Sigma formation in 2707 Stainless Steel

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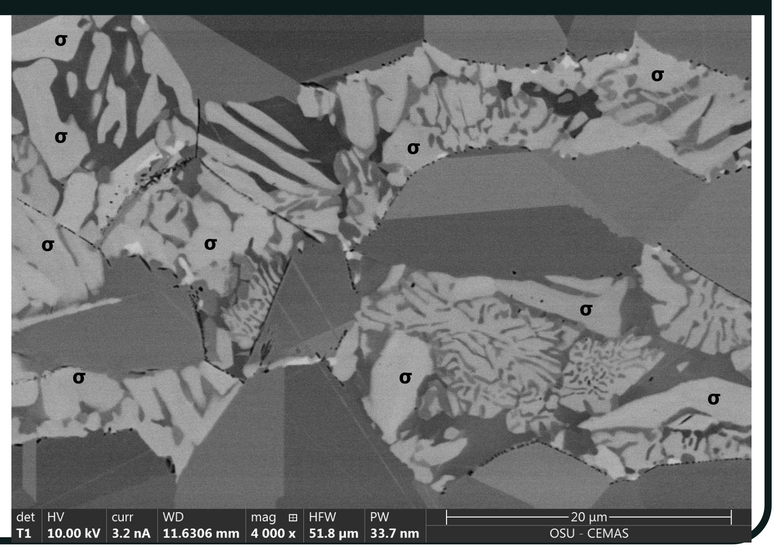
Background

2707 Hyper Duplex Stainless Steel (HDSS) is an advanced material appropriate for extreme service conditions due its outstanding strength and corrosion resistance. However, due to its chemical composition, undesirable intermetallic phases like Sigma and Chi could form during manufacturing and welding operation, compromising the material performance. This study addresses the relationship between thermal history, alloy chemical composition and Sigma phase formation in 2707 HDSS.



The numerous light gray crystals in this picture are mostly sigma phase.

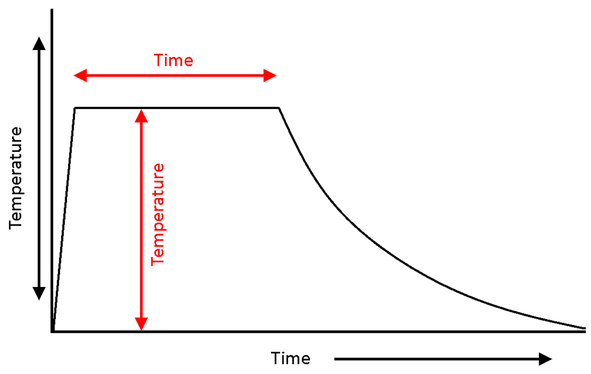
Objectives & Approach

-Develop TTT diagram for Sigma phase formation on HDSS 2707

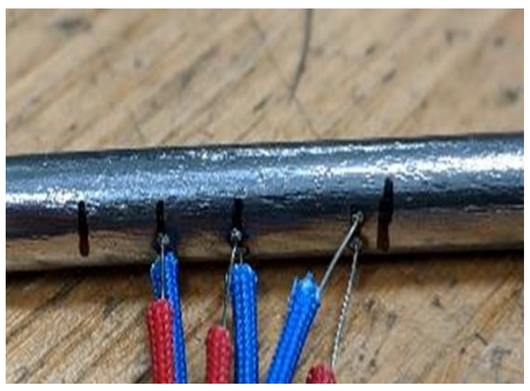
-Understand and model Sigma phase formation.

-Optimize welding parameters and cooling rates to minimize Sigma phase formation on HDSS 2707.

Gleeble testing: samples subjected to controlled temperature and time intervals, and Sigma measured via scanning electron microscopy

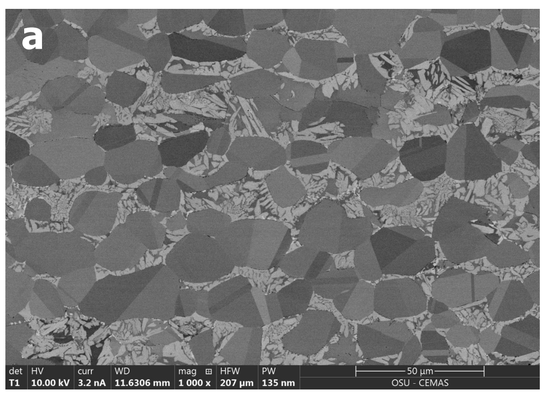


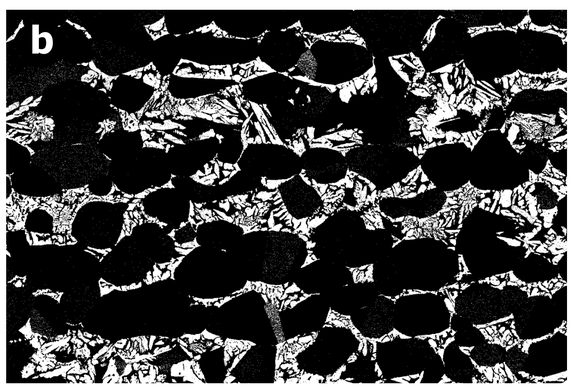
Schematic of thermal history to which samples where subjected.

