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PRELIMINARY ANALYSIS OF VIBRATION SIGNAL TEST RESULTS REGISTERED AT BENCH TEST STAND OF AMV ROSOMAK DRIVING AXIS

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Abstract

The methodology of measuring the vibration signal recorded on the casing of wheeled armoured vehicle ROSOMAK driving axis is presented. The study was performed on a test bench for different transmission conditions. A preliminary analysis of the frequency spectra vibration signals recorded. The test stand allows investigation of the differential axle gears under load similar to load during duty operation. It was possible by using the combustion engine and gearboxes and load transmission by using the dynamometer break. Have been described. Three methods of attaching acceleration sensors to differential gears: using screws, magnetic washers and probe handle. The results of comparisons of measurement results obtained using these methods. Finally, the sensors was mount by using the screw connections. Selected positions and points of temperature and vibration measures were described. Values of characteristic frequencies of differential axle gears vibration by moving the drive torque through these boxes were calculated. The spectra of the vibration signal determined during testing gearboxes were shown. It was state that of amplitude-frequency vibration spectra of signals recorded at selected points of differential axle gears casing are clearly visible characteristic frequencies but the vibration the bridge gear unit bridges distorted by vibration of the internal combustion engine and gearboxes. In a further stage of research should be included much larger number of the driving axis differentials investigated in various states of well-known technical conditions and should be lead accord to requirements of the active diagnostic experiment.

Keywords: *differential axle gears, test bench, vibration of elements, vibration analysis*

1. Introduction

Conducted in Institute of Motor Vehicles and Transportation, Military University of Technology research methods for rapid verification of defective parts of ROSOMAK carrier include evaluation of transmission gear condition. Gears are endanger to damage as a result of the combat use of improvised explosive devices in Afghanistan. These gears often do not have visible “external” injuries. They can be used, but technical condition enable correct operation, including loads transfer that occurs during use.

For assessment of transmission gears condition, proposed to use an existing 359-engine test stand with W-230 dynamometer. Test stand adaptation for gears examination consist of use the same gearboxes at the engine output and dynamometer input, with transmission gears in the centre, allowing adjustment of the working area and the characteristics of the brake torque produced by the engine, held to varying loads that occur during actual operation of the vehicle. The proposed solution for transmission gear of AMV testing and developed methods of investigation are presented in [1, 2].

2. Measurements of vibration signal

The vibration signal measurements were performed at both transmissions gears (PM1 and PM2). Arrangement of measurement points are shown in Fig. 1.

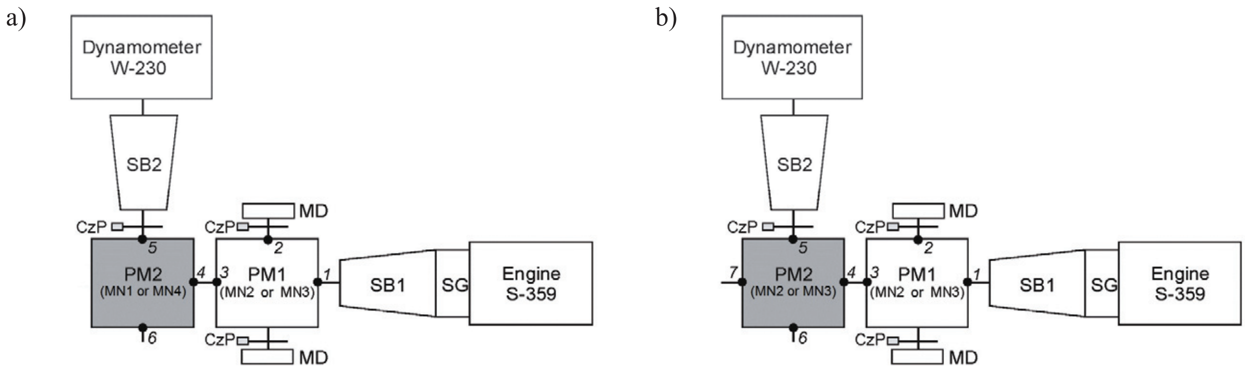

Fig. 1. Arrangement of measurement points: a) configuration of tested gear positions including central gear (PM1) and external (PM2), b) configuration of tested gear positions including the two central gear (PM1 and PM2)

Research were performed by use of industrial vibration analyser Emerson CSI 2130 and accelerometer A0760GP. In the initial phase of the study, the effect of mounting the accelerometer and conditions of transmission gear (defined by gear elements speed).

