The Fissure Bend Test

Careful execution of the test is emphasized to assure comparability among laboratories for establishing the relationship between fissuring tendency and ferrite level

BY C. D. LUNDIN, W. T. DeLONG AND D. F. SPOND

ABSTRACT. A new welding test known as the Fissure Bend Test was recently employed in an investigation sponsored by the Welding Research Council to establish the relationship between fissuring tendency and ferrite level for eight different austenitic stainless steel weld metals. The results of the first phase of testing were reproducible and consistent with the accepted concept of the fissuring phenomena in austenitic stainless steels.

All too often a test is developed and introduced without an adequate explanation of the test variables involved or a specified procedure established for its use. Individual laboratories using the test can then adopt their own set of variables and modify the test with the consequence that the results obtained by different laboratories are not comparable. Since the initial utilization of the Fissure Bend Test produced such promising results, it appeared that other investigators may desire to utilize the testing method in similar studies. To preclude the test proliferation without adequate initial test variable definition, a more thorough investigation of the test parameters was undertaken.

This continued investigation yielded sufficient information as to the importance of variables and a standard test procedure was devised. This article presents the standard procedure and the explanation and significance of the major test variables. Methods of data presentation are also suggested.

In addition to the application of the Fissure Bend Test as a screening test for use by electrode suppliers and fabricators, the test is also useful in studying the metallurgical phenomena surrounding the nature of fissuring. The test has logical extensions beyond the austenitic stainless steels and into the realm of fissuring in nickel base, cupro-nickel and other metallurgically similar alloys.

Introduction

Over thirty different direct* welding tests have been developed to investigate various types of cracking in austenitic stainless steels and other alloys (Ref. 1). Most of these tests were devised to evaluate one particular type of cracking problem such as base metal cracking, cold cracking, or hot cracking. Among other things, a welding test should be (1) economical, (2) simple to conduct and evaluate, (3) reproducible, and above all, (4) capable of showing a direct correlation with fabrication and service conditions. All the hot cracking tests, with the possible exception of the Varestraint Test (Refs. 2, 3) do not fulfill one or more of these criteria. However, the Varestraint Test requires special automated apparatus and finds its greatest versatility and reproducibility when utilizing the GTA process to measure the hot cracking susceptibility of autogenously melted wrought plate or previously deposited weld metal. It is more difficult to apply to directly deposited SMA, SA, and other filler metal-added processes.

Since austenitic stainless steels and other alloys that are susceptible to hot cracking or fissuring are often deposited by the SMA process as multipass welds, there was a need for developing a test to determine fissuring tendencies in multipass weldments in an economical and reproducible manner. Such a test has been developed and has become known as the Fissure Bend Test. The Fissure Bend Test has the favorable features desired in a weldability test in that it is economical, easy to conduct, reproducible, and capable of evaluating fissuring in multipass weldments very similar to those used in current fabrication procedures.

The Fissure Bend Test evolved from the electrode research programs of both the Teledyne McKay Corporation and the A. O. Smith Corporation (Refs. 4, 5). In a
Alignment Pins
or
Additional Bolts

Approx. 21"

Clamps - 6 required - 5/8" x 2" x 6" Heat treated to prevent deformation
Bolts - 6 required - Allen head cap screw, 1/2" - 13
Backup plate - Carbon steel 2" thick (min.)

Fig. 1 — Recommended clamping fixture

Fig. 2 — Fissure bend test weld pad configuration should measure about 1/4 X 1 X 8 in.
long

recent program conducted under the direction and support of the Welding Research Council, the Fissure Bend Test was successfully utilized to establish the relationship between Ferrite Number and fissuring sensitivity of eight different austenitic stainless steel weld metals (Ref. 6).

