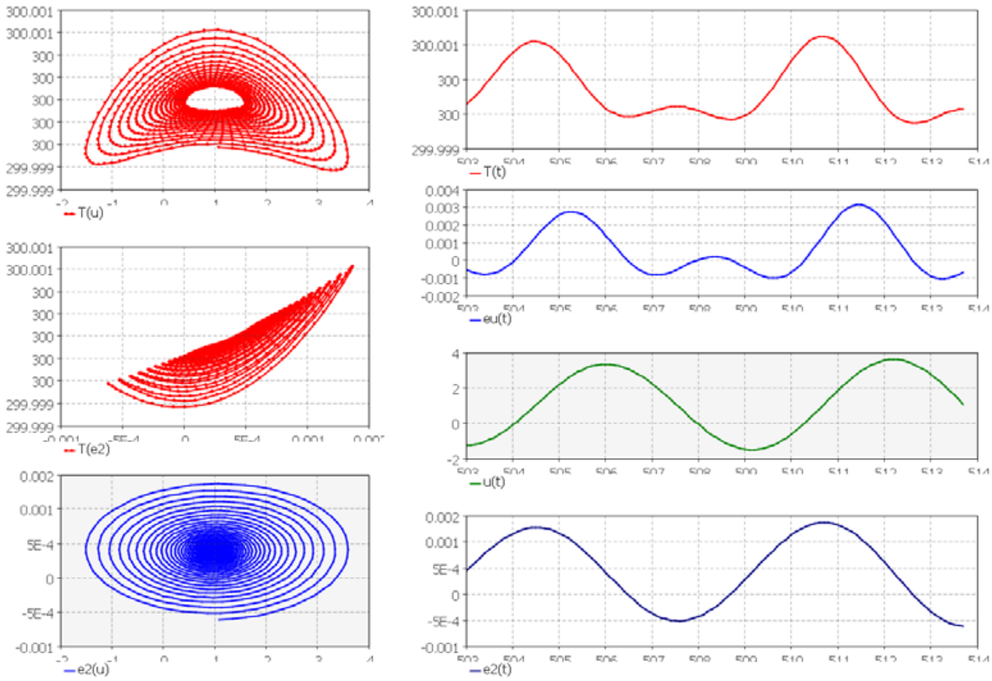


Fig. 2. Phase portrait of the dynamic system through 515 conventional units of time.

