THE INFLUENCE OF WIRE ROPE LENGTH ON VIBRATORY BEHAVIOR OF WIRE ROPE ISOLATORS

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Abstract—The wire rope isolators (WRI) represent efficient solutions for vibration and shock attenuation which can appear in equipment and installations exploitation. Choosing the WRI model which corresponds a certain application is the main objective for the researchers. The aim of this paper is to present the influences of the wire rope length in vibration isolation. Measurements performed with 3 different WRI models offer information on their vibration behavior depending on their length. The obtained results are useful in choosing WRI isolators for vibration attenuation applications.

Keywords—mechanical vibration, overall level, peak-hold, wire rope isolators.

I. INTRODUCTION

Wire rope isolators have found numerous applications in the shock and vibration isolation of industrial machinery, seismic protection of building [1], transportation and military application or other engineering area. 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 [2], [3].

In this paper is studied the influence the cable length on vibrations attenuation. For this, was chosen by calculation the properly WRI type for application it is used. Along the elastic element determined by calculation were also selected two other types of WRI with different length of cable to determine its influence on vibration attenuation. The objective for using such WRI is to reduce high vibration energy that is transmitted through WRI to mounting brackets [4][5]. Identify a suitable wire rope length of elastic element is a way to efficiently use of them in vibration attenuation.

In comparison with rubber elements [6], 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 [7], 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

II. EXPERIMENTAL SETUP

The results presented in this article are based exclusively on measurements [8][9][10] performed on the engine test bench. The measured elastic elements were used to attenuate the exhaust line vibrations for an 1.5dCi engine in the test bench.



Fig. 1. Measurement points ECH:01-RH:01

The exhaust line is installed on WRI isolators in 2 points. It's mentioned the fact that the mounting points are subjected differently to the exhaust line weight, so, the RH:01 point is subjected to a smaller exhaust line weight load and the RH:02 point is subjected to a bigger weight load (Fig. 1. and Fig. 2.).

In this analysis KR WRI isolator's type (Sebert

Tehnologie) were used, with 3.5 mm wire thickness, and length varying from:

- ➤ KR 3,5 7-02 L-78 cable length 78 mm
- ▶ KR 3,5 8-02 L-83 cable length 83 mm
- ➤ KR 3,5 7-02 L-88 cable length 88 mm

The measurements were performed in dynamic conditions in which the engine ran up from 950 rpm to 4500 rpm under full load to cover the entire vibration excitation range.

Triaxial sensors were mounted on the measuring points, for evaluating the vibrations transmitted through the isolators, to the mountings bracket. The measurement directions were considered to be:

X - transverse to the exhaust line (transverse to the crankshaft)

Y – longitudinal to the exhaust line (longitudinal to the crankshaft)

Z - vertical

Data acquisition and post processing have been done using a LMS-TestLab [11] system in which the data acquisition was performed at 256- Hz bandwidth and 5 Hz resolution. The post processing of the acquired data were done in the low and medium frequency range up to 1000 Hz.



Fig. 2. Measurement points ECH:02-RH:02

The graphics extracted from the signal analysis are presented in comparison in order to highlight the cable length influence as well as the vibration behavior of each WRI isolator type. To properly describe the behavior for each elastic element type, the maximum acceleration energy curves were extracted depending on the frequency (peak hold) and the maximum acceleration energy depending on the engine speed (overall level). The analysis is effectuated for each point and the graphical representation is:

- Black curve KR-L-78 –WRI length 78 mm
- Red curve KR-L-83 WRI length 83 mm
- Blue curve KR-L-88 WRI length 88 mm

III. RESULTS

The results of the measurements held on the 3 WRI types are presented as graphics in which are presented the maximum values of the acceleration depending on frequency and the maximum energy of acceleration depending of the engine speed. So, for each measurement point (RH:01 X/Y/Z and RH:02 X/Y/Z) on the three directions, the acceleration amplitudes depending on frequency (peak-hold) and depending on engine speed (overall level) are presented.



Fig. 3. Peak-hold for point RH:01 X/Y/Z

In order to have a quantitative estimation of the attenuation degree for each type of elastic element analyzed, a root mean square value was extracted in the table for each curves type (dB RMS).



Fig. 4. Overall level for point RH:01 X/Y/Z

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In Fig. 3., the measurement analysis results for measurement point RH:01 X/Y/Z depending of frequency are presented. The fact that all types of WRI present the same vibration behavior is observed, and that the acceleration amplitude levels are very similar.

In Fig. 4., de vibration behavior of the WRI depending on the engine speed evaluated in point RH:01 X/Y/Z is presented. In these graphics a similar behavior between the 3 elastic element types is observed, with slightly higher acceleration amplitude levels for type KR-L-88.

