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Friction stir spot welding — Aluminium —

Part 1: Vocabulary

Soudage par friction-malaxage par points — Aluminium —

Partie 1: Vocabulaire

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Foreword

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This document was prepared by the IIW, *International Institute of Welding*, Commission III, *Resistance welding, solid state welding and allied joining*.

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A list of all parts in the ISO 18785 series can be found on the ISO website.

Introduction

Welding processes are widely used in the fabrication of engineered structures. During the second half of the twentieth century, fusion welding processes, wherein fusion is obtained by the melting of parent material and usually a filler metal, dominated the welding of large structures. In 1991, friction stir welding (FSW), which is carried out entirely in the solid phase (no melting), was invented.

Friction stir spot welding (FSSW) processes are spot-like variants of the FSW process. Unlike FSW, there is minimal or no traverse motion of the tool. In basic FSSW, the joint is created by plunging a rotating tool into the work piece and retracting the tool out of the overlapping sheets. Other FSSW variants include additional tool movements. Frictional heat is generated from the contact between the tool and the material to be welded resulting in softening of this material. The softened material is stirred to form a metallurgical connection which is aided by the forge action applied by the tool shoulder contacting the upper sheet surface.

The increasing use of FSSW has created the need for a FSSW standard in order to ensure that welding is carried out in the most effective way and that appropriate control is exercised over all aspects of the operation. The ISO 18785 series focuses on the FSSW of aluminium because, at the time this document was developed, the majority of commercial applications for FSW involved aluminium. Examples include railway cars, consumer products, food processing equipment, automotive components, aerospace structures, and marine vessels.

To be effective, welded structures should be free from serious problems in production and in service. To achieve that goal, it is necessary to provide controls from the design phase through material selection, fabrication, and inspection. For example, poor design can create serious and costly difficulties in the workshop, on site, or in service. Incorrect material selection can result in welding problems such as cracking. Welding procedures need to be correctly formulated and approved to avoid imperfections. To ensure the fabrication of a quality product, management needs to understand the sources of potential trouble and introduce appropriate quality and inspection procedures, and supervision should be implemented to ensure that the specified quality is achieved.

Friction stir spot welding — Aluminium —

Part 1: **Vocabulary**

1 Scope

This document defines friction stir spot welding (FSSW) process terms and definitions.

In this document, the term "aluminium" refers to aluminium and its alloys.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 25239-1, *Friction stir welding — Aluminium — Part 1: Vocabulary*

ISO/TR 25901-1, *Welding and Allied Processes — Vocabulary — Part 1 : General terms*

ISO 14732, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 25239-1, ISO/TR 25901-1, ISO 14732, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

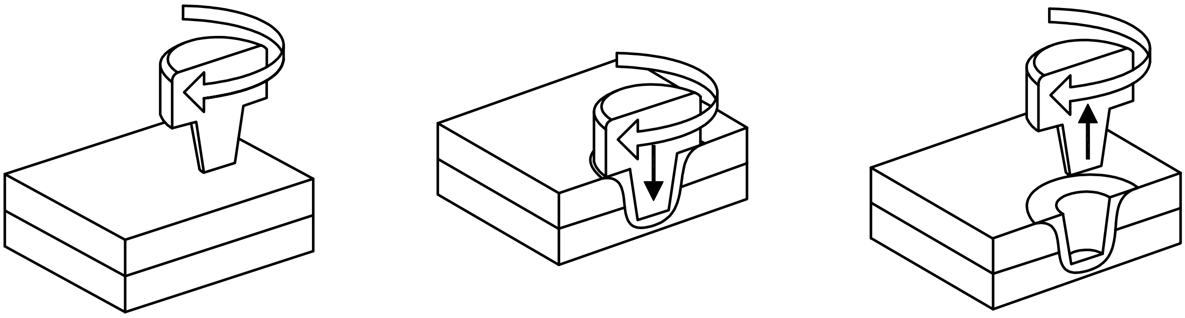
3.1
friction stir spot welding
FSSW
friction stir welding process producing a small aspect ratio, discrete lap weld by frictional heating and mixing of material in the plastic state caused by the plunge and retraction of a rotating *probe* (3.2), with or without traverse movement

Note 1 to entry: See Figure 1.

