Winter, 2018

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# DEFORM News

## Training:

- February 19-22, 2019: DEFORM training will be conducted at our office in Columbus, Ohio.
- April 16-19, 2019: DEFORM training will be conducted at our office in Columbus, Ohio.
- June 18-21, 2019: DEFORM training will be conducted at our office in Columbus, Ohio.
- August 14-17, 2019: DEFORM training will be conducted at our office in Columbus, Ohio.

## Events:

- May 21-23, 2019: SFTC will exhibit at Forge Fair 2019 (Booth 212) in Cleveland, OH. Forge Fair is North America's largest forging industry event.
- August 21-22, 2019: The Die Stress Workshop will be hosted by SFTC in conjunction with Marquette University, at our office in Columbus, Ohio.
- August 23, 2018: A one day training (on the mechanics of die stress analysis in DEFORM) will be conducted following the workshop.

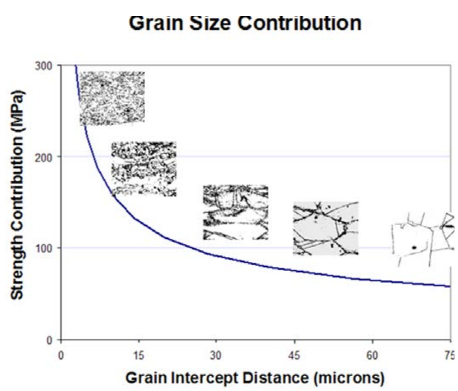
DEFORM®

Design Environment for FORMing

## Alloy 625 Grain Size

Alloy 625 is a nickel based super alloy used in naval, aerospace and energy applications. It is used in highly corrosive environments or applications requiring high strength at elevated temperature. The high temperature strength results in extreme forging loads. Frequently, dies fail after a small number of forged parts.

Fine grain is a strenthening mechanism in alloy 625, as depicted by the image below. A fine grain forging will achieve higher yield and tensile strength values than one with coarse grains. Additionally, individual grains grow quickly at high temperatures. To meet required mechanical properties, a lower forging temperature would be used.

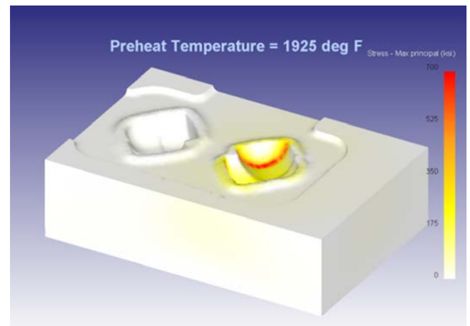



The flow stress of alloy 625 increases rapidly as temperature is reduced. At higher temperatures, the lower flow stress results in lower forging loads to fill the tooling. This reduces the stress in the dies, which always increases tool life. Thus, a higher forging temperature is preferable from the tooling perspective.

Unfortunately, these competing processes pull in opposite directions. The lower forging temperature can yield a finer grain, with improved strength properties. Whereas the higher forging temperature results in improved die life.

The forging process refines the grain size through dynamic, metadynamic and static recrystallization. No simple design rule will ensure that a forging will meet the property requirements without broken tools.

A JMAK model provides a practical estimate of grain size for forgings in a DEFORM simulation. Simulation also allows a die stress analysis to predict the likelihood of tool failure. Thus, a forging engineer can study tradeoffs to successfully forge alloy 625.




U.S. Drop Forge identified such a die failure problem for a 625 elbow. The part was forged at a low temperature to meet the strength requirements. A die stress study depicted an excessive tensile stress (red areas below) coincident with the fracture that occurred after a few forgings.In a PRO-FAST project to develop a grain size model, alloy 625 was tested at Portland State University, to provide data for the grain size models. The testing was performed to cover the temperature, strain rate and strain ranges for a typical 625 forging. These tests were used to build recrystallization and grain growth models.

