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SAFETY GUIDE 31

CONTROL OF STAINLESS STEEL WELDING

A. Introduction

General Design Criterion 1, "Quality Standards and Records," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," requires that measures be established to assure materials control and control of special processes such as welding, and that proper testing be performed. This guide describes an acceptable method of implementing these requirements with regard to the control of welding when fabricating and joining austenitic stainless steel components and systems.

B. Discussion

The ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components,"[1] specifies certain requirements associated with manufacturing Class 1, 2, and 3 components. Although welds fabricated for core support structures of austenitic stainless steel are not presently within the scope of Section III, they should meet Class 1 requirements.

1. Procedure Qualifications

Section III requires adherence to ASME Boiler and Pressure Vessel Code, Section IX, "Welding Qualifications,"[1] one of the requirements being procedure qualifications for welds. Review of the requirements of procedure qualifications stated in Section IX indicates the desirability of supplementary requirements to assure adequate control of weld metal properties when welding austenitic stainless steel. Specifically, the assurance of satisfactory welds in austenitic stainless steel of the AISI 3XX series can be increased significantly and, in particular, the sensitivity to fissuring or hot cracking can be reduced by maintaining the amount of delta-ferrite in the weld metal between 5 and 15 percent.

Experiments indicate that 5-10 percent delta-ferrite in welds for austenitic structures provides optimum resistance to fissuring or hot cracking. An acceptable range of delta-ferrite for welding wrought austenitic structures is 5-12 percent. However, a higher delta-ferrite range of 5-15 percent is acceptable for welding duplex cast structures.

Section IX acceptance standards for fissures or cracks in transverse side bend tests were not intended to cover microfissures as such; however, the subject is covered in specification MIL-E-0022200/2B (SHIPS), dated September 15, 1970, which states that 3 fissures smaller than 1/16 inch (0.015 inch) need not be counted. Although the formation of microfissures in welds also depends on factors other than delta-ferrite content and heat input, it is generally agreed that there will be few, if any, small fissures in a side bend test of weld metal deposited with the proper heat input and containing 5-15 percent delta-ferrite.

In addition to supplementing procedure qualification requirements of Section IX by specifying acceptable delta-ferrite content in the weld metal,

[1] Copies may be obtained from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

tests and examinations should be made to assure that this specification is met and that unacceptable microfissures will not result. The use of chemical analysis of the undiluted weld deposit to determine key constituents combined with the use of the Schaeffler diagram to predict its delta-ferrite content and a nondestructive examination of the weld using a magnetic measurement device, such as the Severn Ferrite indicator, are available techniques to determine delta-ferrite content, and both should be included in the procedure qualifications.

Another important variable in the control of weld metal is heat input. Excessive heat input often results in a large weld puddle and a slow cooling rate of the weld metal. The resulting slower solidification rate has a tendency to diminish ferrite retention and to result in large grain size microstructures, which in turn increase the tendency both for impurities to segregate at the grain boundaries and for fissure formation.

A heat input that gives an acceptable solidification rate (temperature gradient) in a heavy weld cross section may not be acceptable for a thinner weld cross section because of the smaller heat sink. Control of only the maximum interpass temperature, used to assure a satisfactory temperature gradient in a heavy cross section, may not be sufficient to control microfissuring in thinner sections and, consequently, control of heat input should also be utilized. Heat input, measured in kilojoules per lineal inch (kJ/in) of weld, is considered low when less than 25 kJ/in, intermediate in the range 25 to 50 kJ/in, and high above 50 kJ/in. Microfissuring in weld thickness of 1 to 2 inches has been observed in manual arc welded joints which were deposited with an intermediate heat input of about 40 kJ/in. If a low heat input of about 25 kJ/in is utilized, the assurance of a satisfactory weld will be enhanced, regardless of thickness and, in particular, the probability of segregation and microfissuring will be reduced.

