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Welding specification for pressure vessels

压力容器焊接规程

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Welding specification for pressure vessels

1 Scope

This document specifies the basic requirements for welding of steel, aluminum, titanium, copper, nickel, zirconium, composite metal pressure vessels.

This document applies to pressure vessels for gas welding, arc welding, submerged arc welding, gas tungsten arc welding, metal arc welding, plasma arc welding, electron beam welding, gas-electric vertical welding, stud welding, strip electrode cladding.

This document does not apply to welding procedures for gas cylinders.

2 Normative references

The contents of the following documents constitute essential clauses of this document through normative references in the text. Among them, for dated references, only the version corresponding to that date applies to this document; for undated references, the latest version (including all amendments) applies to this document.

GB/T 985.3 Recommended joint preparation for gas-shield arc welding on aluminium and its alloys

GB/T 3375 Welding terminology

GB/T 3670 Covered electrodes for manual metal arc welding of copper and copper alloys

GB/T 9460 Solid wires and rods for fusion welding of copper and copper alloys

GB/T 13814 Nickel and nickel alloy covered welding electrodes

GB/T 15620 Nickel and Nickel alloy wires and rods

GB/T 30583 Specification for post weld heat treatment of pressure equipment

GB/T 39255 Shielding gas for welding and cutting

NB/T 47014 Welding procedure qualification for pressure equipments

NB/T 47016 Mechanical property tests of product welded test coupons for pressure equipments

NB/T 47018 (all parts) Ordering technical conditions for welding consumables for pressure equipment

JB/T 3223 Welding consumables quality management procedures

3 Terms and definitions

The terms and definitions as defined in GB/T 3375 and NB/T 47014 apply to this document. If there is any inconsistency, the terms and definitions in NB/T 47014 shall prevail.

4 General welding procedures

4.1 General provisions

4.1.1 In addition to complying with the provisions of this document, the welding of pressure vessels shall also comply with the technical requirements of the design documents.

4.1.2 In addition to the provisions of this document, any results that have been proven effective through welding test research and practice, after being approved by the relevant parties and included in the enterprise standard, can be used for pressure vessel welding.

4.2 Welding materials

4.2.1 Welding materials include welding rods, welding wires, welding strips, flux, gases, electrodes, gaskets.

4.2.2 The welding seams of pressure vessel's pressure components, the welds welded to pressure components, the welding electrode, welding wire, welding strip, welding flux for positioning welds melted into permanent welds, shall comply with the provisions of NB/T 47018.

4.2.3 The gas used for gas shielded welding of pressure vessels shall comply with the provisions of GB/T 39255.

4.2.4 Principles for selecting welding materials:

The mechanical properties of weld metal shall match those of the parent material. The mechanical properties of weld metal, which is welded according to a reasonable welding process, shall meet the requirements of NB/T 47016 and design documents. When necessary, other properties shall not be lower than the corresponding requirements of the parent material.

4.2.5 The manufacturing (installation) organization shall master the weldability of

welding materials; the welding materials used for pressure vessels shall have a welding test or practice basis.

4.2.6 Welding materials shall have a product quality certificate; the user organization shall accept or re-inspect according to the provisions of the quality management system and relevant standards and design documents.

4.3 Weld position

The weld position is divided into four types: flat weld, vertical weld, lateral weld, overhead weld. The specified methods and ranges are shown in Appendix A.

4.4 Welding procedure qualification and welders

For the following types of welds, the welding procedure shall be qualified according to NB/T 47014; the welder shall be qualified according to TSG Z6002 "Examination rules for welding operators of special equipment":

a) Pressure component welds;

b) Welds welded to pressure components;

c) Positioning welds of the above welds (referring to welding procedure), positioning welds welded into the above permanent welds (referring to welders);

d) Overlay welding and repair welding on the surface of the parent material of the pressure component.

4.5 Preparation before welding

4.5.1 Site

4.5.1.1 The site of high-alloy steel pressure vessels shall be separated from other types of materials; anti-scratch pads shall be laid on the ground.

4.5.1.2 Non-ferrous metal pressure vessels shall be manufactured in a dedicated site or dedicated space; corresponding protective measures shall be taken.

