Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

PARTICULAR CASE STUDY OF DYNAMIC ABSORBER

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Abstract: *The paper presents a theoretical study on a crankshaft with five reduced masses having a dynamic absorber attached. The dynamic absorber is used for the reduction of the amplitude of the torsion vibrations of crankshafts. This paper does not present experimental results; these results will be presented in another paper, upon the completion of the experiment.*
Key words: *dynamic absorber, torsion vibrations, mass*

1. INTRODUCTION

The paper presents a study on the effect of the dynamic absorber on the torsion vibrations produced in a mechanic system composed of reduced masses m_1, m_2, m_3, m_4 and m_5 subjected to a harmonic x.

The dynamic absorber has the specific dimensions of L, l and mass m is attached to the reduced mass m_3.

The necessary and sufficient condition for the most dangerous order x harmonica to be prevented from creating vibratory torsion movements is for the proper pulse of the dynamic absorber to be equal to the pulses of the order x harmonica.

The paper contains the theoretical background and it does not contain experimental data. The experimental results will be presented in another paper, pending the experiment will have been completed.

2. MECHANICAL SYSTEM

This study presents a system with five reduced masses noted m_1, m_2, m_3, m_5, m_6 (Fig. 1.) which are connected through the reduced crankshaft and presenting the elastic constants c_{12}, c_{23}, c_{34}, c_{35}, c_{56}.

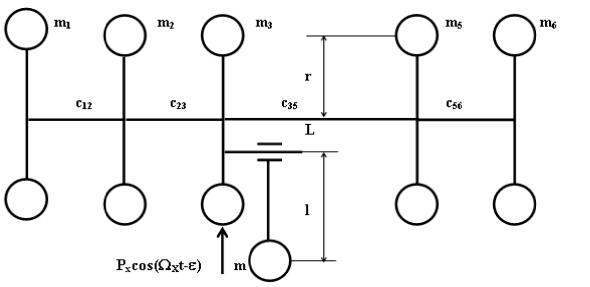

Fig. 1. Mechanical system

3. EQUIVALENT SYSTEM

The dynamic absorber is replaced by a mechanical system of a reduced mass m_4 and the reduced crankshaft with an elastic constant of c_{34} (Fig. 2.) that is restricted to be dynamically equivalent to the dynamic absorber to be applied on the reduced mass m_3 and having the same momentum as the dynamic absorber.

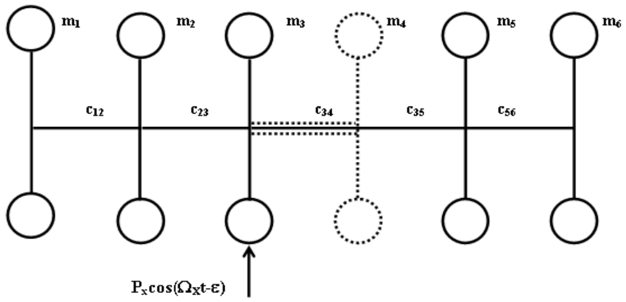

Fig. 2. Equivalent mechanical system

The first stage begins from a system of five differential equations that governs the vibratory torsion movements of the mechanical system represented in figure 2 (Bălcău&Arghir, 2009):

$$m_1 \frac{d^2 a_1}{dt^2} + c_{12}(a_1 - a_2) = 0$$
$$m_2 \frac{d^2 a_2}{dt^2} + c_{12}(a_2 - a_1) + c_{23}(a_2 - a_3) = 0$$
$$m_3 \frac{d^2 a_3}{dt^2} + c_{23}(a_3 - a_2) + c_{34}(a_3 - a_4) + c_{35}(a_3 - a_5) = P_x \cos(\Omega_x t - \varepsilon)$$
$$m_4 \frac{d^2 a_4}{dt^2} + c_{34}(a_4 - a_3) = 0$$
$$m_5 \frac{d^2 a_5}{dt^2} + c_{35}(a_5 - a_3) + c_{56}(a_5 - a_6) = 0$$
$$m_6 \frac{d^2 a_6}{dt^2} + c_{56}(a_6 - a_5) = 0 \qquad (1)$$

