SIMULATION MODELING OF AN ESSENTIALLY NON-LINEAR DYNAMIC SYSTEM

Detelin Vasilev*)

ABSTRACT

The forced vibrations of an essentially non-linear dynamic system are examined. The physical nature of the essential non-linearity is due to the existence of dry friction forces with a changing magnitude. A comparative research of the forced vibrations of the two-mass essentially non-linear system by the presence of dry friction of "harmonics" type is done. A simulation model of a system of differential equations with different parameters is completed from a view of building up an effective vibroprotection system. A board spectrum of a disturbing frequency is searched so that the system completes its functions as a protector against vibrations. Conclusions of the decisions characterizing the influence of the model parameters on the movement of the mechanical system are drawn.

Key words:
simulation modeling, Vibroprotection, Non-linear dynamic system

ABSTRACT

В работе рассматриваются вынужденные колебания существенно нелинейные динамические системы. Физическая природа существенные нелинейности из-за наличия сил сухого трения переменчивая величина. Сделаны сравнительные исследования вынужденных колебаний двух масс существенно нелинейная система наличие сухого трения "гармонического" типа. Имитационная модель системы дифференциальных уравнений с различными параметрами завершена с целью построения эффективной системы виброзащиты. Сделаны выводы решений, характеризующие влияние параметров модели на движение механической системы.

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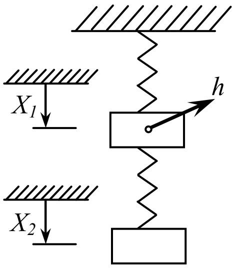
Key words:
Компьютерное моделирование, Виброзащиты, Нелинейная динамическая система

1. DYNAMIC MODELS

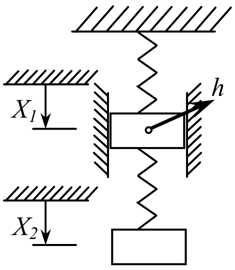
The dynamic dampening of vibrations is a method where additional devices called dynamic dampers are introduced into a vibrating system. They realize the dynamic dampening of vibrations using the principle of redistributing the vibration energy and directing in from the object protected to the damper and the principle of increasing the quantity of scattered energy in the system.

The paper examines the vibrations of the simplest inertia dynamic damper (the so called Fram's damper) in the presence of dry friction of "harmonic" type. Five dynamic models given below are studied. The differential equations describing the oscillations of the corresponding models have the kind of:



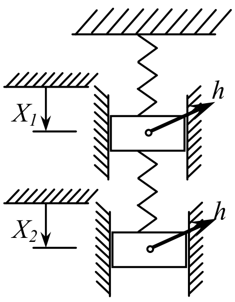
Model-I

$$\begin{cases} \ddot{x}_1 + k_1^2 x_1 - k_2^2 \nu (x_2 - x_1) = h \sin pt, \\ \ddot{x}_2 + k_2^2 (x_2 - x_1) = 0. \end{cases} \quad (1)$$



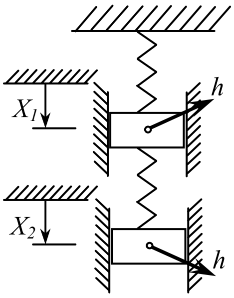
Model-II

$$\begin{cases} \ddot{x}_1 + k_1^2 x_1 - k_2^2 \nu (x_2 - x_1) + f |\cos pt| sign\, \dot{x}_1 = h \sin pt, \\ \ddot{x}_2 + k_2^2 (x_2 - x_1) = 0. \end{cases} \quad (2)$$



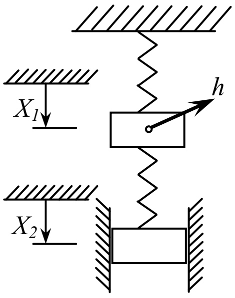
Model-III

$$\begin{cases} \ddot{x}_1 + k_1^2 x_1 - k_2^2 \nu (x_2 - x_1) + f |\cos pt| sign\, \dot{x}_1 = h \sin pt, \\ \ddot{x}_2 + k_2^2 (x_2 - x_1) + f |\cos pt| sign\, \dot{x}_2 = h \sin pt. \end{cases} \quad (3)$$



Model-IV

$$\begin{cases} \ddot{x}_1 + k_1^2 x_1 - k_2^2 \nu (x_2 - x_1) + f |\cos pt| sign\ \dot{x}_1 = h \sin\ pt, \\ \ddot{x}_2 + k_2^2 (x_2 - x_1) + f |\cos pt| sign\ \dot{x}_2 = -h \sin\ pt. \end{cases} \quad (4)$$



