TA23 alloy plate with high impact toughness and high ductility, and its preparation and application

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Translation notes

T-beta denotes the phase-transformation temperature. Paragraph and claim identifiers are retained. The original table, including the V-notch specimen note, was checked visually. M is retained as the source condition code. Reported improvements are reproduced as stated; the elongation changes of 4% and 3.5% correspond to percentage-point differences in the table. The general route specifies third-heat plate in steps (8)-(9), while it expressly allows plate of at least 6 mm to omit the third heat; this source wording is retained.

Abstract

The invention belongs to nonferrous-metal processing and concerns TA23 alloy plate with high impact toughness and high ductility, its preparation and application. A whole-process design concept comprehensively controls ingot composition, forging, rolling, heat treatment and other key operations. The resulting TA23 plate has tensile strength Rm >=740 MPa, yield strength Rp0.2 >=630 MPa, elongation A >=19%, room-temperature impact energy KV2 >=80 J and impact energy at -40 deg C >=30 J, giving excellent overall properties. Room-temperature impact toughness is improved by more than 100%, low-temperature toughness by more than 190% and elongation by more than 3%. All indicators meet customer standards with sufficient property margin, greatly increasing the product safety factor. When used for ship structural components, the plate offers greater impact resistance and safety.

Claims

1. A method for preparing TA23 alloy plate with high impact toughness and high ductility, comprising:

(1) Ingot melting: select grade 0 or higher-quality titanium sponge, zirconium sponge, aluminum pellets and pure iron; batch and compact them into electrode blocks, then melt them to obtain a TA23 alloy ingot. Remove the ingot riser and peel the surface.

(2) Slab forging: forge the ingot from step (1). The first breakdown heat is at T-beta + (50-150) deg C, with at least two upsetting/drawing-out treatments, 60%-80% total deformation and a finishing temperature of at least 850 deg C, sufficiently breaking up the coarse as-cast structure. Then perform second-heat finish forging at T-beta - (20-60) deg C, with at least two upsetting/drawing-out treatments, 60%-85% total deformation and a finishing temperature of at least 800 deg C. Shape and face-mill the product to obtain a rectangular rolling slab.

(3) First rolling heat: heat the slab from step (2) at T-beta - (20-60) deg C, with a holding-time coefficient of 1.5 +/- 0.2 min/mm. Use 5%-30% deformation per pass and 50%-90% deformation over the heat, rolling to the first-heat target thickness in 6-12 passes.

(4) Surface treatment: treat the surface of the first-heat plate from step (3).

(5) Second rolling heat: cross-roll the surface-treated first-heat plate from step (4), perpendicular to the first rolling direction. Heat at T-beta - (70-120) deg C, with a holding-time coefficient of 1.3 +/- 0.2 min/mm, 5%-25% deformation per pass and 40%-85% deformation over the heat. Roll to target thickness in 4-8 passes. For finished thickness at most 5 mm, proceed with steps (6)-(9); for finished thickness at least 6 mm, proceed with steps (8) and (9).

(6) Surface treatment: treat the surface of the second-heat plate from step (5).

(7) Third rolling heat: roll the surface-treated second-heat plate from step (6) in the same direction and at the same heating temperature as the second heat. Use a holding-time coefficient of 1.2 +/- 0.2 min/mm, 4-5 passes to final thickness, 5%-25% deformation per pass and 35%-80% deformation over the third heat.

(8) Heat treatment: anneal the third-heat plate from step (7) in air, then hot-straighten it after removal from the furnace.

(9) Surface treatment: treat the heat-treated third-heat plate from step (8) to obtain TA23 plate with high impact toughness and high ductility.

2. The method of claim 1, wherein the titanium sponge, zirconium sponge, aluminum pellets and pure iron in step (1) have purity greater than 99.5 wt%.

3. The method of claim 1, wherein melting in step (1) comprises three vacuum consumable-electrode arc melts.

4. The method of claim 1, wherein surface treatment in step (4) comprises peeling and polishing the first-heat plate from step (3) to remove surface defects, with grinding perpendicular to the first rolling direction.

5. The method of claim 1, wherein surface treatment in step (6) comprises sandblasting, pickling and grinding the second-heat plate from step (5) to remove surface defects, with grinding parallel to the second rolling direction.

6. The method of claim 1, wherein annealing in step (8) is at 600-750 deg C for 30-60 min.

7. The method of claim 1, wherein surface treatment in step (9) comprises sandblasting, acid pickling or alkali-acid pickling, and grinding to remove oxide scale and defects from the upper and lower surfaces.

