Hot tearing susceptibility was investigated through minor element additions. After casting four molds each separately doped with B, P, Si, and Hf, the microstructural changes were observed to determine correlations to hot tearing. The P and Hf-doped molds exhibited the worst hot tearing properties due to an increased difference in the equilibrium and non-equilibrium solidus during solidification, segregation, and eutectic pool clustering. According to the microstructures, the B-doped mold should have developed a hot tear because it behaved similarly to the P and Hf-doped molds. When casting Ni-based superalloys, elements that contribute to these properties should be avoided to decrease the likelihood of hot tearing.

**Project Background**

Arconic Power and Propulsion is a leader in investment casting superalloys for use in aero engines and industrial gas turbines. A casting defect called hot tearing occurs upon the last stages of the solidification process. Eutectic pools solidify last; thus, grain coalescence makes it difficult to feed the interdendritic regions. This coupled with solidification shrinkage induced tensile stresses can initiate a hot tear and the tendency to hot tear in IN738. The interpretation of solidification temperature and has been linked to hot tearing hot tear specimens, eight tensile specimens, and two boundary coalescence. Phosphorus lowers final solidification and has been linked to hot tearing hot tear specimens, eight tensile specimens, and two boundary coalescence. Phosphorus lowers final solidification and has been linked to hot tearing hot tear specimens, eight tensile specimens, and two boundary coalescence. Phosphorus lowers final solidification and has been linked to hot tearing.

**Equilibrium and Non-Equilibrium Solidification**

The Thermo-Calc analysis shows that all the doped chemistries, with the exception of Si, increase the equilibrium and non-equilibrium final temperature difference ($\Delta T_{\text{eq}}$) above 200°C. Hafnium segregates the heaviest, followed by P and B. Silicon segregates heavily but is the industry standard to prevent hot tears. [2]

**Experimental Procedure**

Arconic investment cast four molds, each containing eight hot tear specimens, eight tensile specimens, and two chemistry slugs. Each mold had a minor element addition. Mold 1 contained 0.034 wt.% B. Mold 2 contained 0.009 wt.% P. Mold 3 contained 0.1 wt.% Si. Mold 4 contained 0.39 wt.% Hf. Boron was added because research suggests it segregates at the grain boundaries and weakens grain boundary coalescence. Phosphorus lowers final solidification temperature and has been linked to hot tearing in industry. Silicon was chosen because it is a tramp element that lowers solidification temperatures, promote segregation, and heavy clustering. By lowering the composition of elements that lower solidification temperatures, promote segregation, and increase the eutectic pool clustering, hot tearing susceptibility can be decreased.

Future work can include looking at solidification rates in the mushy zone. Hafnium had pools were largest but were very spread out throughout the microstructure with the least amount of coarse gamma prime. Large and long eutectic pools create a tortuous feeding path. The voids in the high temperature tensile specimens, caused by tensile stresses during tensile testing, take on the shape of the eutectic pools and occur between dendrite arms. This is where eutectic pools form as solute is partitioned to the interdendritic regions during solidification. The Si-doped sample has the fewest voids as well as the lowest volume fraction of eutectic pools. Under solidification stresses these areas are the first to separate and provide paths for hot tears to form.

**Results & Discussion**

<table>
<thead>
<tr>
<th>Mold</th>
<th>Intergranular Fracture Hot Tear Count</th>
<th>Tensile Voids Near Fracture Count</th>
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<th>Volume Percent of Voids</th>
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<td>Baseline</td>
<td>130</td>
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**Correlation of Tensile Fracture Surfaces with Eutectic Pool Morphology**

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High temperature tensile testing at 2000°F was utilized to replicate intergranular fracture during solidification. Thermo-Calc software was utilized to investigate solidification behavior with element additions. The samples were sectioned, mounted, etched, and analyzed via optical and SEM microscopy.