HYBRID DRIVE VIBRATION SOURCES ANALYSIS

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Summary

The paper is an introductory session dedicated to the sources of vibrations in a hybrid drive, which is meant to propel special tracked vehicle. The analysis was performed according to stand test results of a hybrid drive. It is aimed on individual modes of operation and modes ensuing from cooperation of diesel drive and electric drive.

Keywords: hybrid drive, diesel drive, gas engine, electric drive, vehicle, oscillations, vibrations, shocks.

1. INTRODUCTION

Vibrations (oscillations, shocks) are important qualifiers of technical condition of machines, or machine systems, its workload and functionality. This fact is rather often used for monitoring of technical condition of machines and its diagnostics. The simplest form lies in broadband **measurement of overall vibratory effects**, whether it is in a defined band according to valid rules or according to manufacturer's recommendation for the particular machine pieces. More knowledge is possible to be obtained on the basis of **frequency analysis**. More complex methods and equipment is necessary to **obtain characteristic frequency spectrum** of machine vibrations. The measurements are proceeded systematically, targeted, generally on a machine in perfect technical conditions with more repetitions as time goes with period recommended for particular machine and type of operation. As a machine is wearing out and the conditions are worse, the characteristic frequency spectrum is gradually changing, i.e. foremost its components related to individual machine parts (gear wheels, shafts, bearings, rotors, flywheels, joints etc.). Based on the monitoring and analysis of these spectra changes it is possible to efficiently diagnose, detect, identify, localize eventually prognose emergent failure without disassembly.

It is better to transform the obtained oscillation time history into frequency field, which means to arrange oscillations by its components. This application is called frequency analysis and a band limit spectrum or (as in our case) Fast Fourier Transform (FFT) is used to accomplish this task.

The basic equation describing the process of vibrations is given by:

$$\boldsymbol{M}\ddot{\boldsymbol{U}} + \boldsymbol{C}\dot{\boldsymbol{U}} + \boldsymbol{K}\boldsymbol{U} = \boldsymbol{R}(t). \qquad (1)$$

where $\ddot{\boldsymbol{U}}$ is the vector of acceleration of the mass and $\dot{\boldsymbol{U}}$ is the vector of measuring point's velocity, $\boldsymbol{U}$ is the vector of displacement of the structure and $\boldsymbol{R(t)}$ is time-dependent load function. $\boldsymbol{M}$ is the mass matrix, $\boldsymbol{C}$ is the damping matrix and $\boldsymbol{K}$ is the stiffness matrix. The equation is valid for any point on the measured structure but mostly the center of gravity is examined and other relevant points on the moving parts of the construction.

1.1. Evaluation of Oscillations

This is all about determining an effective velocity of oscillations in the frequency band 1 – 1600 Hz and afterwards comparing it with standard specification or with boundary values given by the manufacturer of the machine [1] (Fig. 1).

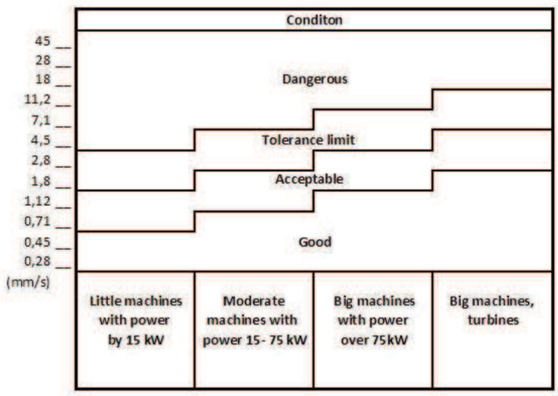

Fig. 1. Values of velocity oscillations

The operating diagnostic of the technical condition of an engine on the basis of vibrations can be divided into:

- The method using spectra with constant relative width of bands CPB (Fig. 2),
- The method using the FFT (Fig. 3).