3.2
probe
<FSSW> part of the tool extending into the parent material to make the weld

Note 1 to entry: The probe can be either fixed or adjustable.

Note 2 to entry: When a probe is not present, the process is known as “probe-less” FSSW.



a) Rotation b) Plunge c) Retract

Figure 1 — Basic principle of friction stir spot welding

3.3
shoulder
<FSSW> portion of the tool that contacts the parent material surface during welding

3.4
rotation speed
<FSSW> speed of spindle rotation

3.5
rotation direction
<FSSW> direction of spindle rotation

3.6
plunge speed
<FSSW> speed at which the *probe* (3.2) penetrates the work piece during the plunging phase of *FSSW* (3.1)

3.7
plunge depth
<FSSW> distance the *probe* (3.2) extends into the work piece

3.8
force control
<FSSW> method to maintain the required force on the tool during welding

3.9
position control
<FSSW> method to maintain the required position of the tool during welding

3.10
dwell time
<FSSW> time interval between when the rotating tool reaches its maximum depth in the parent material and the start of tool retraction

3.11
exit hole
<FSSW> hole remaining at the end of a weld after the withdrawal of the tool

3.12
faying surface
surface of one component that is intended to be in contact with, or in close proximity to, a surface of another component to form a joint

3.13
weld setter
<FSSW> person who sets up *FSSW* (3.1) welding equipment

Note 1 to entry: Does not apply to *welding operators* (3.14) and/or personnel loading/unloading of the *automatic welding* (3.15) unit.

Note 2 to entry: FSSW is an automatic welding process where adjustment of welding variables is not possible during the short welding cycle.

3.14
welding operator
<FSSW> person who operates *FSSW* (3.1) welding equipment

3.15
automatic welding
welding in which all operations are performed without manual intervention during the welding cycle

3.16
set-up
<FSSW welding unit> approved configuration of the welding unit and the work pieces before welding and, if required, modifications to the operating program

3.17
basic FSSW
friction stir spot welding (3.1) where the weld is produced by the plunge and retract of a rotating *probe* (3.2) without traverse movement

Note 1 to entry: In basic FSSW, the joint is created by plunging a rotating tool into the work piece and retracting the tool out of the overlapping sheets (see Figure 1).

3.18
refill FSSW
basic FSSW (3.17) followed by a refill action resulting in no *exit hole* (3.11)

Note 1 to entry: See Figure 2 and Figure 3.

3.18.1
refill FSSW tool
tool composed of a *clamping ring* (3.18.3), an *adjustable shoulder* (3.18.2) which is able to move axially and an adjustable *probe* (3.2)

3.18.2
adjustable shoulder
<refill FSSW> part of the tool that is coaxial to the adjustable *probe* (3.2) and able to rotate and move axially independent of the adjustable probe and the *clamping ring* (3.18.3)

3.18.3
clamping ring
<refill FSSW> non-rotating ring that forms the outer portion of the tool that serves to clamp the work piece components during spot welding

Note 1 to entry: The clamping ring may also serve to contain material to prevent expulsion from the *FSSW* (3.1).

3.18.4
clamping ring force
<refill FSSW> force applied by the *clamping ring* (3.18.3) to the work piece along the axis of the tool

3.18.5
probe plunge mode
<refill FSSW> operating mode in which the plunging element of the tool is the *probe* (3.2)

Note 1 to entry: See Figure 2.

3.18.6
shoulder plunge mode
<refill FSSW> operating mode in which the plunging element of the tool is the *shoulder* (3.3)

Note 1 to entry: See Figure 3.

3.19
stitch FSSW
FSSW (3.1) variant where the weld is produced by the plunge and translation of a rotating tool along a short linear or curvilinear path (see Clause 5)

3.19.1
length of travel
l
<stitch FSSW> distance between tool centres at tool plunge and tool retraction

Note 1 to entry: See Figure 4.

