Microstrain and texture in rotary swaged W-Ni-Co pseudoalloy

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Due to their excellent mechanical properties and high specific mass, tungsten heavy alloys are used in demanding applications, such as kinetic penetrators, gyroscope rotors, or radiation shielding [1]. However, their composite structure, consisting of hard tungsten particles embedded in a soft matrix [2], makes the deformation processing a challenging task. This study focused on the characterization of deformation behaviour during thermomechanical processing of a W-Ni-Co tungsten heavy alloy (produced by powder metallurgy) via the method of rotary swaging (aimed at still improving properties) at ambient temperature and at 900°C.

Swaging changed mechanical properties, and - as an important step to optimize microstructure and mechanical properties is to understand the underlying processes - the aim of the neutron diffraction study was to determine texture and to characterize microstrain, dislocations as well as the active slip system. The strength of neutron diffraction method lies in the information provision from the bulk of the sample, i.e. not only from its near-surface region. This advantage is still amplified for materials with very high X-ray absorption (like tungsten alloys) and/or with large grains.

First, phase identification was done from the diffraction patterns. The detected main phase was corresponding to the original tungsten powder grains of bcc structure, the second (in fact matrix) phase, was Ni-Co solid solution with fcc structure [3]. Peak broadening after swaging was visible in the soft matrix phase.

Further, texture measurement using neutron diffraction was done, which shows that the original as sintered material had for the tungsten phase no texture. It also shows that there were very large grains of Ni-Co matrix phase in the as sintered bar, without any clear preferential orientation. During rotary swaging, the large grains of Ni-Co are fractioned to fine-grained microstructure. A strong texture formed in both phases after rotary swaging [4]. Both bcc phase and fcc phase, after rotary swaging, have the same texture type as for wire drawing. It can be thus concluded that the primary deformation mechanism for rotary swaging was the same as for wire drawing. The textures for cold and hot swaging are qualitatively the same, but stronger for cold swaging which indicates that secondary deformation mechanisms are also active for the hot swaging. The deformation was also connected with formation of residual macrostresses [4,5].

The peak broadening was evaluated for the neutron-diffraction peaks of the relatively soft Ni-Co matrix phase [3]. The modified Williamson-Hall plot shows that the microstrain increased approximately 3 times after rotary swaging. In accord with the texture measurement, the edge dislocations with <110> {111} slip system (typical in fcc) provide such contrast factor, that the integral breaths of the individual reflections fit very well to straight lines. Interesting is the Ni-Co matrix in non-deformed as-sintered bar where the contrast factor for screw <111> dislocation fits best with the measured integral breaths. The dislocation densities from the slope of the modified Williamson-Hall plot were estimated. The dislocation density increased approximately 5 times after rotary swaging, which is linked with the mechanical properties: swaged samples exhibited substantial strengthening - primarily caused by the increase in dislocation density. Further, the dislocation density is 15% higher for the sample swaged at room temperature than for the sample deformed at 900°C, which fits the trend observed in stress-strain curve.

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