TABLE I
RMS VALUE FOR POINT RH:01-PEAK HOLD

WRI Type	RH:01 Peak-Hold m/s ² dB RMS		
	Х	Y	Z
KR 3,5 L-78	10,9	17,9	22,5
KR 3,5 L-83	12,6	19,9	24,4
KR 3,5 L-88	12,3	19,8	24,3

In order to have a quantity estimate of the attenuation level, in table I the root mean square values (dB RMS) of all curves which define the vibration behavior depending on frequency and in table II the root mean square values (dB RMS) of all curves which define the vibration behavior depending on the engine speed which correspond to measurement point RH.01 are presented. Through extracted data analysis in table I, the fact that element KR-L-78 presents an attenuation in the transmitted acceleration energy level with 1-2 dB RMS on all 3 directions compared to the other WRI types, can be observed.

TABLE II RMS value for point RH:01-Overal level			
RH:01 Overall level WRI Type m/s ² dB RMS			el
	Х	Y	Z
KR 3,5 L-78	26,5	30,8	34,7
KR 3,5 L-83	27,4	32,1	36,2
KR 3,5 L-88	29,2	31,8	35,7

By analyzing the root mean square values of the acceleration depending on engine speed are it is observed the fact that element KR-L-78 presents 1-3 dB RMS attenuation.

Through a global behavior analysis for all 3 types of elastic elements, measured in point RH:01 the fact that the WRI element with 78 mm cable length presents a better acceleration amplitude attenuation than the other two, can be highlighted



Fig. 5. Peak-Hold for point RH:02

In Fig. 5., the curves corresponding to the acceleration transmitted through the WRI depending on the frequency in measurement point RH:02 X/Y/Z are presented. By analyzing these graphics, can be observed that the elastic element KR-L-88 has a better vibration attenuation than the other two types studied for a frequency up to 500 Hz can be mentioned, and after that the attenuation degree in decreasing. The same tendency is present and for maximum energy of acceleration related to the engine speed shown in Fig. 6.



Fig. 6. Overall level for point RH:02

Analyzing the extracted acceleration values in table III and table IV, the fact that WRI element KR-L-88 presents better vibration attenuation with 1-3 dB RMS in relation with engine speed on all 3 directions is distinguished

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	TABLE II	Ι	
RMS VALUE FOR POINT RH:02-PEAK HOLD			
RH:02 Peak-Hold			
WRI Type	m/s ² dB RMS		
	Х	Y	Z
KR 3,5 L-78	16,8	4,3	23,0
KR 3,5 L-83	15,1	5,8	21,3
KR 3,5 L-88	13,4	3.2	19,5

Through a global review, it can be highlighted that the elastic element with 88mm cable length has better vibration attenuation qualities in this measuring point

TABLE IV RMS value for point RH:02-Overal level RH:02 Overal level

WRI Type	m/s ² dB RMS		
	Х	Y	Z
KR 3,5 L-78	23,7	23,1	30,0
KR 3,5 L-83	22,7	21,1	29,2
KR 3,5 L-88	21,1	23,1	28,1

By comparing the results obtained from the 2 measuring points, it can be concluded that the elastic element with 78 mm length (KR-L-78) was the most efficient in the point where the elastic element is under a smaller exhaust line weight load, and the elastic element with 88mm cable length was more efficient in the point where the WRI is under a bigger exhaust line weight load.

In order to have a higher degree of exhaust line transmitted vibration attenuation via elastic elements, it is recommended the use of elements with 78 mm cable length in point RH:01 (the point where the WRI is under a smaller exhaust line weight load) and elements with 88 mm cable length in point RH:02 (WRI is under a higher exhaust line weight load)

IV. CONCLUSIONS

In this paper is presented an analysis on the influence of WRI cable length in vibration attenuation. For this purpose, 3 types of elastic elements were tested, regarding vibration attenuation for an exhaust line mounted in engine test bench. This study is based on results obtained exclusively from experiments in which is evaluated the maximum acceleration energy related to frequency and related to the engine speed. By using these two evaluation criteria in the vibration behavior analysis, it was aimed to obtain real and correct information regarding the influence of the cable length in vibration attenuation.

Since the mounting points RH:01 and RH:02, where the measurements have done, were under different exhaust line weight loads, the analysis was performed individually for each point. The graphics corresponding to the maximum acceleration energy in relation to frequency and engine speed were extracted, but it was also accomplished a quantitative evaluation of the vibration attenuation degree for each WRI type. The obtained results from this application showed that in the point where WRI was under a smaller exhaust line weight load, element type tip KR 3,5 L-78 was more efficient, which attenuated vibrations with 1-3 dB RMS in comparison with the other two types.

In the point where WRI was under a higher exhaust line weight load, the elastic element type KR 3,5 L-88 was more efficient, attenuating with 1-3 dB RMS the vibrations transmitted by the exhaust line, on all three directions

Following this analysis, it can be observed that the WRI cable length has a significant role in vibration attenuation. The performed measurements indicated which element type is most suitable for each mounting point even though, preliminary calculations indicated to use a single elastic element type for both mounting points.

WRI represent efficient vibration attenuation solutions and can be used in different applications where a decrease in the vibration energy levels is necessary, In order to successfully use these isolator types it is particularly important to consider the WRI cable length.

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