Using TEAM™ Pegasus to Characterize Intermetallic Phases in Duplex Steel Alloys

Introduction

Duplex steels have a two phase microstructure consisting of ferrite and austenite. They generally have about twice the strength of both ferritic and austenitic stainless steels and better toughness than ferritic stainless alloys. Duplex steels also have similar corrosion resistance behavior to common austenitic stainless grades. Because of the lower alloying element requirements for duplex steels, they are often lower in cost than traditional stainless alloys and because of the higher strength, thinner sections of duplex steel may be used, reducing both cost and weight. However, duplex steels are more susceptible to the precipitation of intermetallic phases due to their higher chromium and molybdenum content. In particular, the sigma phase is a hard phase, which negatively affects toughness and corrosion resistance. If an excess of the sigma phase is present, the alloy properties are reduced below values which are practical for use.

In this technical note, we examine how the EDAX TEAM™ Pegasus Analysis System with simultaneous Energy Dispersive Spectroscopy (EDS) and Electron Backscatter Diffraction (EBSD) can be used to characterize the microstructure of duplex steels and to measure the phase fractions present to determine if a given alloy and heat treatment process produces a usable duplex steel product.

Analysis

In the analysis, duplex steel alloy samples were subjected to heat treatments at one of three temperatures (800°C, 900°C, and 1,000°C) for two hours then prepared for EBSD analysis. TEAM™ Pegasus was used to collect, manage, and analyze data from the three samples.

TEAM™ Pegasus Project

To collect the data, a TEAM™ Pegasus project was created. Ferrite (body-centered cubic), austenite (face-centered cubic), and sigma (tetragonal) structures were selected. Representative patterns are shown in Figure 1. The 3-click workflow in TEAM™ was used to image the area of interest, collect the combined EDS-EBSD dataset, and review the data.

When collecting a simultaneous TEAM™ map, a key feature is the auto-optimization of the EBSD camera. This optimization is content sensitive.

When collecting Point Analysis data, EBSD patterns are optimized for high-resolution and low noise, while EDS spectra are collected for quantitative analysis. When collecting mapping data, the EDS count rate is used to determine a dwell time that produces a statistically significant number of EDS counts per pixel. In turn, the software then automatically sets the EBSD camera exposure to this dwell time to optimize the collection pattern quality. Optimization modes for EBSD-only mode are also available.

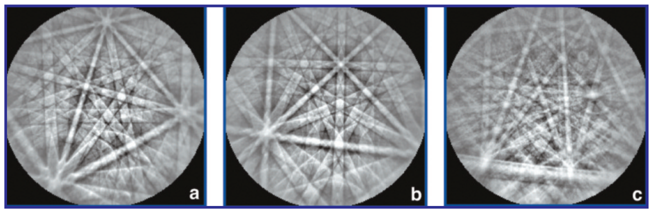

Figure 1. EBSD patterns from the a) ferrite, b) austenite, and c) sigma phases.

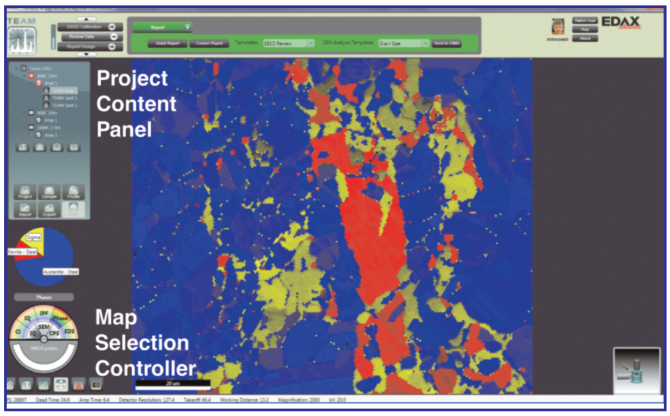

Figure 2. TEAM™ Pegasus user interface showing project management and data review.

A screenshot of the review mode is shown in Figure 2.

Note that the three datasets are easily accessible for review in the Project Content panel. The TEAM™ Map Selection Controller (MASCOT) is the selection tool in the lower left portion of the user interface, where different map types can be selected, both in review mode and dynamically during data collection. In this example, a greyscale Image Quality (IQ) map is combined with a colored phase map.

Other map types are available. For example, Figure 3 shows a blended EDS map for each processing temperature, where molybdenum is shaded red, chromium is shaded blue, and iron is shaded green. This provides some indication of phase distribution. These maps can be compared to the EBSD structural phase maps shown in Figure 4, where ferrite is colored blue, austenite is colored red, and sigma is colored yellow. In these maps, the colored phase information is again combined with the greyscale EBSD image quality contrast to reveal the grain structure within each phase.

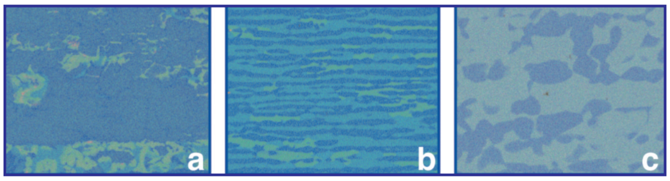

Figure 3. Blended EDS maps for samples heat treated at a) 800°C, b) 900°C, and c) 1,000°C, where molybdenum is colored red, chromium is colored blue, and iron is colored green.

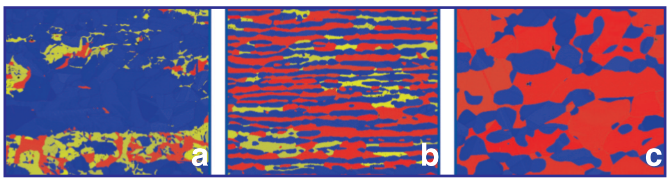

Figure 4. Colored phase maps combined with greyscale EBSD image quality for samples heat treated at a) 800°C, b) 900°C, and c) 1,000°C, where ferrite is colored blue, austenite is colored red and sigma is colored yellow.

Results

The quantitative microstructural results are shown in Table 1. In this case, increasing the annealing temperature has decreased the percentage of sigma phase present but this has coincided with an increase of the average grain size. As increasing grain size often corresponds to a decrease in strength, two competing mechanisms must be controlled. In this case, the grain size needs to be small enough to provide strength high enough for a given application while the sigma fraction must be kept low enough to provide adequate toughness and corrosion resistance.

Conclusion

TEAM™ Pegasus provides the characterization data necessary to understand and optimize the heat treating process in order to provide a material suitable for this application. TEAM™ Pegasus is compatible with Octane and Octane Elite Silicon Drift Detector (SDD) Series EDS detectors and both Hikari and DigiView EBSD cameras.

Annealing Temperature	% Sigma	% Ferrite	% Austenite	Avg. Grain Size (µm)
800°C	14	6	80	1.37
900°C	9	38	53	1.85
1,000°C	0	57	43	4.82

Table 1. Microstructural results vs. annealing temperature.