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The Defect Analysis of Inconel 738LC with Computed Tomography Inspection

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Abstract

In the present paper, computed tomography (CT) inspection is shown. The CT inspection method allowed to rate the density of defects hidden inside a material, which has a significant role in the live material. The method allows to evaluate the reliability of tensile test's results. In our analysis, the position of crack propagation was determined by CT, and the tensile test was performed to check the accuracy of the nondestructive method. The tensile tests were performed on Inconel 738LC [1] samples.

Keywords

computed tomography, CT, material defects, Inconel 738LC, tensile test, chemical analysis, material properties, nondestructive, Inconel

1. Introduction

Some materials, especially steel and nickel-based superalloys, solidify at the dendrite formation. Impurity segregation causes decrease in the melting temperature of materials. It sets up a negative thermal gradient. A tendency to balance the thermal gradient leads to the creation of dendritic structure. Several elements segregate into the dendritic zone and the rest into the interdendritic zone. It causes heterogeneity in concentrations. It also forms disequilibrium phases, enclosures or eutectic phases with a low melting temperature. Interatomic bonds are weakened, and it deteriorates mechanical and creep properties of mentioned alloys [1, 2].

With the rapid development of computer technology, the computed tomography (CT) methods have recently generated intense interest from both scientific studies and practical applications in the nondestructive testing field [3, 4]. Thus, the CT method gives us the possibility to capture material discontinuities, inclusion of impurities and voids, in terms of the so-called defectoscopy [5].

In this paper, the idea of determination of defects by CT inspection, before the tensile test, is proposed. The research was performed in order to propose the nondestructive method of determination of the position of defect formation and probable area of fracture initiation point. The basic idea was to check samples using CT, before the tensile test. During the CT, the number and places of material defects were determined on tensile samples. Then, the tensile samples with defects were examined with tensile tests. The results showed that the CT method allows for prediction of fracture position.

2. Experiment

In the samples for CT inspection, 10 specimens were casted (Figure 1).

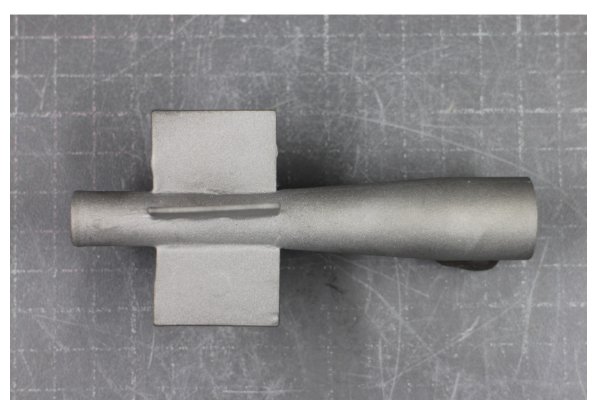

Figure 1. The raw casted sample for computed tomography analysis.

The casted samples were examined by the CT test. The test took 15 min for each sample. The following CT parameters were used: 325 kV, 150 µA, 500 ms, and 1000 projections in Nikon XT H 450 kV Tomograph. Thus, after the tomography inspection, the defect position and its quantity were determined and the

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probable fracture areas were selected. The next step was preparation of the specimens for tensile tests. The tensile test samples were machined from the raw casted specimen with the damage area well defined by CT (Figure 2).
The samples before the tensile tests were again examined by CT in order to find the exact place of the defect intensity – the most favorable place to crack propagation. The following parameters of CT tomography were used: test time 15 min, 175 kV, 150 μA, 333 ms, and 1200 projections in Nikon XT H 225 kV Tomograph.

Finally, the tensile tests were carried out using the Instron-5982 apparatus at an ambient temperature of 21°C for a tensile speed of 0.6%/min.

3. Results

The CT results of the sample prepared for the tensile test are shown in Figure 3. The position of the defects was determined – the red rectangle in Figure 3. The crack should propagate in this position during the tensile test.

