Non-Destructive and Non-Contacting Stress-Strain Characterization of Aerospace Metallic Alloys and Nanocoatings Using Photo-Thermo-Mechanical Radiometry (PTMR) Thermophysical Property Measurements

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Photo-thermo-mechanical radiometry (PTMR) was developed theoretically and experimentally and used for non-contact, non-destructive evaluation of mechanical stress-strain relations in metallic materials. A home-made small-scale tensile rig was devised to apply static uniaxial tensile load on solid samples. The strength of nanocoated/uncoated samples was recorded in terms of strain by an adhesive strain gauge also acting as a PTMR calibration device. A one-dimensional thermal-wave model modified to include mechanical stress explicitly was used to fit experimental data from both frequency scan and stress scan tests and determine the thermal effusivity and diffusivity of an aerospace-industry-relevant aluminum 6061 alloy. Within the elastic regime, the thermal conductivity values measured from both PTMR amplitude and phase showed very good agreement, thereby establishing the self-consistency of the PTMR method. Furthermore, a linear conductivity - stress dependence was found, thus establishing the dominant role this property plays in the ability of PTMR to monitor mechanical changes in the aluminum alloy. It was demonstrated that PTMR can be used as a non-contact “opto-thermal strain gauge” within and far beyond the operational range of commercial strain gauges, up to the fracture point. Both theoretical and experimental results indicated that the presence of a NiCo nanocoating can significantly strengthen the mechanical properties of the coated aluminum substrate. The coating can also provide protection to defective substrates and enhance their mechanical stiffness (strength).