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Optimizing Vibrations Dynamic Absorber (II)

Tănase Dinu

Universitatea Petrol-Gaze din Ploiesti, Bd. Bucuresti 39, Ploiesti
e-mail: tdinu@mail.upg-ploiesti. ro

Abstract

The two papers present a general algorithm for determining the dynamic response of a structure with any type of damping, based on the Galerkin method. The elaborated algorithms are transposed into computer programmes. The paper presents a new method for determining the parameters of dynamic absorbers of vibrations, using a C.R.D. programme.

Key words: *pulsations, damping, simple dynamic absorber, inertial matrix, matrix of rigidity, disturbance force, residue*

Introduction

The paper follows the previous article.

Solution

If the primary system does not have a dynamic absorber attached, then, the system is a one-degree-of-freedom, with no damping. The dynamic reaction can be deduced with the help of the results of the general theory, where the disturbance force is $F(t) = 30 \cdot \cos(\omega \cdot t)$.

The specific pulsation of the system is $p = \sqrt{\frac{20000}{50}} = 20 \cdot s^{-1}$, and the general solution is $\eta(t) = \frac{30}{20000 - 50 \cdot \omega^2}(\cos(\omega \cdot t) - \cos(p \cdot t))$. The amplitude of the movement of the mass m depends on the pulsation of the disturbance force ω.

If $\omega \to p$, then these amplitudes grow towards infinite. As it is required for the vibrations to be smaller in amplitude than 8 *mm*, then we must introduce a dynamic absorber with damping to the system to answer all the requirements, regardless of the pulsation of the disturbance force. According to (14) and (15) we calculate the transmissibility value:

$T = \left| \frac{k \cdot x_1}{F_1} \right| = \frac{20000 \cdot 8 \cdot 10^{-3}}{30} = 5{,}33$, and using (19) we obtain the mass ratio $\mu = \frac{T^2 - 1}{T^2 + 1} = 0{,}932$. As $\mu = \frac{m}{m + m_a}$ then the auxiliary mass of the dynamic absorber is

$m_a = \dfrac{m \cdot (1-\mu)}{\mu} = 3{,}644 Kg$. The ratio of the specific pulsations n is determined by (19) $n = \sqrt{\mu} = 0{,}9654$, and the elastic constant of the dynamic absorber will be $k_a = k \cdot (1-\mu) \cdot \mu = 1267{,}52 \cdot N/m$.

The average value of the damping coefficient can be determined with the relation

$$\gamma_{aom} = \sqrt{\frac{3 \cdot \mu \cdot (1-\mu)}{2}} = 0{,}3083 .$$

The damping constant of the dynamic absorber c_a will be given by the relation

$$\gamma_a = \frac{c_a}{m_a \cdot P_0}, \text{ which means :}$$

$$c_a = \gamma_{aom} \cdot m_a \cdot \sqrt{\frac{k}{m + m_a}} = 21{,}7 \cdot \frac{N \cdot s}{m} . \frac{N \cdot s}{m}$$

In conclusion, the optimal harmonization of the absorber for an amplitude smaller than 8 *mm* corresponds to the following auxiliary parameters:

$$m_a = 3{,}644 \cdot Kg ;\ k = 1267{,}52 \cdot N/m ;\ c_a = 21,692 \ \frac{N \cdot s}{m} .$$

We will study the behavior to stimulation of the new system made of the primary system and the auxiliary one with the parameters specified above with the help of the C.R.D. programme.

The differential equations system (12) with the matrix form (1) has:

$$M = \begin{bmatrix} m & 0 \\ 0 & m_a \end{bmatrix} = \begin{bmatrix} 0{,}05 & 0 \\ 0 & 0{,}003644 \end{bmatrix} ;\ B = \begin{bmatrix} c_a & -c_a \\ -c_a & c_a \end{bmatrix} = \begin{bmatrix} 0{,}021692 & -0{,}021692 \\ -0.021692 & 0.021692 \end{bmatrix} ;$$

$$R = \begin{bmatrix} k + k_a & -k_a \\ -k_a & k_a \end{bmatrix} = \begin{bmatrix} 21{,}2673 & -1{,}2672 \\ -1{,}2672 & 1{,}2672 \end{bmatrix} ;\ F(t) = \begin{pmatrix} 30 \\ 0 \end{pmatrix} \cdot \cos(\omega \cdot t) \ ; u(o) = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \ ; \dot{u}(0) = \begin{pmatrix} 0 \\ 0 \end{pmatrix} .$$

The specific pulsations of this system with damping devices given by the C.R.D. programmme are: $p_1^a = 16{,}824 \cdot s^{-1}$ and $p_2^a = 22{,}017 \cdot s^{-1}$. Considering $\omega = 1 \cdot s^{-1}$ and the time interval [0. 10s], with the programme set C.R.D., we can represent in Fig.1 the oscillations of the two masses, with regard to the components.

