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IDENTIFICATION OF ODS AND DYNAMICS CHARACTERISTICS OF CHAIN SAWS

This article presents methods of identification of dynamics characteristics of chain saws. These methods can be successfully used in the process of identification of resonant frequencies and visualisation of ODS of chain saws. Vibration measurements were done using Laser Doppler Vibrometry. Some examples of identification of dynamics characteristics of chain saws and their operational deflection shapes are presented below.

Keywords: chain saw, vibration, deflection, ODS

Introduction

Operational Deflection Shapes (ODS) are vibration patterns of a structure when it is forced to vibrate under particular stationary operating conditions. ODS can be regarded as visualisation of dynamic behaviour of the structure at a given frequency. An animated display of Operational Deflection Shapes (ODS) can help to solve specific vibration problems of the structure. On-site observation of ODS helps to define modifications that can be made to control vibration and reduce noise [Richardson 1997; Swarz, Richardson 1999].

Noise emitted by operating machine during its work cycle depends on the vibration pattern of the surface of the machine. If some characteristic frequencies can be distinguished in the spectrum of mechanical vibrations then it is possible to determine vibration patterns. Often there is a correlation between the operational deflection shapes of selected details of design and spatial distribution of the sound intensity vector measured in the vicinity of the design.

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Measurements of the operating deflection of chain saws

The test of a chain saw blade was performed at a specially prepared measurement station (fig. 1.). The station consisted of a frame construction made of welded angles down to which the body of a combustion sawing machine was screwed. A specially moulded roller replacing the crankshaft of the sawing machine was driven by a transmission belt of a 3-phase engine with the power of 0.95 kW controlled by pDrive MX basis 22/30 converter. At the other end of the roller a drive wheel was fixed which set the chain saw in revolution on the guide. During the machine operation a stable rotational speed of about 9400 rotation/min was assured, i.e. a rotational speed close to real operating conditions of a chain sawing machine.

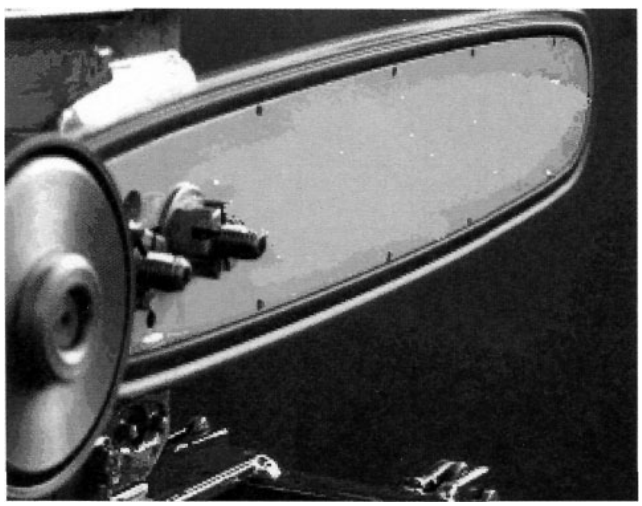

Fig. 1. Measurements of the operational deflection shapes (ODS) in marked points of the guide bar. On the right side there is a visible reflection of the laser beam and on the bottom edge of the guide bar there is a visible oily wave which is a result of the airflow created by the working chain
Rys. 1. Pomiary ODS w oznakowanych punktach prowadnicy. Po prawej stronie widać odbicie wiązki laserowej, a na dolnej krawędzi prowadnicy widać tłustą falę powstałą na skutek działania strumienia powietrza wytwarzanego przez pracujący łańcuch

During the test the load parameters of the engine of the electric station were recorded during cycle controlled operation of the cutting system of the sawing machine. For comparative purposes the level of vibrations and the noise were recorded at the station during lubrication with various oils.

Measurement of operational deflection shapes was done using two sensors of mechanical vibrations. The first one was located at the reference point (position of this sensor did not change during measurements). The second sensor was being moved between selected (nodal) points of the chain saw blade. The geometrical model of the chain saw blade with measurement points marked on it is presented in fig. 2. Vibration measurements at the measurement points on the chain saw blade were obtained using Laser Doppler Vibrometry. It enabled a non-contact measurement of vibrations and minimised measuring errors made due to the change of edge conditions of the system (e.g. adding extra mass) [Laser Vibrometr OFV 2000].