3.19.2
weld width
w
<stitch FSSW> width of area welded by *probe* (3.2) (equivalent to probe diameter) at the *faying surface* (3.12) between the overlapping work pieces

Note 1 to entry: See Figure 4.

3.20
swept FSSW
FSSW (3.1) variant where the weld is produced by the plunge and translation of a rotating tool around a circumscribed path around the *exit hole* (3.11)

Note 1 to entry: See Figure 5.

Note 2 to entry: The circumscribed path can be circular or elliptical.

3.20.1
tool path rotation
<swept FSSW> traverse path degrees of rotation about the axis of the *exit hole* (3.11) beginning at the *plunge location* (3.20.3)

3.20.2
tool path
<swept FSSW> path that the tool traverses around the retract position.

Note 1 to entry: This is typically, but not limited to, a circular path. This path can also spiral inward completing additional rotations around the retract position

3.20.3
plunge location
<swept FSSW> location of the beginning of the *tool path* (3.20.2)

Note 1 to entry: This can be located on the tool path or in the same location as the retract position

3.20.4
shear area diameter
<swept FSSW> area at the *faying surface* (3.12); sum of the *probe* (3.2) diameter and the *tool path* (3.20.2)

3.20.5
weld face outer diameter
<swept FSSW> maximum extent of the processed area; sum of the *shoulder* (3.3) diameter and the *tool path* (3.20.2)

3.21
swing FSSW
FSSW (3.1) variant where the weld is produced by the plunge of a rotating tool followed by a discrete movement along an arc normal to the surface of the work piece

Note 1 to entry: See Figure 6 and Figure 7.

3.21.1
swing length
<swing FSSW> centre distance between tool plunge and tool retraction

3.21.2
swing speed
<swing FSSW> speed of angular (pivoting) motion

3.21.3
pull out speed
<swing FSSW> speed of tool retraction from the work piece at the end of the weld

3.21.4
swing radius
<swing FSSW> the distance from the pivoting axis to the tool tip

3.21.5
swing angle
<swing FSSW> rotation angle around the pivoting axis

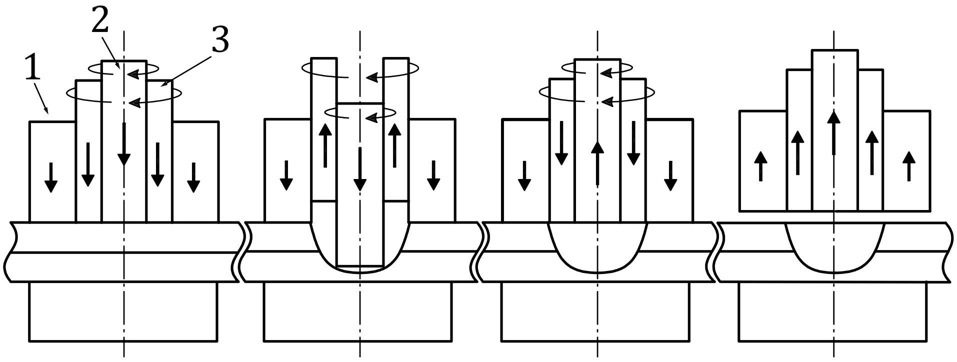
4 Description of Refill FSSW

There are two operating modes depending on the plunging element of the tool:

1) probe plunge;

2) shoulder plunge.

In both operating modes, the stationary clamping ring holds the material against a backing bar in the lap joint configuration, while the probe and shoulder start rotating on the top surface. The probe and shoulder can rotate in the same or opposite directions. The rotating probe and shoulder introduce plastic deformation and generate frictional heating which plasticizes the material. The probe and shoulder are moved in opposite directions to each other. One is plunged into the material while the other moves upwards, creating a gap where the plasticized material is accommodated. After reaching the pre-set plunge depth and dwell time, the probe and shoulder retract back to the surface of the plate forcing the displaced material to completely refill the exit hole. Finally, the tool is retracted from the surface, leaving the weld without an exit hole.