The result is that the maximum amplitude of the $x_1(t)$ component is $2{,}6373 \cdot mm$, much smaller than the maximum amplitude required for small angular velocities of the disturbance force.

By repeating the execution of the C.R.D. programme with the amplitude of the disturbance force of 90*N*, then the same time interval [0, 10s] can be achieved for a maximum oscillation of the primary mass with the value of $7{,}91193 \cdot mm$ for $\omega = 1 \cdot s^{-1}$ (Fig.2) very close to the maximum of the required oscillation.

If the specific pulsation of the disturbance force is close to the specific pulsation of the system with the damping value $\omega = 10 \cdot s^{-1}$, then, the dynamic answer of the system is represented in Fig.3 for the interval [0, 1s] and in Fig.4 for the interval [0, 3s].

It is noticeable in these cases that the specific pulsation of the disturbance force is getting close to the specific pulsation of the system and the maximum amplitude of the primary mass of 6,34 has the required value 8 mm.

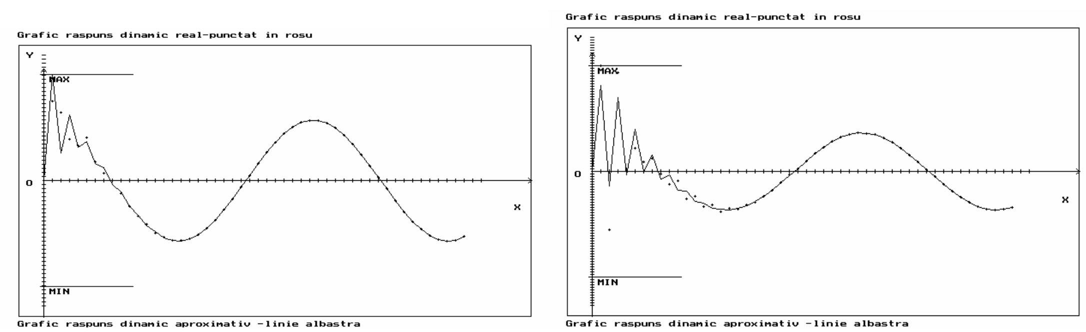
As a conclusion, we can state that the optimal parameters determined for the dynamic absorber correspond to the necessities for which it was designed.

By simulating the dimensions of the dynamic absorber with the C.R.D. programme we found the following *parameters*: $m_a = 4 \cdot Kg$; $k = 1200 \cdot N / m$; $c_a = 20 \cdot N \cdot s / m$, which are close to the parameters determined with the theory presented above.

The dynamic answer for the dynamic system with these parameters is given in Fig.5 and Fig.6. The maximum oscillation of the primary mass is 6,94386 mm.

The graphic representation for the real dynamic response is rendered using dots.
The graphic representation for the approximate dynamic response is rendered using a line.

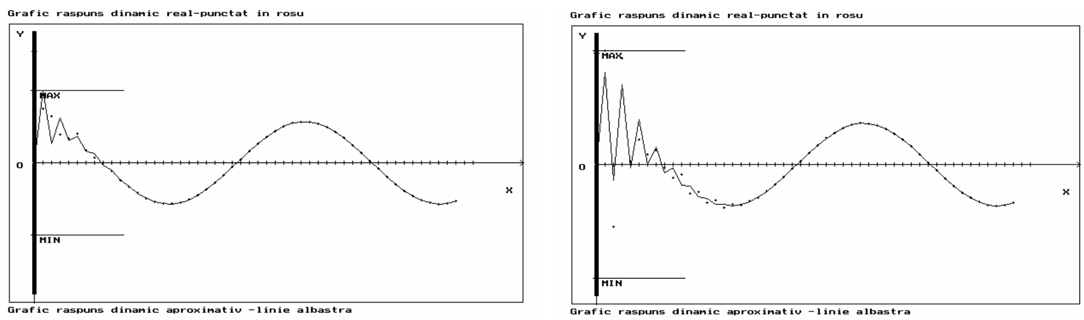
The graphic for component 1 **The graphic for component 2**



The maximum value of oscillation in the module is 2,63731 mm. The maximum value of oscillation in the module is 4,11614mm

Fig. 1. The oscillations of the two masses for n = 2, b=10, nd = 50, $|F| = 30N$, and $\omega = 1 \cdot s^{-1}$.

