TC27 | ENGLISH TRANSLATION

Cold rolling of TC27 titanium alloy tube

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Full technical reference translation

This English edition includes the source abstract, description, claims, all examples, and all tables and drawings present in the technical disclosure. Machine-assisted source text has been reviewed and edited against the Chinese publication. English translation is for reference; the original Chinese publication controls. It is not a certified translation, purchase specification, material certificate, production licence or TiHubs performance guarantee. Original disclosure statements are retained as historical statements, not independently verified current claims.

Abstract

The invention discloses cold rolling of TC27 titanium-alloy tube through ingot melting, homogenisation annealing, breakdown and reforging, hot piercing and pretreatment before cold rolling. Pretreatment heats the furnace to (T-beta +20) to (T-beta +40) degrees C; load the tube shell after the temperature is reached, hold for 0.8-1.0 min/mm of wall thickness and ensure cooling at >=30 degrees C/s. Parameters are simple to set, operation is convenient and the process is controllable. Pretreatment permits greater cold deformation and fewer passes. Ageing after cold rolling gives room-temperature tensile strength >=1150 MPa, yield strength >=1050 MPa, elongation delta >=10%, reduction of area psi >=20%, and K1SCC >=80 MPa sqrt(m) in 3.5% aqueous NaCl at room temperature, substantially improving strength, toughness, life and marine corrosion resistance.

Description

Cold rolling method for TC27 titanium alloy pipe

Technical Field

The invention belongs to the technical field of titanium alloy preparation, relates to a pretreatment method of a TC27 titanium alloy pipe before cold rolling, and particularly relates to a pretreatment method of a TC27 titanium alloy pipe before cold rolling, which has high strength, high toughness and marine environment corrosion resistance.

Background

As available land resources become scarcer, marine space and resources have become an increasingly competitive military and economic field. Offshore exploration, development and use are moving rapidly into deep water. Deep-sea space and oil and gas resources will become strategic spaces and bases for human survival, social development and continued stability and prosperity of coastal countries.

Deep-sea oil and gas development requires improved marine-engineering equipment. Water depth, environmental conditions, geology and reservoir characteristics make this equipment substantially different from equipment used on land.

The ocean engineering equipment is huge, particularly the deep sea environment is very severe, the mining difficulty is large, the risk is high, the requirements of seawater corrosion, surge, ocean current environment, ocean vortex-induced vibration, deep water pressure and the like on the materials for the

ocean engineering equipment are extremely severe, and the materials with high strength, good corrosion resistance, no magnetism and the like and excellent comprehensive performance are required.

Ocean engineering equipment materials are developing towards the trends and directions of high strength, high toughness, light weight, good welding performance and the like. The titanium alloy has the advantages of low density, high specific strength, good corrosion resistance, high impact resistance, seawater scouring resistance, no magnetism, no cold brittleness, high sound transmission coefficient, good forming, casting and welding properties and the like.

Therefore, titanium alloy is increasingly applied to ocean engineering equipment, is known as 'ocean metal', and has become one of the main civil fields.

In the exploration and exploitation of offshore oil and gas resources, titanium alloys were first adopted in the united states and russia to manufacture oceanographic engineering equipment. In the early 70 s of the last century in the united states, titanium alloys were used in their oil fields to make offshore oil platform legs, while tubular and plate heat exchangers, etc. were made of titanium.

At present, titanium alloy is widely used abroad to manufacture offshore oil platform pillars, drill pipes, feeler levers, flexible shafts of screw drilling tools, drilling vertical pipes, oil production pipes, joints, lifting drilling tool devices, drilling boosters, sampling rooms, underwater safety valves and other ocean engineering equipment. Among them, titanium alloys commonly used in the U.S.

for manufacturing ocean engineering equipment include medium-strength and high-strength titanium alloys, mainly including gr.5, gr.6, gr.7, gr.9, gr.11, gr.12, gr.18, gr.19, gr.23, gr.28, gr.29, and titanium alloys commonly used in russia mainly include OT3, BT5-1, PT7M, PT3B, BT6, etc. Titanium alloy drill pipes provided by RMI of the United states for Conoco Norway Inc. have been successfully applied to tens of oil wells, saving system cost by 40%.