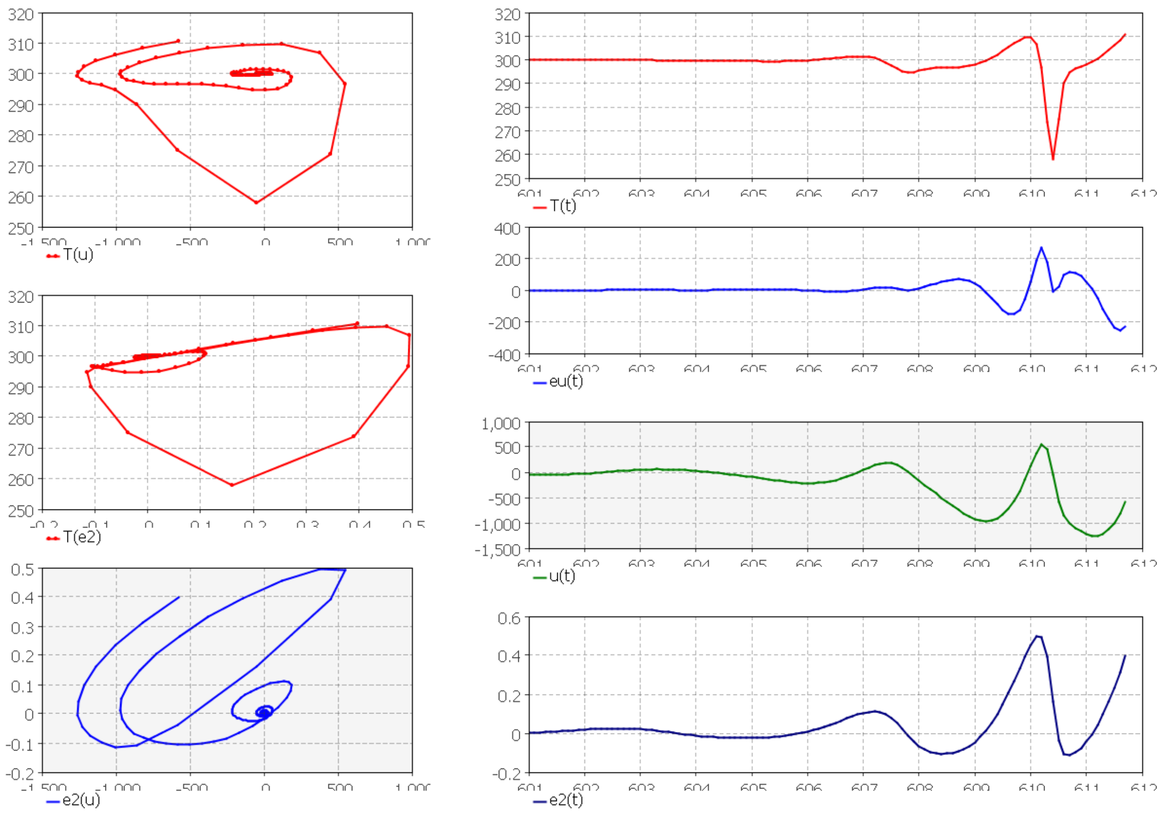


Fig. 3. Phase portrait of the dynamic system through 613 conventional units of time, at the time of bifurcation.

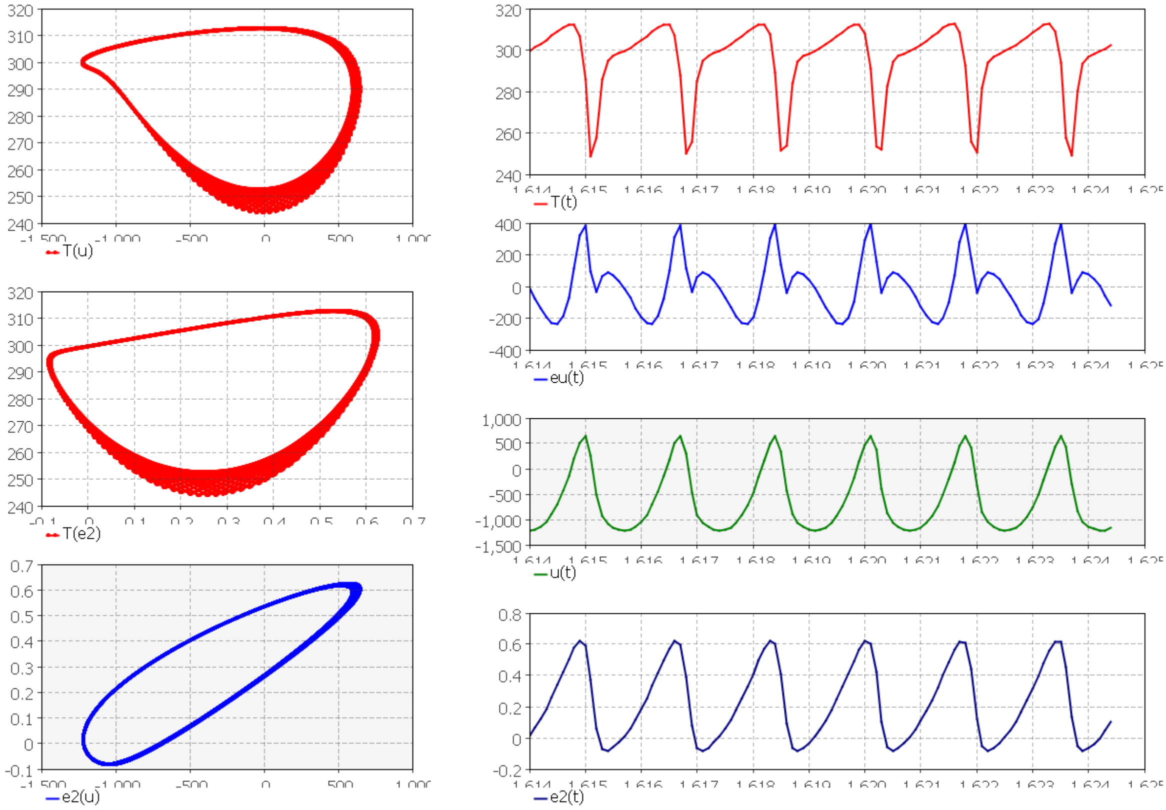


Fig. 4. The final portrait of the dynamic system, in the form of stable limit cycle relaxation self-oscillations, the attractor.

