Direct-write Piezoelectric Ultrasonic Transducers for Determining Plastic Deformation of Alloy Structures

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Direct-write Piezoelectric Ultrasonic Transducers for Determining Plastic Deformation of Alloy Structures Shifeng Guo1,2*, Zhen Li1,2, Yehai Li1,2, Yanhui Zhang1,2, Wei Feng1,2 1Guangdong Provincial Key Lab of Robotics and Intelligent System, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China 2CAS Key Laboratory of Human-Machine Intelligence-Synergy Systems, Shenzhen Institutes of Advanced Technology, Shenzhen 518055, China An overloading that exceeds the yield strength of metallic materials generates permanent damage and may induce catastrophic consequences. It is therefore critical to develop a reliable non-destructive testing technique for identification the plastic deformation of structures. In this work, a second harmonic based nonlinear ultrasonic method using direct-write piezoelectric ultrasonic transducers is introduced to determine the yielding of titanium (Ti) and aluminum (Al) alloy material. Direct-write piezoelectric transducers, in which piezoelectric polymer coatings and electrodes are directly designed and fabricated on the Ti and Al alloy specimens with different plastic deformations. The Rayleigh ultrasonic signals, generated by direct-write transducers and propagating along the alloy specimens, are measured with either laser scanning vibrometer (LSV) or direct-write transducers to obtain the fundamental and second harmonic ultrasonic signals for analyzing the acoustic nonlinearity. The results suggest that the direct-write piezoelectric ultrasonic transducers, with highly reduced profile and mass, can successfully evaluate the plastic deformation of both Ti and Al structures,and the acoustic nonlinearity increases with plastic strain. In addition, the scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray diffraction (XRD) are conducted to correlate micro-structural changes with the acoustic nonlinearity in the Ti and Al alloys. Compared with conventional discrete ultrasonic transducers, the use of direct-write piezoelectric ultrasonic transducers eliminates the procedure of fixing and aligning of transducers on the structure, requires no coupling agents and additional wedges, thus exhibits significantly improved repeatability and consistency in the acoustic nonlinearity measurement.