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ANALYSIS OF DIRECTIONAL DISTRIBUTION OF VIBRATIONS GENERATED BY THE COMBUSTION ENGINE

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Abstract

The article provides a discussion on the studies and analysis of directional distribution of vibrations generated by the combustion engine. The engine is one of the sources of the vibrations in vehicles. The analysis of the vibration propagation from source should take into account the directions of the propagation and the dynamics of the vibration. The experiment was conducted on the vehicles combustion engine and the orthogonal axes vibrations were measured. Analysis of the results allows comparing the values and frequencies of the vibration propagation.

Keywords: *engine vibration, directional distribution of the vibration*

1. Introduction

Road surface roughness often acts as a major source that excites the vibration of the vehicle running on the ground through the tire/wheel assembly and the suspension system [9,10]. There are many of different vibration sources in vehicles as well. One of those is motor-car engine. The engine vibrations are strongly random processes because there are many of different source of vibration in engine. They can have different mechanism of generation and different values and frequencies of vibration. The engine block mainly is characterised by the low coefficient of dumping. The vibrations of low and medium frequencies up to a few kHz are only slightly absorbed. Higher vibration absorbing effects appear only for frequencies of 10 kHz or more [6]. Those parameters are determined by materials used in engine construction. There are a lot of novel materials used in engine with modern production technologies. Thus the optimal material parameters can be obtained [3,7].

Vibration processes in combustion engine are unwanted effects but at the same time the can be very useful. There are many publications on application of vibration signal in diagnostic [1,2,4,5,6,8]. This paper take into account influence of the vibration as the detrimental effect on the safety and comfort in mean of transport. The human response to vibration is depending on the values, frequencies and directions. Perceptibility of the same frequencies and values of vibration in exposure in different directions can be diametrically different.

2. Engine as the source of vibration

The suspension system is very important for reduction of vibration transfer to car body. Before attempting to reduce the vibration levels in a machines or structure of the vehicles by increasing its damping, every effort should be made to reduce the vibration excitation at its source. Motor engine should be considered as one of the vibration generators. Rotating machinery such as motors can generate disturbing forces at several different frequencies such as the rotating speed and blade passing frequency. Reciprocating machinery such as compressors and engines can rarely be perfectly balanced, and an exciting force is produced at the rotating speed and at harmonics. There are two basic types of structural vibration: steady-state vibration caused by continually running machines such as engines, air-conditioning plants and generators either within the structure or situated in a neighbouring structure, and transient vibration caused by a short-duration disturbance such as a lorry or train passing over an expansion joint in a road or over a bridge.

Consider the vibroacoustics analysis of an internal combustion engine one should take into account the fact, that a high level of nominal vibrations is generated, resulting from the target function realisation. Internal combustion engine is an object under the influence of internal and external inputs. Among them there are mainly: burning pressure, the movement of the piston-crank mechanism, inputs from the timing gear system, inputs resulting from the work of the fittings of the engine, inputs transmitted from the motor-car body and the drive transmission system. One of the most important inputs during the work of the piston-crank mechanism are the impacts of the piston by the change of its work direction [4].

