636. Dynamics of a thermal vibro-transporter

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Abstract. Numerical model for the investigation of dynamics of a thermal vibro-transporter is proposed. The model is based on the one dimensional linear bar finite element and the stopping mechanism is being taken into account by the penalty method. Results of performed calculations of vibro-transportation are presented. From the presented results the effect of thermal vibro-transportation is clearly seen.

Keywords: vibromotor, thermal motor, vibro-transporter, finite elements, thermal load, numerical integration, stopping mechanism, penalty method.

Introduction

Numerical model for the investigation of dynamics of a thermal vibro-transporter is proposed on the basis of the material presented in [1, 2, 3]. The model is based on the one dimensional linear bar finite element. Excitation is taken into account assuming the temperature distribution in the bar to be given and using the thermal load vector. Numerical integration of the equations is performed. The stopping mechanism is being taken into account by the penalty method. Results of performed calculations are presented.

There are a number of vibromotors [4 - 11] which find wide practical applications. It is expected that the proposed thermal motor will find useful application in engineering.

Numerical model of the thermal vibro-transporter

The analyzed bar is assumed to be in the direction of the *x* axis of coordinates from $-T_x/2$ to $T_x/2$, here T_x is the length of a periodic part of the structure. The only variable is the longitudinal displacement of the bar *u*. The displacement of the first node is assumed to be equal to the displacement of the last node.

The mass matrix has the form:

$$[M]=\int[N]^T\rho h[N]dx, \qquad (1)$$

where ρ is the density of the material of the bar, h is the thickness of the bar and:

$$[N]=[N_1 \quad N_2], \qquad (2)$$

where N_i are the linear shape functions of the one dimensional finite element.

The stiffness matrix has the form:

$$[K]=\int[B]^T\frac{E}{1-\nu^2}h[B]dx, \qquad (3)$$

where E is the modulus of elasticity of the bar, ν is the Poisson's ratio of the bar and:

$$[B]=\begin{bmatrix} \frac{dN_1}{dx} & \frac{dN_2}{dx} \end{bmatrix}. \tag{4}$$

The loading vector has the form:

$$\{F\}=\int [B]^T \frac{E}{1-\nu^2} h\bar{\alpha}T dx, \tag{5}$$

where $\bar{\alpha}$ is the coefficient of thermal expansion and T is the temperature. The variation of temperature is assumed to be given as:

$$T=\bar{T}\sin\omega t \sin 2\pi \frac{x+u}{T_x}, \tag{6}$$

where $\bar{T}$ is the amplitude of temperature variation, ω is the frequency of temperature variation and t is the time variable.

The damping matrix has the form:

$$[C]=\alpha[M]+\beta[K], \tag{7}$$

where α is the coefficient of external damping and β is the coefficient of internal damping, except for the case described further the damping matrix takes into account the stopping mechanism and is more complicated. If the following condition is satisfied:

$$x_1+u_1 \le 0 < x_2+u_2, \tag{8}$$

where x_i are the nodal coordinates of the finite element and u_i are the nodal displacements of the finite element, then the following shape functions are calculated:

$$\bar{N}_1=\frac{x_2+u_2}{x_2+u_2-x_1-u_1}, \tag{9}$$

$$\bar{N}_2=\frac{-x_1-u_1}{x_2+u_2-x_1-u_1}. \tag{10}$$

They are represented as a row vector of shape functions:

$$[\bar{N}]=[\bar{N}_1 \quad \bar{N}_2]. \tag{11}$$

The displacement is calculated as:

$$\bar{u}=[\bar{N}]\begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix}. \tag{12}$$

If the following condition is satisfied:

$$\bar{u}<\bar{u}_p, \tag{13}$$

where $\bar{u}_p$ denotes the value of $\bar{u}$ for the previous moment of time (from the previous integration step), then the damping matrix has the form:

$$[C]=\alpha[M]+\beta[K]+[\bar{N}]^T \lambda [\bar{N}], \tag{14}$$

where λ is the penalty parameter of the stopping mechanism.

Results of analysis of the thermal vibro-transporter

The displacements during the first period of excitation are presented in Fig. 1. The displacements during the first two periods of excitation are presented in Fig. 2. The displacements during the first four periods of excitation are presented in Fig. 3.