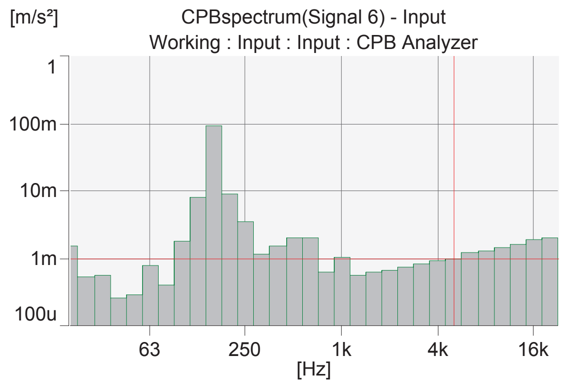

Fig. 2. CPB spectrum

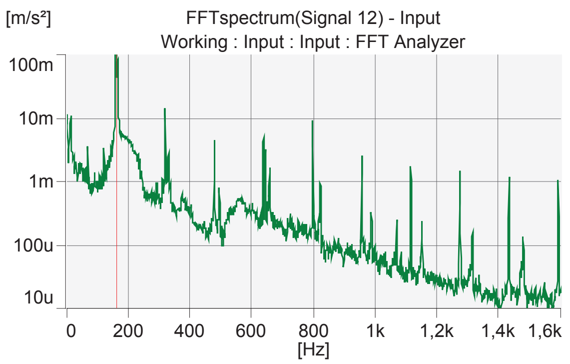

Fig. 3. FFT spectrum

It is a simple, quick and cheap method, which of course gives credit whether the machine has failed or not. It is not giving accurate position of the damage and that is why it is necessary to attach an individual machine part to particular frequency components, which in some cases turn out to be excessively difficult (Fig. 4).

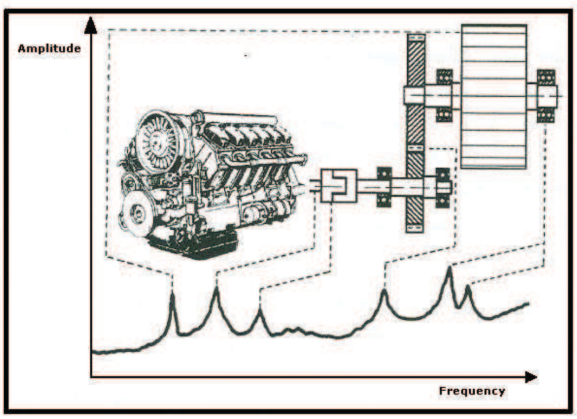

Fig. 4. Particular frequencies

The spectral analysis of vibrations enables detection of the following faults, even without disassembly:

- shaft eccentricity,
- non-axiality of shafts,
- shafts bend,
- imbalance of rotating parts,
- condition of gearing.

2. THE ANALYSIS OF OSCILLATIONS OF HYBRID DRIVE

The operation mode of hybrid drive of a vehicle (Fig. 5) is chosen by driver according to drive conditions and need of the performance of the vehicle. Analyzed hybrid drive is specified for special tracked vehicle (Fig. 6) [2], [3].

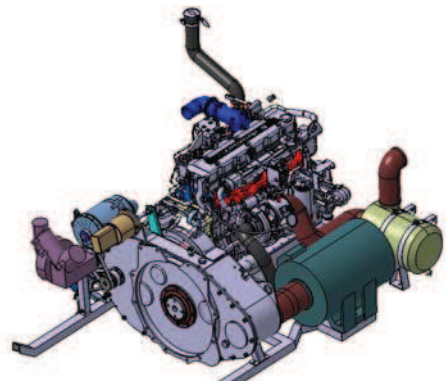

Fig. 5. Hybrid drive system – view from the side of the gearbox

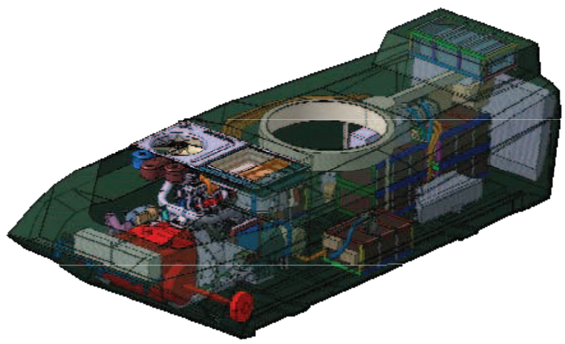

Fig. 6. Hybrid drive system – position in a vehicle

The driving system is able to support following modes of operation:

