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Welding — Friction welding of metallic materials

Soudage — Soudage par friction des matériaux métalliques

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15620 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal working*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

Annexes A to H of this International Standard are for information only.

For the purposes of this International Standard, the CEN annex regarding fulfilment of European Council Directives has been removed.

Contents

Page

Foreword ... **v**

Introduction ... **vi**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms and definitions ... **1**

4 Welding knowledge ... **4**
4.1 Process ... 4
4.2 Materials and material combinations ... 7
4.3 Friction welding machines ... 7

5 Quality requirements ... **9**
5.1 General ... 9
5.2 Pre-welding conditions ... 9
5.3 Post-welding treatment ... 10
5.4 Quality assurance ... 10

6 Welding procedure specification (WPS) ... **11**
6.1 General ... 11
6.2 Information related to the manufacturer ... 11
6.3 Information related to the material ... 11
6.4 Welding parameters ... 11
6.5 Joint ... 12
6.6 Optional devices ... 12

7 Welding procedure approval ... **12**
7.1 Principles ... 12
7.2 Welding procedure tests ... 12
7.3 Welding procedure approval record (WPAR) ... 16
7.4 Previous experience ... 16
7.5 Circumstances mandating requalification ... 16
7.6 Machine-specific nature of a WPS ... 16
7.7 Requalification procedure requirements ... 16

8 Welding personnel ... **16**
8.1 Friction welding machine operator ... 16
8.2 Friction welding machine setter ... 16
8.3 Welding coordination personnel (supervisor) ... 16

Annex A (informative) **– Relationship of welding parameters** ... **17**

Annex B (informative) **– Additional processes based on friction** ... **19**

Annex C (informative) **– Material combinations weldable by friction welding** ... **21**

Annex D (informative) **– Guidelines for quality assurance** ... **22**

Annex E (informative) **– Examination and test** ... **23**

Annex F (informative) **– Manufacturer's friction welding procedure specification (WPS)** ... **25**

Annex G (informative) **– Characteristics of friction welded components** ... **27**

Annex H (informative) **– Welding procedure approval record form (WPAR)** ... **31**

Foreword

The text of EN ISO 15620:2000 has been prepared by Technical Committee CEN/TC 121 "Welding", the secretariat of which is held by DS, in collaboration with Technical Committee ISO/TC 44 "Welding and allied processes".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2001, and conflicting national standards shall be withdrawn at the latest by January 2001.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this standard.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Friction welding is a method for making welds in the solid phase in which one component is moved relative to and in pressure contact with the mating component to produce heat at the faying surfaces, the weld being completed by the application of a force during or after the cessation of relative motion. There are several forms of supplying energy and various forms of relative movements.

The generation of friction heating results in a comparatively low joining temperature at the interface. This is largely the reason why friction welding is suitable for materials and material combinations which are otherwise difficult to weld. The weld region is generally narrow and normally has a refined microstructure.

Whilst the friction welding process deals primarily with components of circular cross section it does not preclude the joining of other component shapes.

1 Scope

This standard specifies requirements for the friction welding of components manufactured from metals.

It specifies requirements particular to rotational friction welding related to welding knowledge, quality requirements, welding procedure specification, welding procedure approval and welding personnel.

This standard is appropriate where a contract, an application standard or regulatory requirement requires the demonstration of the manufacturer' s capability to produce welded constructions of a specified quality. It has been prepared in a comprehensive manner to be used as a reference in contracts. The requirements given may be adopted in full or some may be deleted, if not relevant to the construction concerned.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1289
Non-destructive examination of welds – Penetrant testing of welds – Acceptance levels

EN 1290
Non-destructive examination of welds – Magnetic particle examination of welds

EN 1711
Non-destructive examination of welds – Eddy current examination of welds by complex plane analysis

EN ISO 4063
Welding and allied processes – Nomenclature of processes and reference numbers (ISO 4063:1998)

3 Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1
axial force
Axial force between components to be welded.

3.2
axial pressure
Pressure (force per unit area) on the faying surfaces.

3.3
burn-off length
Loss of length in the friction phase.

3.4
burn-off rate
The rate of shortening of the components during application of the friction force.

3.5
component
A single item before welding.

3.6
component induced braking
Reduction in rotational speed resulting from friction between the interfaces.