4.5.2 Welding groove

4.5.2.1 The welding groove shall be selected from standard grooves or designed by itself according to the design drawings and process conditions. The groove form and size shall consider the following factors:

a) Welding method;

b) Type and thickness of parent material;

4.5.5.5 Both ends of the tack weld melted into the permanent weld shall be easy to start or connect the arc; otherwise, they shall be trimmed.

4.5.6 Preheating

4.5.6.1 The preheating and preheating temperature of the pressure vessel before welding shall be determined based on comprehensive factors such as the delivery status, chemical composition, mechanical properties, diffused hydrogen content of the deposited metal, thickness, weldability of the base material.

4.5.6.2 The preheating temperature of the welded joint shall meet the requirements of relevant standards; if necessary, it can be determined by welding cold crack test; when the ambient temperature is low and the constraint of the welded joint is large, the preheating temperature shall be appropriately increased.

4.5.6.3 When local preheating is adopted, in order to avoid excessive local stress, the preheating range can be appropriately expanded.

4.5.6.4 The preheating range shall be larger than the range shown by the temperature measuring point A (according to Figure 1); the temperature of any point in this range must meet the specified requirements.

4.5.6.5 Measurement of preheating temperature

4.5.6.5.1 The temperature shall be measured on the back of the heating surface. Alternatively, the heating source can be removed first, then the temperature can be measured after the temperature in the thickness direction of the parent material is uniform. The temperature uniformization time is determined by $\frac{T}{25\times 2}$ min (T is the thickness of the parent material).

4.5.6.5.2 Location of temperature measuring point (as shown in Figure 1):

a) When the thickness of the parent material at the weld of the weldment is less than or equal to 50 mm, A is equal to 4 times the thickness of the parent material and does not exceed 50 mm;

b) When the thickness of the parent material at the weld of the weldment is greater than 50 mm, A ≥ 75 mm.

the remaining thickness after grinding shall not be less than the minimum forming thickness marked on the design drawing; otherwise, repair welding shall be performed. For the cladding, overlay, lining layers of the composite plate, the grinding depth shall not exceed 30% of its thickness and shall not exceed 1 mm; otherwise, repair welding shall be performed.

4.6.8 For weldments with impact test requirements, the heat input shall be controlled; the heat input of each weld pass shall not exceed the qualified limit.

4.6.9 For weldments with chromium content greater than or equal to 3% and total alloy element content greater than 5%, when tungsten inert gas shielded welding or metal inert gas shielded welding is used for root welding, argon or other protective gas shall be filled on the back of the weld; or other measures shall be taken to prevent the back weld metal from being oxidized; the back gas shielding shall be terminated only after at least two layers are welded.

4.6.10 The root of the fillet weld shall be fully penetrated.

4.6.11 In multi-pass and multi-layer welding, the joints of different passes of welds shall be staggered by about 50 mm in cross section as far as possible. For welds that are prone to thermal cracks, the arc pit must be filled when the arc is closed. If arc pit cracks are accidentally generated, they shall be polished and removed in time. Pay attention to the cleaning between passes and layers; clean the slag and harmful oxides on the weld surface before continuing welding.

4.6.12 For double-sided welding with full penetration, the weld root must be cleaned and the metal of the tack weld must be removed (except for tack welds supported by qualified welding procedure qualification). For mechanical welding and automatic welding, if it is confirmed by test that the penetration and welding quality can be guaranteed, root cleaning treatment may not be performed.

4.6.13 For double-sided welding of high-alloy materials (except duplex stainless steel) with corrosion resistance requirements, the weld layer in contact with the corrosive medium should be welded last.

4.6.14 During welding, the interpass temperature shall be controlled not to exceed the specified range. When the weldment is required to be preheated, the interpass temperature shall be controlled not lower than the preheating temperature, except for the case where the preheating temperature is appropriately increased to prevent cracking of the base weld.

4.6.15 Each weld should be welded in one go. When welding is interrupted, thermal insulation, post-heating or slow cooling measures shall be taken in time for weldments sensitive to cold cracks. When welding is resumed, preheating according to the original requirements is still required.

4.6.16 For hammerable steel welded joints, hammering shall be used layer by layer to reduce the residual stress of the joints; however, the base layer welds and cover layer welds should not be hammered.

4.6.17 Arc starter plates, lead-out plates, product welded test coupons shall not be removed by hammering.

4.7 Welding repair

4.7.1 The causes of defects that require welding repair shall be analyzed, improvement measures shall be proposed, welding repair process documents shall be prepared according to the qualified welding procedure.

