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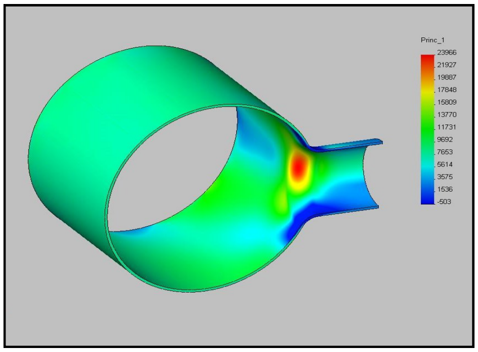
Finite Element Analysis and Computational Mechanics



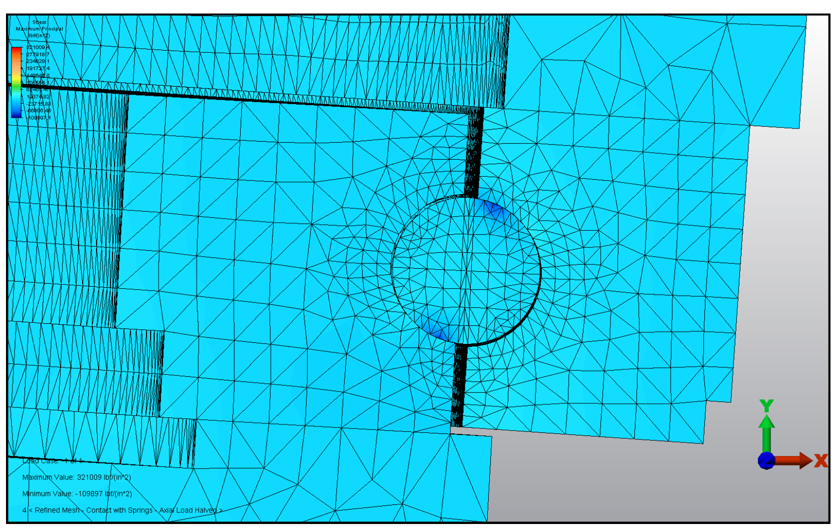
- **Evaluate Design Adequacy of New Equipment**
- **Evaluate Fitness-for-Service of Existing Equipment**
- **Supplement Failure Analysis to Determine Root Causes and Engineer Optimum Repair Solutions**
- **Provide Quick, Practical, Cost-Effective Solutions**

M&M Engineering Associates has used finite element analysis (FEA) to analyze pressure vessels, piping, tanks, turbines, and other industrial equipment and components. FEA is a practical method to assess and accurately evaluate equipment and process interaction.

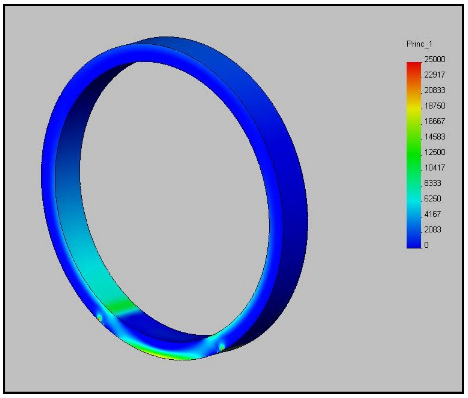
M&M Engineering uses advanced analysis techniques to provide quick turnaround solutions to critical industry problems, which can save clients time and money in avoided repairs, reduced business interruption, and improved reliability.

The use of conventional tools to determine equipment fitness-for-service (FFS) often results in overly conservative assessments, which can then lead to unnecessary repairs, replacements, or non-optimum equipment operation. M&M Engineering specializes in evaluating a wide range of pressure containing equipment and structures using advanced analytic techniques including linear and nonlinear, static and dynamic analyses. In addition to FEA, M&M Engineering utilizes other advanced analytical tools to perform piping analysis, fitness-for-service, and numerical fracture mechanics analysis.

FEA utilizes a computer model of a component or assembly that is usually stressed and analyzed for specific results such as deflection or stress intensity. FEA is most commonly used for new product design or product refinement. However, using FEA to determine or verify failure scenarios is equally practical.



FEA can be done using 2-D modeling or 3-D modeling. 2-D modeling requires less computer resources and allows the analysis to be performed faster. However, interpretation of the data tends to be trickier. 3-D modeling requires significantly more computer resources; however, it produces results that are more visually meaningful. 2-D modeling or 3-D modeling can be either linear or non-linear.



Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and are capable of testing a material all the way to fracture.

FEA uses a complex system of points called *nodes* which make a grid called a *mesh*. The mesh is programmed to contain the material properties that define the stiffness of the structure under loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions of higher stress usually are given a higher node density (tighter grid) than those regions of little or no stress.

There are multiple loading conditions that may be applied to a FEA model. These include point load, pressure, gravity, centrifugal loads, forced displacements, thermal loads, heat flux, and convection, all of which can either be static (constant) or dynamic (variable).

Case Study 1

A paper mill wanted to determine if their "as design" reel spools were capable of increased capacity of linerboard and paper medium accumulated on the reel spools. M&M Engineering performed an evaluation of the reel spools using FEA to determine if the increased load was acceptable.

The FEA model indicated tha increasing the capacity of linerboard overstressed the spool journals by approximately 13% making operation of the reel spool under this loading condition not recommended due to the potential for bending fatigue failure. However, the analysis determined that operation with increased accumulation of paper medium was acceptable.

Case Study 2

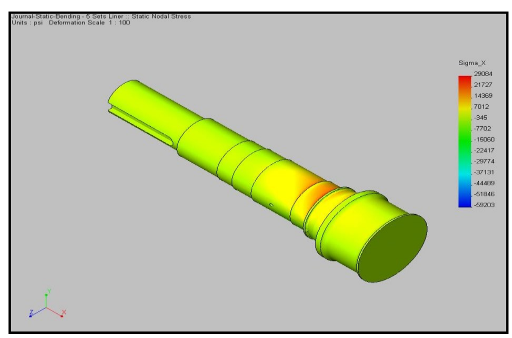
A Plant's previous steam distribution line had failures that were determined to be due to thermal fatigue. These cracks were located at tees and branches near the attemporator nozzles. During operation of the previous steam distribution header, temperature gradients of 200°F around the circumference of the pipe were noted, in particular, downstream of the attemporator nozzles. The main conclusion made by plant personnel was that the steam line was not long enough to promote thorough mixing of the steam and attemporator spray, which resulted in the observed temperature gradients and contributed to the thermal fatigue cracks. Based upon this conclusion, the steam distribution line was lengthened to allow for better mixing of the attemporator spray before reaching a branch or tee. After start-up of the redesigned steam header, temperature measurements identified a circumferential thermal gradient similar to what had been noted in the original header.

M&M Engineering performed a stress analysis on two areas of the steam distribution header that focused on the increased stresses induced by the thermal gradient. FEA determined that the increase in stress due to thermal strain was not significant as to cause alarm under static conditions or cyclical conditions.

Case Study 3

A mill had experienced kiln riding ring failures that were nearly identical. The mechanism of the failure was understood but the root cause of the cracking was not, leaving the remaining riding rings on other kilns suspect. In particular, the mill wanted to know the length of time for cracks to initiate and propagate leading to failure.

M&M Engineering created a three-dimensional model of the kiln riding ring to evaluate the stresses in the ring due to standard operation. According to the results, the peak stresses on the internal surface occur at the two locations tangential to the roller supports. The peak stresses were then utilized in crack propagation calculations to estimate the time for a crack to initiate at a flaw, such as a gouge, and propagate to the critical crack size resulting in ultimate failure.



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