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(71) Applicant: **Chengdu Advanced Metal Materials Industry Technology Research Institute Co., Ltd.
Chengdu, Sichuan 610300 (CN)**

(72) Inventor: **JIANG, Jian
Chengdu, Sichuan 610300 (CN)**

(74) Representative: **Murgitroyd & Company
165-169 Scotland Street
Glasgow G5 8PL (GB)**

(54) **METHOD FOR IMPROVING FLATTENING PERFORMANCE OF TITANIUM ALLOY SEAMLESS TUBE**

(57) Provided in the present invention is a method for improving the flattening performance of a titanium alloy seamless tube. The method comprises the following steps: performing VAR smelting three times to obtain a titanium alloy ingot; preparing the titanium alloy ingot into a titanium alloy round bar, pressing the titanium alloy round bar into a hollow tube blank, and subjecting the interior of the hollow tube blank to wet sand blasting, external grinding and acid pickling to prepare a hollow tube blank; rolling the hollow tube blank into a finished titanium alloy seamless tube; sampling the finished titanium alloy seamless tube, and measuring the maximum depth h1 of a micro-pit in the inner surface and the maximum extension depth h2 of a micro-crack formed by the extension of the micro-pit, subjecting the inner surface of the finished titanium alloy seamless tube to wet sand blasting so as to remove a wall thickness of h1 + 0.02 mm, and subjecting the inner surface of the finished titanium alloy seamless tube to flow acid cleaning so as to remove a wall thickness of h2 +0.02 mm; and subjecting the finished titanium alloy seamless tube in step 6 to vacuum annealing and straightening to obtain a finished tube. In the present invention, proper grain orientation is regulated by means of composition design and optimization, a thermal deformation process and a cold rolling process, and a better inner surface treatment method is used to completely eliminate micro-crack defects on the inner surface of the titanium alloy tube.

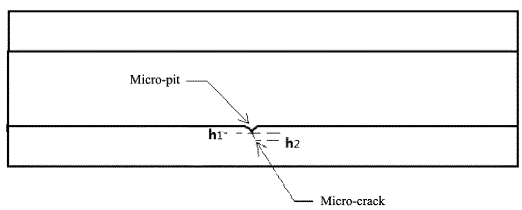

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to the technical field of non-ferrous seamless tube, in particular to a method for improving the flattening performance of a titanium alloy seamless tube.

BACKGROUND ART

[0002] Flattening performance is an important indicator to measure the quality of titanium alloy tubes. Flattening performance is generally tested according to the standard GB/T 246-2017. For example, the space between the flat plates formed by flattening the TA18 titanium alloy tube for aviation is required to be less than 10 times the wall thickness of the tube, that is, the space between the flat plates formed by flattening the titanium alloy tube of 20* 1mm should be less than or equal to 10mm to be qualified. Existing cold rolling, thermal treatment and internal surface treatment processes cannot optimize the flattening performance of titanium alloy tubes, resulting in unqualified flattening performance of TA18 titanium alloy tubes.

[0003] A failure form of a titanium alloy tube with unqualified flattening performance is cracking on the inner surface of a flattened sample. There are two reasons why the flattening performance is unqualified. One is that the design of titanium alloy composition and the distribution of grain orientation are unreasonable; the other is that the flattening performance is unqualified due to the defects on the inner surface of titanium alloy tube, and the form of the inner surface defect is micro-pit with micro-crack.

SUMMARY

[0004] According to the above technical problems, the present invention provides a method for improving flattening performance of titanium alloy seamless tubes. For the aforementioned first reason, the present invention mainly regulates grain orientation, strength and plasticity of the titanium alloy seamless tube by optimizing composition, thermal deformation process and cold rolling process; and for the aforementioned second reason, the present invention completely eliminates the micro-crack defects on the inner surface of the titanium alloy seamless tube by using better inner surface treatment methods.

[0005] Technical solutions adapted by the present invention are as follows:
A method for improving flattening performance of a titanium alloy seamless tube includes the following steps:

S1: Perform vacuum arc remelting (VAR) three times to obtain a titanium alloy ingot, and control an oxygen content of the obtained titanium alloy ingot to be less than or equal to 0.07 %.