Control of both local and gross heat input is important in welding. Experience indicates that welds produced manually are more likely to be unacceptable than welds produced by automatic welding machines. This results principally because local and gross heat inputs are more controllable in automatic rather than manual weld production. In order to control gross and local heat inputs during the welding process (these cannot be measured directly) and to assure a proper solidification rate of weld metal, the variables of amperage, voltage, and speed of travel should all be specified in procedure qualifications. To provide reasonable assurance that there will be no unacceptable microfissures in weld metal, macroscopic examination on a guided transverse side bend test specimen should be included as part of the procedure qualifications. All results of the above tests and examinations should be included in the certified qualification test report required by Section IX.

2. **Production Welds**

Procedure qualification by itself does not assure that production welds will meet the delta-ferrite and heat input requirements specified in the procedure qualification. Section III specifies requirements for welding materials. In addition to meeting these requirements, each Lot and Heat of welding material for production welds should be shown to be satisfactory by analysis to predict the delta-ferrite level. In order to assure that production welds are satisfactory, it is desirable that the production welds themselves be examined nondestructively using a magnetic measurement device such as the Severn ferrite indicator. Since such devices have limitations regarding the physical depth to which they can examine weld material, it may be necessary to perform several examinations for each weld. The number of examinations to be conducted for each weld should reflect the thickness of the weld metal pass, the number of passes per joint, the capability of the instrument used, and the heats of the weld materials. Sufficient examinations should be conducted through the thickness of the weld to provide reasonable assurance that the delta-ferrite content is within the specified limits (the number of examinations required for each weld will vary from weld to weld and is dependent upon the factors enumerated above). In the event the examination indicates that the delta-ferite in the production weld is not within the specified range, macroscopic examinations should be performed on transverse side bend specimens from the welds to determine if cracks or fissures exist. Since high reliance is placed on procedure qualifications, instruments used in examining production welds should be calibrated against the same standard as that used when developing procedure qualifications. In addition to monitoring the normal welding variables during performance of production welds, the voltage, amperage, and speed of travel should be periodically monitored to verify compliance with those included in procedure qualifications.

C. Regulatory Position

Welds for austenitic stainless steel core support structures should comply with the fabrication requirements specified in the ASME Boiler and Pressure Vessel Code (ASME B&PV Code) for Section III, Class 1 components. Weld fabrications for austenitic stainless steel core support structures and Class 1, 2, and 3 components should comply with Section III and Section IX of the ASME B&PV Code supplemented by the following:

1. The procedure qualification[2] should require that:

   a. weld deposits contain between 5 and 12-15 percent delta-ferrite,
   b. chemical analysis be performed on undiluted weld deposits and that delta-ferrite content be predicted by using the Schaeffler diagram[3] or its equivalent,
   c. delta-ferrite content in weld metal be determined using magnetic measurement devices[4] such as the Severn ferrite indicator,
   d. heat input during welding be specified in terms of amperage, voltage, speed of travel, and interpass temperature limits (all values being selected to promote a rapid cooling rate across the weldment),
   e. macroscopic examination be performed on transverse side bend test specimens to determine fissures or cracks (or absence of same) in weld metal.

2. The results of the destructive and nondestructive tests required in regulatory position 1. above should be included in the certified qualification test report.[2]

3. The welding materials used for production welds should meet the requirements of Section III of the ASME B&PV Code. In addition, each Lot or Heat of welding material should meet the requirements of regulatory position 1.a. and 1.b. above.

4. Production welds should be examined to verify that delta-ferrite level is between 5 and 12-15 percent in weld metal. The number of examinations to assure compliance with delta-ferrite level should be based on the thickness of weld metal per pass, the number of passes per joint, the instruments used, and heats of materials. Instruments used should be calibrated against the same standard as that used when developing procedure qualifications.

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[2] ASME Boiler and Pressure Vessel Code, Section IX.

[3] American Society for Metals Handbook, Vol. 6, at 246-47.

[4] Welding Research Council Bull. No. 132, The Measurement of Delta-Ferrite in Austenitic Stainless Steels (August 1968).

5. In the event that requirements of regulatory position 4. above are not met, additional examinations should be performed in accordance with regulatory position 1.e. above.

6. Production welding should be monitored to verify compliance with the requirements in regulatory position 1. above for amperage, voltage, speed of travel, and other essential variables.