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COMPARATIVE ANALYSIS ON VIBRATION ATTENUATION OF RUBBER AND WIRE ROPE ISOLATORS

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Abstract: *The vibration attenuation represent a major objective in automotive industry. Special rubber elastic elements are identified as attenuation solutions, helping in solving this objective. At the present the wire rope isolators represent a good solution for vibration attenuation. This paper presents a comparative analysis of vibration attenuation when using wire rope isolators and rubber elastic elements. The analysis is done in a specific application to attenuate vibration of the exhaust line. The results of the measurements performed for this application present the efficiency of the two compared solutions.*
Keywords: *wire ropes, isolators, elastic elements, vibration attenuation*

1. INTRODUCTION

In order to satisfy the current customer requirements, the automotive industry focuses more on reducing the noise and vibrations produced in modern vehicles. Various isolators are designed for engines as mount system components. Isolators are commercially available in many different resilient materials, in countless shapes and sizes, and with widely diverse characteristics [3].
An important cause for interior noise in vehicles is the structure-borne sound from the engine. The vibrations of the source (engine) are transmitted to the receiver structure (the vehicle) causing interior noise in the vehicle. For this reason the engine is supported by rubber isolators for passive isolation [2]
The properties of a given isolator are dependent not only on the material of which it is fabricated, but also on its configuration and overall construction with respect to the structural material used within the body of the isolator [3].
The function of an isolator is to reduce the magnitude of motion transmitted from a vibrating system to the equipment or to reduce the magnitude of force transmitted from the equipment to its bracket.
Rubber is a unique material that is both elastic and viscous. Rubber parts can therefore function as shock and vibration isolators and/or as dampers. The isolation behavior of rubber isolators strongly depends on the excitation frequency and the pre-deformation of the mount as consequence of the weight of the source to be isolated. For rubber isolators to have a maximum efficiency, the proper installation needs to be taken into account [6].
Wire rope isolators have different response characteristics depending on the diameter of wire rope, number of strands, cable length, cables twist, number of cable per section and on direction of the applied force [6].
In comparison with rubber elements, the wire rope isolators are full metal structure, maintenance-free and are not subject to aging due to external factors like oil, salt water, chemicals and variations in temperature. Most applications of wire rope isolators are found in situations where equipment needs to be mounted against shock or vibration, but where sound isolation is of minor importance.
The other advantages of a wire rope isolator lie in the ability to combine a high level of both shock and vibration isolation, in combination with relatively small dimensions. Wire rope isolators are limited by their own construction and may for this reason be loaded in any direction without the risk of malfunctioning [7].

2. EXPERIMENTAL SETUP

Experiments were performed in the engine test bench where the exhaust line was installed on the two types of isolators: 1 rubber isolator (figure 1) and 2 wire rope isolator (figure 2). The testing was performed by running the engine starting from 950 rpm to 4500rpm at full load, to cover all excitations induced in the mounting brackets.

Figure 1

Figure 2

Comparative measurements were made between a type of rubber elastic element, used for the evaluated exhaust line , and two KR type wire rope isolators elements , with wire thickness of 3mm and 3.5 mm.
As measurement points we chose the positions where the exhaust line is mounted on the bracket (figure 3, figure 4):
- ECH: 01 X/Y/Z and ECH: 02 X/Y/Z : points that evaluate vibration signal on exhaust line, in fact the input signal in these elastic element;
- RH: 01X/Y/Z RH: 02 X/Y/Z points that measure the signal at the exit of the elastic element.

Triaxial accelerometers mounted in measuring points had sensitivity of 1 mV/(m/s^2) and mounted so as to respect coordinates: X perpendicular to the engine, Y-transverse to engine, Z- vertical direction.