4. SOLUTION OF THE DIFFERENTIAL SYSTEM

The expressions at the elongations a_i (i=1~6) for the torsion vibrations executed by the five reduced masses according to the amplitude A_i, (i=1~6) of the same torsion vibrations are the following:

$$a_i = A_i \cos(\Omega_i t - \varepsilon), \quad i=1\sim6 \qquad (2)$$

The expressions (2) and the second time derivatives for the torsional vibration amplitudes are introduced in the differential equation system, and by simplification with the trigonometrical function $\cos(\Omega_x t - \varepsilon)$ we obtain the algebraic equation system (Bălcău& Arghir, 2009).

The system is :

$$\left(\Omega_x^2 - \frac{c_{12}}{m_1}\right)A_1 + \frac{c_{12}}{m_1}A_2 = 0$$
$$\frac{c_{12}}{m_2}A_1 + \left(\Omega_x^2 - \frac{c_{12}}{m_2} - \frac{c_{23}}{m_2}\right)A_2 + \frac{c_{23}}{m_2}A_3 = 0$$
$$\frac{c_{23}}{m_3}A_2 + \left(\Omega_x^2 - \frac{c_{23}}{m_3} - \frac{c_{34}}{m_3} - \frac{c_{35}}{m_3}\right)A_3 + \frac{c_{34}}{m_3}A_4 + \frac{c_{35}}{m_3}A_5 = -\frac{P_x}{m_2}$$
$$\frac{c_{34}}{m_4}A_3 + \left(\Omega_x^2 - \frac{c_{34}}{m_4}\right)A_4 = 0$$

$$\frac{c_{35}}{m_5}A_3+\left(\Omega_x^2-\frac{c_{35}}{m_5}-\frac{c_{56}}{m_5}\right)A_5+\frac{c_{56}}{m_5}A_6=0$$
$$\frac{c_{56}}{m_6}A_5+\left(\Omega_x^2-\frac{c_{56}}{m_6}\right)A_6=0 \qquad (3)$$

The amplitudes of the torsion vibrations executed by the five reduced masses A_i (i=1~6) are provided by the expressions:
$$A_i=\frac{\Delta_i}{\Delta} \quad (i=1\sim5) \qquad (4)$$
therefore this is the solution of the equations system, where the determinants Δ and Δ_i are obtained using the Cramer method used (Haddow& Shaw, 2002).

For the mechanical system formed of reduced mass m_4 and the reduced crankshaft with the elastic constant c_{34} to be dynamically equivalent with the dynamic absorber it is necessary and sufficient for the relations to be fulfilled (Bălcău& Ripianu, 2008):
$$m_4=m\frac{(L+l)^2}{r^2} \qquad c_{34}=m\left[\frac{(L+l)^2}{r^2}\frac{L}{l}\omega_0^2\right] \qquad (5)$$
Results that:
$$\frac{c_{34}}{m_4}=\frac{L}{l}\omega_0^2 \qquad \frac{c_{43}}{m_5}=\frac{m_4}{m_3}\frac{L}{l}\omega_0^2 \qquad (6)$$

If the dynamic absorber is dimensioned in such a say that
$$\frac{L}{l}=x^2 \qquad (7)$$
and taking into account the conditions (3) that have to be met by the reduced mechanic system formed of the reduced mass m_5 and the reduced crankshaft with the elastic constant of c_{45} to be dynamically equivalent with the dynamic absorber (Ripianu& Crăciun, 1999), the expressions of the six determinants Δ_1, Δ_2, Δ_3, Δ_4, Δ_5, Δ_6 become:
$$\Delta_1=-\frac{P_x}{m_3}\omega_{I\,II}^2\omega_{II\,III}^2\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_3}{m_5}\omega_{III\,V}^2+\frac{m_5+m_6}{m_6}\omega_{V\,VI}^2\right)+\frac{m_3}{m_6}\omega_{III\,V}^2\omega_{V\,VI}^2\right]\left(x^2-\frac{L}{l}\right)\omega_0^2$$

