NATIONAL STANDARD OF
THE PEOPLE'S REPUBLIC OF CHINA

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GB/T 8547—2019

(replacing GB/T 8547—2006)

Titanium clad steel plate

钛-钢复合板

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Foreword

This standard was drafted in accordance with the rules given in GB/T 1.1—2009.

This standard replaces GB/T 8547—2006 "Titanium clad steel plate".

Compared with GB/T 8547—2006, the main technical changes are as follows:

—The applications of the clad plates were revised (see Table 1, and Table 1 of the 2006 edition);

—The commercially pure titanium designations of the cladding metal and the applicable standards of the base metal were revised (see Table 2, and Table 2 of the 2006 edition);

—It was added that for Class 2 clad plates, a cladding metal of a lower strength level may be used instead of a cladding metal of a higher strength level (see Table 2);

—"GB 6654 Steel plates for pressure vessels" was deleted (see Table 2 of the 2006 edition);

—The thickness range of the cladding metal was revised (see 4.1.2.2, and 4.3.4 of the 2006 edition);

—The requirements for the permitted seam welding of the cladding metal were revised (see 4.1.2.3, and 4.3.3 of the 2006 edition);

—The heat treatment procedure of the clad plates was revised (see 4.1.3.2, and 4.1.3 of the 2006 edition);

—The requirements for the dimensions and their permissible deviations were revised (see 4.3, and 4.3 of the 2006 edition);

—The requirements for the shearing test were revised (see Table 5, and Table 6 of the 2006 edition);

—The requirements for the bending properties were revised (see Table 6, and Table 6 of the 2006 edition);

—The requirements for the bond area of Class 0 clad plates were revised (see Table 7, and Table 7 of the 2006 edition);

—"Welding" was revised as "repair of clad plates", and the corresponding requirements were revised (see 4.7, and 4.6 of the 2006 edition).

This standard was proposed by the China Nonferrous Metals Industry Association.

This standard is under the jurisdiction of the National Nonferrous Metals Standardization Technical Committee (SAC/TC 243).

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The previous editions of the standard replaced by this standard are:

—GB/T 8547—1987, GB/T 8547—2006.

1 Scope

This standard specifies the technical requirements, test methods, inspection rules, delivery weight, marking, packaging, transport, storage, quality certificate and purchase order (or contract) contents for titanium clad steel plates.

This standard applies to titanium-steel explosive clad plates, explosive-rolling clad plates or rolling clad plates for corrosion-resistant pressure vessels, storage tanks and other applications (hereinafter referred to as clad plates).

2 Normative References

The following documents contain provisions which, through normative reference in this standard, constitute indispensable provisions of this standard. For dated references, only the edition cited applies. For undated references, the latest edition (including all amendments) applies.

Standard No.	Title
GB/T 223 (all parts)	Methods for chemical analysis of iron, steel and alloy
GB/T 700	Carbon structural steels
GB/T 711	Hot-rolled plates and strips of quality carbon structural steels
GB/T 712	Structural steel for ship and ocean engineering
GB/T 713	Steel plates for boilers and pressure vessels
GB/T 3274	Hot-rolled plates and strips of carbon structural steels and low alloy structural steels
GB/T 3531	Steel plates for low temperature pressure vessels
GB/T 3620.1	Designation and composition of titanium and titanium alloys
GB/T 3621	Titanium and titanium alloy plates and sheets
GB/T 4698 (all parts)	Methods for chemical analysis of titanium sponge, titanium and titanium alloys
GB/T 6396	Test methods for mechanical and technological properties of clad steel plates
JB/T 10061	General specifications for type A pulse reflection ultrasonic flaw detector
NB/T 47008	Carbon steel and alloy steel forgings for pressure equipment
NB/T 47009	Low alloy steel forgings for low temperature pressure equipment
NB/T 47013.2—2015	Non-destructive testing of pressure equipment — Part 2: Radiographic testing
NB/T 47013.5—2015	Non-destructive testing of pressure equipment — Part 5: Penetrant testing

3 Terms and Definitions

The terms and definitions defined in GB/T 6396, as well as the following terms and definitions, apply to this document.