Compared with the traditional steel drill pipe, the vertical depth of the titanium alloy drill pipe can reach 9200 m, while the vertical depth of the steel drill pipe is 6100 m, the use of the titanium alloy drill pipe can reduce the pulling force of the rod by 30 percent, and obviously reduce the torque by 30 to 40 percent.

The titanium alloy mainly used by ocean engineering equipment in China is Ti31, Ti75, Ti80, TC4 and the like with medium strength level, and is mainly applied to ships, and the amount of the used titanium alloy is very small.

Therefore, the titanium alloy material and the application technology commonly used in China at present can not meet the development requirements of offshore oil and gas resource exploration and exploitation equipment, the difference from foreign countries is large, the technical level is lagged behind, so that the oil extraction system, the oil storage system, the petroleum primary processing equipment and the like of ocean engineering equipment completely depend on import, the import rate of the ocean engineering equipment reaches 70% -90%, and the development of ocean engineering in China is severely restricted.

The TC27 titanium alloy (the component is disclosed in Chinese patent CN101503771B) is a titanium alloy which is independently developed in China and has a series of advantages of high specific strength, good fracture toughness, strong stress corrosion resistance and the like, belongs to a high-strength grade titanium alloy, has the tensile strength of more than 1100MPa, and is particularly suitable for replacing traditional high-strength steel to manufacture a drill pipe, so that the effect of reducing the weight of the drill pipe is realized, and the purposes of reducing the pulling force of the drill pipe and reducing the torque are achieved.

The method generally adopted by the publicly reported titanium alloy seamless tube mainly comprises the steps of extruding a pierced billet, then carrying out multi-pass cold rolling or cold drawing, carrying out cross rolling and piercing on the pierced billet, and then carrying out multi-pass cold rolling, and is generally directed at the titanium alloy with medium strength (the yield strength is 700 MPa-800 MPa), because the alloy hardness is low after the pierced billet is manufactured by thermal deformation, the deformation resistance is low, the cold rolling difficulty is low, and pretreatment is not needed before cold rolling or only air cooling treatment after common annealing is needed.

However, no pretreatment before cold rolling has been publicly reported for high-strength, high-toughness titanium-alloy tube with yield strength above 1050 MPa and fracture toughness K1SCC >=80 MPa sqrt(m).

The TC27 titanium alloy has high strength and large deformation resistance, and the Rockwell hardness HRC value of the titanium alloy after ordinary annealing can only be controlled between 37 and 40, so that cold rolling deformation cannot be carried out.

Based on the requirements, a pretreatment process before cold rolling of the novel high-strength, high-toughness and marine environment corrosion-resistant TC27 titanium alloy which is independently developed in China needs to be designed.

Disclosure of Invention

The purpose of the invention is: a cold rolling method for a TC27 titanium alloy pipe is designed to adapt to a cold rolling treatment process of a TC27 titanium alloy.

In order to solve the technical problem, the technical scheme of the invention is as follows:

a TC27 titanium alloy pipe cold rolling method is used for preprocessing a pipe blank before cold rolling, and the preprocessing technology is as follows:

Heat the electric furnace to (T-beta +20) to (T-beta +40) degrees C. Load the tube shell once temperature is reached, hold for 0.8-1.0 min/mm of wall thickness and ensure a cooling rate >=30 degrees C/s.

The cold rolling method of the TC27 titanium alloy pipe comprises the following steps:

step one, smelting a TC27 titanium alloy ingot;

step two, heating the electric furnace to 1100-1200 degrees C, loading the ingot obtained in the step one after the temperature is reached, preserving the heat for 18-24 h, carrying out component homogenizing annealing, and then air-cooling to room temperature;

Step 3. Use a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for breakdown and reforging. Control reduction per heat to 45-55% above and 35-45% below the transformation temperature. Drawing-out reduction per stroke is 120-160 mm. Cut the TC27 bar reforged in the two-phase region to specified lengths.

Step 4. Heat the electric furnace to (T-beta +30) to (T-beta +60) degrees C. Load the cut bar from step 3 after temperature is reached, hold for 0.8-1.0 min/mm of bar diameter, hot-pierce and air-cool to room temperature to obtain a tube shell.