8. TA23 alloy plate with high impact toughness and high ductility, prepared by any method of claims 1-7.

9. Use of the TA23 plate of claim 8 in deep-submersible and ship equipment.

Description - Technical field

[0001] The invention belongs to nonferrous-metal processing and specifically concerns TA23 alloy plate with high impact toughness and high ductility, its preparation and application.

Background

[0002] TA23 is a near-alpha titanium alloy of the Ti-2.5Al-2Zr-1Fe system. Its plate combines moderate strength and high ductility: yield strength >=590 MPa, tensile strength >=700 MPa, elongation >=18% and yield/tensile ratio about 80%. The source compares its ductility with similar-strength alloys: TA5 and TA7 plate have tensile strengths >=685 MPa and >=735 MPa respectively, but elongations of only >=12%. TA23 therefore has excellent cold- and hot-formability, as well as good weldability, seawater-corrosion resistance and acoustic-transmission properties. It is well suited to forming large titanium structural components and is a promising ship alloy and sonar-fairing material. As part of a ship structure, the plate must have adequate strength and impact resistance to withstand seawater pressure and impact during operation. Improving TA23 impact toughness is therefore important for complex marine environments and hull safety.

Disclosure of the invention

[0003] The primary objective is to overcome shortcomings of existing technology by providing a method for TA23 plate with high impact toughness and ductility, improving formability and impact resistance.

[0004] A further objective is the resulting plate, with Rm >=740 MPa, Rp0.2 >=630 MPa, A >=19%, room-temperature KV2 >=80 J and impact energy at -40 deg C >=30 J, offering excellent overall properties.

[0005] Another objective is to provide applications for this high-impact-toughness, high-ductility TA23 plate.

[0006] The objectives are achieved through the following technical solution.

[0007] The preparation method comprises the following steps:

[0008] (1) Ingot melting: select grade 0 or higher-quality titanium sponge, zirconium sponge, aluminum pellets and pure iron; batch and compact them into electrode blocks, then melt them to obtain a TA23 (Ti-2.5Al-2Zr-1Fe) alloy ingot. Remove the ingot riser and peel the surface.

[0009] (2) Slab forging: forge the ingot from step (1). The first breakdown heat is at T-beta + (50-150) deg C, i.e. 50-150 deg C above the phase-transformation temperature, with at least two upsetting/drawing-out treatments, 60%-80% total deformation and a finishing temperature of at least 850 deg C, sufficiently breaking up the coarse as-cast structure. Then perform second-heat finish forging at T-beta - (20-60) deg C, with at least two upsetting/drawing-out treatments, 60%-85% total deformation and a finishing temperature of at least 800 deg C. Shape and face-mill the product to obtain a rectangular rolling slab.

[0010] (3) First rolling heat: heat the slab from step (2) at T-beta - (20-60) deg C, with a holding-time coefficient of 1.5 +/- 0.2 min/mm. Use 5%-30% deformation per pass and 50%-90% deformation over the heat, rolling to the first-heat target thickness in 6-12 passes.

[0011] (4) Surface treatment: treat the surface of the first-heat plate from step (3).

[0012] (5) Second rolling heat: cross-roll the surface-treated first-heat plate from step (4), perpendicular to the first rolling direction. Heat at T-beta - (70-120) deg C, with a holding-time coefficient of 1.3 +/- 0.2 min/mm, 5%-25% deformation per pass and 40%-85% deformation over the heat. Roll to target thickness in 4-8 passes. For finished thickness at most 5 mm, proceed with steps (6)-(9); for finished thickness at least 6 mm, proceed with steps (8) and (9).

[0013] (6) Surface treatment: treat the surface of the second-heat plate from step (5).

[0014] (7) Third rolling heat: roll the surface-treated second-heat plate from step (6) in the same direction and at the same heating temperature as the second heat. Use a holding-time coefficient of 1.2 +/- 0.2 min/mm, 4-5 passes to final thickness, 5%-25% deformation per pass and 35%-80% deformation over the third heat.

[0015] (8) Heat treatment: anneal the third-heat plate from step (7) in air, then hot-straighten it after removal from the furnace.

[0016] (9) Surface treatment: treat the heat-treated third-heat plate from step (8) to obtain TA23 plate with high impact toughness and high ductility.

