ForumAcusticum 2005

Damping Evaluation in Case of a Vibration Insulation System

Polidor Bratu
Research Institute for Construction Equipment and technology, 021652 Bucharest, .266 Pantelimon, Romania, **icecon@icecon.ro**

This paper is focused on experimental and calculus evaluation for the damping in case of a system consisting of more identical elements serial or parallel connected. Thus, in case of a system having a constant mass m being in a vibrating motion, the changing of the insulation degree at the base could be performed by various configurations of some identical elements assembly. Each element can be characterized by its eigen rigidity and the critical damping fraction while this element is coupled with the mass m. For the rubber elements serial or parallel mounted, having linear viscoelastic behaviour, the system equivalent damping is presented when the number of elements is increased while subjected to the same static load. Also, some experimental results obtained on the stand putting into evidence the damping changing depending on the number of rubber elements are presented.
Finally, this paper contains the diagrams illustrating the equivalent damping variation (critical damping fraction for the system) as a function of the number of identical elements serial or parallel mounted.

1 Introduction

This paper is focused on the assessment of equivalent damping for a linear viscoelastic system consisting of discrete elements parallel, serial or mixed mounted. The used hypothesis takes into consideration the viscoelastic system takes over the same permanent static load, keeping the mass constant and changing the number of rubber elements. The antivibrating system consists on several rubber elements parallel, serial or mixed assembled

2 Equivalent damping of the system

For the linear viscoelastic model having one freedom degree (see figure 1), consisting of one linear viscoelastic element characterized by m, k, b, excited under steady harmonic regime we define:

$$\xi_1 = \frac{b}{b_0} = \frac{b}{2 \cdot \sqrt{k \cdot m}} \qquad (1)$$

where:

- ξ is the critical damping fraction of the system;
- b – the viscous damping coefficient of the system
- k – the elasticity coefficient of the system ;
- m – the total mass.

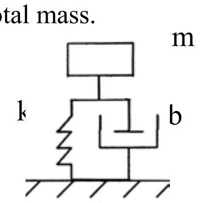

Figure 1: Linear viscoelastic system, one-freedom degree

In case of antivibrating system consisting of N_s identical elements serial mounted (see figure 2a), we have:

$$\xi_s = \frac{b}{N_s} \frac{\sqrt{N_s}}{2 \cdot \sqrt{k \cdot m}}$$

or

$$\xi_s = \frac{1}{\sqrt{N_s}} \cdot \xi_1 \qquad (2)$$

where ξ_1 represents the critical damping fraction for the system consisting of a single viscous element and having the individual characteristics k, b, ξ_1 and m (see figure 1). The calculus model equivalent to the serial grouping is illustrated in figure 2b.

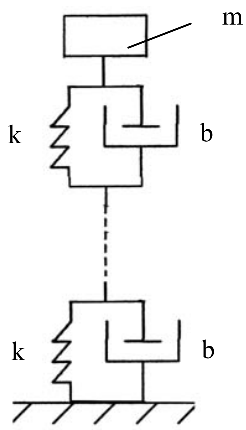

Figure 2 a: Antivibrating system, serial mounted elements

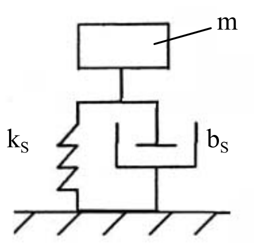

Figure 2b: Calculus model for serial mounted elements

In case of the antivibrating system consisting of N_p identical elements parallel mounted we have:

