StressCheck

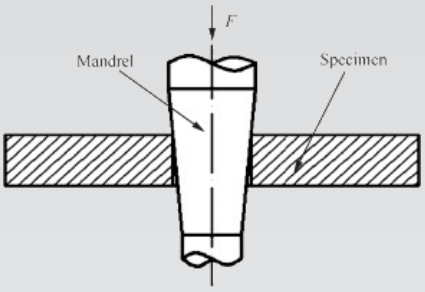
COLD WORKED HOLE ANALYSIS

Advanced CX Analysis Features

Representing cold working processes is a must for any structural integrity engineer: mandrel insertion, removal and subsequent reloading/unloading of holes to evaluate residual stresses due to CX (cold expansion) of holes is a key feature of StressCheck®.

The cold worked hole analysis capabilities of StressCheck were developed in response to demand by the aerospace industry. Conventional FEA-based techniques were time consuming and error prone, and others were based on limited closed-form approximations. These did not account for the variety of situations that appear in real structural components. With StressCheck you can accurately predict residual stresses due to cold working complex parts.

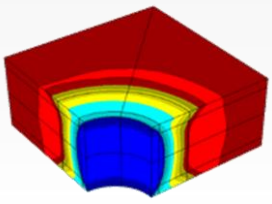
StressCheck delivers state of the art cold work functionality with three objectives: reliability, flexibility and efficiency. Simple cold worked hole analysis (single hole, no reverse plasticity) can be performed using the 2D Coldworking Analysis module. For analysis of multiple holes and/or reverse plasticity, users may define any number of CX events to be solved by the Nonlinear Analysis module. Whether you are supporting an aging fleet of aircraft or performing up-front design, StressCheck's cold worked hole features will provide you with robust and reliable simulations. You can now accurately predict residual stresses in complex structural joints in a timely manner, leading to improved fatigue life predictions for interference fit fasteners and cold-expanded holes.



"The addition of incremental theory of plasticity in StressCheck has greatly improved our ability to accurately predict the fatigue life of joints with interference fit fasteners and cold worked holes. This ability is especially important, not only in support of maintaining aging aircraft but also in analyzing some of the new cold working techniques that have been introduced in recent years.

Prior to this implementation, analysts often relied on closed-form approximations or simple factors that were often overly conservative and sometimes even unconservative when used in life prediction. Now, not only can we more accurately predict residual stresses in these complex structural joints, but we can also do so in a timely manner given the modeling and analysis efficiency that exists with a p-version FEA code such as StressCheck."

The Boeing Company



StressCheck

A powerful, reliable tool for detailed stress analysis of cold working methods in the industry – from unique modeling capabilities, to advanced analysis technology, to powerful post-processing functions. Only StressCheck® brings this power to you in an easy-to-use framework. See why StressCheck can be one of the most important tools in your design and analysis toolbox.

COLD WORKED HOLE ANALYSIS OVERVIEW

The cold worked hole analysis capabilities implemented in StressCheck were developed with three objectives in mind:

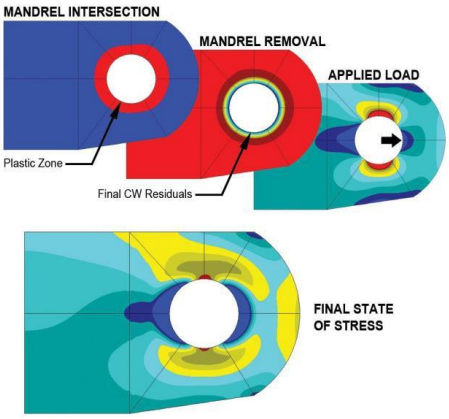
1. **Reliability:** Provide verified solutions for the residual stresses at each step of the cold working operation.
2. **Flexibility:**
   a. An ease-of-use module for simple analysis: Provide for the standardization of cold working process simulation, so that persons who do not have expertise in FEA can safely and reliably perform simulation.
   b. A powerful implementation for advanced analysis: Using incremental theory of plasticity cold work of multiple holes can be analyzed for simultaneous or sequential cold working. Also, reverse plasticity and additional plasticity caused by sequential loads is captured.
3. **Efficiency:** Minimize the solution time to the maximum extent possible.

With StressCheck you can estimate residual stresses caused by loading into the plastic range, followed by unloading, using either the deformation theory of plasticity or the incremental theory of plasticity. The deformation theory of plasticity is applicable only when the unloading does not produce plastic strains, otherwise incremental theory should be used. StressCheck will automatically issue a warning if you selected the deformation theory and reverse plasticity is detected. This choice of theory option empowers you to select the simplest model that will satisfy the goals of analysis. This is because StressCheck implements a hierarchic modeling framework: each model is viewed as a special case of a more comprehensive and therefore more complicated model. In cold working, for example, the use of the deformation theory of plasticity, coupled with linear superposition, is practical when reverse plasticity is not present. This is much simpler than the much more comprehensive incremental theory of plasticity, which introduces options such as isotropic or kinematic hardening laws. StressCheck provides you with both choices.

StressCheck's cold working capabilities are available in the Cold Work Analysis module and the Nonlinear Analysis module. The Cold Work Analysis module provides a simple interface, based on the deformation theory of plasticity, for analyzing a single cold worked hole in a 2D setting, while the Nonlinear Analysis module allows for multiple cold worked holes in 2D and 3D.

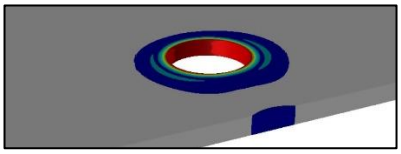
The **Cold Work Analysis module** utilizes superposition to combine the effects of the loads and constraints with the effects of the cold working operation. The following steps describe a typical cold working analysis:

- Determination of the plastic zone due to mandrel insertion.
- Determination of the residual stresses due to mandrel removal.
- The solution corresponding to any specified loads.
- The combined solution, utilizing superposition, of the residual stresses and the specified loads.

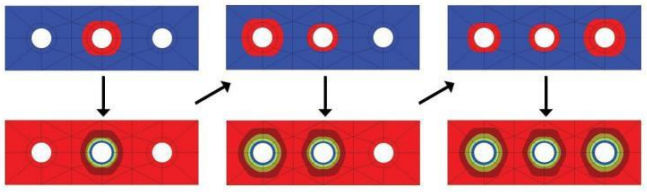


For more complex cold worked hole applications, StressCheck's **Nonlinear Analysis module**, which also incorporates the incremental theory of plasticity (ITP) and nonlinear event sequences, can analyze the following:

- Cold working of multiple holes in 2D or 3D.
- Multiple loading and unloading events.
- The effects of reverse plasticity using isotropic or kinematic hardening.
- The hardening behavior of typical engineering materials.
- Applying fastener loads with different materials for the fasteners after cold working.



The Nonlinear Analysis module supports the analysis of much more complex cold working problems. The effects of various mandrel loading/unloading and applied load scenarios can be analyzed. Superposition is not used, rather the stress distribution is determined by incremental analysis. You can analyze the effects of cold working of multiple holes and determine the optimal order in which the holes should be cold worked. For example, the effect of cold working the middle hole, then the left, and finally the right holes is shown below.



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