However, it is not often that the variables of a new test are thoroughly investigated or the procedures firmly established early in the development of the test. The consequence is that individual laboratories often establish their own variations of the test so that results obtained by different laboratories are not comparable. Thus it is the intention of this article to set forth the procedure for conducting the Fissure Bend Test and to explain in detail the important test variables. This will be accomplished in two parts. Part I presents the detailed procedure for conducting the Fissure Bend Test. It is anticipated that this section can be used directly by laboratories to prepare specimens and conduct the test. It is also believed that by strict adherence to this procedure results obtained by different laboratories will be directly comparable. Part II presents the details and explanation of the variables for conducting the test, and it should be sufficient for understanding the influence each variable has on the test results.

PART I
Procedure for the Conduct of the Fissure Bend Test

1. General
The Fissure Bend Test employs a multi-run, double-layer, weld pad to permit the evaluation of fissuring on relatively undiluted weld metal. The weld pad is deposited by the shielded metal-arc process on a rigidly clamped base plate as twelve 8 in. long stringer beads, six beads to each layer. The pad is then ground to produce a smooth surface for examination. The Ferrite Number of the deposit is determined on the ground surface. Examination of the pad for fissuring is conducted both before bending and after bending. For each weld pad, the relationship between the Ferrite Number and the number of fissures observed on the bent pad is developed. Data obtained in this manner permit the ranking of weld metals as to their fissuring tendency and the influence of ferrite on the fissuring behavior.

2. Test Plate Preparation and Fixturing
Cut the 304 or 304L base plates to specimen size: 1/2 in. thick, 2 in. wide, 9 in. long. Remove the scale on the base metal by grinding or grit blasting. Restrain the plates by clamping each end to a heavy backing plate to prevent excessive bowing. The clamping fixture shown in Fig. 1 can accommodate three test plates and is recommended for use. To facilitate the subsequent grinding of the specimens while still retained in this fixture, the test plates are notched on the ends. Thus the clamps will not project above the height of the ground weld pad surface.

Since the weld pad restraint technique does not appear to influence the test results, alternate methods of restraint may be used. The base plates may be fillet welded either on the ends or all-around to a heavy backup thus eliminating the need for the clamps. This, however, hinders the specimen removal for subsequent testing.

3. Welding
The welding conditions recommended below are suitable for use with 1/8 in. covered electrodes. To help maintain proper position and alignment of the first bead, scribe or punch a guide line onto the base plate. Direct the arc into the prior bead to minimize dilution from the base plate. Beads should be about 8 in. long and bead overlap should be such as to produce as flat a deposit as possible. The resulting pad should be approximately 1/4 X 1 X 8 in. with its configuration as shown in Fig. 2. A cross-section of the pad is shown in Fig. 3a. The bead sequence indicated should be followed unless double thermal cycling of beads in the top layer is desired.

The welding conditions given may have to be varied slightly depending on the electrode and the power source, but they are to be regarded as aims (redness of the flux covering is
often a better criteria than amperage; a red stub about 2 1/2 in. long should result after completing the 8 in. long bead). It is recommended that the welder produce a practice pad in order to make the adjustments necessary so that pad configuration falls within the prescribed dimensions.

**Recommended Conditions, 1/8 in. AC-DC Electrode**

- Current: 96 A dcrp
- Voltage: use good "close arc" stainless practice
- Travel speed: aim 8 ipm
- Interpass temp.: 200 °F
- Heat input: ≈ 16-17 kJ/in.

It is recognized that it may be desired to evaluate other sizes and types of electrodes and welding techniques. For welding conditions other than those given here it may be difficult to maintain the pad size recommended and/or keep six beads in each layer. To facilitate comparison of data when such variations are unavoidable, see Part II Sections 1 and 2 for recommended procedural techniques.

(NOTE: It is often advisable to determine the Ferrite Number on the as-welded pad surface. If this is desired, make the determination as outlined in Section 5 below.)

