Neural Network Alloy Design Process for Cast Heat Resistant Grades

AMC
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Program Overview and Objectives: Lehigh University, through AMC's Innovative Casting Technologies (ICT) Program, is establishing relationships between carbide type/morphology and mechanical properties and is developing a neural network alloy design process that can be used for composition control. Heat resistant cast austenitic stainless steels are commonly used in high temperature (>850°C) corrosive environments such as ethylene pyrolysis tubes (Figure 1) and in heat treatment furnaces for industrial and DoD components. Both ambient and high temperature properties are controlled by the type, amount, and distribution of carbides which in turn are controlled by composition. The detailed relationships between composition, carbide type/morphology, and resultant properties need to be determined so that acceptable properties can be achieved in cast heat resistant grades.

Figure 1. Heat resistant pipes for high temperature applications.

SUCCESS STORY

Problem: Heat resistant grades have broad compositional specifications, leading to a variety of microstructures and properties. In some cases, a continuous carbide network can form, leading to a reduction in room temperature ductility and an increased likelihood of cracking during welding and fabrication. A systematic study is needed to determine the relationship between the composition, microstructure (carbide networking) and mechanical properties (ductility) in order to improve the reliability.

Solution: Large differences in the type and amount of carbides were seen when cast alloys were prepared with systemic variations in composition. A quantitative image analysis (QIA) procedure was developed to quantify the amount of carbide and carbide networking (Figure 2). Regression analysis identified the relationship between the composition, carbide connectivity, and ductility (Figure 3), with the minimum elongation requirements plotted for each ASTM specification. A model was validated to predict carbide content based on composition.

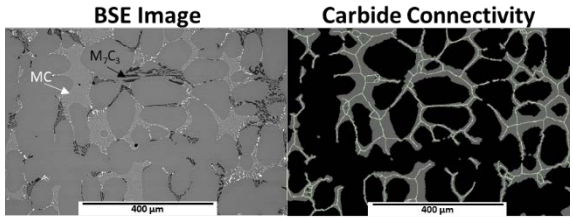

Figure 2. QIA method for identifying the carbide connectivity of the backscatter electron (BSE) image.

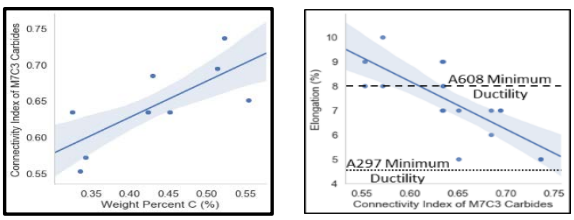

Figure 3. Connectivity index of M7C3 carbides as a function of nominal carbon content and relationship between the M7C3 carbide connectivity and percent elongation.

Benefits: This neural network model could be expanded and applied to other alloys used in DoD applications. This is a low cost, high capability ICME method that advances industry's capability to improve manufacturability and optimize performance of DoD alloys used in spare parts and assemblies.

"Heat resistant cast alloys are used extensively for a broad range of industrial high-temperature applications. These materials were initially developed over decades of trial and error alloying methods. On this project, we are able to rapidly optimize alloy compositions using computational modeling to predict composition-structure-property relationships."

Roman Pankiw, Vice President Engineering and Sales, Duraloy Technologies Inc.

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