Pressure Vessel FEA Consulting Services

ASME Section VIII, Division 2 Design-By-Analysis: Elastic-Plastic Analysis

The ASME code provides significant leeway in the classification of pressure vessels as fit-for-service within the Section VIII, Division 2 code. In this case study, interior, load-bearing structural components were failing under the standard linear stress design-by-analysis classification methods. Upon closer inspection of the stress results, it was noted that the non-complying high stress regions were localized and that the surrounding steel had stresses mostly below the yield stress of the material. This combination opened the door for another route toward classification of the pressure vessel, namely via Elastic-Plastic Analysis and Protection Against Plastic Collapse (see ASME BPVC VIII 2 Chapter 5.2 and Table 5.5). The application of this procedure is straightforward as: i.) scale all mechanical loads by 2.4; ii) set material behavior as elastic, perfectly plastic (most conservative approach); iii) include all nonlinear behavior in model involving contact and plastic deformation of the material; and iv) statically solve the model and verify that it can statically withstand the loading with no global or local collapse. We'll walk through our procedure and show a few of the results that one might expect to see in other applications of this technique.

Note: This FEA consulting services project was part of a much larger project involving very large vessels used to treat noxious organic glasses generated within common industrial processes.

ASME Section VIII, Division 2 Design-By-Analysis Fit-For-Service by Elastic-Plastic Analysis