S2: Perform open die forging for 4 heating numbers and radial forging for 2 heating numbers to the titanium alloy ingot to prepare a titanium alloy round bar, wherein each heating number of open die forging performs three upsetting-drawing processes, and the prepared round bar is up to the AA level of the standard GB/T5193 by inspection.

S3: Extrude the titanium alloy round bar to form a hollow tube blank, and subject an inner side of the hollow tube blank to wet sandblasting, an outer side of that to grinding, and both the sides to acid pickling to prepared a hollow tube blank with no defects both inner and outer surfaces. Sandblasting is performed with a mixture of 100-mesh green silicon carbide particles and water mixed in a weight ratio of 1:2, and a grain orientation of the hollow tube blank is α-phase <11-20>//radial direction of tube blank and <10-10>//axial direction of tube blank.

S4: Perform cold rolling to the hollow tube blank with no defects on both inner and outer surfaces in a two-roll cold-rolling mill 3-4 passes to prepare a semi-finished titanium alloy seamless tube, and perform vacuum annealing after each pass of the cold rolling, where the cold rolling process requires that a *K* value of each pass of the cold rolling is greater than or equal to 1, and a deformation rate ε and the *K* value of each pass of the cold rolling are larger than those of the previous pass. A grain orientation of the semi-finished titanium alloy seamless tube is α-phase <0001>//radial direction of tube and α-phase <10-10>//axial direction of tube. Perform cold rolling to a hollow tube blank with a diameter D1 and a wall thickness S1 for 1 pass to obtain a hollow tube blank with a diameter D2 and a wall thickness S2, and a calculation formula of deformation rate ε of this pass of cold rolling satisfies: $\varepsilon=((D1-S1)\times S1-(D2-S2)\times S2)/((D1-S1)\times S1)$; and a calculation formula of *K* value of this pass of cold rolling satisfies: $K=(S1-S2)\times D1/(D1-D2)\times S1$.

S5: Sample multiple groups (preferably 10 groups) of transverse and longitudinal metallographic structures from the semi-finished titanium alloy seamless tube obtained in step S4, observe the metallographic structure samples, and measuring micro-pits on the inner surface of the titanium alloy tube to obtain a maximum depth h1 of the micro-pits and measuring micro-cracks extending from the micro-pits on the inner surface to obtain a maximum extension depth h2 of the micro-cracks.

S6: Wet sandblast the inner surface of the semi-finished titanium alloy seamless tube obtained in step S4 to reduce a thickness of the tube wall by h1+0.02 mm, cover the outer surface of the titanium alloy tube with plastic bags after sandblasting, and perform flow pickling to the inner surface of the covered semi-finished titanium alloy seamless tube to reduce a thickness of the tube wall by h2+0.02 mm.

Sandblasting is performed with a mixture of 100-mesh green silicon carbide particles and water mixed in a weight ratio of 1: 2 to reduce a wall thickness of the tube by h1+0.02 mm, the outer surface of the titanium alloy tube is covered with a plastic bag after sandblasting, and then the inner surface of the covered semi-finished titanium alloy seamless tube is subjected to flow pickling with a pickling solution. The pickling solution is a mixture of HF acid, HNO_3 acid and water mixed in a weight ratio of 5:20:75, and flows through the inner surface of the titanium alloy tube at a speed of more than or equal to 2 m/min.

S7: Vacuum anneal, straighten and flaw detect the semi-finished titanium alloy seamless tube obtained in step S6. A sample tube for flaw detection has an engraving groove with a depth of 0.04 mm, a width of 0.10 mm and a length of 1.52 mm. After passing inspection by flaw detection, take samples from the tube for tensile performance and flattening performance inspection, and obtain a qualified finished tube after passing inspection.

