ABSTRACT

The aim of this project was to investigate the techniques for determining the residual stresses in WC-17Co thermal sprayed coatings and to study the effect of residual stress on abrasion resistance on different substrates. The choice of the substrate was due to their different coefficients of thermal expansion (aluminium, super-invar, 304L stainless steel, mild steel and brass). Coatings of about 200µm were successfully deposited on all the substrates.

Coatings were deposited by a high velocity oxyl-fuel spraying system (HVOF), and characterized by evaluating the coating phases and wear resistance, and the residual stresses were determined via non-destructive methods. Investigations involved both as-sprayed and their annealed counterparts to ascertain the effect of heat treatment.

Non-destructive determination of residual stresses in the WC-Co coated systems was exceptionally challenging in that the coatings were only 200 microns thick. The best suited techniques for investigation of WC were diffraction-based strain scanning using penetrating radiation such as thermal neutrons (most penetrating), high energy synchrotron X-rays (100 keV enables 20 micron penetration) and laboratory X-rays (limited to 5 micron penetration). Laboratory X-rays (Necsa, using Co radiation), thermal neutrons (ANSTO, Australia) and X-ray synchrotron (ESRF, France) were successfully employed to resolve the stress conditions. The neutron investigations enabled two approaches for the determination of the in-surface stresses, direct measurements (good results for the low neutron attenuation substrates), and indirect determination using stress balance conditions inferred from the through thickness depth profiles measured in the substrates (applicable to all the higher neutron attenuating substrates). Investigations were expanded to the study of the influence of annealing at 40% of the respective substrate melting temperatures. For each substrate, the through thickness stress profile differences between the grit-blasted reference material (final before the HVOF coating) and the grit-blast coated samples were used to determine the elastic contributions purely ascribed to the coating process. This required exceptional positional resolution neutron diffraction investigations (positional accuracies better than 0.01 mm). There were both small compressive and low tensile stresses on the as-sprayed coated samples. After annealing, the stresses became substantially more compressive. The near-surface trends of the grit-blasted substrates were completely relaxed after annealing, with thermal stresses being the dominant mechanism for residual stress induced due to the large difference in the coefficients of thermal expansion (CTE) between the WC coatings and the substrates.

The three-body abrasive tests were carried out on the parent materials (substrate), grit blasted substrates, as-sprayed coatings and heat treated coatings. The contributions of each coating process were established. There was about 45-50% reduction in the wear of grit-blasted samples compared to the substrates, whilst 80-95% reduction in the wear of the coatings compared to substrates was found. The wear resistance is due to many different contributions, but there was a strong correlation between the residual stress and wear resistance of the coating.