Grain-subgrain structure analyses of hot deformed superalloy Allvac 718plus™ by EBSD

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The nickel-based superalloy Allvac 718Plus™ was developed in order to combine the relatively low costs and good formability of Alloy 718 with high temperature strength of Alloy 720 [1,2]. Typical applications for this new material are turbine disks that are produced by closed die forging, e.g. by screw pressing. The final mechanical properties are strongly related to the microstructure, which evolves during hot forming.

Triple melted (vacuum induction melted VIM, electro slag remelted ESR, vacuum arc remelted VAR) nickel-based superalloy Allvac 718Plus™ was compressed to different strains (0.2, 0.4 and 0.9) in order to study the grain and subgrain structure. The experiments were carried out on a Servotest thermo-mechanical treatment simulator varying the temperature (900°C - 1050°C) and the strain rate (0.1 /s – 10 /s). Water quenching after compression retained the obtained microstructure.

Cross sections of these specimens were analyzed on a Zeiss Ultra 55 (primary electron energy: 20 keV; probe current: 5.4 nA) equipped with an EDAX-TSL-system (CCD-Digiview-camera, OIM™ 5.2 software). An area of 250 µm x 250 µm was scanned with a step size of 0.5 µm (hexagonal pixels). Grain boundaries were characterized by misorientation of larger than 15° between neighboring measurement points. The discrimination between the still deformed and the recrystallized grains was carried out with the grain orientation spread (Details see [3]).

Figure 1 shows the microstructure of the specimen compressed at 950°C and a strain rate of 1 /s. It is clear to see that only at $\varepsilon = 0.9$ a fine grained microstructure is obtainable. A closer look at the grain – subgrain structure in Figure 2a ($T = 950°C$, $\varepsilon = 0.4$, $\dot{\varepsilon} = 1$ /s) depicts the formation of subgrain structures at grain boundaries as well as inside the grains. Moreover, the substructure varies from grain to grain. This behaviour suggests that at these forming conditions the continuous (CDRX) and discontinuous dynamic recrystallization (DDRX) (details about these mechanisms see [4]) is responsible for the resulted microstructure. In contrary specimens formed at $T = 1050°C$ and $\dot{\varepsilon} = 10$ /s show nearly no subgrain structures (see Figure 2b and c). The “line substructures” are caused by scratches from the polishing and not due to the forming process. Additionally, the recrystallization predominately starts at the grain boundaries and leads to a typical necklace structure. These results indicate that for those specimens the DDRX is the main mechanism for the obtained microstructure.

The recrystallized fraction and the size of the recrystallized grains strongly depend on the temperature, the strain rate and the strain (see Figure 3). The recrystallized fraction decreases, especially at low strain, by lowering the forming temperature and the strain rate. Also the size of the recrystallized grains decreases by lowering the temperature and the strain rate. Additionally, there is an increase of the grain size (recrystallized fraction) observable by

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an increase of the strain, which is more significant at higher temperature and higher strain rate.

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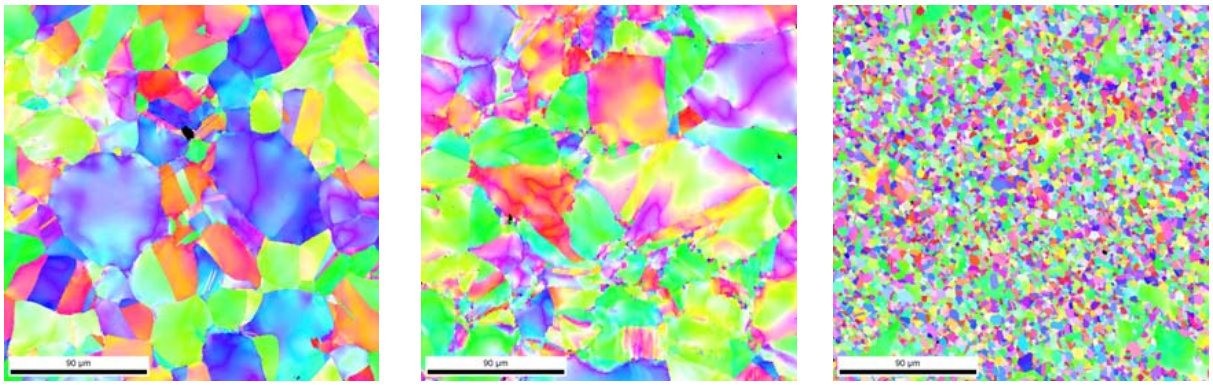