4.7.2 Defects shall be cleaned before repair; non-destructive testing can be used for confirmation if necessary.

4.7.3 The repaired parts shall be prepared with grooves; the shape and size of the grooves shall prevent welding defects and be convenient for welders to operate.

4.7.4 If preheating is required, the preheating temperature shall be appropriately higher than that of the original welded joint.

4.7.5 For pressure vessels or pressure-bearing components with corrosion resistance requirements, the repaired parts still need to ensure that the corrosion resistance is not lower than the original, meanwhile the performance of the repaired welded joints meets the quality requirements.

4.8 Welding inspection and testing items

4.8.1 Before welding:

a) Base steel designation and welding material model and designation;

b) Welding equipment, instruments, process equipment;

c) Storage, preservation, drying, distribution of welding materials;

d) Assembly and cleaning of welding grooves and joints;

e) Welder qualifications;

f) Welding process documents.

4.8.2 During welding:

a) Welding methods, use of welding materials, etc.;

b) Inspection and record of welding specification parameters;

experience and test data. The welding materials recommended for commonly used steel designations can refer to Table D.1 in Appendix D.

5.2.6 When welding steels of different steel designations, the principles for selecting welding materials are as follows:

a) When welding between low-carbon steels, between low-carbon steels and low-alloy steels, between low-alloy steels, the selected welding materials shall ensure that the tensile strength of the weld metal is higher than or equal to the lower limit of the tensile strength of the parent material on the lower strength side; meanwhile it should not exceed the upper limit specified by the standard of the parent material on the higher strength side.

b) When welding low-carbon steel, low-alloy steel and austenitic stainless steel, when the design temperature is higher than 370 °C, nickel-based welding materials shall be used.

c) When welding low-carbon steel, low-alloy steel and ferritic stainless steel or duplex stainless steel, welding materials suitable for welding dissimilar steels can be used. Duplex steel welding materials can also be used for welding with duplex stainless steel.

d) When welding between heat-resistant low-alloy steels or between heat-resistant low-alloy steels and other low-alloy steels, welding materials with low chromium and molybdenum content should be selected.

5.2.7 For welding of stainless steel-steel composite plate base, the selection of welding materials must comply with the provisions of the base material; the welding materials for transition layer welds must be selected considering the dilution effect of the base; the welding materials for cladding materials shall ensure that the corrosion resistance of the weld metal is equivalent to that of the parent material. When the cladding participates in the strength calculation, it must also comply with the provisions of the cladding material.

5.2.8 The gas used for gas shielded welding shall comply with the requirements of the process documents.

5.3 Storage and use of welding materials

5.3.1 The storage and issuance of welding materials shall comply with the provisions of JB/T 3223.

5.3.2 Before using welding materials, the welding wire needs to be free of oil and rust; the shielding gas shall be kept dry.

5.3.3 Except for vacuum packaging, welding rods and flux shall be dried according to the recommended specifications on the welding material quality certificate. The storage

groove with a higher chromium-molybdenum content, meanwhile the corresponding heat treatment can be carried out on that side (if the weld metal strength does not meet the requirements after the heat treatment of the isolation layer, welding consumables with a higher strength level in the corresponding category can be selected); then the welding consumables on the other side can be used to weld with the other side. The final post-weld heat treatment is carried out according to the requirements of the other side.

5.7 Post-heating

5.7.1 For low-alloy steels with greater sensitivity to cold cracks, weldments with thicker walls and greater restraint, post-heating shall be carried out immediately after welding.

5.7.2 The post-heating temperature should be 200 °C ~ 350 °C; the holding time is related to the post-heating temperature and the weld metal thickness, which is generally not less than 30 minutes.

5.7.3 If heat treatment is carried out immediately after welding, post-heating is not required.

5.8 Post-weld heat treatment

5.8.1 Post-weld heat treatment of pressure vessels shall be carried out in accordance with GB/T 30583.

5.8.2 When welding between low carbon steel, low alloy steel and cladding isolation layer and austenitic stainless steel, ferritic stainless steel or duplex stainless steel, use by the use of austenitic stainless steel welding materials or nickel-based welding materials for welding of dissimilar steels, post-weld heat treatment is not required.

5.8.3 When welding between low carbon steel, low alloy steel and cladding isolation layer and duplex stainless steel, by the use of duplex stainless steel welding materials, post-weld heat treatment is not required.