Examined transmissions consists of two casing joined by bolts. One half made of steel (ferrous), which is the base for fixing gear elements (bearings and shafts). Second casing is made of aluminum alloy, devoid of magnetic properties. Due to the specific construction of gear and to determine the ability to measure the vibration signal of real object, recorded at the same points of transmission gear as on test bench, at initial test stage (for the variant configuration, shown on Fig. 1a), vibration signals were registered at all measurement points, fastening the accelerator using ticked - with special glue for measuring vibration - washers with thread (Fig. 2a). Using a permanent magnet - only steel housing parts - (Fig. 2b), and using a manual probe (Fig. 2c).

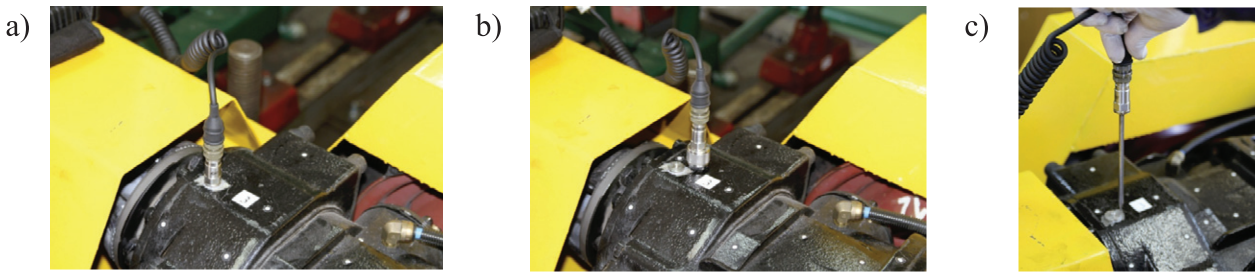

Fig. 2. A view of an accelerometer mounting: a) using the adhesive pads to the housing, b) a magnet, c) using the „manual" probe

Measurements were performed at unloaded gear (with the engine running at idle n_{bjal} and with a maximum speed n_{max}) and for loaded gears. In the second case, the measurements were performed during engine operation:

- of peak torque speed of about 1500 rpm,
- from the $n_{Mo\text{-}Ne}$at maximum power about 2800 rpm,
- intermediate speed, between the above mentioned speed, approximately 2100 rpm.

During the test, gear differentials of both driving axles were locked.

The exact parameters of the measured vibration signal recordings (analysed frequency range and resolution of the spectrum) were determined analytically, adapted to the applied test bench configuration, and switched gears in transmissions SB1 and SB2.

Measurements showed that the vibration signals recorded at the same measurement point for the three-accelerometer “fixing” ways have similar characteristics. Fig. 3 show an example.

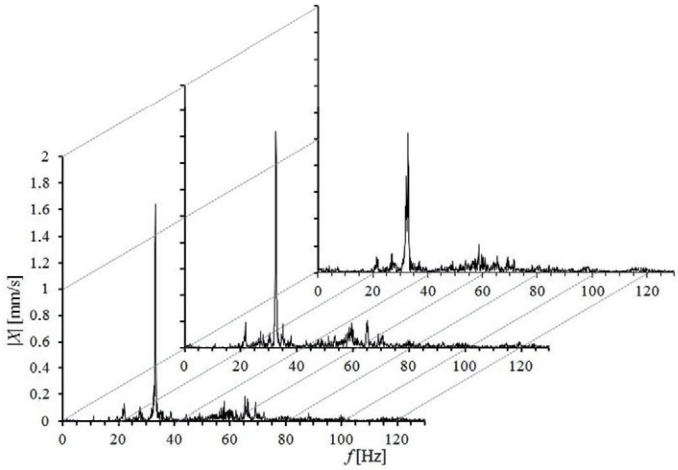

Fig. 3. Comparison of spectra of vibration signals recorded at the measuring point No. 3 at 359 engine at idle speed for three ways of the used accelerometer mounting (washer with thread - the first graph, using the permanent magnet - the middle graph, using a hand probe - the third graph)

Hence, the rest of the research were carried out by screwing acceleration sensor used for sticky pads in these locations to test gear housing.

In the next stage of the vibration signal recording, tests were made for different gear ratio transmissions position. Selected results of registration shown in Fig. 4.

