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Effect of welding parameters on microstructure, mechanical properties and hot cracking phenomenon in Udimet 520 superalloy

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ABSTRACT

In the present research, different weld layers were deposited on a 1.2714 steel die by gas tungsten arc (GTA) welding with the weld wire of Udimet 520, and effects of welding parameters on microstructure and mechanical properties of Udimet 520 superalloy were investigated. The results showed Udimet 520 weld with cellular–dendritic and rarely dendritic structure including γ matrix rich of Cr, Mo and W, low percentage associated with order morphology and relative uniform distribution of MC type carbides. Udimet 520 alloy showed high resistance against hot cracking during welding and hot cracking occurred only at high input heat values. Also, cracking during welding occurred at the places that the concentration of Al and Ti is high. Investigation of the effect of welding parameters on the hardness of GTA welded Udimet 520 showed that with increasing welding speed and decreasing input heat, the hardness of the weld improved. Increase in hardness of GTA welded Udimet 520 due to increasing welding rate and decreasing heat input is attributed to the fineness of columnar structure and solid solution strengthening.

1. Introduction

Udimet 520 superalloy is a precipitation-hardenable nickel base superalloy with an exceptional combination of high-temperature mechanical properties, corrosion resistance and forgeability characteristics. This alloy is developed for use in the 1400–1700 °F (760–927 °C) temperature range, and has excellent structural stability and unusually good fabricability. The primary application for this alloy is balding for aircraft and land-based gas turbines. Some applications for Udimet 520 superalloy require the alloy to be welded.

The stability and creep resistance of superalloys depend on the precipitate morphology and volume fraction of precipitates, which strengthen the γ-phase matrix [1]. The investigation of solidification of these alloys needs determination of equilibrium distribution coefficient from phase diagram and knowledge of accurate position of closed lines of ternary phases, which are specified for some multi alloy systems [2]. The main differences between solidification in casting and welding are high solidification rate and high thermal gradient at solidification front in welding. As a result of none – equilibrium cooling of welds, amount and morphology of phases especially in Ni-based super alloys change severely.

The solidification of weld has the following stages [2]:

- First stage of the solidification is performed epitaxially on molten grains of base metal.
- At start, crystals grow slowly and faceted structure forms. Then the formation of fine cellular structure occurs.
- Crystalline growth is cellular–dendritic at intermediate stage and leads to the formation of coarse columnar growth in $\langle 100 \rangle$ direction at cubic systems.
- Final stage of solidification is associated with quick growth of grains and local concentration of particles. Therefore, final dendritic structure forms proportional to weld conditions.

Research of Lucas [3] on these alloys has shown that solidification cracking happens during welding. During the solidification of the weld pool, columnar grains grow from boundary of base metal and melt at central region of metal. Most of alloying elements and inclusions are rejected to the solidification front and concentrate in molten region. This causes compositional undercooling. The molten region remains liquid until the columnar grains reach together and the solidification complete. This fused layer decreases the adherence between contacting area of grains, and increases malleability of weld metal. Finally, shrinkage stresses induced during cooling process produce intergranular cracks. Other forms of solidification cracks have been studied by Ojo et al. [4]. According to their research, the elements as S, Pb, and some low

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