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INFLUENCE OF THE LÜDERS BAND FRONT ON THE RAYLEIGH WAVE VELOCITY IN LOW-CARBON STEEL

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The aim of this paper is to study how the velocity of ultrasonic Rayleigh waves changes depending on strain localization on the yield plateau in low-carbon steel.

The investigation was performed on specimens of low-carbon steel (C – 0.17–0.24%; Mn – 0.35–0.65%; Si – 0.17–0.37%) cut from hot rolled steel in the form of dog-bone-shape with gage section dimensions 2×10×50 mm and annealed in vacuum at a temperature of 900 °C for 1 hour. The specimens were subjected to uniaxial loading at a constant rate of 6.67×10^{-5} s^{-1} at room temperature in the grips of a universal LFM-125 testing machine.

The plastic strain localization patterns were recorded during specimen deformation by the method of digital statistical speckle photography for the in situ recording of Lüders deformation fronts, which excludes the intensive computation of the displacement vector fields [1].

The acoustic informative parameter was the velocity of ultrasonic Rayleigh waves at a frequency of 5 MHz. The Rayleigh wave velocity was determined as the ratio of the wave path length in the specimen to the signal delay time at the receiving transducer relative to the transmitting one. The delay time was measured by an oscillogram recorded using a digital oscilloscope with a sampling rate of 2 GHz. The measurement accuracy was 10^4–10^5.

The studies were carried out for the curve portion corresponding to the yield plateau. the yield plateau is not smooth, with deformation stress fluctuations and slight hardening. There is a pronounced sharp yield point characteristic of low-carbon steels. The stress drops (reverse yield point) before the beginning of the hardening stage. The length of the yield plateau for the studied steel is ≈ 2.5% of the deformation.

In this case, the deformation is provided by two successively propagating Lüders bands. The fronts of the both bands move with interrelated velocities. First, a single band appears near the moving grip. It is bounded by the front propagating with the velocity $V_f = 0.28$ mm/s.

When the front enters the acoustic measurement area, the ultrasonic wave velocity drops and decreases as the front advances. The second band is formed near the opposite grip, bounded by the front propagating with the velocity $V_f = 0.22$ mm/s. The formation of the second band is accompanied by a decrease in the velocity of an existing front down to $V_f = 0.12$ mm/s, as a result of which the slope of the curve of the ultrasonic wave velocity changes. When the second front reaches the acoustic measurement area, the slope of the ultrasonic wave velocity curve also changes. The reverse yield point on the flow diagram corresponds to the “collapse” of the propagating Lüders bands and the final transition of the material to the plastically deformed state.

Owing to the constant propagation rate of the Lüders bands, the rate of expansion of the plastically deformed region in the specimen on the yield plateau is also constant and, thus, the increase in the area of the plastically deformed region in the specimen is correlated with the ultrasonic wave velocity.

The obtained correlation between the change in the Rayleigh wave velocity and the area of the deformed region within the acoustic measurement area can be explained from the viewpoint of the theory of dislocation damping, formulated for the first time by Granato and Lucke [2].

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