$$\Delta_2=\frac{P_x}{m_3}\omega_{II\,III}^2\left(x^2\omega_0^2-\omega_{I\,II}^2\right)\left\{x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_3}{m_5}\omega_{III\,V}^2+\frac{m_5+m_6}{m_6}\omega_{V\,VI}^2\right\}+\frac{m_3}{m_6}\omega_{III\,V}^2\omega_{V\,VI}^2\right]\left(x^2-\frac{L}{l}\right)\omega_0^2$$
$$\Delta_3=-\frac{P_x}{m_3}\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_1+m_2}{m_2}\omega_{I\,II}^2+\omega_{II\,III}^2\right)+\omega_{I\,II}^2\omega_{II\,III}^2\right]\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_3}{m_5}\omega_{III\,V}^2+\frac{m_5+m_6}{m_6}\omega_{V\,VI}^2\right)+\frac{m_3}{m_6}\omega_{III\,V}^2\omega_{V\,VI}^2\right]\left(x^2-\frac{L}{l}\right)\omega_0^2$$

$$\Delta_4=\frac{P_x}{m_3}\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_1+m_2}{m_2}\omega_{I\,II}^2+\omega_{II\,III}^2\right)+\omega_{I\,II}^2\omega_{II\,III}^2\right]\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_3}{m_5}\omega_{III\,V}^2+\frac{m_5+m_6}{m_{06}}\omega_{V\,VI}^2\right)+\frac{m_3}{m_6}\omega_{III\,V}^2\omega_{V\,VI}^2\right]\frac{L}{l}\omega_0^2$$
$$\Delta_5=\frac{P_x}{m_5}\omega_{III\,V}^2\left(x^2\omega_0^2-\frac{m_5}{m_6}\omega_{V\,VI}^2\right)\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_1+m_2}{m_2}\omega_{I\,II}^2+\omega_{II\,III}^2\right)+\omega_{I\,II}^2\omega_{II\,III}^2\right]\left(x^2-\frac{L}{l}\right)\omega_0^2$$

$$\Delta_6=-\frac{P_x}{m_6}\omega_{III\,V}^2\omega_{V\,VI}^2\left[x^4\omega_0^4-x^2\omega_0^2\left(\frac{m_1+m_2}{m_2}\omega_{I\,II}^2+\omega_{II\,III}^2\right)+\omega_{I\,II}^2\omega_{II\,III}^2\right]\left(x^2-\frac{L}{l}\right)\omega_0^2 \qquad (8)$$

The amplitudes of the torsion vibrations executed by the six reduced masses A_i (i=1~6) are provided by the expressions:
$$A_i=\frac{\Delta_i}{\Delta} \quad (i=1\sim6) \qquad (9)$$
because it is the solution of the system of equations, where the determinants are Δ and Δ_i.

The mass m_4 will execute torsion vibrations and the other masses will not execute any torsion vibrations if:

- the dynamic absorber is dimensioned in such a way that it fulfills the relation (7);
- we take into account the relations (9), which characterize the torsion vibrations of the equivalent mechanical system;
- the reduced mass m_4 and the part of the crankshaft (which is reduced and has the elastic constant c_{34}) is equivalent from a dynamic point of view with the dynamic absorber – relations (5) and (6).

$$A_1=0 \quad A_2=0 \quad A_3=0 \quad A_4\neq0 \quad A_5=0 \quad A_6=0 \qquad (10)$$

5. CONCLUSIONS

If the dynamic absorber is built so that
$$\frac{L}{l}=x^2$$
then this device does not introduce a new resonance phenomena, irrespective of the order of the harmonica induced inside the mechanical system which caused the forced vibrations.

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