Step 5. Heat to (T-beta +20) to (T-beta +40) degrees C. Load the shell from step 4 after temperature is reached, hold for 0.8-1.0 min/mm of wall thickness and cool at >=30 degrees C/s. This retains a supercooled single beta phase and controls Rockwell hardness to HRC 30-35.

Step 6. Cold-roll the shell from step 5 with simultaneous diameter and wall reduction for 2-3 passes to obtain the tube blank.

and step seven, heating the vacuum electric furnace to 580-630 degrees C, loading the tube blank obtained in the step six after the temperature is reached, preserving the heat for 6-10 h, and then cooling the tube blank to room temperature in air.

And in the sixth step, during cold rolling deformation, the cold rolling reduction rate of each pass is controlled to be between 5% and 15%, the wall reduction amount is controlled to be between 10% and 25%, and the elongation coefficient is controlled to be between 1.5 and 2.5.

Preferably, ingot casting cogging and forge changing are carried out 6-10 times in the third step.

Preferably, the pipe blank in the fifth step is cooled in a water cooling or oil cooling mode after heat preservation.

Preferably, cutting the head and the tail of the pretreated pipe blank, and removing oxide skin defects on the inner surface and the outer surface;

preferably, in the sixth step, after the 1 st pass of cold rolling, the fifth step is repeated once, and then the 2 nd pass of cold rolling deformation is performed.

In the first step, a 3-ton TC27 titanium alloy ingot is smelted by a triple vacuum consumable-electrode melting, the TC27 titanium alloy ingot is a 3-ton ingot with the diameter phi of more than or equal to 600mm, and the ingot is cut into two parts according to the length after being scalped and head and tail cut.

Preferably, the cast ingot in the second step needs to be coated with a special high-temperature anti-oxidation coating for the TC27 titanium alloy or a copper sheath when being subjected to homogenizing annealing.

The TC27 titanium alloy comprises the following alloy components in percentage by weight: 5.0 to 6.5 percent of Al, 3.5 to 5.0 percent of Mo, 5.0 to 6.5 percent of V, 1.5 to 2.5 percent of Nb, 0.5 to 1.5 percent of Fe, and the balance of Ti and unavoidable impurities, wherein the nominal chemical composition of the ingot is Ti-5.5Al-4Mo-6V-2Nb-1 Fe.

Preferably, ingot cogging is directly performed after ingot homogenization in the second step.

And fifthly, removing the defects of oxide skins on the inner surface and the outer surface by adopting an internal reaming and grinding mode after the pipe blank is pretreated.

The invention has the beneficial effects that:

aiming at novel high-strength, high-toughness and marine environment corrosion-resistant TC27 titanium alloy independently developed in China, pretreatment before cold rolling of a titanium alloy pipe is carried out, the method provided by the invention is simple in process parameter setting, convenient to operate and controllable in process flow, cold rolling deformation can be improved after the pipe is pretreated before cold rolling, cold rolling passes are reduced, after cold rolling, aging treatment can be carried out to ensure that the tensile strength of the pipe at room temperature is more than or equal to 1150MPa, the yield strength is more than or equal to 1050MPa, the elongation delta is more than or equal to 10%, the reduction of area psi is more than or equal to 20%, the impact energy aku is more than or equal to 30J, and when Kt is 1, R is 0.06, N is 10^7, fatigue limit sigma-D >=890 MPa, and fracture toughness K1SCC >=80 MPa sqrt(m) in 3.5% aqueous NaCl at room temperature.

The strength, toughness, service life and marine environment corrosion resistance of the TC27 titanium alloy are obviously improved.

The TC27 titanium alloy in the invention has high strength and large deformation resistance, and can not be subjected to cold rolling deformation after ordinary annealing.

Accordingly, pretreatment is tailored to TC27: hold at (T-beta +20) to (T-beta +40) degrees C and cool at >=30 degrees C/s to retain a supercooled single beta phase and HRC 30-35. Two or three cold-rolling passes reducing diameter and wall then produce high-strength, high-toughness tube.

Detailed Description

In order to make the objects, technical solutions and advantages of the embodiments of the present invention more apparent, the technical solutions of the present invention will be clearly and completely described below with reference to the embodiments of the present invention. It is to be understood that the embodiments described are only a few embodiments of the present invention, and not all embodiments.

