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THE IMPACT OF STIFFNESS OF ENGINE SUSPENSION CUSHIONS IN AN ALL-TERRAIN VEHICLE ON ITS TRANSVERSE DISPLACEMENT

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Abstract:

The article presents the results of experimental research carried out for different types of diesel engine suspension cushions (plate connectors) in two all-terrain cars. The study was performed using three types of engines in three combustion engines operating conditions. The analyzed parameters were transverse displacement engine vibrations caused during various engine operating conditions between the engine and body of the vehicle.

The results of the tests of different types of plate connectors for engine suspension can be useful when designing propulsion systems for military vehicles and military utility all-terrain cars, or as shown by the author [4,5] to modernize the existing military vehicles. Vibrations transmitted to the body chassis can also have a significant impact on the operation of the vehicle mounted equipment and weaponry.

Keywords:

machinery diagnostics, engine vibration, rubber vibration isolation, military all-terrain vehicle

INTRODUCTION

A typical characteristic of small military all-terrain vehicles is that they can operate in peace conditions as well as situations posing danger to people and stabilisation missions. All-terrain vehicles are means of transport for infantry and are also used to fight due to their good mobility in terrain. In these vehicles the main source of vibration is the power transmission system (engine, transmission system and exhaust system) whose work is cyclical and is characterised by changeable nature [1]. These vibration sources generate vibration also when the vehicle is stopped but the engine is in operation. In the issues related to vehicle dynamics there are also kinematic forced vibrations caused by an uneven road surface or a trajectory [5]. The frequency range in which the phenomena caused by these sources occur are located in various frequency bands, thus their transfer paths will be respectively different [4]. Rough road surfaces cause extortions in the wide band, from 0.5 to 250 Hz. Vibrations from the power transmission system occur in the same band [4]. The analysis of the influence of these vibrations and modification of vehicle structure currently are one of the more important problems which are the subject of experimental and theoretical research [1,3,4,5,10]. Various frequency ranges of proper vibration influence properties of the vibration form. In the frequency range 0.5÷15 Hz the main element of vibration transfer are special elastic-damping systems. The purpose of each damping system and element is minimisation of vibration impact on the other systems and people in a vehicle [3]. In the suspension of vehicle engines there are plate connectors usually made of two metal plates covered with a rubber layer, there are also sleeve connectors. To prevent frame deformation transfer to the engine and body vibration to the vehicle, thick rubber cushions are placed under assembly holders [11]. Wrongly adjusted stiffness and inappropriate distribution of cushions result in significant engine vibration [9],which is transferred to the car body especially in idle running. In dynamic loading conditions rubber stiffness increases according to the formula (1) c_{dyn} [6]:

$$c_{dyn} = X \cdot C \tag{1}$$

where:

- c_{dyn} – dynamic stiffness,
- X – stiffness coefficient,
- C – freedom degrees number.

The stiffness coefficient X for rubber with a hardness of 35 ÷ 95 °ShA (IRHD) is assumed to be in the range of 1.1 ÷ 1.4 [6]. In a system with C degrees of freedom, just like in the suspension of a car power transmission system, the frequency of proper vibrations for each direction is taken into account. One of the main characteristics of elastic rubber elements is the ability to transfer complex loadings and absorb shocks [7].

The common denominator of the results of the research related to combustion engines diagnostics presented in the scientific literature frequently is their purely empirical character [8]. The goal of the conducted experimental research, presented in this article, was determination of the influence of stiffness differences in the cushions of the front suspension of the four- and six-cylinder auto-ignition engine of an all-terrain vehicle on the transverse displacement of the engine with respect to the body. The conducted research will allow to determine how the modification of a combustion engine suspension or a change of the drive unit of a small military all-terrain vehicle influences body construction vibration. It is especially important when firing from a car or when the apparatus the vehicle is equipped with is in operation when the motor is running.

1. DYNAMIC TESTS OF ENGINE CUSHIONS

The subject of the research was: a passenger all-terrain vehicle UAZ-31512 (earlier 469B) with two different four-cylinder engines: 4C90 Andoria with turbulence chamber injection, which was later replaced with a supercharged engine with auto-ignition – 2.5TD with direct injection, used in Land Rover Discovery vehicles, 200 series, and Nissan Patrol K260 with a six-cylinder engine with turbulence chambers 2.8TD (RD28T). The UAZ-31512 vehicle with the 4C90 Andoria engine was tested at two values of front suspension cushion stiffness. The tests were conducted using a specially constructed device for tests of the displacement resulting from the vibration between the engine and the body [3]. The way of mounting the measurement system in the engine chambers of the tested vehicles is presented in Figure 1.

