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THE IMPACT OF DAMAGE IN ANNELING INCONEL 718 ON HARDNESS MEASURED BY THE VICKERS METHOD

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Abstract

In the previous work [1] it was shown that strain hardening had considerable impact on the hardness of Inconel 718. In order to verify the weakening of the material associated with the damage mechanism in the tested material, the hardness tests were performed on the stretched specimen which was subsequently heat treated. The tests revealed that, after heat treatment, the measured hardness was reduced with an increasing degree of the plastic deformation present prior to heat treatment.

Keywords: Damage parameter, Vickers hardness, Inconel 718, Tensile test, Heat treatment.

INTRODUCTION

During stretching, strain hardening occurs alongside material damage. Relative to plastic strain yield stress in the damaged material can be formulated as [2]:

$$\sigma_s = (\sigma_y + X + R)\cdot(1 - D) \quad (1)$$

Where σy is yield strength, X is back stress, R is stress due to isotropic hardening. Hardness in the damaged material can be described as linear function of σ_S. For this reason, the damage parameter estimated from the hardness test is calculated using the material properties determined from the tensile test [3], [4]. The impact of R on the measured hardness value in the tested material (Inconel 718) was so big that there was no visible weakening of the material caused by the damage mechanism [1]. The damage mechanism is related to cracked, detached of primary carbides from the plastic matrix [1]. It was assumed that this type of damage represented irreversible changes in the material state and the thermal treatment should not change this.

METHODOLOGY

The tensile test was conducted on a specimen with a variable cross-section area [1]. Sample geometry allows to obtain different degree of strain hardening of tested material in one specimen. In the next step, the X-ray diffraction measurements were performed. The level of strengthening of the material was estimated from full width at half maximum of X-ray diffractions picks (FWHM). The measurements were performed with the Stersstech X-ray diffractometer (model Xstress 3000). Prior to taking X-ray measurements, the specimen was electropolished to reduce residual stress resulting from the preparation of the metallographic specimen (grinding and polishing). For this purpose, electrolyte consisting of ethanol, perchloric acid, and propandiol-1,2 was used.

After that, the specimen was heated in the oven at 1030°C for 51 minutes. Next, the specimen was cooled down together with the furnace. During the process, two termocouples placed on the surface of the sample (Figure 1) measured the temperature on the specimen.

After heat treatment, the specimen was again metallographically prepared, electropolished and measured on the X-ray diffractometer.

After that, the specimen was mechanically polished and the hardness measurements were performed according to ASTM E384 standard.

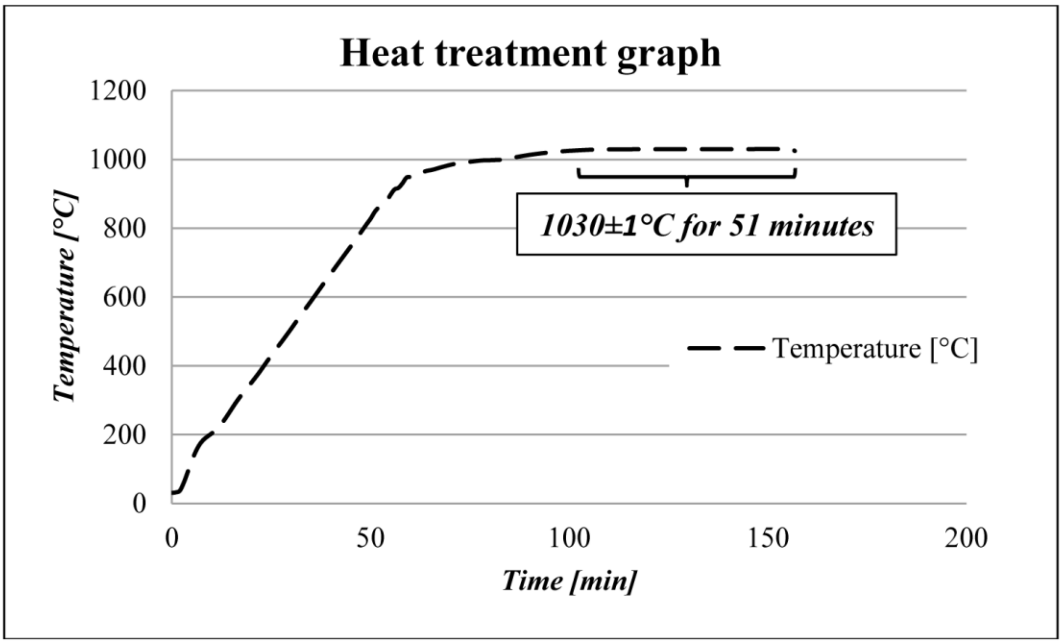


Fig. 1. Graph showing the heat treatment process.

