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ANALYSIS OF THE ANTI-SEISMIC PASSIVE ISOLATION SYSTEM BASED ON THE VIRTUAL PROTOTYPING

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ABSTRACT

This work propose a new onset for dynamic behaviour analysis of the passive anti-seismic and/or anti-vibrational elastic elements and systems. The basics of this new approach are constituted by the virtual prototyping techniques, which consisted by a deep interaction between the different software packages dedicated to separated analysis domains, like stress & strain analysis, kinetical links analysis, dynamic analysis, numerical computing, a.s.o. Nearby of these softwares, is necessary to use a different types of models (physical, mathematical, numerical), which simulate less or more precisely, the real nature of the considered system. In this paper is proposed a new type of passive elastic element, that are analysed from a point of view of isolation performances.

1. Introduction

Anti-seismic isolation systems ought to assure the protection of the systems, equipments or buildings against the nacive actions of the seismical waves produced by the different sources (e.g. earthquakes, detonations, a.s.o.). At this time exist and it is used a many types of isolation systems: active, semi-active, passive. From all of these, the passive protection systems are very useful because of the simplicity and the facilely maintenance. Cause of these, the behaviour analysis, specialy the dynamic behaviour, have a very much importance.

The basics of this new approach, proposed in this work, are guided by the virtual prototyping techniques, which consisted by a deep interaction between the different software packages dedicated to separated analysis domains, like stress & strain analysis, kinetical links analysis, dynamic analysis, numerical computing, a.s.o., and the relative newly theoretical domains , like computational mechanics, non-linear vibration, a.s.o. All of these could or could not be included into the namely CASE - Computer ASsisted Engineers.

The problematics of anti-seismic and anti-vibrational isolation suppose the existance of the elements, parts or systems, with the reducing or eliminating role, for the transmision phenomenon of the seismic waves or vibrations produced by certain source, towards the included equipment or system into the construction, and to whose operation state must be keeping on unconcerned the external conditions.

From the class of the anti-seismic isolation systems the passive protection elements make an important category. These are composed by the elements which have a preponderant behaviour into the elastic domain - metallic springs, vulcanized rubber, a.s.o. - pure mounted between the isolated system and the base, or included into the complex structures, which allowed the high values for static and dynamic deformations.

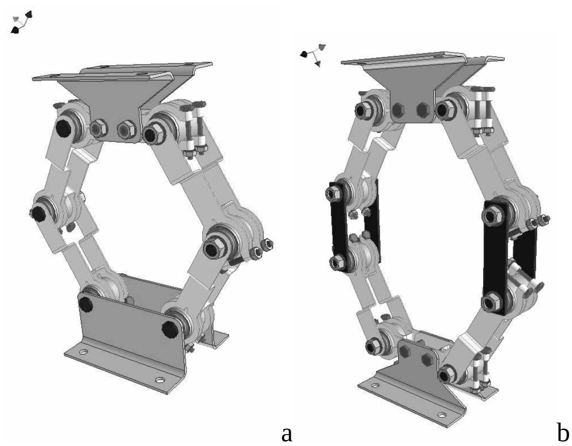
The mainly advantages of the passive elastic anti-seismic protection systems are: first, these systems are not fill in the energy into the isolation ensemble, and second, the construction principle are very simple that are allow the very easiness mentenance operations.

The working principle of this type of anti-seismical and anti-vibrational insulated systems is to stopped the propagation process of the seismic waves or vibrations from the disturbing source to the vital equipment, by using the capacity of the rubber elements to incorporate the movement energy (kinetical energy) and transforming this into the deformation potential

energy, and giving back to the disturbing source by the inverse transformation. This systems can be used for bidirectional isolation, as follows: for stoped the influences from the foundation to the vital equipment, or for isolation of the sources of dangerous vibrations from the rest of the building that contained this sources.
The principal request from these systems is to magnify at most the static and the dynamic deformations values. This fact means that it will be obtained the low values for the eigen frequencies of the isolation system, and the protected system will be working in post-resonance state, faraway of the eigen value zone of the disturbing forces.