- mode **„DIESEL"**,
- mode **„ELECTRIC MOTOR"**,
- mode **„HYBRID"**.

Besides of these basic operation modes are also important so called transition modes and battery charging, including:

- accelerating period of vehicle,
- coupling of couplings by transition to hybrid drive,
- decoupling of couplings by transition to diesel or electric drive,
- batteries charging (electric motor withdraws power from diesel engine).

2.1. Hybrid drive oscillations measurement

The measurements were performed with PULSE system, which we are using on our workplace. The manufacturer of the diagnostic system is Danish – Germany firm Brüel & Kjaer [6]. The values measured were exported into MS OFFICE application, where they were handled and its time history graphically modeled.

The transferability of the system allows us to setup PULSE system according to our needs on hardware and software and in any case a possibility of upgrade. Big advantage is availability of multi-analysis, where PULSE system performs multiple analyses in real time, for example parallel CPB and FFT analysis etc. [4], [5].

In Fig. 7 - 13 is shown dependency of velocity on frequency along individual axes for hybrid drive. The sensor was positioned on a cover of coupling gearbox and the measurements were performed on a test stand, where the operational conditions of a tracked vehicle were simulated.

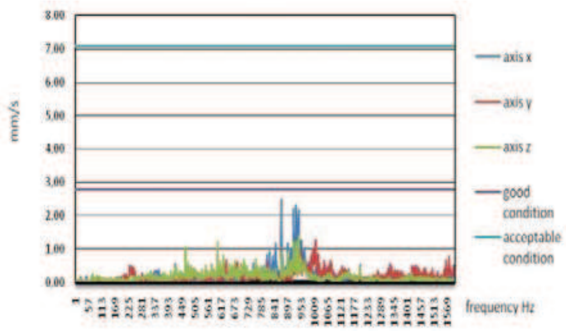

Fig. 7. Speed up of the vehicle

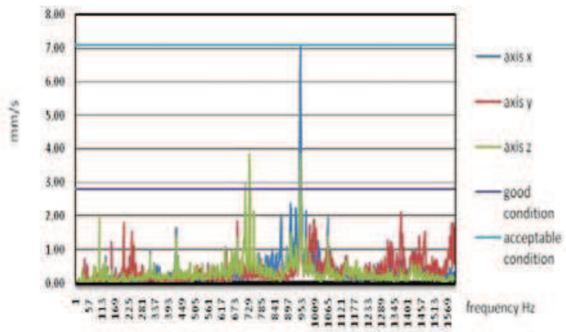

Fig. 8. Coupling the gas engine

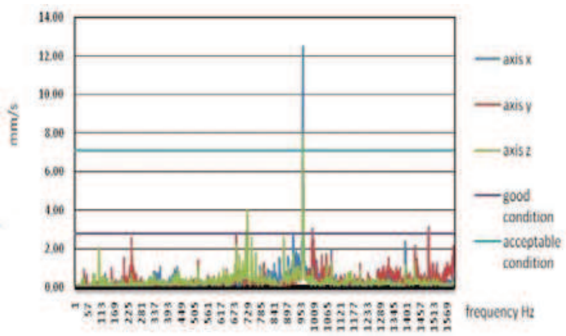

Fig. 9. Batteries charging

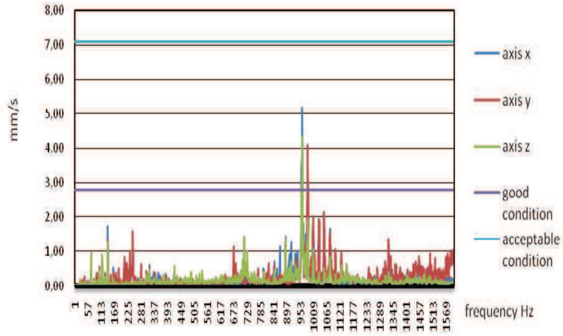

Fig. 10. Decoupling the gas engine

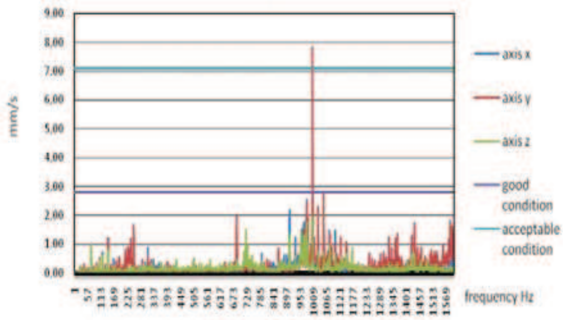

Fig. 11. Diesel mode – propelled by gas engine

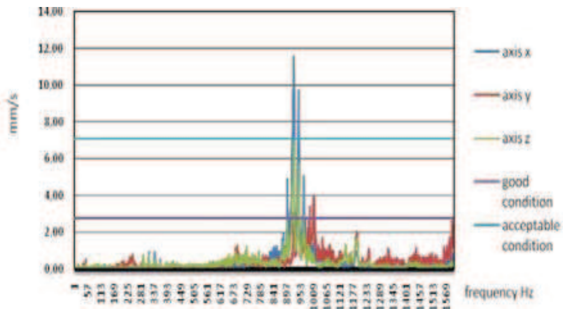

Fig. 12. Coupling the diesel drive with electric drive

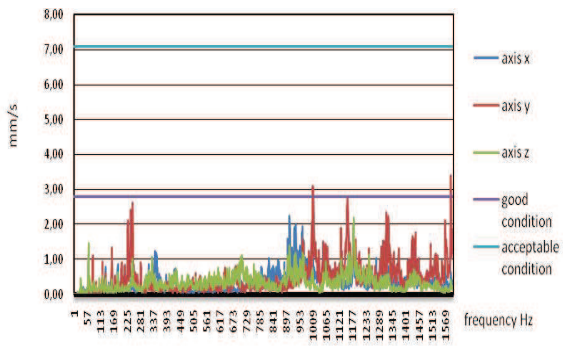