a) b)

Fig. 1. The way of mounting the measurement system in the engine chambers of the tested vehicles, a) UAZ, b) Nissan Patrol, 1 – suspension structure of the clamping arm, 2 – potentiometer arm, 3 – linear potentiometer

Source: own elaboration

Dynamic tests of cushions were conducted on an engine in operation, at selected values of crankshaft rotational speed. The values of engine to body transverse displacement resulting from internal combustion processes of air-fuel mixture were registered. The engine displacement was measured using a specially constructed arm with a potentiometer which transformed it into voltage and transferred to the oscilloscope DSO-2902 256K. The potentiometer transducer, A-linear type with 22 kΩ resistance and 0.5 % linear tolerance.

The diagram of the measurement trajectory of engine to body displacement is presented in Figure 2.

1.1. An analysis of experimental research results

The research was conducted for three engine operating conditions: starting, idle operation at constant rotational speed (a condition outside start-up and stoppage when the vibration level is the highest [3]) and stopping the engine. The device scale was selected in such a way that the voltage value corresponded with the appropriate displacement value (1V = 1.6 mm). In Nissan Patrol the potentiometer was mounted 540 mm above the crankshaft axis (WK), while in UAZ-31512 at the level of 580 mm, so similar to the other vehicle.

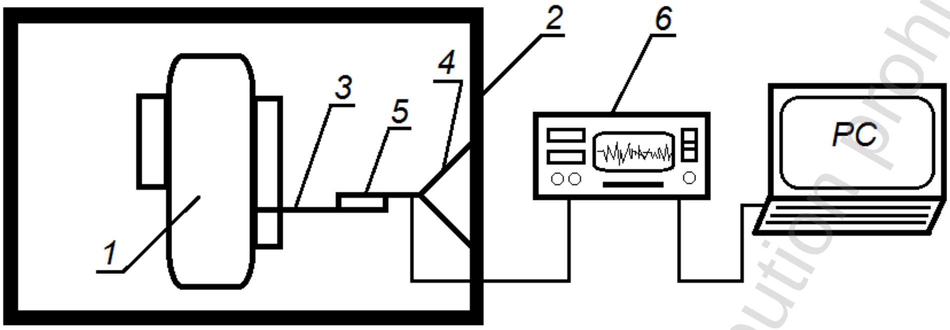


Fig. 2. The diagram of the measurement trajectory for engine to body displacement, 1 – engine, 2 – vehicle body, 3 – potentiometer arm, 4 – load-bearing structure, 5 – linear potentiometer, 6 – oscilloscope and a PC

Source: own elaboration

In the case of 2.8TD engine in Nissan Patrol, due to a low level of vibration, only two conditions were registered: starting (it is presented as a line graph in Figure 3) and stopping the engine. During idle operation vibration generated by the engine was close to the noise level coming from the apparatus with noise level lower than 0.1mm. This confirms an advantage of in-line six-cylinder engines which is good balance. Additionally, thanks to the use of turbulence chambers, the operation of the six-cylinder engine is characterised by a lower gear hardness degree in comparison with one of the engines tested in the other investigated vehicle.

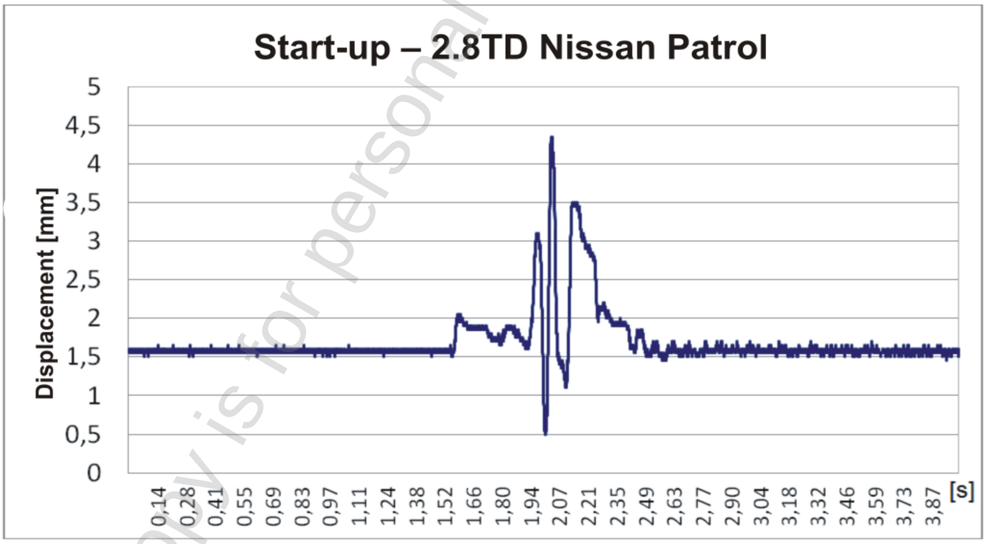


Fig. 3. A sample vibration of the six-cylinder engine 2.8TD of Nissan Patrol, displacement [mm] as a function of time [s]