2. Physical Model for the Isolation System

The proposed and analysed isolation system have a poligonal shape, and are composed by the elastic rubber torsional elements, consolidated beetween them with rigid levers. This kind of passive protection system are presented in the Figure 1 (a- the six sides poligonal system, and b- the eight sides poligonal system).



a b

Figure 1. Poligonal shape anti-seismic systems

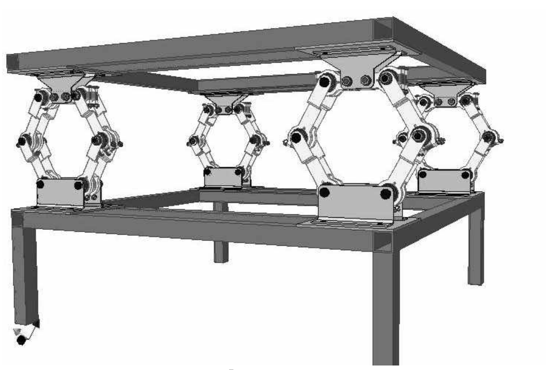


Figure 2. Complex anti-seismic system

In the Figure 2 it is presented a complex isolation system, composed by four identical parts with six elastic nodes (fig. 1 a).

3. Mathematical Model of the System

In the Figure 3 the author present a proposed model for numerical evaluation of the dynamic behaviour of the poligonal shape anti-seismic system that have been previously presented.
The simplified hypothesis was that the system movement was contained into the xOz plane (the case of the plane-parallel movement). It was considered that the system have all the degree of freedom, coresponding to the working hypothesis case.

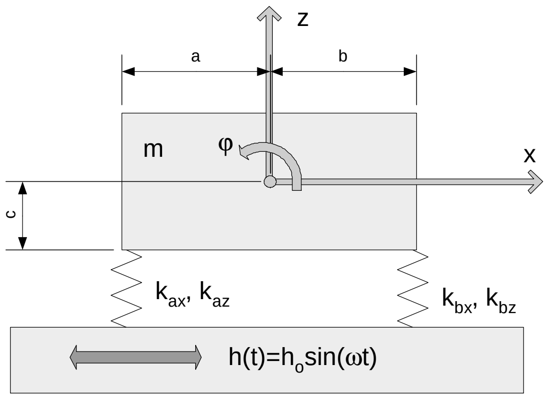


Figure 3. Physical model for analytic computations

The movement equations system for the case presented into the Fig. 3 was written in a matrix form

$$[M][\ddot{q}]+[K][q]=[K][H] \qquad (1)$$

in which

$$[M]=\begin{bmatrix} m & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & J \end{bmatrix}$$ is the inertial matrix,

$$[K]=\begin{bmatrix} k_{az}+k_{bz} & 0 & -k_{az}a+k_{bz}b \\ 0 & k_{ax}+k_{bx} & k_{ax}c+k_{bx}c \\ k_{az}a+k_{bz}b & k_{ax}c+k_{bx}c & k_{ax}c^2+k_{bx}c^2-k_{az}a^2+k_{bz}b^2 \end{bmatrix}$$

is the stiffness matrix,

$$[H]=\begin{bmatrix} \delta \\ h \\ 0 \end{bmatrix}$$ is the disturbances vector,

$[q]=\begin{bmatrix} z \\ x \\ \varphi \end{bmatrix}$ is the deplacement vector,

$h(t)$ is the perturbance on the Ox direction, and

$\delta=\sqrt{l_o^2+h^2}-l_o$ is the perturbance on the Oz direction (l_o is the elastic element length for the initial position, witout the h(t) action).

