PRACTICAL STUDY ON ISOLATION CHARACTERISTIC FOR THE POLYGONAL SHAPE ELASTIC ISOLATION DEVICES

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Abstract: This issue is a part of the large study performed for analyse and validate the polygonal shape elastic isolation devices (*PoSEID*) dynamic behaviour. Initially, it was proposed a group of elastic isolation systems, with a complex configurations - with multistairs or polygonal functional structure. The analitical analysis, completed with the experimental laboratory tests, leads to the final variant of these isolation systems to a polygonal regular shape with six visco-elastic torsional rubber elements. The main part of analysis was dedicated for analysis of these devices, from the next points of view: static and dynamic stability, functional performances, vibration isolation degree. In this paper it was presented the analitical approach of the isolation degree calculus, for a system with three degree of freedom, that was insulated on a symmetrical PoSEID configuration. The conclusions of this study was performed arround the global isolation degree values, and leads to validate the utilization of these systems on large area of applications, supposing the sensitive equipments isolation against vibrations. Finally, it is necessary to mention the fact that these devices was analysed both with virtual prototyping techniques, and with real lab experimental tests. This complex approach help to evaluate the disturbances on the designing and leads to obtaine the usable functional configuration for a doable and reliable vibration isolation system.

Keywords: isolation performances, vibration, isolation devices.

1. INTRODUCTION

The level of the isolation performances is one of the most important parameter for the isolation devices against vibration, shocks or seismical waves. This indicator offer a global information, in a direct and concise way, and create the right frame for adoption, designing and/or exploitation of the antivibrational devices. These devices have a large variety of constructive and functional structure so that the isolation performances evaluation process have to be geared to each class. The general theory of force transmissibility was developed for an theoretical single degree of freedom model, because of clarity and simplicity of the demonstration. In practice, this case have a limited utilization. Most of the technical systems have more than a single element and the reduction at a model with one degree of freedom causes a serious errors on specifical parameters values estimations. For this reason, it is necessary to develop a concrete methods for estimation and evaluation the behaviour of the dynamic systems, in a direct and tight bond with the realistic exploitation configuration.

According to the previous considerations, this study propose and underlie a physico-mathematical model for evaluation and analysis of the dynamic systems behaviour, which could be simulated through a three degree of freedom rigid body, elastic underpined to ground. Beside the structural configuration of the entire equipment - isolation - ground ensemble, the elastic isolation devices structure and the elastic element characteristics, are the most important parameters on a passive elastic antivibrational isolation. Thus that, the author was developed and analyzed some types of rubber elements, sundries devices and complex systems, useable in a passive antivibrational projects. It was taken a simple rubber elements, for compression or torsion external loads, and it was mounted in a simple or complex configuration, based on multistair structure or polygonal shape configurations. Thus, the performances of one element was improved, and the global level of dynamic performance acquire a high values.

2. THE DESCRIPTION OF THE COMPUTING MODEL

In the Figure 1 is presented the schematic diagram of the proposed model - a rigid body with three degree of freedom underpined to the ground through the visco-elastic elements [1,2]. For this phase of the study, the viscous component of the links are ignored.

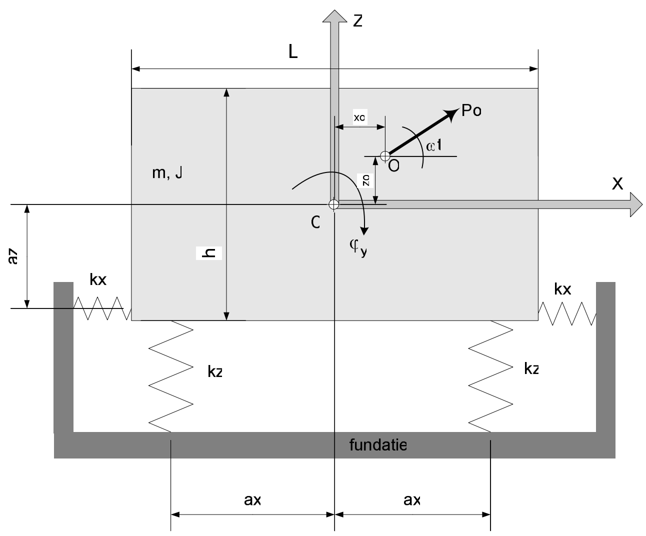


Fig. 1. The computing model for the incorporated equipments antivibratory isolation