Source: own elaboration

In the case of the four-cylinder 2.5TD engine of UAZ-31512 the measurements were made for three operating conditions. Displacements are presented in Fig. 4 and 5. In an earlier work [3] the authors presented the research on the stiffness of two types of suspension cushions for the same vehicle with the 4C90 Andoria engine. In the further part of this work the authors refer to the already conducted research in comparison with the UAZ-31512 vehicle with 2.5TD engine.

In the vibrations registered during the operation of measured UAZ-31512 at constant rotational speed, it is possible to observe a cyclical irregularity, a kind of "sinusoid" which reoccurs every 4 maxima. It probably results from the injection order and the irregularity of the combustion process in particular cylinders which could be a consequence of high engine wear and possible faults.

Figure 5 presents a graph showing displacements during starting and stopping the four-cylinder 2.5TD engine of UAZ-31512. During the start-up of the engine the displacement reached a maximum value of 8.2 mm. After achieving the idle running rotational speed the displacement is about 0.8 mm. When the engine is being stopped the maximum displacement is about half as big as the displacement during the start-up and its maximum value is not higher than 4.1 mm.

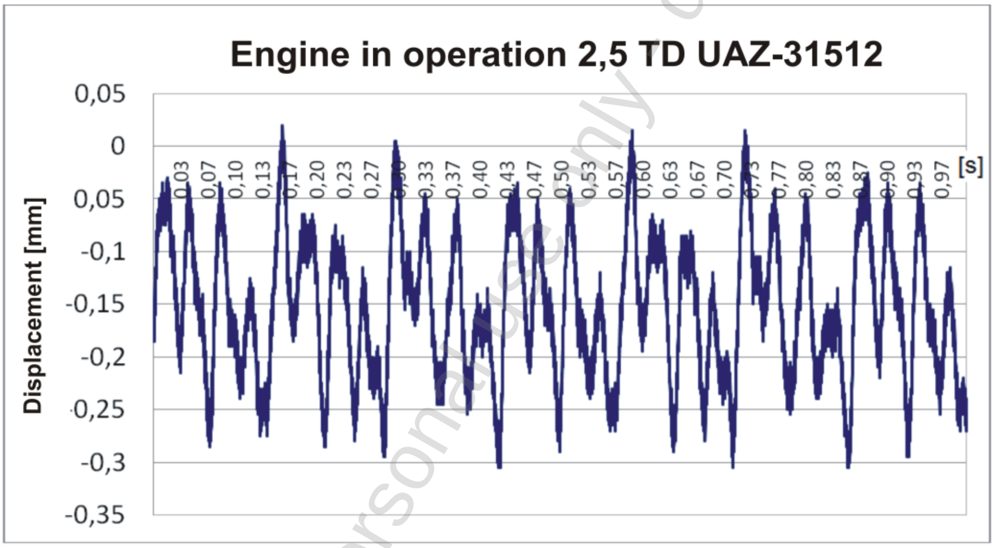


Fig. 4. Vibration of the four-cylinder engine 2.5TD UAZ-31512 in operation at constant rotational speed 1000 rpm, displacement [mm] as a function of time [s]

Source: own elaboration

Figure 6 presents a comparison of engine to body displacements in a vehicle with the tested suspension cushions in the following engines: 2.5TD and 4C90 in UAZ-31512 as well as 2.8TD in Nissan Patrol during a start-up, operation at the established rotational speed (1000 rpm) and stoppage.

The chart clearly shows that the biggest displacements occur in the case of the 4C90 engine. Significantly smaller engine to body displacements (about 50%) are observed in the case of the 2.5TD which replaced 4C90 in the tested vehicle. The smallest displacement value in the tested conditions was observed in the six-cylinder 2.8TD engine in Nissan Patrol.