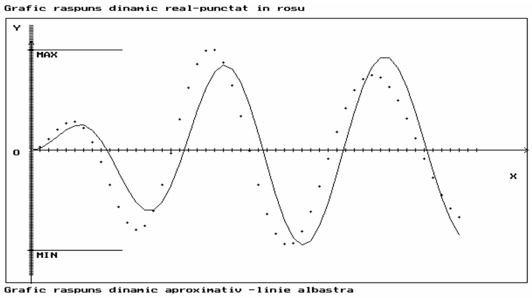
The graphic for component 1 **The graphic for component 2**



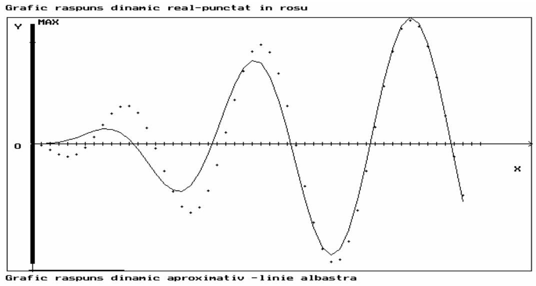
The maximum value of oscillation in the module is 7,91193 mm. The maximum value of oscillation in the module is 12,34842 mm.

Fig. 2. The oscillations of the two masses for n = 2, b=10, nd = 50, $|F| = 90N$, and $\omega = 1 \cdot s^{-1}$.

The graphic for component 1



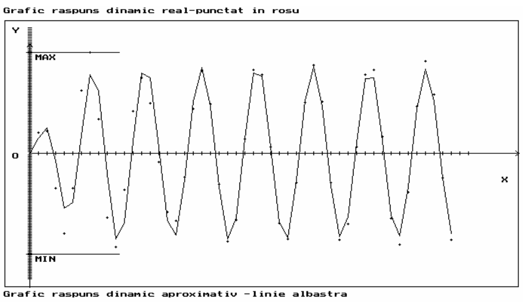
The graphic for component 2



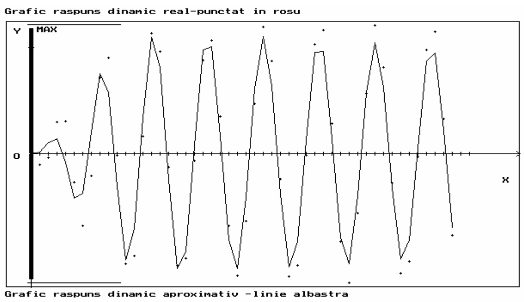
The maximum value of oscillation in the module is 6,34022 mm. The maximum value of oscillation in the module is 16,69185 mm.

Fig. 3. The oscillations of the two masses for n = 2, b=1, nd = 50, $|F|=30N$, and $\omega = 16 \cdot s^{-1}$.

The graphic for component 1



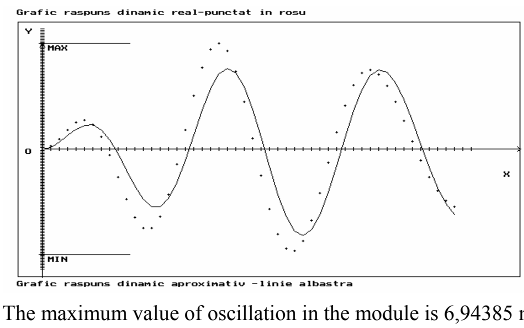
The graphic for component 2



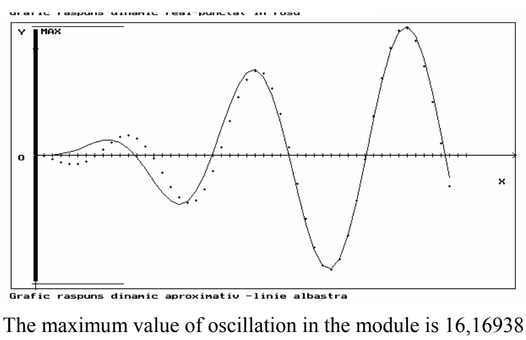
The maximum value of oscillation in the module is 6,34022 mm. The maximum value of oscillation in the module is 16,2228 mm.