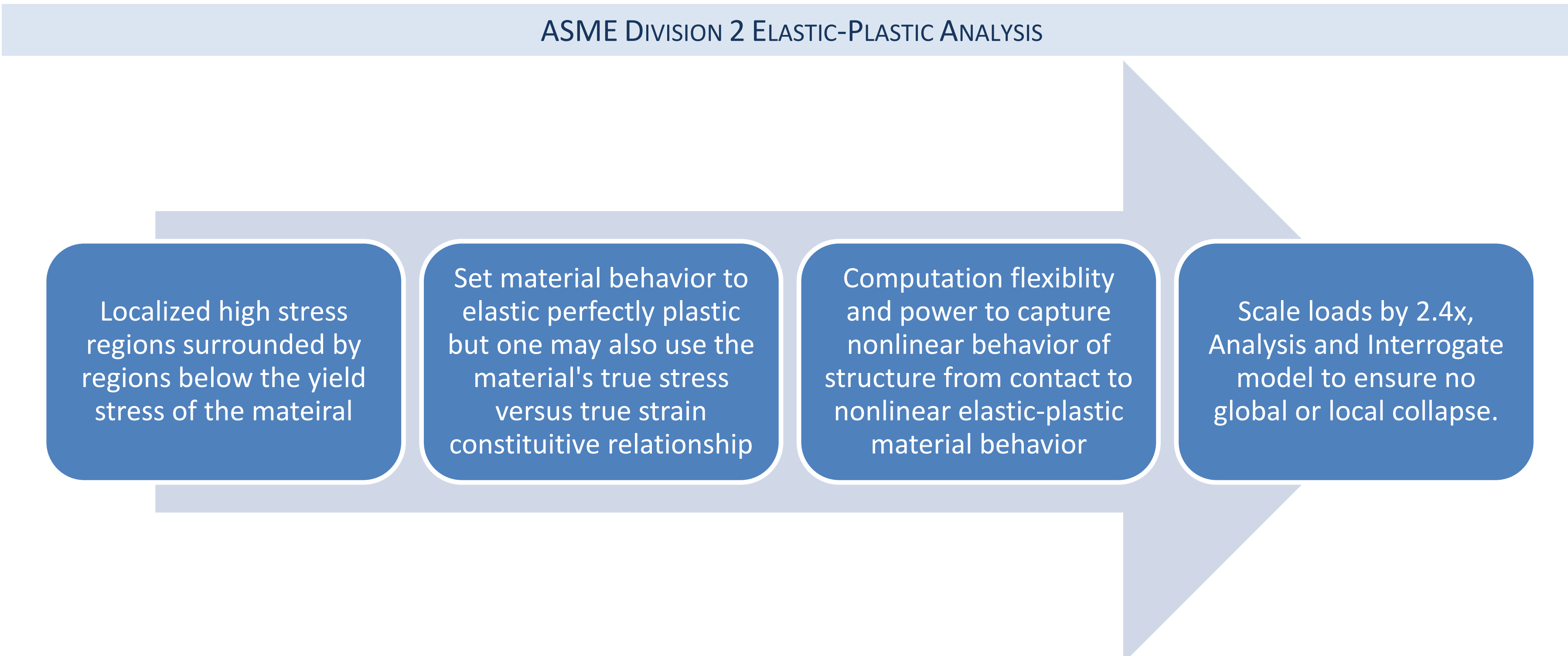


Figure 1: ASME Section VIII, Division 2 Plastic Analysis – How it Works

This technique is not applicable to all BPVC applications. The key requirement is that the high stress region (stress exceeding the yield stress of the material) is localized and is surrounded by regions of material with stresses under the yield stress. This provides a measure of confidence that when the model is run as elastic-plastic, localized plastic flow will occur but stay contained within this region and not spread to such an extent to cause collapse. Nevertheless, every structure or vessel is unique and such rules-of-thumb are only just that, guidelines that can provide the analyst with some confidence moving forward.

FEA Engineering Application of Design-By-Analysis via Elastic-Plastic Analysis

Engineering Application of Elastic-Plastic Analysis

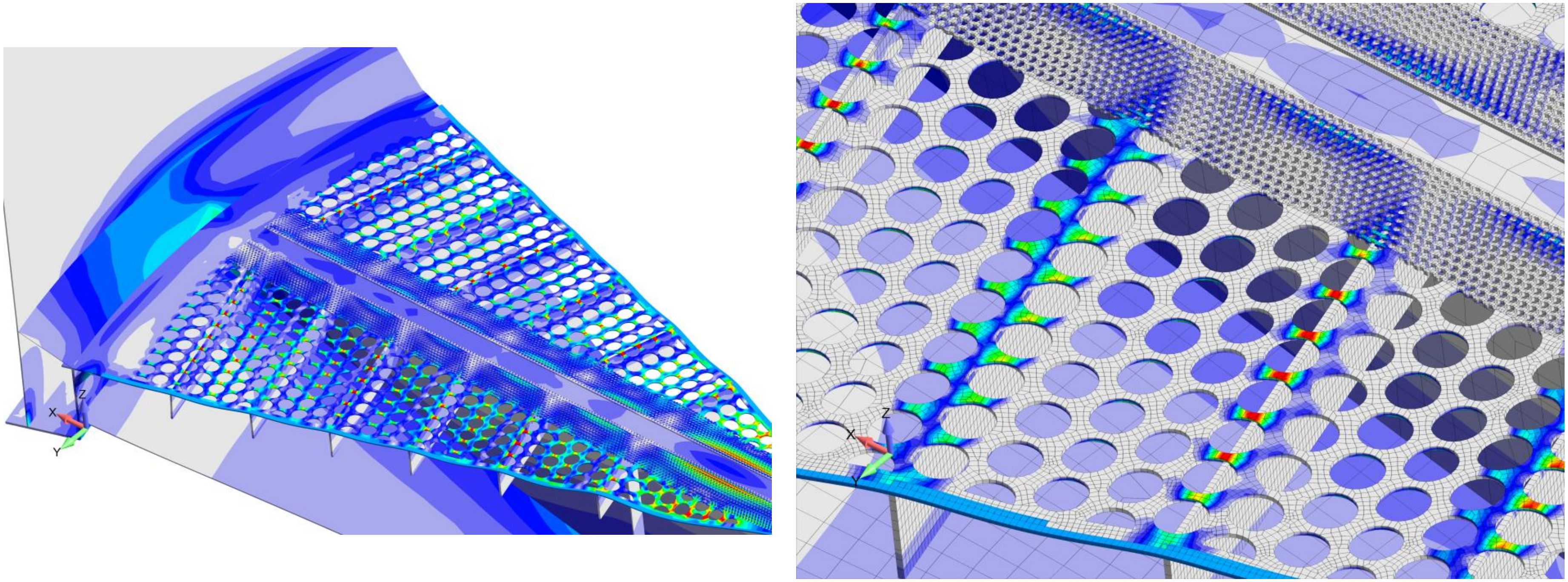
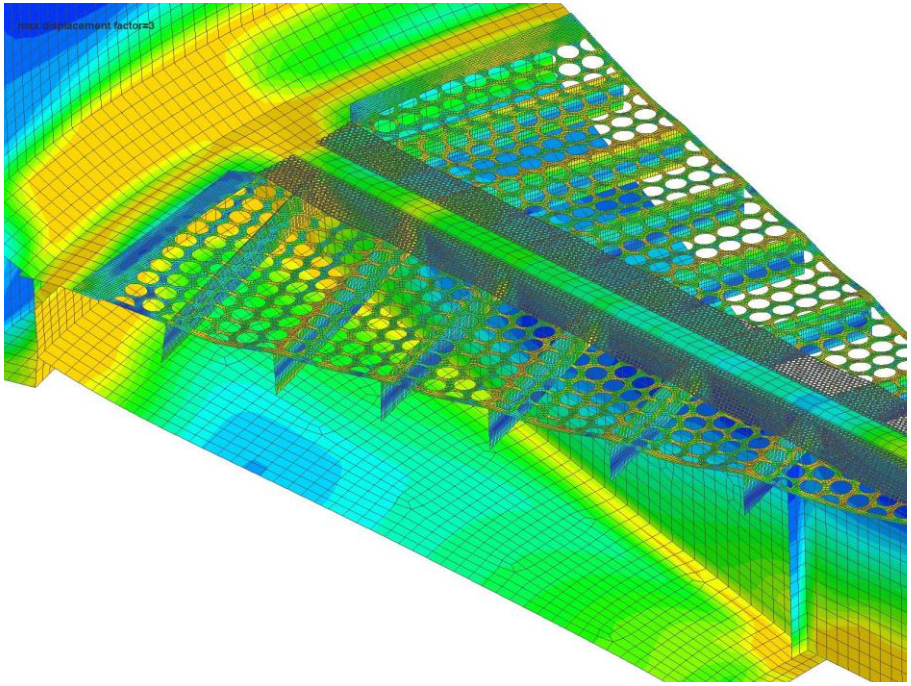


