T002: User-Defined Flow Stress Data

Introduction

This document describes how to add user-defined flow stress data to DEFORM.

Problem Description

DEFORM allows users to input their own material properties based on published or test data. The following outlines how to properly input flow stress data. Focus is placed on adding a new material definition and creating room-temperature flow stress data from yield and tensile strength properties.

Background Information

Flow stress data is the primary material property required in metal forming simulations. It captures how a metal flows based on the type, grade, alloy and prior treatment of the material.

In a forming model, each flow stress data set represents a single history, anneal condition, hardness, grain size, etc. Microstructure simulation can account for some history effects, but this is considerably more complex. Most materials used in simulations are described with simple flow stress data based on strain, strain rate and temperature.

Flow stress is available from a range of published sources or it can be derived from testing. DEFORM requires isothermal true stress vs. true strain curves that have been corrected for adiabatic heating. Flow stress will be defined in a full matrix at combinations of strain, strain rate, and temperature. All flow stress values in the matrix are required to be non-zero.

To the extent possible, the data should cover the range of temperature, strain, and strain rate expected in the process. This includes not only the starting temperature of the forging or forming process, but also temperature increases due to deformation heating and temperature drops due to air cooling and die chilling.

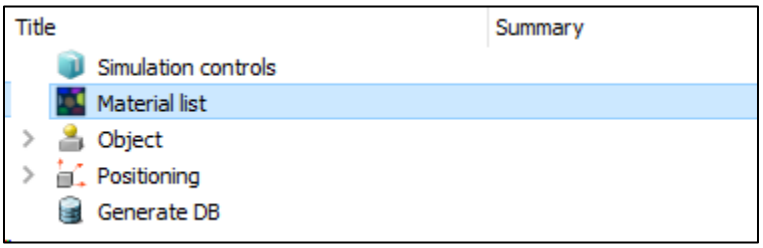
The flow stress of low alloy steels is relatively constant over the typical range of deformation heating seen in cold forming (up to around 800 °F/ 400 °C). Other materials may exhibit significant softening due to deformation heating even when starting at room temperature. If low elevated temperature data is available, it can improve the accuracy of a simulation.

Solution

Adding a new material in DEFORM

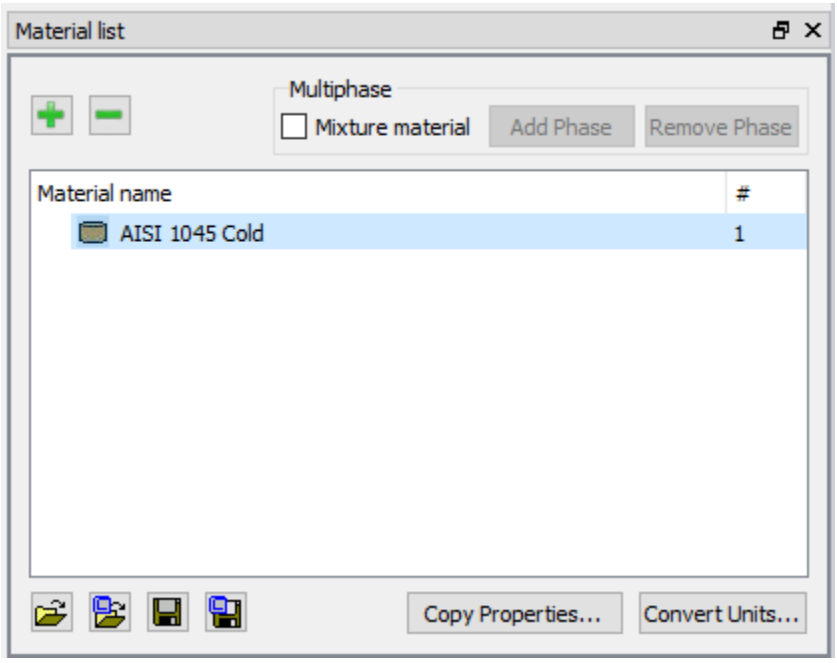
Adding flow stress data to DEFORM is straightforward.

