

Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications



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Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications

3rd Edition

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Prepared by the
American Welding Society (AWS) D17 Committee on Welding in the Aircraft and Aerospace Industry

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification covers the general requirements for the friction stir welding of aluminum alloys for aerospace applications. It includes the requirements for weldment design, qualification of personnel and procedures, fabrication, and inspection.



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Foreword

This foreword is not part of this standard but is included for informational purposes only.

In the fall of 1993, aerospace welding personnel gathered together under the auspices of the American Welding Society (AWS) to develop an aerospace fusion welding specification to replace MIL-STD-1595A, *Qualification of Aircraft, Missile, and Aerospace Fusion Welders*, and MIL-STD-2219, *Fusion Welding for Aerospace Applications*. The result of this initial meeting was the formation of the AWS D17 Committee on Welding in the Aircraft and Aerospace Industries. The overriding theme voiced by the committee members was that the aviation industry had changed and a new specification was needed. In 2001, after years of hard work by the committee members, the American Welding Society issued AWS D17.1:2001, *Specification for Fusion Welding for Aerospace Applications*.

Specifications used for aerospace welding deal primarily with fusion welding, except for the relatively few that deal with friction welding. Fusion welding is used to produce the vast majority of large, structural, welded components, as opposed to friction welding, which usually is used to join smaller, circular cross-section detail parts. In 1991, The Welding Institute, in the United Kingdom, patented a new welding process called friction stir welding (FSW). The question soon arose as to which requirements were necessary to specify and control this new welding process. Fusion welding specifications could not adequately address FSW because it is a solid-state welding process. Friction welding specifications also could not adequately address the FSW process because, unlike friction welding, the FSW process uses a third body, the welding tool.

The AWS D17 Committee on Welding in the Aircraft and Aerospace Industries determined that it was necessary to form a subcommittee to write a specification for friction stir welding. It was appropriate that the setting for the subcommittee's kickoff meeting was at the Kennedy Space Center in Florida. Kennedy Space Center is where the first friction stir welded commercial aerospace component, the fuel tank for the Delta launch vehicle, went into service. Representatives from industry, welding institutes, government agencies, and universities met to dedicate themselves to form a specification for the friction stir welding of aluminum for aerospace applications. AWS D17.1:2001, served as the model for this specification.

This is the third edition of AWS D17.3/D17.3M, *Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications*. A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2016 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D17 Committee on Welding in the Aircraft and Aerospace Industries, American Welding Society, 8669 NW 36 St, #130, Miami, FL 33166.

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Amendment

The following Amendments have been identified and are incorporated in this reprint.

Amendment Number: 1

Subject: The welding operators are qualified to the Class of weld specified on the WPS and should be noted on the qualification record. Therefore, the last sentence in Subclause 7.1.2 has been amended as follows to revert to the previous version of the specification:

7.1.2 Test Weld. One of the test coupons in Figures 7.1 through 7.4 shall be used for the welding operator qualification test. The test coupon shall be welded in accordance with a WPS. The operator being qualified shall verify all aspects of the weld that would normally be required to make the weld in the production operation, in accordance with the WPS. Operators shall be qualified to the class of weld specified on the WPS, unless otherwise approved by the Engineering Authority.

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Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications

1. General Requirements

1.1 Scope. This specification contains the requirements for friction stir welding (FSW) of aluminum aerospace hardware. The requirements include design of welded joints, qualification of procedures and operators, fabrication and inspection. The FSW methods covered by this specification are conventional FSW, retractable probe FSW, stationary shoulder FSW, and self-reacting FSW.

1.2 Units of Measure. This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([]) or in appropriate columns in tables and figures. The measurements may not be the exact equivalents; therefore, each system must be used independently.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard and therefore are not addressed herein. Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website.

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers.

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments or revisions of the publications may not apply since the relevant requirements may have changed.

AWS documents:

- AWS A1.1, *Metric Practice Guide for the Welding Industry*;
- AWS A2.4, *Standard Symbols for Welding, Brazing and Nondestructive Examination*;

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*;

AWS B5.2, *Specification for the Qualification of Welding Inspector Specialists and Welding Inspector Assistants*;

AWS QC1, *Standard for AWS Certification of Welding Inspectors*;

AWS D17.1/D17.1M, *Specification for Fusion Welding for Aerospace Applications*;

AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*.

AIA/NAS document:

NAS 410, *NAS Certification & Qualification of Nondestructive Test Personnel*.

ANSI document:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

ASTM documents:

ASTM B881, *Standard Terminology Relating to Aluminum- and Magnesium-Alloy Products*;

ASTM E164, *Standard Practice for Ultrasonic Contact Examination of Weldments*;

ASTM E1417, *Standard Practice for Liquid Penetrant Examination*;

ASTM E1742, *Standard Practice for Radiographic Examination*.

ASTM E2700, *Standard Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays*.

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terms and definitions used herein. Terms and definitions from ASTM B881, *Standard Terminology Relating to Aluminum- and Magnesium-Alloy Products*, are also used. However, the following terms and definitions are included below to accommodate usage specific to this document.

angular distortion. Distortion between two welded pieces such that their surface planes are not parallel (see Figure 3.2).

angular mismatch. Mismatch between two unwelded pieces such that their surface planes are not parallel.

NOTE: In this specification, angular mismatch is measured the same as angular distortion (see Figure 3.2).

anvil. Structure supporting the root side of the joint.

axial force. Force applied to the workpiece along the axis of tool rotation (see Figure 3.1).

bobbin tool. Nonstandard term for self-reacting tools.

cavity. Void-type discontinuity within a solid-state weld (see Figure 3.3).

complex weld joint. Continuous weld joint with variations in section thickness and/or tapered thickness transitions, per the engineering drawing.

conventional FSW. Friction stir weld using a fixed length probe where the axial force is reacted by an anvil.

direction of tool rotation. Rotation as viewed from the spindle that is rotating the tool (see Figure 3.1).

dwelt time. The period of time the rotating shoulder(s) (once in full contact with the workpiece) remains stationary before travel begins.

Engineering Authority. Contracting agency or corporate organization that acts for and on behalf of the Customer on all matters within the scope of this specification. The Engineering Authority has the responsibility for the structural integrity or maintenance of airworthiness of the hardware and compliance with all contract documents.

exit hole. Hole remaining at the end of a weld after the withdrawal of the probe (see Figure 3.1).