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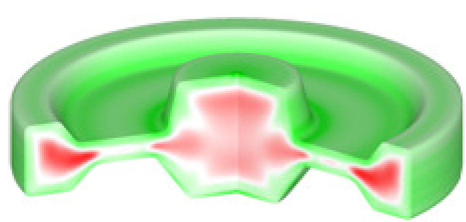
DEFORM™ News

Machining Distortion

Machining processes that have uncontrolled or unpredictable part distortion adversely impact the quality, scrap rate and cost of a component. Process simulation can be used to accurately model and predict the machining distortion. The simulation provides a better understanding of the critical factors that affect the distortion, allowing significant process and design improvements to be made.

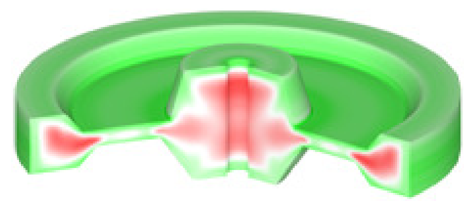
The residual stress distribution in a component is the result of prior thermo-mechanical processing, especially heat treatment. Heat treating is necessary to achieve the required mechanical property response of a part. The component geometry and cooling rate during the heat treatment influence the residual stress distribution. The machining process also contributes to the residual stress, especially near the surface. Currently, DEFORM does not account for the workpiece - cutting tool interface effects, which change with speed, feed and depth of cut.

After heat treatment, a component will typically have compressive residual stresses on the surface and tensile residual stresses in the core. The image below depicts the residual stress in a turbine disk after heat treatment, but prior to final machining. The green regions show compressive stresses and the red regions are tensile.



After material is removed in subsequent machining processes, the internal stresses are redistributed. Part deflection is the result of these internal stresses finding a new equilibrium. This is the cause of the machining distortion.

Note that residual stresses are still present in the final machined component, as shown in the image below.



DEFORM has a machining distortion template that helps in the quick set up and modeling of these processes. This capability was first introduced to DEFORM in the late 1990s, as part of an Air Force SBIR program. Since then, SFTC has continuously improved and enhanced the machining distortion modeling capability for both 2D and 3D applications. Machining distortion has been a topic in other funded programs, including Material Affordability Initiative (MAI) projects. Through these programs, various industrial machining distortion cases were modeled and the distortion predictions were validated against experimental results.

A machining distortion analysis is set up by reading the stressed component from a heat treat simulation into the machining distortion template. In a real machining process, the order sequence of machining passes and the amount of material removal impact the magnitude and trend of the distortion. These details can be input into the machining template to model the various machining options. DEFORM can then be used to model these various machining pass alternatives to determine their impact on machining distortion.

Multiple fixtures can be defined in the template, and the effect of fixture loading and unloading is considered in the machining distortion prediction. As the simulation steps through multiple machining passes, the changes in part geometry and residual stress distribution are carried over. This allows the user to visualize the intermediate as well as final machining distortion patterns. This is shown in the images at the top of the next page.

Events:

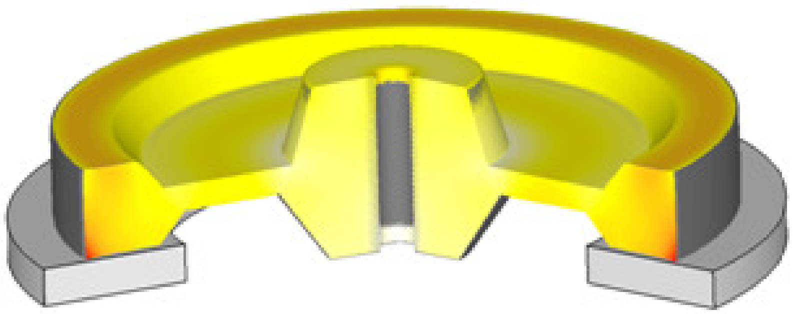
- May 3, 2011: DEFORM Distributors meeting will be held in Naples, Florida.
- May 4 & 5, 2011: The U.S. DEFORM User Group Meeting will be held at the Naples Grande Beach Resort in Naples, Florida in conjunction with the DEFORM Distributors Meeting.
- May 23-25, 2011: SFTC will exhibit DEFORM at Aeromat 2011 in Long Beach, California.