[0006] Compared with the prior art, the present invention has the following advantages:
Three times of VAR smelting are adopted, ensuring a uniform composition of the titanium alloy. The oxygen content is controlled to be less than or equal to 0.07%, which improves the flattening performance of the finished titanium alloy tube. The thermal deformation process combination of three times upsetting-drawing process for cogging and radial forging ensures that the titanium alloy round bar is uniform in structure and performances, and the obtained titanium alloy round bar can be up to the AA level of the standard GB/T 5193 by flaw detection. The extrusion process adjusts the grain orientation of the tube blank to be α-phase <11-20>//radial direction of tube blank and <10-10>//axial direction of the tube blank, an axial direction of tube blank, improving the flattening performance of the titanium alloy tube. The defects on the inner and outer surfaces of the hollow tube blank are eliminated by means of the combination of performing sandblasting to the inner side, grinding to the outer side, and acid pickling to both the sides, avoiding larger defects in the cold rolling process caused by tube blank defects. The deformation rate ε and the *K* value of the cold rolling process ensure that the grain orientation of the semi-finished titanium alloy seamless tube is reasonable and the structure is fine and uniform. The grain orientation of the semi-finished titanium alloy seamless tube is α-phase <0001>//radial direction of tube and <10-10>//axial direction of tube, ensuring the flattening performance of the semi-finished titanium alloy tube. The maximum depth h1 of the micro-pit 2 on the inner surface of the titanium alloy tube and the maximum extension depth h2 of the micro-crack 3 extending from the micro-pit on the inner surface are measured by means of metallographic observation. A corresponding defect elimination process is formulated for the defect morphology of the inner surface of the titanium alloy tube, that is, firstly, wet sandblasting is adopted to remove the micro-pits on the inner surface of the titanium alloy tube - the heat generated by sandblasting friction on the inner wall of the titanium tube results in the temperature to rise, which will affect the microstructure and performance of the titanium tube, while wet sandblasting can avoid this damage due to water cooling to reduce temperature - then flow pickling is adopted to remove the micro-cracks on the inner surface of the titanium alloy, and an additional thickness of 0.02 mm is removed to ensure that the defects are completely eliminated. The combination treatment process for the inner surface of the titanium tube completely eliminates the influence of defects on the inner surface of the titanium alloy tube on the flattening performance of the titanium alloy tube. The shallowest depth of engraving groove that can be achieved at present is 0.04mm. The defect removal effect is inspected by ultrasonic flaw detection on the full-length of each finished titanium alloy seamless tube, and a finished product tube is obtained after sampling and passing inspection of tensile performance and flattening performance.

[0007] Based on the above reasons, the present invention can be widely popularized in the fields of titanium alloy seamless tubes and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In order to more clearly illustrate the technical solution in the embodiments of the present invention or the prior art, the following is a brief introduction of the accompanying drawings required to be used in the description of the embodiment or the prior art. Obviously, the accompanying drawings in the description below are some embodiments of the present invention. For those ordinary in the art, other accompanying drawings can also be obtained from these accompanying drawings without creative labor.

[0009] FIG. 1 shows a schematic diagram of a micro-pit and a micro-crack on an inner surface of a semi-finished titanium alloy seamless tube according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0010] It should be noted that, in the case of no conflicts, the embodiments and the features in the embodiments of the present invention can be combined mutually. The present invention will be described in detail below with reference to the accompanying drawings and the embodiments.

[0011] To make the objectives, technical solutions, and advantages of the present invention clearer, the following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are merely some rather than all of the embodiments. The following description of at least one exemplary embodiment is actually only illustrative, and in no way serves as any limitation on the present invention and its application or use. Based on the embodiments of the present invention, all the other embodiments obtained by those of ordinary skill in the art without inventive effort are within the protection scope of the present invention.

[0012] It should be noted that the terms used herein are only intended to describe specific embodiments and are not intended to limit the exemplary embodiments of the present invention. As used herein, unless indicated obviously in the context, a singular form is intended to include a plural form. Furthermore, it should be further understood that the terms "include" and/or "comprise" used in this specification specify the presence of features, steps, operations, devices, components and/or of combinations thereof.

[0013] Unless specifically stated otherwise, the relative arrangement of components and steps, numerical expressions, and numerical values set forth in these embodiments do not limit the scope of the present invention. In addition, it should be clear that, for ease of description, sizes of the various components shown in the accompanying drawings are not drawn according to actual proportional relationships. Technologies, methods, and devices known to those of ordinary skill in the relevant fields may not be discussed in detail, but where appropriate, the technologies, methods, and devices should be considered as a part of the authorization specification. In all the embodiments shown and discussed herein, any specific value should be interpreted as merely being exemplary rather than limiting. Therefore, other embodiments of the exemplary embodiment may have different values. It should be noted that similar reference signs and letters represent similar items in the accompanying drawings below. Therefore, once an item is defined in one accompanying drawing, the item does not need to be further discussed in a subsequent accompanying drawing.

