THERMOACOUSTIC DIAGNOSTICS OF COOLING PROPERTIES OF QUENCHING LIQUIDS

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Hardening of steel products is widely used in industrial technologies for metal finishing, as a result of which hardness and other important performance characteristics of products increase. The Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine has developed an installation for recording temperature-time characteristics and calculating the cooling capacity of quenching media used for heat treatment. Requirements for the methods of such experiments are defined by international standards, in particular ISO 9950 [1].

The proposed version of the measuring system provides a sufficiently high accuracy and speed of temperature registration in fast processes of non-stationary heat transfer. An additional submersible acoustic sensor (hydrophone) with a spherical sensitive element based on piezoceramics is additionally included in the measuring system of the installation. The hydrophone registers impulse signals when vapor bubbles form on the metal surface. The acoustic signals of the hydrophone in the sound range of 0–20 kHz were measured in a double complex "Frequency – Amplitude", while the first parameter reflects the frequency of generation of vapor bubbles in the heat transfer mechanism, the second – the integral power of the removed heat. Acoustic measurements supplemented traditional thermometric ones. Based on the amplitude of the coussic signal, it is possible to conclude with high certainty about the intensity of heat transfer during boiling, and in some cases, about the change character and mode of boiling.

To determine the optimal concentration of coolants, the authors of the article [2, p. 1] proposed a new method for estimating the optimal concentration of water-salt solutions, based on the analysis of sound signals. This testing method is quite simple and has several advantages, including the ability to detect local film boiling. It does not require the preparation of thermocouples (TK) and their calibration.

One of the means of evaluating such an important hardening parameter as the cooling rate is metal thermometering, which consists in registering the

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temperature field of the product using thermocouples located in different sections of the workpiece. For example, for a cylindrical sample – in the center of the cylinder, at a distance of ½ radius from the surface, and on the surface.

In this case, there is a possibility of the effects of attenuation and delay of temperature pulses during the turbulent and chaotic heat transfer occurring on the surface, which reduces the sensitivity of diagnostics on the sample [3, p. 80].

The experimental data processing program made it possible to obtain a number of graphical dependencies. The main one was the dependence of the temperature of the thermal probe on time, the so-called "temperature cooling curve". On its basis, in accordance with the requirements of the standard, the second dependence is built – the cooling rate on time, as well as on the temperature of the probe.

The acoustic signal processing program made it possible to determine the noise intensity using two algorithms. According to the first method, the noise intensity values are fixed almost in real time, without carrying out a frequency analysis of the noise spectrum and was the broadband total boiling noise power.

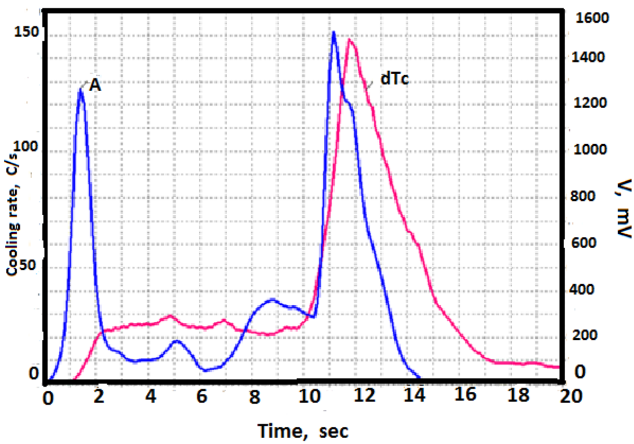

Figure 1. Dependencies of the cooling rate (dT) and acoustic signal intensity (A) on the cooling time of a 10x50 mm TK in distilled water + 0.65% Na-KMZ

Second method uses the results of processing the input signal from the hydrophone using the fast Fourier transform, which allows decomposing the noise in the form of the dependence A = F(f) and obtaining graphs of the amplitude-frequency characteristic of the signal for any time interval of the sample cooling process. The spectral characteristic of the noise during liquid boiling makes it possible to obtain information both about the onset and duration of boiling when the sample is cooled, and about the dynamics of an increase or decrease in the boiling intensity. In addition, indirectly, about the surface temperature, cooling rate and heat flux density.

The plot of the dependence of the amplitude of the acoustic signal on time (Figure 1) almost completely repeats the plot of the cooling rate on time, ahead of it by a certain time interval. It is assumed that the advance occurs due to the fact that the acoustic method is inertialess, and the magnitude of the advance depends on the delay in the response of the thermocouple at the center of the sample.

Conclusions. The acoustic method can be an alternative to the thermometric method when sealing thermocouples is not possible or is difficult. Acoustic signal similar to a thermometric information about the rate of cooling of the thermal probe, also accurately fixes the moments of the beginning and end of the two-phase boiling process. The main advantages of the acoustic method include its practical inertia-free and ease of use as a non-contact type sensor.

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