Winter, 2016

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DEFORM™ News

Training:

- February 16-19, 2016: SFTC will host DEFORM training at our office in Columbus, Ohio.
- April 19-22, 2016: SFTC will host DEFORM training at our office in Columbus, Ohio.
- June 21-24, 2016: SFTC will host DEFORM training at our office in Columbus, Ohio.
- August 25, 2016: A one day training workshop, focused on Die Stress analysis in DEFORM, will be conducted at our office in Columbus, Ohio.

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Events:

- May 3-4, 2016: The DEFORM User Group Meeting will be conducted in Columbus, Ohio. (Tentative)
- August 23-24, 2016: The 20th annual Die Stress Workshop will be hosted by SFTC, in conjunction with Marquette University, at our office in Columbus, Ohio.

Design Environment for FORMing

Texture and Anisotropy

When performing large deformation simulations, it is typically assumed that the workpiece is isotropic. This means that the thermomechanical properties of the material do not have any directional dependence. However, this assumption may not always be appropriate since many polycrystalline materials develop anisotropic (directionally-dependent) properties with increasing deformation. Anisotropy can be caused by changes in the microstructure due to deformation. DEFORM offers several options to model anisotropic behavior and texture evolution (described in detail below).

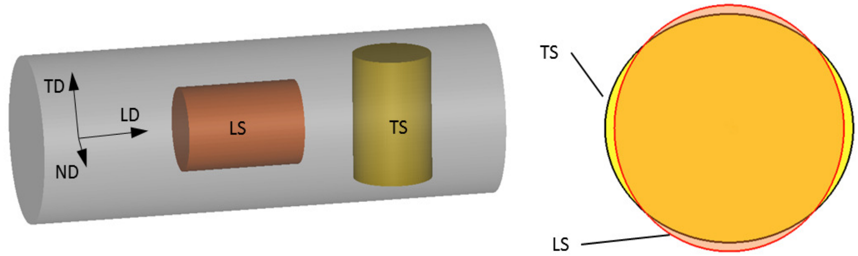
A polycrystalline material contains many grains, each of which has an independent orientation. Depending on the previous thermomechanical processing, a polycrystalline material may initially appear to be isotropic due to a random orientation distribution of the grains. When a bulk polycrystalline material is plastically deformed, the grains will rotate to accommodate the deformation and to align their active slip systems with the direction of deformation. As deformation continues, the orientation distribution of the grains will become less random. When the concentration of grains with similar orientations is significant, the material is said to have texture. A material will begin to demonstrate anisotropic behavior as texture develops, and the degree of anisotropy is proportional to the amount of "texturing" in the material.

Anisotropic Yield Criteria

The simplest way to model anisotropic behavior, without modeling the evolution of texture, is an anisotropic yield criterion. A yield criterion describes the elastic limit of a material for any and all loading conditions. In plasticity, the Quadratic Hill yield criterion is the most frequently used anisotropic model. Hill's yield surface is defined by the applied stress state and six anisotropic material coefficients (three normal and three shear). To account for anisotropy in a bulk forming simulation, DEFORM uses the generalized Hill yield definition together with location dependent material axes. To account for planar anisotropy, typical for sheet forming applications, the six coefficients can be reduced to three Lankford coefficients.

During the simulation, the orientation of the material axes at each element update with deformation. The deformation of each element is based on the orientation of the local material axes and the global anisotropic coefficients. For this type of anisotropic simulation, the overall simulation procedure and computational requirements are similar to a typical isotropic simulation. When using one of these models, the anisotropy coefficients usually do not evolve with deformation.

The first example used Hill's model to predict anisotropic distortion during an upset. Two cylindrical billets were cut from material that was strengthened only in the longitudinal direction (LD). When upset, the final shape and forming load were affected by the orientation of the compression axis with respect to LD. The longitudinal billet (LS) was upset parallel to LD. It demonstrated a higher forming load and uniform radial deformation. The transverse billet (TS) was upset normal to LD, resulting in a distorted shape and a lower forming load.