[0014] In the description of the present invention, it should be noted that orientations or position relationships indicated by orientation terms "front, rear, upper, lower, left, and right", "transverse, vertical, perpendicular, and horizontal", "top and bottom", and the like are usually based on orientations or position relationships shown in the accompanying drawings, and these terms are only used to facilitate description of the present invention and simplification of the description. In the absence of description to the contrary, these orientation terms do not indicate or imply that the apparatus or element referred to must have a specific orientation or be constructed and operated in a specific orientation, and therefore cannot be understood as a limitation on the protection scope of the present invention: orientation words "inner and outer" refer to the inside and outside relative to the contour of each component.

[0015] For ease of description, spatially relative terms such as "on", "over", "on the upper surface", and "above" can be used here to describe a spatial positional relationship between one device/feature and another device/feature shown in the figures. It should be understood that the spatially relative terms are intended to include different orientations in use or operation other than the orientation of the device described in the figure. For example, if the device in the figure is inverted, the device described as "above another device or structure" or "on another device or structure" is then be positioned as being "below another device or structure" or "beneath a device or structure". Therefore, the exemplary term "above" can include both orientations "above" and "below". The device can also be positioned in other different ways (rotating by 90 degrees or in another orientation), and the spatially relative description used herein is explained accordingly.

[0016] In addition, it should be noted that using terms such as "first" and "second" to define components is only for the convenience of distinguishing the corresponding components. Unless otherwise stated, the foregoing words have no special meaning and therefore cannot be understood as a limitation on the protection scope of the present invention.

[0017] A method for improving the flattening performance of a titanium alloy seamless tube includes the following steps:

S1: Perform VAR smelting three times to obtain a titanium alloy ingot, and control the oxygen content of the obtained titanium alloy ingot to be less than or equal to 0.07 %.

S2: Perform open die forging for 4 heating numbers and radial forging for 2 heating numbers to the titanium alloy ingot to prepare a titanium alloy round bar. Each heating number of open die forging performs three upsetting-drawing processes, and the prepared titanium alloy round bar is up to the AA level of the standard GB/T5193 by inspection.

S3: Extrude the titanium alloy round bar to form a hollow tube blank, subject an inner side of the hollow tube blank to wet sandblasting, and outer side of that to grinding, and both sides to acid pickling to prepared a hollow tube blank with no defects both inner and outer surfaces. Sandblasting is performed with a mixture of 100-mesh green silicon carbide particles and water mixed in a weight ratio of 1:2. Grain orientation of the hollow tube blank is α-phase <11-20>//radial direction of tube blank and <10-10>// axial direction of tube blank.

S4: Perform cold rolling to the hollow tube blank with no defects on both inner and outer surfaces in a two-roll cold-rolling mill 3-4 passes to prepare a semi-finished titanium alloy seamless tube, and perform vacuum annealing after each pass of the cold rolling. The cold rolling process requires that a K value of each pass of the cold rolling is greater than or equal to 1, and a deformation rate ε and the K value of each pass of the cold rolling are larger than those of the previous pass. The grain orientation of the semi-finished titanium alloy seamless tube is α-phase <0001>//radial direction of tube and <10-10>//axial direction of tube. Perform cold rolling to a hollow tube blank with a diameter D1 and a wall thickness S1 for 1 pass to obtain a hollow tube blank with a diameter D2 and a wall thickness S2, and a calculation formula of deformation rate ε of this pass of cold rolling satisfies: $\varepsilon=((D1-S1)\times S1-(D2-S2)\times S2)/((D1-S1)\times S1)$; and a calculation formula of the K value of this pass of cold rolling satisfies: $K=(S1-S2)\times D1/(D1-D2)\times S1$.

S5: Sample 10 groups of transverse and longitudinal metallographic structures from the semi-finished titanium alloy seamless tube obtained in step S4, and observe the metallographic structure samples, and measure micro-pits on the inner surface of the titanium alloy tube to obtain the maximum depth h1 of the micro-pits and measure micro-cracks extending from the micro-pits on the inner surface to obtain the maximum depth h2 of the micro-cracks.