3.1 titanium clad steel plate

A metal composite plate in which titanium (the cladding metal) and steel (the base metal) achieve metallurgical bonding by the explosive, explosive-rolling or rolling method.

4 Technical Requirements

4.1 Product Classification

4.1.1 Classification and Codes

The classification and codes of the clad plates shall conform to the provisions of Table 1.

Table 1 — Classification and codes

Production method	Class	Code	Recommended application
Explosive clad plate	Class 0	B0	
	Class 1	B1	
	Class 2	B2	
Explosive-rolling clad plate	Class 1	BR1	
	Class 2	BR2	
Rolling clad plate	Class 1	R1	
	Class 2	R2	

Class 0: clad plates with high bond strength, such as transition joints and flanges.

Class 1: clad plates in which the cladding metal serves as part of the design strength, such as tube sheets.

Class 2: clad plates in which the cladding metal does not serve as part of the design strength, such as corrosion-resistant linings.

4.1.2 Applicable Materials

4.1.2.1

The cladding metal of the clad plates shall conform to the provisions of GB/T 3621, and the base metal shall conform to one of the standards listed in Table 2; the cladding metals and base metals specified in the standards in the table may be freely combined.

Table 2 — Cladding metal and base metal

Cladding metal	Base metal
TA1G, TA2G, TA3G, TA9, TA10 in GB/T 3621	GB/T 700, GB/T 711, GB/T 712, GB/T 713, GB/T 3274, GB/T 3531, NB/T 47008, NB/T 47009

Note: Where the cladding metal is TA1G, TA2G or TA3G, for Class 2 clad plates, a cladding metal of a lower strength level is permitted to be used instead of a cladding metal of a higher strength level, e.g. TA1G instead of TA2G.

4.1.2.2

The thickness of the cladding metal is generally 0.3 mm to 15.0 mm; where the thickness of the cladding metal is greater than 10.0 mm, the cladding metal may be composed of multiple layers as agreed between the supplier and the purchaser.

4.1.2.3

Where the width of the clad plate is greater than 1 100 mm or the length is greater than 3 000 mm, the cladding metal is permitted to be seam-welded, and the width or length of the seam-welded cladding metal shall be not less than 300 mm; the seam welds shall be subjected to penetrant testing, and the test results shall conform to the provisions of Grade II in Table 6 of NB/T 47013.5—2015; where required by the purchaser and specified in the contract, the seam welds shall be subjected to radiographic testing, and the test results shall conform to the provisions of Grade II in Table 22 of NB/T 47013.2—2015.

4.1.3 Supply Conditions

4.1.3.1

The clad plates may be supplied in the explosive state (B), the explosive-rolling state (BR) or the rolling state (R).

4.1.3.2

Where the explosive clad plates are supplied in the stress-relieved state (m), the recommended heat treatment procedure is: 540 ℃ to 650 ℃, with a holding time of not less than 1 h, and a heating and cooling rate of 50 ℃/h to 200 ℃/h.

4.1.4 Designation Examples

The product designation is expressed in the order of cladding metal designation/base metal designation, code, supply condition, specification and standard number. The designation examples are as follows:

Example 1: A Class 1 explosive clad plate with a cladding metal thickness of 6 mm (TA2G), a base metal thickness of 30 mm (Q235B steel), a width of 1 000 mm, a length of 3 000 mm and in the stress-relieved state is designated as:

TA2G/Q235B B1 m 6/30×1 000×3 000 GB/T 8547—2019

Example 2: A Class 2 explosive-rolling clad plate with a cladding metal thickness of 2 mm (TA1G), a base metal thickness of 10 mm (Q235B steel), a width of 1 100 mm and a length of 3 500 mm is designated as:

TA1G/Q235B BR2 2/10×1 100×3 500 GB/T 8547—2019

4.2 Chemical Composition

4.2.1

The chemical composition of the cladding metal shall conform to the provisions of GB/T 3620.1.

4.2.2

The chemical composition of the base metal shall conform to the provisions of the corresponding base metal standard.

