TIME-FREQUENCY ANALYSIS OF NONSTATIONARY SIGNALS FROM AXIALLY SYMMETRIC SLENDER BODIES IN SUPERSONIC MOTION

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This paper describes the possibilities of obtaining additional information from analysed nonstationary signals of recorded pressure disturbances generated by axially symmetric slender bodies moving at supersonic speed. Selected examples of the considered types of nonstationary signals and the graphical form of their spectral distributions are presented too.

Keywords: time-frequency analysis, nonstationary signal, motion of axially symmetric body.

Axially symmetric slender bodies moving at supersonic speeds in a homogeneous medium generate characteristic nonlinear pressure disturbances in the form of a weak shock wave.

In the theory of shock waves, Whitham's postulates [1, 2] occupy an especially important place. These apply to the prediction of parameters of disturbances in the medium generated by axially symmetric slender bodies (such as projectiles). Whitham was the first to use the laws of linear wave theory to describe strongly nonlinear disturbances, finding them to be dependent on the geometrical dimensions of their source. Whitham's model may be used to determine the characteristic parameters of pressure disturbances, namely the amplitude (Δp) and duration (T) of the disturbance. It should be noted that the assumptions made in Whitham's model relating to the linear form of the pressure distribution, described by two parameters, reflect — to a certain degree of approximation — the nature of the disturbances in the medium created by an object moving at supersonic speed, and make that distribution dependent on the dimensions of the object.

Although the nature of the changes in pressure disturbances for different types of axially symmetrical bodies is qualitatively similar, the values of the characteristic parameters of the resulting pressure distribution differ fundamentally, and they cannot serve as a basis for making a full identification of the source of the disturbance (which is the principal research problem). These differences result from the fact that the objects under consideration have other kinematic characteristics besides their dimensions. It cannot be excluded that for the same values of the characteristic parameters (Δp or T), the recorded nonstationary signals may originate from different objects moving at different distances from the measuring apparatus.

It is therefore fully justified to carry out time–frequency analyses of recorded nonstationary signals to obtain additional information, and to determine the possibility of using certain frequency parameters to make a full and unambiguous identification of the type of the source of disturbances at various distances of propagation of the analysed signal from the disturbance.

In the case of spectral analyses, the problem of nonstationarity of signals may be solved by simultaneous determination of the time and frequency characteristics of the recorded signal [3]. Hence, for time–frequency studies and analyses of nonstationary signals, it was decided to use the fundamental methods of spectral analysis, namely the Fourier transform, wavelet transform and Wigner–Ville distribution. In this way a determination was made of numerical spectral distributions for the recorded signals, the set (database) of which was used in the final stage of the study to determine effective classifiers, used to create and optimise algorithms for the automatic identification and classification of types of sources of disturbances in automated systems for the acoustic location of objects. An example of the considered types of nonstationary signals in pressure disturbances and the graphical form of their spectral distributions for two different distances are shown in Fig. 1.

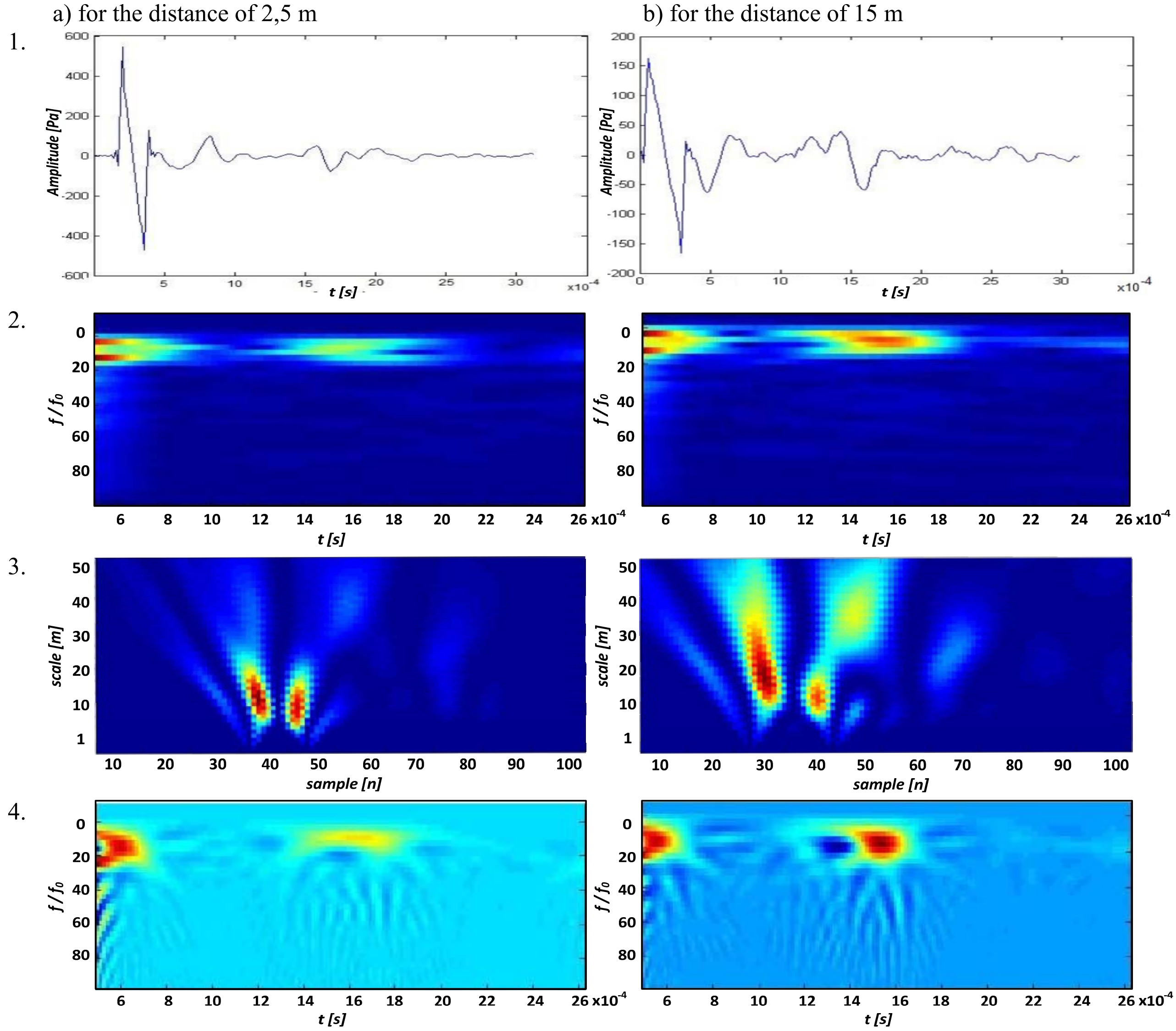

Fig. 1. Selected results of time-frequency characteristics of registered pressure disturbances from 7,62 mm projectiles: *1* — waveforms; *2* — STFTs; *3* — wavelet transforms; *4* — Wigner–Ville distributions

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Частотно-временной анализ нестационарных сигналов от тонких аксиально-симметричных тел при сверхзвуковом движении

Представлены возможности получения дополнительной информации при анализе нестационарных сигналов в условиях возмущения давления, создаваемого тонкими осесимметричными телами, движущимися со сверхзвуковой скоростью. Полученные результаты приведены в виде частотных и временных характеристик анализируемых сигналов.

Ключевые слова: частотно-временной анализ, нестационарный сигнал, движение осесимметричного тела.