Recrystallization Behavior and Microstructural Evolution of Nickel Base Superalloy AD730 Billet during Hot Forging at Subsolvus Temperatures

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Abstract : Nickel superalloys are used to manufacture high-temperature rotary engine parts such as high-pressure disks in gas turbine engines. High strength at high operating temperatures is required due to the levels of stress and heat the disk must withstand. Therefore it is necessary parts made from materials that can maintain mechanical strength at high temperatures whilst remain comparatively low in cost. A manufacturing process referred to as the triple melt process has made the production of cast and wrought (C&W) nickel superalloys possible. This means that the balance of cost and performance at high temperature may be optimized. AD730TM is a newly developed Ni-based superalloy for turbine disk applications, with reported superior service properties around 700°C when compared to Inconel 718 and several other alloys. The cast ingot is converted into billet during either cogging process or open die forging. The semi-finished billet is then further processed into its final geometry by forging, heat treating, and machining. Conventional ingot-to-billet conversion is an expensive and complex operation, requiring a significant amount of steps to break up the coarse as-cast structure and interdendritic regions. Due to the size of conventional ingots, it is difficult to achieve a uniformly high level of strain for recrystallization, resulting in non-recrystallized regions that retain large unrecrystallized grains. Non-uniform grain distributions will also affect the ultrasonic inspectability response, which is used to find defects in the final component. The main aim is to analyze the recrystallization behavior and microstructural evolution of AD730 at subsolvus temperatures from a semi-finished product (billet) under conditions representative of both cogging and hot forging operations. Special attention to the presence of large unrecrystallized grains was paid. Double truncated cones (DTCs) were hot forged at subsolvus temperatures in hydraulic press, followed by air cooling. SEM and EBSD analysis were conducted in the as-received (billet) and the as-forged conditions. AD730 from billet alloy presents a complex microstructure characterized by a mixture of several constituents. Large unrecrystallized grains present a substructure characterized by large misorientation gradients with the formation of medium to high angle boundaries in their interior, especially close to the grain boundaries, denoting inhomogeneous strain distribution. A fine distribution of intragranular precipitates was found in their interior, playing a key role on strain distribution and subsequent recrystallization behaviour during hot forging. Continuous dynamic recrystallization (CDRX) mechanism was found to be operating in the large unrecrystallized grains, promoting the formation intragranular DRX grains and the gradual recrystallization of these grains. Evidences that hetero-epitaxial recrystallization mechanism is operating in AD730 billet material were found. Coherent γ-shells around primary γ’ precipitates were found. However, no significant contribution to the overall recrystallization during hot forging was found. By contrast, strain presents the strongest effect on the microstructural evolution of AD730, increasing the recrystallization fraction and refining the structure. Regions with low level of deformation ($\varepsilon \leq 0.6$) were translated into large fractions of unrecrystallized structures (strain accumulation). The presence of undissolved secondary γ’ precipitates (pinning effect), prior to hot forging operations, could explain these results.

Keywords : AD730 alloy, continuous dynamic recrystallization, hot forging, γ’ precipitates
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