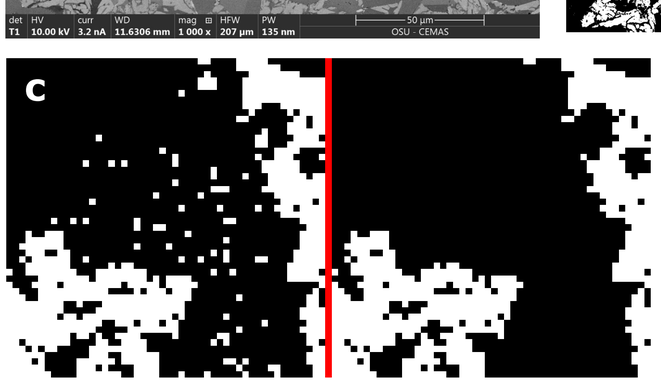


A gleeble sample with thermocouples attached.

Phase counting: SEM images digitally processed with a binary threshold and particle counter to measure sigma content.





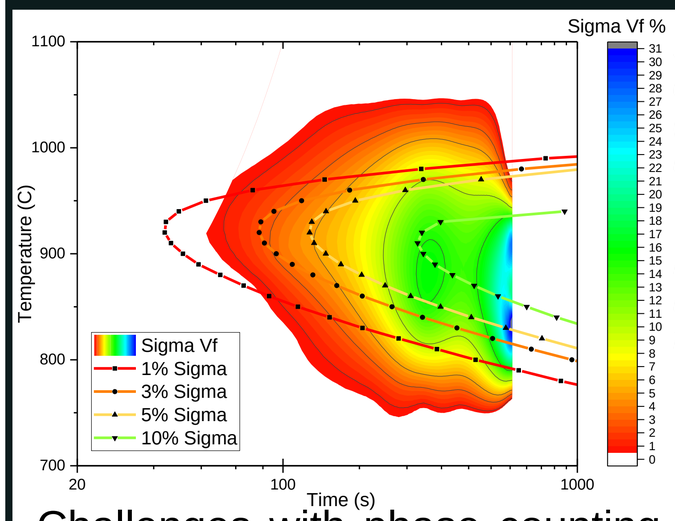


a) An unprocessed SEM image.

b) An SEM image with threshold applied.

c) before-and-after close-up of particle counter effects.

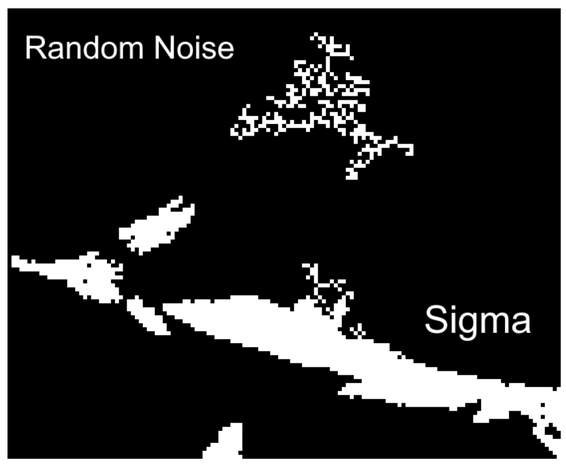
Results & Discussion

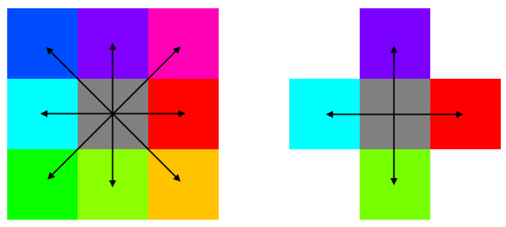


Sigma phase formation TTT diagram including the model (lines) and experimental data from isothermal testing on the Gleeble .

Lines+symbols are from a kinetic model of the process, Heatmap is from the isothermal experiments.

Challenges with phase counting on low-contrast images: occasionally binary threshold picks up random noise in non-sigma particles





How it was addressed:

- Automatic counter uses 8 connection- 4 connection is more desirable but requires manual highlighting
- Manual counting allows user to distinguish between random noise and actual sigma
- Manual counting on a sample image yielded comparable results (~1% sigma difference)
- However, process is time consuming and operator dependent.

Future Work

-Perform and evaluate welded material.

-Further improve the kinetic model supported by additional gleeble testing.