5.8.4 After welding repair of the following vessels, post-weld heat treatment shall be re-performed on the repaired parts:

a) Pressure vessels with stress corrosion indicated in the design documents;

b) Pressure vessels containing extremely or highly toxic media;

c) Low temperature pressure vessels;

d) Vessels that require re-heat treatment in the design documents.

5.8.5 If the following conditions are met, post-weld heat treatment is not required after welding repair:

a) Limited to Fe-1-1, Fe-1-2, Fe-1-3 groups and Fe-3 category in NB/T 47014.

b) For groups Fe-1-1, Fe-1-2, Fe-1-3, the thickness of the repaired weld is less than the thickness of the weld that needs post-weld heat treatment in the corresponding product standards.

c) The thickness of the Fe-3 category welding repair weld is less than 1/3 of the parent material thickness δ_s and not more than 13 mm.

d) Technical requirements for welding repair:

1) The groove of the repaired weld needs to be tested for surface non-destructive testing to confirm that there are no defects.

2) Low-hydrogen coated electrodes are required.

3) For steels of groups Fe-1-1, Fe-1-2, Fe-1-3, the preheating temperature is higher than or equal to 100 °C.

For category Fe-3 steel, the preheating temperature is higher than or equal to 180 °C; the interpass temperature does not exceed 230 °C.

4) The maximum width of the weld pass is 4 times the diameter of the weld core.

5) For category Fe-3 steel, the half-weld pass plus tempering pass technology is required for welding repair:

① Use a welding rod with a maximum diameter of 3.2 mm to weld a layer on the groove surface;

② Before welding the second layer, grind off half the thickness of the weld metal on the groove surface layer;

③ Use a welding rod with a maximum diameter of 4 mm to continue welding;

④ Weld the tempering bead on the surface of the repair weld;

⑤ After the repair weld and tempering bead are completed, carry out post-heat treatment: keep at 200 °C ~ 250 °C for 4 h;

⑥ Grind off the excess height of the tempering bead; make a smooth transition with the surface of the parent material;

6) The repair weld shall be non-destructively tested at least 24 h after welding. For category Fe-3 steel, it is non-destructively tested at least 48 h after welding. Repair welds with a thickness greater than 10 mm shall be radiographically tested.

welding; pure tungsten electrode, thorium tungsten electrode, etc. can also be used.

6.3 Groove preparation

6.3.1 The groove form and size for gas shielded welding refer to GB/T 985.3.

6.3.2 Groove processing shall be cold processing method, or plasma cutting. Before welding, the groove shall be ground or cold processed to remove oxides, until the metallic luster is exposed and polished flat.

6.4 Cleaning before welding

6.4.1 The weld groove, backing, welding wire shall be cleaned before pairing and welding. The surface of the groove and the area within 50 mm on both sides shall be strictly cleaned to remove moisture, dust, metal chips, oil, paint, oxide film, hydrogen-containing substances, and attachments. The surface oil stain shall be removed with organic solvents such as acetone first; then the surface oxide film shall be removed mechanically or chemically; however, grinding wheels or sandpaper shall not be used. The mechanical or chemical cleaning methods are as follows:

a) Mechanical cleaning: The groove and the surfaces on both sides can be cleaned by cutting to reveal the metallic luster. The cutting tool can be an electric milling cutter or a scraper. For thinner oxide films, reamer and stainless steel wire brush can also be used for cleaning.

b) Chemical cleaning: 5% ~ 10% sodium hydroxide solution at a temperature of about 70 °C shall be used; soak for 30 s ~ 60 s; then rinse with water; soak in about 15% nitric acid at room temperature for 2 minutes; then rinse with warm water.

6.4.2 The cleaned weldment and welding wire shall be kept dry and protected; welding shall be carried out in time without water marks, alkali marks or contamination.

6.4.3 If the weldment and welding wire are not welded for more than 8 hours after cleaning, meanwhile there are no effective protection measures, they shall be cleaned again before welding.

6.5 Preheating

6.5.1 Weldments that meet one of the following conditions should be preheated before welding:

a) When using tungsten inert gas argon shielded welding, the weldment thickness is greater than 10 mm;

b) When using tungsten inert gas argon shielded welding, the weldment thickness is greater than 15 mm;

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