Spring, 2007

Volume 5, No. 2

DEFORM™ News

Events:

- April 30 & May 1: The DEFORM International Distributors Meeting will be held in St. Petersburg, Florida.
- May 1 & 2: The Spring DEFORM User Group Meeting in North America will be held in St. Petersburg, Florida. Information is available in the User Area of the web site and was sent to all active Users. Please mark your calendar.

Training:

- April 17 & 18, 2007: DEFORM-2D training (includes DEFORM-F2) will be conducted at SFTC in Columbus, Ohio.
- April 19 & 20, 2007: DEFORM-3D training (includes DEFORM-F3) will be conducted at the SFTC office.
- August 22 & 23, 2007: The annual Die Stress Analyis Workshop will be conducted at Marquette University in Milwaukee, Wisconsin.

DEFORM™
Design Environment for FORMing

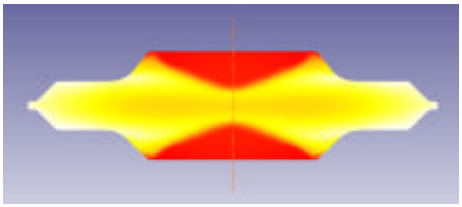
Microstructure Modeling

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 therefore paramount to successful process and product design.

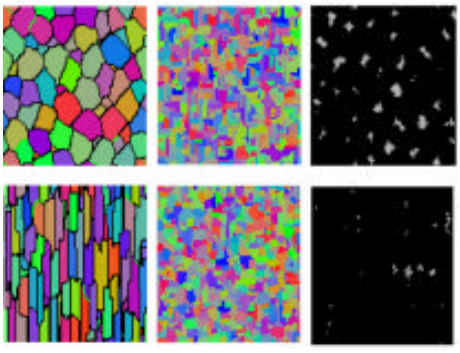
DEFORM offers two different approaches to modeling microstructure evolution during forging and heat treatment processes. The first method is the traditional Johnson-Mehl-Avrami-Kolmogorov (JMAK) approach which was implemented in DEFORM in 1999 and has been available to the DEFORM users since then. The latest approach in simulating microstructure evolution in DEFORM is the discrete lattice method implementing a Cellular Automata algorithm. This exciting new development will be available in DEFORM 3D version 6.1.

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 evolution 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 reasonably accurate.

An example of grain size evolution in a typical Waspalloy disk at the end of supersolvus forging operation is shown. In this model, the light colors represent a finer grain size, with coarse grains represented by red.



The JMAK method does not consider formation of precipitates or their effect on grain growth. Neither does it account for different grain shapes. Starting microstructures with the same average grain size but with different shapes do not have the same microstructure evolution kinetics. The classic JMAK models are insensitive to grain shape, thus limit the value for production applications.



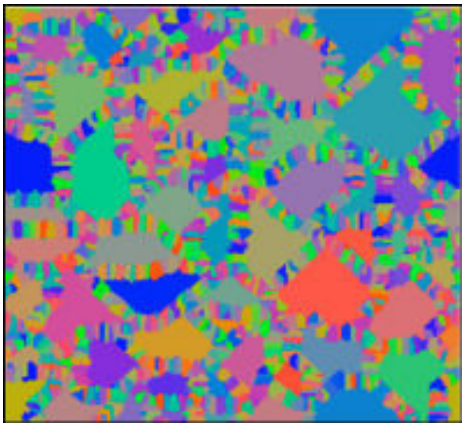
In this example, two different starting microstructures (equiaxed - top left & elongated - bottom left) are shown. The final microstructures are shown in the center. The unrecrystallized grains (gray) are shown on the right.