Fig. 13. Hybrid mode drive – (diesel + electric drive)

2.2. Evaluations of measuremens

Based on performed measurements and its graphical evaluation it is safe to state that:

- the electric drive mode and hybrid drive mode shows low values of oscillation velocity – it did not overlap values given by mechanical constructions in the category (specific for relatively light operation),

- higher values of velocity manifest in modes of coupling and decoupling of the gas engine drive, where the velocities are in acceptable intervals or they do not significantly overlap them,
- the highest values of velocity are represented by coupling of the diesel drive with electric drive, where the velocities overlap recommended values and this can have unfavorable influence on the reliability and lasting of the drive mechanism and its components.

3. CONCLUSIONS

Analysis of vibrations of hybrid drive is based on measurement results of characteristic parameters of vibrations. Possible detection of system failure is through comparison of overall level of vibrations with standard apriority attached criterions. Disadvantage of the method lies in inability to catch nucleating failures which emits signals of very short time intervals and that is why it is not shown in overall level of vibrations. In the same manner the overall noise level do not recover information about failure localization.

It is necessary to note that our task does not end by these measurements and it is necessary to repeat these measurements after the hybrid drive unit is mounted into real vehicle. Afterwards evaluate and compare with the analysis performed on the test stand.

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This paper was elaborated using support from project of Academy grant agency no. 6/2007 „Analysis of vibrations and noise load of mobile technics and evaluation of materials used in the construction".