RESULTS AND DISCUSSION

The presented structure of the tested material after annealing consisted of equiaxed grains and primary carbides and is changed significantly in comparison with the structure of the material before the heat treatment (Figure 2).

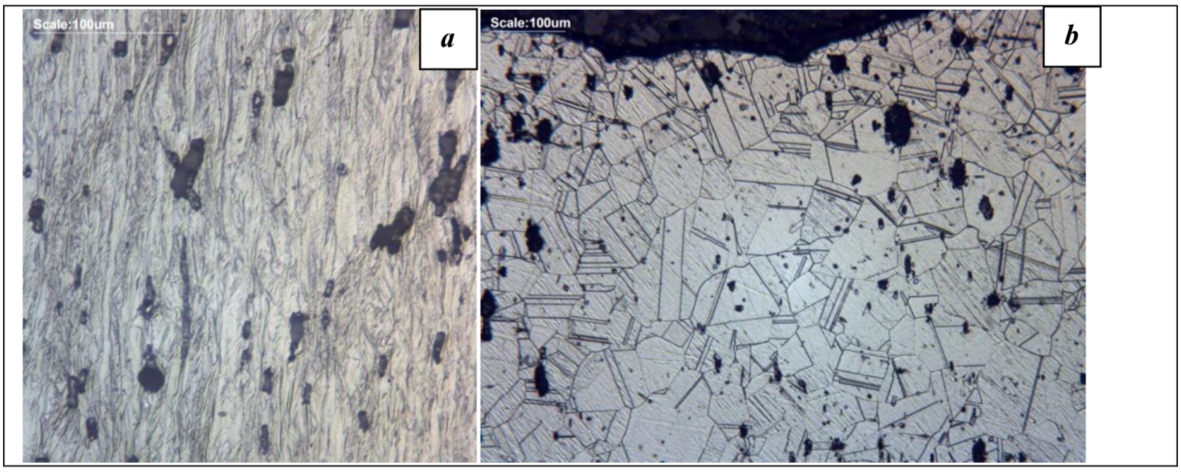
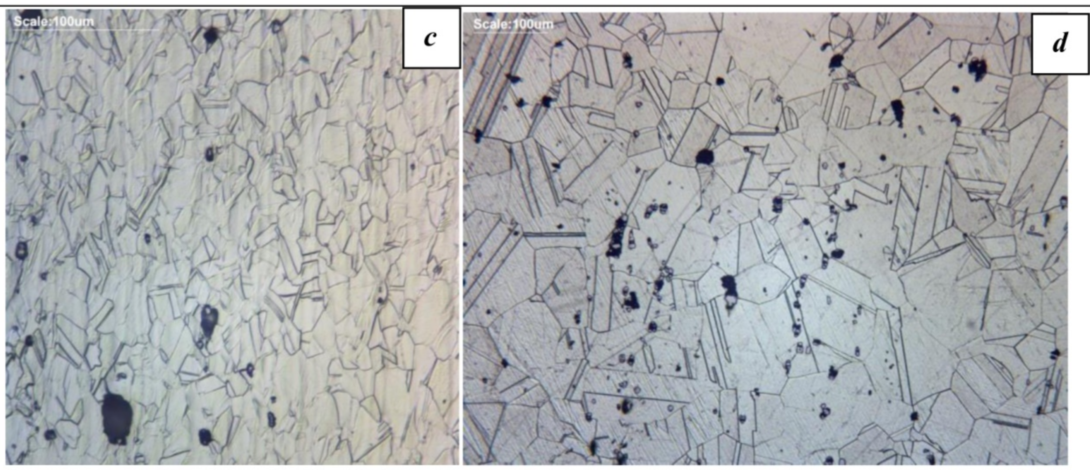
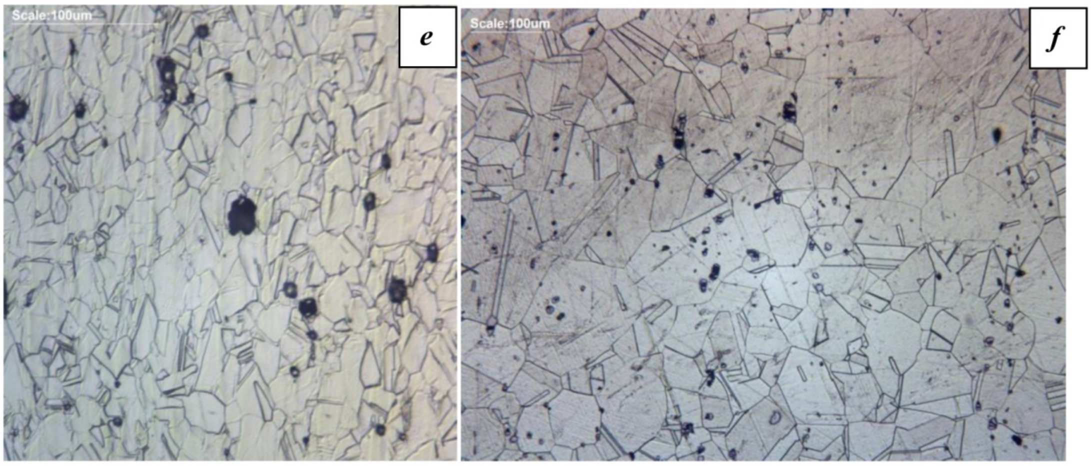