S6: Wet sandblast the inner surface of the semi-finished titanium alloy seamless tube obtained in step S4 to reduce a thickness of the tube wall by h1+0.02 mm, cover the outer surface of the titanium alloy tube with a plastic bag after sandblasting, and perform flow pickling to the inner surface of the covered semi-finished titanium alloy seamless tube to reduce a thickness of the tube wall by h2+0.02 mm.
Sandblasting is performed with a mixture of 100-mesh green silicon carbide particles and water mixed in a weight ratio of 1: 2 to reduce the wall thickness of the tube by h1+0.02 mm, the outer surface of the titanium alloy tube is covered with a plastic bag after sandblasting, and then the inner surface of the covered semi-finished titanium alloy seamless tube is subjected to flow pickling with a pickling solution. The pickling solution is a mixture of HF acid, HNO_3 acid and water mixed in a weight ratio of 5:20:75, and flows through the inner surface of the titanium alloy tube at a speed of more than or equal to 2 m/min.

S7: Vacuum anneal, straighten and flaw detect the semi-finished titanium alloy seamless tube obtained in step S6. A sample tube for flaw detection has an engraving groove with a depth of 0.04 mm, a width of 0.10 mm and a length of 1.52 mm. After passing inspection by flaw detection, take samples from the tube for tensile performance and flattening performance inspection, and obtain a qualified finished tube after passing inspection.

Example 1

[0018] TA16 titanium alloy seamless tube with a specification of Φ14×0.8 mm was produced adopting the following production process:
Titanium sponge and alloy components were used for three times of VAR to prepare a round TA16 titanium alloy ingot with Φ490 and an oxygen content of 0.059-0.065 %. The ingot was subjected to open die forging for 4 heating numbers by a hydraulic forging press to prepare a Φ170 round rod, where each number of open die forging performs three upsetting-drawing processes. Then Φ170 round rod was subjected to radial forging for 2 heating numbers to prepare a Φ70 black surface round rod. The Φ70 black surface round rod was extruded to obtain a hollow tube blank, and then the tube blank was subjected to wet sandblasting on inner side, grinding on outer side, and pickling on both side to prepare a Φ54*5 hollow tube blank. The Φ54*5 hollow tube blank was cold rolled by a LG30 two-roll cold-rolling mill to prepare a Φ33×3 titanium tube (ε of 63.3% and K value of 1.03). After holding at 740 °C for 1h and vacuum annealing, the Φ33×3 titanium tube was cold rolled by a LG15 two-roll cold-rolling mill to prepare a Φ21×1.7 titanium tube (ε of 63.5% and K value of 1.19). After holding at 740 °C for 1h and vacuum annealing, the Φ21×1.7 titanium tube was cold rolled by a LG15 two-roll cold-rolling mill to prepare a Φ14×0.8 titanium tube (ε of 67.8% and K value of 1.59). After holding at 750 °C for 1h, vacuum annealing and straightening, 10 groups of transverse and longitudinal metallographic

structure samples from the Φ14×0.8 titanium tube were taken and observed, and the maximum depth 0.02 mm of micro-pits on the inner surface of the titanium alloy tube and the maximum extension depth 0.02 mm of micro-cracks extending from the micro-pits of the inner surface were measured from the samples. Then the inner surface of the Φ14×0.8 titanium tube was sandblasted to reduce a thickness of the tube wall by 0.04 mm, and was flow pickled to reduce the thickness of the tube wall by 0.04 mm. Then the Φ14×0.8 titanium tube was ultrasonically flaw detected for full-length (using a flaw detection sample tube having an engraving groove with a depth of 0.04 mm, a width of 0.10 mm, and a length of 1.52 mm). Tensile performance and flattening performance of the titanium tube was inspected. The titanium tube was packaged after passing inspection.

[0019] The TA16 titanium alloy seamless tube with a specification of Φ14×0.8 mm obtained in this example has a yield strength of 470 MPa, a tensile strength of 590 MPa, and an elongation of 25%, and the sample does not crack when the space between the flat plates formed by flattening is up to 6 mm.

