ISSN 1392-2114 ULTRAGARSAS, Nr.2(55). 2005.

Use of auto vibration for energy transformation

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Introduction

There are many different sources of disturbance in humans surrounding nature (wind, river flow, rough sea, various manufacture processes, intense noise, etc.), which can cause auto vibrations of dynamical systems. These processes can be applied for converting mechanical vibration energy to electrical energy. Results of research in this field [1-3] showed that effective solutions are possible in this field and possibilities of their adjustment are very wide.

System consisting of elastically set plate with auto vibration caused by air flow is investigated in this paper. Small outer disturbance is added in order to synchronize the system's vibration with a needed frequency. Auto vibration's existence zones in parameters' c and q_3 plane are designated in this research. Auto vibrations with dominant first harmonic zones in parameters' f and υ plane are designated in the range around $\upsilon \approx 1$.

Model of the system

Elementary mechanical vibrating system (a plate elastically set to immobile ground) is investigated. It is affected by air (water) flow and auto vibration of the plate is caused in particular conditions. The plate is affected by following forces:

- useful resistance $H\dot{x}$,
- elastic resistance- $\left(k_1 + k_3 x^2\right)x$,
- impact of air flow - $\left(Q_1 - Q_3 \dot{x}^2\right)\dot{x}$,
- auto vibration synchronizing power of outer disturbance $F \cos wt$.

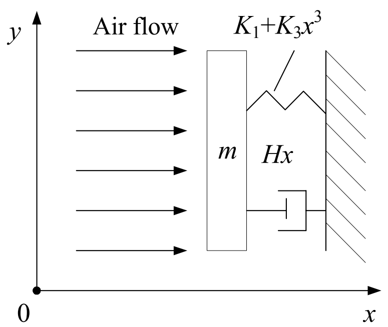


Fig. 1. **Model of the system**

Vibration of the element with mass m is approximately described by the following differential equation:

$$m\ddot{x} + H\dot{x} + \left(k_1 + k_3 x^2\right)x - \left(Q_1 - Q_3 \dot{x}^2\right)\dot{x} = F \cos wt \qquad (1)$$

Here m- mass of the plate; H- coefficient of vibration suppression; k_1, k_3- constituents of tightness coefficient of elastic elements; Q_1, Q_3- coefficients characterizing air (water) flow; F and w- amplitude and frequency of small power of outer disturbance respectively; t- time; $\dot{}=d/dt$.

Purpose of small power of the outer disturbance F is to affect systems vibration in such a way that its frequency would be attracted to the frequency of an electrical network.

The following notations will be used in Eq.1:

$$\frac{k_1}{m} = p^2, \frac{k_3}{m} = p_3^2, \tau = pt, \nu = \frac{w}{p},$$

$$h = \frac{H}{mp}, q_1 = \frac{Q_1}{mp}, q_3 = \frac{pQ_3}{m}, f = \frac{F}{mp^2} = \frac{F}{k_1}, \dot{x} = px', \lambda = \left(\frac{p_3}{p}\right)^2.$$

Then it is transformed to the following form:

$$x'' + \left(h - q_1\right)x' + x + \lambda x^3 + q_3 x'^3 = f \cos \nu\tau . \qquad (2)$$

Eq.2 is a generalized equation of Duffing and Van der Pol.

Analysis of solutions of plate's movement equation

Numerical analysis of Eq.2 was performed by using the Newmark method and MATLAB software. This method is compatible in zone where $\upsilon \approx 1$.

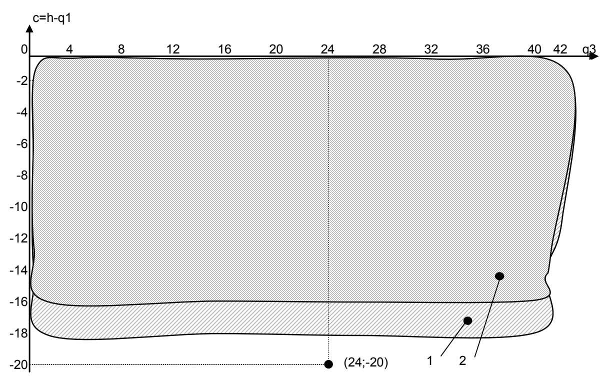


Fig. 2 **Existence zones of auto vibration when** h**=0,1,** λ**=0,5,** υ**=1: 1-** f**=0; 2-** f**=0,1**

Auto vibration's existence zone with a small outer disturbance is smaller than such zone without outer disturbance and fits inside the latter zone.