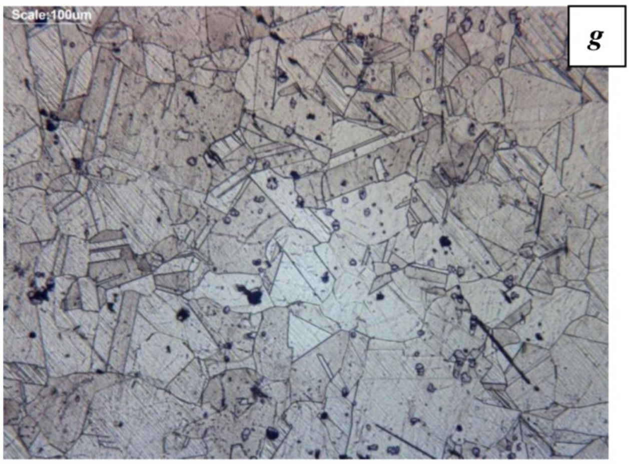
Fig. 2. Tested material structure from fracture area before (a) and after heat treatment (b).



19 mm from fracture. Before (a) and after heat treatment (b).



26.7 mm from fracture. Before (a) and after heat treatment (b).



50 mm from fracture (material without plastic deformation present prior to heat treatment).

Fig. 2 C.D. Material structure from selected specimens areas.
Before (c, e) and after heat treatment (d, f, g).

The X-ray measurement shows that FWHM at different distances from fracture is approximately the same [Figure 3]. Results of metallographic and X-ray studies investigation indicate that strengthening of the material after heat treatment was homogenized and reduced.