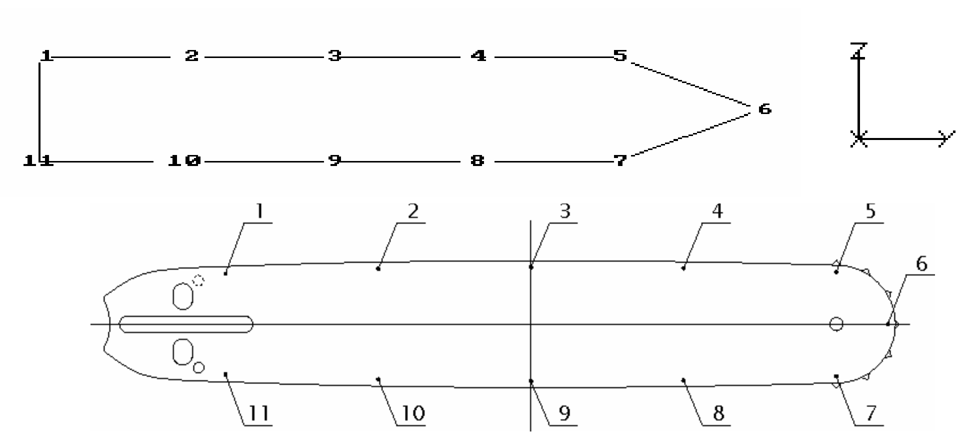

Fig. 2. A schematic view of the location of the measurement points on the chain saw blade

Rys. 2. Schematyczne przedstawienie umiejscowienia punktów pomiarowych na ostrzu piły mechanicznej

As a result individual and relative (cross-) spectra of the accelerations as well as the functions of spectral transmissibility $T_{ij}(\omega)$ were obtained.

Matrix $T_{ij}(\omega)$ is the complex transmissibility function of acceleration/acceleration type. The latter can be formulated as:

$$T(\omega)_{ij} = \frac{X(\omega)_i}{X(\omega)_j} = \frac{\sum_k H(\omega)_{ik} F_k}{\sum_k H(\omega)_{jk} F_k} \qquad (1)$$

where "j" is the index of the fixed point (reference location), whereas "i" refers to the movable test-point monitoring the structure.

T_{ij} (ω) quantity is the ratio between the Fourier spectra of a test degree of freedom (DOF) and the reference DOF, arising as a result of forces F_k occurring during operational cycle of a chain saw. The coherence of transmissibility measurements must be very high in the frequency range of interest to avoid gross errors in the measurement.

Determination of the operational deflection shapes is based on measuring the dominant (peak) components of vibration acceleration spectra or spectral transmissibilities (fig. 3.).

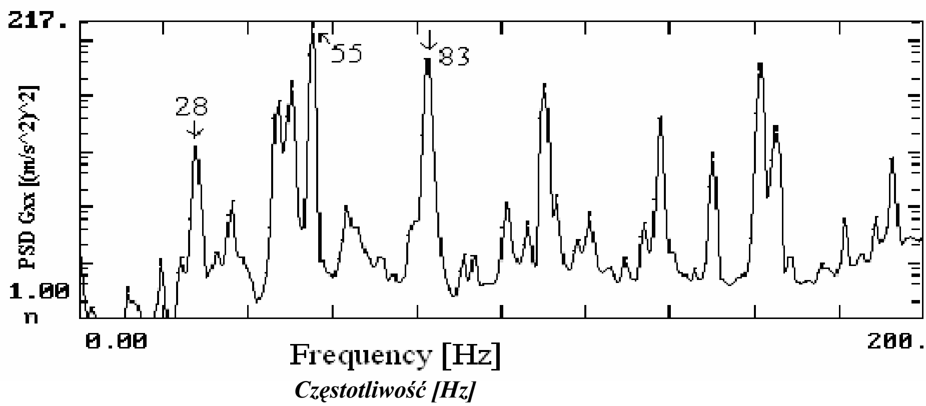

Fig. 3. An example of the power spectrum of mechanic vibration acceleration determined in the point of the guide clamping to the station

Rys. 3. Przykład spektrum siły przyspieszenia wibracji mechanicznej określonej w punkcie umocowania prowadnicy do stanowiska

The relative magnitudes and phase of ODS of the chain saw guide bar are similar, whereas absolute values of ODS are different and depend on physical parameters of oils. Geometric model of the chain saw guide bar (without deformation) is shown in fig. 4.

