IMPACT: International Journal of Computational Sciences and Information Technology (IMPACT: IJCSIT)
Vol. 1, Issue 1, Dec 2015, 13- 20

ALGORITHM FOR CALCULATION OF PARAMETERS OF THE BEARING ELEMENTS OF OIL HEATING INSTALLATIONS

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ABSTRACT

Load-bearing elements of oil heating installation in the shape of rods, as well as load-bearing elements of gas-generator plants, internal combustion engines, flight-type engines, and hydrogen engines work in a complex thermal and force field. To ensure the reliability of these installations, it is necessary to provide the load-bearing structure elements with thermal strength. Many load-bearing structure elements have the shape of a rod with limited length of constant and variable cross section. Depending on the use of these elements, local surfaces may be partially isolated locally. In addition, these load-bearing elements are under the simultaneous effect of different sources of heat and axial force. To investigate thermal strength parameters of these load-bearing elements operating in the complex thermal and force field, it is necessary to develop specific methods; these methods cannot be analytical, because operative factors involved are too diverse and heterogeneous. Therefore, it is necessary to develop a universal software package, that allows exploration of the thermal strength of these load-bearing elements based on the availability of heterogeneous heat sources and partial local thermal insulation. In addition, this complex of programs should be based on relevant computational algorithms and methods. But these algorithms and methods must rely on fundamental law of energy conservation. Therefore, the development of computational algorithms, methods and software package contribute to investigate numerically condition of load-bearing elements in the shape of rods with a limited length of constant and variable cross section considering the availability of heterogeneous heat sources is an urgent problem.

KEYWORDS: The Temperature, The Rod, The Thermal Energy, The Algorithm

INTRODUCTION

Development of mathematical model of the universal computing algorithm based on minimization of functionality of total thermal energy on nodal values of temperature and then after the construction of the field distribution of temperature, potential-energy functional thermo-elastic deformation rod of variable cross-sectional nodal displacement values. On them construction the deformation field and stress. The article deals with the mathematical model, computational algorithm and complex applications on object-oriented programming language allow to take into account all the actions under consideration by the rod, variable cross-section, the local temperature, heat flow, heat transfer and partial heat insulation.

For achievement of a goal, the following is considered

- On the basis of procedure of minimization of total thermal energy to construct a mathematical model of the steady temperature field distribution along the rod of variable cross-section and of limited length, taking into account the simultaneous presence of partial insulation, local temperature, thermal a stream, heat exchange;
- On the basis of procedure of minimizing the functional potential energy to construct a mathematical model of thermo-mechanical state variable cross-section of limited length, taking into account the simultaneous presence of partial insulation, local temperature, thermal a stream and heat exchange;
- The corresponding computational algorithm for minimizing the potential energy of deformation thermo-elastic rod of variable cross-section and length limited by nodal displacement values with regard to the relevant boundary conditions;
- The development of the corresponding computational algorithms and creation of complex applications in an object - oriented programming language, as well as solving problems of thermal stress state partially thermally insulated rod of variable cross-section and of limited length, rigidly clamped at the two ends of the impact of local temperature, a thermal stream and heat exchange;
- The received results need to experiment, and the results received analytically compared with the end result computed software package.

For a more detailed explanation of the problem shown below compute using the software package We write the execution algorithm problem.

SAMPLES AND ANALYTICAL METHODS

Consider the two ends of the rod clamped limited length, cross-section which varies along its length and a circle. The radius of the cross section depends linearly on the coordinates. The left end of the radius is denoted by r_0, the right end through r_L, and the length of the rod through *L*. Then the radius depends on the coordinates as follows [1; 6]