The dynamic equations of this model was developed with the approaching of the next hypothesis

- ✓ both the equipment, and the building are supposed as a rigid bodies, with two symmetry planes XCY and YCZ;
- ✓ the linkages between the mass and the ground are maded with the special elastic systems, the montage of these assuring a isolation on the three ortogonal directions;
- ✓ the elastic isolators have the characteristic rigidites k_x, k_y, k_z;
- ✓ the dynamic external loads (excitation) have innertial type and is generated by the rotational force P_o;
- ✓ the rotational force axis is parallel with CY axis, and the coordinates (x_o, z_o) characterize the application point (O) of this force.

Taking into account the fact pursuant to, on dynamic state, are excited only the vibrational modes on the *X, Z*, and φ_Y axis, the analysis will be developed for the plane case. The dynamic equations of the model are

$$\begin{cases} m\ddot{x} + 4k_x x + 4a_z k_x \varphi_y = P_o \cos \omega t \\ J_y \ddot{\varphi}_y + 4\varphi_y \left(k_z a_x^2 + k_x a_z^2\right) + 4a_z k_x x = P_o l \sin(\omega t - \alpha) \\ m\ddot{z} + 4k_z z = P_o \sin \omega t \end{cases} \tag{1}$$

where

$$l = \sqrt{x_o^2 + z_o^2} \text{ and } \alpha = arctg\left({}^{z_o}\!\big/_{x_o} \right) \tag{2}$$

The equations of the natural frequencies, for the system (1), are

$$\frac{p_{x,\varphi_y}^2}{\omega_z^2} = \frac{1}{2}\left\{ \frac{k_x}{k_z}\left[1 + \left(\frac{a_z}{\rho_y}\right)^2\right] + \frac{a_x^2}{\rho_y^2} \pm \sqrt{\left[\frac{k_x}{k_z}\left(1 + \frac{a_z^2}{\rho_y^2}\right) + \frac{a_x^2}{\rho_y^2}\right]^2 - 4\frac{k_x}{k_z}\frac{a_x^2}{\rho_y^2}} \right\} \tag{4'}$$

$$p_z = \sqrt{4\frac{k_z}{m}} = \omega_z \tag{4''}$$

where $\rho_y^2 m = J_y$.

The magnitude of the global forces transmited to the foundation, on the *OX* direction, have the expression

$$F_{tx} = 4k_x \sqrt{A_x^2 - 2a_z A_x A_\varphi \cos(\psi_x - \psi_\varphi) + a_z^2 A_\varphi^2} \tag{5}$$

where

$$tg\,\psi_x = \frac{\frac{k_x}{k_z}\frac{a_z}{\rho_y}\left(\frac{a_z}{\rho_y} - \frac{z_o}{\rho_y}\right) + \left(\frac{a_x}{\rho_y}\right)^2 - \left(\frac{\omega}{\omega_z}\right)^2}{\frac{k_x}{k_z}\frac{a_z}{\rho_y}\frac{x_o}{\rho_y}},$$

$$tg\,\psi_\varphi = \frac{\frac{k_x}{k_z}\left(\frac{a_z}{\rho_y} - \frac{z_o}{\rho_y}\right) + \frac{z_o}{\rho_y}\left(\frac{\omega}{\omega_z}\right)^2}{\frac{x_o}{\rho_y}\left[\frac{k_x}{k_z} - \left(\frac{\omega}{\omega_z}\right)^2\right]}. \tag{6}$$

On *OZ* direction, the magnitude of the global transmited forces could be evaluated with the expression

$$F_{tz} = 4k_z A_z \tag{7}$$

The coupled opposites and parallel forces on *OZ* direction generates a couple, with magnitude given by