If it is supposed that the disturbances on the two directions are approximate equals $\delta \cong h(t)$ result that the deplacements vector become

$$[H]=\begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix} h(t) \tag{2}$$

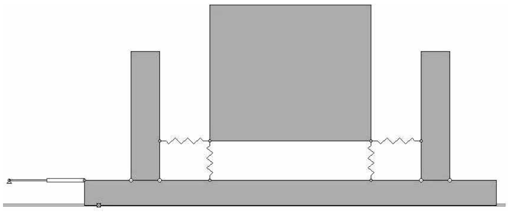


Figure 4. MSC-WorkingModel2D model

4. Dynamic Behaviour Analysis

For solving the equations system previously prezented we have two ways: first it could be use a numerical computation software, which have dedicated commands for solving (with less errors) the differential equations of the model. Whatever the software type, it is necessary to know both physical, and mathematical model for the analised system.

Second way consist by useing of a very simple, but a very powerful software package for dynamic and kinetic analysis, that need only the diagram of the physical model. After this operation the software automatic assemble the moving equations system, and solve it.

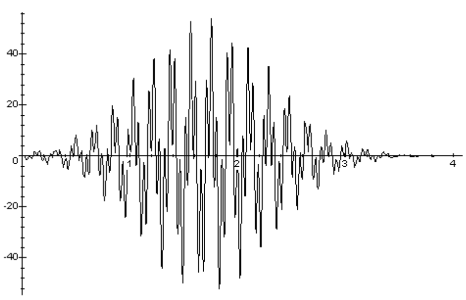


Figure 5. The seismic virtual perturbation

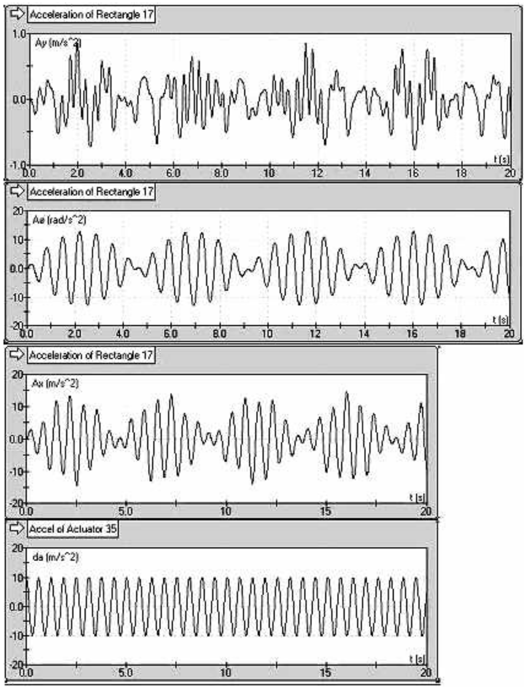


Figure 6. Evolution of the system for a simple excitation

For this example, the author choose the second way and use the MSC-WorkingModel2D-release2004© software for analyse the dynamic behaviour of the anti-seismic system. The physical model used in this case are presented in the Figure 4.

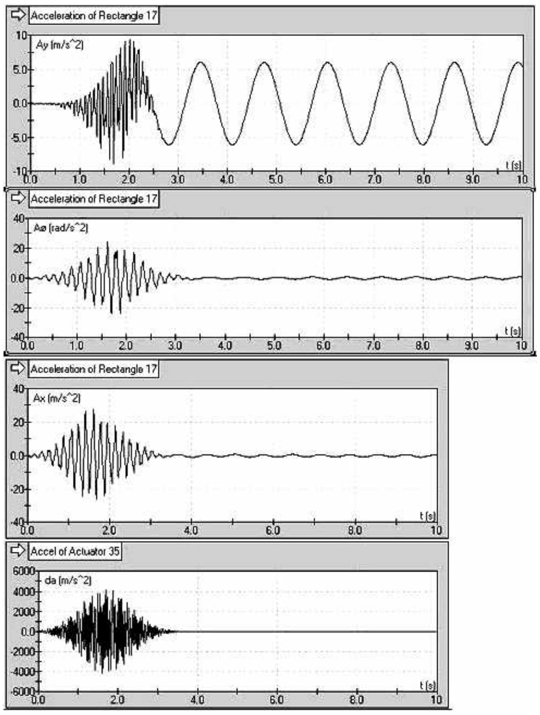


Figure 7. Evolution of the system for a seismical type virtual perturbation

In the Figure 6 is presented the diagrams for accelerations of all the degree of freedom for the insulation mass. These diagrams have been obtained in the case of harmonical disturbation signal. In the Figure 7 are presented the same type of diagrams, but for a seismical type virtual perturbation (Figure 5).
For each case are also furnished the shape of the disturbing signal.