**4. Surface Preparation**

With the pads still in the clamping fixture (or fillet welded to a backup), mill the surface using a 0.010 in. depth of cut on each pass until the surface in the center 4 inches of length is clear of almost all irregularities. Then grind the pad surfaces on a surface grinder using a wheel recommended for stainless steel (do not use a cup-type grinder that leaves arc-shaped grinding scratches). A twelve pass sequence is recommended with water-soluble ink all linear indications by optical microscopy at 40-50X; then count and measure the length of those indications verified as fissures. Inspect each of these indications in the center 4 inches of the pad. These indications generally denote fissures. Inspect each of these linear indications by optical microscopy at 40-50X; then count and measure the length of those indications verified as fissures. Bend the specimen to an included angle of 120 deg in a fixture similar to the one shown in Fig. 5. Repeat the entire fissure evaluation process on the bent specimen and record the number and size of the fissures on the bent pad as was done on the unbent pad.

**5. Ferrite Number Determination**

Measure the Ferrite Number in the center 4 inches of the ground pad at a series of locations using a Magne Gage calibrated to AWS A4.2-74. It is recommended that a 15 intersection grid layout as shown in Fig. 4 be used to insure a sufficient number of determinations for computation of a statistically significant average value. The average value of the Ferrite Number is used in the development of the ferrite-fissuring relationship (see Section 7).

**6. Fissure Evaluation**

Fissure evaluation is performed in the center 4 inches of each specimen. This evaluation is a two step process: (1) fluorescent penetrant testing to detect surface indications, (2) binocular microscopic examination of these indications.

Apply a light coating of the fluorescent penetrant onto the weld pad surface. Allow a penetration time of 10-15 min to permit the penetrant to soak into all fissures and other surface discontinuities. Remove the penetrant by rinsing the weld pad for 30 s with a warm water spray wash. Dry each specimen under a warm air dryer or in a recirculating oven. Drying time should be just long enough to remove moisture from the pad surface. Allow a developing time of 10 min to permit the penetrant to exude from fissures and other surface discontinuities and then inspect the pad under a standard black light in a dark area. The indications of discontinuities will fluoresce with a brilliant yellow-green light in the darkness. Count and circle with water-soluble ink all linear indications (1) fluorescent penetrant testing to detect surface indications, (2) binocular microscopic examination of these indications. Count and circle with water-soluble ink all linear indications in the center 4 inches of the pad. These indications generally denote fissures. Inspect each of these linear indications by optical microscopy at 40-50X; then count and measure the length of those indications verified as fissures. Bend the specimen to an included angle of 120 deg in a fixture similar to the one shown in Fig. 5. Repeat the entire fissure evaluation process on the bent specimen and record the number and size of the fissures on the bent pad as was done on the unbent pad.

**7. The Ferrite-Fissuring Relationship**

The relationship between Ferrite Number and fissuring sensitivity is best expessed in graphical form such as shown in Fig. 6. In this figure each data point represents the number of verified fissures found on a singular weld pad in the bent condition as a function of the Ferrite Number of the ground, unbent pad. Testing a number of weld pads of differing Ferrite Numbers produces a series of data points thereby illustrating the ferrite-fissuring relationship.

An important aspect of this relationship is the minimum Ferrite Number needed to eliminate fissuring (3 FN in Fig. 6). To compare the ferrite-fissuring behavior for more than one type of weld metal under investigation, the data can be presented as a series of locations using a Magne Gage calibrated to AWS A4.2-74. It is recommended that a 15 intersection grid layout as shown in Fig. 4 be used to insure a sufficient number of determinations for computation of a statistically significant average value. The average value of the Ferrite Number is used in the development of the ferrite-fissuring relationship (see Section 7).

**Plane of Examination**

Fig. 3 — (a) Weld pad cross section showing recommended bead sequence. Weld pad must be within these limits to minimize variation in total pad surface area and variation in pad height. (b) Weld pad cross section showing alternate bead sequence resulting in two high peak temperature HAZ thermal cycles in bead 2. (c) Weld pad cross section showing recommended plane of examination.