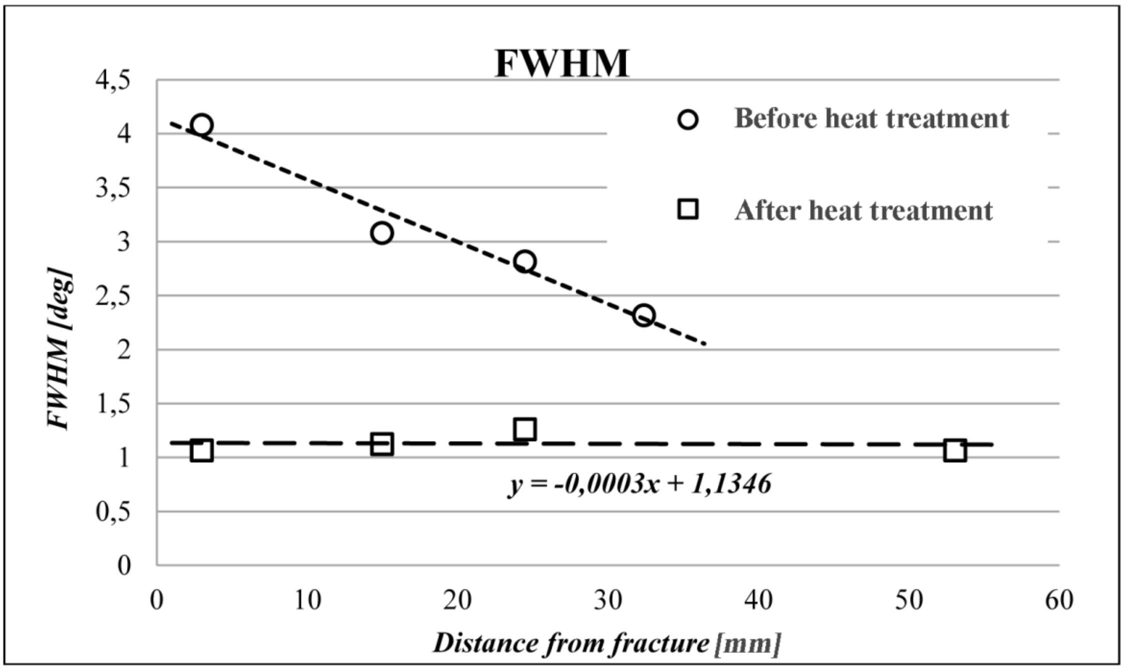


Fig. 3. Graph showing FWHM value of stretched specimen made from Inconel 718 before and after heat treatment.

Hardness measurements were performed with different loads (Figure 4). Decrease of hardness with an increasing degree of strain hardening present prior to annealing was found using 30Kgf. Hardness measurement has to be performed in the volume in which the enough amount of primary carbides is present. This may be one of the reasons why the decrease in hardness is found using high loads applied on the intender.

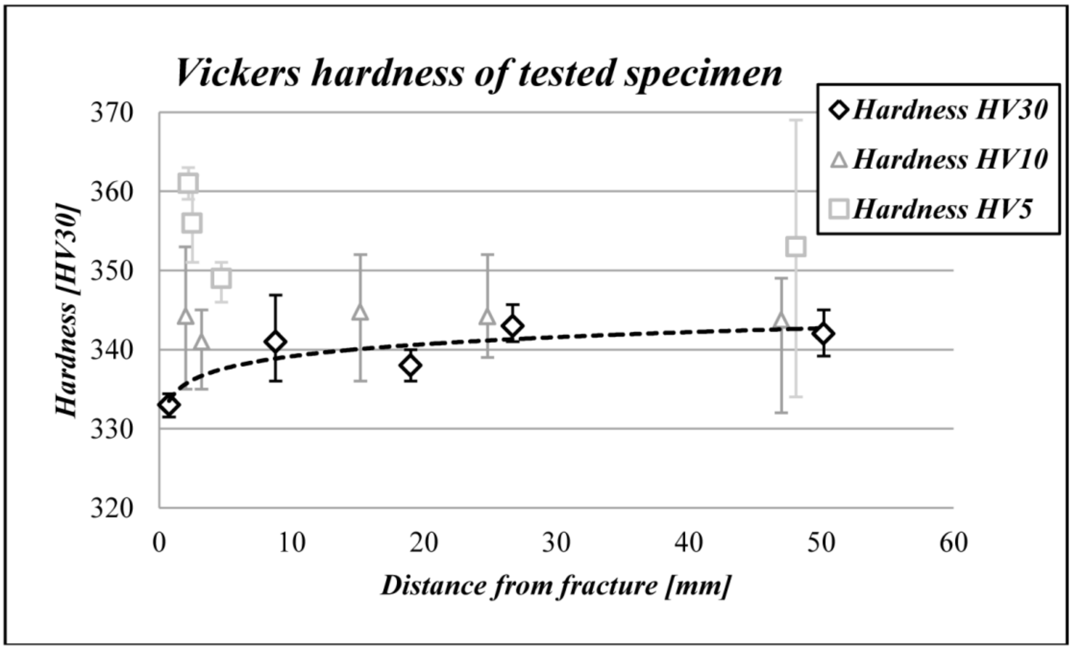


Fig. 4. Vickers hardness of tested specimen made from stretched Inconel 718 after heat treatment.

SUMMARY AND CONCLUSIONS

- X-ray diffraction measurements revealed reduced plastic deformation and, consequently, stain hardening in the material after annealing.
- It was observed that, after annealing previously deformed specimen, hardness was reduced with an increasing degree of plastic deformation present in the specimen prior to annealing.

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