4.3 Dimensions and Their Permissible Deviations

4.3.1

The permissible deviation of the cladding metal thickness of the clad plates shall be not greater than ±10 % of the nominal thickness of the cladding metal, but shall not exceed ±1.0 mm.

4.3.2

The permissible deviation of the base metal thickness of the clad plates shall be not greater than the positive and negative permissible deviations of the base metal standard each reduced by 0.5 mm.

4.3.3

The permissible deviation of the thickness of the clad plates shall be not greater than the sum of the permissible deviation of the cladding metal thickness and the permissible deviation of the base metal thickness.

4.3.4

The permissible deviations of the width (or diameter) and the length of the clad plates shall conform to the provisions of the corresponding base metal standard.

4.3.5

The flatness of the clad plates shall conform to the provisions of Table 3.

Table 3 — Flatness

Class of clad plate	Flatness within the specified thickness range	
	Thickness ≤30 mm	Thickness >30 mm
Class 0	≤8 mm/m	≤6 mm/m
Class 1	≤8 mm/m	≤6 mm/m
Class 2	≤15 mm/m	≤15 mm/m

Note: The flatness of clad plates with a forged steel base metal shall be agreed between the two parties.

4.4 Mechanical Properties

4.4.1

Where the cladding metal does not serve as part of the design strength, only the tensile property test of the base metal of the clad plates is carried out, and the test results shall conform to the provisions of the corresponding base metal standard.

4.4.2

Where the cladding metal serves as part of the design strength, the tensile properties of the clad plates shall conform to the provisions of Table 4, in which the theoretical lower limit value of the tensile strength Rmj is calculated by formula (1):

$$Rmj = (t1Rm1 + t2Rm2) / (t1 + t2) \quad \ldots(1)$$

Where:

t1 — thickness of the base metal, in millimetre (mm);

t2 — thickness of the cladding metal, in millimetre (mm);

Rm1 — lower limit value of the standard tensile strength of the base metal, in megapascal (MPa);

Rm2 — lower limit value of the standard tensile strength of the cladding metal, in megapascal (MPa).

Table 4 — Tensile properties

Tensile strength Rm, MPa	Percentage elongation after fracture A, %
Greater than Rmj	Not less than the lower percentage elongation after fracture specified in the cladding metal or base metal standard

4.4.3

The shearing strength of the clad plates shall conform to the provisions of Table 5. Where the thickness of the cladding metal is less than 1.5 mm, the lap-shear specimen may be used for the shearing test; where the thickness of the cladding metal is not less than 1.5 mm, the shear specimen may be used for the shearing test.

Table 5 — Shearing strength

Class of clad plate	Shearing strength τ, MPa
Class 0	≥196
Class 1	≥140
Class 2	≥140

4.4.4

Where the corresponding base metal standard specifies the impact property test, the impact property requirements of the base metal of the clad plates shall conform to the provisions of the corresponding base metal standard.

4.5 Bending Properties

The bending properties of the clad plates shall conform to the provisions of Table 6. No cracks shall be generated on the outer surface of the bent part of the specimens, and the clad interface shall not delaminate.

Table 6 — Bending properties

Bending category	Bending angle α, (°)	Bending diameter D, mm
Inner bending	180	Executed in accordance with the provisions of the base metal standard; where less than 2 times, execute at 2 times
Outer bending	105	3 times the thickness of the clad plate

Note: Where the base metal is a forged product or the clad plate is used as a tube sheet, the bending test is not carried out.

4.6 Bond Area

The bond area of the clad plates shall conform to the provisions of Table 7.

Table 7 — Bond area

Class of clad plate	Class 0	Class 1	Class 2
Bond area	Area bonding rate of 100 %, excluding the detonation point defects not greater than 25 mm	Area bonding rate greater than 98 %; the length of a single unbonded zone is not greater than 75 mm, and its area is not greater than 45 cm^2	Area bonding rate greater than 95 %; the area of a single unbonded zone is not greater than 60 cm^2

4.7 Repair of Clad Plates

4.7.1

Unless otherwise specified, non-penetrating defects on the surfaces of the cladding metal and the base metal may be repaired by welding.