**Fig. 4 — Recommended grid spacing for Ferrite Number determination**
PART II
Investigation and Evaluation of the Test Variables

1. Weld Pad

The weld pad width should be maintained within the limits for the 1/8 in. electrode welding conditions given previously. This will ensure that the pads investigated will have the same amount of surface area on which the examination for fissuring will be performed. Furthermore, if the pad width is held constant, the pad height will be nearly identical for each specimen (approximately 1/4 in.) and thus the amount of strain from bending on the outer surface of the pad will be the same for all specimens. In like manner, a uniform pad height of approximately 1/4 in. will provide dilution control and minimize dilution in the top layer of weld beads. When fissuring is evaluated in a relatively undiluted top layer, the base plate used in the test is not a significant variable and either type 304 or 304L stainless steel is recommended.

If welding conditions resulting in significant dilution are to be used, it is suggested that the first layer of weld beads be deposited with a low dilution technique such as that recommended for the 1/8 in. electrodes. The second layer of weld beads can then be deposited in the manner desired thus minimizing the overall dilution effect.

The number of fissures found on the pad surface examined is considered to be a function of the area evaluated (4 sq in. in the initial testing) and the length of the interpass boundaries in the center 4 inch evaluation section. With 6 beads there will be 5 interpass boundaries and thus 20 linear inches of interpass boundary across the 4 inch evaluation section. If the pad width and the number of passes vary with the welding conditions or technique used, the essential variables in the data evaluation will likewise be altered. It is suggested that two procedures be used to normalize the data. Divide the fissure count by: (1) The ratio of the pad width used in a specific test scheme to the standard 1 in. pad width; (2) The ratio of the total linear interpass boundary length utilized to the 20 linear inches of interpass boundary in the standard. A double normalization may be used if both the width and number of beads are varied in the same testing scheme.

This normalization technique has not been verified in the current work but it is anticipated that it will help to provide comparative data evaluation. Regardless of whether a normalization procedure is attempted, the minimum ferrite level to eliminate fissuring should not be altered to any great extent by slight variations from the standard weld pad configuration.

2. Bead Sequence

The sequence of weld beads deposited on the base plate is of prime importance in the conduct of the Fissure Bend Test. The recommended sequence is that shown in Fig. 3a in which the beads of the top layer are deposited only after all beads of the bottom layer have been deposited. Thus each bead in the top layer (specifically 7-11) experiences essentially only one high peak temperature HAZ thermal cycle, that produced by the immediately succeeding bead. Altering the bead sequence can result in a bead of the top layer receiving multiple HAZ thermal cycles from succeeding weld beads. Test specimens deposited with altered bead sequences showed that fissuring in a bead subjected to multiple HAZ thermal cycles can be increased several fold. This aspect of enhanced fissuring tendency resulting from multiple thermal cycles will be explained in a subsequent article (Ref. 7).

If one wishes to incorporate the influence of multiple thermal cycles in a single test specimen, a bead sequence such as shown in Fig. 3b may be used. In this sequence bead 2 will receive double, overlapping HAZ thermal cycles with relatively high peak temperatures from beads 3 and 8. Other sequences can be devised to provide a double thermal cycle on each weld bead or on every other weld bead. When techniques such as these are utilized, the fissure count on the pad surface should be made to reflect the location of the fissures as well as the number of fissures. This separation may be used to evaluate production multipass sequences where double or multiple HAZ thermal cycling is known to occur.

Another aspect of the pad height control and surface roughness control of the top layer is that when pad preparation is undertaken, the final pad surface is a plane passing through the top layer beads only (see Fig. 3c). However, if excessive material is removed in pad preparation, the plane of evaluation will pass into the first layer of beads and will reflect multiple HAZ thermal cycling as well as dilution effects. In such a circumstance, the ferrite potential of the base plate would have to be considered, and thus the base plate would become an important variable in the
test. Careful control is the key to a successful testing program which will truly reveal the phenomena of interest.