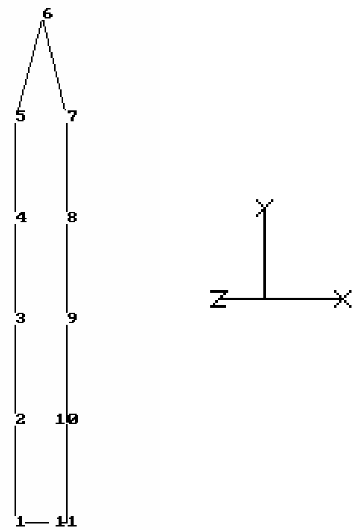

Fig. 4. Geometric model of the chain saw guide bar (without deformation)
Rys. 4. Geometryczny model prowadnicy piły łańcuchowej (bez deformacji)

Table 1. An example of the relative magnitudes and phase of ODS (DOF – degree of freedom) (fig. 5–7)
Tabela 1. Przykład względnych wielkości oraz fazy ODS (DOF – stopień swobody) (Rys. 5–7)

Relative magnitudes and phase of ODS *Względne wielkości oraz faza ODS*								
Frequency 27.7 Hz *Częstotliwość 27,7 Hz*			Frequency 55.0 Hz *Częstotliwość 55,70Hz*			Frequency 82.7 Hz *Częstotliwość 82,7 Hz*		
DOF	Relative Amplitude	Phase	DOF	Relative Amplitude	Phase	DOF	Relative Amplitude	Phase
1/ 1	0.126	-0.	1/ 1	0.799	5.	1/ 1	0.863	-27.
2/ 1	0.131	2.	2/ 1	0.681	12.	2/ 1	0.959	-28.
3/ 1	0.320	-2.	3/ 1	0.475	12.	3/ 1	0.949	-25.
4/ 1	0.519	4.	4/ 1	0.212	11.	4/ 1	0.823	-14.
5/ 1	0.601	-0.	5/ 1	0.286	-137.	5/ 1	0.488	12.
6/ 1	1.000	0.	6/ 1	0.710	-145.	6/ 1	0.500	119.
7/ 1	0.887	1.	7/ 1	0.645	-141.	7/ 1	0.845	178.
8/ 1	0.544	4.	8/ 1	0.236	-114.	8/ 1	0.855	-145.
9/ 1	0.345	7.	9/ 1	0.198	-26.	9/ 1	0.906	-123.
10/ 1	0.148	9.	10/ 1	0.424	2.	10/ 1	0.791	-102.
11/ 1	0.105	9.	11/ 1	0.580	-1.	11/ 1	0.596	-81.
Faza względnej amplitudy DOF			*Faza względnej amplitudy DOF*			*Faza względnej amplitudy DOF*		