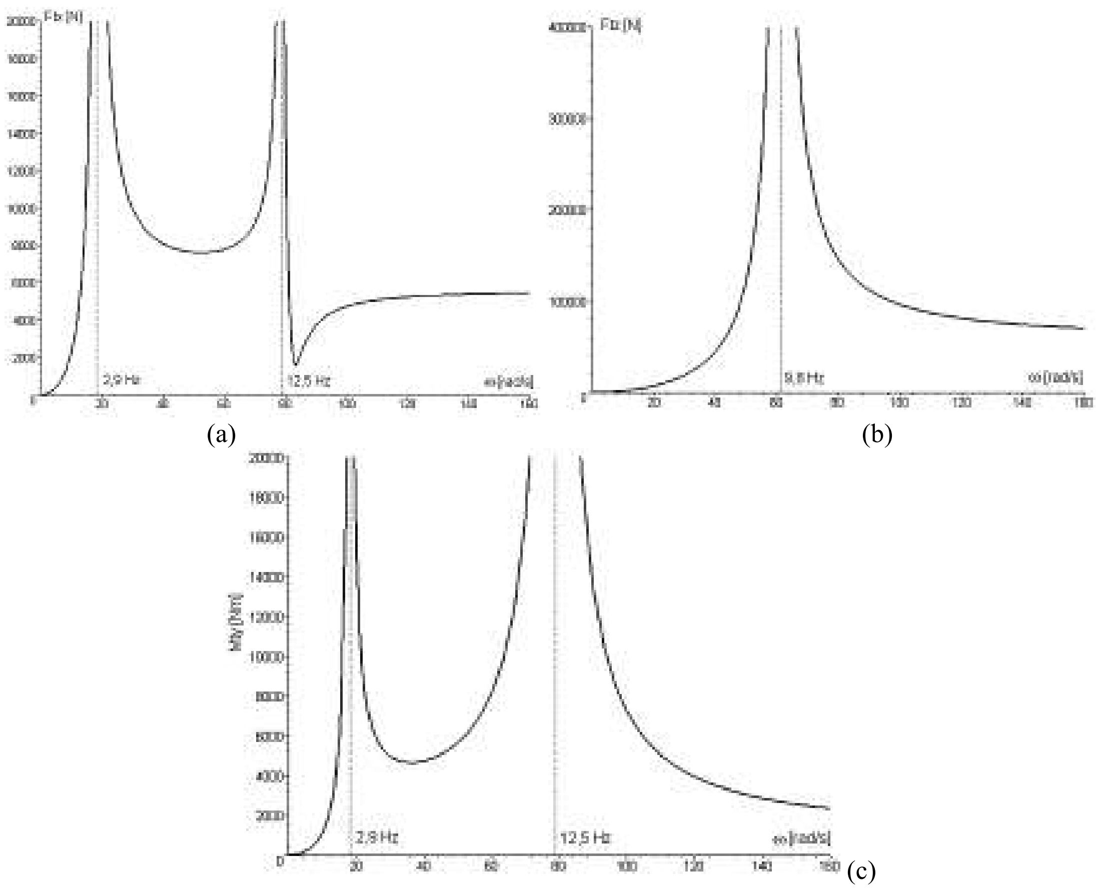
$$M_{ty} = 4k_z a_x^2 A_\varphi \tag{8}$$

3. THE STUDY OF CASE

The numerical computation, based on previous presented model, was developed with taking into account of a medium capacity fan (HVAC equipment class), with the characteristic values depicted in Table 1. It was computed both the displacement magnitudes, and the magnitudes of the forces transmitted to the foundation, on each degree of freedom. Knowing the expression of the excitation, it was possible to evaluate the transmissibility magnitude on each degree of freedom too.

The characteristic values for the HVAC equipment. Table 1.

Parameter	*Unit rate*	*Value*
mass m	kg	100
general dimensions	m	1.00x1.00x1.00
nominal value of angular speed	rpm	1500
stiffness k_x	N/m	$0.91\ 10^4$
stiffness k_z	N/m	$9.39\ 10^4$
distance a_x	m	0.50
distance a_z	m	0.50
distance x_o	m	0.01
distance z_o	m	0.01
static moment $m_o r$	kgm	16



(a) (b) (c)

Fig. 2. The magnitudes of the transmited forces at the foundation

In the Figure 2, its presented the diagrams of the magnitude of the forces transmitted to the foundation through the elastic underpine devices. Obviously, as it can see on the differential equations (1), the movement on the *OZ* axis is uncoupled, as long as the other two are coupled. For the fan equipment, with numerical values from table 1, the transmissibility, on each degree of freedom, acquires subunitary values, less the resonance zones - see Figure 3. PoSEID utilization, in this case, was assured the high performance level on vibration isolation, this computation beeing checked up on laboratory experimental tests.

