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Determination of the Dissolution Curve of Gamma Prime Precipitates in Ni-base Super-Alloys through Image Analysis

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The gamma prime (γ') phase is one the main reinforcing phases in Ni-base super-alloys used in aircraft turbines, being critical in the creep behavior at high temperatures. With increasing temperatures, the phase tends to dissolve, compromising the mechanical behavior of the material [1]. Thus, the turbine temperature is continuously monitored and once the occurrence of over temperature is determined during a flight, the affected part must be analyzed to verify the integrity of the microstructure. Traditionally, the microstructure is visually compared to reference images obtained at several temperatures. In principle, it is possible to determine the maximum temperature to which the alloy was exposed by observing the γ' fraction and size distribution. However, visual comparison does not allow enough accuracy, and quantitative metallography methods must be employed.

In the present study, the dissolution curve of γ' in a specific Ni-based super-alloy was accurately determined using digital image analysis. Identical samples of a nickel base super-alloy were heat treated to 10 different temperatures and prepared for metallographic evaluation. Several samples per temperature were analyzed. For each sample, dozens of fields were imaged using the back scattered electron mode (BSE) in a scanning electron microscope (SEM) with digital image acquisition at 1024 x 768 pixels. In total, 429 images were analyzed.

The image processing and analysis sequence followed the steps of segmentation, post-processing and feature extraction [2]. The Otsu [3] automatic thresholding method was used to discriminate the dark γ' particles from the brighter surrounding matrix. The BSE images provide sufficient contrast to allow good discrimination in all cases. The post-processing step involved small particle elimination, hole filling and touching particle separation through the watershed method. See Figure 1.

At the end of the procedure over 225000 particles were measured. The following parameters were obtained for the γ' phase: area fraction, number of particles per image, area and feret ratio of each particle. Statistical analysis of the results for each temperature employed the average, standard deviation, 95% Confidence Interval (CI) and % Relative Accuracy (RA). The obtained dissolution curve is shown in Figure 2, along with a cubic fit to the experimental data.[4]

References

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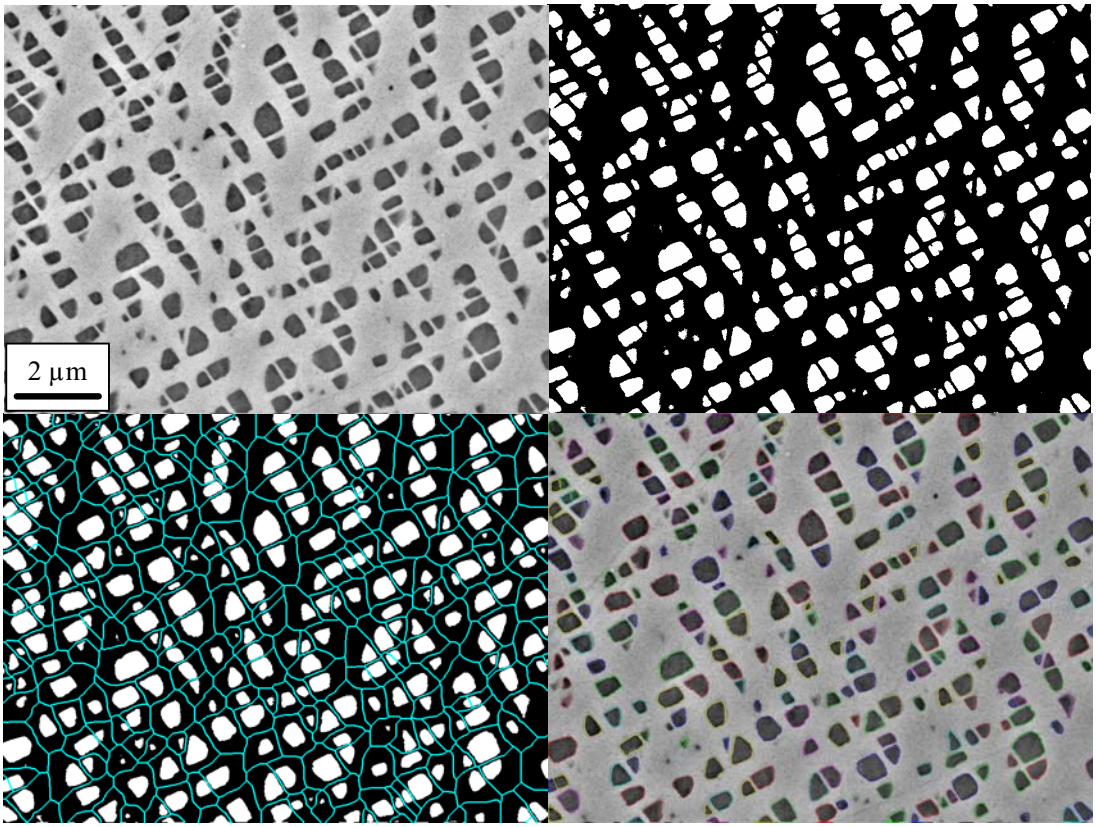

FIG. 1. Typical image analysis sequence. (a) Original Image. (b) Automatic threshold result. (c) Watershed separation. (d) Detected edges superimposed on original image.

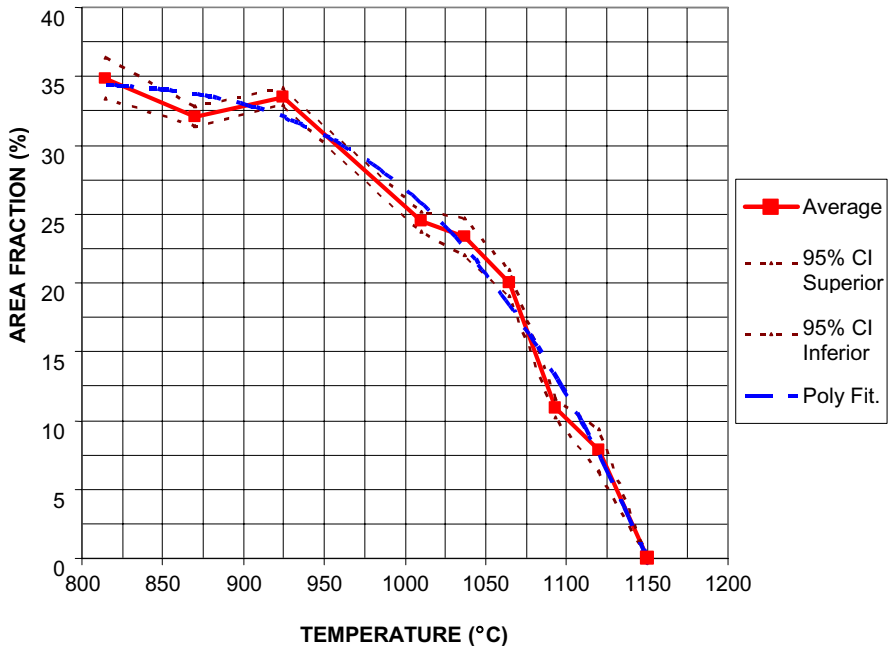

FIG. 2. Dissolution Curve for the γ' phase. The red curve joins the average values for each temperature. The dotted lines show the top and bottom 95% confidence intervals. The blue line is a cubic fit to the experimental data.

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