Pressure Vessel FEA Consulting Services

ASME Section VIII, Division 2 Fatigue Analysis of Pressure Vessels and Heat Exchangers

Within the ASME Section VIII, Division 2 code, the design-by-analysis requirement provides significant flexibility to ensure that non-standard designs will be safe for service. In particular, the fatigue requirement has seen significant changes over the years. Predictive Engineering’s FEA consulting services have continued to evolve over the years and to address the more complex requirements of the code, we have developed our own fatigue analysis software that is marketed under the name Fatigue Essentials. In current work, we have leveraged Fatigue Essentials to demonstrate compliance with the ASME fatigue code specifications. One example is a basic multi-chamber pressure vessel while the other is a more complex thermal-stress analysis of an evaporative heat exchanger that is has several large bolted flanges. In both cases, the analysis results showed that the vessels met the core mechanical requirements and also the more stringent fatigue requirements.
ASME Section VIII, Division 2 Fatigue Analysis of Multi-Chamber Pressure Vessel

Figure 1: Fatigue Essentials workflow to meet the ASME fatigue requirements under ASME Section VIII, Division 2

The work flow process for a fatigue analysis starts with a description of the load and their cycles. With this in hand, the rainflow counting method can be constructed within Fatigue Essentials. A stress versus cycle to failure relationship is then determined (data from the ASME code) and given high quality stress results, the fatigue damage can be calculated.
Multi-Chamber Pressure Vessel Stress Results to ASME Weld Fatigue Damage Verification

Figure 2: Given stress results and ASME fatigue reduction factors – the weld fatigue life can be calculated

Basic ASME fatigue work is somewhat like accounting. One starts with clear understanding of the stress state of the vessel and then apply various corrections or adjustments, multiply some numbers and the fatigue damage can be calculated. Predictive Engineering has over 15 years’ experience with the ASME Section VIII, Division 2 code with respect to fatigue and it can still be challenging to correctly interpret the code such that a vessel can be shown to pass.
Figure 3: The large bolted flanges on the heat exchanger were fully modeled with bolt preload and contact between parts using LS-DYNA

To capture the correct mechanical stress in the heat exchanger prior to the application of the thermal loads, it was necessary to model the bolt preload effects of the large flanges clamping against the other structural components of the locking rings and tubesheet channel. A nonlinear implicit analysis was done using LS-DYNA and confirmed that the tubesheet intersection to shell region was not affected by bolt preload clamping stresses.
Steady-State Thermal Analysis to Thermal-Stress to ASME Fatigue Analysis of Evaporator Vessel

Figure 4: Thermal Analysis to Thermal-Stress to ASME Section VIII, Division 2 Fatigue Analysis

The analysis workflow starts with a steady-state conduction analysis using Nastran and then mapping these temperatures onto the LS-DYNA model within FEMAP. With temperature and bolt preloads, a nonlinear analysis with contact was done to capture the final stress state in the heat exchanger. Stress results were then used to calculate the fatigue life of the vessel using the 2015 ASME Section VIII, Division 2 fatigue procedures. Results showed that the evaporative heat exchanger would pass with margin.