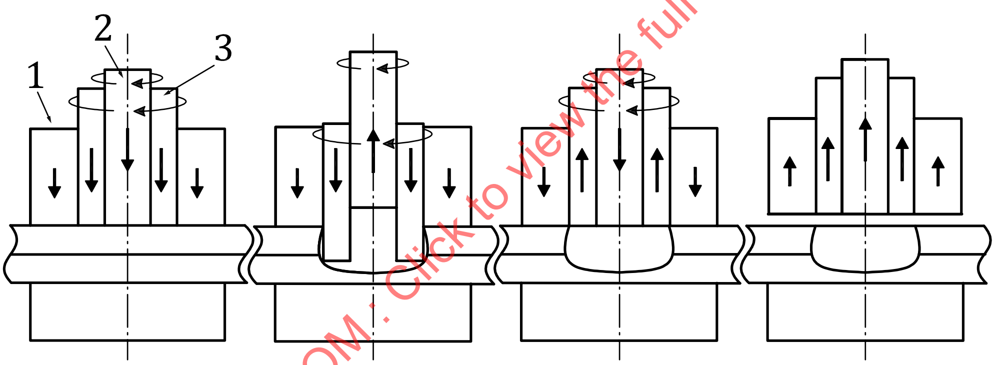


a) **Clamping and tool rotation** b) **Probe plunge and shoulder retraction** c) **Parts back to surface level** d) **Tool retraction**

Key

1 clamping ring (stationary)
2 probe (rotating)
3 shoulder (rotating)

Figure 2 — Illustration of refill FSSW process using probe plunge mode



a) **Clamping and tool rotation** b) **Shoulder plunge and probe retraction** c) **Parts back to surface level** d) **Tool retraction**

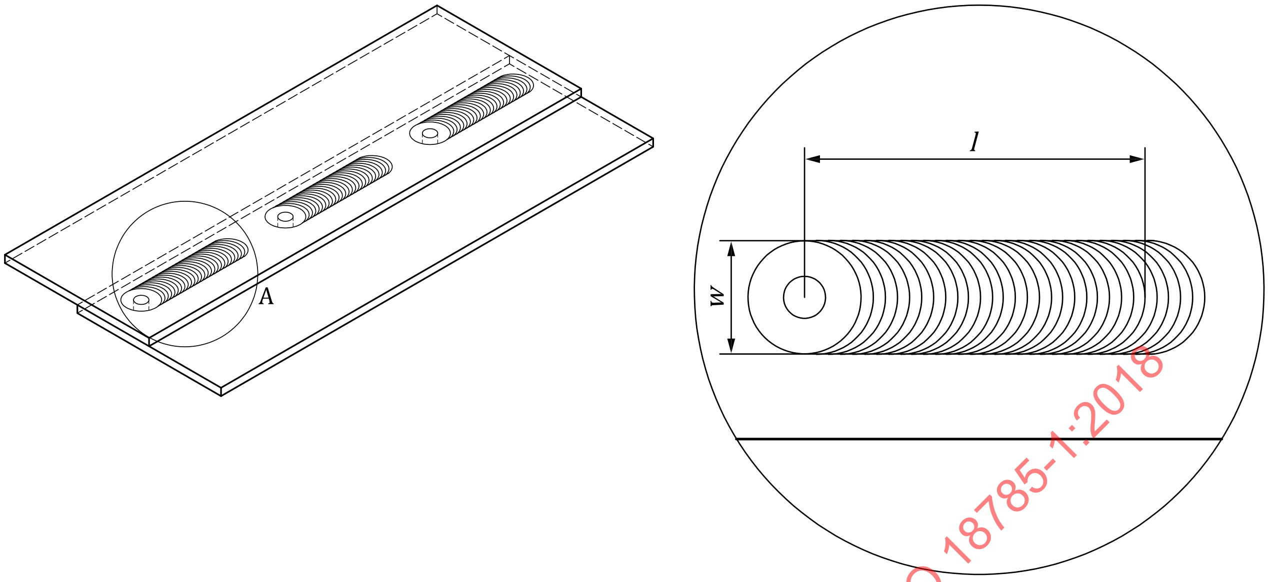
Key

1 clamping ring (stationary)
2 probe (rotating)
3 shoulder (rotating)

