SLOVENSKI STANDARD
SIST EN 1011-2:2001

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Varjenje - Priporočila za varjenje kovinskih materialov - 2. del: Obločno varjenje feritnih jekel

Welding - Recommendations for welding of metallic materials - Part 2: Arc welding of ferritic steels

Schweißen - Empfehlungen zum Schweißen metallischer Werkstoffe - Teil 2: Lichtbogenschweißen von ferritischen Stählen

Soudage - Recommandations pour le soudage des matériaux métalliques - Partie 2: Soudage a l'arc des aciers ferritiques

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Welding - Recommendations for welding of metallic materials - Part 2: Arc welding of ferritic steels

Soudage - Recommandations pour le soudage des matériaux métalliques - Partie 2: Soudage à l'arc des aciers ferritiques

Schweißen - Empfehlungen zum Schweißen metallischer Werkstoffe - Teil 2: Lichtbogenschweißen von ferritischen Stählen

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 121 "Welding", the secretariat of which is held by DS.

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of an identical text or by endorsement, at the latest by July 2001, and conflicting national standards shall be withdrawn at the latest by July 2001.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

This European Standard supplements Part 1. It is issued with several annexes in order that it can be extended to cover the different types of steel which are produced to all the European steel standards for ferritic steels (see clause 5).

This standard gives general guidance for the satisfactory production and control of welds in ferritic steels. Details concerning the possible detrimental phenomena which can occur are given with advice on methods by which they can be avoided. This standard is generally applicable to all ferritic steels and is appropriate regardless of the type of fabrication involved, although the application standard can have additional requirements.

1 Scope

This European Standard gives guidance for manual, semi-mechanised, mechanised and automatic arc welding of ferritic steels (see clause 5), excluding ferritic stainless steels, in all product forms.

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 288-2:1997, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding*

EN 1011-1:1998, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

EN 29692, *Metal-arc welding with covered electrode, gas-shielded metal-arc — welding and gas welding — Joint preparations for steel (ISO 9692:1992)*

EN ISO 13916, *Welding — Guidance for the measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:1996)*

CR ISO 15608, *Welding — Guidelines for a metallic material grouping system (ISO/TR 15608:2000)*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions listed in EN 1011-1:1998 and the following apply:

3.1
cooling time $t_{8/5}$
the time taken, during cooling, for a weld run and its heat affected zone to pass through the temperature range from 800 °C to 500 °C

3.2
run out length
the length of a run produced by the melting of a covered electrode

3.3
run out ratio R_r
the ratio of the run out length to the length of electrode consumed

3.4
shape factor F_x
describes the influence of the form of a weld on the cooling time $t_{8/5}$. In the case of two-dimensional heat flow it is called F_2 and in the case of three-dimensional heat flow it is called F_3

3.5
three-dimensional heat flow
the heat introduced during welding which flows parallel and perpendicular to the plate surface

3.6
transition thickness d_t
plate thickness at which the transition from three-dimensional to two-dimensional heat flow takes place

3.7
two-dimensional heat flow
the heat introduced during welding which flows only parallel to the plate surface

3.8
preheat maintenance temperature T_m
the minimum temperature in the weld zone which should be maintained if welding is interrupted

4 Symbols and abbreviations

Table 1 — Symbols and abbreviation

Symbols/Abbreviations	Terms	Units
CE	Carbon equivalent (see C.2.1)	%
CET	Carbon equivalent (see C.3.2)	%
D	Diameter	mm
d	Thickness of plate	mm
d_t	Transition thickness	mm
F_2	Shape factor for two-dimensional heat flow	–
F_3	Shape factor for three-dimensional heat flow	–
HAZ	Heat affected zone	–
HD	Diffusable hydrogen content	ml/100g deposited weld metal
Q	Heat input	kJ/mm
R_r	Run out ratio	–
$t_{8/5}$	Cooling time (from 800 °C to 500 °C)	s
t	Melting time of an electrode	s
T_i	Interpass temperature	°C
T_m	Preheat maintenance temperature	°C
T_o	Initial plate temperature	°C
T_p	Preheat temperature	°C
T_t	Impact transition temperature	°C
UCS	Unit of crack susceptibility	–
λ	Thermal conductivity	J/cm K s
ρ	Density	kg/m^3
c	Specific heat capacity	J/kg K

5 Parent metal

This standard applies to ferritic steels excluding ferritic stainless steels. This includes steels referenced in groups 1 to 7 of CR ISO 15608. When ordering steel it may be necessary to specify requirements concerning weldability, which can involve specifying additional requirements to those given in the relevant steel standard.