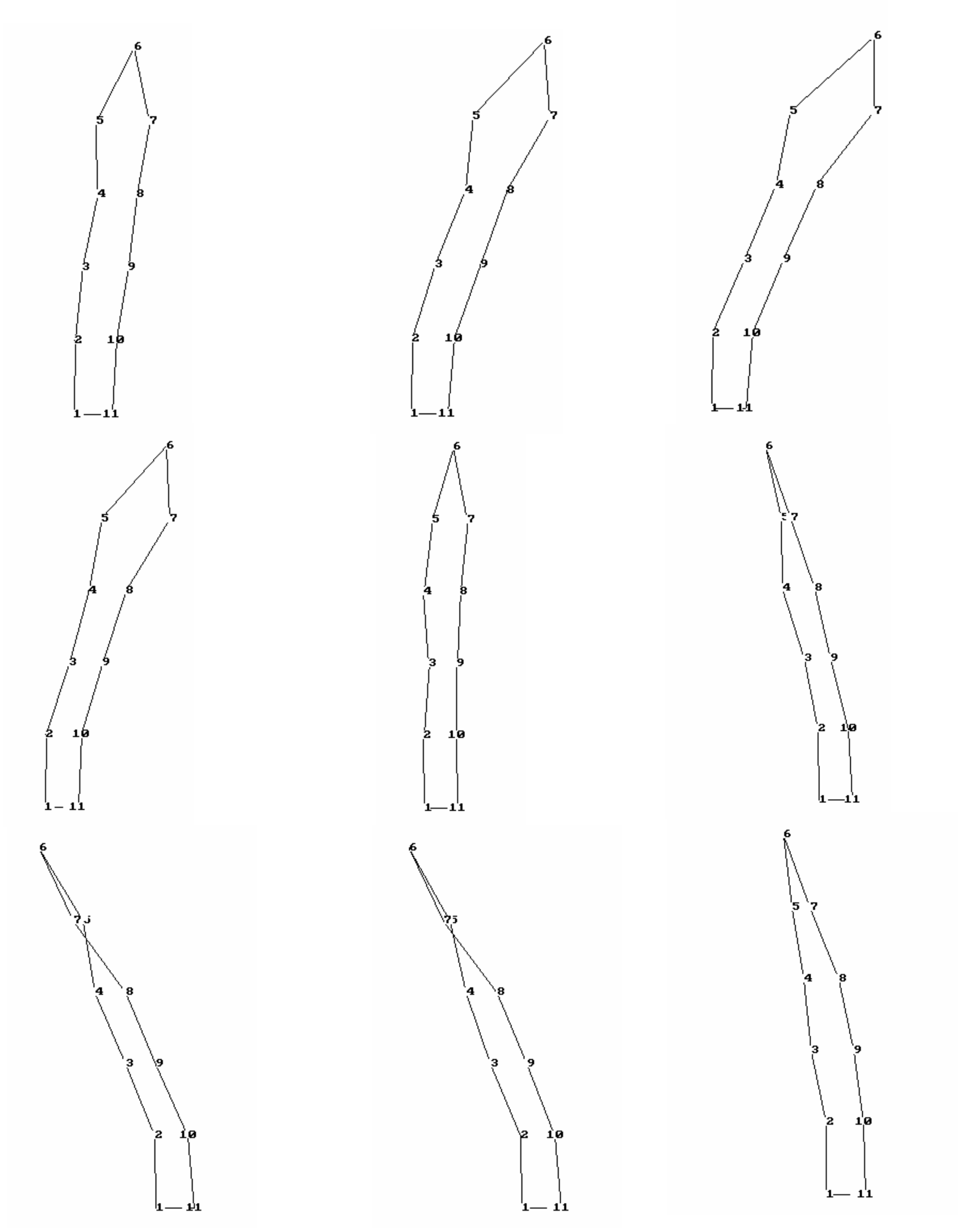

Fig. 5. An example of Operating Deflection Shape of the chain saw guide bar at 27.7 Hz