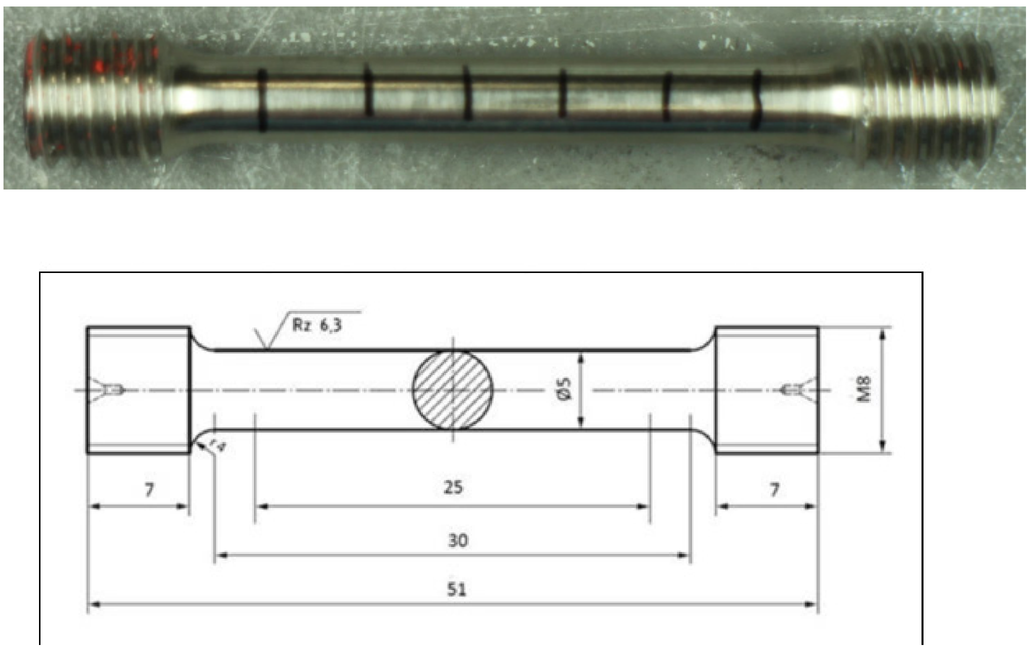


Figure 2. The machined sample for tensile tests with its dimensions.

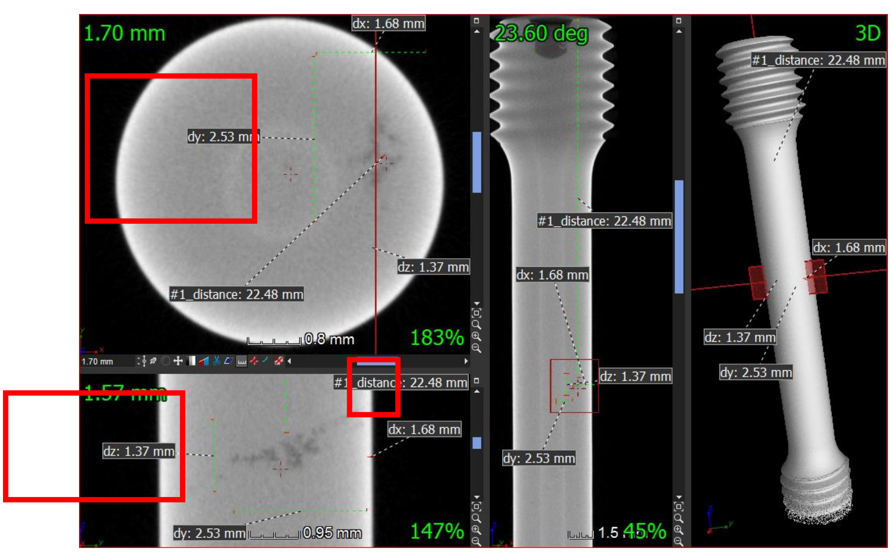


Figure 3. The computed tomography of the sample prepared for the tensile test.

When the defect position was determined, the sample was tested in the tensile testing machine. The results after the tensile test when no defects were found and with defects are shown in Figure 4a and b, respectively.
After the tensile test, again the CT observation was performed. It is clearly seen that the sample broke at the place of higher defect concentration (Figure 5).
Moreover to confirm the results, the cross-section of the sample was prepared. The microstructure of the sample is shown in Figure 6.