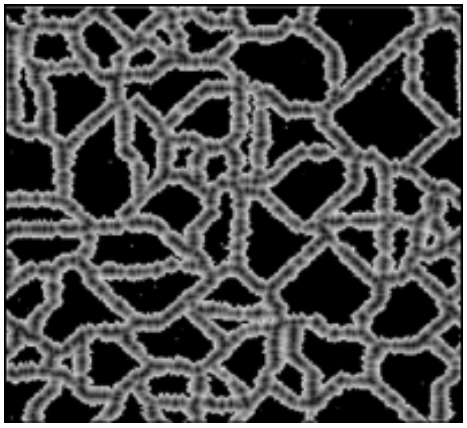
To address the deficiencies of the JMAK method, a discrete lattice based Cellular Automata (CA) model is being implemented in DEFORM. Cellular Automata models represent a microstructure as a discrete lattice of regularly arrayed points. Each point represents microstructure features such as crystallographic orientation, dislocation density, precipitate distribution, etc. Such a model, which represents grains and grain boundaries explicitly, rather than as an "average" value, is sensitive to local variations in grain geometry and morphology. Thus, CA models capture the recrystallization and grain evolution more realistically and accurately than classical JMAK models.

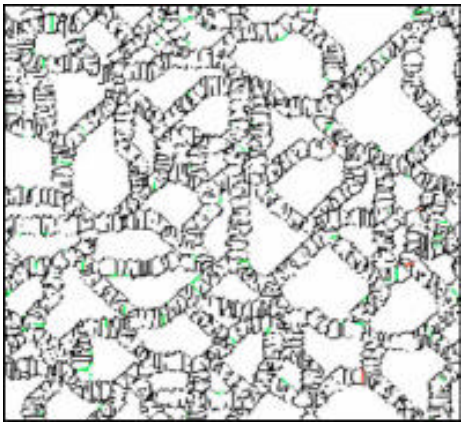
The CA model can simulate microstructural phenomena such as work hardening, recovery, dynamic recrystallization, metadynamic recrystallization, static recrystallization, and grain growth. The CA models can include the effects of strain, strain rate, temperature, crystallographic orientation, grain boundary misorientation and dislocation density. Typical output from the CA model is shown and described below. Future work will focus on including the effects of precipitation and phase transformation on grain size evolution.

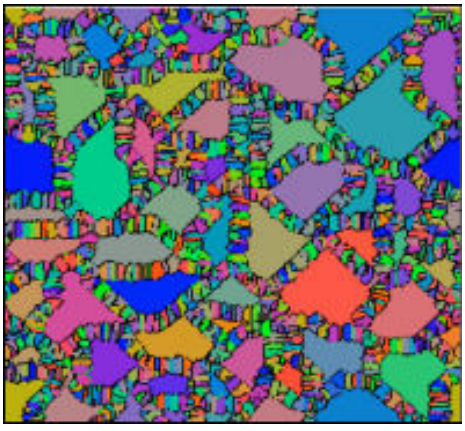
In the example below, the grain structure crystallographic orientation is shown on the top-left. Top-right represents a dislocation density map, where dark areas are a high dislocation density (deformed material) and light regions represent a low density (recrystallized material). The grain boundary map is shown on the bottom-left. A composite map of grain orientations and grain boundary misorientations is on the bottom-right.

Our current development efforts on the Cellular Automata based microstructural modeling is being funded by US Air Force SBIR Contract FA 8650-05-M-5205.









Releases:

During 2006, DEFORM-2D and DEFORM-F2 version 9.0 were released. DEFORM-3D and DEFORM-F3 version 6.0 were also distributed.

During 2007, we are finalizing a very aggressive development plan. The current plan will start with a DEFORM-3D version 6.1 beta in the spring. This will be followed by a formal release in the summer. DEFORM-3D version 6.1 will include:

- the ring rolling system;
- enhanced shape rolling;
- improved geometry handling, import and export;
- microstructure modeling prototype ;
- 3D induction heating (FEM only);
- local remeshing (3D);
- improved parallel computing, and
- the machining (cutting) preprocessor will include enhanced capabilities in defining drill geometry.

Additional developments in 2007 will include:

- ongoing shape rolling development;
- coupled die stress;
- speed and functionality in parallel computing and
- 2D to 3D integration, to name a few.

Ongoing microstructure developments will continue throughout the coming years. Scientific Forming Technologies is partnering with customers, research institutes and government agencies to push the 'state of the art' in microstructure and machining distortion modeling to new levels over the next few years.

For a complete list of all the improvements, please refer to the release notes on the DEFORM User Area.

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