All other embodiments, which can be derived by a person skilled in the art from the embodiments given herein without making any creative effort, shall fall within the protection scope of the present invention.

Features of various aspects of embodiments of the invention will be described in detail below. In the following detailed description, numerous specific details are set forth in order to provide a thorough

understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details.

The following description of the embodiments is merely intended to better understand the present invention by illustrating examples thereof. The present invention is not limited to any particular arrangement or method provided below, but rather covers all product structures, any modifications, alterations, etc. of the method covered without departing from the spirit of the invention.

In the following description, well-known structures and techniques are not shown to avoid unnecessarily obscuring the present invention. The steps of the invention are specifically described by adopting a triple vacuum consumable-electrode melting to smelt a 3-ton TC27 titanium alloy ingot with the diameter phi of more than or equal to 600mm, and taking the finally obtained drill pipe with the diameter of 127mm, the wall thickness of 9.6mm and the length of more than or equal to 10m as an example.

Example 1:

step one, smelting a 3-ton TC27 titanium alloy cast ingot by adopting a triple vacuum consumable-electrode melting, wherein the weight percentage of each alloy comprises 5.5% of Al, 3.5% of Mo, 5.5% of V, 2.0% of Nb, 0.5% of Fe and the balance of Ti and unavoidable impurities, the 3-ton TC27 titanium alloy cast ingot is 610mm in diameter phi, the cast ingot is sawed into two parts according to the length after being scalped and head and tail cut, and each section is 580mm multiplied by 1100mm in size after being sawed, and the step two is carried out;

and step two, heating the electric furnace to 1100 degrees C, loading the ingot obtained in the step two after the temperature is reached, preheating the ingot to 200 degrees C before loading, and uniformly spraying TC27 titanium alloy special high-temperature anti-oxidation coating on the surface of the ingot so as to reduce the thickness of an oxidation layer formed in the high-temperature heat preservation process.

And 2 cast ingots are filled into each furnace, the temperature is preserved for 24 hours after the temperature of the furnace is increased again, the components are subjected to homogenization annealing, and then the ingots are cooled to room temperature in air.

Step 3. Apply a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for 10 heats of breakdown and reforging. Reduction per heat is 50% above and 40% below the transformation temperature. Drawing-out reduction is 160 mm per stroke. Cut the bar reforged in the two-phase region to diameter 150 mm x 2500 mm.

Metallography gives a transformation temperature T-beta of 870 degrees C for this TC27 batch.

Step 4. Heat the furnace to 900 degrees C and load the cut bar from step 3 after temperature is reached. Hold for 1.0 min/mm of diameter. Use a diameter-150 mm piercing mill and its tooling to hot-pierce a 160 mm outside-diameter, 18 mm wall shell, then air-cool to room temperature.

Step 5. Heat the furnace to 900 degrees C and load the shell from step 4 after temperature is reached. Hold for 1.0 min/mm of wall thickness, then cool in water at >=30 degrees C/s to retain a supercooled single beta phase and HRC 30-35. Crop both ends and remove internal and external scale and defects by internal reaming and grinding.

and sixthly, the tube blank obtained in the fifth step is subjected to a cold rolling process of reducing the diameter and reducing the wall at the same time, a cold rolling tube mill with the diameter of 120mm and a tool die are subjected to cold rolling deformation of 3 times, the fifth step is repeated after the cold rolling of the 1 st time, and then the cold rolling deformation of the 2 nd time is carried out.

The reduction rate of each cold rolling is controlled to be about 10 percent, the wall reduction amount is controlled to be about 15 percent, and the elongation coefficient is controlled to be about 2.0. Finally obtaining a tube blank with the diameter of 127mm, the wall thickness of 9.6mm and the length of more than or equal to 10 m;

and step seven, heating the vacuum electric furnace to 600 degrees C, filling the pipe blank obtained in the step six after reaching the temperature, preserving the heat for 8 hours, and then cooling the pipe blank to the room temperature in air.

The properties of the cold-rolled drill pipes after ageing (600 degrees C/8h/AC) are shown in Table 2.

