ABSTRACT

This study investigated the effect of microstructure on properties of selected Pt-based alloys. Six alloys of different compositions were analysed after heat treatment at 1500°C for 18 hours, followed by quenching in water; then annealed at 1100°C for 120 hours and air cooled, equivalent to a potential industrial specification. Microstructural characterisation utilised OM, SEM, AFM, TEM and EDX. Further characterisation was carried out using a nanoindentation hardness tester for nanohardness and elastic modulus measurements. The research focus was to characterize the different morphologies of γ′ ~Pt_3Al precipitates during a single heat treatment, and to understand the nano-mechanical properties of the γ′ precipitates and γ (Pt) matrix, taking their proportions into account.

In the present work, the samples were successfully etched, (which was not possible before) allowing optical microscopy and SEM to give much clearer microstructures than previously. The precipitate volume fractions were measured from SEM and AFM images, and agreed well. The γ′ volume fraction (expressed as percent) of nominal Pt_{78}:Al_{11}:Cr_6:Ru_5 (at.%) alloy was 51 ± 6% (SEM) and 57 ± 10% (AFM), while for nominal Pt_{85}:Al_7:Cr_5:Ru_3 (at.%) it was 45 ± 6% (SEM) and 48 ± 8% (AFM). A comparison of the γ′ volume fractions obtained from TEM showed that, compared to SEM, as the γ′ volume fraction observed with SEM increased, the γ′ volume fraction measured in TEM increased, although the TEM volume fraction results are believed to have considerable error due to TEM only revealing the microstructure of relatively small regions compared to SEM. Comparing with Pt-Al-Cr-Ni alternatives with γ′ volume fractions of 51-57%, the nominal Pt_{78}:Al_{11}:Cr_6:Ru_5 and nominal Pt_{85}:Al_7:Cr_5:Ru_3 (at.%) alloys have comparable γ′ volume fractions within, experimental error, and are considered as promising. From a microstructural viewpoint, these alloys were identified as the most promising.

TEM revealed that at the specific heat treatment there were multiple size ranges of γ′ precipitates. The ~Pt_3Al precipitate structure was found to be cubic $L1_2$, rather than tetragonal. The orientation relationship between the γ matrix and γ′ precipitates was found to be $[114]_M||[114]_P$; $[001]_M||[001]_P$; $[103]_M||[103]_P$.

The nano-mechanical properties of the γ matrix and γ′ precipitates of Pt-Al-Cr-Ru alloys were investigated for the first time. At 2.5mN, it was possible to measure mechanical

properties inside the individual γ′ precipitates and γ matrix channels, and in all six alloys the γ′ precipitates were the harder phase. The hardness of γ′, γ and the overall alloy was a function of the Pt content, and the hardness of the overall alloy was also a function of the Al content. The overall alloy hardness for nominal $Pt_{85}:Al_{7}:Cr_{5}:Ru_{3}$ (at.%) was 9.0 ± 0.3GPa and 9.2 ± 0.3GPa for nominal $Pt_{78}:Al_{11}:Cr_{6}:Ru_{5}$ (at.%).

The new findings on image analysis showed that the precipitate volume fractions of nominal $Pt_{78}:Al_{11}:Cr_{6}:Ru_{5}$, nominal $Pt_{85}:Al_{7}:Cr_{5}:Ru_{3}$ and nominal $Pt_{78}:Al_{11}:Cr_{8}:Ru_{3}$ (at.%) were comparable to commercial nickel-based superalloys (NBSAs). TEM has shown that the precipitate morphology was similar to that of NBSAs, while nanoindentation studies indicated that the Pt-Al-Cr-Ru alloys' overall, γ and γ phase nanohardnesses and elastic moduli were also similar to NBSAs. These results were encouraging, since the NBSAs already have commercial applications. Thus, more research efforts are encouraged on the Pt-Al-Cr-Ru alloys in order to further improve the properties of these alloys.