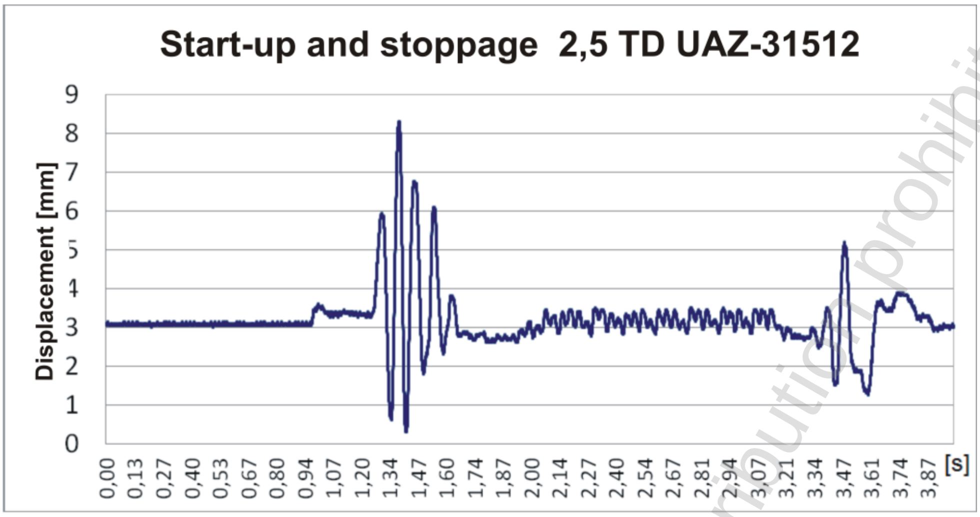
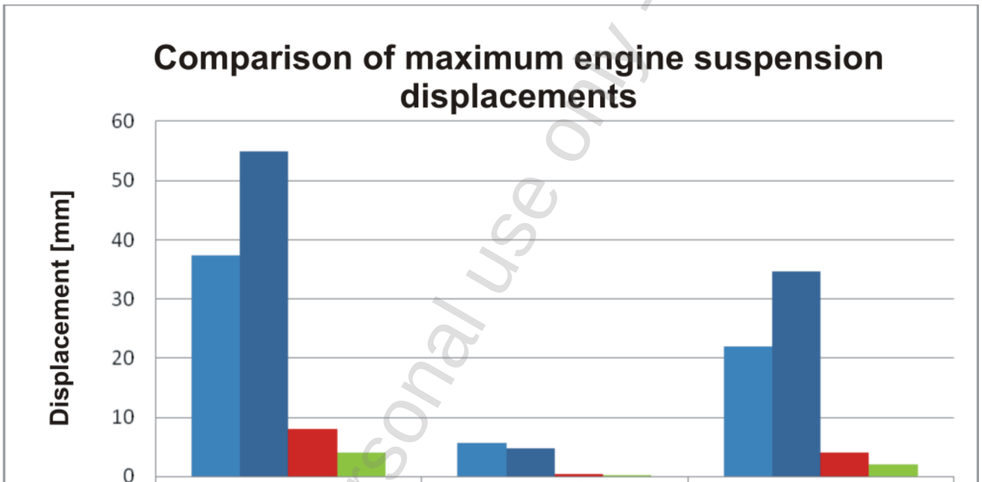


Fig. 5. A sample vibration of the four-cylinder 2.5TD engine of UAZ-31512 during start-up and stopping the engine, displacement [mm] as a function of time [s]

Source: own elaboration



	START-UP	1000 RPM	STOPPAGE
4C90 TW	37,32	5,65	21,94
4C90 M	54,98	4,83	34,57
2,5TD	8,08	0,32	4,02
2,8TD	4,04	0,001	2,12

Fig. 6. A comparison of suspension displacement values of the following engines: 2.5TD and 4C90 in UAZ-31512 as well as 2.8TD in Nissan Patrol at various operating conditions. The data of the 4C90 engine were taken from [3], TW – hard cushions, M – soft cushions

Source: own elaboration

CONCLUSIONS

The conducted tests of engine suspension cushions of three different engines used in all-terrain vehicles showed big differences in engine to body displacements in the tested vehicles. It is the effect of differences in the number of cylinders, type of combustion of the mixture from the engine and its technical condition.

The highest values of transverse displacement between the engine and the body occurs during a start-up. This can have a negative influence on the operation equipment assembled in the vehicle and in the case of military vehicles also weaponry.

An in-line six-cylinder engine is a significantly smaller source of vibration generated in operation than a four-cylinder one.

The measurement results of the value of engine to body transverse displacement can be an interesting engine testing parameter both from the cognitive and diagnostic perspective. The conducted measurements should be supplemented with transverse acceleration of both drive units and bodies of tested vehicles.

The research on the types of plate connectors used in engine suspension can be useful in designing vibration damping systems in military vehicles and military-all-terrain vehicles or, as it was shown by the author [4,5], in modernisation of the existing fleet of military vehicles [3].

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BIOGRAPHICAL NOTES

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