E. Extending the Life of Single Crystal Turbine Blades with Weld Repair

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Repair technologies for single crystal nickel-based superalloy components are desired because of the very high intrinsic cost of these components. However, repairs often lead to diminished performance due to compromises that must be made. For example, to avoid cracking during weld repair, alternative filler metals are used that have reduced levels of the strengthening gamma prime phase. In addition, the optimum single crystal grain structure is destroyed during current repair practices. This paper addresses the issue of stray grain formation during weld repair. Extensive research has led to an in-depth understanding of the mechanism of stray grain formation and the means for avoiding them during repair (Figure 1).

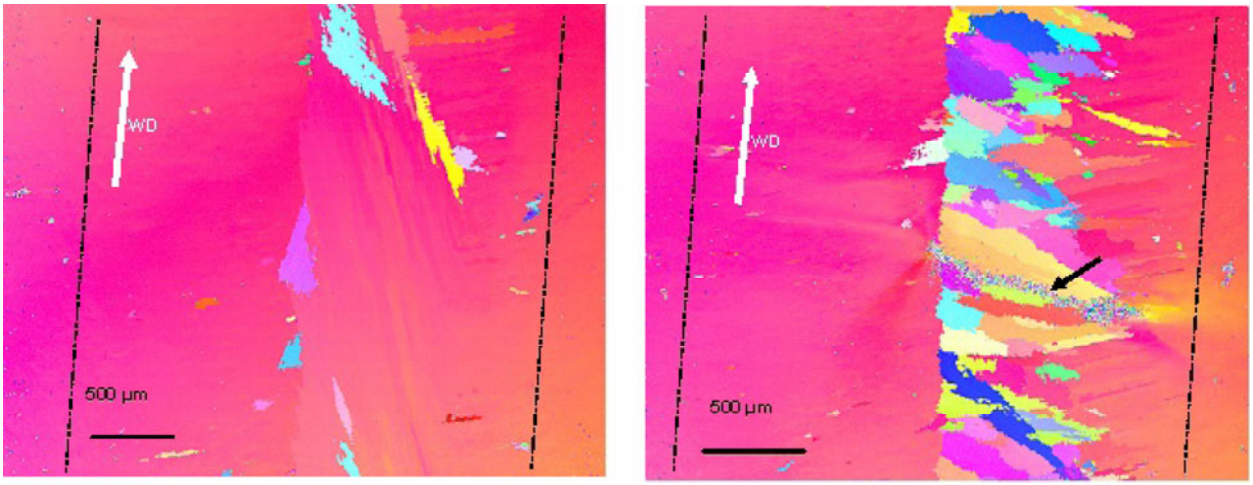

Figure 1: Orientation Imaging Microscopy images of two autogenous welds made on single crystal Rene N5 under different welding conditions, showing very few stray grains (regions of different colors) in one weld on left while multiple stray grains formed on one side of weld on right.

This work identifies promising new methods for weld repair that avoid stray grain formation. The effect of welding conditions (weld power and weld speed) on the tendency to form stray grains has been quantified by combining thermal models that describe the weld pool shape, geometric models that identify the active dendrite growth directions as a function of position within the weld pool, and nucleation and growth models that quantify the extent of nucleation and growth of new (stray) grains during solidification (Figure 2). The absence of stray grains has two desirable consequences: it maintains the original single crystal microstructure (and thereby, high strength) and it helps to avoid cracking along high-angle grain boundaries. The research also shows that alternative, inferior filler metal compositions are not necessary, so that the high gamma prime content can be maintained. Finally, the work shows that successful weld repairs may be possible for a wide range of geometries, so repairs could be applied to single crystal components regardless of the location of the repair.

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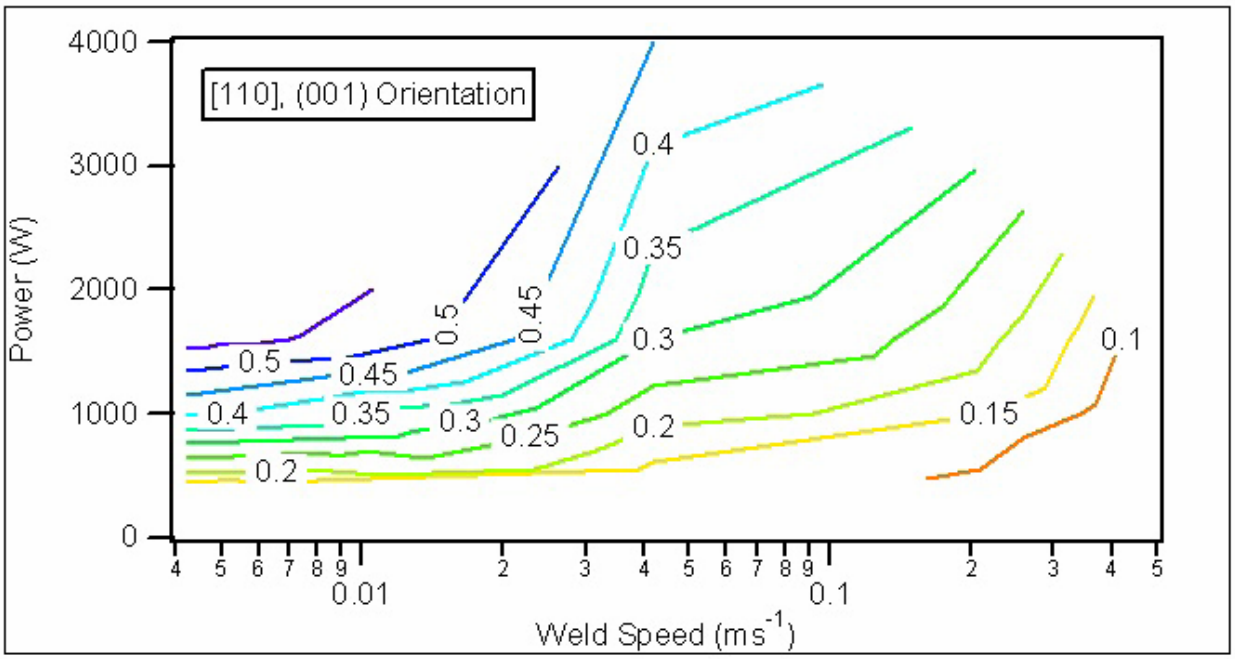

Figure 2: Results from model calculations showing contour lines for variation of factor phi (which represents extent of stray grain formation ahead of growing solidification front; 0 = no stray grains, 1 = 100% stray grain formation) as a function of weld power and weld speed.