Figure 2: Example of engineering application of design-by-analysis of BPVC elastic-plastic analysis

In this example, an interior support structure shows localized high stress regions that are surrounded by much lower stressed regions. This type of structure provides a good opportunity for an elastic-plastic analysis since it is most likely to work and justify the investment in engineering analysis time as versus redesigning the structure with heavier plate.

FEA Engineering Application of ASME Division 2 Elastic-Plastic Analysis with LS-DYNA

LS-DYNA NONLINEAR IMPLICIT ANALYSIS (CONTACT AND ELASTIC-PLASTIC MATERIAL BEHAVIOR)



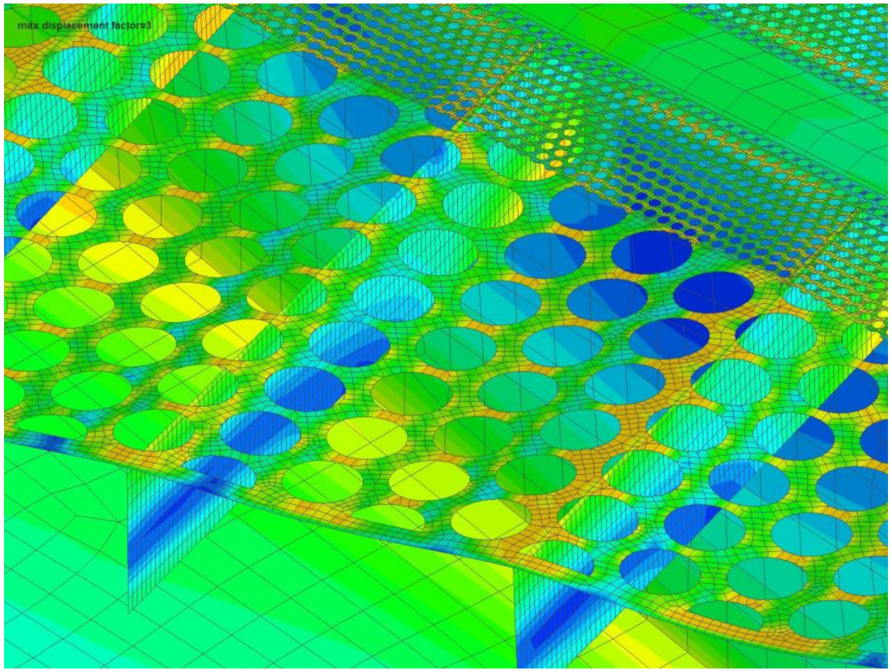


Figure 3: LS-DYNA analysis of model with loads scaled by 2.4x

As the steel plastically deforms, the stresses become more uniform and the high stress regions disappear or plastically dissipate into the surrounding material. If the structure is stable both globally and locally under the scaled loads, then it is considered to meet the ASME Section VIII, Division 2 classification requirements.

By employing this more complicated analysis technique the client avoided having to redesign their structure and importantly, having to incur unnecessary construction costs. This is one of the advantages of using the design-by-analysis provisions within the ASME BPVC code such that the pressure vessel is optimized to meet the classification requirements with minimal materials and costs.