$$r = \frac{r_L - r_0}{L} \cdot x + r_0 \qquad (1)$$

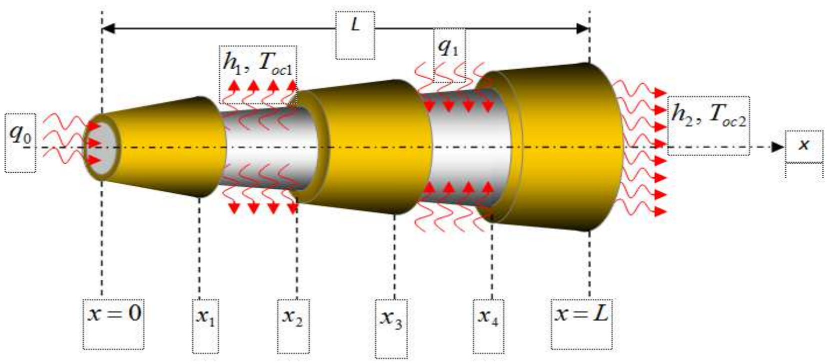


Figure 1: Calculation Scheme of the Problem

Entrapment of the left end set temperature $T(x=0)=T_1$, on the right $T(x=L)=T_{2n+1}$. Lateral surfaces of sites $(0 \le x \le x_1)$, $(x_2 \le x \le x_3)$ and $(x_4 \le x \le x_L)$ insulated rod [7]. Through the lateral surface area $(x_1 \le x \le x_2)$ a heat exchange with the environment. The coefficient of heat exchange *h*, ambient temperature is T_{co}. On the lateral surface area $(x_3 \le x \le x_4)$ is let down by a constant heat flux intensity *q*. Requires numerically investigate the influence of the value $T_0 \in [(-150\ ^{\circ}C) \div (+150\ ^{\circ}C)]$.

In the field of the temperature distribution $(T=T(x))$, of the elastic displacement $(u=u(x))$, and the deformation of component $(\varepsilon_x=\varepsilon_x(x);\ \varepsilon_T=\varepsilon_T(x);\ \varepsilon=\varepsilon(x))$ and stress $(\sigma_x=\sigma_x(x);\ \sigma_T=\sigma_T(x);\ \sigma=\sigma(x))$. In order to develop a mathematical model of the temperature distribution of the field along the length of the considered part of a thermally insulated rod of limited length, it is sampled using quadratic elements with three nodes. It will be general number of elements *n*. Then the total number of nodes will be $(2n+1)$. When this discrimination is conducted in such a manner that the boundaries of the elements will coincide with the boundaries of a heat-insulated part of the rod. Further for each item is written functional expression that characterizes its total thermal energy. In particular, for elements belonging to the rod portion have insulated [2; 8]

$$I_i=\int_{V_i}\frac{K_{xx}}{2}\left(\frac{\partial T}{\partial x}\right)^2 dV,\quad (i=1,2,...) \tag{2}$$

where V_i - volume *i* element.

The general expression of functional full thermal energy for the considered partially thermally insulated rod of variable cross-section based on the availability of local temperatures, heat flow and heat exchange [3; 9]

$$I=\sum_{t=1}^{n} I_t \tag{3}$$

Minimizing this functional at nodal temperatures of the mathematical model of temperature distribution field along the length of the test rod in the form of a resolution of the system of linear algebraic equations

$$\frac{\partial I}{\partial T_t}=0,\quad (t=2,3,...,2n) \tag{4}$$

Since T_1 and T_{2n+1} are considered as given, then the number of equations in the system (4) is equal to $(2n+1)$.

After constructing the field of temperature distribution along the length of the rod, a mathematical model of the field distributions of the elastic displacement and components of deformation and stress. For this investigated is discredited rod $\left(N=\frac{n}{2}\right)$ quadratic elements with three nodes. Then for each element expression of functionality of potential energy of elastic deformation, which has the form

$$\Pi_i = \int_{V_i} \frac{\sigma_x \varepsilon_x}{2} dV - \int_{V_i} \alpha E T(x) dV, \quad (i=1, 2, ..., N) \qquad 5)$$

where V_i - volume *i*- element, $u=u(x)$ field distributions of the elastic moving, $\varepsilon_x = \frac{\partial u}{\partial x}$ - field distribution of the elastic component of deformation, $\sigma_x = E\varepsilon_x = E \cdot \frac{\partial u}{\partial x}$ field distribution of the elastic component of the voltage, *E* elastic modulus of the rod material, α coefficient of thermal expansion of the rod material, $T=T(x)$ - field temperature distribution determined by solving the system (4).