3.7
contact force
Axial force on contact of components.

3.8
contact torque
Reaction torque after friction start.

3.9
external braking
External braking reducing the rotational speed.

3.10
faying surface
A surface of one component that is to be in contact with a surface of another component to form a joint.

3.11
forge force
The force applied normal to the faying surfaces at the time when relative movement between the components is ceasing or has ceased.

3.12
forge length
The amount by which the overall length of the components is reduced during the application of the forge force.

3.13
forge phase
In the friction welding cycle the interval between the start and finish of application of the forge force.

3.14
forge pressure
The pressure (force per unit area) on the faying surfaces resulting from the axial forge force.

3.15
forge rate
The rate of shortening of the components during the application of forge force.

3.16
forge time
The time for which the forge force is applied to the components.

3.17
friction force(s)
The force(s) applied normal to the faying surfaces during the time that there is relative movement between the components.

3.18
friction phase
In the friction welding cycle the interval in which the heat necessary for making a weld is generated by relative motion and the friction force(s) between the components, i.e. from contact of components to the start of deceleration.

3.19
friction pressure(s)
The pressure(s) (force per unit area) on the faying surfaces resulting from the axial friction force.

3.20
friction time
The time during which relative movement between the components takes place at rotational speed and under application of the friction force(s).

3.21
interface
The contact area developed between the faying surfaces after completion of the welding operation.

3.22
length allowance
Extra material to allow for loss of length.

3.23
overhang
The distance a component projects from the fixture, or chuck in the direction of the mating component.

3.24
peripherial velocity
Velocity of outer diameter of faying surfaces to be welded.

3.25
rotational speed
Revolutions per minute of rotating component.

3.26
stopping phase
In the friction welding cycle the interval in which the relative motion of the components is decelerated to zero.

3.27
stopping time
The time required by the moving component to decelerate from friction speed to zero speed.

3.28
torque curve
Torque characteristic between the two interfaces based on time (contact, equilibrium, final torque).

3.29
total length loss (upset)
The loss of length that occurs as a result of friction welding, i.e. the sum of the burn-off length and the forge length.

3.30
total weld time
Time elapsed between component contact and end of forging phase.

3.31
upset metal (flash)
Parent metal proud of the normal surfaces of the weldment as a result of friction welding.

3.32
weld cross-section
The areas to be welded.

3.33
welding cycle
The succession of operations effected by the machine for making a weldment and the return to the initial position (excluding component-handling operations).

3.34
weldment
Two or more components joined by welding.

3.35
pressure contact area
The surface contact area of the components through which the force is transmitted.

4 Welding knowledge

4.1 Process

The classification of friction welding processes are listed in table 1.

Table 1 - Classification of friction welding processes

Friction welding

Relative motion classification

Energy classification

Continuous drive

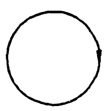
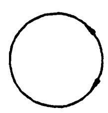
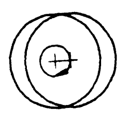
The process variant where power or energy is provided by an infinite duration source and maintained for a preset period

Stored energy

The process variant where the energy for welding is supplied by the kinetic energy stored in a rotating system or fluid storage system

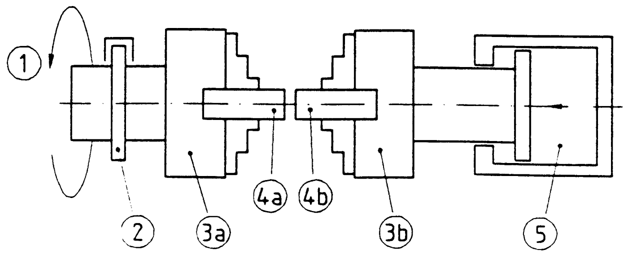
Hybrid system

Combining some features of both methods

Rotational	Linear reciprocation	Angular oscillation	Orbital
A method in which one component is rotated relative to and in contact with the mating face of another component or components.	A method in which one component is moved in a linear oscillating motion relative to and in contact with the mating face of another component.	A method in which one component is moved in an angular oscillating motion about a common component axis relative to and in contact with the mating face of another component.	A method in which one component is moved in a small circular motion relative to and in contact with the mating face of another component.
			