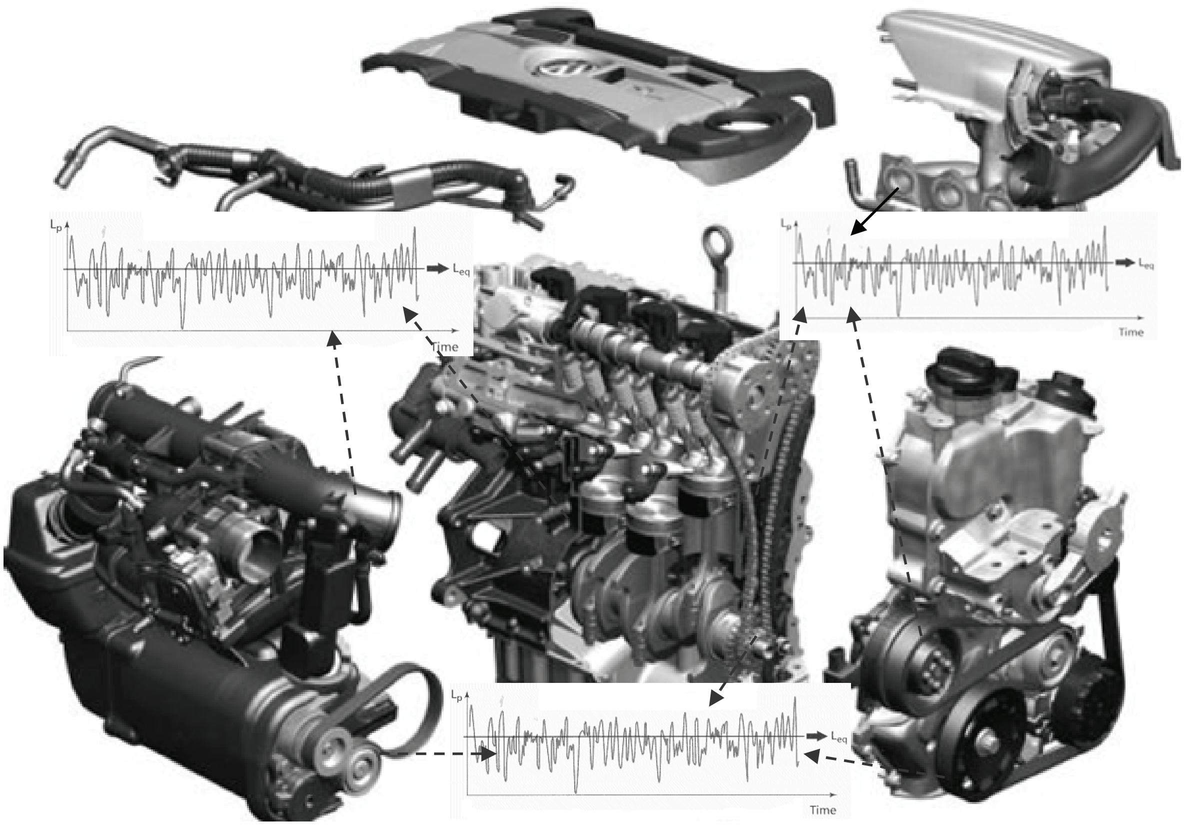

Fig. 1. Motor engine as the vibration generator

3. Research

The research goal was analysis of directional distribution of vibrations generated by the combustion engine. The acceleration of vibration sensors type ADXL were used. The ADXL are complete acceleration measurement systems on a single, monolithic IC. It was used the dual-axis accelerometer. The acceleration converters are characterised by big direction selectivity, the proper sensor placement enables the spatial selection of the diagnostic signal. The studies were block of the combustion engine. Under the studies in question, active experiments were undertaken featuring measurements of vibration accelerations in a three directions. It were recorded the vibration in three orthogonal axes (X,Y,Z). The position and directions of measurements has been depicted in Fig. 2.

