NEUTRON AND X-RAY RESIDUAL STRESS MAPPING IN VEHICLE TURBOCHARGER SHAFT WHEEL ASSEMBLIES

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Turbochargers are key elements in advanced fuel-efficient engines, so ensuring their reliability is important to manufacturers of these engine boosters. The goal of this study is to quantify the role that residual stresses play in the lifetime of shaft-wheel-assemblies (SWA). A two-pronged study to better understand residual stresses following electron-beam welding and residual stress relief in the weld region of turbocharger shaft wheel assemblies (SWAs) used neutron and x-ray diffraction mapping in regions of the shaft of as-welded, standard "stress relieved", and furnace "stress relieved" SWA samples.

The martensitic IDB-6108 shaft is electron-beam (EB) welded to the IDM 5383 alloy turbine wheel. One element of the experimental plan was to create a map of the residual strains in the region near the EB weld joining the shaft to the turbine wheel in both through-thickness and circumferentially using the NRSF2, the engineering materials neutron residual stress mapping facility at the High Flux Isotope Reactor at ORNL. NRSF2's combination of small gauge volumes (1.5 × 1.5 × 0.5 mm slits were used) and good intensity made these through-thickness measurements feasible. The non-destructive penetration that only neutrons provide was critical for the mapping of stresses near the EB weld. The team observed significant changes in hoop and radial strains around the circumference with deviations from the average localized within a 30° angular range of the as-welded and also in the standard "stress relieved" SWAs. These changes show that the industry's standard manufacturing method is not fully effective in relieving residual stresses that arose from the EB weld operation. In comparison measurements on a SWA subjected to 1,100°C furnace stress relief showed that effectively all residual stresses were relieved and no localized stresses remained.

The second element of the study was to map with X-ray diffraction the near-surface residual stresses and peak breadth along the shaft in each of the two bearing races. The peak breadth served as a measure of defect density. A PROTO LXRD system was used to map the hoop residual stresses at multiple locations along the axial direction. Critical to the study was the use of the PROTO touch probe to determine the XYZ location of the crown before measurements were initiated. Using this careful alignment approach, stress mappings were collected on SWAs in three conditions: as-welded, standard stress relieved, and furnace-treated at 1100°C. Hoop and shear stresses and peak breadth were obtained at each location. Mappings show localized stress and breadth changes at the mid point of each bearing race in the as-welded and standard "stress relieved" SWAs. For the furnace heat treated sample the X-ray results agree with the neutron scattering results and further confirm that furnace heat treatment fully removed the residual stresses and reduced defect density introduced by manufacturing steps.

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