TABLE 2 room temperature tensile properties (600 degrees C/8h/AC) after aging of the drill pipes of example 1

No.	Rm MPa	Rp0.2 MPa	delta5 %	psi %	aku J	K1SCC MPa sqrt(m)	sigma-D MPa
1	1180	1120	16.8	32.4	33	85.1	895
2	1185	1135	15.2	35.0	35	86.9	900
3	1160	1085	16.5	40.0	38	88.5	902

Table note: axial fatigue, Kt = 1, R = 0.06, N >=10^7.

Example 2:

step one, smelting a 3-ton TC27 titanium alloy cast ingot by adopting a triple vacuum consumable-electrode melting, wherein the weight percentage of each alloy comprises 5.0% of Al, 4.5% of Mo, 6.5% of V, 1.5% of Nb, 1.0% of Fe and the balance of Ti and unavoidable impurities, the 3-ton TC27 titanium alloy cast ingot is 610mm in diameter phi, the cast ingot is sawed into two parts according to the length after being scalped and head and tail cut, and each section is 570mm multiplied by 1150mm in size after being sawed, and the step two is carried out;

and step two, heating the electric furnace to 1200 degrees C, and filling the ingot obtained in the step two after the temperature is reached, wherein the ingot is protected by adopting a copper-clad sleeve so as to reduce the thickness of an oxide layer formed in the high-temperature heat preservation process.

And 2 ingots are filled into each furnace, the furnace is insulated for 20 hours after reaching the temperature again for component homogenizing annealing, and then the ingots are directly transferred to the step three for ingot casting and cogging on the phase change point.

Step 3. Apply a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for 8 heats of breakdown and reforging. Reduction per heat is 55% above and 45% below the transformation temperature. Drawing-out reduction is 140 mm per stroke. Cut the bar reforged in the two-phase region to diameter 150 mm x 2500 mm.

Metallography gives a transformation temperature T-beta of 880 degrees C for this TC27 batch.

Step 4. Heat the furnace to 920 degrees C and load the cut bar from step 3 after temperature is reached. Hold for 0.9 min/mm of diameter. Use a diameter-150 mm piercing mill and its tooling to hot-pierce a 160 mm outside-diameter, 18 mm wall shell, then air-cool to room temperature.

Step 5. Heat the furnace to 920 degrees C and load the shell from step 4 after temperature is reached. Hold for 0.9 min/mm of wall thickness, then cool in water at >=30 degrees C/s to retain a supercooled single beta phase and HRC 30-35. Crop both ends and remove internal and external scale and defects by internal reaming and grinding.

and sixthly, the tube blank obtained in the fifth step is subjected to a cold rolling process of reducing the diameter and reducing the wall at the same time, a cold rolling tube mill with the diameter of 120mm and a tool die are subjected to cold rolling deformation of 3 times, the fifth step is repeated after the cold rolling of the 1 st time, and then the cold rolling deformation of the 2 nd time is carried out.

The reducing rate of each cold rolling is controlled to be about 12 percent, the wall reducing amount is controlled to be about 20 percent, and the elongation coefficient is controlled to be about 2.2. Finally obtaining a tube blank with the diameter of 127mm, the wall thickness of 9.6mm and the length of more than or equal to 10 m;

and step seven, heating the vacuum electric furnace to 580 degrees C, filling the tube blank obtained in the step six after the temperature is reached, preserving the heat for 10 hours, and then cooling the tube blank to the room temperature in air.

The properties of the cold-rolled drill pipes after ageing (580 degrees C/10h/AC) are shown in Table 3.

TABLE 3 room temperature tensile properties (580 degrees C/10 h/AC) after aging of the drill pipes of example 2

No.	Rm MPa	Rp0.2 MPa	delta5 %	psi %	aku J	K1SCC MPa sqrt(m)	sigma-D MPa
1	1210	1150	14.8	30.2	35	84.2	898
2	1190	1125	17.1	38.0	39	89.6	910
3	1200	1145	15.5	40.0	37	87.3	896

Table note: axial fatigue, Kt = 1, R = 0.06, N >=10^7.