Rys. 5. Przykład ODS dla prowadnicy piły łańcuchowej przy częstotliwości 27,7 Hz

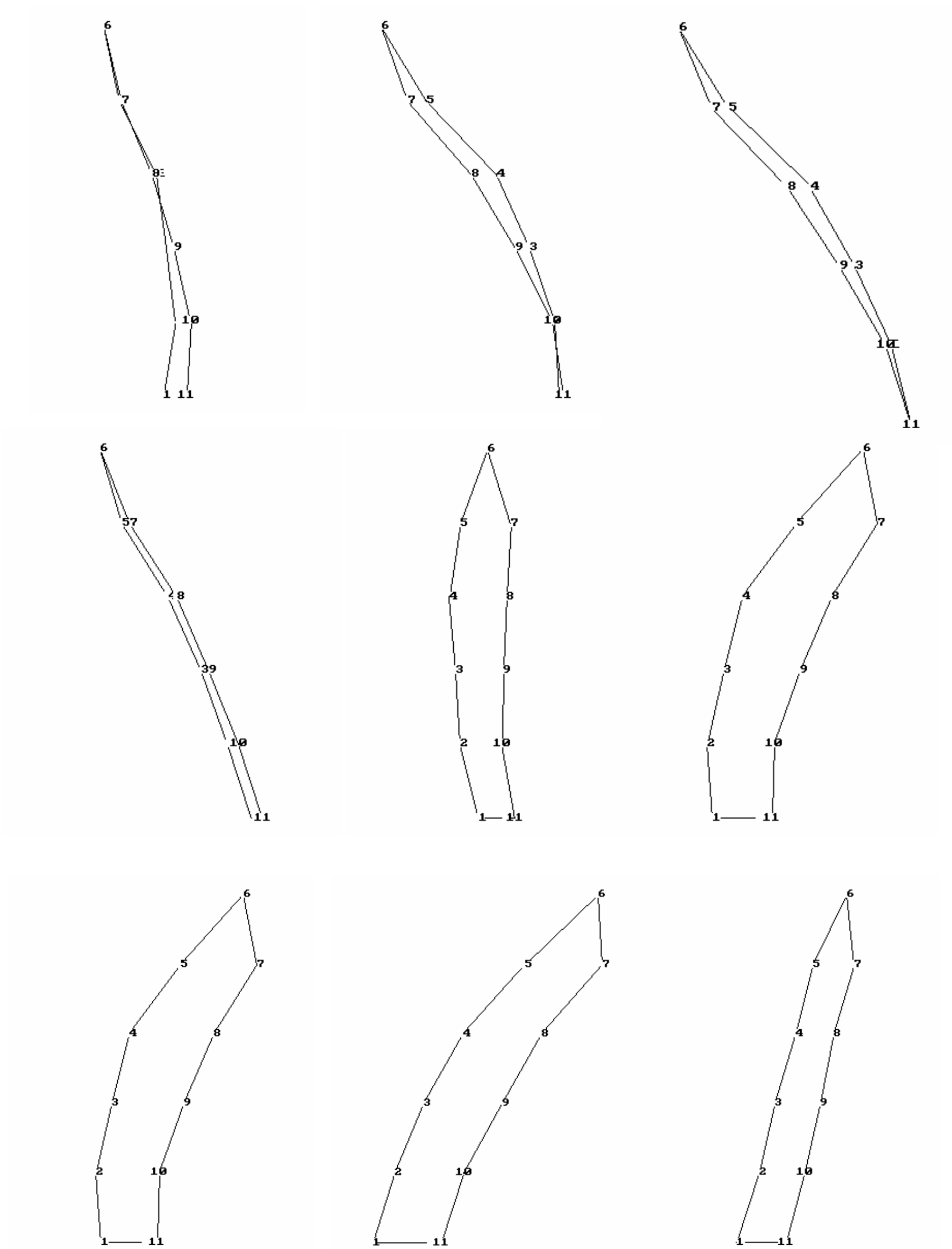

Fig. 6. An example of Operating Deflection Shape of the chain saw guide bar at 55 Hz

