Advances on Structural Optimization of Neoprene Passive Vibroisolation Devices

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Abstract: - This paper presents the identification and evaluation of the operational methods to improve the isolation characteristics for neoprene passive vibroisolation devices. The area of this study is framed by the passive isolation against shocks and vibration, due to the different technological equipments, of the sensitive embedded systems. The study is based on the large sets of virtual and instrumental tests, performed on different types of vibroisolation devices, with various structural and functional configurations. All of these was developed supposing the basic compressing and torsion rubber elastic elements, their working principle, and their functional restraints. Through the comparative analysis of the acquired results, it was fixed some final structural configurations. It is also present a few theoretical and operational aspects regarding the base isolation technique, which frame the basis of using of these vibroisolation devices. The main concluding remark denotes the way to use simple neoprene elastic elements, mounted on a lever structural and spatial configuration, to obtain a high global level of dynamic isolation.

Key-Words: - Vibration, Passive isolation, Rubber, Structural optimization, Isolation efficacy

1 Introduction

The protection against vibration acquire a high dimension due to the next factors: the antivibration protection necessity for the vital equipments and for the inside buildings human being, because of the development and implementation of a new types of incorporated equipments; the intensive development of new industrial zones and the stringent necessity of the environment protection against the vibratory pollution generated by these; the necessity of protection for a parts of systems or equipments against the vibration generated by the working state of the system/equipment itself.

The concept of random dynamic actions protection was based on limits of demotions, of disables, as well as the avoidances of the structural and non-structural elements, equipments and fixtures collapses, for the next aims: the human life losses or hurtings avoidance; the avoidance of disconnections of the activities and essential services for social an economical life continuity maintenances, both during the earthquake, and right away after; the destructions and demotions avoidance for a high level value cultural and artistic assets; the avoidance of dangerous substances (poisonous, explosive, a.s.o.); the corporeal damages avoidance.

The basic idea of this theoretical and applicative research had the root on the operational improvement of the passive vibration insulation devices, and was framed by the rubber and neoprene elastic elements utilization area. Using these elements and the simple, but effective lever principle, it could be possible the amplification of static deflection with direct influences on reducing of natural frequency. This is the main hypothesis of the passive vibration isolation devices.

On this paper it was presented the common theoretical suppositions, the concept implementation aspects, and the experimental results, both on computer simulation with virtual prototyping, and on real laboratory tests.

2 Theoretical Suppositions

Let's starting this study with a few unsophisticated theoretical suppositions about the transmissibility, degree of isolation, excitation characteristics and theirs relationships with the nature of the practically application. Analysing the Figure 1, where is presented the variation of the transmissibility function, for a SDOF system with low damping characteristic, it have been observed four major areas, from the isolation viewpoint. Thus, these areas are

\[ \text{amplification area} \text{ - to be avoided;} \]
the non-critical applications area - providing low degree of isolation; used for common applications;

the critical applications area - providing acceptable isolation performances level; used for special applications;

the extremely critical applications area - providing high isolation performances level; used for very special applications.

Figure 1. The isolation areas classification

Figure 2. The influence of rigidity decreasing on transmisibility for SDOF isolation system

Supposing the previously ideas, result two main directions to improve isolation, namely: to move the relative pulsation to the high values - acting on the source of disturbance, or move the resonance area (the amplification area) to the left, to the low values - acting on the receiver / propagation way. While the vibration source has the fixed characteristics, the only mode within reach is to tuning up the isolation systems thus that the resonance has been produced at very low frequencies. In Figure 2 is shown the influence of the rigidity modification about the transmisibility/isolation. Analysing this diagram results that at one time with the rigidity diminution, the resonance area shift on the low values, and the magnitude of transmisibility acquire lower peak values. The last observation helps the main idea of this study - reducing the vibration transmisibility.