Example 3:

step one, smelting a 3-ton TC27 titanium alloy cast ingot by adopting a triple vacuum consumable-electrode melting, wherein the weight percentage of each alloy comprises 6.0 percent of Al, 5.0 percent of Mo, 5.0 percent of V, 2.5 percent of Nb, 1.5 percent of Fe, and the balance of Ti and unavoidable impurities, the specification of the 3-ton TC27 titanium alloy cast ingot is that the diameter phi is 610mm, the cast ingot is sawed into two parts according to the length after being scalped and head and tail cut, and the size of each part is phi 585mm multiplied by 1160mm after being sawed, and then transferring to step two;

and step two, heating the electric furnace to 1150 degrees C, loading the ingot obtained in the step two after the temperature is reached, preheating the ingot to 200 degrees C before loading, and uniformly spraying TC27 titanium alloy special high-temperature anti-oxidation coating on the surface of the ingot so as to reduce the thickness of an oxidation layer formed in the high-temperature heat preservation process.

4 ingots are loaded in each furnace, the furnace is insulated for 20 hours after reaching the temperature again for component homogenizing annealing, and then the ingots are directly transferred to the step three for ingot casting and cogging on the phase change point.

Step 3. Apply a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for 9 heats of breakdown and reforging. Reduction per heat is 45% above and 35% below the transformation temperature. Drawing-out reduction is 120 mm per stroke. Cut the bar reforged in the two-phase region to diameter 150 mm x 2500 mm.

Metallography gives a transformation temperature T-beta of 865 degrees C for this TC27 batch.

Step 4. Heat the furnace to 915 degrees C and load the cut bar from step 3 after temperature is reached. Hold for 0.8 min/mm of diameter. Use a diameter-150 mm piercing mill and its tooling to hot-pierce a 160 mm outside-diameter, 18 mm wall shell, then air-cool to room temperature.

Step 5. Heat the furnace to 890 degrees C and load the shell from step 4 after temperature is reached. Hold for 0.9 min/mm of wall thickness, then cool in oil at >=30 degrees C/s to retain a supercooled single beta phase and HRC 30-35. Crop both ends and remove internal and external scale and defects by internal reaming and grinding.

and sixthly, the tube blank obtained in the fifth step is subjected to a cold rolling process of reducing the diameter and reducing the wall at the same time, a cold rolling tube mill with the diameter of 120mm and a tool die are subjected to cold rolling deformation of 2 passes, the fifth step is repeated after the cold rolling of the 1 st pass, and then the cold rolling deformation of the 2 nd pass is carried out.

The reducing rate of each cold rolling is controlled to be about 15 percent, the wall reducing amount is controlled to be about 25 percent, and the elongation coefficient is controlled to be about 2.5. Finally obtaining a tube blank with the diameter of 127mm, the wall thickness of 9.6mm and the length of more than or equal to 10 m;

and step seven, heating the vacuum electric furnace to 630 degrees C, filling the tube blank obtained in the step six after the temperature is reached, preserving the heat for 9 hours, and then cooling the tube blank to the room temperature in air.

The properties of the cold-rolled drill pipes after ageing (630 degrees C/9h/AC) are shown in Table 4.

TABLE 4 room temperature tensile properties (630 degrees C/9h/AC) after aging of the drill pipes of example 3

No.	Rm MPa	Rp0.2 MPa	delta5 %	psi %	aku J	K1SCC MPa sqrt(m)	sigma-D MPa
1	1170	1080	16.2	28.1	36	88.7	911
2	1160	1075	15.1	32.2	38	90.6	898
3	1195	1115	14.3	26.9	33	85.5	897

Table note: axial fatigue, Kt = 1, R = 0.06, N >=10^7.

Example 4:

step one, smelting a 3-ton TC27 titanium alloy cast ingot by adopting a triple vacuum consumable-electrode melting, wherein the weight percentage of each alloy comprises 6.5% of Al, 4.0% of Mo, 6.0% of V, 2.0% of Nb, 1.0% of Fe and the balance of Ti and unavoidable impurities, the 3-ton TC27 titanium alloy cast ingot is 610mm in diameter phi, the cast ingot is sawed into two parts according to the length after being scalped and head and tail cut, and each section is 580mm multiplied by 1110mm after being sawed, and the step two is carried out;

and step two, heating the electric furnace to 1180 degrees C, loading the ingot obtained in the step two after the temperature is reached, preheating the ingot to 200 degrees C before loading, and uniformly spraying TC27 titanium alloy special high-temperature anti-oxidation coating on the surface of the ingot so as to reduce the thickness of an oxidation layer formed in the high-temperature heat preservation process.