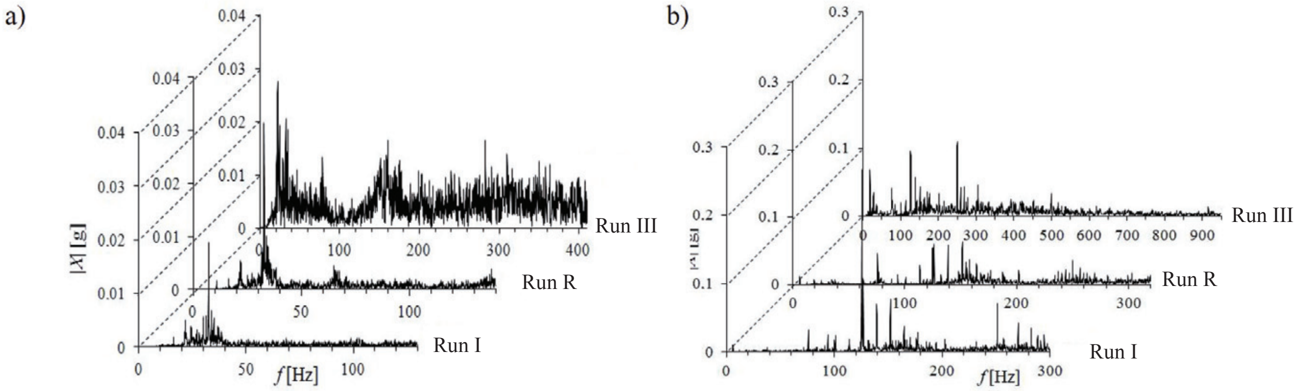

Fig. 4. A comparison of the spectra recorded vibration signals for transmission gear PM1 at the measurement point 1 when the engine is driving at a speed of: a) neutral, b) the maximum torque

Measurements made, showed different spectra course vibration signals measured at the same measuring point for the different transmission ratios. It was observed that the recorded spectra are reproducible for the same rotational speed of the drive motor, in particular for reverse and first gear. However, while the two gearboxes in second or third gear in the recorded spectra observed the emergence of broadband noise associated with the operation of the drive motor and gearbox. They "mask" identified by the registered theoretical vibration signal components originating from different sources (including the meshing of gears in gearboxes, engine, etc. – Tab. 1). The form of the frequency spectrum is affected by the conditions of the transmission gear (speed gearbox shafts, gears work load or no load).

Tab. 1. Sources and occurrence of the identified spectral components recorded vibration signals

Source component	Frequency component during gear in gearboxes switched on	
	first gear	reverse gear
frequency of the engine rotation	f_{wks}	
meshingfrequency ofthe crankshaft/intermediate shaft in the gearboxwith the engine	$f_{z1sbs} = 19\, f_{wks}$	
frequency of rotation of the intermediate shaft in the gearbox with the engine	$f_{wpsbs} = f_{z1sbs} / 46 = 19\, f_{wks} / 46$	
meshing frequency of the intermediate shaft / output shaft or intermediate shaft back in gear with the engine	$f_{z2sbs} = 12\, f_{wpsbs} = 114\, f_{wks} / 23$	
frequency of rotation of the intermediate shaft in the reverse gear when the engine	No concern	$f_{wpwsbs} = f_{z2sbs} / 21 =$ $= 38\, f_{wks} / 161$
meshing frequency of the intermediate shaft reverse / output shaft in the gearbox with the engine	No concern	$f_{z3sbs} = 21\, f_{wpwsbs} =$ $= 114\, f_{wks} / 23$
frequency of the output shaft of the gearbox with the engine - propeller shaft rotational frequency	$f_{wn} = f_{z2sbs} / 42 =$ $= 19\, f_{wks} / 161$	$f_{wn} = f_{z3sbs} / 39 =$ $= 38\, f_{wks} / 299$
main gear meshing frequency	$f_{zpg} = 24\, f_{wn} =$ $= 456\, f_{wks} /$ 161	$f_{zpg} = 24\, f_{wn} =$ $= 912\, f_{wks} / 299$
rotational frequency of the drive shafts (locked differentials)	$f_{pn} = f_{zpg} / 32 =$ $= 57\, f_{wks} / 644$	$f_{pn} = f_{zpg} / 32 =$ $= 114\, f_{wks} / 1196$
meshing frequency of the output shaft / intermediate shaft in the gearbox back on the brake	No concern	$f_{z3sbh} = 39\, f_{pn} =$ $= 171\, f_{wks} / 46$
frequency of rotation of the intermediate shaft in the gearbox back on the brake	No concern	$f_{wpwsbh} = f_{z3sbh} / 21 =$ $= 57\, f_{wks} / 322$
meshing frequency of the output shaft or intermediate shaft reverse / intermediate shaft in the gearbox on the brake	$f_{z2sbh} = 42\, f_{pn} =$ $= 171\, f_{wks} / 46$	$f_{z2sbh} = 21\, f_{wpwsbh} =$
frequency of rotation of the intermediate shaft in the gearbox on the brake	$f_{wpsbh} = f_{z2sbh} / 12 = 57\, f_{wks} / 184$	
meshing frequency of the intermediate shaft / input shaft in the gearbox on the brake	$f_{z1sbh} = 46\, f_{wpsbh} = 57\, f_{wks} / 4$	
frequency of rotation of the input shaft in the gearbox on the brake - the frequency of rotation of the input shaft to the brake	$f_{wh} = f_{z1sbh} /19 = 3\, f_{wks} / 4$	