Rys. 6. Przykład ODS dla prowadnicy piły łańcuchowej przy częstotliwości 55 Hz

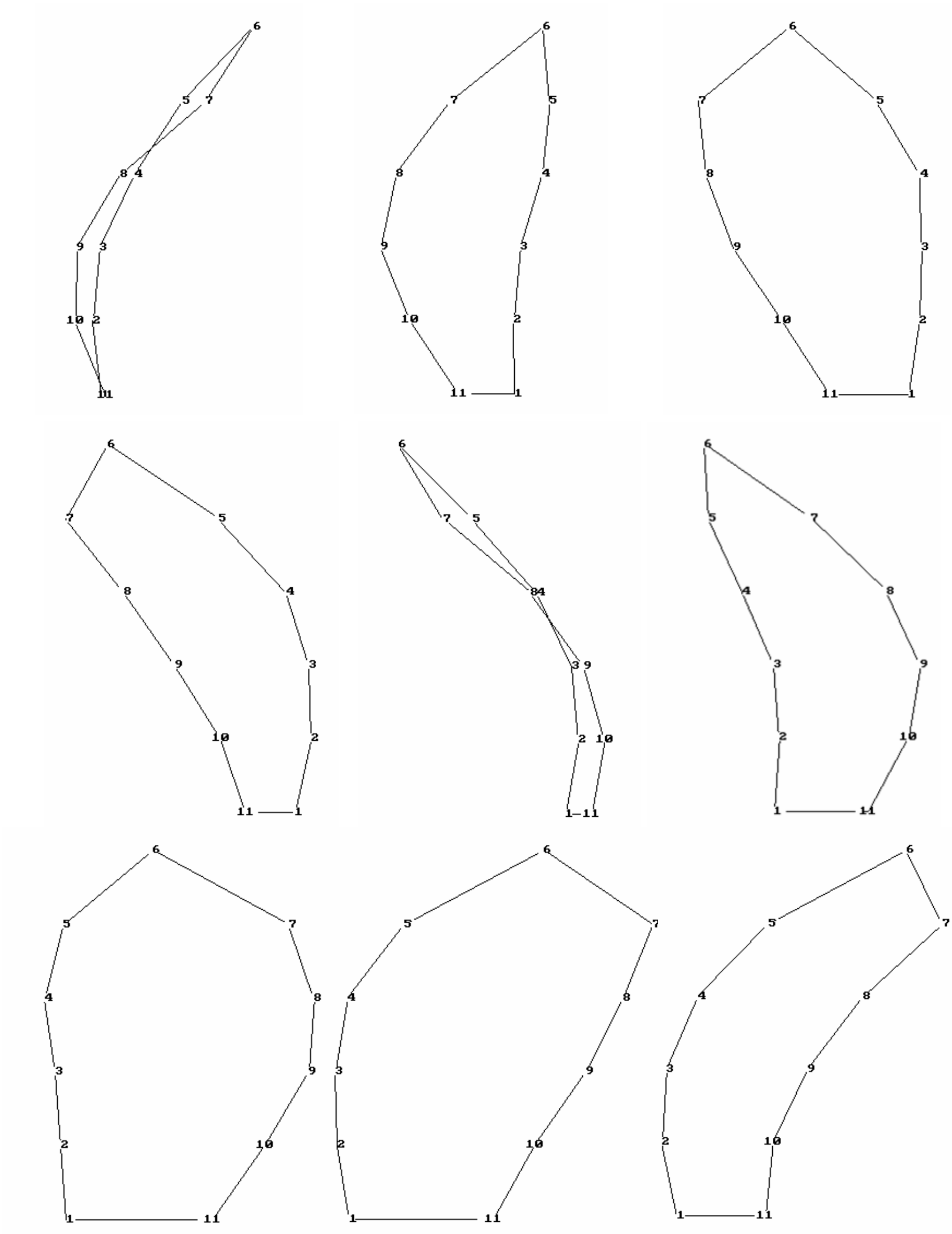

Fig. 7. An example of Operating Deflection Shape of the chain saw guide bar at 82.7 Hz

Rys. 7. Przykład ODS dla prowadnicy piły łańcuchowej przy częstotliwości 82,7 Hz

Identification of chain saw modal parameter

Modal parameter identification is a procedure used to determine dynamic properties of vibrating systems on the basis of experimental data such as damping, frequencies, mode shapes, and modal participation factors, which are referred to as modal parameters.

Modal analysis is based on the fact that the vibration response of a linear dynamic system can be expressed as a linear combination of a set of simple harmonic motions called the natural modes of vibration [Uhl, Lisowski 1999].

Fig. 8 shows the layout of the measurement setup used in identifying a chain saw by the method of experimental modal analysis (the frequency response function (FRF) method). The chain saw at the station for experimental model identification is show in fig. 9.

The artificial excitation forces are applied at a subset of locations and the corresponding excitation force signals (the "inputs") as well as vibration responses at all locations (the "outputs") are measured. The modal parameters are extracted from this data using the system identification methods.

From the FRF the modal parameters, i.e. modal frequencies, modal damping, and the mode shape (modal matrix), are obtained. The modal parameters allow determination of FRF matrix between all points (each point) of the structure.

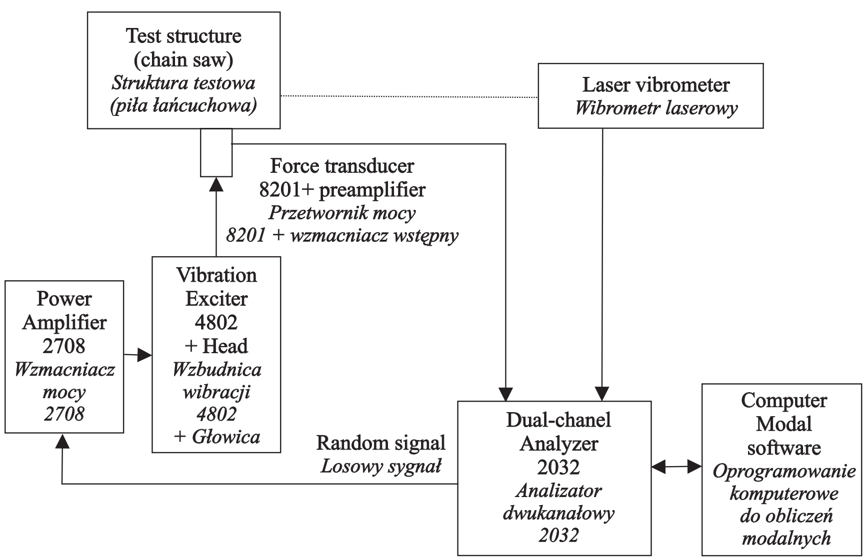

Fig. 8. Layout of the instrumentation used in experimental modal analysis of a structure design

