Grain Size Prediction

Background:

Carmel Forge, Israel, manufactures a wide range of titanium and nickel based alloy forgings for the jet engine and power generation industries. Carmel Forge uses DEFORM-2D, with the Microstructure module for their process development and optimization. DEFORM has helped Carmel Forge to optimize their forging processes, lower production costs and significantly reduce the lead time between order placement and delivery of products.

Microstructure:

The microstructure of a material provides information linking its composition and processing to its properties and performance. Microstructure defines the quality of the product. Predicting and controlling microstructure is paramount to successful process and product design.

Over the past two decades, leading forging companies around the world have used DEFORM to predict the metal flow, detect defects, reduce tooling stress and understand the influence of strain and temperature in the part. This information is critical in designing tool progression and qualitatively judging microstructure and property responses of the part. Recent advances in the DEFORM microstructure module make it practical for industrial grain size modeling.

Waspalloy Grain Size:

In this example, provided by Carmel Forge, the DEFORM Microstructure Module was used to predict the final grain size of a multi-step hot die forging of a waspalloy jet engine disk.

During the forging process, the grain growth and recrystallization kinetics were modeled. Final grain size distribution and percentage recrystallization were predicted for the waspalloy disk. The predicted results matched very well with the actual grain size distribution observed in the cut up section of the waspalloy disk.

A uniform grain size of ASTM 6 - 7 was predicted for most of the disk geometry. The model accurately predicted a coarser grain size near the top hub and bottom of the disk.

A macro section of a Waspalloy turbine disk is shown - courtesy of Carmel Forge.

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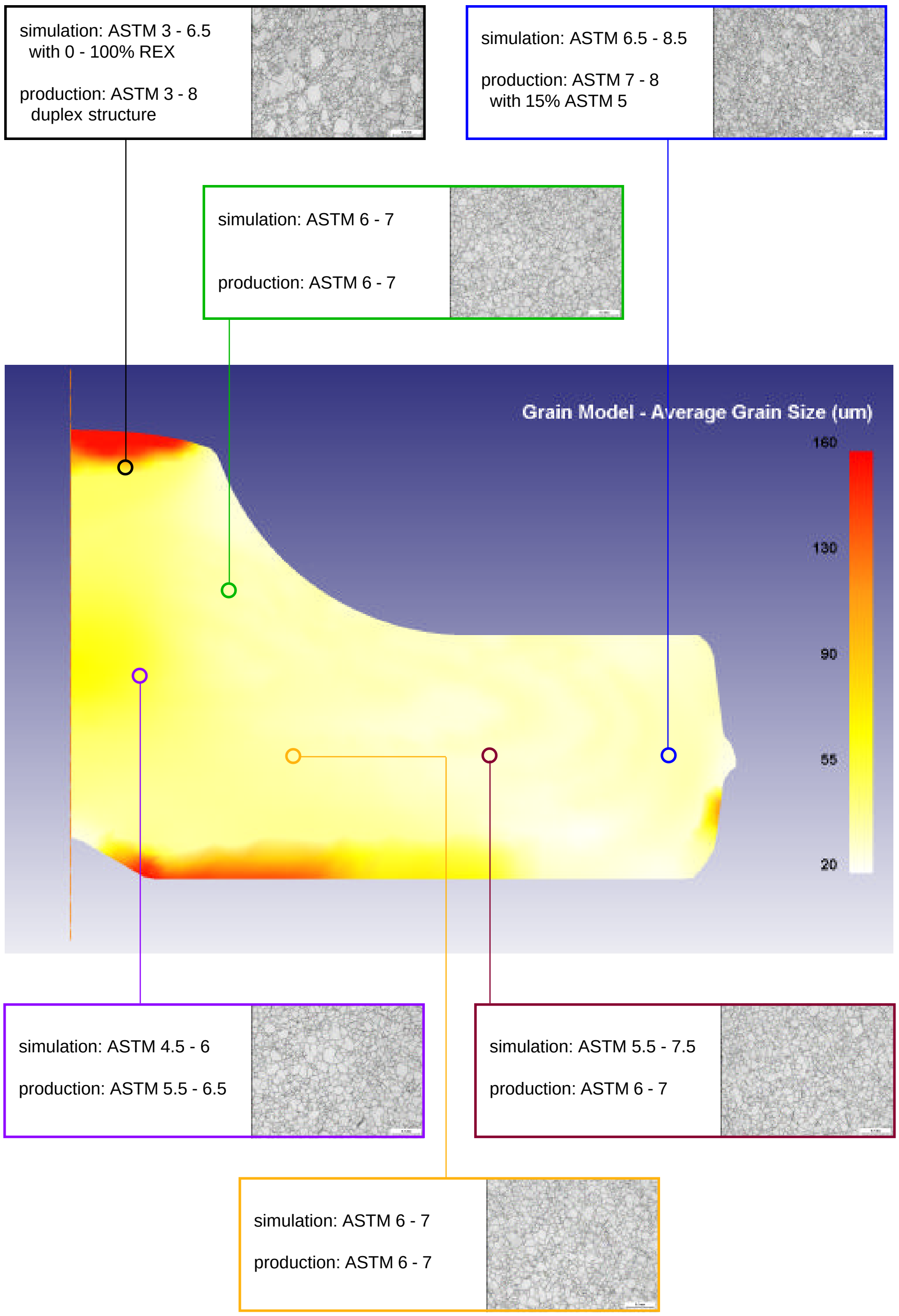

JMAK Modeling:

DEFORM employs the traditional Johnson-Mehl-Avrami-Kolmogorov (JMAK) approach to model recrystallization kinetics and grain size evolution that occurs during forging and heat treatment process. JMAK models have been available to the DEFORM users since they were implemented in 1999.

In the JMAK method, the final average grain size is computed based on initial average grain size, some material constants and field variables such as strain, temperature, strain rate and time. Grain growth and recrystallization kinetics (namely dynamic, metadynamic and static) are modeled. For the material of interest, grain growth and recrystallization kinetics equations need to be developed to predict average grain size and percentage recrystallization. Developing such equations involves material characterization tests to study the grain size evaluation over a range of strain, temperature and strain rate that are encountered during forging and heat treatment processes.

The DEFORM material database currently has the necessary JMAK equations to model grain size evolution in Waspalloy and Inconel 718. The JMAK technique is computationally efficient and is practically accurate.

The process and grain size correlation was provided by Carmel Forge, Israel.
This case study was conducted by Mr. O. Hen of Carmel Forge.

Scientific Forming Technologies Corporation
2545 Farmers Drive
Suite 200
Columbus, OH 43235
Tel: (614) 451-8330
Fax: (614) 451-8325
www.deform.com