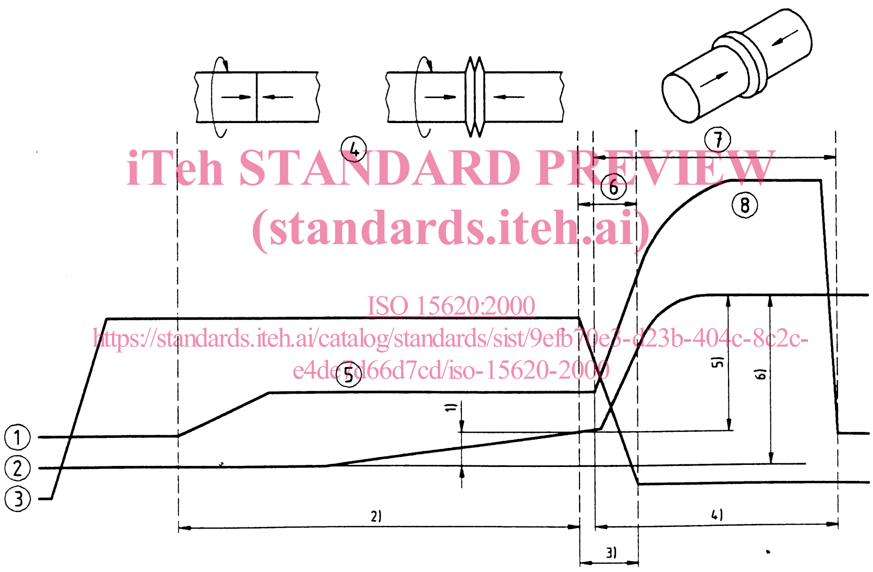
4.1.1 Direct drive rotational friction welding

The energy input is provided by direct drive at predetermined rotational speed or speeds, figures 1 and 2.



1 Drive motor
2 Brake
3a Rotating clamp
3b Stationary clamp
4a Rotating workpiece
4b Stationary workpiece
5 Forge cylinder

Figure 1 - Diagram showing direct drive rotational friction welding



1 Axial force
2 Axial displacement
3 Rotational speed
4 Friction phase
5 Friction force
6 Stopping phase
7 Forge phase
8 Forge force

1) Burn-off length
2) Friction time
3) Stopping time
4) Forge time
5) Forge length
6) Total length loss (upset)

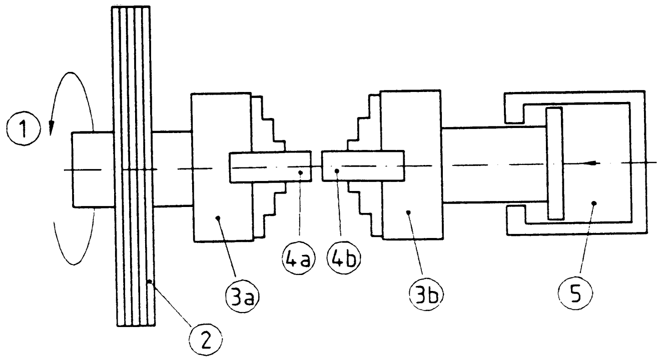
Figure 2 - Diagram showing typical relationships of characteristics for friction welding at constant rotational speed (friction welding, process No. 42 in accordance with EN ISO 4063)

The spindle is either decelerated at a predetermined rate or stopped by external braking or component induced braking. The main welding parameters are listed below and their relationship is given in Annex A:

– rotational speed(s);
– predetermined friction force(s);
– friction time or burn-off;
– predetermined forge force(s);
– forge time;
– stopping time and forge delay.