Rys. 8. Rozmieszczenie przyrządów wykorzystanych do eksperymentalnej analizy modalnej wzoru struktury

Fig. 9. The chain saw at the station for experimental modal identification
Rys. 9. Piła łańcuchowa na stanowisku do eksperymentalnej identyfikacji modalnej

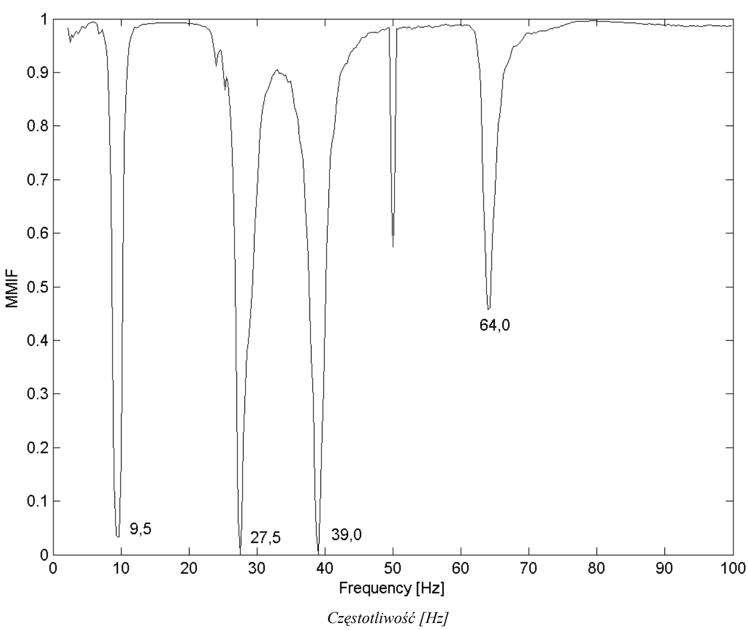

Fig. 10. Experimental modal analysis of the chain saw – Multivariate Mode Indication Function
Rys. 10. Eksperymentalna analiza modalna piły łańcuchowej – Multivariate Mode Indication Function