Fluctuations of system parameters is a constant increase in their amplitude. Diagram of any information on e2 (u) shows the fixed costs of internal energy during deformation. In the initial period, fluctuations of the parameters are close to harmonic. The dynamics of the process occurs with a delay of strain and temperature stress. Moreover, the oscillation frequency of the three parameters of the system are equal. Phase shift between stress and strain, and exactly as temperature and tension, is π / 2, indicating that the orthogonality of the functions.

The energy value of the dynamic system (8) are shown in a diagram of e2 (u) in Fig. 2. According to this chart, the deformation energy is increased for each cycle of oscillation. Absolute deformation just marginally increased in each of the next cycle.

Internal stresses local dynamical system is gradually increasing, and reaching a point of the material, the system obviously be considered destroyed (Fig. 3).

Dynamic in question, showing all the signs of avtokolyvnoyi system. Which as a result of negative feedback interaction σ and ε in the first equation of system (8) there is a force that coincides with the phase velocity of deformation or strain ahead to π / 2.

Analysis of the evolution of a dynamical system indicates that as a result of the gradual increase in amplitude σ and ε, while preserve the phase shift between them gradually work strain rate doubles. This results in a doubling of the frequency fluctuations of temperature (Fig. 2). A further increase in the amplitude of oscillation parameters of the system leads to its bifurcation (Fig. 3), and in the transition region stable limit cycle, ie attractor. This flow of energy from outside the system equals its spending within the system (Fig. 4).

At the beginning of the evolution of form almost harmonic oscillation, and the oscillation frequency is mainly determined by the natural frequency of oscillation of the system. As a result, the system goes into the bifurcation region relaxation self-oscillations that are not sharply sinusoidal and system parameters change abruptly.

## Conclusions

1. Cross-impact effect of thermal expansion and thermoelastic effect, in the field of external heat and power loads, leads to self-oscillation of the dynamic system, which can be defined as thermostatic oscillator.
2. Orthogonality functions of local internal stresses and local deformations internal, cause an increase in amplitude of oscillation. That in turn leads to a doubling of the oscillation frequency of the local temperature.
3. Bifurcation dynamic system due to a doubling of frequency temperature variations, puts the system in the region of stable limit cycle attractor.

## References


1. *Kovalenko AD* Introduction to termoupruhost / AD Kovalenko. - K.: Naukova Dumka, 1965. - 204 p.
2. *Kuhlman SM* Nonlinear deformation and fracture of composite materials based on wood / *SM* Kuhlman // Scientific Bulletin NUBiP Ukraine / Series "Forestry and ornamental plants. - 2011 - Vol. 164, p. 1. - S. 250 - 255.
3. *Kuhlman SM* Nonlinear dynamics of deformation and fracture of composite materials based on wood / *SM* Kuhlman // Scientific Bulletin NUBiP Ukraine / Series "Forestry and ornamental plants. - 2012 - Vol. 171, p. 2. - S. 200 - 207.
4. *Kuhlman SM* Kinetics of long-term strength of composite materials based on wood / SM Kuhlman // Scientific Papers Podolski State Agricultural and Technical University. Special Issue VI to scientific and practical conference "Modern problems of sustainable nature." - Kamenetz-Podolsk, PDATU, 2011. - S. 196 - 206.



*Effect Perekrestnoe the effect termycheskoho building and termoupruhoho the effect, in the field of power and External thermal nahruzok, lead for the occurrence avtokolebanyy dynamycheskoy system. Orthogonality functions lokalnыh the inner tense and lokalnыh the inner deformation amplitudes Increase javljaetsja prychynoy s oscillations. What to bring for your Queue udvoenyyu frequency oscillations lokalnoy temperature. Byfurkatsyya dynamycheskoy system,*

*udvoenyya Due to transfer system in the area of sustainable predelnoho cycle, attractor.*

***Kompozytsyonnыe materials, nonlinear dynamics, Durability, oscillator, attractor, avtokolebanyya.***

*Cross impact effect of thermal expansion and thermoelastic effect in the field of external heat and power loads, leads to oscillations of the dynamical system. Orthogonality of local internal stresses and local internal strain causes an increase of the amplitudes of the oscillations. Which in turn leads to a doubling of the frequency of the local temperature fluctuations. Bifurcation of the dynamical system, because the doubling system into the region of the stable limit cycle attractor.*

***Composite materials, nonlinear dynamics, durability, oscillator attractor oscillations.***