For consideration of the rod as a whole, the expression of the potential energy of the elastic deformation is as follows:

$$\Pi = \sum_{i=1}^{N} \Pi_i \qquad (6)$$

Minimizing the latest on key values of the elastic displacement mathematical model of the elastic displacement distribution along the length of the test rod in the form of the following system of linear algebraic equations [4; 10]

$$\frac{\partial \Pi}{\partial u_i} = 0, \quad (i=1, 2, ..., (2N+1)) \qquad (7)$$

Solving this system is determined by the distribution of the elastic displacement field $u=u(x)$ along the length of the rod under consideration. On them corresponding field components distribution deformations and stresses as follows [5]

$$\varepsilon_x = \frac{\partial u}{\partial x}; \ \varepsilon_T = -\alpha T(x); \ \varepsilon = \varepsilon_x + \varepsilon_T \qquad (8)$$

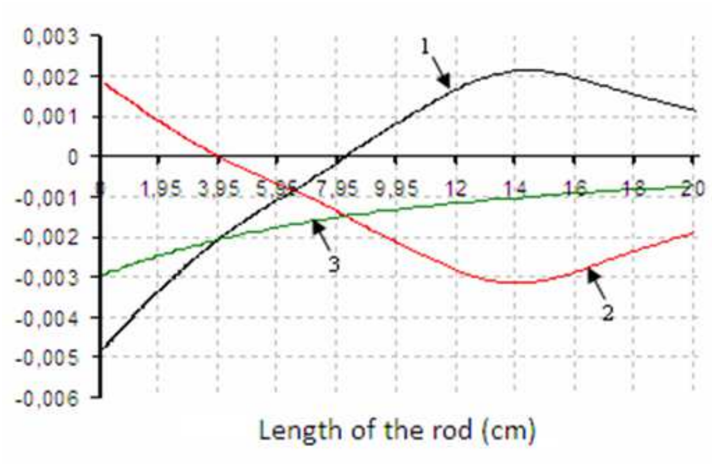
$$\sigma_x = E\varepsilon_x; \ \sigma_T = E\varepsilon_T; \ \sigma = (\sigma_x + \sigma_T) \qquad (9)$$

RESULTS AND DISCUSSIONS

For numerical studies for the initial data we use the following:

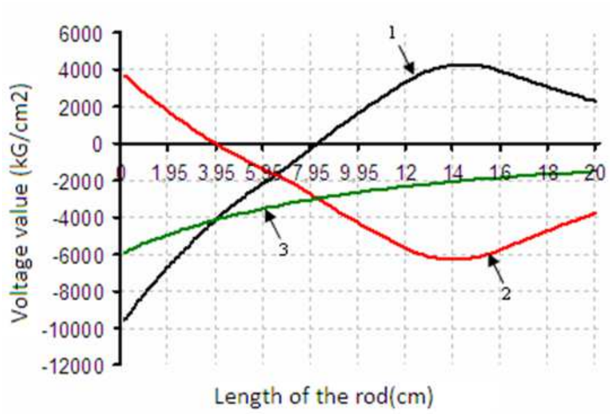
$L = 20\,(см)$, $r_0 = 1\,(см)$, $r_\ell = 2\,(см)$, $n = 200$, $N = \frac{n}{2} = 100$, $q = -1000\,(Вт/см^2)$, $K_{xx} = 100\,(Вт/(см{\cdot}^\circ C))$, $h = 10\,(Вт/(см^2{\cdot}^\circ C))$, $T_{co} = 40\,(^\circ C)$, $T_{401} = 150\,(^\circ C)$, and vary the value of $T_1 \in [(-150\ ^\circ C) \div (+150\ ^\circ C)]$ with a step $(-50\ ^\circ C)$.

Consider this example, except to T_1, the value of all the parameters are fixed. The diagrams in Figures.