Figure 1. Inverse pole figure map of specimens formed at T = 950°C and a strain rate of 1 /s; left: ε = 0.2, centre: ε = 0.4, right: ε = 0.9

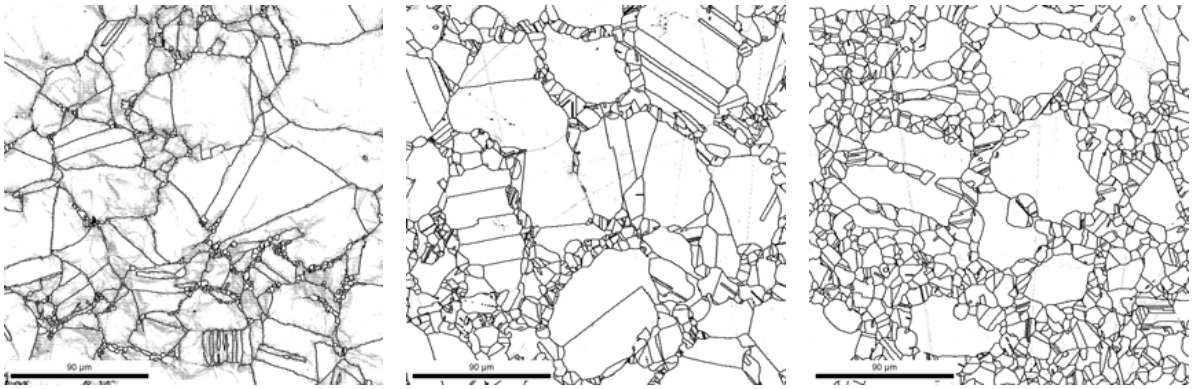

Figure 2. Boundary maps of left: specimen formed at 950°C and strain rate 1 /s to ε = 0.2; centre: specimen (T = 1050°C, $\dot{\varepsilon}$ = 10 /s, ε = 0.2) right: specimen (T = 1050°C, $\dot{\varepsilon}$ = 10 /s, ε = 0.4); black: rotation angle >15°, gray: rotation angle <15°

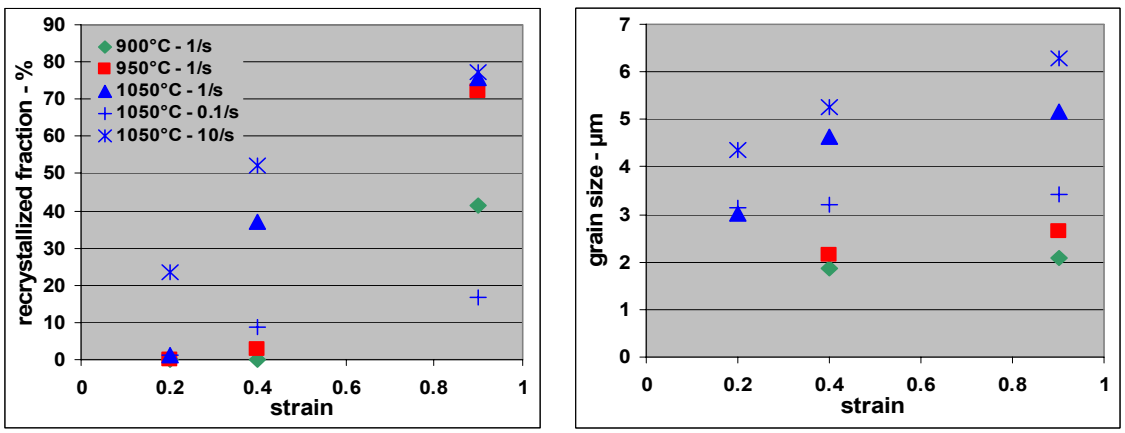

Figure 3. Recrystallized fraction (left) and size of the recrystallized grains (right) in dependence on the strain and the forming parameters; legend see figure left

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