University Turbines Systems Research (UTSR)

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Metallography Studies for the Purpose of Materials-Processing-Properties Relationship

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Abstract

Metallographic analyses were conducted on a number of samples under different conditions. Measurements included primary dendrite arm spacing, secondary dendrite arm spacing, grain size, degree of solutioning, porosity, hardness, roughness, and a study in serial sectioning. These measurements were conducted to help improve the database used to relate processing, microstructure and properties.

Introduction

The Gas Turbine Materials Development group operates out of General Electric's Greenville, SC campus. They are in charge of material testing and reviewing material specifics. Important aspects of this are understanding and developing the relationship between heat treatment, microstructure, and mechanical properties of the alloys. A number of studies were undertaken on different alloys and geometries to help develop a database from which to draw these relationships.

Many of these alloys are used in the hot section of the turbine and undergo high temperatures, high stresses, and high cycles. Understanding how a materials microstructure can affect a parts lifetime can help project when a part should be refurbished or increase its' cycles to failure.

In directionally solidified materials, the solidification front of the metal moves from the chill plate up. This encourages the dendrites to form in this direction. The dendrites are then measured along the solidification front between dendrites, primary dendrite arm spacing (PDAS), and tangential to the front between arms, secondary dendrite arm spacing (SDAS). Samples were etched in order to see the dendrite formations and measured according to in house specifications.

Grain size was measured according to ASTM E112-13, using grain intercepts along concentric circles of known circumference.

Degree of solutioning is the comparison of course versus fine precipitates in a material. This was determined according to in house specifications on etched samples.

Porosity was measured on un-etched samples .

Hardness was measured with a hand-held Leeb Hardness tester.

Roughness was measured on un-treated cast samples using a desk-top profilometer.

Creep test Characterization

Creep samples were taken after failure and characterized. For this study materials of different grades and processing were taken from creep tests at two test conditions and compared. Test conditions were chosen where all three materials had undergone or currently were currently being tested. For each condition, only two were available at the time of this study, Table 1 describes the conditions and materials of each group.

Table 1 Testing conditions and materials

Low temperature, high stress	High temperature, low stress
Liquid Metal Cooling, Grade 1 material	Bridgeman Processed, Grade 1 material
Bridgeman Processed, Grade 3 material	Bridgeman Processed, Grade 3 material

Samples were taken from the threads on a traditional creep test bar. In the low temperature, high stress test condition the LMC had smaller primary dendrite arm spacing (PDAS) and secondary dendrite arm spacing (SDAS). It was also more solutioned than the Bridgeman processed. Both samples had negligible amounts of porosity.

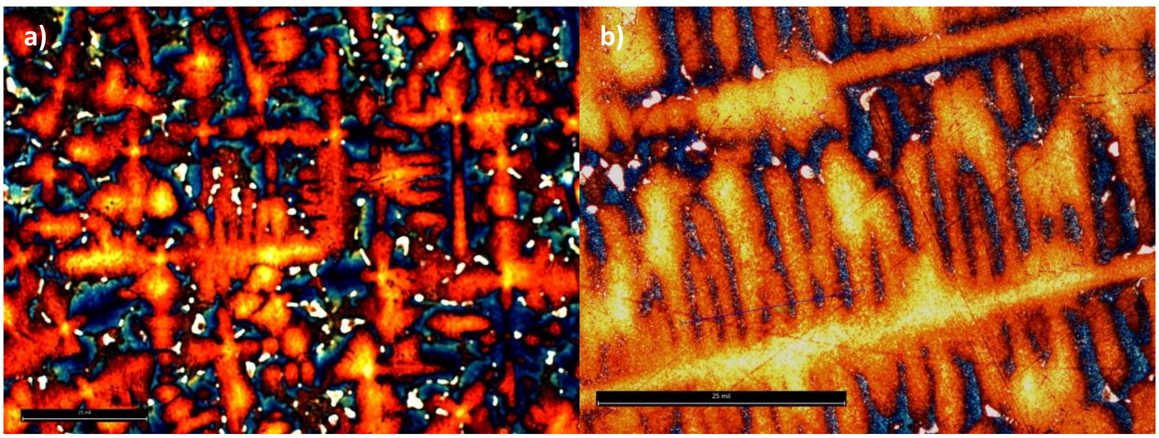

Figure 1 Representative images of (a) PDAS and (b) SDAS

The high temperature, low stress condition both samples had similar PDAS and SDAS. The grade 1 material was better solutioned. Both had negligible percent porosity.

