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RESEARCH REGARDING DAMAGE DETECTION IN THE INERTIAL DAMPERS OF THE ELECTRIC VEHICLE

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Abstract: *The paper presents some research on inertial dampers wich ensure, through the structural design, mechanical energy dissipation due to vibration or noise generating source. These dampers offer a good vibration energy dissipation in volume of plastics on the one hand and a dissipative higher power efficiency and stability on the other hand (due to the high energy absorption distributed system).*
Keywords : *inertial damper, structural design, mechanical enery, vibration*

1. INTRODUCTION

Inertial dampers ensure, through the structural design, mechanical energy dissipation due to vibration or noise generating source. Also these dampers allow, as result of vibration energy dissipation in volume of plastics on the one hand and as result of dissipative higher power efficiency and stability on the other hand (due to the high energy absorption distributed system) the use of corresponding nonlinear zone flexibility based plastics. Moreover, the spatial distribution of inertial masses ensure a more uniform thermal loading plastic base and can be achieved without breaking conditions thereby avoiding pregnancy and the development of concentrators zones in basic plastic. The same spatial distribution in conjunction with inertial masses form, their surface roughness and especially the flexibility of plastics allow obtaining anisotropic features extremely useful in terms of optimal adaptation in relation to the type of shock absorber damping designed for this task. In [11] such a solution is presented that allows vibration damping electronic control circuit due to the commutation of a stepper motor power. If evoked system consists of silicone plastic housed in a hermetic housing, and moving inertial masses is limited mechanically. If plastic studied system consists of a silicone housed in a hermetic housing and the motion of the inertial masses is limited mechanically.
In [1] are shown the theoretical equations of motion corresponding inertial mass immersed in basic plastic. In the paper [2] such dampers are included in the class of 'meta-materials', mechanical hybrid structures respectively (composite) that allow "predicting the mechanical properties of the design phase" and damping properties in relation to specific needs in system which the damper is included. Such systems are found in the living world that can fulfill both dissipation function but also amplification and therefore accelerations of vibration transmitted through the damper. These issues are extremely important in case of electric vehicles, as a result their shareholders through either the power of synchronous motors or asynchronous motors with the control based on the electric commutation circuit occurring two categories of sources of vibration or noise frequency bands with two distinct areas. First, lower, corresponding to the fundamental frequency applied to the electric motor that is dependent on variable angular speed.
The second frequency range of vibration is due to electrical switchgear and circuit characteristics and correspond to higher frequencies such as those produced by electrical switching circuit. This second field will vary very little in relation to the angular speed of the engine or the velocity of the vehicle. This second area is intended to be covered by the damping characteristics (band pass filter) that can perform inertial damper.
Alternative solutions, involving the development of an annulator of oscillations in electric commutation type Wiener filter [8], which both in terms of reliability, energy consumption, especially high computing power necessary to implement satisfy only partially the needs of applications involving a rotating as uniform for electric vehicle drive system. The Wiener filter operation is based on fundamental control signal adding an estimated signal so that the resulting signal at the output compensate the vibrations due to the commutation electric power applied to the electric motor. The use of a computer system in real time requires high computing

power or specialized circuits but also requires a certain energy and so strictly administered in case of an electric vehicle. Furthermore, if for some reason practically disappears the power control system of the torsional vibration, disappears too the possibility to decrease the vibrations.

2. TECHNICAL REQUIREMENTS

In figure 1 a standard model of an inertial damper is presented. The damper is made by rubber reinforced with balls. In the paper two cases are considered: the balls are made by steel and, alternately, by aluminium (Al). The results are similar, which is why we only present the case where steel balls are. The properties for rubber and steel are those currently used in engineering