$$\xi_p = b \cdot N_p \cdot \frac{1}{2 \cdot \sqrt{N_p \cdot k \cdot m}}$$

or

$$\xi_p = \xi_1 \cdot \sqrt{N_p} \qquad (3)$$

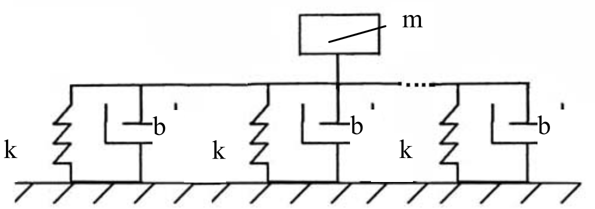

Figure 3a: Antivibrating system, parallel mounted elements

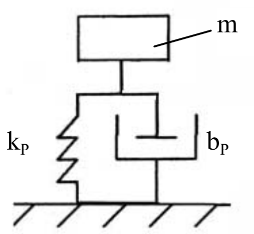

Figure 3b: Calculus model for parallel mounted elements

In case of the antivibrating system consisting of identical elements mixed mounted, namely N' elements on a column serial mounted and N" viscoelastic columns parallel mounted (see figure 4) we have:

$$\xi_m = \frac{N^{"}}{N^{'}} b \cdot \frac{1}{2 \cdot \sqrt{\frac{N^{"}}{N'} \cdot k \cdot m}}$$

or noting $N^* = \frac{N^{"}}{N^{'}}$ it results in :

$$\xi_m = \xi_1 \cdot \sqrt{N^*} \qquad (4)$$

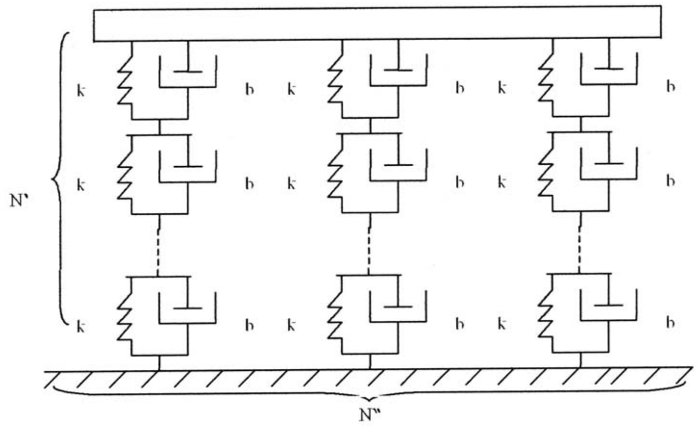

Figure 4: Antivibrating system, mixed mounted elements

Considering N' = 1 and N" = 1 we obtain N* = N" with $\xi_m = \xi_p = \xi_1 \cdot \sqrt{N^{"}}$ and $\xi_m = \xi_s = \frac{1}{\sqrt{N^{'}}} \xi_1$ respectively

In order to have a periodical motion for the system the equivalent damping of the system ξ sub-unit, namely ξ < 1. Thus we have the following conditions:

– for the serial system :

$$N_s > \xi_1^2 \qquad (5)$$

– for the parallel system:

$$N_p < \frac{1}{\xi_1^2} \qquad (6)$$

– for the mixed system:

$$\frac{N^{"}}{N^{'}} < \frac{1}{\xi_1^2} \qquad (7)$$

3 Equivalent damping variation depending on the system construction

For the composed antivibrating systems consisting of identical elements serial assembled the variation of the equivalent damping coefficient ζ_s expressing the critical damping fraction is illustrated in figure 5. Thus, one could ascertain that as the serial mounted elements are more and more the system damping decreases.

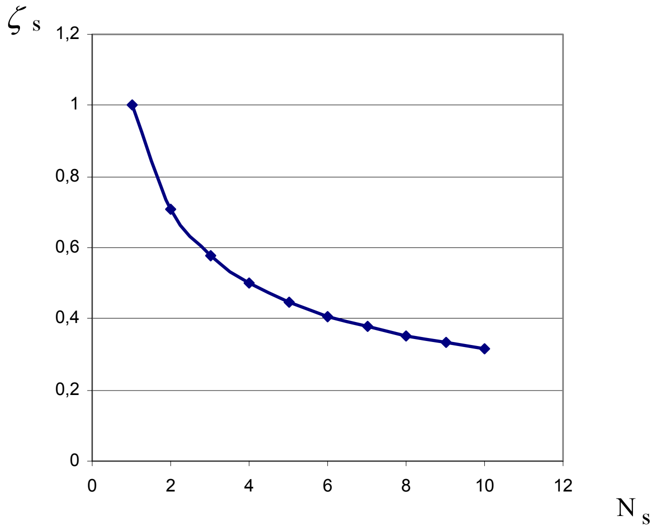

Figure 5: Variation of critical damping fraction (serial mounted elements)

For the composed antivibrating system consisting of identical elements parallel mounted, the variation of the critical damping fraction ζ_p is presented in figure 6, This signifies a slow increase in respect to the number of elements N_p.