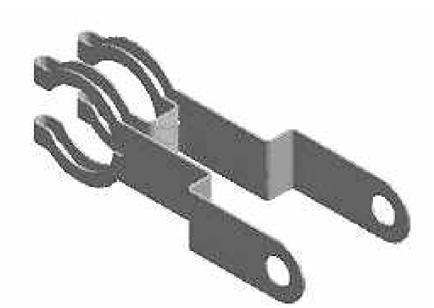
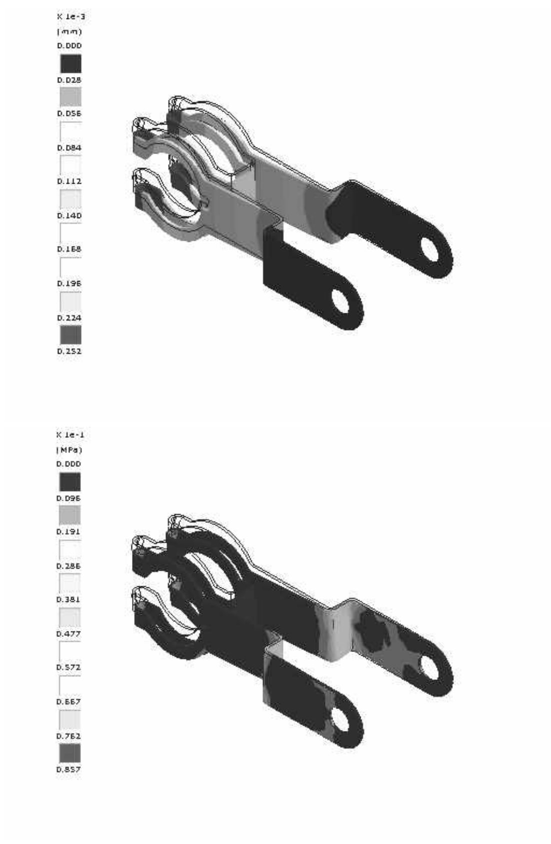


