Swagelok

Product Test Report

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TITLE

Rotary Flexure Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following stainless steel Swagelok tube fittings were tested with stainless steel tubing. Each tubing size was represented with a minimum of 4 samples.

The following data sets include product tested 2013 through 2015.

Ordering Number	**Form**	**Tubing Size**	**Tubing Hardness** HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.028	86
SS-600-1-4	Bar stock	3/8 × 0.035	84
SS-810-1-4	Bar stock	1/2 × 0.035	81
SS-1010-1-8	Bar stock	5/8 × 0.049	84
SS-1210-1-8	Bar stock	3/4 × 0.049	79
SS-1410-1-8	Bar stock	7/8 × 0.049	78
SS-1610-1-8	Bar stock	1 × 0.065	78
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 0.8	80
SS-10M0-1-4	Bar stock	10 × 1.0	83
SS-12M0-1-4	Bar stock	12 × 1.0	86
SS-14M0-1-8	Bar stock	14 × 1.0	78
SS-15M0-1-8	Bar stock	15 × 1.0	78
SS-16M0-1-8	Bar stock	16 × 1.2	82
SS-18M0-1-8	Bar stock	18 × 1.2	79
SS-20M0-1-8	Bar stock	20 × 1.2	80
SS-22M0-1-8	Bar stock	22 × 1.2	78
SS-25M0-1-8	Bar stock	25 × 1.8	79

PURPOSE

The assemblies were tested to observe the fatigue endurance of 316 stainless steel Swagelok tube fittings with advanced geometry back ferrules under laboratory conditions at various levels of applied alternating bending stress of the tube.

TEST CONDITIONS

Original Test Date: September 2012

- Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok tube fitting installation instructions.
- Test conducted at room temperature.

TEST METHOD

Rotary flexure testing procedures have been derived from SAE-ARP-1185. This method applies a completely reversed bending stress on the fitting connection while pressurized with hydraulic oil at the tubing working pressure. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first. ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 µin./in. peak-to-peak strain level results in frequent piping system failures. For stainless steel, the 200 µin./in. strain level calculates to an alternating stress of 2800 lb/in.^{2} (19.2 MPa). ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

The ASME BPV Code, Section III NC-3673, lists stress intensification factors for various types of fittings. For example, for certain butt-welds i = 1.0, socket welds i = 1.3 to 1.9, brazed joints i = 2.1 and pipe joints i = 2.3. The stress intensity lines, i = 1.0, 1.3, and 2.3, that are shown on the graph are based on fatigue bend testing of mild carbon steel fittings. The lines allow visual comparison to other fitting types and are defined by the following equation from the ASME BPV Code, Section III, NC-3673:

$$i \times S = 245\,000 \times N^{-0.2}$$

S = amplitude of the applied bending stress at the point of failure, (lb/in.^{2})
N = number of cycles to failure
i = stress intensification factor

The following procedure was followed:

1. Each test sample was attached to a rotary flex test stand. Refer to figure 1.

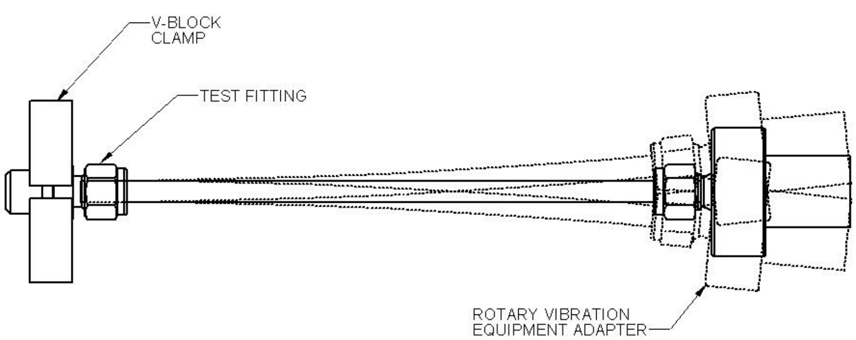


Figure 1

2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate a stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.
3. The alternating bending stress was computed from the actual measured flexure strain in the tubing (1/2 of alternating peak-to-peak flexure range).