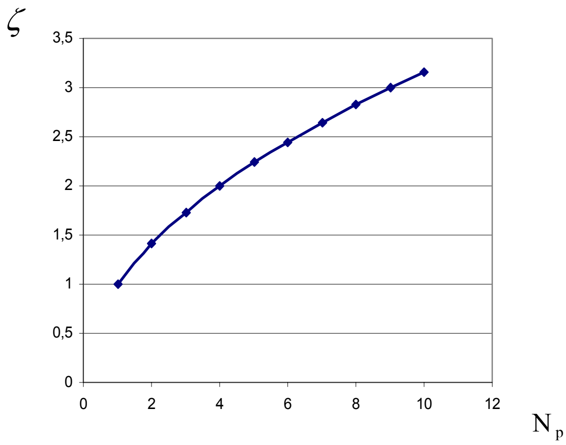

Figure 6: Variation of critical damping fraction (parallel mounted elements)

For the compose antivibrating system consisting of identical elements mixed mounted, the variation of the critical damping fraction ζ_m is illustrated in figures 7 and 8 as curve families with the parameter either the number of identical elements N' in a column or the number of identical columns N". Thus, for the curve in figure 6 we have the relation:

$$\zeta_m = \zeta_1 \sqrt{N''} \cdot \frac{1}{\sqrt{N'}} \qquad (8)$$

In case of a given value of N" the variation of N' leads to a decrease of the system equivalent damping.

If N'' = p = constant, then $\zeta_m = \zeta_1 \sqrt{p} \cdot \frac{1}{\sqrt{N'}}$ represented as the curve in figure 7.

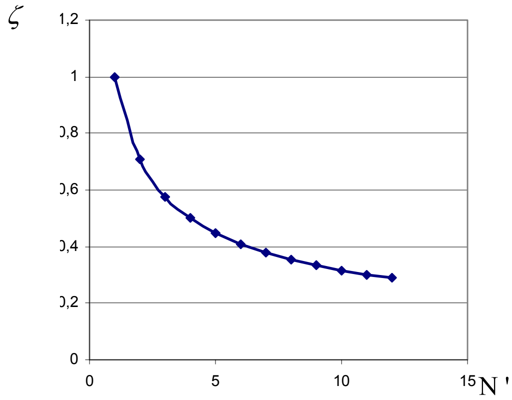

Figure 7: Decreasing of the system equivalent damping

In the second case according to figure 8, for N' = s = constant the increasing the number of columns N'' parallel connected leads to a increase of the system damping observing the law :

$$\zeta_m = \frac{\zeta_1}{\sqrt{s}} \sqrt{N''} \qquad (9)$$

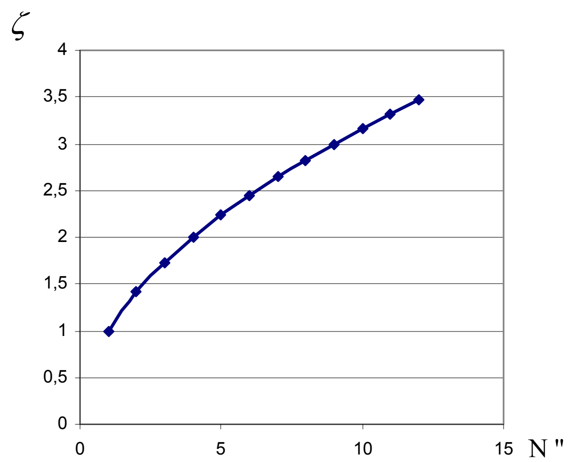

Figure 8: Increasing of the system equivalent damping

Figure 9 represents the curve families for a discrete increase of the number of serial elements in each column $N'' = \overline{1,5}$ and $N' = 1, 2, \ldots, 10$.