Model-V

$$\begin{cases} \ddot{x}_1 + k_1^2 x_1 - k_2^2 \nu (x_2 - x_1) = h \sin\ pt, \\ \ddot{x}_2 + k_2^2 (x_2 - x_1) + f\ sign\ \dot{x}_2 = 0. \end{cases} \quad (5)$$

Here x_1 and x_2 are the generalized co-ordinates corresponding to the dynamic models; k_1 and k_2 are the corresponding natural frequencies; p is the frequency of the disturbing force; $\nu = \frac{m_2}{m_1}$ is the ratio between inertia features of the two masses. Coefficient h characterizes the amplitude of the harmonic disturbing force and coefficient f characterizes the amplitude of the dry friction force, which is of "harmonic" type as it can be seen.

2. RESULTS OF SIMULATIONS

Using MATLAB software package, simulation modeling of the differential equations written above has been done. The integration is based on an explicit Runge-Kutta (4,5) formula, the Domain-Prince pair. The following parameters of the system have been accepted: p=1; h=1; f=0,1; ν=0,5.

Natural frequencies k_1 and k_2 change while carrying out the simulation modeling. A frequency analysis of the oscillations along the two generalized co-ordinates is made for corresponding combination. The distribution of the maximal values of the amplitude special density with different values of k_1 and k_2 (k_1^2 and k_2^2 vary in the range of 10÷40) is given in next ten figures.

