January 2020

WELDED STRUCTURE FATIGUE ANALYSIS

DJH Engineering Technical Newsletter

DJH engineering center, inc. INTERNATIONAL
QUALITY MANAGEMNT SYSTEM
ISO 9001:2015
CERTIFIED

In this issue:

Common Welded Structure Design Challenges

The most common challenges we hear from our customers who are struggling to design optimized welded structures are:

1. Inability to predict life of weldment using virtual tools.
2. Structure durability is limited by welded joints.
3. Inability to reduce weight / cost (ie material thickness, high strength steels, etc) due to failures in welded joints.

Fatigue Analysis Introduction

The method of fatigue analysis performed by DJHEC takes finite element analysis (FEA) to the next level by accurately predicting a structure or components cycles to failure.

Instead of iterating individual load cases based on the stress, strain, and displacement, several load case events are combined into a duty cycle to determine the summation of damage. The output of the analysis is a plot not of stress or strain, but rather a plot of B10 or B50 life.

This process reduces analysis time and significantly shortens the number of iterations required to meet the structures design specifications. DJHEC frequently utilizes this process to reduce our customers product development cycle times.

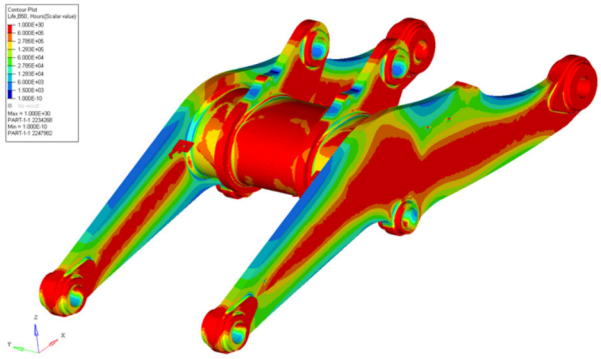

Figure 1. Fatigue Contour Plot of Loader Boom. Contour plot is B10 life of composite of multiple load cases.

Welding Challenges

Welding is an economical way to fabricate strong joints on a metal structure by using high heat to melt the metal structure together. The high heat changes the base materials properties in the area surrounding the weld (weld toe or heat affected zone). These property changes (residual stress and reduced material strength) within the weld toe are usually undesirable and can have a negative impact on the fatigue strength of the structure. As a result of these property changes the welded joints tend to be the critical failure point and most susceptible to fatigue.

Weld Fatigue Analysis Process

Fatigue analysis of a welded structure begins with the development of a FEA model with load cases that represent the stress/strain seen in the structure or product application. The load cases and duty cycle are created to simulate operations done by the structure over a given amount of time. Life in a structure is predicted using the strain-life curve of a given material and the duty cycle. When defining the material properties, it is important to properly define the fatigue notch factor (K_f), and residual stress offset. Because a small change in K_f can have large impact to the predicted life, it is important to take in account tensor direction, weld type, and surface treatment. To improve the accuracy of fatigue life predictions it is important to correlate FEA results with testing .

Options to Improve Welded Structure Life

There are many simple design practices that can be implemented to reduce the stress concentrations in a structure and improve fatigue life. Weld placement is key to the joints survival: placing welds outside of high stress areas can greatly improve weld life. Modifying the structures' geometry to pull stress from a welded joint into an edge is also another way to increase life. An example of the effect of a relief near a weld joint can be seen in Figures 2 and 3. In addition to good design applications, many weld toe treatment options are available. These treatments work by reducing the stress concentrations at the weld toe. High frequency impact treatment (HFMI) for example introduces compressive residual forces at the weld toe by hammering the toe with a hardened pin at a high frequency. The compressive residual stresses are favorable for fatigue strength. Follow on testing of welded joints with HFMI have shown over 4-8x life improvements. This process can be an ideal solution if weight reduction and cost savings offset the cost of HFMI.

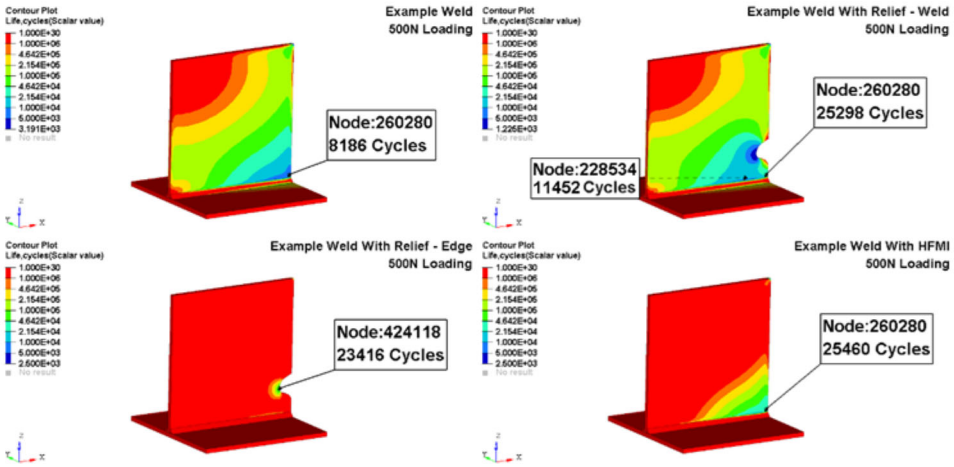

Figure 2. Predicted Fatigue Cycle Count of Simple Weld

40% Life Increase With Relief & over 200% Life Increase with HFMI

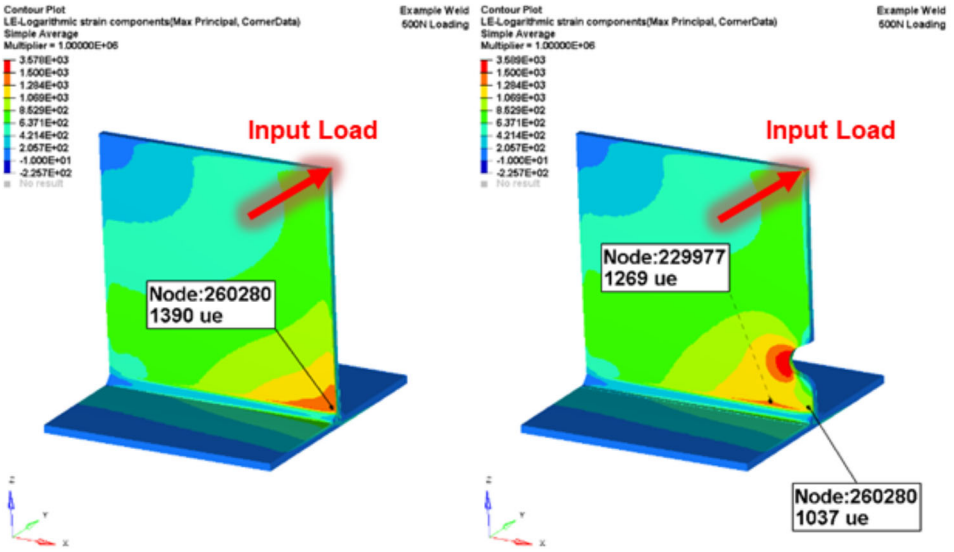

Figure 3. Simple Weld Strain Reduction with Relief