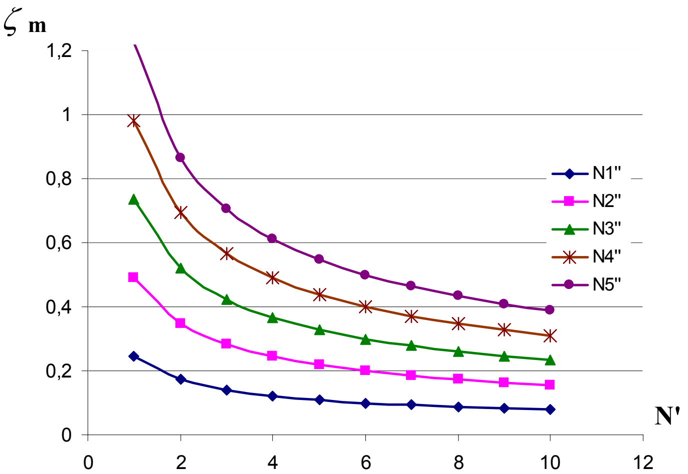

Figure 9: Curve families for a discrete increase of the number of serial elements in each column

The curve families for a discrete increase of the number of parallel elements in each column $N' = \overline{1,5}$ and N'' = 1, 2, …, 10 are illustrated in figure 10.

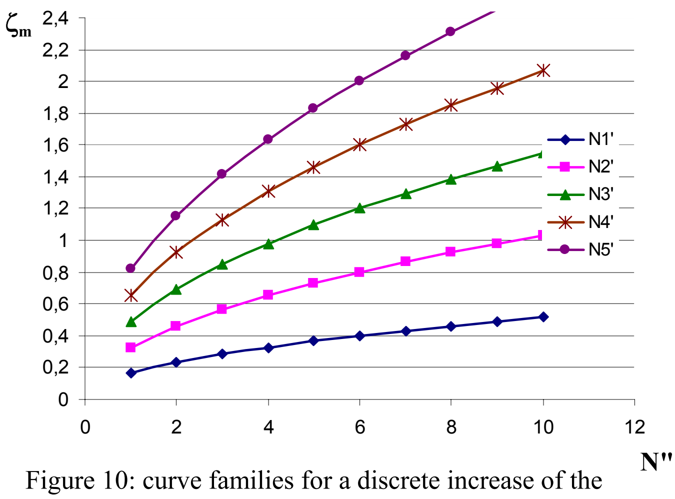

Figure 10: curve families for a discrete increase of the number of parallel elements in each column

4 Conclusions

Analyzing the relations and basing on the experimental results obtained by a large number of researchers upon various viscoelastic configurations one can conclude the following items:

a) for the viscoelastic system consisting of serial mounte elements the equivalent damping is in inverse ratio to the square root of the total number of elements;

b) for the viscoelastic system consisting of parallel mounted elements only the equivalent damping is directly proportional to the square root of the total number of elements;

c) for the antivibrating system consisting of mixed mounted elements the equivalent damping is directly proportional to the square root of the ratio between the number of columns parallel mounted and the number of identical elements serial mounted.

We can conclude the most important damping is obtained in case of antivibrating systems where the number of identical elements parallel mounted is very large.

References

[1] P. Bratu, Sisteme elastice de rezemare pentru maşini şi utilaje (Elastic systems inteded for machinery supporting), Editura Tehnică, Bucharest **(**2000)

[2] Gh. Buzdugan Izolarea antivibratorie (Antivibrating isolation), Editura Academiei, Bucharest (1993)

[3] S.S. Rao Mechanical vibrations. Third edition. Addison-Wesley Publ. Comp (1995)