3. Weld Pad Restraint

In the Fissure Bend Test the weld pad is deposited directly onto the surface of the restrained base plate and not into a groove, and the level of restraint on the weld metal would be expected to be fairly low. However, two methods of base plate fixturing were utilized and evaluated with regard to their possible effect on fissuring tendency: (1) clamping the base plates on the ends to a heavy backup (the recommended procedure), (2) 1/4 in. fillet welding the base plates all-around to a heavy backup. The results of this evaluation indicate that there is no significant difference in weld metal fissuring tendency between the two types of base plate restraint, and thus restraint technique is not an important test variable. An investigator, therefore, has the option to choose either method of base plate restraint, be it clamping or welding the base plates on the ends or all-around. For convenience it is recommended that the base plate be notched on the ends and then clamped in a fixture as shown in Fig. 1. This fixture can accommodate three test specimens and has proven its utility in the testing of over 40 specimens.

4. Surface Preparation

In the Fissure Bend Test the top surface of the weld pads is prepared to provide a smooth surface to allow the detection of fissures. The weld pads are ground while they are still in the restraining fixture. Three different surface preparation techniques were used and evaluated with regard to detection of fissures: (1) "Milled"—milling the surface and finishing with a 0.002 in. milling cut, (2) "Surface ground"—milking the surface followed by grinding with eight passes of 0.001 in. and finishing with four passes of 0.0005 in., (3) "Metallographically polished"—milling followed by grinding with eight passes of 0.001 in. and four passes of 0.0005 in. and finished by metallographically polishing the surface.

To compare these three methods of surface preparation, three pairs of 308 (0.4 FN) specimens and three pairs of 316 (0.4 FN) specimens were prepared. For each type of weld metal, one pair was milled, a second pair was surface ground, and the third pair was metallographically polished. The comparison of the three preparation methods shows that there is a significant difference in the number of fissures detected for both weld metal types (see Table 1).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Milled</td>
<td>6</td>
<td>0.016 in.</td>
<td>8</td>
<td>0.013 in.</td>
</tr>
<tr>
<td>Surface ground</td>
<td>44</td>
<td>0.008 in.</td>
<td>17</td>
<td>0.009 in.</td>
</tr>
<tr>
<td>Metallographically polished</td>
<td>151</td>
<td>0.004 in.</td>
<td>102</td>
<td>0.005 in.</td>
</tr>
</tbody>
</table>

Table 1 — Average Number of Fissures and Average Fissure Size (Based on Disc Assumption) for 308 and 316 Weld Metal as a Function of Pad Surface Preparation Technique (Measured on Bent Sample)

It is believed that fissures are present in the weld metal in different sizes and are approximately in the shape of a disc. Thus they appear as linear discontinuities (indications) when detected on the prepared surface. Any plane of cut through the surface of the weld pad will expose a segment of each fissure intersecting the surface. The segment length depends on the location of the plane of cut, and only a small fraction of the fissures will be cut through their major dimension. Using quantitative metallographic techniques, the true average fissure dimension, based on the disc assumption, can be calculated. These calculated sizes are shown for both 308 and 316 weld metal as a function of pad preparation technique in Table 1. It is clear from these data that the detectability of each fissure depends on the size of the fissure and on the degree of weld pad surface roughness. On the metallographically polished surfaces it is possible to detect most, if not all, of the fissures present in the plane of examination including the small fissures and short segments of larger fissures. However, relatively few of the smaller fissures are revealed on the surface of ground pads, and furthermore, only the larger fissures can be detected on the milled pads.

This detectability limit is also a function of the resolution of the type of microscope used. In the case of the polished samples, examination was conducted at 50X magnification. It is also of interest to note that fluorescent penetrant examination of the polished samples readily revealed approximately 70% of the fissures. The remaining 30% apparently are beyond the resolution of the penetrant technique. While the "milled" surface preparation does not reveal many of the fissures present in the weld metal, it is felt that enough fissures are revealed to assess a ferrite-fissuring relationship on a go-no-go basis.