Example 2

[0020] TA18 titanium alloy seamless tube with a specification of Φ15×1 mm was produced adopting the following production process:

Titanium sponge and alloy components were used for three times of VAR to prepare a round TA18 titanium alloy ingot with Φ490 and an oxygen content of 0.059-0.068 %. The ingot was subjected to open die forging for 4 heating numbers by a hydraulic forging press to prepare a Φ170 round rod, where each number of open die forging performs three upsetting-drawing processes. Then Φ170 round rod was subjected to radial forging for 2 heating numbers to prepare a Φ70 black surface round rod. The Φ70 black surface round rod was extruded to obtain a hollow tube blank, and then the tube blank was subjected to wet sandblasting on inner side, grinding on outer side, and pickling on both side to prepare a Φ50*5.5 hollow tube blank. The Φ50*5.5 hollow tube blank was cold rolled by a LG30 two-roll cold-rolling mill to prepare a Φ32×3.4 titanium tube (ε of 60.3% and K value of 1.06). After holding at 700 °C for 1h and vacuum annealing, the Φ32×3.4 titanium tube was cold rolled by a LG15 two-roll cold-rolling mill to prepare a Φ21×2 titanium tube (ε of 60.9% and K value of 1.2). After holding at 700 °C for 1h and vacuum annealing, the Φ21×2 titanium tube was cold rolled by a LG15 two-roll cold-rolling mill to prepare a Φ15×1 titanium tube (ε of 63.2% and K value of 1.75). After holding at 720 °C for 1h, vacuum annealing and straightening, 10 groups of transverse and longitudinal metallographic structure samples from the Φ15×1 titanium tube were taken and observed, and the maximum depth 0.03 mm of micro-pits on the inner surface of the titanium alloy tube and the maximum extension depth 0.03 mm of micro-cracks extending from the micro-pits of the inner surface were measured from the samples. Then the inner surface of the Φ15×1 titanium tube was sandblasted to reduce a thickness of the tube wall by 0.05 mm, and was flow pickled to reduce the thickness of the tube wall by 0.05 mm. Then the Φ15×1 titanium tube was ultrasonically flaw detected for full-length (using a flaw detection sample tube having an engraving groove with a depth of 0.04 mm, a width of 0.10 mm, and a length of 1.52 mm). Tensile performance and flattening performance of the titanium tube was inspected. The titanium tube was packaged after passing inspection.

[0021] The TA18 titanium alloy seamless tube with a specification of Φ15×1 mm obtained in this example has a yield strength of 540 MPa, a tensile strength of 650 MPa, and an elongation of 20%, and the sample does not crack when the space between the flat plates formed by flattening is up to 9 mm.

[0022] Finally, it should be noted that the above embodiments are only used to illustrate the technical solutions of the present invention without limiting; although the present invention is described in detail with reference to the foregoing embodiments, the ordinary skilled in the art shall understand that they may still make amendments to the technical solutions disclosed in the foregoing embodiments, or make equal replacements for some or all of their technical characteristics; these amendments or replacements do not remove the essence of the corresponding technical solutions from the scope of the technical solution of each embodiment of the present invention.

Claims

1. A method for improving flattening performance of a titanium alloy seamless tube, comprising following steps of:

S1: performing VAR smelting three times to obtain a titanium alloy ingot with an oxygen content of less than or equal to 0.07 %;

S2: performing open die forging for 4 heating numbers and radial forging for 2 heating numbers to the titanium alloy ingot to prepare a titanium alloy round bar, wherein each heating number of open die forging performs three upsetting-drawing processes;

S3: extruding the titanium alloy round bar to form a hollow tube blank, and subjecting an inner side of the hollow tube blank to wet sandblasting, an outer side of that to grinding, and both the sides to acid pickling to prepared a hollow tube blank with no defects on both inner and outer surfaces;

S4: performing cold rolling to the hollow tube blank with no defects on both inner and outer surfaces in a two-roll cold-rolling mill 3-4 passes to prepare a semi-finished titanium alloy seamless tube, and performing vacuum annealing after each pass of the cold rolling, wherein the cold rolling process requires that a K value of each pass of the cold rolling is greater than or equal to 1, and a deformation rate ε and the K value of each pass of the cold rolling are larger than those of a previous pass;

performing cold rolling to a hollow tube blank with a diameter D1 and a wall thickness S1 for 1 pass, obtaining a hollow tube blank with a diameter D2 and a wall thickness S2, and a calculation formula of deformation rate ε of this pass of cold rolling satisfying:

$$\varepsilon=((D1-S1)\times S1-(D2-S2)\times S2)/((D1-S1)\times S1);$$

a calculation formula of K value of this pass of cold rolling satisfying: $K=(S1-S2)\times D1/(D1-D2)\times S1$;