6 Weldability factors

The properties and the quality of welds are particularly influenced by the welding conditions. Thus, the following factors should be taken into consideration:

— Joint design;

— Hydrogen induced cracking;

— Toughness and hardness of the heat affected zone (*HAZ*);

— Solidification cracking;

— Lamellar tearing;

— Corrosion.

The mechanical and technological properties, in particular the hardness and toughness of the heat affected zone in a narrowly delineated area, can be influenced to a greater or lesser degree, compared with the properties of the parent metal and depend on the welding conditions. Experience and tests indicate that not only the properties of the narrow affected zone of lower strength and better flexibility, but also the load distribution effect of the tougher adjacent zones should be taken into account when assessing the ductility and safety against fracture of welded joints as this could affect the choice of steel.

7 Handling of welding consumables

When special protection or other treatment during storage or immediately prior to use is recommended by the consumable manufacturer, these consumables should be treated in accordance with the conditions detailed by the manufacturer.

When drying or baking, consumables should be removed from their original containers. After removal from the oven, the consumables should be protected from exposure to conditions conducive to moisture absorption. In the case of welding consumables that have been specially packaged, e.g. vacuum or other moisture resistance means, advice from the consumable manufacturer should be sought as to further steps required for drying and baking.

If controlled hydrogen levels are required, it is recommended that welders be issued with electrodes in heated quivers or sealed containers.

Drying ovens, e.g. for welding consumables, shall be provided with means of measuring the oven temperature.

8 Weld details

8.1 Butt welds

Butt joints between parts of unequal cross-section should be made and subsequently shaped such that a severe stress concentration at the junction is avoided.

Some examples of joint preparations for use with metal-arc welding with covered electrodes and gas-shielded metal-arc welding are given in EN 29692.

Partial penetration butt joints may be permitted dependant on the design specification. Consideration should be given to the choice of weld preparation and welding consumables in order to achieve the specified throat thickness.

Under fatigue conditions, partial penetration joints or the use of permanent backing material may be undesirable.

Backing material may consist of another steel part of the structure when this is appropriate.

When it is not appropriate to use part of the structure as backing material, the material to be used shall be such that detrimental effects on the structure are avoided and shall be agreed in the design specification.

Care shall be taken when using copper as a backing material as there is a risk of copper pick-up in the weld metal.

Where temporary or permanent backing material is employed, the joint shall be arranged in such a way as to ensure that complete fusion of the parts to be joined is readily achieved.

Wherever the fabrication sequence allows, tack welds attaching permanent backing should be positioned for subsequent incorporation into the weld (see clause 14 of EN 1011-1:1998).

8.2 Fillet welds

Unless otherwise specified, the edges and surfaces to be joined by fillet welding shall be in as close contact as possible since any gap may increase the risk of cracking. Unless otherwise specified, the gap shall not exceed 3 mm. Consideration shall be given to the need to increase the throat of the fillet weld to compensate for a large gap.

Unless otherwise specified, welding should not start/stop near corners, instead, it should be continued around the corners.

9 Welds in holes or slots

Due to the risk of cracking, holes or slots should not be filled with weld metal unless required by the design specification. Holes or slots that are required to be filled with weld metal shall only be filled after the first run has been found to be acceptable (see also B.4).

10 Preparation of joint face

10.1 General

Any large notches or any other errors in joint geometry which might occur shall be corrected by applying a weld deposit according to an approved welding procedure. Subsequently, they shall be ground smooth and flush with the adjacent surface to produce an acceptable finish.

Prefabrication primers (shop primers) may be left on the joint faces provided that it is demonstrated they do not adversely affect the welding.

10.2 Fusion faces

When shearing is used, the effect of work hardening should be taken into account and precautions shall be taken to ensure that there is no cracking of the edges.

Single- and double-U and single-J weld preparations usually have to be machined. In assessing the methods of preparation and type of joint, the requirements of the chosen welding process should be taken into account.