1. Go to the “Material list” in the Tree.



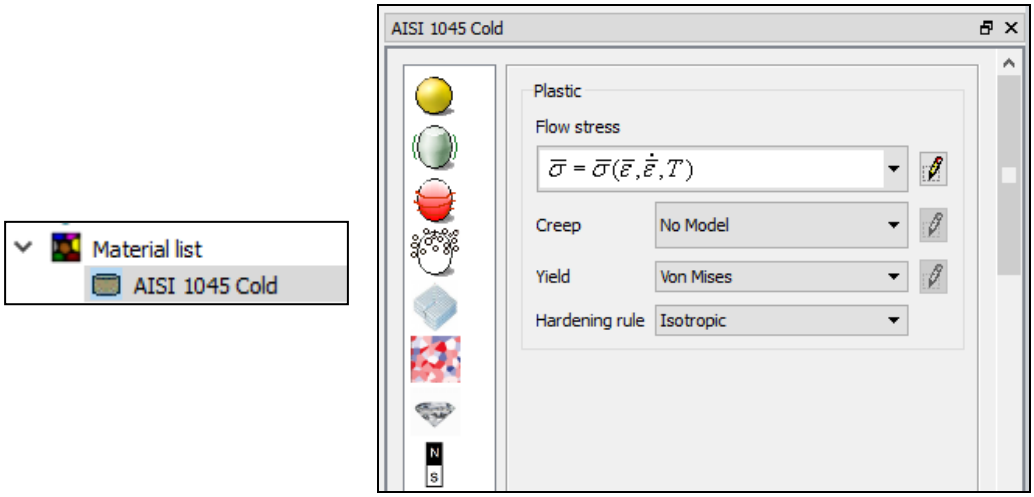
2. Click on  to create a new material.

3. Double-click on the “New Material” material name, and type in the name of the material. For this example, we are using "AISI 1045 Cold".



4. Click 

. The new material will be highlighted in the Tree and the properties page will be displayed. The tabular flow stress format, $\bar{\sigma} = \bar{\sigma}(\bar{\varepsilon}, \dot{\bar{\varepsilon}}, T)$, will be selected by default. Click the Edit  icon to open the tabular data.



5. Fill in the temperature, strain rate, and strain values at the top of the flow stress dialog.

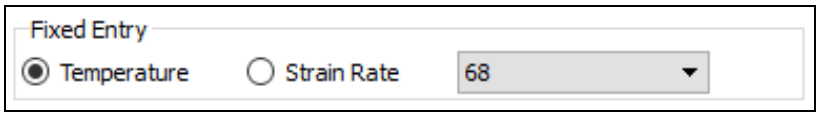


6. For rigid-plastic materials, a bit of rate sensitivity helps with convergence. If only a single rate curve is available, creating a 2nd higher strain rate curve with values 1% higher than the first is useful.

7. The first value for strain should be exactly zero (0, not 0.1 or 0.001). This value will be the yield strength of the material. Including 7 to 15 values for strain are appropriate. An excessive number of strain entries can hinder simulation performance.

Enter stresses for each strain/strain rate combination. If desired, data can easily be copied and pasted from a spreadsheet.

8. The drop-down box in the “Fixed Entry” area shows the temperature for which data is being entered. When data exists at multiple temperatures, change the temperature in this field and fill in the flow stress data at each temperature.



9. In the “Interpolation” field, use "Log" interpolation because it is typically closer to physical reality.

A non-zero flow stress value must be provided for all combinations of strain, strain rate, and temperature. Zeros in the flow stress field will cause errors during the simulation. If experimental data is not available for all combinations, values can be entered by manually interpolating between known values.

Converting Yield and Ultimate Strength to DEFORM curves

A simple tension test can provide yield strength (YS) and ultimate tensile strength (UTS) of a material. While the data is not as complete as curves obtained from a compression test, the values are widely available and reasonably representative of strength and work hardening behavior at room temperature.

The attached spreadsheet can be used to convert YS and UTS to a table of flow stress data. Flow stress is given as a function of strain for a user-defined list of strain values (typically 0 to 2).

After the conversion, the strain column can be copied from the spreadsheet into the strain field in the DEFORM material dialog. Then the flow stresses can be copied into the appropriate block at the bottom of the dialog.

For rigid-plastic material, convergence can be improved by adding a 2nd strain rate of 100. Use flow stress values of 1.01 times the initially calculated flow stress curve (provided in the spreadsheet).

In DEFORM v12.0, users will be able to input the YS and UTS directly into the GUI and have the flow stress curves generated automatically.

Related Information

The provided spreadsheet generates flow stress curves based on yield and ultimate tensile strength values. The attached .pdf document provides a theoretical background for the calculations performed in the spreadsheet.