$1-\varepsilon_x;\ 2-\varepsilon_T;\ 3-\varepsilon = \varepsilon_x + \varepsilon_T$

Figure 2: Field Distribution Component Deformations At $T(x=0) = T_1 = -150\ (^\circ C)$



$1-\sigma_x;\ 2-\sigma_T;\ 3-\sigma = \sigma_x + \sigma_T$

Figure 3: Field Distribution of Stress Components at $T(x=0) = T_1 = -150\ (^\circ C)$

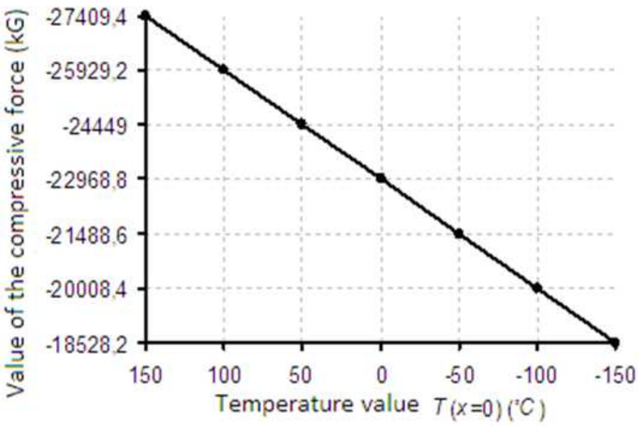


Figure 4: The Relation Between $T(x=0)$ and *R*

Table1: Effect of value $T(x=0)=T_1$ on the value of the compressive force arising R

№ P/P	T_1 $(^{\circ}C)$	T_{max} $(^{\circ}C)$	**Coord. Section (*Cm*)**	u_{max} **(*Cm*)**	**Coord. Section (*Cm*)**	**Compressing** $\varepsilon_x(\max)$	**Coord. Section (*Cm*)**	$\varepsilon_x(\max)$	**Coord. Section (*Cm*)**
1	150	264,153	$x=13,75$	-0,0135704	$x=8,9$	-0,0024920	$x=0,15$	0,0017948	$x=14,45$
2	100	262,089	$x=13,80$	-0,0142153	$x=8,8$	-0,0028639	$x=0,15$	0,0018518	$x=14,45$
3	50	260,034	$x=13,85$	-0,0148657	$x=8,7$	-0,0032431	$x=0,05$	0,0019087	$x=14,45$
4	0	257,993	$x=13,85$	-0,0155244	$x=8,6$	-0,0036275	$x=0,05$	0,0019657	$x=14,45$
5	-50	255,968	$x=13,90$	-0,0161891	$x=8,4$	-0,0040118	$x=0,05$	0,0020226	$x=14,45$
6	-100	253,952	$x=13,95$	-0,0168614	$x=8,3$	-0,0043962	$x=0,05$	0,0020795	$x=14,45$
7	-150	251,950	$x=13,95$	-0,0175417	$x=8,2$	-0,0047805	$x=0,05$	0,0021365	$x=14,45$

Compressing $\varepsilon_T(\max)$	**Coord. Section (*Cm*)**	ε (max)	**Coord. Section (*Cm*)**	**Compres. Forces** R_i **(Kg)**	**%**
-0,0033019	$x=13,75$	-0,0043406	$x=0,05$	-27409,4769	100
-0,0032759	$x=13,85$	-0,0041062	$x=0,05$	-25929,2052	94,6
-0,0032504	$x=13,85$	-0,0038718	$x=0,05$	-24448,9304	89,2
-0,0032249	$x=13,85$	-0,0036374	$x=0,05$	-22968,6555	83,8
-0,0031994	$x=13,95$	-0,0034029	$x=0,05$	-21488,3838	78,4
-0,0031744	$x=13,95$	-0,0031685	$x=0,05$	-20008,1089	72,9
-0,0031494	$x=13,95$	-0,0029341	$x=0,05$	-18527,8372	67,6

CONCLUSIONS

It should be noted that the developed model based on the energy conservation law is universal in the sense in dealing with the class of similar challenges. Also obtained numerical solutions are highly accurate. The developed mathematical model , computational algorithm and complex applications on object- oriented programming language to accommodate all existing at the reporting rod of variable cross -section , the local temperature , heat flow, heat transfer and partial heat insulation . As well as drawing the corresponding computational algorithms and the creation of complex applications in an object - oriented programming language.

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