Preliminary tests also shown differences in the form of frequency spectra recorded vibration signals for each point in the measurement of vibration (Fig. 5).

Detailed analysis of test results for the different transmission ratios and the respect of all the data points showed that the most favourable (from the point of view of minimizing the disruption of the measured vibration signal) is to carry out measurements on first gear or reverse. Thus, the basic test cycle, including measurements made at three different external gear (PPM) and three different middle gear (located both as a transmission PM1 and PPM) measurements were performed using both transmissions gear (SB1 and SB2) while running the first or the reverse gear.

Sample selected from over a hundred shelled during the research and opinion of the authors characteristic vibration signal registration results using the above ratios for the different test conditions of transmission gears (motor speed and load) is shown in Fig. 6.

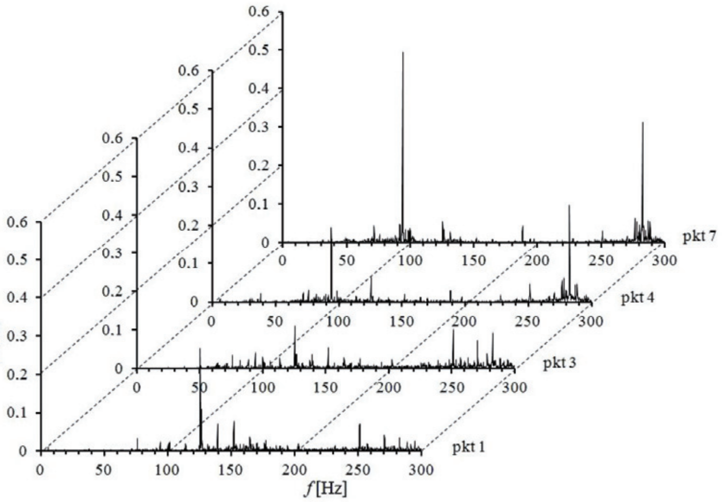

Fig. 5. A comparison of the spectra of signals recorded in the vicinity of the bearings inputs (points 1 and 4) and output (points 3 and 7), drive shafts to and from driving axles powered by an engine running at maximum torque corresponding to diesel fuel, and while the first gear in both transmissions (SB1 and SB2)

In all recorded spectra are visible typical components whose source came from 359 engine and SB1 and SB2 gearboxes. The share of each component in the recorded spectrum depends on the measurement signal transmission, and working conditions. For example, for the spectrum shown in Fig. 6a is the frequency of the dominant component $3\,f_{\mathrm{wks}}$ (~ 33 Hz). From this point, the signal amplitude is greater than the corresponding amplitude recorded at the same speed at the measuring point No. 3, and less than 2 points, offset from the axis of the drive shafts. Component associated with the driving axles of respondents work in this spectral component is f_{zpg} frequency (~ 32 Hz), corresponding to the co-main transmission gears.

