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An American National Standard

Guide to Ultrasonic Assembly of Thermoplastics

American Welding Society

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Guide to Ultrasonic Assembly of Thermoplastics

1st Edition

Prepared by the
American Welding Society (AWS) G1 Committee on Joining of Plastics and Composites

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This guide details the ultrasonic equipment and the processes used in industry for fabricating thermoplastic parts, including welding, staking, swaging, insertion, forming, degating, cutting, and trimming. Included are sections on safety, equipment setup, joint and part design, testing, and process optimization.

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Foreword

This foreword is not a part of AWS G1.1M/G1.1:2006, *Guide to Ultrasonic Assembly of Thermoplastics*, but is included for informational purposes only.

This guide was developed by the AWS G1 Committee on Joining Plastics and Composites in response to an industry demand for a document on ultrasonic welding of plastics that would serve as a guide for management personnel, engineers, foremen, and welders. The AWS G1 Committee on Joining Plastics and Composites was formed in 1988. This is the first issue of this standard.

This document defines this welding process, the materials that can be welded, and the required welding equipment. Included are part and joint design, welding process overview and optimization, testing, and the ultrasonic techniques of staking, swaging, insertion, forming, degating, cutting, trimming, and spot welding.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS G1 Committee on Joining of Plastics and Composites, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society (see Annex A). A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Guide to Ultrasonic Assembly of Thermoplastics

1. General

1.1 Scope

This guide details the ultrasonic equipment and the processes for welding thermoplastic parts. It also describes staking, swaging, insertion, forming, degating, cutting, and trimming. Included are discussions on joint and part design, testing, and process optimization. The information provided should be sufficient to enable the reader to understand the processes and select a suitable method.

Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein (see 1.8). Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* and applicable federal and state regulations.

Information on welding procedure and performance qualification for thermoplastics is available in AWS B2.4, *Specification for Welding Procedure and Performance Qualification for Thermoplastics*.

1.2 Introduction

Clauses 4, 5, and 6 provide overviews of the materials, process, and equipment used in ultrasonic welding. Specific information regarding joint design appears in Clause 7. Clauses 8 and 9 provide guidelines for optimization and troubleshooting which will be useful in process setup. Clauses 10 and 11 discuss testing methods for ultrasonic welds and other applications for ultrasonic energy. Included in Clause 3 is a glossary of terms commonly used in ultrasonic assembly.

The use of polymers and polymeric composites in both structural and nonstructural applications is rapidly growing due to their many advantages. These include high strength-to-weight and stiffness-to-weight ratios, corrosion resistance, long service life, design flexibility, and relatively low manufacturing costs.

Generally, thermoplastic joints must meet specific mechanical, physical, environmental, and aesthetic requirements, and be produced at high speed and low cost. Therefore, the selection of the most suitable assembly or joining methods is critical to both the design and manufacture of the product.

Several methods are commercially used for joining plastics and composites. These include mechanical fasteners, adhesive bonding, and welding by fusing the parts with heat. Mechanical joining and adhesive bonding methods can be used for thermosets and thermoplastics. Welding is restricted to joining thermoplastic materials. Welding of thermoplastics can be achieved by three heating methods:

1. *External.* The heat is supplied by a hot plate, hot gas, resistance, induction, laser, or infrared;

2. *Internal.* The welding results from mechanical motion applied to the parts resulting in energy dissipation and heating. Examples are ultrasonic, vibration, and spin welding; and

3. *Electromagnetic.* The heat is generated by an electric current or electromagnetic field passing through the polymer joint interface. Examples are radio-frequency (r-f), microwave, and induction.

The selection of a joining process depends on the requirements for the joint, the materials used, and the geometry of the part or structure.

1.3 Ultrasonic Assembly

In this process, low-amplitude, high-frequency mechanical vibration (ultrasonic energy) is used to soften or melt thermoplastic materials to effect blending, and upon cooling, a weld.

Ultrasonic energy can also be used for insertion of metal components into plastic parts, and to reform thermoplastic studs or ridges to mechanically join parts using

staking or swaging processes. Ultrasonic vibration is also used to degate (separate) injection molded components from their runners.

In each of these processes, the thermoplastic parts are subjected to low-amplitude, high-frequency mechanical vibrations. This energy is converted into heat within the thermoplastic through intermolecular friction, which softens or melts the polymer. The processes of welding, insertion, staking, swaging, and degating use essentially the same equipment. The joint requirements, materials and geometries determine which of these processes will best meet the final assembly needs.

