Quantitative Analysis of Grain Refinement via Residual Stress Measurements in Cast Aluminum Alloys by Neutron Diffraction

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In this study, reduction of hot tearing by grain refinement in B206 aluminum alloy was directly correlated to residual strain along the casting. This research was part of a comprehensive study to investigate the hot tearing mechanisms in the B206 alloy.

Neutron diffraction strain mapping was carried out on three B206 castings with varying levels of titanium (i.e. unrefined, 0.02 and 0.05 wt%) and subsequent varying levels of hot tearing severity (i.e. full tear, hairline tear and no tear). Representative profiles of residual strain are shown in Figures 1 and 2 for the unrefined and 0.05 wt% Ti alloys, respectively.

In the case of the unrefined alloy, Figure 1 depicts an initial region of compressive strain along the casting followed by an area of tension and finally another region of compression. The region of tensile strain corresponded to the location of the hot tear. Thermal analysis also confirmed this area as the hot spot region. Thus, the results of neutron diffraction and thermal analysis suggested that once molten metal filled the casting cavity, the regions adjacent to the hot spot solidified first and contracted in opposite directions (toward the cooler regions of the mold). The free (unrestrained) contraction of these adjacent regions generated compressive strain, as confirmed in Figure 1, while tensile strain was generated along the hot spot region as the interlocking coarse dendrite arms of the unrefined alloy attempted to accommodate such shrinkage. Such tension ultimately led to hot tearing in the unrefined alloy.

In contrast, the profile of residual strain for the 0.05 wt% Ti alloy in Figure 2 depicts compressive strain along the length of the casting. Such uniform compression suggests that this casting was able to contract freely during solidification. As a result, hot tears did not initiate along the casting for this alloy. This was further confirmed in Figure 3 which illustrates the variance in strain magnitude for the three casting conditions. The results indicate that the distribution of strain was nearly twice as uniform along the refined castings as compared to that along the unrefined casting. These findings were directly attributed to the microstructure of the alloys, as the smaller more globular grains in the refined alloys were more capable of accommodating shrinkage during solidification and were therefore less prone to hot tearing than the coarse dendrites in the unrefined alloy.

Figure 1. Residual strain profile along unrefined B206 casting.

