# OPTIMIZING TECHNOLOGY-ORIENTED CONSTRUCTIONAL PARAMETERS OF COMPLEX DYNAMIC SYSTEMS

S. M. Novak* DYNASENS Ltd.
POB 408, Kiryat Shmona , 11013, Israel

* Conference Lecturer

## ABSTRACT

*Creating optimal vibrosystems requires sequential* solving of a few problems: selecting the basic pattern of dynamic actions, synthesizing the dynamic active systems, optimizing technological, technical, economic and design parameters.

This approach is illustrated by an example of a high-efficiency vibrosystem synthesized for forming building structure components. When using only one single source to excite oscillations, resonance oscillations are imparted to the product to be formed in the horizontal and vertical planes. In order to obtain versatile and dynamically optimized parameters, a factor is introduced into the differential equations of the motion, accounting for the relationship between the parameters, which determine the frequency characteristics of the system and the parameter variation range. This results in obtaining non-sophisticated mathematical models of the system under investigation, convenient for optimization and for engineering design and calculations as well.

## INTRODUCTION

Dynamic processes and vibration technologies are among the scientific and technical trends, which afford important and fundamental opportunities. However, these processes often get bogged down in their own design, energetic, theoretical, constructional and technological crisis. Almost insuperable difficulties arise when synthesizing and analyzing dynamic systems, which are connected with the design of complicated dynamic systems and with getting over the energetic barrier (use of high-power and high-speed machines and mechanisms), as well as the functional and social barriers linked with the harmful effect of vibrations, noise and exposure to high dynamic and acoustic action.

The most judicious and, in a wide sense, optimized technical systems can be created only by combining the best technical solutions for: a) selection of the basic configuration of the dynamic action to provide the best vibration field for a specific technology; b) synthesizing dynamic active systems, which could create the required vibration field at the best technical and economic capacities; c) optimizing design and technology parameters; d) correlating these solutions into an adequate mathematical model, suitable for optimization .

## DESCRIPTION

The methods for solving the specified problem can be *illustrated*, for example, by an *original* vibration system intended for forming extra long reinforced concrete products. Fig. 1 shows its schematic design.

The frame 1, which accommodates the form 2 with the mix to be compacted, is linked at one end with the plate 4 of the vibration exciter 5 by means of working resilient ties 3, its bearing surface being connected with the resilient working braces 6. The opposite ends of the braces 6 are fastened to the plate of the reaction frame 7, resting on the supporting resilient ties 8. The limiters 9 ensure location of the vibroplatform in the initial position on the foundation 10. The form with the concrete mix is fastened to the frame by means of the devices 11 and 12.

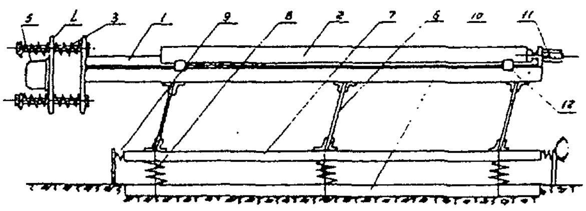

Fig. 1.

The dynamic model represents an oscillating system made up of 3 masses. The basic technologic idea consists in creating an efficient combined vibration field acting simultaneously in the vertical and horizontal planes.

The constructional idea consists in providing oscillations by a single vibrodrive of limited power, the oscillations being oriented in the direction of the greatest stiffness of the form. The vertical component of the oscillations arises due to periodical changes of the parameters of the resilient ties in charge with vertically oriented oscillations.

The dynamic idea consists in the most complete use of the oscillations amplification owing to resonance and by providing the system to a full extent with the properties of its natural dynamic activity

Fig. 2 shows the design diagram for the horizontal oscillations, where: $M_1$- is the resonator mass; $M_2$ - the mass of the form jointly with the mass of the concrete and that of the frame elements rigidly fastened to the form; $M_3$ - the mass of the reactive frame; $C_1$ and $C_2$ - stiffness coefficients of the working resilient ties in the horizontal direction; $C_3$ - stiffness coefficient of the supporting resilient ties in the horizontal direction; $P$ - amplitude value of the exciting force; ω - frequency of forced oscillations; $x_1$; $x_2$; $x_3$ - horizontal displacement of the respective masses.

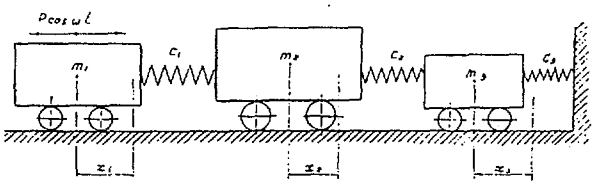

Fig. 2.

It is obvious, that the laws of the system motion in the horizontal direction can be described by a set of differential equations, whose solutions, at no resistance, can be written as follows:

where: $A_1$; $A_2$; $A_3$ - are the oscillation amplitudes which correspond to the masses $M_1$; $M_2$; $M_3$.

Let us choose and define the values of the constructional dynamic parameters.

The partial frequencies:

$$\sqrt{\frac{C_1}{M_1}};\ \sqrt{\frac{C_2}{M_2}};\ \sqrt{\frac{C_3}{M_3}} \tag{4}$$

and the ratios of the oscillating masses:

$$\frac{M_2}{M_1} \text{ and } \frac{M_3}{M_4} \tag{5}$$

can serve the purpose.

Now, let us set some limits for the variation range of the factors involved. Considerations on the efficiency of the exciting horizontal oscillations require the partial frequency $\sqrt{\frac{C_1}{M_1}}$ to approach the forced frequency ω.