10.3 Un-welded faces

Where a cut edge is not a fusion face, the effect of embrittlement from shearing, thermal cutting or gouging shall not be such as to adversely affect the workpiece.

Local hardening can be reduced by suitable thermal treatment or removed by mechanical treatment. The removal of 1 mm to 2 mm from a cut face normally eliminates the hardened layer. When using thermal cutting, local hardening can be lessened by a reduction in usual cutting speed or by preheating before cutting. If necessary the steel supplier should be consulted for recommendations on achieving a reduction in hardness.

U and J weld preparations as compared with V and bevel weld preparations serve to reduce distortion by virtue of the smaller amount of weld metal required. Likewise, double preparations are better than single preparations in that the weld metal can be deposited in alternate runs on each side of the joint. In the control of distortion, accuracy of preparation and fit-up of parts are important considerations, as well as a carefully planned and controlled welding procedure.

11 Alignment of butt welds before welding

Unless specified otherwise (e.g. in a welding procedure specification or an application standard), the root edges or root faces of butt joints shall not be out of alignment by more than 25 % of the thickness of the thinner material for material up to and including 12 mm thick, or by more than 3 mm for material thicker than 12 mm.

For certain applications and welding processes, closer tolerances may be necessary.

NOTE For the purposes of Directive 97/23/EC, an application standard means a relevant product standard.

12 Preheating

The points of temperature measurement shall be in accordance with EN ISO 13916 except that for all thicknesses the distance for measurement shall be at least 75 mm from the weld centre line.

Particular attention should be paid to the need for preheating when making low heat input welds, e.g. tack welds.

13 Tack welds

It is recommended that the minimum length of a tack weld should be 50 mm, but for material thicknesses less than 12 mm the minimum length of a tack weld shall be four times the thicker part. For materials of thickness greater than 50 mm or of yield strength over 500 N/mm^2 consideration should be given to increasing the length and size of tack welds, which may involve the use of a two run technique. Consideration should also be given to the use of lower strength and/or higher ductility consumables when welding higher alloy steel.

14 Temporary attachments

If a thermal process is used to remove a temporary attachment or run on/off pieces after welding, sufficient attachment or run on/off piece shall be left to allow subsequent removal of the heat-affected material by careful grinding.

15 Heat input

Heat input is calculated from the weld travel speed (see clause 19 of EN 1011-1 : 1998). When weaving with manual metal-arc welding, the weave width should be restricted to three times the diameter of the core rod.

For multi-wire arc welding, the heat input is calculated as the sum of the heat input for each individual wire using the individual current and voltage parameters.

16 Welding procedure specification

The welding procedure specification shall comply with EN 288-2 and shall include the following:

a) whether shop or site welding;

b) maximum combined thickness (see C.2.4), if annex C.2 is applied; plate thickness, if annex C.3 is applied;

c) heat input (see clause 15);

d) hydrogen scale (see C.2.3 and C.3.2);

e) tack welds (see clause 13).

17 Identification

Where the use of hard stamp marks is required by the contract, guidance on their location and size shall be given. Indentations used for marking in radiographic examination require equal consideration.

18 Inspection and testing

Due to the risk of delayed cracking, a period of at least 16 h is generally required before the final inspection is made of as-welded fabrications. The minimum time may be reduced for thin materials below 500 N/mm^2 yield strength or increased for materials of thickness greater than 50 mm or of yield strength over 500 N/mm^2. Whatever period is used it shall be stated in the inspection records.

Welds that have been heat-treated to reduce the hydrogen content or which have been stress relieved, need no additional time interval following the heat treatment before final inspection is made.

Tungsten inert gas welding (TIG) and other re-melting processes, if required for post weld treatment, shall be performed before final inspection.

Welds which are to be inspected and approved shall not be painted or otherwise treated until they have been accepted.

19 Correction of non-conforming welds

All welds which do not conform to the design specification shall be corrected.

NOTE Fracture mechanics or other assessment techniques may be used to determine whether a non-conforming weld needs to be corrected.

20 Correction of distortion

The temperature of heated areas, measured by appropriate methods, should be in accordance with the recommendations of the material supplier or the design specification.