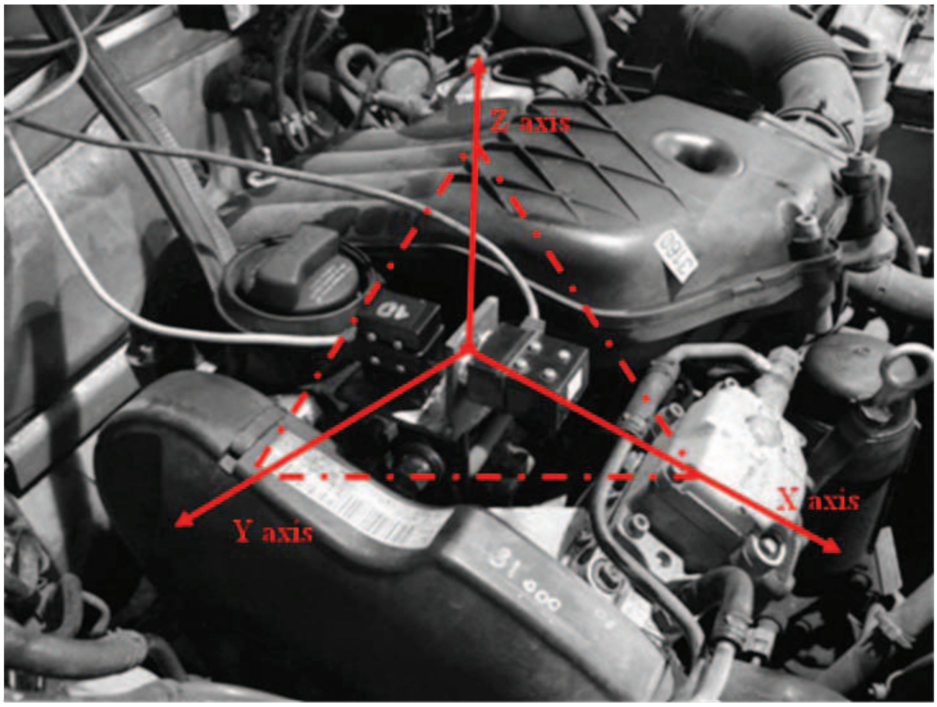

Fig. 2. Measurement of vibration of combustion engine in 3 directions

The recorded signals for idle gear of engine load have been depicted in Fig. 3-5.