The zones 1 and 2 of steady auto vibration (Fig. 2) overlap and stretch into infinity in abscissa's direction and in ordinate's direction they stretch until some finite meanings. Using of the outer disturbance narrows the zone of existence of auto vibration. The systems movement character in the plane *x*O*x*' (Fig. 3 and 4) is of the enclosed shape. Only outside the zone of existence besides steady regimes we can notice beginning of a chaotic movement (Fig. 3 a, b, Fig.4 a, and b).

attracting its frequency. Auto vibration's existence zones with dominant first harmonic were designated in resonance zone where $\upsilon \approx 1$. Zone in case f=0,1 is smaller iand fits in zone when f=0.

Newmark method and MATLAB software were used for generalized Duffing ant Van der Pol equation calculation.

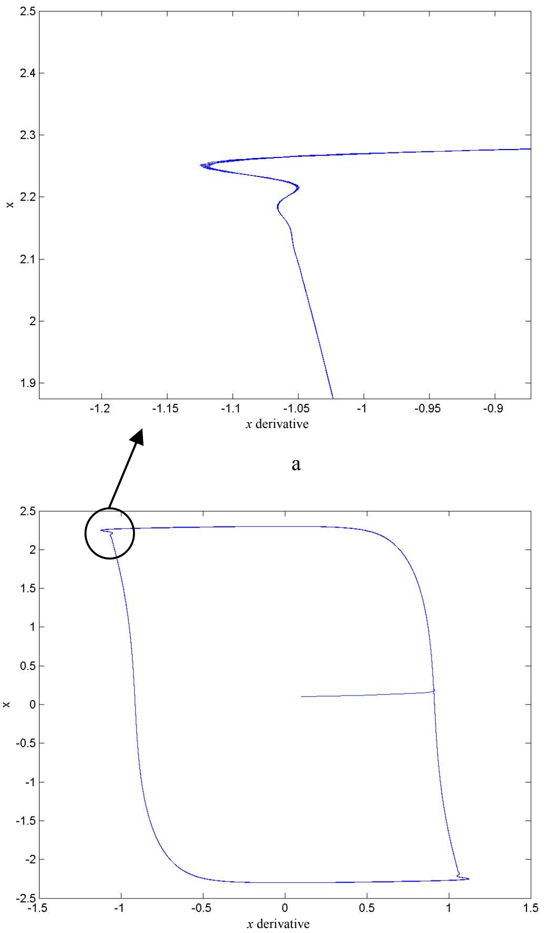


Fig. 3. **Plate's movement character in the plane *x*O*x*' when *h*=0,1, λ=0,5, υ=1: 1- *f*=0; 2- *f*=0. Here q_3=24, *c*=-20**

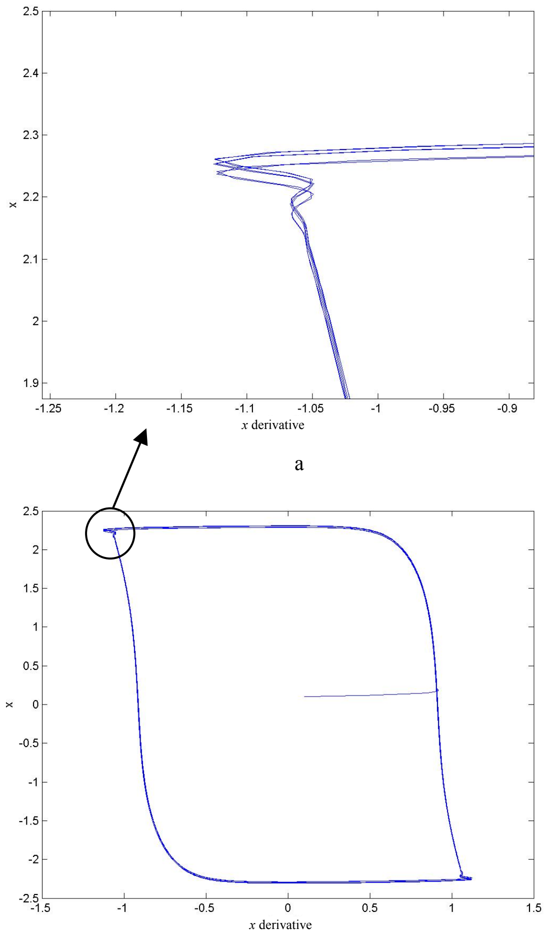


Fig. 4. **Plate's movement character in the plane *x*O*x*' when *h*=0,1, λ=0,5, υ=1: 1- *f*=0; 2- *f*=0,1. Here q_3=24, *c*=-20**

Auto vibration's existence zone where the first harmonic is dominant is significantly smaller in the case when f=0,1 than in the case when f=0 (Fig. 5).

Auto vibration's with dominant the first harmonic existence zones were designated in the resonance range around υ=1 (Fig. 6).