[0017] Preferably, the titanium sponge, zirconium sponge, aluminum pellets and pure iron in step (1) have purity greater than 99.5 wt%.

[0018] Preferably, melting in step (1) comprises three vacuum consumable-electrode arc melts.

[0019] The preferred surface treatment in step (4) is as follows:

[0020] Peel and polish the first-heat plate from step (3) to remove surface defects such as cracks and indentations. Grind perpendicular to the first rolling direction.

[0021] The preferred surface treatment in step (6) is as follows:

[0022] Sandblast, pickle and grind the second-heat plate from step (5) to remove surface defects such as cracks and indentations. Grind parallel to the second rolling direction.

[0023] Preferably, annealing in step (8) is at 600-750 deg C with a 30-60 min hold.

[0024] The preferred surface treatment in step (9) is as follows:

[0025] Use sandblasting, acid pickling or alkali-acid pickling, and grinding to remove oxide scale and defects from both surfaces.

[0026] TA23 alloy plate with high impact toughness and high ductility is obtained by the above method.

[0027] The plate is applied in deep-submersible and ship equipment.

[0028] Relative to existing technology, the invention has the following advantages and effects:

[0029] (1) The new route uses a whole-process design concept and comprehensively controls ingot composition, forging, rolling, heat treatment and other key processes. The resulting plate has excellent overall properties. Room-temperature impact toughness increases by more than 100%, low-temperature toughness by more than 190% and elongation by more than 3%. All indicators meet customer standards with ample margin, greatly increasing the product safety factor.

[0030] (2) When used for ship structural components, the TA23 plate has greater impact resistance and safety.

[0031] (3) Hot rolling is performed in the lower-temperature region below T-beta. Direct hot straightening after annealing replaces conventional hot-press straightening, reducing energy consumption while favoring microstructural refinement and better overall properties.

[0032] (4) The equipment and process are simple and suitable for batch production.

Detailed embodiments

[0033] The invention is described in further detail through examples below, but is not limited to them.

[0034] The titanium sponge, zirconium sponge, aluminum pellets and pure iron used in the examples all have purity greater than 99.5 wt%.

Example 1

[0035] Example 1.

[0036] (1) Ingot melting: batch grade 0 titanium sponge, zirconium sponge, aluminum pellets and pure iron, compact electrode blocks, and melt three times in a vacuum consumable-electrode arc furnace to obtain a TA23 ingot. The phase-transformation temperature measured metallographically is 945 deg C.

[0037] (2) Slab forging: first-heat breakdown forging is at 1050 deg C (T-beta +105 deg C), with two upsetting and two drawing-out operations, 70% total deformation and a finishing temperature of 865 deg C, sufficiently breaking up the coarse cast structure. Second-heat finish forging is at 920 deg C (T-beta -25 deg C), again with two upsetting/drawing-out treatments, 73% total deformation and finishing temperature 812 deg C. Shape and face-mill to obtain a 150 mm rolling slab. Its structure is equiaxed alpha plus intergranular beta, and it meets class A ultrasonic inspection under GB/T 5193-2007.

[0038] (3) First rolling heat: heat at 900 deg C with a holding-time coefficient of 1.5 min/mm, and roll to 24 mm in eight passes. Successive pass deformations are 18%, 19%, 23%, 23%, 22%, 21%, 19% and 18%, with 84% deformation over the heat.

[0039] (4) Intermediate grinding: peel and polish the first-heat plate to remove surface cracks, indentations and other defects. Grind perpendicular to the first rolling direction.

[0040] (5) Second rolling heat: cross-roll perpendicular to the first direction. Heat at 850 deg C with a coefficient of 1.3 min/mm and roll to 10 mm in five passes. Successive deformations are 14%, 16%, 20%, 16% and 14%, with 58% deformation over the heat.

[0041] (6) Surface treatment: sandblast, pickle and grind the second-heat plate to remove cracks, indentations and other surface defects. Grind parallel to the second rolling direction.

[0042] (7) Third rolling heat: roll in the same direction as the second heat at 850 deg C with a coefficient of 1.2 min/mm. Roll to 5 mm in four passes with successive deformations of 14%, 16%, 18% and 15%, totaling 50% over the heat.

[0043] (8) Heat treatment: anneal in air at 640 deg C for 45 min, hot-straighten directly after removal from the furnace, then air cool.

[0044] (9) Surface treatment: sandblast, pickle and grind to remove oxide scale and defects from both surfaces, obtaining TA23 plate with high impact toughness and ductility. Mechanical properties are in Table 1.