4.7.2

The weld-repaired areas shall be subjected to penetrant testing and ultrasonic testing; the penetrant testing results shall conform to the provisions of Grade II in Table 6 of NB/T 47013.5—2015, and the ultrasonic testing results shall conform to the requirements of 4.6.

4.7.3

The positions, scopes and testing results of the weld-repaired areas shall be submitted to the purchaser as part of the quality certificate.

4.8 Surface Quality

4.8.1

The clad plates shall be delivered with sand-blasted, pickled or polished surfaces.

4.8.2

The surfaces of the cladding metal of the clad plates shall be free from cracks, peeling, folds, metallic or non-metallic inclusions and other defects; scratches, dents, indentations and other defects not exceeding half of the permissible deviation of the cladding metal thickness are permitted.

4.8.3

Local defects on the surfaces of the cladding metal may be removed along the processing direction, provided that the thickness of the cladding metal after removal is not less than its minimum permissible thickness.

5 Test Methods

5.1

The arbitration analysis of the chemical composition of the cladding metal shall be carried out in accordance with the provisions of GB/T 4698, and the arbitration analysis of the chemical composition of the base metal shall be carried out in accordance with the provisions of GB/T 223.

5.2

The permissible deviation of the cladding metal thickness shall be measured in accordance with GB/T 6396; the thickness shall be measured at positions not less than 100 mm from the top corner and not less than 20 mm from the edge, and the other permissible deviations shall be measured with measuring tools of appropriate accuracy.

5.3

The tensile properties, shearing strength and bending properties of the clad plates shall be tested in accordance with GB/T 6396.

5.4

The bond area of the clad plates shall be inspected in accordance with the provisions of Annex A; where the provisions of Annex A are exceeded, the matter shall be agreed between the two parties.

5.5

The surface quality of the clad plates shall be inspected by visual inspection.

5.6

The penetrant testing shall be carried out in accordance with NB/T 47013.5—2015.

5.7

The radiographic testing shall be carried out in accordance with NB/T 47013.2—2015.

6 Inspection Rules

6.1 Inspection and Acceptance

6.1.1

The products shall be inspected by the supplier to ensure that the product quality conforms to the requirements of this standard.

6.1.2

The purchaser shall re-verify the received products in accordance with the provisions of this standard. Where the re-verification results do not conform to the provisions of this standard and the purchase order (or contract), a written claim shall be submitted to the supplier, and the matter shall be settled through consultation between the

supplier and the purchaser. Claims on the dimensions and the surface quality shall be submitted within one month from the date of receipt of the products, and claims on other properties shall be submitted within three months from the date of receipt of the products. Where arbitration is required, it shall be agreed between the supplier and the purchaser.

6.2 Batching

The clad plates shall be submitted for acceptance in batches. Each batch shall consist of products of the same designation (cladding metal and base metal), class, specification (cladding metal and base metal), condition and processing technology. For large-quantity supply, the batching method may be agreed between the supplier and the purchaser.

6.3 Inspection Items

The inspection items of each batch of products shall conform to the provisions of Table 8.

Table 8 — Inspection items of the products

Inspection item	Batching basis	Sampling	Test method
Chemical composition	Per batch	Per batch, 1 specimen	5.1
Tensile properties	Per batch	1 plate per batch, 1 transverse specimen for each test item	5.3
Shearing strength	Per batch	1 plate per batch, 1 specimen (the specimen type not specified)	5.3
Bending properties	Per batch	1 plate per batch, 1 transverse specimen	5.3
Bond area	Per plate	Per plate, in accordance with Table 9	5.4
Dimensions and their permissible deviations	Per plate	Per plate	5.2
Surface quality	Per plate	Per plate	5.5

6.4 Sampling Positions and Sampling Quantities

6.4.1

The chemical composition of the cladding metal shall be reported by the chemical composition of the original ingot or the certificate of the original plate, and the chemical composition of the base metal shall be reported in accordance with the original certificate.