5. Plane of Examination

Only those fissures intersecting the prepared surface are subject to penetrant revelation. Therefore, only a fraction of the fissures present are actually counted. The test is thus predicated on the assumption that a representative fraction (fixed in proportion to the total number) of fissures is exposed to the plane of examination both before and after bending. This assumption must not be a function of the weld metal type and composition.

The amount of weld metal milled and ground from the weld pad surface should be just sufficient to remove most of the irregularities from

Fig. 8 — Longitudinal strain and Ferrite Number as a function of location on a bent specimen
6. Etching of the Prepared Surface

Macroetching of the milled or ground weld pad surfaces for removal of disturbed surface metal in anticipation of enhanced fissure detection is not recommended. Spurious effects are often produced by macroetching and cracks of unusual morphology (unrelated to fissuring) may occur. However, if the weld pads are metallographically polished, macroetching may be desirable for revealing the bead interpass boundaries, the microstructure, fissure morphology, and the relationship of the fissures to the microstructural features.

The following etchant has been found to be highly suitable for revealing the microstructure without producing undesirable side effects and is recommended for use after metallographic polishing is accomplished:

25 gm CrO₃
133 ml Acetic Acid
7 ml H₂O

Use electrolytically with a stainless steel cathode at 7-10 V for approximately 30 to 60 s.

7. Bending the Test Specimen

In the majority of weld metals tested to date (308, 308L, 316L, 309, 16-8-2), fissures are seldom detected on a ground, unbent weld pad (Ref. 6). Even with complete metallographic preparation and observation at 200X magnification, few fissures can be found. Thus, to facilitate detection of fissures on the prepared pad surface, the weld pad surface is bent in tension to an included angle of 120 deg. Through careful examination of the surfaces of many specimens in the optical and scanning electron microscopes, it has been determined that the bending does not cause rupture of the weld metal but merely opens up fissures already present in the weld metal. Also the fissures present do not have any tendency to propagate during bending.

The bend fixture shown in Fig. 5 is designed with positive stops to consistently provide a reproducible bend angle of 120 deg included. The use of this fixture is recommended to those who undertake to employ the Fissure Bend Test. The 120 deg angle of bend is adequate to open for detection a sufficient number of the fissures present across the center 4 inches of the pad surface and provide a basis for evaluation of fissuring tendency. In general, it has been observed that the number of fissures detectable is proportional to the bend angle. (It has also been observed that the number of fissures revealed is a function of surface preparation and the resolution of the detection technique. See Section 4).

8. Fissure Determination

To provide accurate fissure detection and identification on the prepared weld pad surface, all specimens should be subjected to a two-fold method of inspection: fluorescent penetrant inspection followed by binocular microscopic verification, at 40-50X, of all fluorescent indications. This method proves successful in (1) differentiating fissures from other surface defects, (2) distinguishing the presence of closely spaced fissures that were denoted by a single fluorescent indication, and (3) determining the size of fissures. A fluorescent, self-emulsifying and self-developing liquid penetrant is recommended for use in the test. When the pads are penetrant tested and inspected under a black light, the fissures fluoresce as linear indications on the pad surfaces.

Generally, the greater the magnification, the greater will be the number of fissures found, especially on a metallographically polished, etched, and bent specimen. However, for a ground or milled bent weld pad, 40-50X magnification is sufficient to resolve most of the larger exposed fissures and to provide a ferrite-fissuring relationship or a weld metal-to-weld metal fissuring comparison.