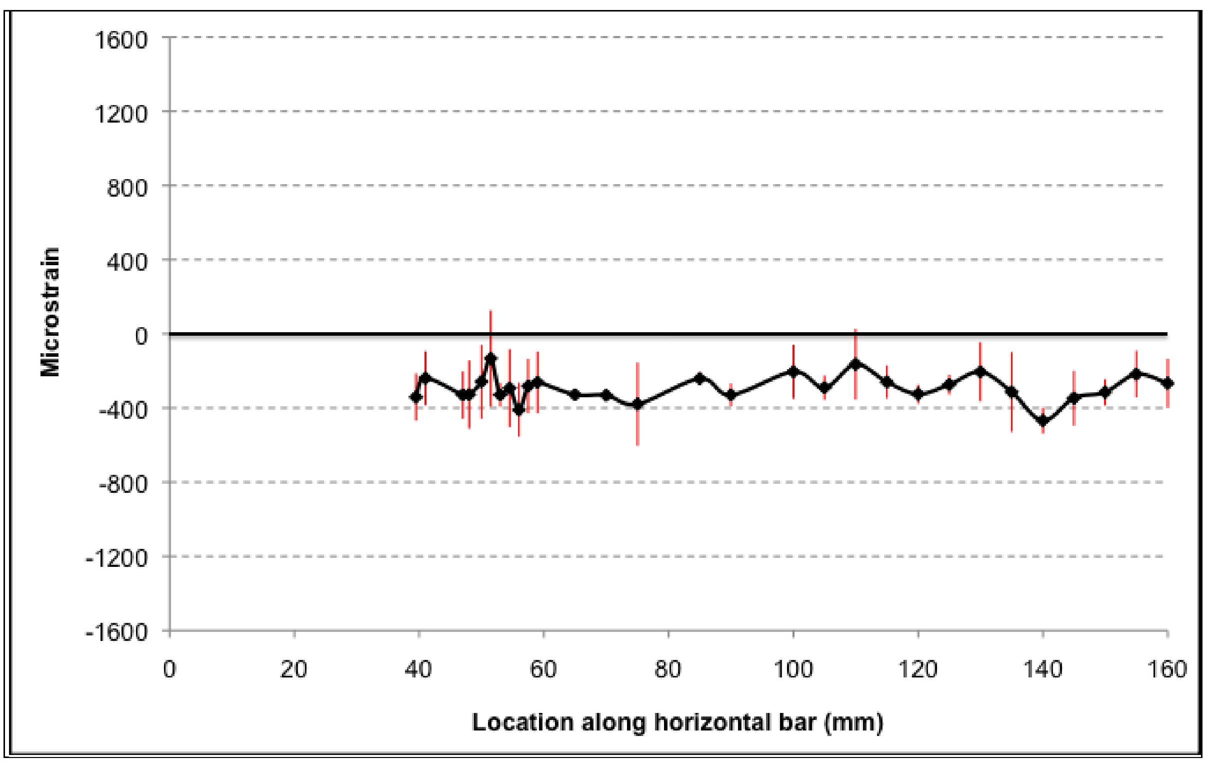

Figure 2. Residual strain profile along 0.05 wt% Ti B206 casting.

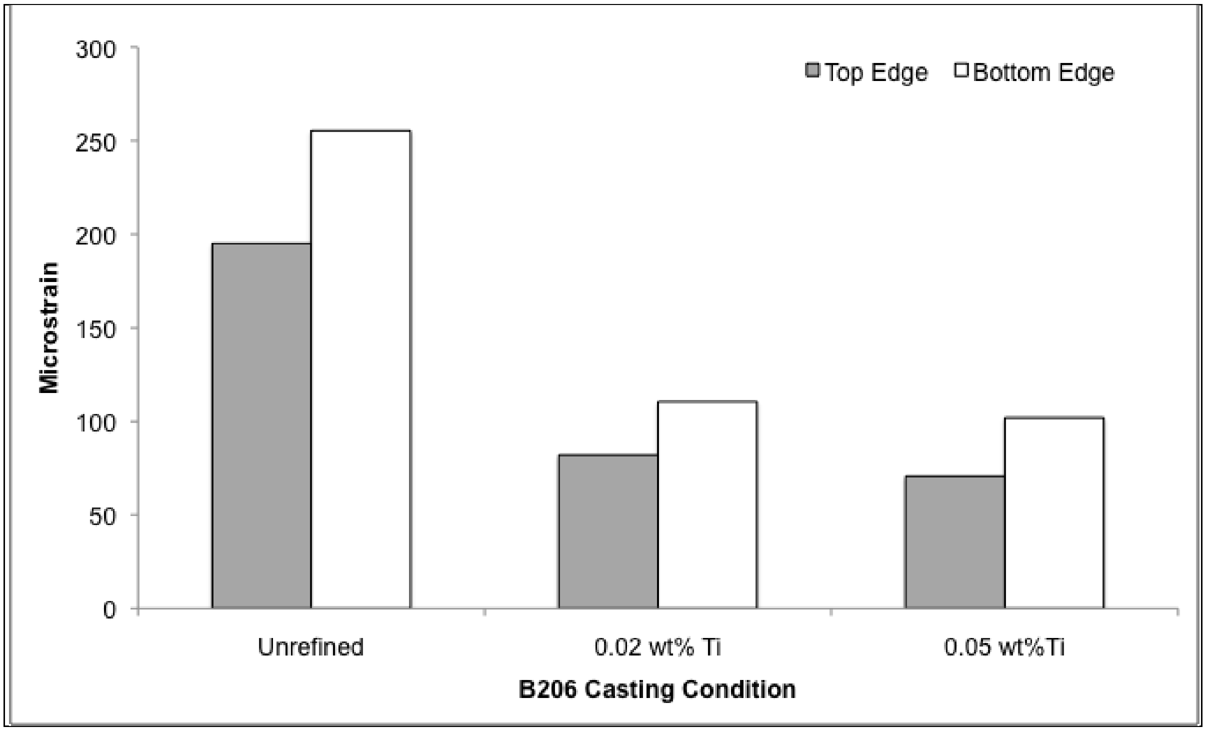

Figure 3. Variance in strain magnitude along the three B206 castings.