Example 2

[0045] Example 2.

[0046] (1) Ingot melting: batch grade 0 titanium sponge, zirconium sponge, aluminum pellets and pure iron, compact electrode blocks and melt three times in a vacuum consumable-electrode arc furnace to obtain a TA23 ingot. Its metallographically measured phase-transformation temperature is 950 deg C.

[0047] (2) Slab forging: first-heat breakdown forging is at 1080 deg C (T-beta +130 deg C), with two upsetting and two drawing-out operations, 78% total deformation and a finishing temperature of 852 deg C, sufficiently breaking up the coarse cast structure. Second-heat finish forging is at 930 deg C (T-beta -20 deg C), again with two upsetting/drawing-out treatments, 75% total deformation and finishing temperature 803 deg C. Shape and face-mill to a 120 mm rolling slab with equiaxed alpha plus intergranular beta structure, meeting class A ultrasonic inspection under GB/T 5193-2007.

[0048] (3) First rolling heat: heat at 900 deg C with a coefficient of 1.5 min/mm and roll to 21 mm in nine passes. Successive pass deformations are 17%, 20%, 21%, 20%, 18%, 17%, 16%, 15% and 14%, with 83% deformation over the heat.

[0049] (4) Intermediate grinding: peel and polish to remove surface cracks, indentations and other defects. Grind perpendicular to the first rolling direction.

[0050] (5) Second rolling heat: cross-roll perpendicular to the first direction at 850 deg C with a coefficient of 1.3 min/mm. Roll to 6 mm in six passes, with successive deformations of 19%, 21%, 20%, 19%, 18% and 15%, totaling 71% over the heat.

[0051] (6) Heat treatment: anneal in air at 600 deg C for 45 min, then hot-straighten directly after removal from the furnace.

[0052] (7) Surface treatment: sandblast, pickle and grind to remove oxide scale and defects from both surfaces, obtaining TA23 plate with high impact toughness and ductility. Mechanical properties are in Table 1.

Comparative example 1

[0053] Comparative example 1.

[0054] The finished thickness is 5 mm, as in Example 1. All parameters are the same except that grade 1 titanium sponge is used, the first and second hot-rolling heats are at 950 deg C and 900 deg C, and annealing is 670 deg C / 45 min followed by air cooling. Mechanical properties are in Table 1.

Comparative example 2

[0055] Comparative example 2.

[0056] The finished thickness is 6 mm, as in Example 2. All parameters are the same except that grade 1 titanium sponge is used, the first and second hot-rolling heats are at 950 deg C and 900 deg C, and annealing is 690 deg C / 45 min followed by air cooling. Mechanical properties are in Table 1.

Performance evaluation

[0057] Performance evaluation.

[0058] Transverse tensile properties and impact properties at room and low temperature were tested for plate from Examples 1-2 and Comparative examples 1-2. The results are shown in Table 1.

[0059] Table 1. Microstructure type and properties of products processed by the invention.

[0060] The complete test table is reproduced below.

Table 1. Room-temperature tensile properties and impact energy KV2.

Item	Grade	Thickness (mm)	Condition	Yield (MPa)	Tensile (MPa)	Elong. (%)	RT KV2 (J)	-40 deg C KV2 (J)
Customer criteria	Ti70	4-10	M	>=590	>=700	>=18	>=47	>=14
Example 1	Ti70	5	M	672	759	24	102	73
Example 2	Ti70	6	M	686	751	21.5	96	68
Comparative 1	Ti70	5	M	626	725	20	51	25
Comparative 2	Ti70	6	M	616	738	18	48	22

Table note: impact tests used V-notched 5 x 10 x 55 mm specimens taken transversely from the plate, with the notch axis perpendicular to the rolling plane.

[0061] Table 1 shows that plate from Examples 1 and 2 meets the customer mechanical and impact requirements. Compared with Comparative examples 1 and 2, the finished plate has higher impact toughness and elongation and substantially improved overall properties. Relative to Comparative example 1, Example 1 increases room-temperature impact performance by 100%, low-temperature performance by 192% and elongation by 4%. Relative to Comparative example 2, Example 2 increases room-temperature impact performance by 100%, low-temperature performance by 209% and elongation by 3.5%.

[0062] The examples are preferred embodiments but do not limit the invention. Any changes, modifications, substitutions, combinations or simplifications that do not depart from its spirit and principles are equivalent substitutions and fall within its scope of protection.