Figure 3: Exhaust line on rubber elements

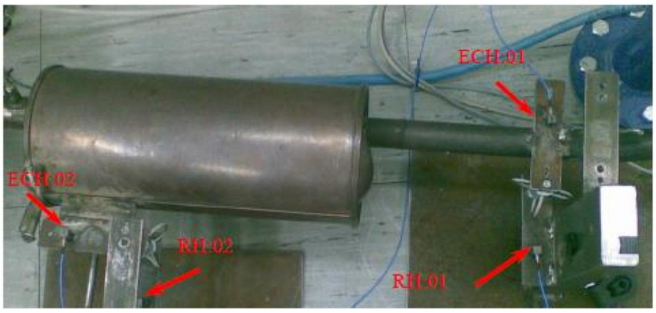

Figure 4: Exhaust line on wire rope elements

Signal acquisition was performed with a complete LMS testing system for which it was considered a signal acquisition bandwidth of 2560 Hz at 5 Hz resolution. The results extract from the post-processing analysis was the maximum level of acceleration amplitude (peak-hold) which are transmitted through elastic element but also the impact in second order.
During the post-processing were monitored the maximum level of acceleration amplitude (peak-hold) which are transmitted through elastic element and the second order impact.

3. RESULTS

A Fast Fourier Transformation (FFT) was applied to the vibration time signal in order to have the results in frequency spectra. The frequency spectrum shows the vibration amplitude as a function of frequency. When the environment is not constant in time it may be necessary to measure the peak hold (called "maximum rms") vibration levels.
For the results it was considered that on the same graph the evolution of each type of analyzed element is represented as it follows:
- With black curve-rubber element,
- red curve-wire rope isolator KR 3
- blue curve-wire rope isolator KR 3.5

To make sure that the same input signal is used, the signal measured at the points ECH: 01 and ECH: 02 on the vertical direction are represented in figure 5. It can be noticed that the system engine-exhaust line, responsible for the vibration transmitted and induced in elastic brackets, have the same amplitude level of acceleration and the same vibration behavior for all three analyzed cases.

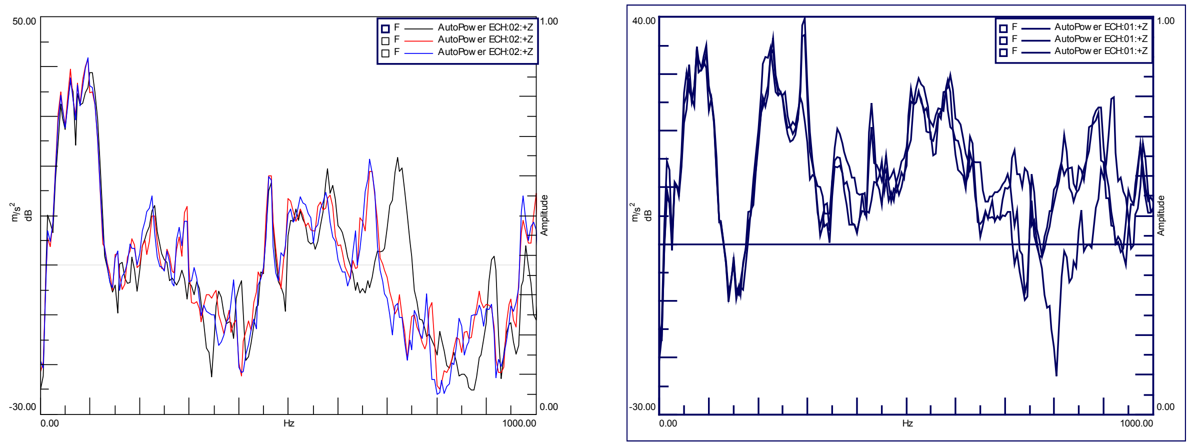

Figure 5: Peak-hold for input points

By analyzing the graphs which present the maximum vibration level (figure 6) it can be noticed two distinct situations:

- the results obtained in measurement point RH:01, the amplitude level of vibration transmitted through wire rope isolator in the range 1-500 Hz is much smaller than the rubber element. In the range 500-1000 Hz, amplitude of vibrations level transmitted through elastic elements is much higher than rubber.