3 ingots are loaded into each furnace, the furnace is insulated for 18 hours after reaching the temperature again for component homogenizing annealing, and then the ingots are directly transferred to the step three for ingot casting and cogging on the phase change point.

Step 3. Apply a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for 10 heats of breakdown and reforging. Reduction per heat is 50% above and 45% below the transformation temperature. Drawing-out reduction is 140 mm per stroke. Cut the bar reforged in the two-phase region to diameter 150 mm x 2500 mm.

Metallography gives a transformation temperature T-beta of 875 degrees C for this TC27 batch.

Step 4. Heat the furnace to 935 degrees C and load the cut bar from step 3 after temperature is reached. Hold for 0.8 min/mm of diameter. Use a diameter-150 mm piercing mill and its tooling to hot-pierce a 160 mm outside-diameter, 18 mm wall shell, then air-cool to room temperature.

Step 5. Heat the furnace to 895 degrees C and load the shell from step 4 after temperature is reached. Hold for 1.0 min/mm of wall thickness, then cool in oil at >=30 degrees C/s to retain a supercooled single beta phase and HRC 30-35. Crop both ends and remove internal and external scale and defects by internal reaming and grinding.

and sixthly, the tube blank obtained in the fifth step is subjected to a cold rolling process of reducing the diameter and reducing the wall at the same time, a cold rolling tube mill with the diameter of 120mm and a tool die are subjected to cold rolling deformation of 3 times, the fifth step is repeated after the cold rolling of the 1 st time, and then the cold rolling deformation of the 2 nd time is carried out.

The reducing rate of each cold rolling is controlled to be about 5 percent, the wall reducing amount is controlled to be about 10 percent, and the elongation coefficient is controlled to be about 1.5. Finally obtaining a tube blank with the diameter of 127mm, the wall thickness of 9.6mm and the length of more than or equal to 10 m;

and step seven, heating the vacuum electric furnace to 610 degrees C, filling the pipe blank obtained in the step six after reaching the temperature, preserving the heat for 6 hours, and then cooling the pipe blank to the room temperature in air.

The properties of the cold-rolled drill pipes after ageing (610 degrees C/6h/AC) are shown in Table 5.

TABLE 5 room temperature tensile properties (610 degrees C/6 h/AC) after aging of the drill pipes of example 4

No.	Rm MPa	Rp0.2 MPa	delta5 %	psi %	aku J	K1SCC MPa sqrt(m)	sigma-D MPa
1	1225	1160	13.1	25.2	32	82.6	892
2	1200	1125	12.8	27.7	34	86.5	895
3	1190	1100	14.6	25.8	35	87.4	900

Table note: axial fatigue, Kt = 1, R = 0.06, N >=10^7.

The preparation of multiple batches of TC27 titanium alloy drill pipes is completed by adopting the method, and the prepared drill pipes have the advantages of good surface quality, high dimensional accuracy, high batch stability and good repeatability.

In addition, the invention has simple process parameter setting and convenient operation, the cold rolling deformation of the drill pipe can be improved after the pretreatment before the cold rolling, the cold rolling passes are reduced, the room temperature tensile strength of the drill pipe can be more than or equal to 1150MPa, the yield strength can be more than or equal to 1050MPa, the elongation delta can be more than or equal to 10 percent, the reduction of area psi can be more than or equal to 20 percent, the impact energy aku can be more than or equal to 30J by the aging treatment after the cold rolling, and when Kt is 1, R is 0.06, N is 10^7, fatigue limit sigma-D >=890 MPa, and fracture toughness K1SCC >=80 MPa sqrt(m) in 3.5% aqueous NaCl at room temperature.

The strength, toughness, service life and marine environment corrosion resistance of the TC27 titanium alloy are obviously improved.

Finally, it should be noted that: the above embodiments are only for illustrating the technical solutions of the present invention, but the scope of the present invention is not limited thereto, and any person skilled in the art can easily conceive various equivalent modifications or substitutions within the technical scope of the present invention, and these modifications or substitutions should be covered within the scope of the present invention.