21 Post weld heat treatment

When post weld heat treatment of welds is required but no application standard exists, the heat treatment details shall be stated in the design specification taking account of the effect on the properties of the parent metal, *HAZ* and weld metal.

Annex A
(informative)

Possible detrimental phenomena resulting from welding of steels, not covered by other annexes

Possible detrimental phenomena resulting from welding	Causes	Counter measures
Stress relief heat treatment cracks	Carbide or nitride precipitation can occur during stress relief heat treatment if the stress relief heat treatment and/or steel composition are unfavourable. This can reduce the ductility of the steel such that relaxation of stress leads not only to plastic deformation but also to crack formation.	Reduce stress concentrations by grinding the toes of welds. Minimize the amount of coarse grained *HAZ* by correct weld run sequence. Use optimum heat treatment procedures.
Corrosion a) General attack	Differences in chemical composition, grain size and stress levels between the weld and the parent material can lead to different corrosion rates. In most cases the weld and heat affected zone are attacked preferentially.	Avoid large differences in plate and weld metal compositions.
b) Stress corrosion cracking	Caused by a critical combination of stress, micro-structure and environment.	Avoid stress concentrations. Minimize weld stress levels. Reduce hardness levels.

Annex B
(informative)

Guidance on joint detail design (when there is no application standard)

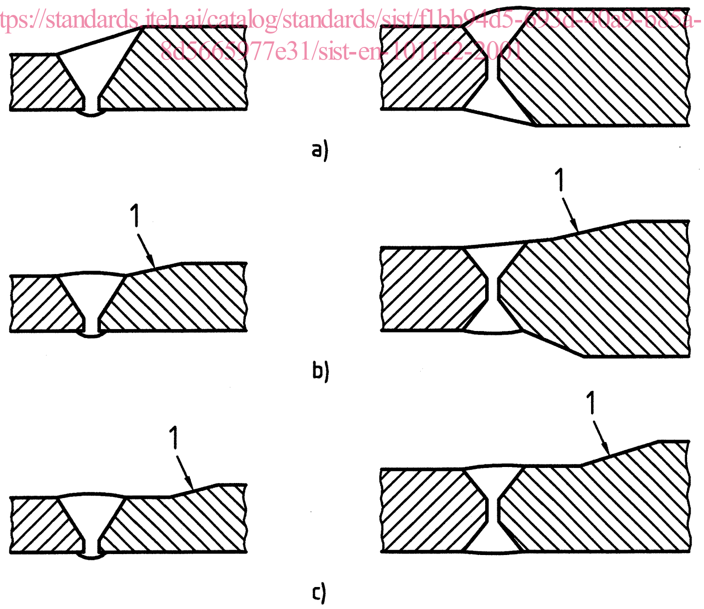
B.1 General

This annex may be used where no guidance from an application standard exists. Further information is given in other documents e.g. EN 1708-1:1999, EN 1708-2. Particular guidance on design to avoid lamellar tearing is given by Annex F.

B.2 Butt joints

Butt joints between parts of unequal cross-section, arranged in line, will result in a local increase in stress in addition to the stress concentration caused by the profile of the weld itself. If the centre planes of the two parts joined do not coincide, local bending also will be induced at the joint. If the stresses induced by these effects are unacceptable, then the parts should be shaped before welding by a slope of not greater than 1 in 4 so as to reduce the stresses. Examples of plain and shaped parts are shown in figure B.1, where a) and b) are the more common types with c) being a special configuration to facilitate non-destructive testing.

A partial penetration butt weld which is welded from one side only should not be subjected to a bending moment about the longitudinal axis of a weld. It would cause the root of the weld to be in tension. Therefore it should be avoided and only used when permitted by the design. Under such circumstances it may be allowed by an application standard or contract.