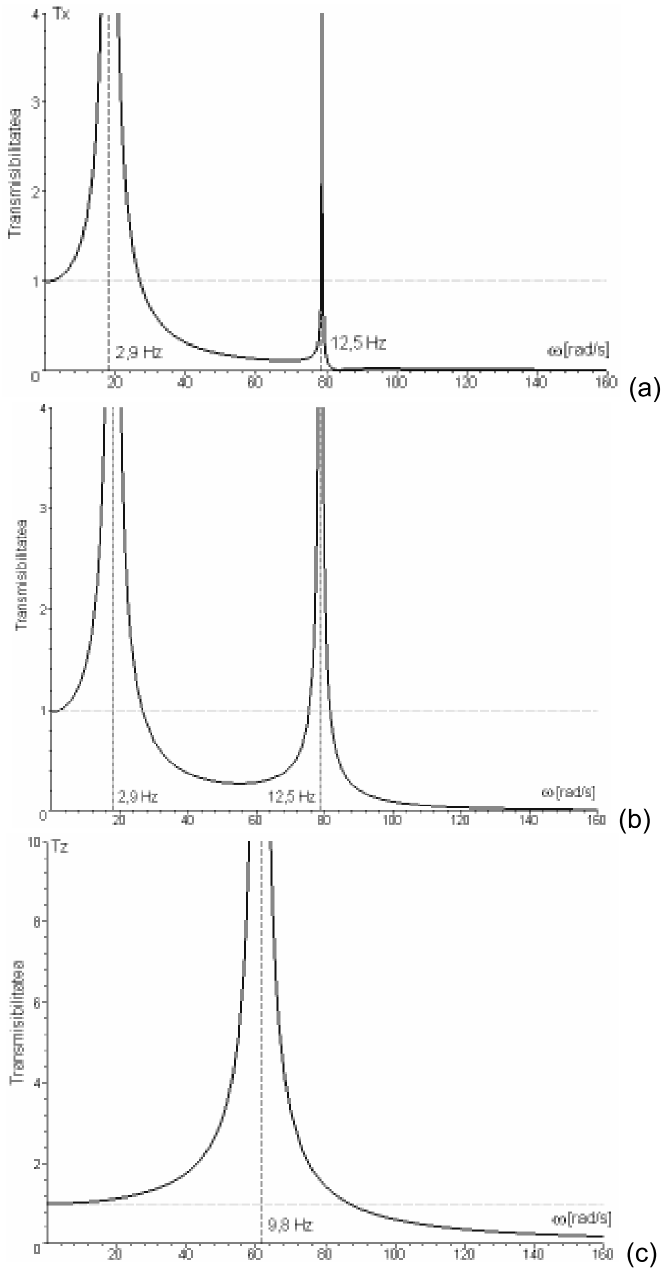


Fig. 3. The magnitudes of the transmissibility for each degree of freedom

4. CONCLUDING REMARKS

This study is a practical application of PoSEID's to the HVAC equipments isolation against vibration. Many of these construction included equipments are vibration sources generators, which produce the dynamic loads into the part of, or into the whole construction structure. The main purpose of the vibration isolation devices, mounted on the HVAC equipments, consist scarcely on reduction of these nocive influences about the construction.

Finally, it must be said that the dynamic characteristics of the PoSEID's that was used on this analysis, were experimentally determined, combined with the lab tests and the numerical computations [3,4]. But, the major inconvenience of this computation, and not alone, consist by putting into the evidence the real characteristic and, practical, included these on the analitical approaches, taking into account that all technical systems have a non-linear behaviour.

This study is one part on the large set of practical applications, which try to evaluate and qualify the behaviour, the influences and the optimum utilisation mode, for this type of vibration isolation devices on technical and civil dynamic systems, and it will be developed in the future for the entire range of construction included equipments (HVAC).

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