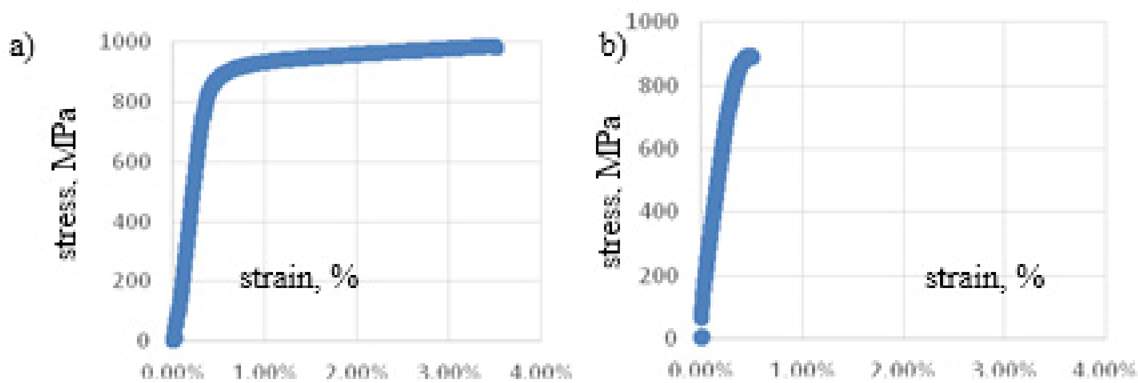


Figure 4. The results after the tensile test when no defects were found (a) and a sample with defects (b).

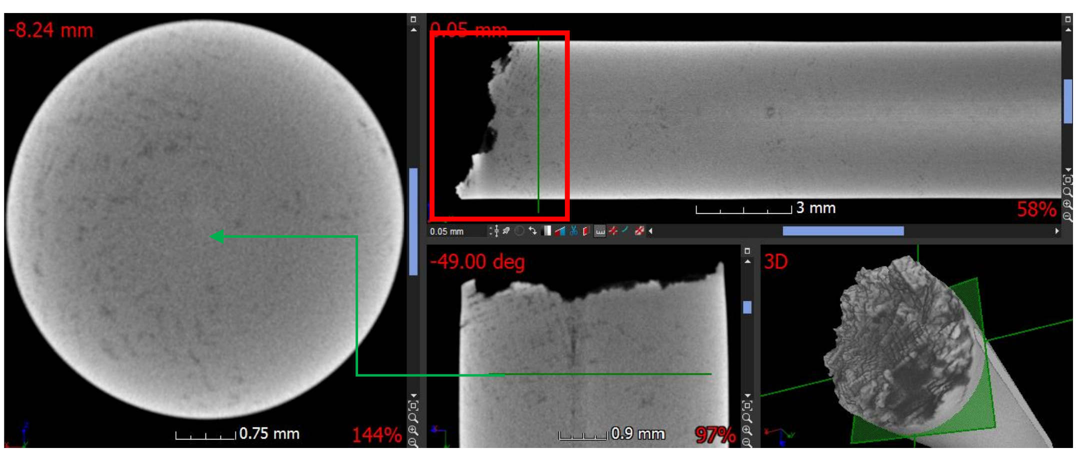


Figure 5. Computed tomography results of broken sample at highest defect concentration position.

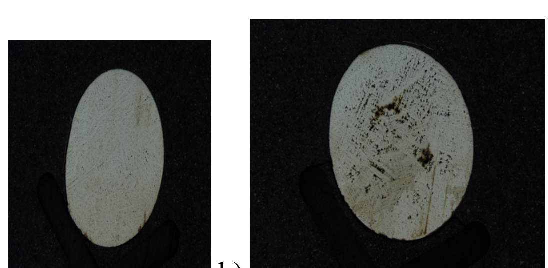
a)  b)

Figure 6. The microstructure view. Section without defects (a) and with defects (b).

4. Conclusions

CT allows to determine material discontinuities/defects inside a specimen, before a tensile test. It was shown that when the CT method localizes the defects inside the sample, the tensile test confirms the crack propagation at the highest density of defect position. Thus, the CT method can be used for nondestructive analysis of defects inside the materials.
The following conclusions can be formulated:

- Samples damage in places where material defects are accumulated.
- Samples marked as "without defects" (Figures 4a and 6a) in the tensile test were subjected to greater stretching. Moreover, the position of crack propagation started in the center of specimen.
- The small defects with high accumulation and dispersion will have a potential contribution to crack propagation.
- Concentration of defects characterized by a regular shape does not affect crack formation in relation to diffuse defects.
- The total density of the defects in the cross-section decides about the position of crack formation.

Acknowledgment

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