Basing on the previously theoretical suppositions, the main objective of this study is to find a simple, practical and effective way to provide a stiffness diminution for the passive isolation devices. The very simple manner to begin this applicable study starting with the basic elastic element for torsion loads - see Figure 3.

Figure 3. The basic elastic element

This kind of elements provides an elastic reaction under the external angular charges. If the external loads actuate on the linear direction, these elements usually become feckless. For some practical situations, it could be possible to improve the working of these basic elements with the help of rigid levers, which convert the linear movement into the angular one. This simple montage is shown in Figure 4.

Figure 4. The basic principle of torsion element utilization for compressing/stretch loads

Using this montage it will be assure both the utilization of torsion compact elements, for working under complex loadings, and a simple way to increase the static deformation for isolation system. In the next figures it was presented some schematic diagrams for different structural configurations of insulation systems, based on elastic torsion element utilization.
Hereby, the schematics on Figure 5 depicted three types of structural configurations based on elastic torsion element - like that on the top of the diagram. It was depicted the quad, hexa and octa active points montages. For the last two types, in Figure 6 was depicted a criss cross montage variants; these assures a high values for static deformation because of the greater length of levers.

In Figure 5 it was depicted a regular polygon basic configurations. In practice, the shape of the structural configuration could be adopted as a function of available space, of required working characteristics, of available elastic elements and their linkage type, a.s.o. Thus, the shape could be regular or irregular, or it could be used one of the criss cross shapes presented in Figure 6.

Figure 5. Basic multiple structural configurations

Figure 6. Variants of multiple structural configurations with six / eight active points

Whatever the variant of special isolation system will be finally adopted, it is necessary to analyse the evolution of angular deformations for each active point, and for each possible structural configuration. Thus, with some computing simplifier hypothesis, the graphic representation of these dependencies is depicted in Figure 7. It was supposed two main typical situations, namely:

- **constant side** analysis - when the levers have the same length, regardless the number of active points; in this case the total height of the elastic isolator growing up with the number of active points.
- **constant height** analysis - when the total height of the elastic isolation system become a constant value, regardless the number of active points; in
this case, the levers diminish theirs length with increasing the number of active elements.

The numerical results presented on Figure 7 was obtained with a lever length of 0.5m (or total height, in the second hypothesis), and a global deflection of elastic system of 0.1m.

Figure 8. The evolution of equivalent rigidity for single, double or quad montages of 1...6 points arms

Both hypothesis have practical justification, but the last - of const. height - is more applicative; first reason is given by the reduction of lever length, that imply a relative small angular deflections on each torsion elements; the second reason is because in practice the available space for montage is restricted, and this hypothesis assure all conditions for tuning the functional performances without global dimensions changes.

Analysing the proposed structures for passive elastic isolators, results that a computational model for global estimation of isolation performances is based on the visco-elastic individual behaviour, and succession / derivation montages of identical components. At this point, it had to be mentioned that the entire research supposed identical active elements utilization. According with this basic technical requirement, whichever of these isolation devices are based on the identical arms derivation montage. It can be used a various number of active elements, but identical for each arm (usual 2..4 rubber elastic elements). A serviceable montage contains one, two or four identical arms, with three or four active elements per arm. In Figure 8 is depicted a parametric diagram for relative equivalent rigidity evolution versus number of active points. The analysis was maded for single, double and quad montages. All the active elements have the same characteristics, and all the arms have identical structure.

3 Basic Concept Implementations

Basing on the theoretical suppositions and practical technical requirements, presented in the previous paragraph, it was developed a few types of special isolation devices. The proposed devices for antivibrational protection of superstructures have modulated configuration, which included both the rubber elastic elements - with the main purpose that take over the deformation energy of the entire system, and the rigid metallic levers - to take over and re-allocates the external loads, and to assures a certain rigidity and stability of the entire system framed by superstructure - insulation and protection device - base structure.

The modulated structure have the main advantage, namely: the basic structure of these insulation / isolation system can be conceived and re-configured with minimum of manual labour and materials input, on concrete requirements of the real isolation situation.