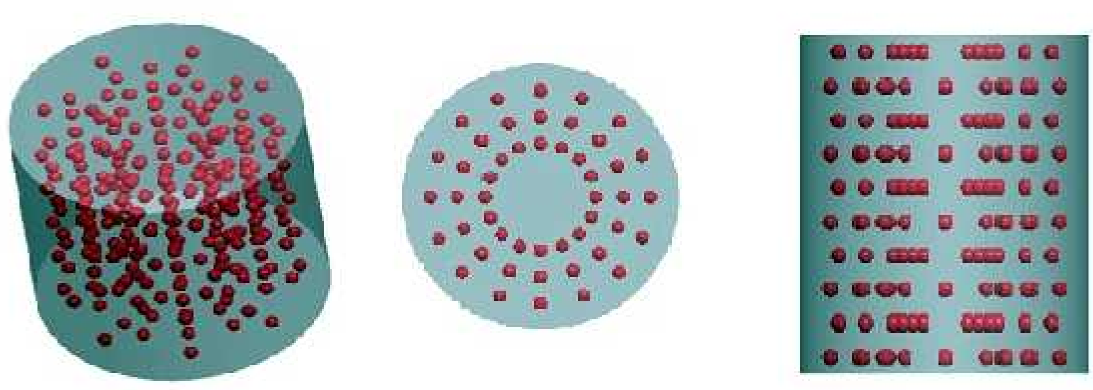

Figure 1. Physical model of the inertial damper

A finite element model for the damper is presented in Fig.2. The main goal of the paper is to determine the eigenvalues for a functional structure and for the damaged structure. Making an analysis in the eigenfrequencies changes is possible to identify the moment when the damage is produced. The method was presented in previous paper as [3],[4],[7]. Analytical methods in the field of the eigenvalues can be found in many paper (see [5],[6]).