Table 1	
Nominal Alternating Bending Stress① lb/in.^{2} (MPa)	**Samples Tested**
20 000 (137.8)	154
15 000 (103.3)	154
10 000 (68.9)	154
TOTAL	**462**

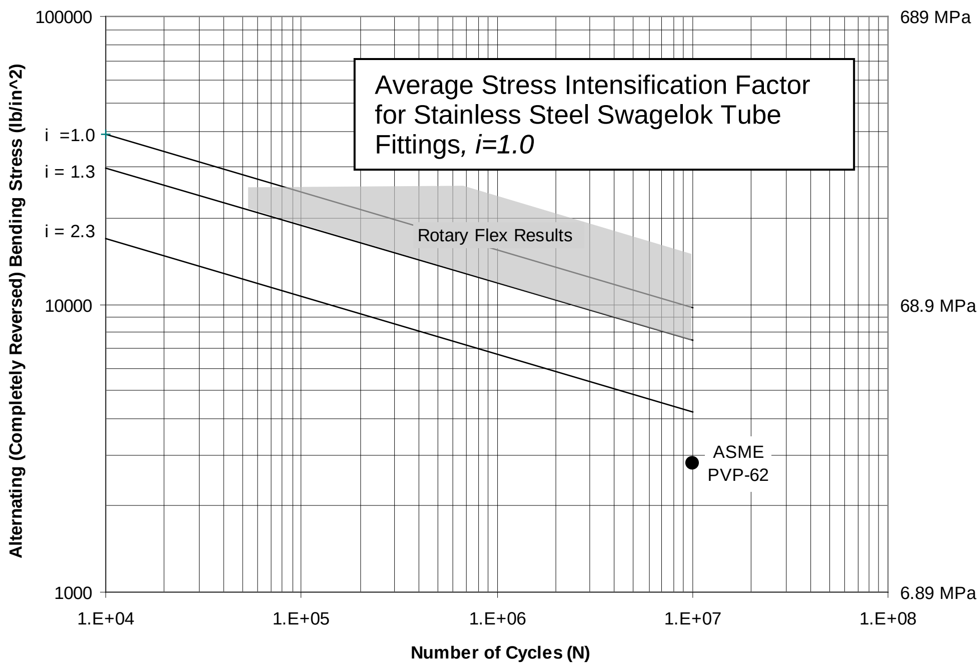
① Zero to Peak stress

4. Test samples were pressurized to the working pressure of the tube with hydraulic oil.
5. The test samples were flexed until either the fitting leaked, the tube fractured, or 10 million cycles were achieved, whichever occurred first. An in-line pressure transducer stopped the test if fitting leakage or tube fatigue fracture occurred.
6. A bending stress versus number of cycles graph (S/N) was made from the data and the results were compared to the ASME based data describe earlier.
7. Test samples pass the rotary flex test if all samples remain leak-tight over the duration of the test and demonstrate for a given bending stress the number of cycles that meets or exceeds the predicted number of cycles for fittings having a stress intensification factor of i = 1.3.

TEST RESULTS

- No fitting leakage was detected throughout the test. The test was stopped when the tube fractured or the test sample exceeded 10 million cycles.
- The shaded area of the following S/N graph envelopes the test results of the stainless steel Swagelok tube fitting rotary flex test. The shaded area is truncated at 10 million cycles to indicate testing was suspended without leakage at 10 million cycles in accordance with the test method.
- Point AMSE PVP-62 on the graph is the intersection of 2800 lb/in.^{2} (19.2 MPa) and 10 million cycles.
- The 316 stainless steel Swagelok tube fitting remained leak tight while protecting the tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of i = 1.3 as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.
- ASME B31J, *Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components,* recommends reporting the average stress intensification, *i*, factor from several tests. The average stress intensification factor for the stainless steel Swagelok Tube Fitting is *i = 1.0*

Rotary Flex Testing of Swagelok Stainless Steel Tube Fitting



These tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. Test results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

Referenced Documents:

SAE-ARP-1185, *Flexure Testing of Hydraulic Tubing Joints and Fittings,* SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

ASME *Pressure Vessel and Piping (PVP),* Vol. 62, 1982, ASME B31J-2008, *Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components* and ASME *Boiler and Pressure Vessel (BPV) Code, Section III*, 2007, ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org