1.4 Process Description

Ultrasonic assembly is the joining or reforming of thermoplastics using high-frequency vibrations to generate heat. For example, a metal object becomes warmer when repeatedly struck with a hammer. The kinetic energy of the hammering transforms into thermal energy (heat) as the molecules in the object move more vigorously. These molecules are likewise excited to move vigorously when subjected to the impact (hammering) of high-frequency ultrasonic vibrations.

An ultrasonic welding system applies high-frequency energy (vibrations) through one part, focusing the energy into the junction of the two parts. The focusing of the energy is critical. The details of this method are presented elsewhere in this document.

1.5 System Component Functions

The basic assembly system consists of four major components:

1. Power supply/generator,
2. Converter,
3. Booster, and
4. Horn.

The power supply/generator converts commonly available line voltage electrical power into high-frequency electrical energy. Although any frequency between 15 kHz and 70 kHz could be used, 20 kHz is the most popular.

The converter changes the electrical energy into longitudinal (axial), low-amplitude mechanical vibrations of the same frequency.

The booster couples the mechanical vibrations from the converter to the horn, and depending on its size and shape, can increase or decrease the amplitude of these vibrations.

The horn transmits the vibrational energy from the booster into the workpiece. The horn design is critical, since, like the booster, its size and shape affect the amplitude of the vibrations and consequently the heating of the thermoplastic parts.

1.6 Systems for Applying Energy to Work

A press system is recommended for critical, precisely controlled applications. When consistency and appearance are not critical, a hand-held unit may be adequate. Many manufacturers use compact actuators in applications where an automated press system would be too large. These actuators offer press control in a smaller package that is better suited to custom mounting. When production rates demand faster speeds than standard press systems can provide, rotary index systems can be used. Fully automated systems are available for ultra-high-speed assembly operations.

1.7 Process Advantages and Limitations

1.7.1 Advantages. Ultrasonic assembly can have the following advantages over other joining techniques:

1. Uniform joining is achieved because heating occurs rapidly and is confined to the immediate joint area;

2. The weld strength can be as strong as the unreinforced base material;

3. No solvents, adhesives, or external heating are required;

4. Dissimilar materials can be assembled using ultrasonic process; and

5. Ultrasonic assembly is considerably faster than other methods, resulting in higher efficiency and greater economy.

1.7.2 Disadvantages

1. Ultrasonic assembly equipment is moderately expensive;

2. Initial equipment and process setup can be complicated; and

3. Flash, particulates, and stresses occasionally appear at the joint after welding.

1.8 Safety and Health

Ultrasonic assembly operations involve potentially hazardous equipment and materials. Personnel should be trained in the proper use of the equipment, and the safety and health practices mandated by OSHA and local codes, and those recommended by the equipment and materials suppliers. Proper work attire, including safety glasses and hearing protection, should be specified and enforced. Material safety data sheets (MSDSs) should be available to personnel for all materials and chemicals used in the manufacturing area. For additional help on improving plant safety, consult ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, available from American Welding Society. Some basic safety rules to observe include:

1. Keep hands away from under the horn. An energized horn in contact with skin can cause burns. Also, a moving horn can cause rapid, crushing forces;

2. To prevent electrical hazards, verify all equipment is electrically grounded, verify the power supply is OFF before making any electrical connections, and unplug the power supply before removing its cover. Never operate the unit with the cover removed;

3. Do not press the power supply TEST if either the RF cable or the converter is disconnected as this may cause potential damage to the generator;

4. Verify no one is in contact with the horn when the TEST button is activated to prevent skin burns; and

5. Use hearing protection to prevent hearing loss if the operation is noisy.

1.9 Units of Measurement

This standard makes use of both International System of Units and U.S. Customary Units. The latter are shown within parentheses or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system shall be used independently.

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2. Referenced Documents

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

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

2. ASTM D 256, *Test Method for Determining the Izod Pendulum Impact Resistance of Notched Specimens of Plastics*[2]

3. ASTM D 4065, *Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics*

4. AWS A3.0, *Standard Welding Terms and Definitions*[3]

5. AWS B2.4, AWS B2.4, *Specification for Welding Procedure and Performance Qualification for Thermoplastics*

6. DIN 53455, *Testing of Plastics Tensile Test*[4]

7. DVS 2203, *Testing of Welding Joints of Thermoplastics*[5]

1. ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.
2. ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
3. AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.
4. Available from Deutsches Institut für Normung e.V., 10772 Berlin, Germany.
5. Available from Deutscher Verband für Schweißen und verwandte Verfahren e.V. (German Welding Society), Aachener Str. 172, D-40223 Düsseldorf, Germany.

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