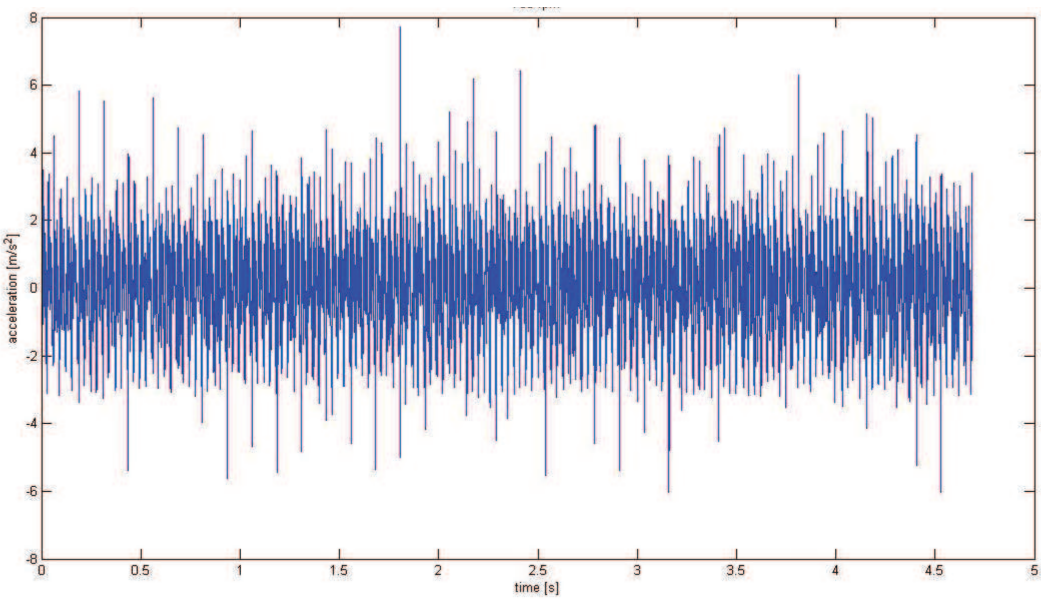

Fig. 3. Vibration signal recorded in X axis

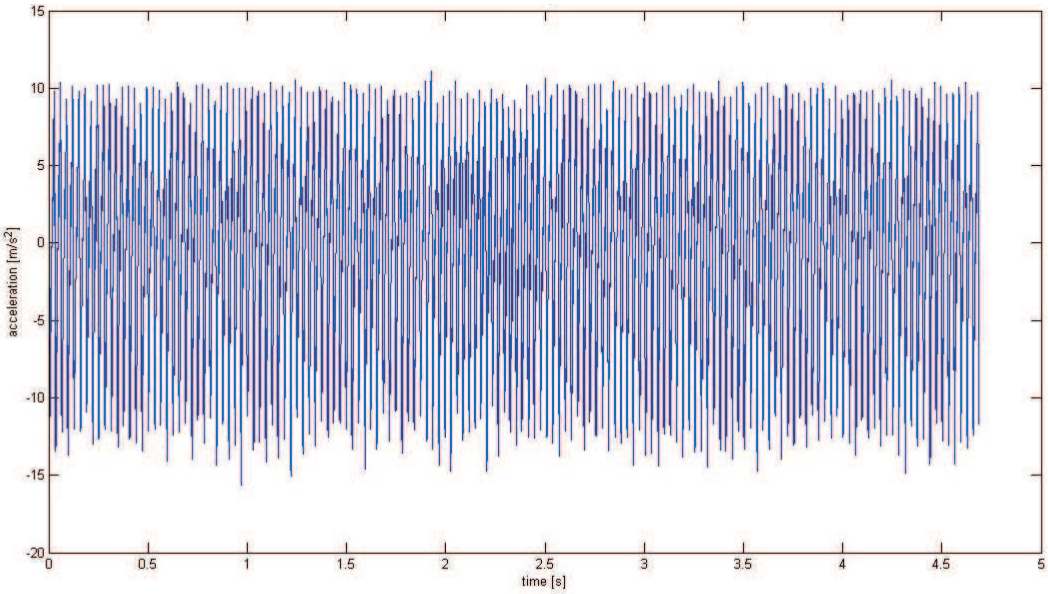

Fig. 4. Vibration signal recorded in Y axis

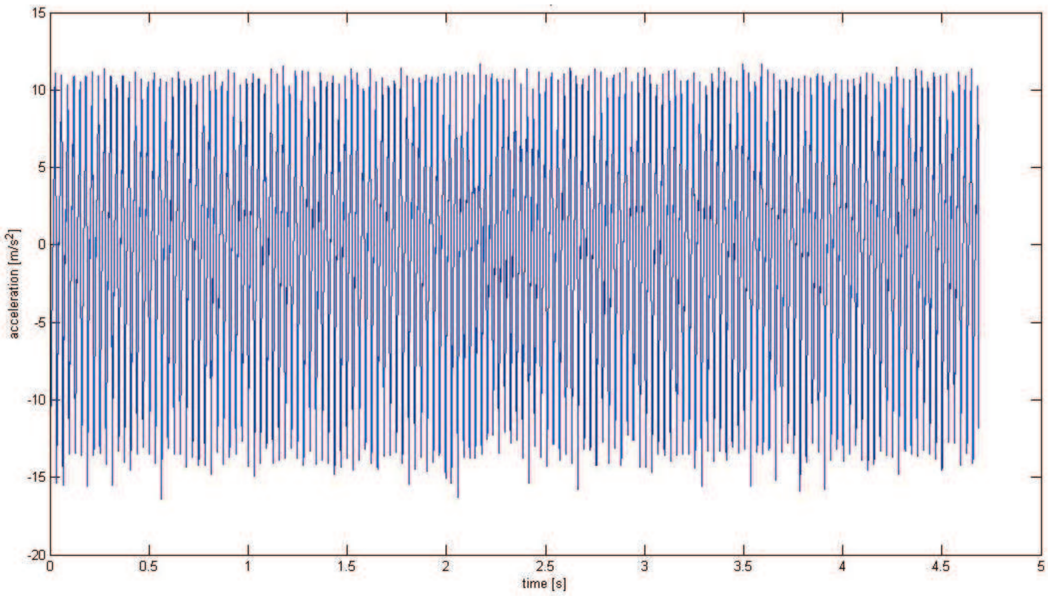

Fig. 5. Vibration signal recorded in Z axis

Based on the analysis of the acceleration of vibration in time dimension it can be assumed that the vibrations acceleration in vertical direction (Z axis) are the larger value of amplitude. The longitudinal vibrations (X axis) have smallest amplitudes. For the analysis the dynamics of the vibration in directions the spectrum of the signal can be very helpful. The Fast Fourier Transformations (FFT) of the recorded signals were done. The results of the FFT for signals in 3 directions have been depicted in Fig. 6-8.