9. Ferrite

The Ferrite Numbers are recorded on a grid pattern over the center 4 inches of the pad as shown in Fig. 4. The average value of the measurements should be used as the Ferrite Number of the weld pad. A Magne Gage or other magnetic instrument calibrated in accordance with AWS A4.2-74 should be employed to measure the Ferrite Numbers. The Ferrite Numbers measured on prepared pads tend to be slightly higher than those measured on the as-welded surface by approximately 5%. The increase in Ferrite Numbers between the as-welded and prepared pad surface can be the result of: (1) enhanced nitrogen pick-up near the weld surface thus reducing ferrite, (2) surface roughness influencing "magnetic linkage" between the Magne Gage magnet and the deposited metal, and (3) the formation of strain-induced martensite due to machining. The total effect may be a result of a combination of all three influences.

The Ferrite Numbers measured on the prepared surface where fissuring will be evaluated should be those used in deriving the ferrite-fissuring relationship. Furthermore, because the recommended surface preparation operation does not significantly change the Ferrite Number, this relationship should be accurate.

The bending operation tends to increase the Ferrite Number measured on the center 4 inches of the weld pad. This increase averaged 10-20% for all but one of the weld metals tested. The exception was 16-8-2 weld metal for which the average increase was 120%. Because bending of the test specimens increases the Ferrite Number substantially (especially for 16-8-2), it is again suggested that the Ferrite Numbers to use in the data presentation are those made on the surface prepared, unbent pads.

The very nature of the bending operation induces both elastic and plastic strains in the weld pad. These strains are of a tensile nature parallel to the pad length and they vary in magnitude from the center towards the ends of the specimen. The transverse strain on the pad surface is compressive and it too varies with location. The extent of these strains also varies according to pad height and width. To determine the magnitude and extent of these strains, a grid network was scribed on one pad surface. Grid spacing measurements made before and after bending enabled the determination of the extent of strain experienced by the weld pad surface. Figure 8 shows the longitudinal strain as a function of location on a bent specimen. Note that the maximum strain occurs at the center of a span and is approximately equal to 20%. Strains of this magnitude would certainly be expected to in-
duce the formation of strain-sensitive martensite in the weld pads. The 16-8-2 material was by far the most prone in reflecting an increase in Ferrite Number as a result of this martensite formation. The Ferrite Numbers plotted on Fig. 8 shows an increase in ferrite level from 1 FN in the low strain areas to 5 FN in the most highly strained center section of the weld pad. Type 308, 308L, 316, 316L, 309, 318 and 347 weld metals exhibited the same tendency but were far less sensitive to strain-induced martensite formation. Plastic strains of this same magnitude (20%) have been reported to occur in the center of thick 308, 316, and 16-8-2 stainless steel weldments (Ref. 8). Thus it appears that the strains experienced by Fissure Bend Test specimens are not necessarily out of line with strains experienced in actual weldments.

Closure

In light of the above discussions which amplify many of the test variables, it is anticipated that the investigator utilizing the Fissure Bend Test technique will have an adequate basis for starting his evaluation. Undoubtedly, future investigators will uncover more aspects of significance. The Fissure Bend Test concept should not be considered to be relegated only to the type of usage indicated in this article. The test has capabilities of providing both pragmatic and fundamental information. The test method may be extended quite readily to other welding processes such as SA, GTA with filler metal added, and GMA. Since the test involves the actual deposition of the weld metal to be evaluated, virtually all the welding process variables can be made a part of the testing scheme and their influence on the fissuring tendency can be determined. Furthermore, while the initial evaluation of the Fissure Bend Test was carried out with austenitic stainless steel weld metals, there is no reason why the test method cannot be applied to other weld metals. It is readily apparent that this extension can be made without modification to the studying of nickel-base, cupro-nickel, aluminum, and other similarly ductile materials. The simplicity of the test lends itself also to the study of the effect of postweld thermal treatments on the fissuring sensitivity and ductility.

Acknowledgment

The authors acknowledge the financial support of the Welding Research Council in this investigation. They also wish to thank Mr. Raymond Bellamy of the University of Tennessee staff for the preparation of the test specimens. Their special thanks are due to Ms. Sylvia Goode for her assistance in the testing and evaluation of the specimens.

References