6.4.2

The dimensions and their permissible deviations of the clad plates shall be inspected plate by plate; the measurement of the cladding metal thickness is permitted to be carried out on one plate taken per batch.

6.4.3

The tensile properties and shearing strength of the clad plates shall be tested by taking one plate at random from each batch of products, and one transverse specimen for each test item (the specimen type of the shearing test not specified). Specimens are permitted to be cut from the test plates or offcuts of the same production period and the same process.

6.4.4

The bending property inspection of the clad plates shall be carried out by taking one plate at random from each batch of products and one transverse specimen. Specimens are permitted to be cut from the test plates or offcuts of the same production period and the same process.

6.4.5

The bond area of the clad plates shall be inspected plate by plate, and the inspection positions shall conform to the provisions of Table 9.

6.4.6

The surface quality of the clad plates shall be inspected plate by plate.

Table 9 — Inspection positions of the bond area

Class	Inspection positions
Class 0	Continuous inspection within a zone of 50 mm width along the periphery; the remaining area inspected along a grid at intervals of 200 mm
Class 1	Continuous inspection within a zone of 50 mm width along the periphery; the remaining area inspected along a grid at intervals of 200 mm
Class 2	Continuous inspection within a zone of 50 mm width along the periphery; the remaining area inspected along a grid at intervals of 200 mm

6.5 Judgment of Inspection Results

6.5.1

Where the chemical composition inspection result fails, one repeated inspection of the nonconforming elements is permitted. Where the repeated inspection still fails, that batch of products shall be judged as nonconforming.

6.5.2

In the tensile property, shearing strength and bending property inspections, where the inspection result of one specimen fails, double the number of specimens shall be taken from that batch of products for the repeated inspection of the nonconforming item. Where one specimen still fails in the repeated inspection, that batch of products shall be judged as nonconforming. However, the supplier is permitted to inspect the nonconforming item plate by plate, and the qualified ones shall be re-batched.

6.5.3

Where the inspection results of the dimensions and their permissible deviations, the bond area and the surface quality fail, the single plate shall be judged as nonconforming.

7 Delivery Weight

7.1

The clad plates are all delivered by theoretical weight.

7.2

The theoretical weight of the clad plates is calculated from the thicknesses of the cladding metal and the base metal and the length and width of the clad plate. The theoretical weights of 1 mm thick titanium plates and steel plates are 4.51 kg/m² and 7.85 kg/m², respectively.

8 Marking, Packaging, Transport, Storage and Quality Certificate

8.1 Product Marking

The qualified products shall be marked (or labelled) as follows:

a) name of the manufacturer;

b) product designation, specification and condition;

c) product batch number;

d) the detonation point of the clad plate (where required by the purchaser and specified in the contract).

8.2 Packaging, Transport and Storage

8.2.1

The clad plates are supplied in nude packing. The cladding metal surfaces of two plates face each other, with moisture-proof paper interposed in between, and the outside is fastened with metal wire. Where there are special requirements for the packaging, they shall be agreed between the supplier and the purchaser.

8.2.2

The products shall be protected against collision, moisture and the erosion of active chemicals during transport and storage.

8.3 Quality Certificate

Each batch of products shall be accompanied by a quality certificate consistent with that batch of products, stating:

a) name of the manufacturer;

b) product name or code;

c) product designation (cladding metal and base metal), specification and condition;

d) batch number of the products, batch number of the base metal and heat number of the cladding metal;

e) batch weight and number of pieces;

f) results of all analyses and inspections, and the seal of the inspection department;

g) number of this standard;

h) date of packaging.

9 Contents of the Purchase Order (or Contract)

The purchase order (or contract) for ordering the materials specified in this standard shall include the following contents:

a) product name;

b) designation;

c) class;

d) dimensions and specification;

e) weight or number of plates;

f) special technical requirements;

g) the agreed results of the contents beyond this standard.

Annex A (Normative) — Ultrasonic testing method for titanium clad steel plates

A.1 Scope

This method is the ultrasonic testing method for explosive, explosive-rolling and rolling clad plates with steel as the base metal, titanium as the cladding metal, a total thickness greater than 4 mm and multiple-layer cladding.