Amplitude a_1 | Amplitude a_2

Model - I

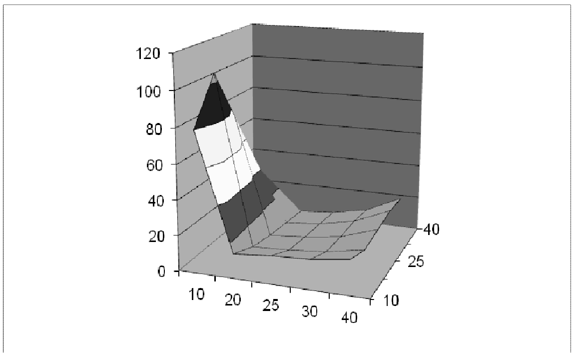


Figure 1

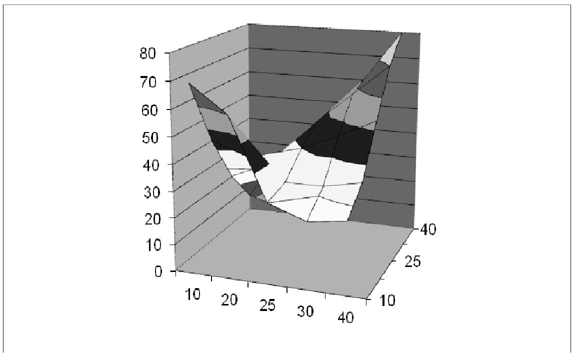


Figure 2

Model - II

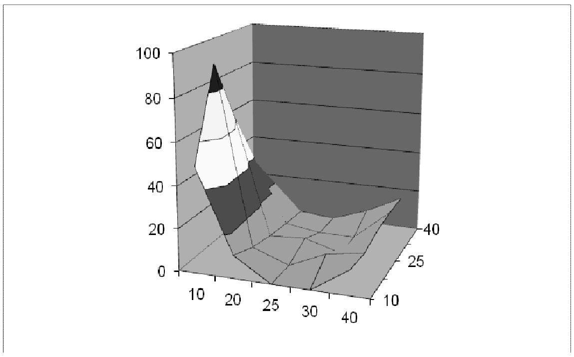


Figure 3

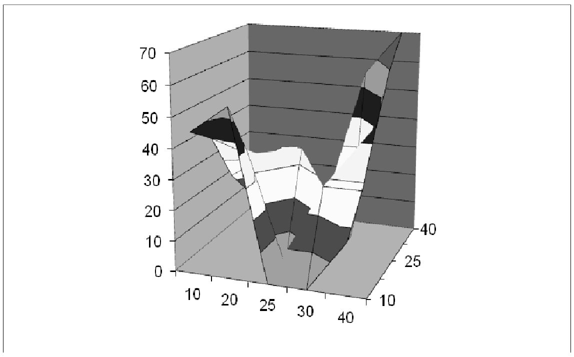


Figure 4

Model - III

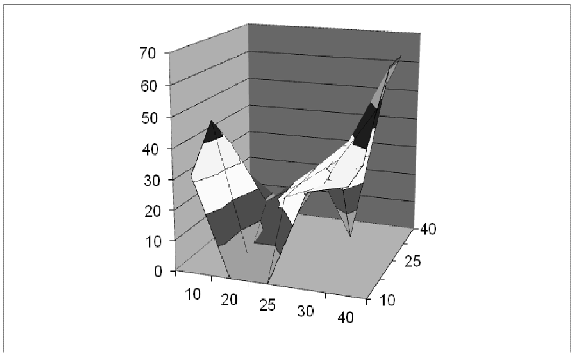
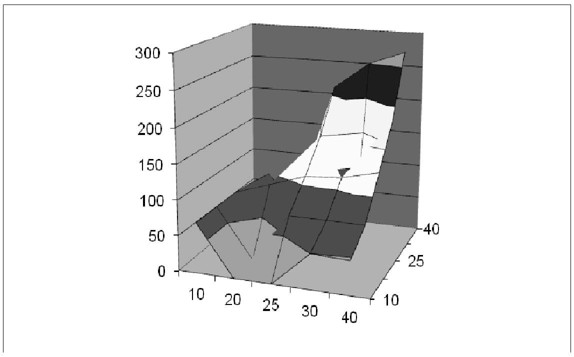


Figure 5



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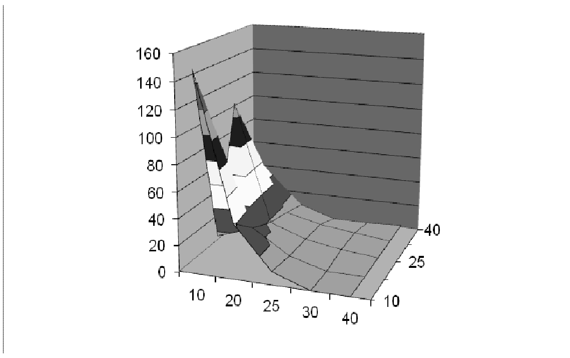
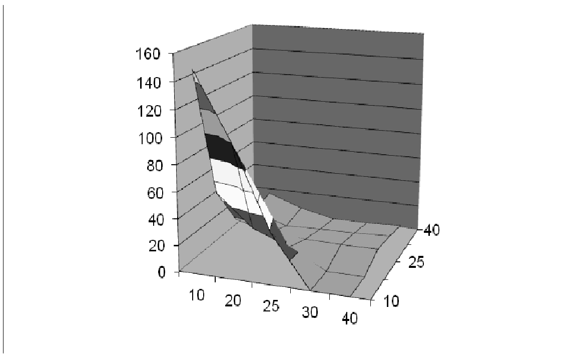
Model - IV





Amplitude a_1 | Amplitude a_2

Figure 7 | *Figure 8*

Model - V

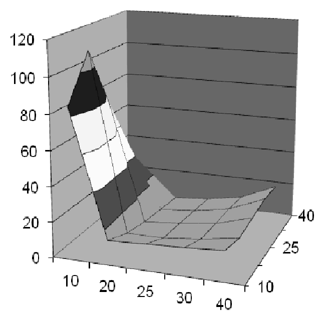


Figure 9

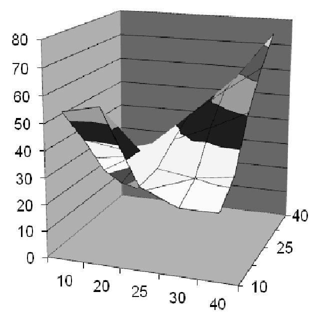


Figure 10

3. CONCLUSIONS

The general analysis of the results shows the following peculiarities:

1. The amplitude of the basic mass a_1 decreases insignificantly in comparison to the basic model-I with switching to the damper with dry friction of “harmonics” type (model-V). Here it is characteristic that the system “locking” has not been watched of the both models as it is of systems with dry friction and a constant magnitude.
2. Zones of system ‘locking” have been watched in the presence of disturbing and resistance forces acting together on both of the masses. These zones are in the area of high natural frequencies with anti-phase disturbances (model-IV) and mainly around the resonance areas with synchronic disturbances (model-III).
3. Without looking for the coefficient of vibroprotection efficiency, we can estimate that a wide area around the resonance is characteristic for model-II: low values of basic mass a_1 amplitude have been watched in that area.

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