Claims (9)

1. A cold rolling method of TC27 titanium alloy pipes is characterized in that: the cold rolling method is used for preprocessing a pipe blank before cold rolling, and the preprocessing process comprises the following steps:

Heat the electric furnace to (T-beta +20) to (T-beta +40) degrees C. Load the tube shell once temperature is reached, hold for 0.8-1.0 min/mm of wall thickness and ensure a cooling rate >=30 degrees C/s.

the cold rolling method comprises the following steps:

step one, smelting a TC27 titanium alloy ingot;

step two, heating the electric furnace to 1100-1200 degrees C, loading the ingot obtained in the step one after the temperature is reached, preserving the heat for 18-24 h, carrying out component homogenizing annealing, and then air-cooling to room temperature;

Step 3. Use a high-low-high sequence above and below the transformation temperature, combining repeated upsetting and drawing-out for breakdown and reforging. Control reduction per heat to 45-55% above and 35-45% below the transformation temperature. Drawing-out reduction per stroke is 120-160 mm. Cut the TC27 bar reforged in the two-phase region to specified lengths.

Step 4. Heat the electric furnace to (T-beta +30) to (T-beta +60) degrees C. Load the cut bar from step 3 after temperature is reached, hold for 0.8-1.0 min/mm of bar diameter, hot-pierce and air-cool to room temperature to obtain a tube shell.

Step 5. Heat to (T-beta +20) to (T-beta +40) degrees C. Load the shell from step 4 after temperature is reached, hold for 0.8-1.0 min/mm of wall thickness and cool at >=30 degrees C/s. This retains a supercooled single beta phase and controls Rockwell hardness to HRC 30-35.

Step 6. Cold-roll the shell from step 5 with simultaneous diameter and wall reduction for 2-3 passes to obtain the tube blank.

and step seven, heating the vacuum electric furnace to 580-630 degrees C, loading the tube blank obtained in the step six after the temperature is reached, preserving the heat for 6-10 h, and then cooling the tube blank to room temperature in air.

2. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: and in the sixth step, during cold rolling deformation, the cold rolling reduction rate of each pass is controlled to be between 5% and 15%, the wall reduction amount is controlled to be between 10% and 25%, and the elongation coefficient is controlled to be between 1.5 and 2.5.

3. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: and in the third step, 6-10 times of heating ingot casting cogging and forging change are carried out.

4. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: and step five, cooling the pipe blank by adopting a water cooling or oil cooling mode after heat preservation.

5. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: and fifthly, cutting the head and the tail of the pretreated pipe blank, and removing the oxide skin defects on the inner surface and the outer surface.

6. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: in the sixth step, after the 1 st pass of cold rolling, the fifth step is repeated once, and then the 2 nd pass of cold rolling deformation is carried out.

7. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: the first step is specifically as follows: 3-ton TC27 titanium alloy ingots are smelted by a triple vacuum consumable-electrode melting, the TC27 titanium alloy ingots are 3-ton ingots with the diameter phi of more than or equal to 600mm, and the ingots are peeled off, cut head and tail, and then cut into two parts according to the length.

8. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: and in the second step, the cast ingot needs to be coated with a special high-temperature anti-oxidation coating for TC27 titanium alloy or a copper sheath when being subjected to homogenizing annealing.

9. The TC27 titanium alloy tube cold rolling method according to claim 1, wherein: the TC27 titanium alloy comprises the following alloy components in percentage by weight: 5.0 to 6.5 percent of Al, 3.5 to 5.0 percent of Mo, 5.0 to 6.5 percent of V, 1.5 to 2.5 percent of Nb, 0.5 to 1.5 percent of Fe, and the balance of Ti and unavoidable impurities, wherein the nominal chemical composition of the ingot is Ti-5.5Al-4Mo-6V-2Nb-1 Fe.

Translation notes

T-beta denotes the beta transformation temperature; AC denotes air cooling. Original table numbering begins with Table 2 and is retained. Source examples refer in step 2 to an ingot obtained in step 2; that source cross-reference is preserved. No drawings are included in the original publication. Statements and figures belong to the original patent disclosure and are not TiHubs performance guarantees.