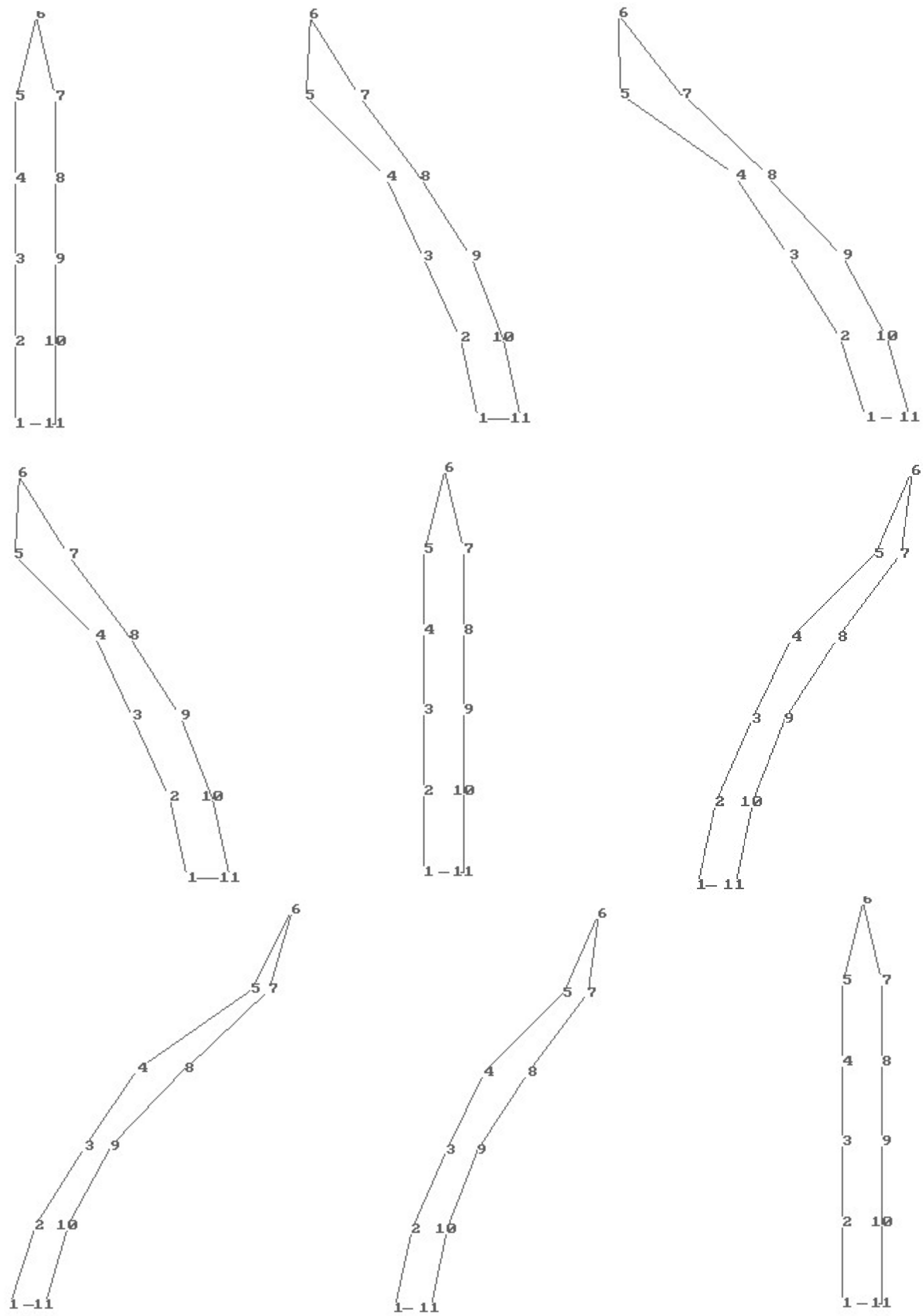

Fig. 11. An example of the modal shape of the chain saw guide bar at 27.5 Hz
Rys. 11. Przykład modalnego kształtu prowadnicy piły łańcuchowej przy częstotliwości 27,5 Hz

Multivariate Mode Indication Function (MMIF) is used for identification of modal frequencies. The mode indicator functions seek to combine data from several input/output pairs of a MIMO transfer function into a single response that gives the user a visual indication of pole locations. For structures that are mostly elastic (with low damping) resonances are sharp and have properties similar to those of isolated modes. Thus the MMIF drops to zero (fig. 10).

The identified modal frequencies from MMIF are 9.5, 27.5, and 39.0 Hz. The second modal frequency is identical with the operational frequency of 27.5 Hz. An example of modal shape of the chain saw guide bar at the frequency od 27.5 Hz is shown in fig. 11.

Conclusions

The noise level of most chain saws used in regular forest works exceeds 100 dBA. The operator is exposed to this noise level for 2 to 5 hours daily. In Sweden around 30% of chain saw operators have serious hearing impairment (according to the data of the International Occupational Safety and Health Information Centre). Chain saws produce high levels of vibration which can cause permanent damage to hands and arms. “White finger” disease has been a major problem for some forest workers operating chain saws.

In co-operation with the Chair of Forestry Engineering at the Poznań University of Life Sciences, the Industrial Institute of Agricultural Engineering in Poznan carried out pioneer research on a few mineral and biodegradable oils with respect to the efficiency of machine cutting system lubrication, and vibration and noise generated in operational condition.

Thanks to more effective measurement, analysis, and using the ODS and modal techniques, it is possible to efficiently identify the root causes of noise and vibration.

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IDENTYFIKACJA ODS ORAZ CHARAKTERYSTYKA DYNAMICZNA PILAREK ŁAŃCUCHOWYCH

Streszczenie

Przedstawiono wyniki badań charakterystyki dynamicznej pilarki łańcuchowej. Pomiarów wibracji dokonano z wykorzystaniem techniki laserowej. Przeprowadzono analizę modalną układu. Zaprezentowano przykłady ODS (*Operational Deflection Shapers*) prowadnicy pilarki łańcuchowej.

Słowa kluczowe: ODS, pilarka łańcuchowa, wibracje, odkształcenie