Abstract

The aim of the current investigations is to characterize different microstructural features evolved through various heat treatments, to evaluate the mechanical properties and to correlate these with different ultrasonic parameters in various metallic materials such as, 9Cr-1Mo ferritic steels, $\alpha+\beta$ Ti-alloys (Ti-4.5Al-3Mo-1V and Ti-6Al-4V) and Ni-base superalloy Inconel 625. Firstly, to establish a nondestructive methodology for the characterization of solution annealing behaviour, various specimens of ferritic steel and titanium alloys have been heat treated at different temperatures followed by rapid quenching. Ultrasonic parameters have been correlated with hardness measurements and microstructural features studied using optical microscopy. Ultrasonic velocity measurement, attenuation measurement and two new parameters, spectral peak ratio (SPR) and time domain peak ratio (TPR), have been used for characterization of the microstructures obtained by various heat treatments. Secondly, to characterize the precipitation behaviour through ultrasonic measurements, various specimens of ferritic steel have been thermally aged at 793 and 873 K for durations upto 5000 h. In order to generate the specimens for longer ageing durations and to study the creep deformation, the specimens were taken from the shoulder and gauge regions of some creep tested specimens respectively. The variation in ultrasonic velocity in these specimens has been correlated with the microhardness measurements and the precipitation behaviour studied using transmission electron microscopy. In continuation of this study in Inconel 625, the service-exposed (SE) alloy that consisted of various intra and inter granular precipitates, has been used as the initial condition. The SE alloy was thermally aged at different temperatures (923 K, 1023 K and 1123 K) for different durations upto 500 h. The SE alloy was also re-solution annealed at 1423 K for 0.5 h and subsequently aged at 923 K and 1123 K upto 500 h. The variation in ultrasonic velocity in these specimens has been correlated with the tensile properties and the dissolution/ precipitation of various phases studied using optical, scanning electron and transmission electron microscopies. Specific softwares have been developed in LabVIEW programming system for on-line accurate measurement of various ultrasonic parameters. Attempt has also been made to study possible correlation between two independent elastic properties, ultrasonic shear wave velocity and Poisson's ratio, for isotropic solid materials, using a large set of data collected from literature for various elements, intermetallics, ceramics, glasses and polymers as well as the data generated in this study.

The study revealed that ultrasonic velocity and attenuation measurements can be used in a complementary manner for complete characterization of solution annealing behaviour in

ferritic steel and Ti-alloys. It has been demonstrated for the first time that ultrasonic parameters can be used for the identification of various critical temperatures in ferritic steels, such as Ac_1, Ac_3 and Ac_4 temperatures and β-transus temperature in Ti-alloys. A few new ultrasonic parameters, such as SPR, TPR etc., have been identified and their potential has been demonstrated for microstructural characterization in ferritic steel and Ti-alloys. TPR has been found to vary linearly with SPR, indicating that TPR can be used to study the frequency dependent attenuation in time domain itself. Further, it has also been shown by both mathematical and graphical modeling that the linear relationship between TPR and SPR is valid for any transducer exhibiting double peak behaviour in the autopower spectrum of the first backwall echo. The study of precipitation behaviour exhibited that ultrasonic velocity increases with the precipitation of various phases and decreases with coarsening/dissolution of the precipitates in both ferritic steel and Inconel 625. Ultrasonic velocity measurements could also reveal the faster kinetics of precipitation at higher temperature and in creep tested conditions in ferritic steel. The study has also brought out, for the first time, the influence of various individual precipitates on the correlation between elastic (ultrasonic velocity) and plastic (yield stress) properties in Inconel 625. A new correlation between two independent elastic properties, ultrasonic shear wave velocity and Poisson's ratio, has been established for isotropic solid materials. It has been shown, for the first time, that for solid isotropic materials, Poisson's ratio decreases linearly with increase in shear wave velocity and the slope of this correlation is almost constant for any given alloy system with different microstructures associated with various heat treatments, alloying elements, grain size, temperature etc.. This new correlation between two independent elastic constants may lead to the reduction in independent elastic constants for isotropic solid materials from two to one, at least for a given alloy system with different microstructural conditions. Further, it has also been established that ultrasonic shear wave velocity is a better parameter than longitudinal wave velocity for material characterization applications.