Very detailed and very meticulous analysis of recorded frequency spectrum allowed observing the following relationships:

- for the speed $n_{bjał}$ of the test position (working without external load) in the spectra of vibration signals recorded on:
  - internal transmission gear dominant component has a frequency of $3\,f_{\mathrm{wks}}$ (~ 33 Hz), the only component associated with the work test is driving axles f_{zpg} frequency component (~ 32 Hz), attributed to the cooperation of teeth in the main gearbox and unfortunately situated very close to the dominant component (Fig. 6a),
  - for external transmission gear is no apparent significant component,
- for the speed n_{Mo} of the test position (working with the most used external load) in the spectra of vibration signals registered at:
  - internal gear component is the strongest transmission gear f_{z2sbs} frequency (~ 126 Hz), and the only component associated with the work test driving axles is very weak, but noticeable component $2\,f_{wn}$ frequency (~ 6 Hz), attributed to the second harmonic of the rotation frequency drive shafts (Fig. 6b),
  - external transmission gear strongest component has a frequency of $3\,f_{z2sbs}$ (~ 283 Hz), and is much weaker f_{z2sbh} frequency component (Fig. 6c),
- for the speed n_{Mo} test stand work study positions (working with a selected intermediate external load) in the spectra of vibration signals registered at:
  - internal gear component is the strongest transmission gear f_{z2sbs} frequency (~ 189 Hz), and components related to the work test driving axles are weak, but noticeable components at frequencies 2, 4 and 6 f_{wn} (~ 9 ~ 18 and ~ 27 Hz), assigned to the other, fourth and sixth harmonic of the rotation frequency drive shafts (Fig. 6d),
  - external transmission gear the strongest component has a frequency of $2\,f_{z2sbh}$ (~ 283 Hz) – Fig. 6e,