Figure 8. The mainly part of the rigid structure of the anti-seismic system



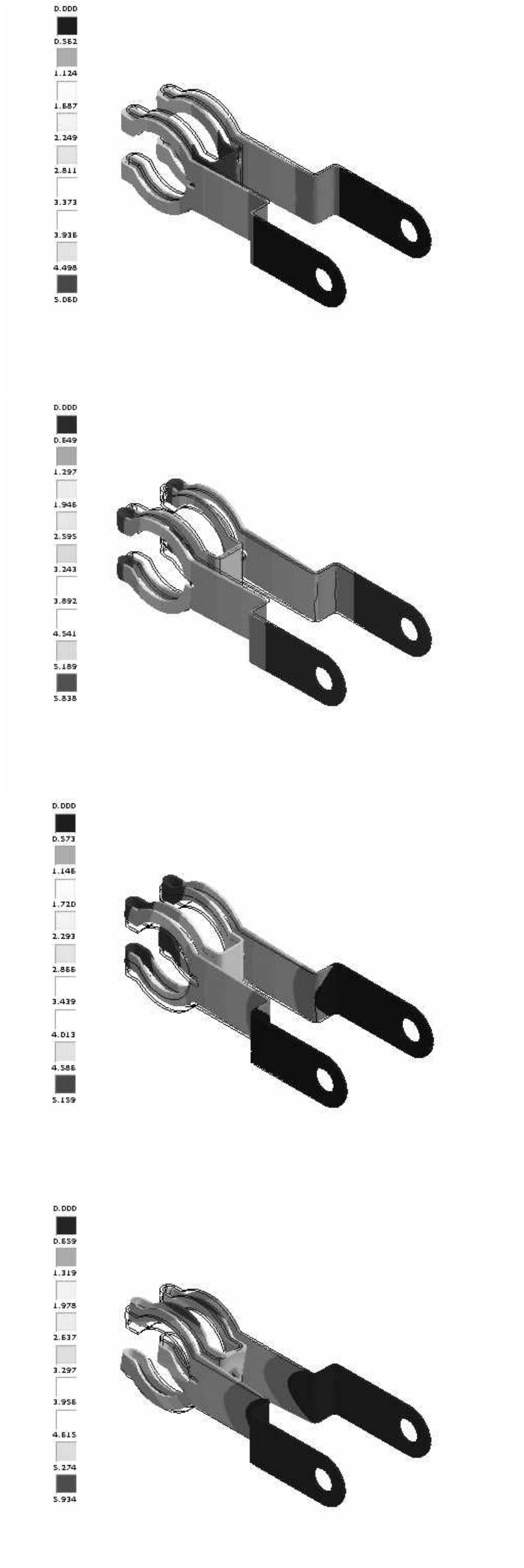
a

b

Figure 1. Static analysis of the system part
a - deformations; b - stresses.

5. FEM Analysis & Results

One of working hypothesis proposed that the system structure are rigid, and all the model used for dynamic analysis supposed that only the rubber element aquire deformations under the external loads.



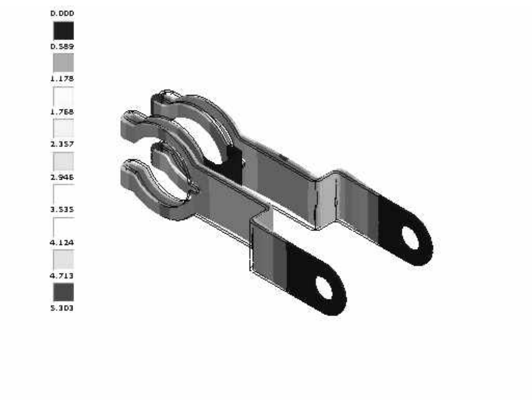
a

b

c

d

Figure 10. Dynamic analysis of the system part
Contours for : a - 1st frequency mode; b - 2nd frequency mode; c - 3rd frequency mode; d - 4th frequency mode; e - 5th frequency mode.



e

Figure 10. Dynamic analysis of the system part (continued from previous)
Contours for : a - 1st frequency mode; b - 2nd frequency mode; c - 3rd frequency mode; d - 4th frequency mode; e - 5th frequency mode.

The reality show that all the elements have deformations, less or more, when they are stressed. To analyse this aspect, and to compute the natural frequencies of the metallic structure parts, it was used a software dedicated for Finite Element Method Analysis. It was analysed only the mainly part of the rigid structure of the anti-seismic system - Figure 8.
In the Figure 9 are shows the results of the FEM analysis for the proposed model, in terms of the maximum deformations (a) and maximum stresses (b).
In the Figure 10 are shows the contours for the natural frequencies of the part, in order 1st to 5th values.

6. Concluding Remarks

This work try to put into the evidence the advantages and the facilely working with this new concept of virtual prototyping. The author briefly present the deep interaction of a part of the CASE softwares and analytical methods, with the final scope to solve and to analyse the new type of a product - in this particularly case, the anti-seismic passive protection system.
The main conclusion of this paper is generate by the full ensemble of the results presented into the previous paragraphs, and consist both by the seriously of the numerical values obtained with the specialised softwares, and by the possibility of the comparation between the different kind of the result. In this way, it solve the fundamental necessity of the interaction between the results, with final scope to use the entire values group for analysing, characterisation and optimisation the functional parametrs of the initial proposed technical system.

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