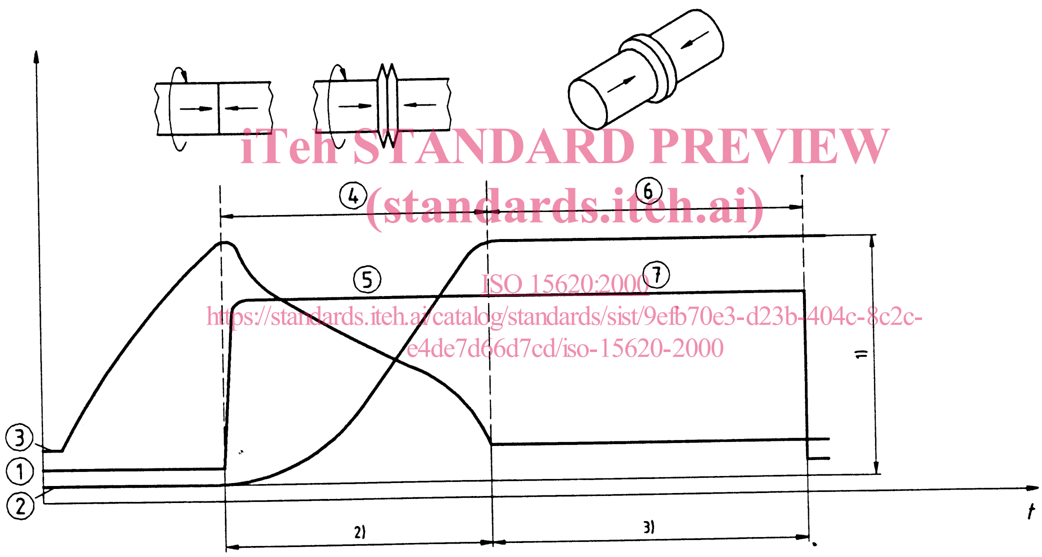
4.1.2 Stored energy (inertia) friction welding

Energy stored in an inertia mass is used up in the friction welding process by component induced braking, see figures 3 and 4.



1 Drive motor
2 Inertia mass, variable
3a Rotating clamp
3b Stationary clamp
4a Rotating workpiece
4b Stationary workpiece
5 Forge cylinder

Figure 3 - Diagram showing inertia friction welding



1 Axial force
2 Axial displacement
3 Rotational speed
4 Friction phase
5 Friction force
6 Forge phase
7 Forge force

1) Total length loss (upset)
2) Friction time
3) Forge time

Figure 4 - Diagram showing typical relationships of characteristics for inertia friction welding (friction welding, process No. 42 in accordance with EN ISO 4063)

The main welding parameters are listed below and their relationship is given in Annex A:

– rotational speed;
– inertia mass;
– predetermined friction force(s);
– predetermined forge force(s).

4.1.3 Further processes

Further processes are listed in Annex B.

4.1.4 Friction welding arrangements

The following methods of rotational friction welding (see figure 5) can be distinguished:

– friction welding with the rotation of one of the components to be welded or one of the parts to be joined and linear movement of the other (figure 5a) i.e. fixed head friction welding machine;

– welding with rotation and linear movement of one of the components to be welded and the other one held static (figure 5b) i.e. sliding head friction welding machine;

– rotation and linear movement of two components against a static middle component (figure 5c) i.e. double ended friction welding machine;

– rotation of central component with linear movement of two end components (figure 5d).

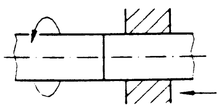


Figure 5a

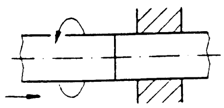


Figure 5b

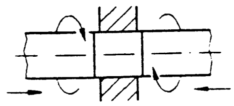


Figure 5c

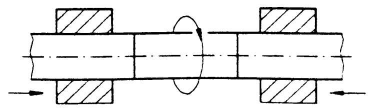


Figure 5d

Figure 5 - Rotational friction welding methods

4.2 Materials and material combinations

Experience of friction welding many metallic materials and combinations is already well-documented (see Annex C). Weldability criteria for other welding processes is not always valid for friction welding. More materials and their combinations can be friction welded when compared with most other welding processes. The data shown in Annex C is based upon actual experience from test welds but it is not necessarily complete. For many materials and material combinations there is further data available which is only valid for particular geometries.

The following factors can affect welding quality:

– amount, distribution and shape of non-metallic inclusions in the parent material(s);
– formation of intermetallic phases in the weld;
– formation of low melting point phases in the weld;
– porosity in parent material(s);
– thermal softening of hardened materials in the weld;
– hardening of the weld metal heat affected zone;
– hydrogen in parent material(s).

It may be possible to negate some of the above by critical selection of parameters or heat treatment.

4.3 Friction welding machines

4.3.1 General

Friction welding is not positionally sensitive and may be performed in any plane.

Machine design and build are dependent upon the welding application and there are preconditions for exact and repeatable production. A schematic diagram of a horizontal friction welding machine is shown in figure 6.