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DYNAMIC STRENGTH AND STIFFNESS ASSESSMENT OF CIRCUIT CARDS WITH RESPECT TO THEIR GEOMETRIC PARAMETERS

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1. Introduction

The main bearing parts in electronic packages introduced by printed circuit boards (PCBs), case walls and other structural elements subjected to vibration and shocks while their operation transmit dynamic forces to electronic components they mechanically support. Numerous publications on dynamic forces analysis in engineering [1–3] and in electronic equipment [4, 5] subjected to vibrations, vibration reduction and suppression design [6, 7] indicate insufficient strength and reliability of modern equipment exposed to variety of impacts such as mechanical shocks and vibration. The research conducted before [8, 9] demonstrates that dynamic forces may increase manifold to damage parts and components especially at resonant oscillations.

2. Mathematical model of the oscillatory system

The current research represents mathematical modeling aimed at dynamic force analysis of printed circuit boards in order to eliminate or reduce dynamic stresses to an acceptable level and to provide strength and reliability in design of printed circuit boards subjected to vibration. The represented model describes a printed circuit board as unique oscillatory system simulated as prismatic beam with single concentrated mass set on two oscillating supports. Here PCBs simulation considers cylindrical bending as set of beam-strips with rectangular cross-sections, thus their stress and strain calculation can be performed by conventional methods applied in civil engineering and strength of materials [10]. Harmonic oscillations are generated by the shaker in vertical direction. Taking into account the non-inertial frame of reference the solution to differential equation of motion is identical to [8] and expressed by:

$$f(t)=\frac{Z_0\omega^2}{\sqrt{\left(\omega_0{}^2-\omega^2\right)^2+\left(2n\omega\right)^2}}\sin\left(\omega t-\operatorname{arcctg}\left(\frac{\omega_0{}^2-\omega^2}{2n\omega}\right)\right), \quad (1)$$

where Z_0 – generated oscillation amplitude; ω – angular frequency; ω_0 – natural frequency; t – time; n – damping.

The total displacement of the mass is produced by the net force P, which represents the common action of dynamic elastic force and static force of gravity from the concentrated mass m:

$$P=mZ_0\omega^2\cdot\frac{1}{\sqrt{\left(1-\frac{\omega^2}{\omega_0{}^2}\right)^2+\frac{4n^2\omega^2}{\omega_0{}^4}}}+mg, \quad (2)$$

or in brief notation: f(t) = A sin(ωt – φ) and $P=P_0k_{dyn}+P_{st}$, where $P_0=mZ_0\omega^2$ – amplitude of dynamic force; k_{dyn} – dynamic coefficient; P_{st} – static force of gravity.

Strength assessment is performed by maximal total normal stress defined by:

$$\sigma^t_{max}=\left[Z_0\omega^2m\frac{1}{\sqrt{\left(1-\frac{\omega^2}{\omega_0{}^2}\right)^2+\frac{4n^2\omega^2}{\omega_0{}^4}}}+mg\right]\times\frac{6x}{bh^2}\left(1-\frac{x}{l}\right), \quad (3)$$

where l – length, b – width and h – thickness of the beam; x – distance to m from nearest support (linear coordinate).

Stiffness assessment is proposed to perform by the value of maximal displacements (deflections) of the beam, which without significant errors under 3 % may be considered as deflection in the middle point of the beam:

$$\sigma^{t}_{max} \approx \frac{P\left(3xl^2 - 4x^3\right)}{48EJ}. \quad (4)$$

3. Analysis of obtained functions

Functional dependences revealed for maximal total normal stress and deflection with respect to geometric parameters of PCB have provided recommendations for their specification, which ensure strength and stiffness of printed circuit boards subjected to dynamic forces.

Analysis of maximal total normal stress function of linear coordinate of the concentrated mass, when dynamic force amplitude P_0 is constant, what is provided by its constant acceleration, in resonance conditions, has revealed that neglecting static gravity force being considerably lower than dynamic elastic force then maximal stress does not depend on linear coordinate of the concentrated mass and may be used in engineering calculations with no respect to linear coordinate of the concentrated mass:

$$\sigma^{t}_{max} = P_0 \cdot \frac{1}{2n}\sqrt{\frac{3EJ}{m_{ç}l}} \cdot \frac{1}{W_{îñ}}. \quad (5)$$

Comparative analysis of dependences obtained by mathematical modeling and MatLab simulation of PCB oscillations demonstrates their similarity and negligible deviations in absolute values of their parameters, such as resonance frequency, maximal total normal stress, deflection, threshold limit values of the length and linear coordinate of the concentrated mass of PCB, and may be considered as verification for the mathematical model.

4. Conclusions

Mathematical model for dynamic stress and deformation analysis in printed circuit boards and their dynamic strength and stiffness assessment has been designed with respect to geometric parameters of printed circuit boards and recommendations for their specification have been provided for engineering calculations, which ensure strength and stiffness of printed circuit boards subjected to dynamic forces.

Comparative analysis of dependences obtained by mathematical modeling and MatLab simulation demonstrates similarity and negligible deviations in absolute values of obtained results and may be considered as verification for the mathematical model.

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ВПЛИВ КОНСТРУКТИВНИХ ПАРАМЕТРІВ ПРУЖНО-В'ЯЗКИХ ЕЛЕМЕНТІВ МАШИН БАРАБАННОГО ТИПУ З ГОРИЗОНТАЛЬНОЮ ВІССЮ ОБЕРТАННЯ НА ЇХ ВІБРОАКТИВНІСТЬ

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Питання зниження вібрації, спричиненої обертовими роторами на частоті першої роторної гармоніки (роторної вібрації) відносяться