A.2 General Requirements

A.2.1 Purpose

Mainly used to detect the degree of bonding between the cladding metal and the base metal of the clad plates.

A.2.2 Method Category

This standard specifies that the longitudinal wave pulse-echo method (or the multiple pulse-echo method) is adopted for the ultrasonic testing. Either the contact method or the immersion method may be used.

A.2.3 Requirements for the Testing Personnel

The testing operators shall reach the level of Grade Ⅱ or above of the ministry-level or equivalent society-level non-destructive testing personnel; the personnel issuing and interpreting the inspection reports shall reach the level of Grade Ⅲ or above of the ministry-level or equivalent society-level non-destructive testing personnel.

A.2.4 Testing Surfaces

A.2.4.1

The surfaces of the clad plates shall be free from mill scale, oil contamination, rust and other dirt affecting the testing.

A.2.4.2

The surface roughness Ra of the testing surfaces shall be not greater than 5 μm.

A.2.4.3

At the specified testing sensitivity, the noise level of the material shall be not greater than 5 %.

A.3 Testing Equipment

A.3.1 Testing Instruments

A pulse-echo ultrasonic flaw detector shall be used. The flaw detector shall conform to the technical performance indices specified in JB/T 10061.

A.3.2 Probes

A.3.2.1

Straight probes with cylindrical or rectangular crystals shall be used. Twin-crystal probes may also be used.

A.3.2.2

The dimensions of the cylindrical crystals are generally φ10 mm to φ30 mm, and the dimensions of the rectangular crystals may be selected as (15 mm~30 mm) × (10 mm~20 mm), with a frequency of 2 MHz to 5 MHz.

A.3.3 Couplant

For the contact method, clean tap water may be used as the couplant, and machine oil, soluble oil and other substances may also be used.

A.3.4 Reference Blocks

A.3.4.1

The reference blocks shall be made of clad plate materials with the same or similar material, thickness, acoustic properties and surface state as the clad plates to be tested.

A.3.4.2

The forms and dimensions of reference block A and block B are shown in Figure A.1.

A.4 Testing

A.4.1 Selection of the Testing Surface

According to the surface state of the plate to be tested, the cladding metal thickness, the acoustic impedance and the appearance shape, it is decided whether to test from the cladding metal surface or from the base metal surface.

A.4.2 Testing Sensitivity

A.4.2.1

The testing sensitivity is adjusted according to the cladding layer thickness of the plate to be tested.

A.4.2.2

Where the cladding layer thickness is relatively large, the testing sensitivity is adjusted with the reference blocks according to the following requirements:

a) When testing from the cladding metal surface, place the probe on the defective part of reference block A; the defect echo wave appears on the fluorescent screen, and its amplitude is adjusted to 80 % of the full scale of the fluorescent screen.

b) When testing from the base metal surface, place the probe on the centre of the defect of reference block B; the defect echo wave appears on the fluorescent screen, and its amplitude is adjusted to 80 % of the full scale of the fluorescent screen.

A.4.2.3

Where the cladding layer thickness is relatively small, the testing sensitivity is adjusted by the multiple pulse-echo method using the bottom echo. Place the probe on the fully bonded part of the plate to be tested, so that at least three bottom echoes appear on the horizontal baseline of the fluorescent screen of the flaw detector, and adjust the amplitudes of the three bottom echoes to 80 % of the full scale of the fluorescent screen.

A.4.3 Determination of the Unbonded Zones

A.4.3.1 Definition of the Unbonded Zone

During the testing process, where the initial pulse signal widens, the bottom pulse disappears, or the defect pulse widens, rises and moves forward, that zone is an unbonded zone.

A.4.3.2 Judgment Criteria

The position of the unbonded zone shall be judged by the position where the defect echo wave first appears during the scanning of the probe; the scope of the unbonded zone is determined by the positions where the defect echo wave appears at the boundary of the bonded and unbonded zones. The bond area rate of the clad plate is calculated and judged in accordance with 4.6 of this standard.