S5: sampling multiple groups of transverse and longitudinal metallographic structures from the semi-finished titanium alloy seamless tube obtained in S4, observing the metallographic structure samples, and measuring micro-pits on the inner surface of the titanium alloy tube to obtain a maximum depth h1 of the micro-pits and measuring micro-cracks extending from the micro-pits on the inner surface to obtain a maximum extension depth h2 of the micro-cracks;

S6: wet sandblasting the inner surface of the semi-finished titanium alloy seamless tube obtained in step S4 to reduce a thickness of the tube wall by h1+0.02 mm, covering the outer surface of the titanium alloy tube after sandblasting, and performing flow pickling to the inner surface of the covered semi-finished titanium alloy seamless tube to reduce the thickness of the tube wall by h2+0.02 mm; and

S7: vacuum annealing and straightening the semi-finished titanium alloy seamless tube obtained in S6 to obtain the finished titanium alloy seamless tube.

2. The method for improving the flattening performance of the titanium alloy seamless tube according to claim 1, wherein the titanium alloy round bar obtained in step S2 is up to the AA level of the standard GB/T5193 by inspection.

3. The method for improving the flattening performance of the titanium alloy seamless tube according to claim 1, wherein in the step S3 and step S6, sandblasting is performed with a mixture of 100-mesh green silicon carbide particles and water mixed in a weight ratio of 1:2.

4. The method for improving the flattening performance of the titanium alloy seamless tube according to claim 1, wherein a grain orientation of the hollow tube blank obtained in step S3 is α-phase <11-20>//radial direction of tube blank and <10-10>// axial direction of tube blank.

5. The method for improving the flattening performance of the titanium alloy seamless tube according to claim 4, wherein a grain orientation of the semi-finished titanium alloy seamless tube obtained in step S4 is α-phase <0001>//radial direction of tube and <10-10>//axial direction of tube.

6. The method for improving the flattening performance of the titanium alloy seamless tube according to claim 1, wherein in step S6, a pickling solution is a mixture of HF acid, HNO_3 acid and water mixed in a weight ratio of 5:20:75, and flows through the inner surface of the titanium alloy tube at a speed of more than or equal to 2 m/min.

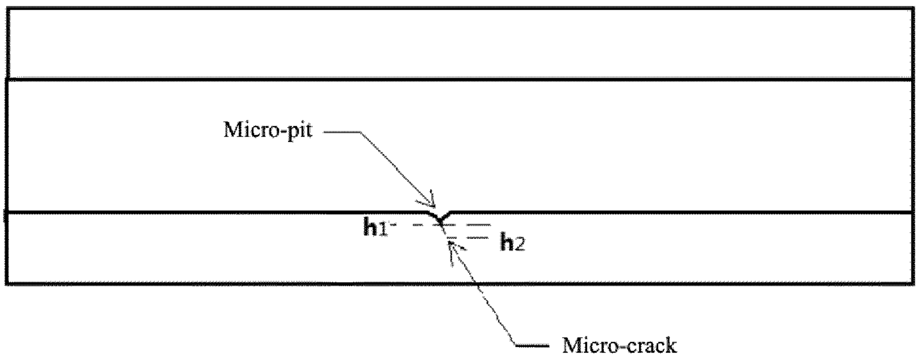

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/102287

A. CLASSIFICATION OF SUBJECT MATTER

B21C37/06(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:B21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, ENTXTC, CNKI: 无缝, 管, 压扁, 轧, 裂纹, 开裂, 喷砂, 酸洗; VEN, USTXT, EPTXT, WOTXT, ENTXT, WPABS: seamless, tube, pipe, flatten, mill, crack, abrasive, acid.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 115647107 A (CHENGDU ADVANCED METAL MATERIALS INDUSTRY TECHNOLOGY RESEARCH INSTITUTE CO., LTD.) 31 January 2023 (2023-01-31) claims 1-6, and figure 1	1-6
PX	CN 115647106 A (CHENGDU ADVANCED METAL MATERIALS INDUSTRY TECHNOLOGY RESEARCH INSTITUTE CO., LTD.) 31 January 2023 (2023-01-31) description, paragraphs 4-21	1-6
A	CN 106493187 A (NANJING BAOTAI SPECIAL MATERIALS CO., LTD. et al.) 15 March 2017 (2017-03-15) description, paragraphs 5-35	1-6
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☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
03 September 2023	**23 September 2023**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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