JMAK models, which predict the average grain size and percent recrystallization at the part level, can run during a forging simulation in DEFORM. They have been shown to be a practical production engineering tool with IN-718 aerospace applications for over 20 years. Once the testing is performed, the test data can be used to define JMAK variables for a required material type. The expectation is a prediction within one or two ASTM grain size in the majority of the part.

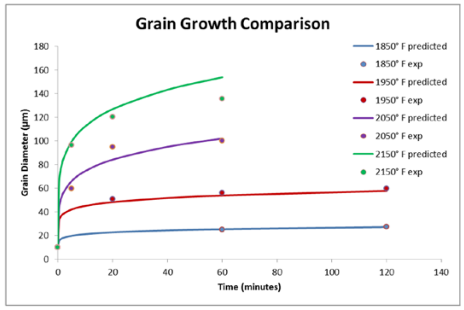
DEFORM Material Suite was used to fit the test data to the JMAK equations. The equations used for dynamic recrystallization are shown below on the left. On the right is a graphical representation of the grain growth, which is a strong function of temperature.

$$\varepsilon_p = a_1 d_0^{n_1} \dot{\varepsilon}^{m_1} \exp\left(\frac{Q_1}{RT}\right) + c_1$$

$$\varepsilon_{0.5} = a_5 d_0^{n_5} \dot{\varepsilon}^{m_5} \exp\left(\frac{Q_5}{RT}\right) + c_5$$

$$X_{DRX} = 1 - \exp\left[-\beta_D \left(\frac{\varepsilon - a_{10}\varepsilon_p}{\varepsilon_{0.5}}\right)^{k_d}\right]$$

$$d_{DRX} = a_8 d_0^{h_8} \varepsilon^{n_8} \dot{\varepsilon}^{m_8} \exp\left(\frac{Q_8}{RT}\right) + c_8$$




Manually fitting these complex equations is iterative, tedious and time consuming, without a direct solution. DEFORM Material Suite has tools to dramatically reduce this effort (from a week or more to a matter of hours) with excellent results.


The new grain size model was initially studied on production 625 elbows forged on a hammer at U.S. Drop Forge. A cross-section of the forging showed the grain size through the center section. The actual production grain size in the center was ASTM 4. In the model, the predicted grain size was ASTM 4.5. The subsurface microstructure was predicted within 1.5 ASTM points. Another press forging at California Amforge was also tested with the new model. Grain size predictions were equally impressive.

The JMAK model is imperfect, but practical. Some of these cases were simulated by engineers in mid-sized forge shops, with guidance from SFTC staff. These models require calibration, and some model coefficients may vary between press and hammer forgings.

To learn more about this capability, contact SFTC or your local DEFORM distributor.

This work was performed in a PRO-FAST project, under the direction of the Forging Defense Manufacturing Consortium. The project was sponsored by the Logistics Research & Development Program within the Defense Logistics Agency, Fort Belvoir, VA.

## Releases:

DEFORM V11.3 enhancements and new features include:

- MO user variable initialization
- Operation “Open task folder”
- Thermal property scheduling
- Step Editor magnifier on/off
- Operation copy/paste numbering
- DB merging
- Friction window preview
- Copy object
- STL 3D window import
- Custom total strain plots
- Enhanced velocity plotting
- “Diff step” options
- Report backward point tracking
- Cooling curve graph
- Cylindrical point tracking graph
- View back
- State variable default plot type
- State variable default color bar type
- Viewport settings
- PIP windows/graphing
- 2D contact area calculation
- Slicing improvements
- Discrete DOE iterations
- Spring/sliding die DOE variable
- Forming Express error checking
- Material Suite additions
- License/queue server improvements
- IMI 834 material data
- Titanium material data updates
- New lab exercises
- New license manager
- DEFORM Service Control update

The complete list of the new features can be found in the V11.3 release notes. Release notes are included with the software installation and available on the DEFORM User Area.

Version 12.0 is tentatively planned for release in early 2019.

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