Key

1 Slope approximately 1 in 4

a) Slope in the weld
b) Slope in the thicker plate
c) Special configuration to facilitate non-destructive testing

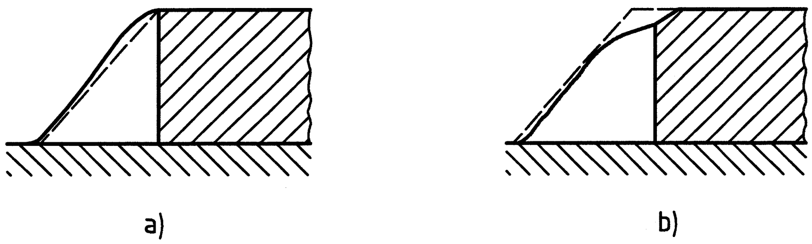
Figure B.1 — Butt joints of unequal cross-section

B.3 Fillet welds

The effective length of an open ended fillet weld should be taken as the overall length less twice the leg length. In any case, the effective length should be not less than 25 mm or four times the leg length whichever is the greater.

For fillet welded joints carrying a compressive load, it should not be assumed that the parts joined are in contact under the joint. For critical applications the use of a partial or even a full penetration butt weld should be considered.

Where the specified leg length of a fillet weld, at the edge of a plate or section, is such that the parent metal does not project beyond the weld, melting of the outer corner or corners, which reduces the throat thickness, is not allowed (see figure B.2).



a) Desirable
b) Not acceptable because of reduced throat thickness

Figure B.2 — Fillet welds applied to the edge of a part

A single fillet weld should not be subjected to a bending moment about the longitudinal axis of the joint which would cause the root of the weld to be in tension.

Fillet welds connecting parts, where the fusion faces form an angle of more than 120° or less than 60°, should not be relied upon to transmit calculated loads at the full working stresses unless permitted to do so by the application standard.

The design throat thickness of a flat or convex fillet weld connecting parts, where the fusion faces form an angle between 60° and 120°, can be derived by multiplying the leg length by the appropriate factor as given in table B.1.

Table B.1 — Factors for deriving design throat thickness of flat or convex fillet welds based on leg angle

Angle between fusion faces (degrees)	Factor
60 to 90	0,7
91 to 100	0,65
101 to 106	0,60
107 to 113	0,55
114 to 120	0,50

Due account should be taken of fabrication, transport, and erection stresses particularly for those fillet welds which have been designed to carry only a light load during service.

B.4 Holes and slots

In order to provide access for welding, the diameter of a hole or the width of a slot should be not less than three times the material thickness or 25 mm, whichever is the greater. Ends of slots should be rounded with a radius or not less than 1,5 times the material thickness or 12 mm whichever is the greater. The distance between the edge of the part and the edge of the hole or slot, or between the adjacent slots or holes, should be not less than twice the thickness and not less than 25 mm for holes (see also clause 9).

Annex C
(informative)

Avoidance of hydrogen cracking (also known as cold cracking)

C.1 General

This annex gives recommendations for the avoidance of hydrogen cracking.

In preparing this annex, full account was taken of the fact that many methods have been proposed for predicting preheat temperatures to avoid hydrogen cracking in non-alloyed, fine grained and low alloy steel weldments. Examples are given in IIW documents IX-1602-90 and IX-1631-91. Two methods are included in this annex as C.2 and C.3. Method A given in C.2 is based on extensive experience and data which is mainly, but not exclusively, for carbon manganese type steels. Method B given in C.3 is based on experience and data which is mainly, but not exclusively, for low alloy high strength steels. The differences in origin and experience used to develop these two methods can be used as a guide as to their application.

The method described under C.4 shall be used for creep resisting and low temperature steels.

The recommendations apply only to normal fabrication restraint conditions. Higher restraint situations may need higher preheat temperature or other precautions to prevent hydrogen cracking.

Clauses C.2 and C.3 refer to welding of parent metal at temperatures above 0 °C. When welding is carried out below this temperature it is possible that special requirements will be needed.

Alternative procedures to those derived from this annex may be used, for example lower preheat temperatures, provided they are supported by evidence of their effectiveness. The evidence should include all the factors also considered for the welding procedures as given in this annex.

C.2 Method A for the avoidance of hydrogen cracking in non-alloyed, fine grained and low alloy steels

C.2.1 Parent metal

Clause C.2 covers non-alloyed, fine grained and low alloy steels.

The range of chemical composition in percentage by weight of the main alloy constituents is:

— Carbon 0,05 to 0,25

— Silicon 0,8 max.

— Manganese 1,7 max.

— Chromium 0,9 max.

— Copper 1,0 max.

— Nickel 2,5 max.

— Molybdenum 0,75 max.

— Vanadium 0,20 max.