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Process Optimization for Welding Single Crystal Nickel-Based Superalloys[1]

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Nickel-based single crystals are used extensively in advanced gas turbine power systems because of their superior mechanical properties. Because of the high cost of components made from these single crystals, a successful weld repair technology is desired to maximize component lifetime. Such a weld repair technology can be used to refurbish components that exhibit normal wear, but it can also be used to restore parts compromised by physical or corrosive damage.

A U. S. Department of Energy program aimed at characterizing and understanding the welding behavior of commercial single-crystal nickel-based superalloys used for turbine system applications is nearing completion at ORNL. A major challenge for weld repair of single crystals is to produce welds that retain the single crystal nature of the base metal and avoid the formation of new ("stray") grains during weld solidification. One of the aims of the current program was to identify the mechanism of stray grain formation in single crystal weldments and to identify optimum weld procedures to avoid stray grain formation.

It was found that stray grain formation, and cracking associated with high-angle stray grain boundaries, was sensitive to welding conditions and the crystallographic orientation of the material. As shown in Figure 1, extensive stray grain formation and cracking occurred on one side of an autogenous laser weld but not on the other, even though the thermal conditions were identical on both sides of the weld. These and other experiments led to the conclusion that stray grain formation is controlled by constitutional supercooling ahead of the advancing weld solidification front.

Once the mechanism of stray grain formation was identified, the effect of weld conditions on promoting or hindering stray grain formation could be assessed. The influence of weld power, weld speed, and crystallographic orientation were evaluated. The paper will describe the results of these studies, and will help to identify the best welding conditions for producing stray-grain free, crack-free, single crystal welds.

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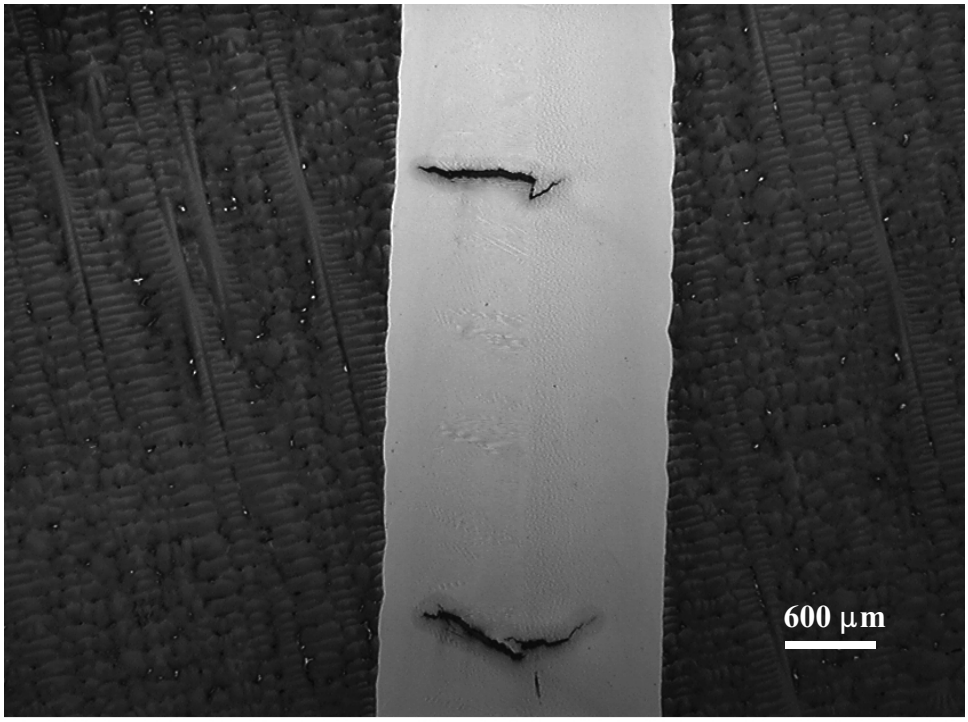
a)



b)

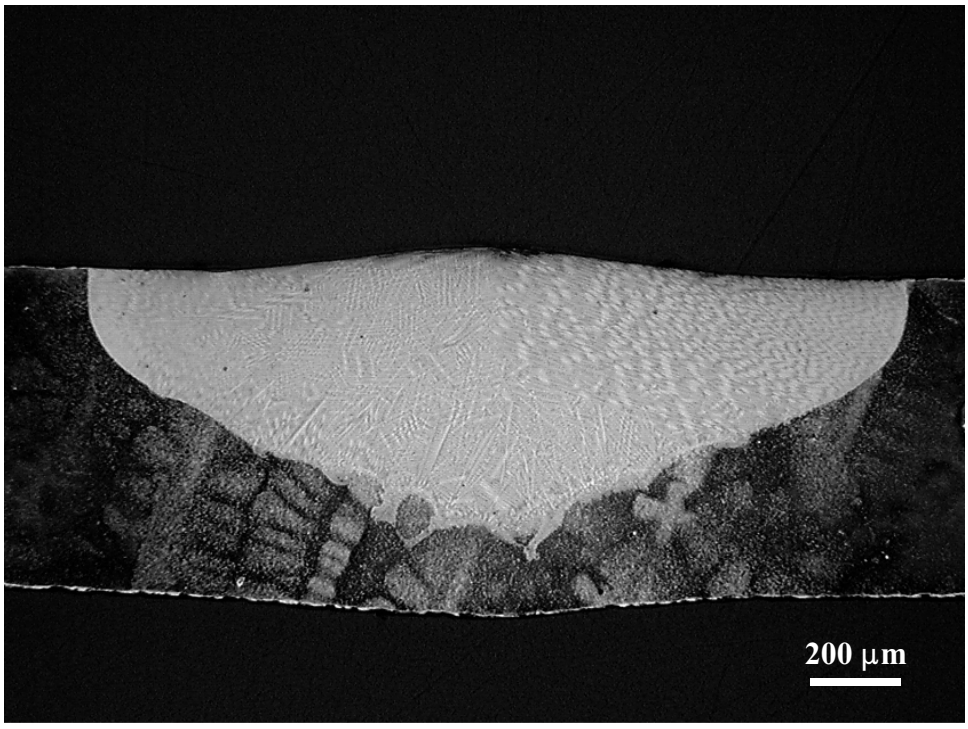


Figure 1: Laser weld made on thin sheet of commercial alloy Rene N5 showing (a) top view with more extensive cracking on left side and (b) transverse view with more extensive stray-grain formation on left side, same side that shows cracking.