Abstract: Carpenter Technology® is seeking to characterize the formation of titanium nitride (TiN) inclusions during the solidification of specialty alloy Custom 465®. Several samples were taken from a Custom 465 VIM ingot, and an optical analysis method for identification and statistical analysis of TiN was used to characterize inclusions within the material. From this analysis, statistical data relating to the particle area and inclusion area fraction were determined and compared to literature values. In addition, an equilibrium solidification simulation was run in Thermo-Calc® 2023a to determine the volume fraction of TiN in Custom 465.

### Experimental Methods

Thirteen samples of Custom 465 stainless steel produced via Vacuum Induction Melting (VIM) were supplied by Carpenter Technology. These samples were removed from a ¾ inch slice at the ‘top’, ‘middle’, or ‘bottom’ of the resulting VIM ingot. The top slice was 4.25” from the top edge, the middle slice was 20.25” from the top edge, and the bottom slice was 35.25” from the top edge. Within these slices, samples could either be taken from the ‘middle’ of the slice or the ‘surface’.

Additionally, samples would either be polished in the ‘transverse’ or ‘longitudinal’ direction of the ingot.

Individual samples were sectioned and mounted in Bakelite before being polished for optical analysis. TiN has the benefit of being visible in the matrix due to unique coloration, so etching was unnecessary. Samples were ultrasonicated in ethanol for 30 minutes for cleaning and then imaged using an optical microscope at 20x magnification. Six images were taken of each sample by moving in a 2x3 grid-like pattern to avoid unintentional bias in image selection.

### Statistical Inclusion Analysis

#### Inclusion Area Fraction

- **Top**: 0.000394
- **Mid**: 0.000449
- **Bottom**: 0.000413
- **Average**: 0.000418

#### Average Inclusion Area (μm²)

- **Top**: 14.12
- **Mid**: 16.19
- **Bottom**: 10.98
- **Average**: 13.76

### Thermodynamic Simulations

Thermo-Calc® 2023a and the TiFe8 database were used to generate a Scheil solidification diagram and an equilibrium property diagram based on composition data of Custom 465, provided by Carpenter.

### Future Work

More analysis of inclusions on Custom 465 with iterated VAR cycles is necessary to determine how TiN inclusions vary with further processing. The methods we have established can be used to quickly assess sample surfaces and compare with the VIM only samples analyzed here. The results will show the trend of TiN formation and behavior with added VAR cycles.

The resulting trend should then be compared to the models we generated here to determine their accuracy. Using the experimental data, a more accurate model can be developed to analyze TiN behavior and ideally reduce the inclusions and their impact.

### References

1. [Image or data courtesy of Carpenter Technology]

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