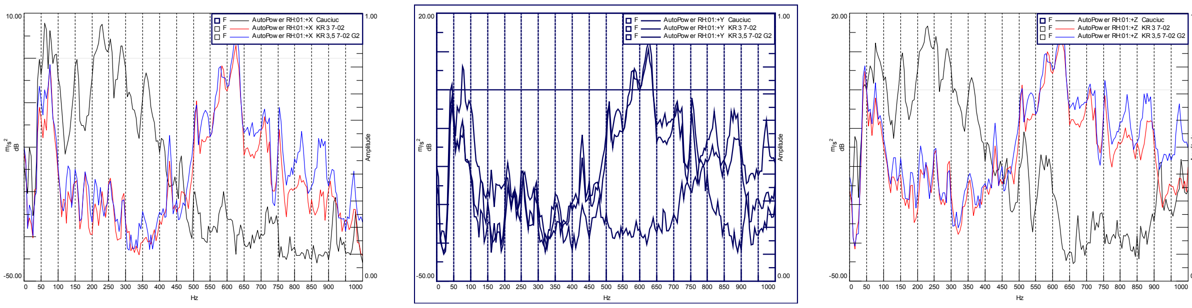

Figure 6: Peak-hold on RH:01 X/Y/Z

- in the second point of measurement RH:02, . the wire rope isolators show a level of acceleration amplitude lower then rubber elements for low frequencies but for frequencies up to 1000 Hz is comparable and equal to that of the rubber elements.

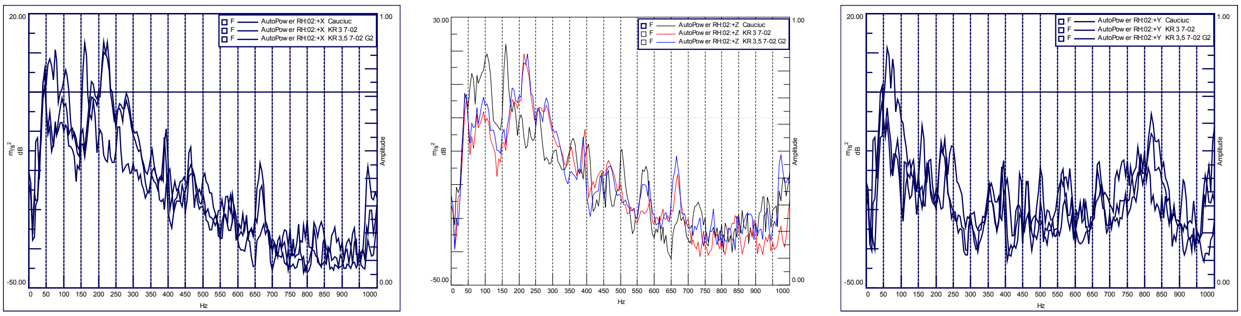

Figure 7: Peak-hold on RH:02 X/Y/Z

For rotating machinery most signal phenomena are related to the rotational speed and its harmonics [4]. A rotational speed harmonic is called an order. It is the proportionality constant between the rotational speed and the frequency. In case of 4 stroke engines with 4 cylinders the most energetic harmonics is order 2. Using graphics which represent second order harmonics, it can be identified the critical engine speeds that influence behavior but also vibrational frequencies at which significant changes occur.

For the two points of measurement (RH: 01, RH: 02) it can be observed that the wire rope isolators show a level of acceleration amplitudes much smaller than that of the rubber element. For wire rope isolators the critical speed is1300 rpm corresponding to 45 Hz frequency with amplitude which does not exceeds that of the rubber element. Comparing, the rubber element has two speeds for which the acceleration amplitude shows peaks: 1850 rpm and 2300 rpm .

