Optimization Of SMA Weld Metal Composition

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Introduction

Traditionally, production of a new weld metal composition involved series of experimentation for several months/years. This has contributed to a large database relating composition and process parameters to mechanical properties; which in turn have been beneficially used to create empirical models with non-linear regression methods like artificial neural networks (ANN). However, the factor of trial and error that was ever present in experimentation could not be eliminated. Further, finding an optimum composition using models in a set involving 14 or more variables could lead to a difficult task. Use of optimization methods may eliminate this problem.

Coupled Models

ANN models are capable of predicting Charpy toughness to a reasonable accuracy. These models were combined with multipurpose optimization software which implements different optimizers (downhill simplex, genetic algorithms or sequential-quadratic programming) at each stage of the optimization process to find a global optimum. This coupled model was used to optimize the carbon, nickel, and manganese concentrations in a weld (Fe-0.65Si-0.006S-0.013P-0.21Cr-0.4Mo-0.011V-0.03Cu-0.038O-0.008Ti-0.018N) to achieve a maximum toughness of 120 J at –60 °C. This coupled model uses both linear and non-linear techniques to explore the possible combination of carbon, manganese, and nickel concentrations for a given set of welding process parameters.

Results and Discussion

The goal of the coupled model was to optimize the concentrations of C, Mn, and Ni to obtain a maximum Charpy toughness of 120 J at –60 °C. None of the combinations that the optimizers tried resulted in a toughness more than 87 J, in the specified range of C(0-0.4), Mn (0-5) and Ni (0-10); thus making this toughness the maximum achievable toughness.

An optimum weld metal composition was achieved only with non-linear methods. However, the number of iterations and the exploration of input parameter space varied depending upon the type of nonlinear technique. Each nonlinear optimizer when allowed to optimize for C, Mn, and Ni, arrived at the optimum at different number of iterations. Downhill simplex took the least number of iterations (=67) followed by genetic algorithms (323 iterations) and Sequential quadratic methods (1836 iterations). However, genetic algorithms explored most of the input space when compared to the other two. The hybrid optimizer which uses all the optimizers alternatively, explored all of the input space in 2840 iterations. It is ideal to use downhill simplex methods in order to get something working quickly, but the optimum may not be always global. Whereas, hybrid optimizer which explores all of the input space can be relied upon, when looking for a global optimum. All the optimizers including the hybrid optimizer arrived at a composition (C, Mn, and Ni concentrations) that was in agreement with published results; the optimum for C, Mn, and Ni concentrations being at 0.034, 0.0, and 7.6 wt%, respectively. This is in agreement with previous experimental work.

Summary

Artificial neural network models coupled with optimization techniques like downhill simplex, genetic algorithms or sequential-quadratic methods can be used to optimize the input variables for a given toughness value. In the present case, all the optimizers converged on a composition pertaining to 87 J of toughness. The global optimum was found at a composition Fe-**C0.034**-**Mn0.0**-**Ni7.6**-0.65Si-0.006S-0.013P-0.21Cr-0.4Mo-0.011V-0.03Cu-0.038O-0.008Ti-0.018N.

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