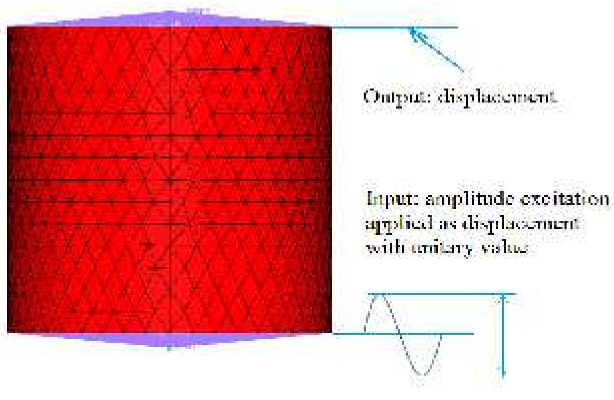

Figure 2. Finite element model of the damper

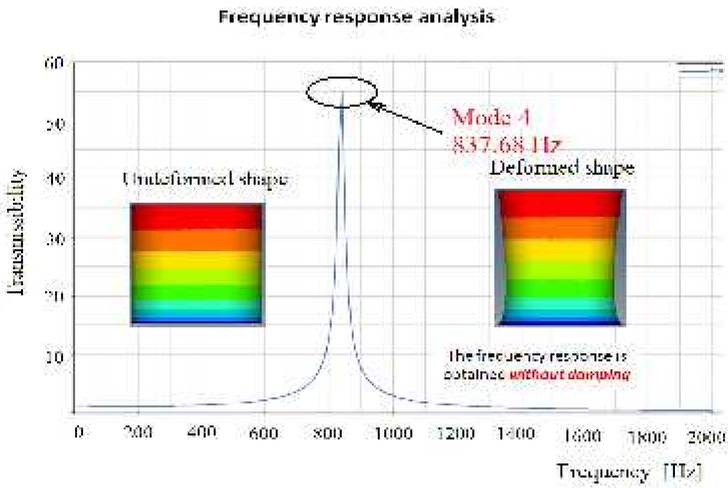

Figure 3. Frequency response for a rubber model

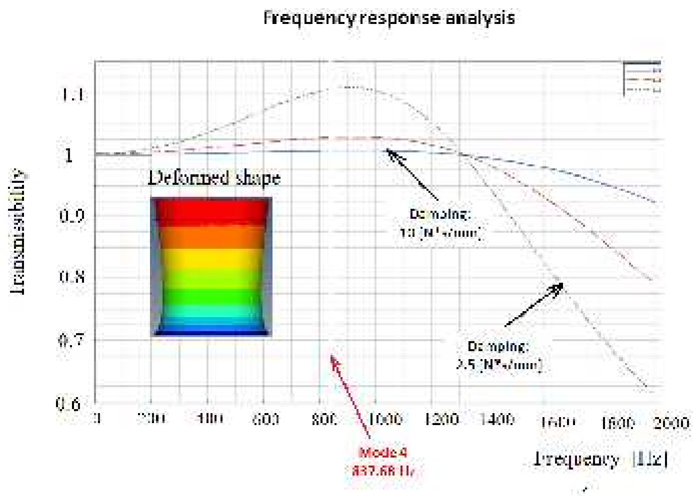

Figure 4. Frequency reponse for an inertial damper with steel balls

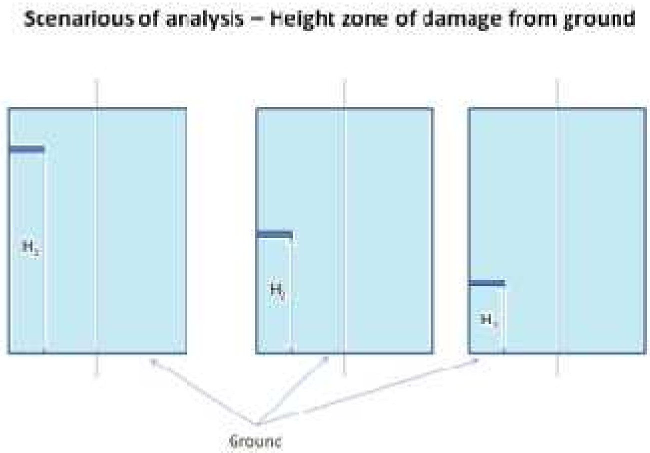

Figure 5. Damage scenarious for the damper

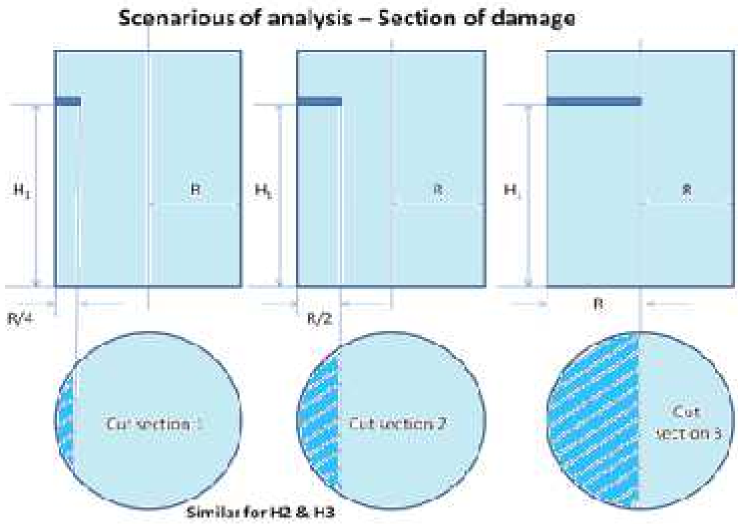

Figure 6. Damage scenarios for the damper

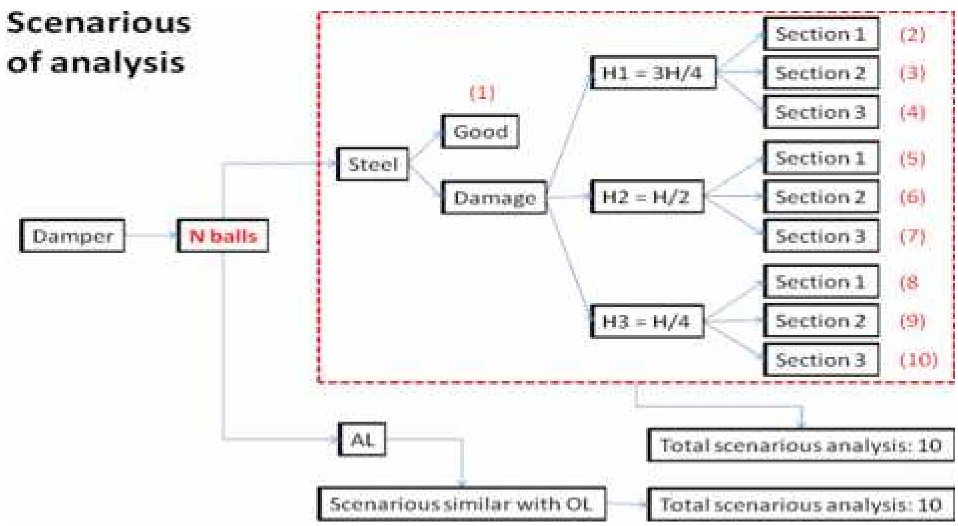

Figure 7. Scenarious of analysis

3. EIGENVALUES FOR THE DAMAGED DAMPER

The eigenvalues and eigenmodes were computed using a finite element soft. The result for the eigenvalues computed for the scenarious presented in Fig. 7 are presented in Table nr.1.

Table nr. 1. Eigenvalues for the first 10 scenarious

Mode no.	**Frequency [Hz]**									
	Good (1)	D1 (2)	D2 (3)	D3 (4)	D4 (5)	D5 (6)	D6 (7)	D7 (8)	D8 (9)	D9 (10)
1	320	320	320	305	318	302	212	312	280	170
2	320	321	321	311	320	310	243	318	305	223
3	459	460	458	437	456	438	383	451	427	349
4	837	835	814	554	824	711	461	822	730	500
5	879	874	859	727	860	852	711	863	835	671
6	879	876	864	843	880	858	844	872	854	803
7	1379	1356	1245	934	1366	1270	1009	1381	1383	1375

8	1559	1541	1460	1140	1547	1487	1232	1559	1555	1495
9	1560	1554	1519	1289	1562	1515	1369	1561	1560	1505
10	1600	1600	1588	1382	1602	1590	1548	1600	1592	1570

A representation of the first ten eigenvalues for the scenarious considered is made in the Fig. 8-12

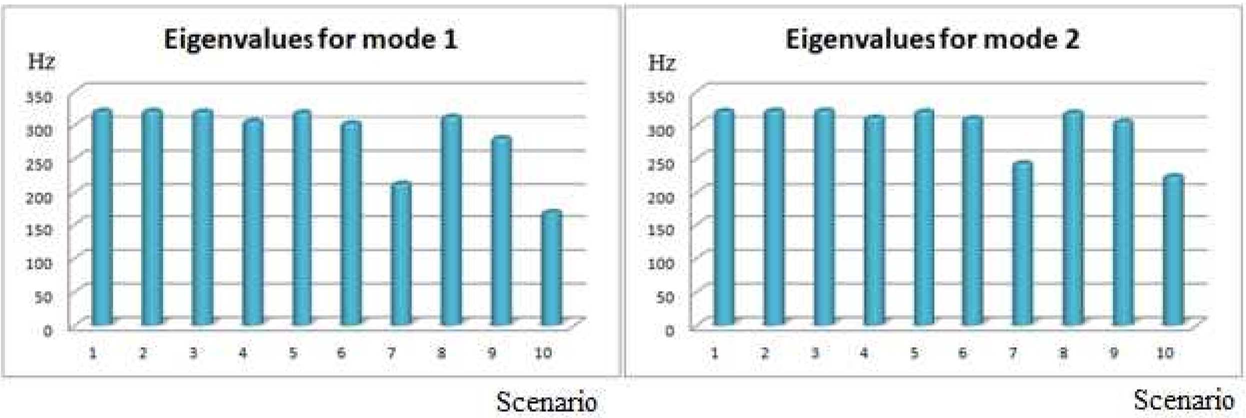

Figure 8. The first two eigenvalues for the ten scenarious

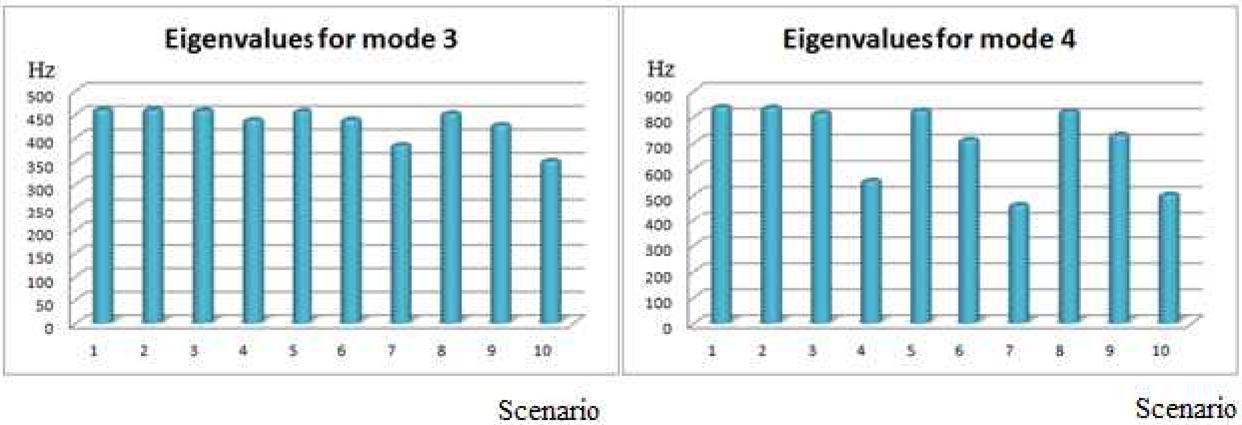

Figure 9. The 3rd and 4th eigenvalues for the ten scenarious

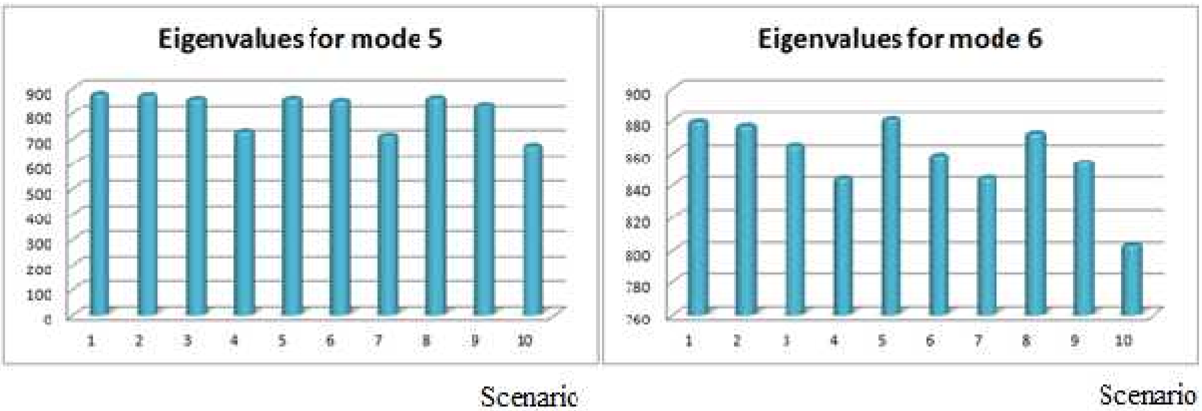

Figure 11. The 7th and 8th eigenvalues for the ten scenarious

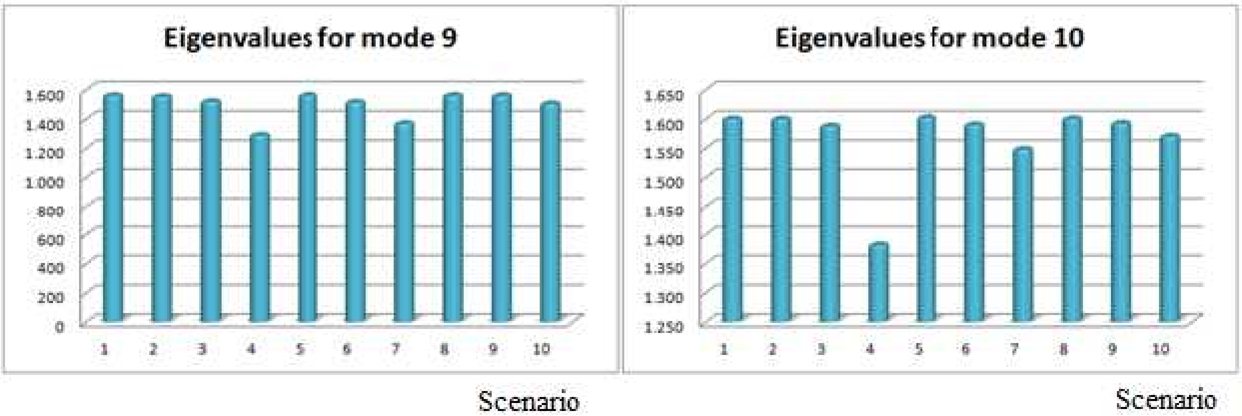

Figure 12. The 9th and 10th eigenvalues for the ten scenarious

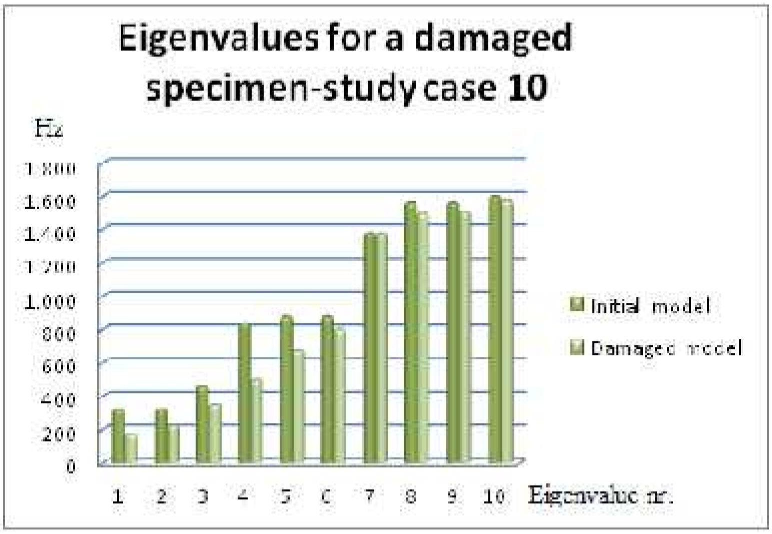

Figure 13. The first 10 eigenvalues for the scenario nr. 10 (initial and damaged model)

Symmetric modes gives equal eigenvalues [9], [10] but a crack in the material makes one of the eigenmodes to keep his value while the other will change. That is why it is necessary to consider various eigenmodes each time to make comparison. Some eigenvalues, despite the emergence of crack and damage of the damper, do not change (it can compare, for example, line 1 and 2 of Table 1).

If we analyze one of the cases, for example, the last case (version 10 - Figure 13) you can see that the eigenmode 7, for example, is not changed although the case study shows a consistent fissure. In contrast to most other eigenvalues are severely affected. It will result so that some eigenvalues are not altered by a change in material continuity while others give some consistent differences. It follows therefore that for detecting a beginning of damage is necessary to consider several vibration modes to be comparable to the initial situation.

Table 2. Eigenvalues for the next 10 scenarious (balls made of aluminium)

Mode no.	Frequency [Hz]									
	Good (11)	D1 (12)	D2 (13)	D3 (14)	D4 (15)	D5 (16)	D6 (17)	D7 (18)	D8 (19)	D9 (20)
1	327	327	326	312	325	309	217	318	286	174
2	327	328	328	317	326	316	248	325	311	228
3	467	467	465	445	464	446	390	459	434	356
4	855	853	831	565	841	725	471	839	745	511
5	895	891	876	741	877	870	725	879	851	684
6	895	893	881	861	897	875	861	888	871	819
7	1401	1379	1265	951	1389	1291	1029	1404	1406	1398
8	1592	1574	1489	1164	1579	1516	1258	1592	1588	1526
9	1592	1587	1550	1315	1594	1546	1394	1594	1593	1536
10	1634	1634	1621	1408	1637	1624	1580	1634	1626	1605

When we use balls made by aluminum the results are presented in Table 2. The conclusions analyzing the values presented in Table 2 offer similar conclusions as for the values presented in Table 2, from a qualitative point of view. The density of aluminum being smaller as the density for steel, the quantitative results differ.

4. CONCLUSION

In the operation of a vibration damper, insert mode of the balls inertial in the mass damper rubber makes it vulnerable to damage. It is, of course, be very useful to detect early failures of this damper before damage. It can thus avoid significant material expenses. A periodic visual inspection requires expenses and waste of time. For this reason it can be very useful to find a method of early detection of cracks in the rubber body. In this paper we propose the use of their eigenfrequencies damper measurement and comparison to baseline. If there are significant differences the damper may be replaced. As seen in the presented figures, some eigenfrequencies can differ more or less, depending on the place and dimension of the fissure. For this reason it should be analyzed and compared multiple frequencies simultaneously. We must not confine ourselves to the study of a single frequency of failure because there may be cases where the eigenfrequency corresponding to a particular mode of vibration, not be influenced by the mechanism of destruction, but other frequencies are affected.
The analysis was carried out for a single shock absorber, attached at one end. In practice it may be more useful to consider the damper mounted in the mechanical system. This arrangement makes its eigenfrequencies of the damper to change. They can be determined from a more complex calculus but the findings of this study do not change. From the results presented it can be concluded that a change of eigenfrequency more than 5% can pull the alarm on the possibility of cracks in the structure while a difference of more than 10% should lead to a revision of the whole assembly to determine the cause of this change.

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