In Figure 9 have been presented three basic types of the special elastic systems with polygonal structural configuration, namely: (a) quad structural configuration; (b) regular hexagon configuration; (c) irregular octagon configuration. All the variants have two complete equiped arms with two, three, and respective four active elements. The advantages of these practical configurations are the simplicity and the adaptability, relative to the high degree of isolation provided both as a single, and as a group montages. The great disadvantage takes around the
working principle. Thus, these systems working on
a single vertical plane, all the components having
plane-parallel movements.

Optimization activities for improvement of
structural configuration, to provide 3D movements
insulation, were leaded to the device depicted in
Figure 10. This is a 3D CAD full model, with a
detail for understanding of movement's
combination. This type of antivibrational protection
device assure full insulation for five degrees of
freedom - see Figure 10.a. Basically, it is composed
by two identical plane insulation systems, mounted
at 90° one from other, articulated at top and bottom
with external linkage frames. Each system assure a
vertical and one horizontal direction insulation, the
criss cross montage combines these directions of
linear movements, and the top/bottom rolling
articulations provides the two rotational movements
on vertical planes. This working manner supplies a
vertical rigidity with double value comparative by
the horizontals.

![Figure 10. Spatial configuration on quad arms with four active points; (a) full computer simulation model and (b) working principle detail](image)

4 Experimental Results

In Figure 11 it is depicted two constructive types of
the proposed devices, namely: (a) plane device with
six active elements; (b) plane device with eight active elements, both with single layer
configuration. All these devices have been designed
for low values of external loads, within 100 ... 140
daN.

All the proposed devices have the active
elements framed by a single rubber elastic element
special designed for torsion charges. Instead of these
elements it could be used a complex cartridge of
rubber elastic elements, designed for torsion global
deflection. A type of this cartridge is shown in
Figure 12: (a) a general view, and (b) detail of an
elastic component.

![Figure 11. The special elastic systems with polygonal configuration; hexagon (a) and octagon (b) montages](image)

![Figure 12. The complex elastic cartridge for torsion charges; ensemble view (a) and basic elastic element (b)](image)

For instances of the proposed devices, in Figure
13 are depicted the diagrams of relationship between
one of the essential structural parameter of the active
element (usual elastic rubber element), the ratio
n=D/d between the inner and the outer diameters of
the elastic sector, and the length of the lever a, about
the equivalent rigidity - see Fig.13.a, respectively
about the natural frequency of the isolation device -
see Fig.13.b.

In Figure 14 is depicted the experimental
stiffness characteristic for the insulation devices
presented in Figure 11. The instrumental tests were
developed on real devices with simple torsion rubber
elastic element with 40mm length and 50mm inner
diameter. On the Fig. 14, the "SEP-6" means the
device with six active points - see Fig. 11.a, and
"SEP-8" means the other one - see Fig. 11.b. The dashed line pattern for the "SEP-6" curve, for displacements greater than 14mm, means an extrapolation of the serviceable area until the operation limit of "SEP-8".

5 Concluding Remarks
Taking into account the conclusions enunciated on each paragraphs, results: all the proposed configurations provides, a satisfactory results regarding the global degree of isolation, under the experimental tests; some basic structural configurations it have to be re-shaped, for the stability improvement; the criss cross configurations assures more stability on operation, but it is more difficult to materialize and debugged them; it have to evaluate the optimum ratio between the number of active points, and the structural stability; also, it have to estimate the optimum value of natural frequency, thus that it will be avoid a large number of elastic elements and/or large size of levers or other linkage elements; structural and functional optimization of complex elastic cartridge, and using these ensemble instead of the single elastic element, could assure a high level of performances and safety on operation.

The future research directions alludes to the structural configuration improvement, the re-shaping of components, growing up the vibration insulation performances, reduce the structural complexity and increase the dynamic stability.

References: