

What is a Stress Intensification Factor (SIF)?

A stress intensification factor is a multiplier on nominal stress for typically bend and intersection components so that the effect of geometry and welding can be considered in a beam analysis.

Stress Intensification Factors (SIFs) form the basis of most stress analysis of piping systems.

The stress intensification factor is used in a pipe stress analysis as shown in the equation below:

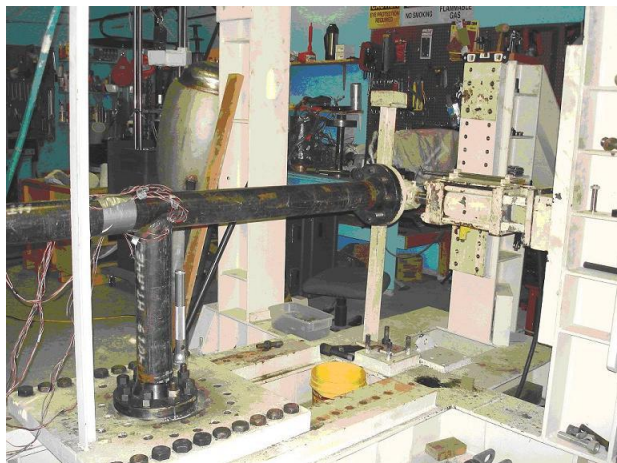
$$(\text{Beam Stress})(\text{SIF}) < (\text{Allowable Stress})$$

Expanding the terms gives the following equation using the SIF:

$$(M/Z)(\text{SIF}) < 6N^{-0.2}(1.25(S_c + S_h) - S_l)$$

SIFs are obtained from tests and equations written to extend the usefulness of the tests. The Markl machine is the standard machine used to develop SIFs.

First mount the water-filled specimen to be tested in a Markl machine as shown below at PRG in Houston.



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What is a SIF?

Cycle the specimen back and forth until water leaks from a crack as shown below.

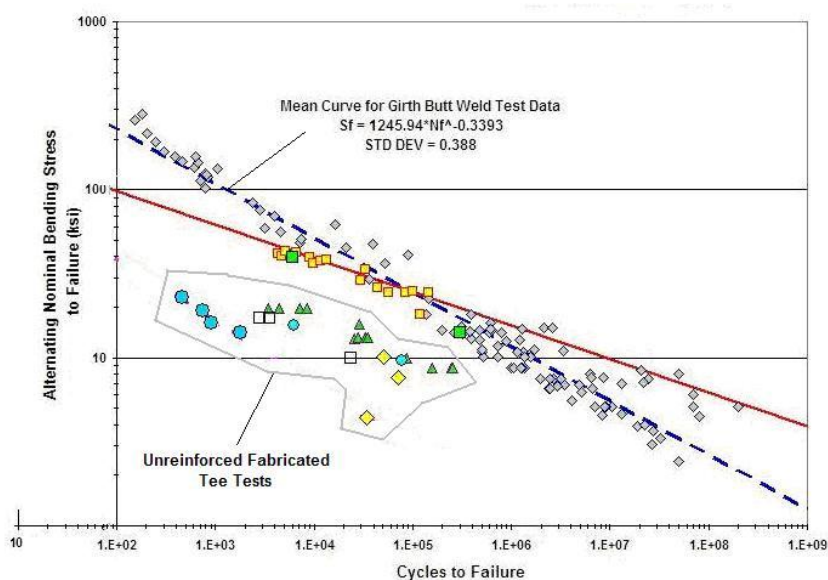


Multiply the displacement used in the test by the linear stiffness of the specimen to get the linear force used in the test.

Multiply the linear force used in the test by the distance between the point of application of the force and the point where water started coming out of the failed specimen. This product is the linear moment used in the test.

Divide the linear moment used in the test by the section modulus of the matching pipe to get the nominal failure stress.

Put the nominal failure stress on a graph with other failure points as shown below.



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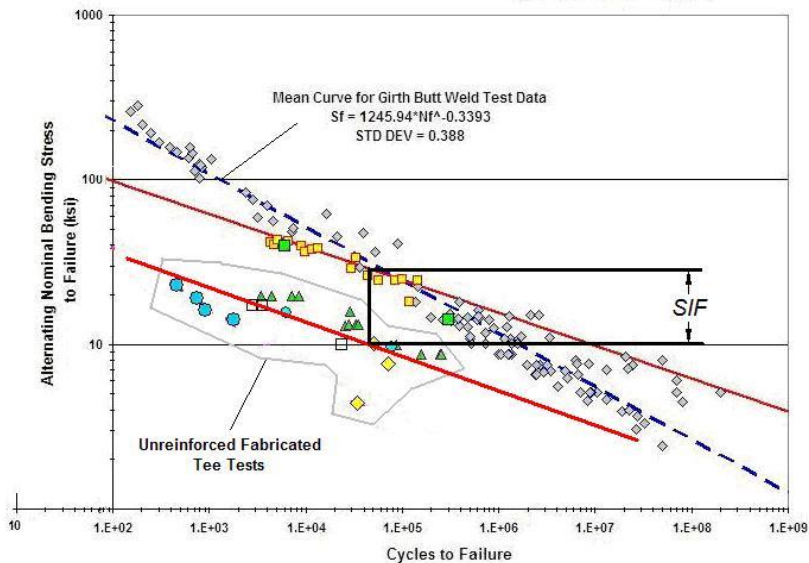
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What is a SIF?

Use the nominal failure stress as calculated above and the number of cycles of displacement until water began to leak from the test.

Fit a straight line through the test data points with a slope of -0.2 on a log log plot, and find the test SIF as the ratio of the Markl girth butt weld straight line and the test data point straight line. (See the diagram on the next page. Real SIF generation is considerably more complicated, although the basic concepts are the same.)



Since the measured SIF is typically only for a single 4 inch geometry, an equation must be developed for other pipe sizes so that the SIF can be used in a pipe stress program.

The equation should include properties of the geometry – typically nozzle diameter (d), nozzle thickness (t), vessel diameter (D), vessel thickness (T), etc. A typical form for a SIF equation is:

$$SIF = (C_0)(d/D)^a (D/T)^b (t/T)^c$$

This equation would be used when the pipe stress program is run to determine the SIF for the system being analyzed.

When finding SIFs from an FEA calculation first benchmark the boundary condition and intersection model being used against the test data. WRC 335 can be used as a source for many existing SIF tests.

Once the FEA approach is validated, the SIF can be found from:

For shell elements:

$$SIF = (\text{Membrane+Bending Stress Intensity from FEA})(FSRF) / [(2)(M/Z)]$$

For brick elements:

$$SIF = (\text{Maximum Nonsingularity Stress Intensity}) / [(2)(M/Z)]$$

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Membrane + Bending Stress Intensity is $P_I + P_b + Q$ in the ASME Code. M/Z is the nominal bending stress in the matching pipe at the point of failure. M is the applied moment in the finite element model.

FESIF performs the finite element calculation automatically for the user's entered geometry.

B31.3-2006 Appendix D Table D300 Note 12 States:

"The out-of-plane stress intensification factor (SIF) for a reducing branch connection with branch-to-run diameter ratio of $0.5 < d/D < 1.0$ may be nonconservative. A smooth concave weld contour has been shown to reduce the SIF. Selection of the appropriate SIF is the designer's responsibility."

"The effective SIF is the designer's responsibility."

When $0.5 < d/D < 1.0$ the designer should check to see about how nonconservative the Appendix D approach is when the stress state is critical.

Noncyclic conditions, i.e. cycles less than 1000, or very low stress states do not require further inspection. Cyclic, highly loaded intersections should be checked using FEA or test.

Note that flexibilities can easily produce larger errors in stress calculations than SIFs.

FESIF computes both flexibilities and SIFs.