Training:

- February 8 & 9, 2011: DEFORM-2D training (includes DEFORM-F2) will be conducted at the SFTC office.
- February 10 & 11, 2011: DEFORM-3D training (includes DEFORM-F3) will be conducted at the SFTC office.
- April 12 & 13, 2011: DEFORM-2D training (includes DEFORM-F2) will be conducted at the SFTC office.
- April 14 & 15, 2011: DEFORM-3D training (includes DEFORM-F3) will be conducted at the SFTC office.
- May 5 & 6, 2011: DEFORM Advanced Training will be held in conjunction with the Spring User Group Meeting in Naples, Florida.

DEFORM™

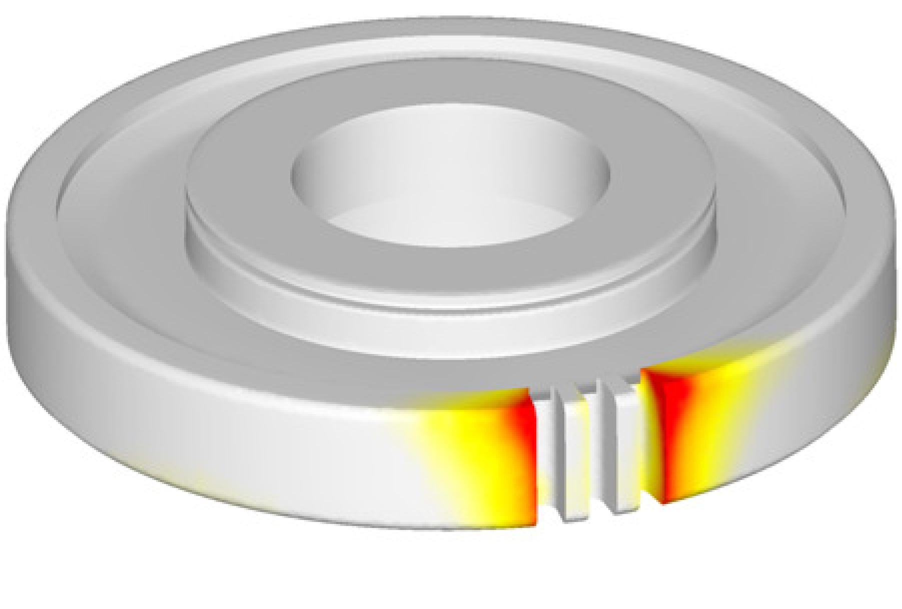
Design Environment for FORMing



The upper image shows the distortion that occurs during an intermediate machining pass, while the lower image displays the distortion in the final pass.

For typical axisymmetric jet engine components, a 2D machining distortion analysis would suffice. By considering prior processing-induced residual stresses in the component, along with machining pass sequences and fixture locations, DEFORM industrial users are able to predict machining distortion accurately, since the most important components of residual stress are accounted for. This has been validated against production experience by leading DEFORM Users.

2D machining distortion models have matured to the extent they are applicable for a production environment. For complex components such as airframe structures, 3D machining distortion modeling is required. While 3D machining distortion is available in DEFORM-3D, applications would be most suited to simple geometry. The image below shows the distortion in a 3D disk due to the milling of three slots. Note the large distortion (red) causing the top of the rim to cave in towards the central teeth. For modeling very thin sections of complex air frame parts, cutting induced residual stresses, which are currently not considered, may play a significant role. SFTC is currently in an on-going effort to improve and enhance the 3D machining distortion capability of DEFORM.



Releases:

DEFORM v10.2 and v11.0 (beta) are planned for release in the first half of 2011. Planned improvements include:

- Systems will be built using Absoft f90 v11.0 compiler for improved performance.
- More stable and efficient Mpich2 libraries are used for parallel runs in multi CPU environments.
- 64 bit FEM systems will include support for user routines for both Linux and PC environments.
- The 3D geometry tool has been enhanced.
- There will be improved handling of parallel FEM runs on clusters.
- Improvements have been made in CG solver handling convergence issues in the thermal solution.
- Improvements in 2D-3D converter to handle phase transformation data have been made.
- Facilities to import PATRAN data into DEFORM are now available.
- Mesoscale modeling facilities and resistance heating in 3D have been implemented.
- Induction heating functionality to handle dual frequencies has been implemented.
- Windows 7, CentOS 5.5 Linux and Suse Enterprise Linux will be supported.
- Enhanced 3D extrusion module and the corresponding improvements in the FEM engine (v11.0 beta) have been made.
- A 3D flowform module will be able to handle an ALE mesh system with up to four forming rolls (v11.0 beta).
- Procedures will be developed to carry out optimization runs in 3D (v11.0 beta).
- Batch post processing will be added (v11.0 beta).

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