Inside the marked zones the first vibration harmonic is dominant and plate's movement character in the plane *x*O*x*' is elliptic (Fig. 7).

Conclusions

Energy transformation is performed by auto vibration of the plate set with non-linear elasticity. Small outer disturbance is used for auto vibration synchronization by

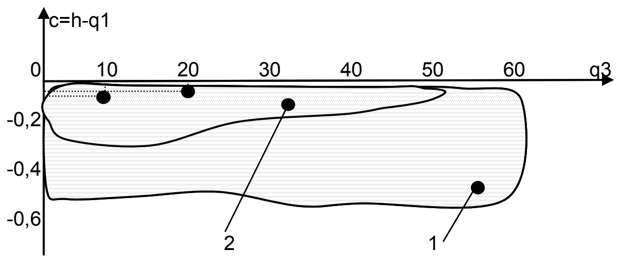
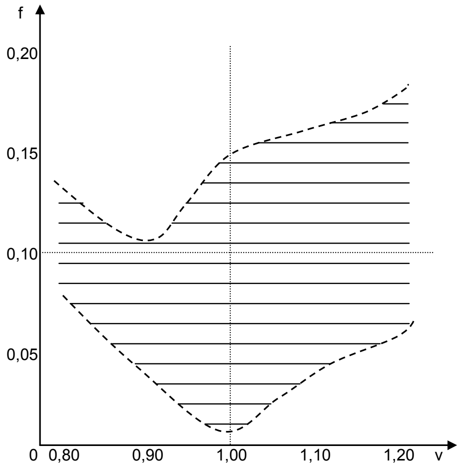
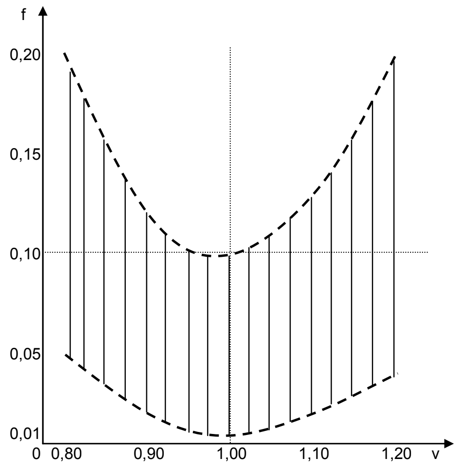


Fig. 5. **Auto vibration existence zones with the dominant first harmonic when *h*=0,1, λ=0,5, υ=1: 1- *f*=0; 2- *f*=0,1**



a



b

Fig. 6. **Auto vibration's with dominant first harmonic existence zones when *h*=0,1, *λ*=0,5, *υ*=1: a) q_3=20, *c*=-0,05; b) q_3=10, *c*=-0,1**

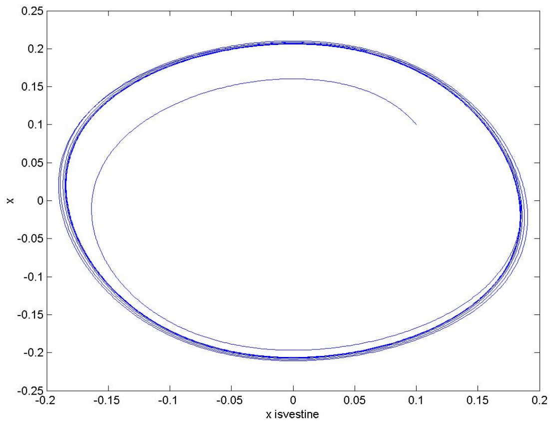


Fig. 7. **Plate's movement character in the plane *x*O*x*' when *h*=0,1, *λ*=0,5, *υ*=0,9, *f*=0,05. Here q_3=24, *c*=-20**

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Autovirpesių naudojimas energijai transformuoti

Reziumė

Energijai transformuoti naudojami tampriai įtvirtintos plokštelės autovirpesiai. Jiems sinchronizuoti naudojamas išorinis sužadinimas, prie kurio dažnio priartinamas plokštelės autovirpesių dažnis. Nustatytos autovirpesių buvimo zonos parametrų *c* ir q_3 plokštumoje. Kai naudojamas išorinis sužadinimas, autovirpesių zona yra mažesnė ir telpa zonoje tuo atveju, kai išorinis sužadinimas nenaudojamas.

Srityje $\upsilon \approx 1$ nustatytos autovirpesių zonos. Čia vyrauja virpesių pirmoji harmonika. Skaičiavimams naudojamas programinis paketas MATLAB, apibendrintosios lygties sprendiniams rasti - Niumarko metodas.

Pateikta spaudai 2005 06 14

DOI: 10.5755/j01.u.55.2.16933