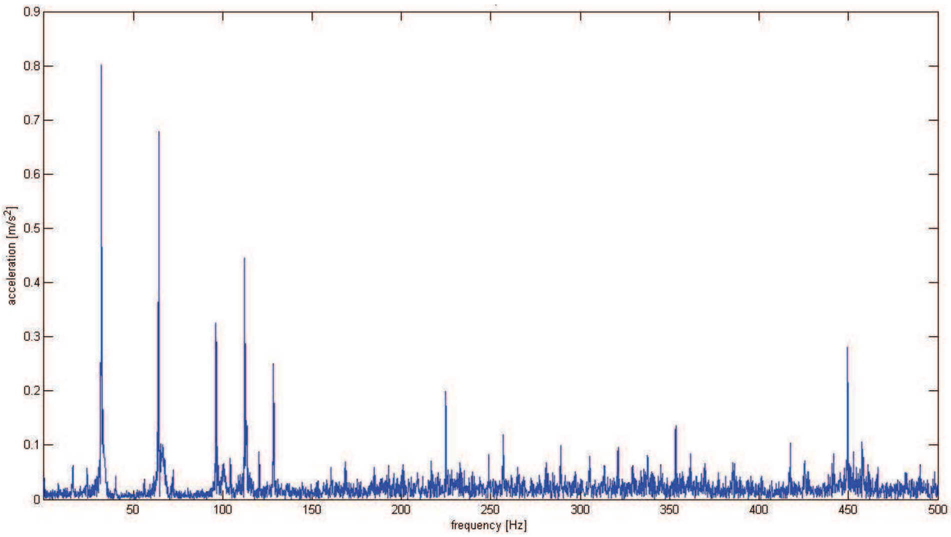

Fig. 6. Spectrum of the vibration signal recorded in X axis

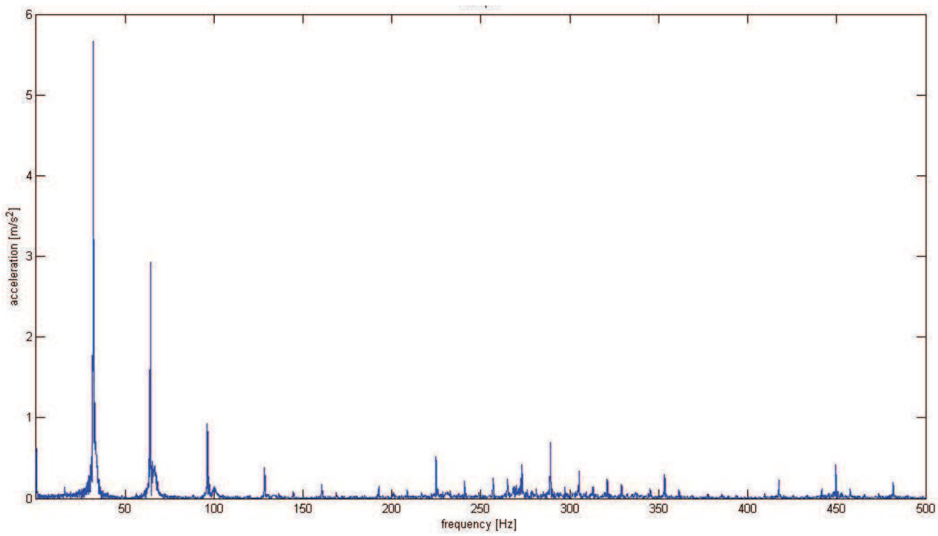

Fig. 7. Spectrum of the vibration signal recorded in Y axis

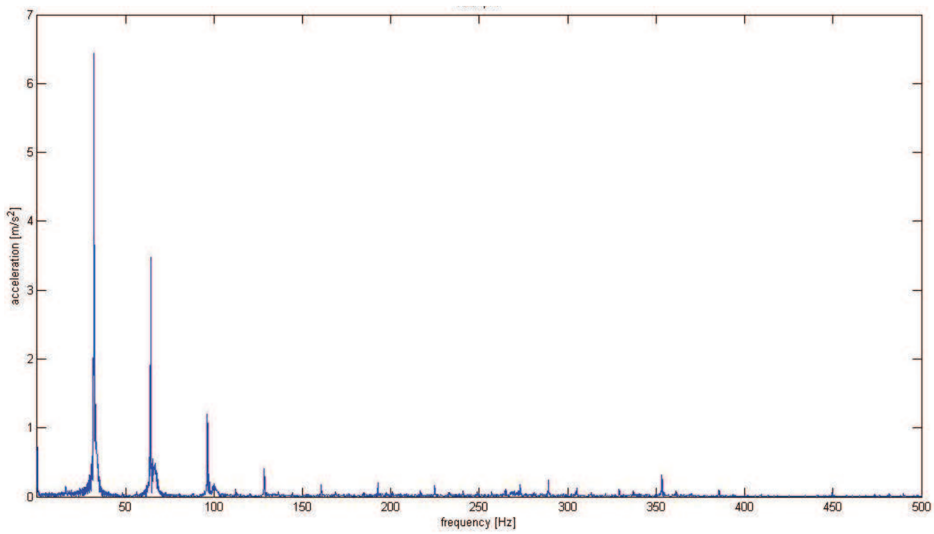

Fig. 8. Spectrum of the vibration signal recorded in Z axis

4. Conclusion

In the spectrum of the signals the characteristics frequencies can be identifying. The ca. 32 Hz frequency is correlated with rotation velocity of the idle gear of the engine. The vertical vibrations have the largest amplitude but the signal is most stationary. The frequencies not correlated with rotation velocity of the idle gear of the engine (1-3 harmonics) are very low energy. The horizontal vibration have more frequencies, especially in the spectrum of the X axis vibration can be identified many of different frequencies. The directional distribution of vibration can be resulted from the elements and systems of the suspension and the mounting of engine. It can be resulted of the unbalance of the rotating elements of the engine or other defects.

The received signal is strongly interfered by various vibration sources and that is why there is a necessity to use advanced methods of signal selection and observation in time-frequency domains.

References

[1] Burdzik, R., *The research of vibration of vehicle floor panel*, Silesian University of Technology Scientific Papers, s. Transport 67, pp. 23-30, Gliwice: Silesian University of Technology Academic Press, 2010.