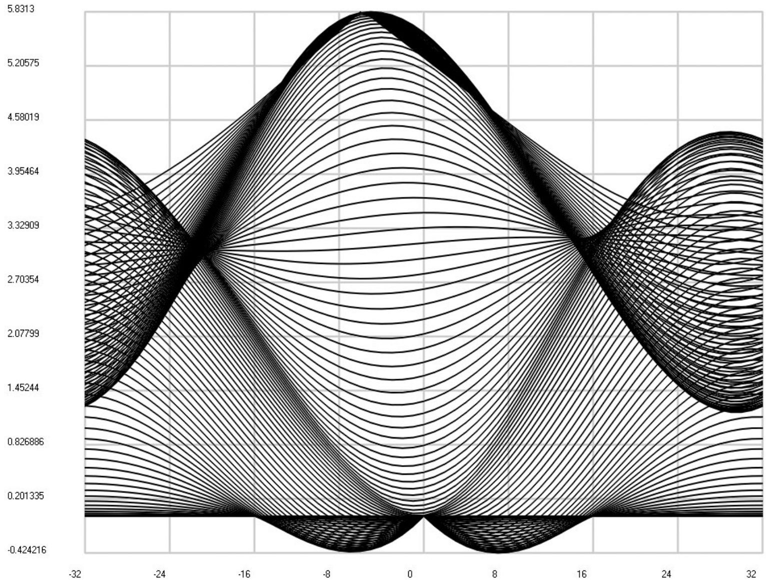

Fig. 1. Displacements during the first period of excitation

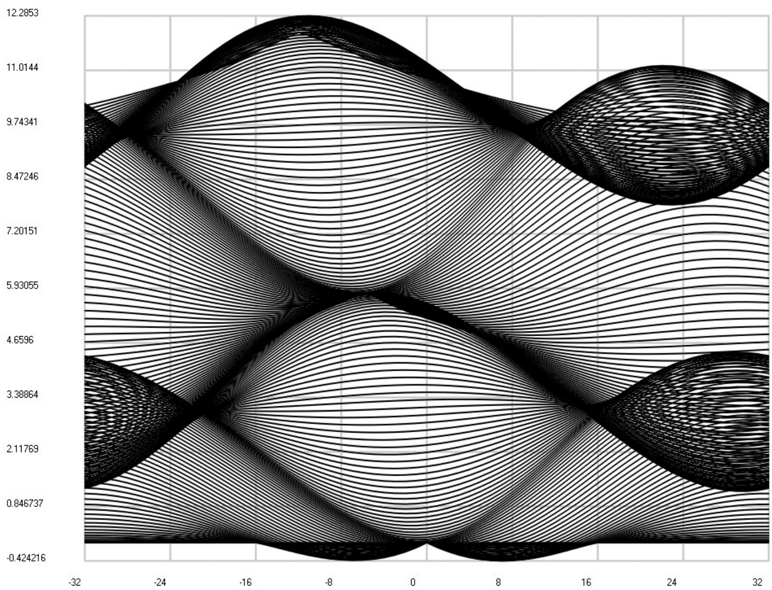

Fig. 2. Displacements during the first two periods of excitation

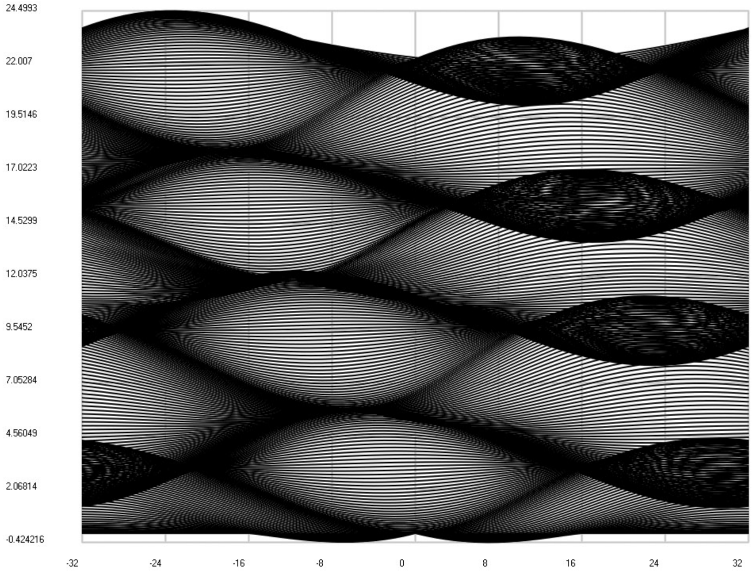

Fig. 3. Displacements during the first four periods of excitation

From the presented results the effect of thermal vibro-transportation is clearly seen.

Conclusions

Investigation of dynamics of a thermal vibro-transporter is performed. Excitation is taken into account by using the thermal load vector. The operation of the stopping mechanism is analyzed. Results of performed calculations graphically showing the displacements of the structure during the several first periods of excitation are presented. From the obtained results the effect of thermal vibro-transportation is clearly seen.

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