Figure 3 — Illustration of refill FSSW process using shoulder plunge mode

5 Description of Stitch FSSW

FSSW technique which produces short discontinuous welds made by traversing the tool for a short linear distance (see Figure 4).



a) General view

b) Detail A

Key

l length of travel

w weld width (equivalent to probe diameter)

Figure 4 — Illustration of stitch FSSW

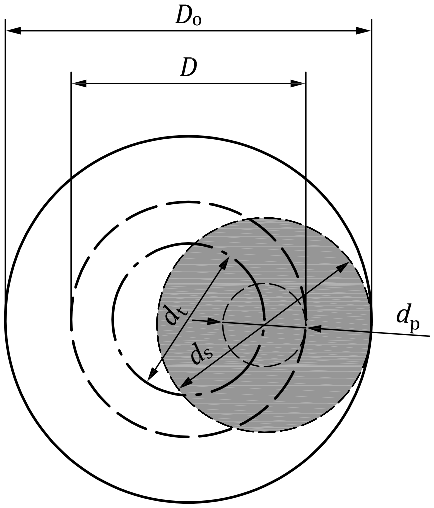
Table 1 gives limitations on the maximum length of travel, l_{max}, and minimum weld width, w_{min}, for stitch FSSW.

Table 1 — Recommendations for stitch FSSW dimensions

Dimension	Measurement as a function of plate thickness, *t*	
Maximum length of travel, l_{max}	15 *t*	
Minimum weld width, w_{min}	$t < 3$ mm	3 *t*
	$t \geq 3$ mm	2,5 *t*

6 Description of Swept FSSW

FSSW caused by the plunge and translation of a rotating tool in a circular or elliptical path around the exit hole. Tool translation is about the work piece surface along a curvilinear path creating a complete or nearly complete closed or circumscribed loop (see Figure 5 and Table 2).



Key

D_o weld face outer diameter (top face of work piece)

d_S tool shoulder diameter

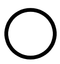
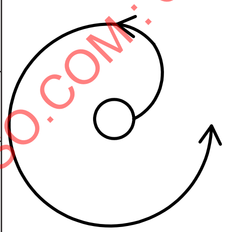
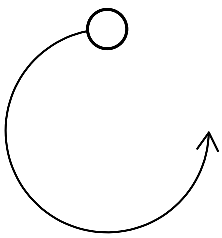
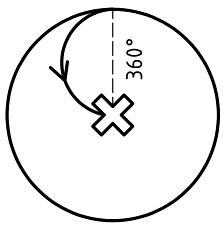
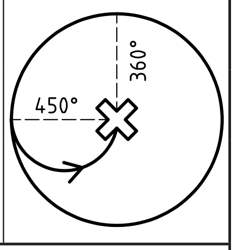
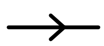
d_p probe diameter

d_t diameter of the tool path

D shear area diameter

Figure 5 — Illustration of swept FSSW (circular path) showing geometric construction of faying surface shear area

Table 2 — Path variables for swept FSSW

Key		**Plunge location**		**Tool path rotation**	
Plunge	**Retract**	**Centre**	**Side**	**360°**	**450°**[a]
					
Tool path	° from start of weld				
	450°				
[a] Path rotation is not limited to the degrees of rotation shown.					

7 Description of Swing FSSW

FSSW produced by plunging and sideways (pivoting) motion of a rotating tool approximately perpendicular to the axis of its rotation (see Figure 6 and Figure 7). The pivoting motion is an arc with a radius that is large compared to the thickness of the sheet being joined and the lateral distance travelled.