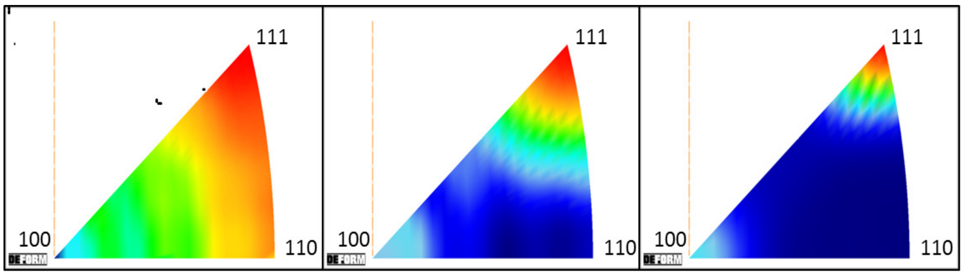


Crystal Plasticity

Crystal plasticity (CP) models are useful when directly modeling the evolution of texture with deformation. In general, CP models use a set of weighted orientations to represent a polycrystal as a discrete number of grains. In the ideal case, texture and texture-dependent anisotropy are computed and updated for each integration point at every step of the simulation. However, CP models often have extremely long runtimes which diminish the practicality of using a “runtime” CP model in an industrial setting.

In DEFORM, a viscoplastic self-consistent (VPSC) and a Taylor CP model are available as a postprocessor material point simulator. Results are obtained in a reasonable amount of time by only evaluating the evolution of texture at specific points of interest. However, since this model is implemented as a postprocessing tool, a nominal run is required prior to its use. The texture evolution calculations are then made from the deformation and temperature history carried over from the nominal run.

The provided inverse pole figures were obtained using the VPSC CP model to predict evolution of texture at the center of a copper wire cold drawn to a 54% reduction. The figures show the concentration of material directions parallel to the drawing direction. From left to right, the figures represent the initial texture, texture after the first pass, and the final texture. A texture develops that is typical for drawn FCC materials (strong 111 and weak 100). This example took advantage of a tool available in Material Suite that fits CP model parameters to experimental flow stress data.



Texture Based Yield Surface

The texture based yield surface uses the generalized Hill model and local material axes to simultaneously account for evolving texture and anisotropic material properties during deformation. To minimize the computing time, a crystal plasticity model is converted to pre-computed Hill coefficients for each orientation. The initial texture is represented at each element, and can be defined by EBSD or a user specified orientation distribution of the grains. The overall anisotropic material flow stress coefficients for each element are computed based on the local texture, material axes, and associated pre-computed single crystal responses. Like many other state variables, the texture for each element is updated at the end of each solution step. Computational efficiency is achieved by eliminating the need to calculate the texture-dependent flow stress at every integration point for each step. This allows the user to run a coupled texture and anisotropic metal flow simulation in a reasonable amount of time. A tool is available in Material Suite that will convert a working CP model into this pre-computed tabular data format.

Conclusions

DEFORM offers a variety of options to model texture evolution and anisotropic behavior. Oulined in the table below, each method has capabilities and limitations that make it suitable for certain applications. For more information, contact your DEFORM distributor.

Model	Run Time	Capabilities	Limitations
Anisotropic Yield Criteria	FEM	Anisotropic flow stresses Anisotropic shape distortion	Preserves anisotropy No texture evolution
Crystal Plasticity	Post-Processor	Texture prediction Different crystal types Fast results	No texture dependent flow Requires CP material model
Texture Based Yield Surface	FEM	Coupled deformation and texture evolution Fast acting model	Requires procedure to develop tabular data

DEFORM V11.0.2 Release

DEFORM V11.0.2 was released in December 2014. Important GUI improvements include:

- Target volume calculations were restored in **Forming Express** (3D).
- Report generator was improved.
- Support was added for scheduled rotation across passes in ALE shape rolling with quarter symmetry.
- Picture-in-picture was revamped in the postprocessor.
- Updating of reference points across multiple operations was enhanced.
- Improvements were made to coupled die stress analysis with EP objects.
- The sub-stepping procedures were improved for hyper-elastic models.
- Frictional heat computations were enhanced for models with multiple deforming objects containing regular and mixture materials.

New Features in V11.1

DEFORM V11.1 is being targeted for early 2016 release. Some of the new features include:

- new preprocessor
- improved license manager
- enhanced batch queue server
- revamped simulation server
- multiple DOE simulation servers
- CAD (SolidWorks) integration
- improved postprocessor
- improved material Suite
- new DEFORM viewer
- 2.5D FEM functionality in new shape rolling template
- new 2D and 3D cutting templates
- new **Forming Express**
- database comparison in postprocessor
- improved contact search options
- 64 Bit 2D FEM engine
- discrete DOE variables
- domain decomposition FEM solver
- dual mesh FEM solver
- solidification and melting modeling
- multiple 64 bit modules
- various bug fixes

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