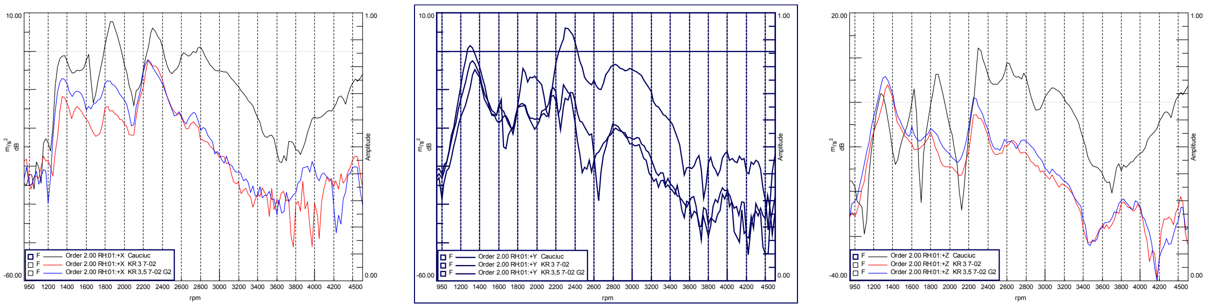

Figure 8: Order 2 for RH:01 X/Y/Z

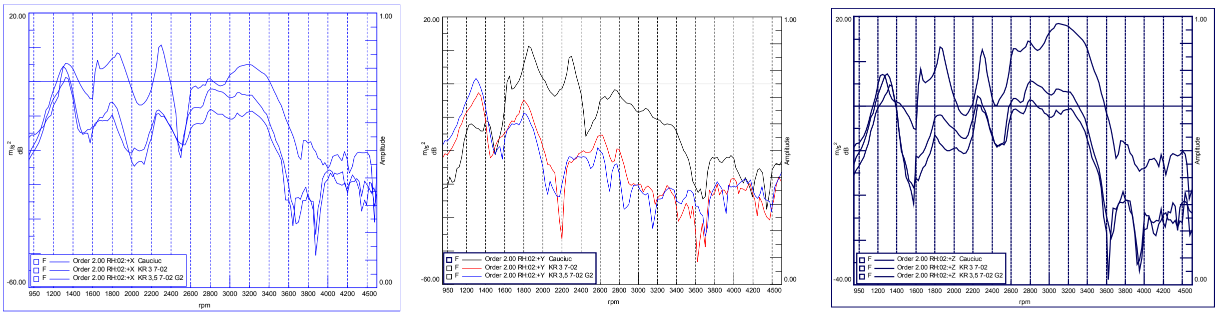

Figure 9: Order 2 for RH:02 X/Y/Z

The analysis of second order curves, corresponding to wire rope isolator, shows a much lower level of vibration amplitude in the low frequencies. Because second order examines a range of up to 180 Hz, an area where many mechanical engine components have impact, it can be concluded that wire rope isolators show considerable efficiency in attenuation acceleration level up to 20 dB at low frequency.

4. CONCLUSIONS

This paper presents comparative analyzes between measurements performed on a rubber elastic element and two types of wire rope isolator. The goal is to evaluate the attenuation of vibration transmitted through the elastic elements to mounting brackets. The two types of elastic elements, rubber and wire rope isolator, were mounted to attenuate vibrations of exhaust line.

Measurement results highlight that in this application wire rope isolators show good qualities in vibration levels attenuation up to 200 Hz frequency. The two distinct situations generated by the location points of the elastic elements have highlighted two completely distinct behaviors of these types of isolators. In point RH: 02, where the wire rope isolator has undergone greater weight loads of the exhaust line, the vibration level at medium-frequency up to 1000 Hz , the behavior is very close to that of the rubber one. In measurement point RH: 01 it was identified for wire rope isolator a low level of vibration transmitted through elastic element up to 500 Hz and above this frequency up to 1000 Hz a very low attenuation of acceleration level transmitted through elastic elements.

It can be said that a different loading of the wire rope isolator lead to different behavior in vibration attenuation and the vibration attenuation qualities of wire rope isolators can be highlighted only if these element’s elastic work under proper load.

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