Slab Characterization

Samples were taken from an equi-axed slab of heat treated material in a grid pattern described in Figure 2. Grains were slightly larger on the bottom edge of the slab, example of grains in Figure 3. Little porosity was seen across all areas and similar values for degree solutioned were found.

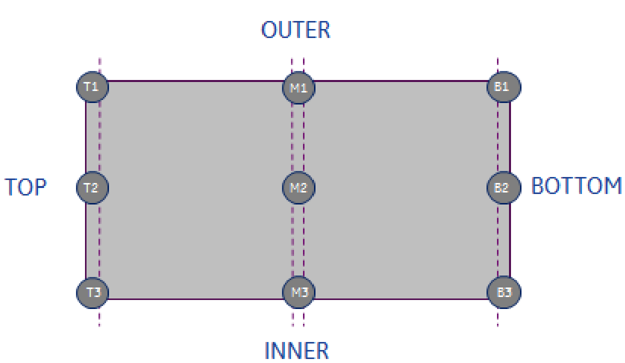

Figure 2 Cut up plan for slab

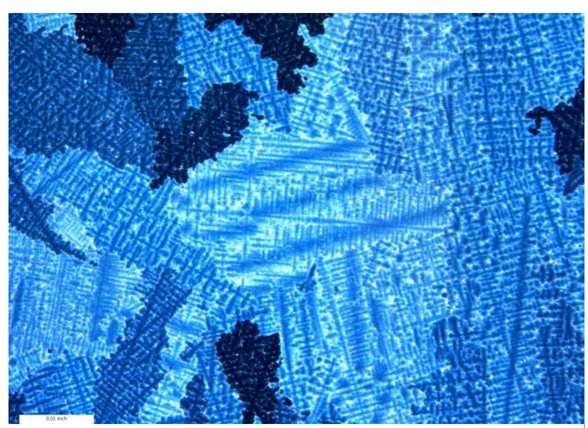

Figure 3 Image of grains

Study on Cast parts

This study was conducted to see if there was any difference in internal or external casting surfaces. Similar roughness values were found for both sides on four different cast parts. A microscope study was conducted on the edges where no oxidation or surface reactions were found, Figure 4.

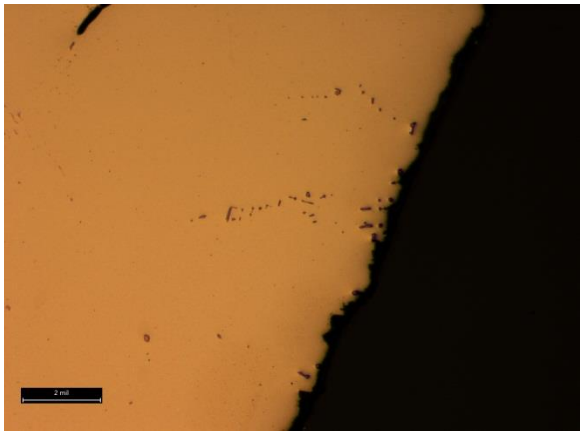

Figure 4 Surface of part

Hardness Study

Hardness values across different geometries were measured on first, second, and third stage buckets for the purpose of marking techniques. Hardness values were found to increase on sections with thin walls but on the sections of interest for marking, they were found to be similar.

Shroud Fillet Study

Serial sectioning was conducted from the blade into the fillet to follow the path of grains and see if any new grains were nucleated. Thus far, no new grains were seen on the forward edge of the fillet.

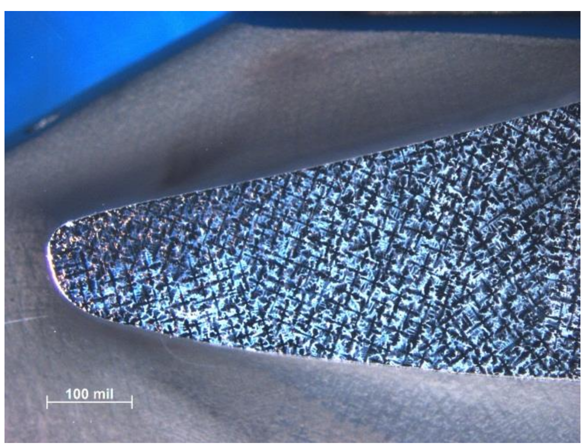

Figure 5 Blade tip cross section

Conclusion

A number of studies were conducted on materials of interest and documented for the purpose of improving microstructure to properties relationship. New skills were developed, as well as, improved critical thinking skills and understanding of industrial gas turbines.

Acknowledgements

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