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Laser - Ultrasonic Method for the Measurement of Residual Stresses in Metals

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Abstract : The theoretical analysis is carried out to get the relation between the ultrasonic wave velocity and the value of residual stresses. The laser-ultrasonic method is developed to evaluate the residual stresses and subsurface defects in metals. The method is based on the laser thermooptical excitation of longitudinal ultrasonic wave sand their detection by a broadband piezoelectric detector. A laser pulse with the time duration of 8 ns of the full width at half of maximum and with the energy of 300 μJ is absorbed in a thin layer of the special generator that is inclined relative to the object under study. The non-uniform heating of the generator causes the formation of a broadband powerful pulse of longitudinal ultrasonic waves. It is shown that the temporal profile of this pulse is the convolution of the temporal envelope of the laser pulse and the profile of the in-depth distribution of the heat sources. The ultrasonic waves reach the surface of the object through the prism that serves as an acoustic duct. At the interface ‚laser-ultrasonic transducer-object' the conversion of the most part of the longitudinal wave energy takes place into the shear, subsurface longitudinal and Rayleigh waves. They spread within the subsurface layer of the studied object and are detected by the piezoelectric detector. The electrical signal that corresponds to the detected acoustic signal is acquired by an analog-to-digital converter and when is mathematically processed and visualized with a personal computer. The distance between the generator and the piezodetector as well as the spread times of acoustic waves in the acoustic ducts are the characteristic parameters of the laser-ultrasonic transducer and are determined using the calibration samples. There lative precision of the measurement of the velocity of longitudinal ultrasonic waves is 0.05% that corresponds to approximately ±3 m/s for the steels of conventional quality. This precision allows one to determine the mechanical stress in the steel samples with the minimal detection threshold of approximately 22.7 MPa. The results are presented for the measured dependencies of the velocity of longitudinal ultrasonic waves in the samples on the values of the applied compression stress in the range of 20-100 MPa.

Keywords : laser-ultrasonic method, longitudinal ultrasonic waves, metals, residual stresses
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