We assume: $$\frac{C_1}{M_1} = (0.95 - 0.98)\,\omega^2 \tag{6}$$

Efficient vibroinsulation and minimum oscillation build up on the reactive mass $M_2$ will be obtained at

partial frequencies: $$\sqrt{\frac{C_2}{M_2}} \text{ and } \sqrt{\frac{C_3}{M_3}} \tag{7}$$

Let us assume $$\frac{C_2}{M_2} = (0.1 - 0.2)\,\omega^2 \tag{8}$$

and $$\frac{C_3}{M_3} = (0.1 - 0.2)\,\omega^2 \tag{9}$$

---

$$|A_1| = \frac{P}{M}\bullet\frac{\left(\omega^2-\frac{c_1+c_2}{M_2}\right)\left(\omega^2-\frac{c_2+c_3}{M_3}\right)-\frac{c_2^3}{M_2M_3}}{\left(\omega^2-\frac{c_1}{M_1}\right)\left(\omega^2-\frac{c_1+c_2}{M_2}\right)\left(\omega^2-\frac{c_2+c_3}{M_3}\right)-\left(\omega^2-\frac{c_1}{M_1}\right)\frac{c_2^2}{M_2M_1}-\left(\omega^2-\frac{c_2+c_3}{M_3}\right)\frac{c_1^2}{M_1M_2}} \tag{1}$$

$$|A_2| = \frac{P}{M}\bullet\frac{\frac{c_1}{M_2}\left(\omega^2-\frac{c_2+c_3}{M_3}\right)}{\left(\omega^2-\frac{c_1}{M_1}\right)\left(\omega^2-\frac{c_1+c_2}{M_2}\right)\left(\omega^2-\frac{c_2+c_3}{M_3}\right)-\left(\omega^2-\frac{c_1}{M_1}\right)\frac{c_2^2}{M_2M_1}-\left(\omega^2-\frac{c_2+c_3}{M_3}\right)\frac{c_1^2}{M_1M_2}} \quad (2$$

$$|A_3| = \frac{P}{M}\bullet\frac{\frac{c_1}{M_2}\bullet\frac{c_2}{M_3}}{\left(\omega^2-\frac{c_1}{M_1}\right)\left(\omega^2-\frac{c_1+c_2}{M_2}\right)\left(\omega^2-\frac{c_2+c_3}{M_3}\right)-\left(\omega^2-\frac{c_1}{M_1}\right)\frac{c_2^2}{M_2M_1}-\left(\omega^2-\frac{c_2+c_3}{M_3}\right)\frac{c_1^2}{M_1M_2}} \tag{3}$$

With regard to the conditions of stable operation of the resonance setup we set: $\frac{M_2}{M_1} = 6 \div 10$ (10)

The value $\frac{M_2}{M_3}$ shall be determined by the magnitude of the vertical displacements due to the fact that $M_3$ is the reactor of the mass $M_2$ in the vertical plane.

Let us set $\frac{M_3}{M_2} = 6 \div 10$ (11)

Similar considerations are taken into account when analyzing the vertical oscillations with due regard for the necessity to keep oscillations in the resonance mode in the vertical plane as well.

The method used for selecting and setting parameters (6...11) enables to draw up relatively non-sophisticated mathematical models for complex dynamic systems, these models being convenient for engineering calculations.

For convenience's sake we allot symbols to the parameters (6...11), namely:

$$y_1, y_2, y_3, y_4, y_5 \qquad (12).$$

With the assumed variation limits of the parameters, the set of differential equations (1), (2), (3) can be solved using the factor experiment methodology. After having performed the standard calculation procedures based on type $2^{5-2}$ planning, we obtain the regression equations to be used for determining the amplitude of the oscillations, which can be written in codes in the following way:

$$|A_1| = \frac{P}{M_1\omega^2}(13.92 - 7.4\,y_1 - 6.47\,y_2 - 1.03\,y_3 - 7.71\,y_4 + 1.22\,y_5 + 1.16\,y_2 y_3 - 1.09\,y_1 y_2 y_3); \qquad (13)$$

$$|A_2| = \frac{P}{M_1\omega^2}(1.99 - 0.85\,y_1 - 0.59\,y_2 - 0.11\,y_3 + 0.58\,y_4 + 0.13\,y_5 + 0.14\,y_1 y_2 - 0.15\,y_1 y_2 y_3); \qquad (14)$$

$$|A_3| = \frac{P}{M_1\omega^2}(0.04 - 0.02\,y_1 - 0.001\,y_2 + 0.01\,y_3 + 0.01\,y_4 - 0.01\,y_5 - 0.04\,y_1 y_2 + 0.001\,y_1 y_2 y_3). \qquad (15)$$

To bring the equations (13), (14), (15) to the dimensional form, one should divide the equations coefficients by the variation range of the respective independent variables.

Now, the obtained formulae permit of calculating the values of the oscillation amplitudes by substituting the values of the natural parameters into the formulae, either counting off from the experiment planning center, or substituting the absolute values of the variables with an appropriate writing.

Getting to equations like (13), (14), and (15) enables not only to solve dynamic systems with three or more degrees of freedom just by engineering methods (which was impossible up to now), but to obtain optimization models as well, suitable for dynamic systems analysis and synthesis.

## REFERENCES

William T. Thompson. Vibration Theory and Applications. London. GEORGE ALLEN & UNWIN LTD. RUSKIN HOUSE . MUSEUM STREET