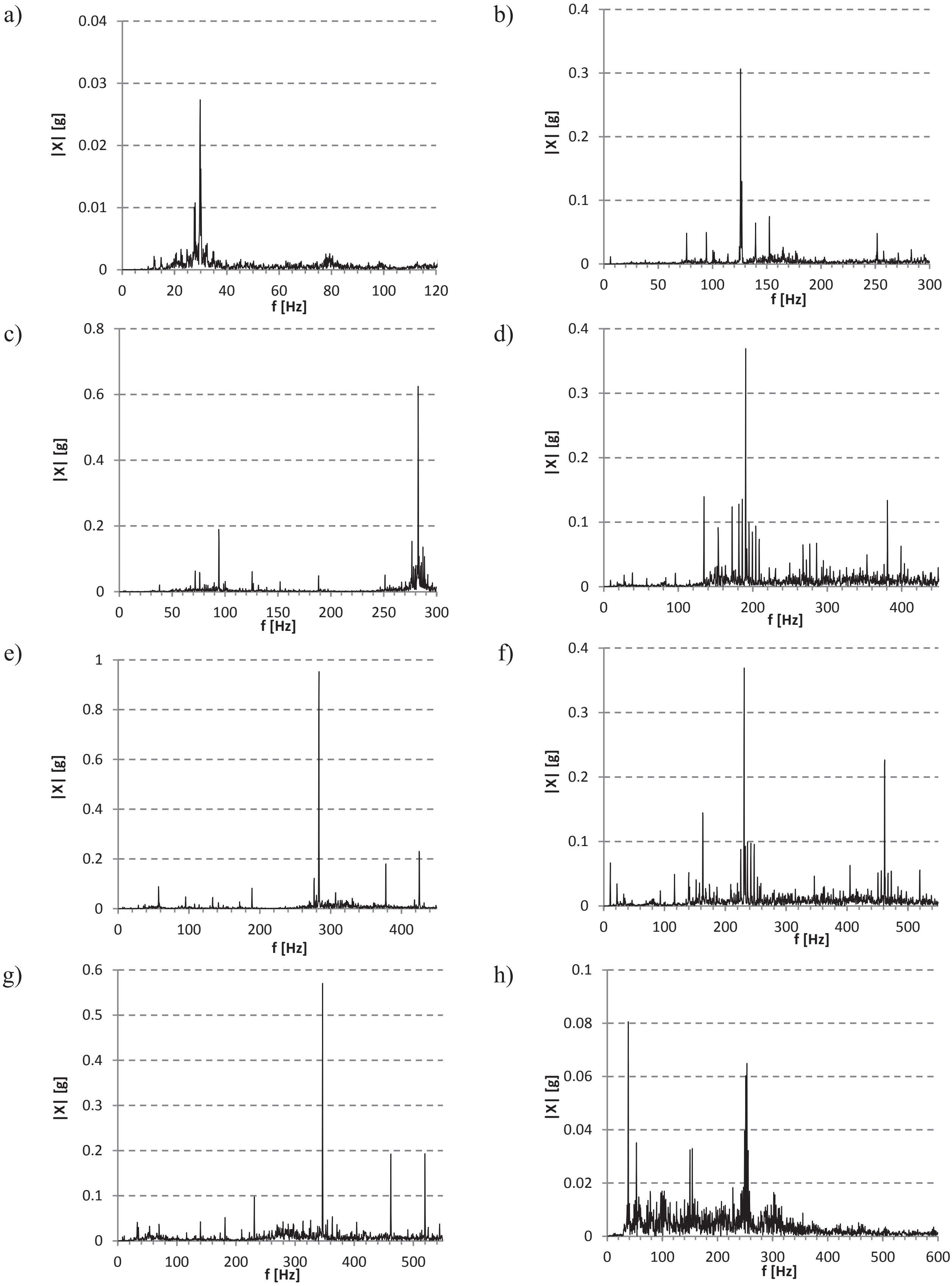

Fig. 6. Sample spectra of vibration signals recorded during the tests: a) the internal gear, measuring point 1, n_{bjal}, b) internal gear, measuring point 2, n_{Mo}, c) the gear extreme,measuring point 5, n_{Mo}, d) the internal gear, measuring point 1, $n_{Mo\text{-}Ne}$, e) extreme gear, measuring point 5, $n_{Mo\text{-}Ne}$, f) the internal gear, measuring point 1, n_{Ne}, g) on the gear extreme, measuring point 5, n_{Ne}, h) on the gear measuring point 5, n_{max}

- for the speed n_{Ne} test stand study working position (working with the smallest non-zero applied external load) in the spectra of vibration signals recorded on:
  - internal gear component is the strongest transmission gear f_{z2sbs} frequency (~ 230.3 Hz), and components related to the work test driving axles are weak, but noticeable components at frequencies 2, 4 and 6 f_{wn} (~ 11, ~ 22 and ~ 33 Hz) – Fig. 6f,
  - external transmission gear, the strongest component has a frequency of 2 f_{z2sbh} (~ 345.5 Hz), and the frequency components 2 and 6 f_{wn} (~ 11 and ~ 33 Hz) can be seen (Fig. 6g),
- for the speed n_{max} test stand study working positions (operation without external load) in the spectra of vibration signals recorded on:
  - internal transmission gear strongest component has a frequency of 2 f_{wks} (~ 101 Hz), is also a strong component f_{z2sbs} frequency (~ 253 Hz),
  - external transmission gear have the strongest frequency component f_{wh} (~ 37.9 Hz), similarly to the inner transmission gear is also a strong frequency component f_{z2sbs} (Fig. 6h).

The obtained spectra, especially for the work of the respondents transmission gear under load, differentiating components are examined copies of these transmissions, but the diagnostic use of this fact requires further analysis, including identification of all relevant spectral components and technical analysis of the impact of test gear to transmit vibration signals from space the formation of the measurement points.

4. Conclusion

1. In the spectra of amplitude-frequency vibration signals recorded at selected points of transmission gear casing are clearly visible characteristic frequencies, most of which have been assigned to work specific mechanisms occurring on the test bench. Unfortunately, the source of most of the components of a diesel engine and two transmissions (SB1 and SB2). This makes it difficult to diagnose significant potential transmission gear from the spectral analysis of recorded measurement signal.
2. For the test, gear external transmission gear found some correlation spectra as obtained from vibration signals switched gears in both transmissions. Observed differences may be due to differences in both the construction and the technical condition of different transmission gear (front and rear).
3. Analysis of the obtained amplitude-frequency characteristics (spectra) allowed identifying specific differences in their characters appearing for different copies of the same driving axis. This applies especially to the external transmission gear; the greater the differences observed in the amplitudes of the components recognized as distortion than the component associated with the test transmission gear.
4. In order to link the unidentified spectral components visible in the spectra recorded vibration signals work gear mechanisms studied transmission gear is required to obtain a broader knowledge of their structure.
5. In a further stage of research, it is advisable to perform the test with a much larger number of the driving axis differentials in various states of well-known technical or active diagnostic experiment with the possibility of interference with the structure of the test-driving axles.

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