Fig.4. The oscillations of the two masses for n = 2, b=3, nd = 50, $|F|=30N$, and $\omega = 16 \cdot s^{-1}$.

The graphic for component 1



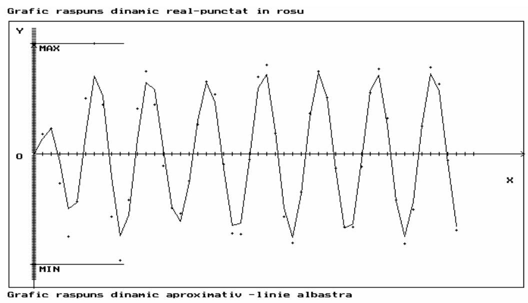
The graphic for component 2



The maximum value of oscillation in the module is 6,94385 mm. The maximum value of oscillation in the module is 16,16938 mm.

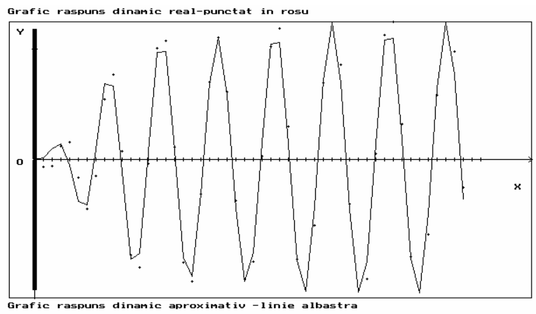
Fig.5. The oscillations of the two masses for n = 2, b=1, nd = 50, $|F|=30N$, and $\omega = 16 \cdot s^{-1}$.

The graphic for component 1



The maximum value of oscillation in the module is 6,94385 mm.

The graphic for component 2



The maximum value of oscillation in the module is 18,47173 mm.

Fig.6. The oscillations of the two masses for n = 2, b=3, nd = 50, $|F| = 30N$, and $\omega = 16 \cdot s^{-1}$.

Conclusions

The absorber can be attached when the specific vibration of the primary system is close to the frequency of the disturbing forces. Its efficiency depends on its parameters: mass, elastic constant and damping constant. The theoretic methods for studying the efficiency of the passive dynamic absorbers are very difficult and require a particularly delicate formal calculation to determine the relations between the parameters of the dynamic absorber. Moreover, these methods operate with some excessively high approximations for obtaining a simple dependence relation between the parameters of the absorber. Considering that the introduction of a dynamic absorber in a structure causes the increase in the number of degrees of freedom, then the study of the dynamic absorbers can be made with the programme C.R.D., by using the method of the differential equations. In this case, after the differential equations for the oscillations of the system masses has been written (equations (1)), then we can make the simulation on this mathematic model with the programme C.R.D. for various values of the parameters of the dynamic absorber: auxiliary masses, damping constants, damping coefficient. We will take into consideration the combination for which the dynamic absorber works efficiently in the structure where it is attached, that is for which the oscillations of the primary mass are the smallest. The programme C.R.D. can determine the specific pulsations with no damping involved, the specific pulsation with damping and the dynamic response for each component of the system separately. This dynamic response is given both in the transition stage and in the stage when the movement is stabilized by the iterative-residual method. Moreover the programme renders in a graphical form the harmonic movement of every mass and the theoretical methods do not represent a theoretical support of the dynamic response in the transition stage, which is from the priming of the machine to the stage where it gets into the stabile movement.

We presented these types of dynamic absorbers to emphasize on the fact that their designing was very demanding even in the simple cases we mentioned. When the dynamic absorber becomes more complex (having auxiliary masses attached with springs and other damping devices), then the theoretical study of its efficiency is actually impossible. One can make a study with the C.R.D. programme by simulating various parameters and noting only the combination that gives small amplitudes.

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Optimizarea absorbitorilor dinamici (II)

Rezumat

Aceste două lucrări prezintă algoritmul general al răspunsului dinamic al unei structuri cu amortizare oarecare folosind metoda Galerkin. Acest algoritm a fost transpus pe calculator în programul care dă răspunsul dinamic (C.R.D.). Lucrarea prezintă o nouă metodă de determinare a parametrilor absorbitorilor dinamici de vibrații, utilizând programul C.R.D.