[2] Burdzik, R., Stanik, Z., Warczek J., *Method of assessing the impact of material properties on the propagation of vibrations excited with a single force impulse*, Archives of Materials and Metallurgy vol. 57 issue 2, pp. 409-416, 2012.

[3] Burdzik, R., Węgrzyn, T., *Effect of Mn and Mo on the quality of welding trucks steel supporting structures*, Journal of Achievements in Materials and Manufacturing Engineering JAMME, 43(1), pp. 276-279, 2010.

[4] Czech, P., Łazarz, B., Madej, H., Wojnar, G., *Vibration diagnosis of car motor engines*, Acta Tech. t. 3 fasc. 1, pp. 37-42, Corviniensis - Bull. Eng. 2010.

[5] Jamro, E., Wielgosz, M., Bieniasz, S., Cioch, W., *FPGA – ARM heterogeneous system for high speed signal analysis*, Solid State Phenomena, vol. 180, pp. 207—213, 2012.

[6] Madej H., *Wykorzystanie analizy modalnej w diagnostyce WA silników spalinowych,* Zeszyty Naukowe Politechniki Śląskiej, s. Transport, z. 63, pp.61-68, Gliwice 2006.

[7] Oleksiak, B., Siwiec, G., Blacha, A., Lipart, J., *Influence of iron on the surface tension of copper*, Archives of Materials Science and Engineering 44 (1), pp. 39-42, 2010.

[8] Piecha, J., Węgrzyn, T. Ed., *Transactions on Transport Systems, Telematics and Safety*, [in:] Burdzik, R., *Research of the vibration in 3 axes of car body for different idle gear rotational speed*, pp. 203-214, Gliwice: Silesian University of Technology Academic Press, 2011.

[9] Wong, J.Y., *Theory of ground vehicle, 3rd Edition*, Wiley, USA, NewYork 2001.

[10] Xua, Y.L., Guo, W.H., *Effects of bridge motion and crosswind on ride comfort of road vehicles*, Journal of Wind Engineering and Industrial Aerodynamics 92, 2004.