Preparation method for improving the mechanical properties of TB13 titanium alloy wire for spectacle frames

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Applicant / assignee: Chengdu Advanced Metal Materials Industry Technology Research Institute Co., Ltd.

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Inventors: Sun Sibo; Wang Zelong; Feng Zhaolong; Liu Zhenglin

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Translation notes

All description paragraph identifiers and table values are retained. The source writes the rotary-swaging feed-rate unit as /min without a numerator; that notation is retained rather than corrected by assumption. Example 3 specifies a second-heat starting temperature of 1050 deg C although the general method states 900-1000 deg C. This source discrepancy is preserved. Claims and the general description split the last drawing-size range across a line/paragraph break; it is joined here for readability.

Abstract

The invention discloses a preparation method for improving the mechanical properties of TB13 titanium alloy wire for spectacle frames. Rotary swaging and roller-die drawing are used for cold diameter reduction and cold drawing to improve wire properties. It overcomes technical disadvantages of conventional hot-drawing reduction: absorption of harmful atmospheric elements by heated wire, reduced material performance, low production efficiency, increased dimensional tolerance, surface scoring, high energy consumption and high pollution. TB13 ingots are made into spectacle-frame wire through forging, hot rolling, rotary swaging and roller-die drawing. Large deformation and relatively low processing temperatures in billet breakdown and rolling break up the coarse microstructure to an extent and improve the internal structure. The entire process avoids pickling and electrolysis, with no increase in hydrogen, oxygen or nitrogen during production and high compositional purity. The wire has low surface residual stress and excellent finished mechanical properties.

Claims

1. A preparation method for improving the mechanical properties of TB13 titanium alloy wire for spectacle frames, comprising the following steps:

(1) Forging: peel the TB13 ingot and remove the riser to obtain the billet. Break down the billet in two heats. In the first heat, use three upsetting and three drawing-out operations, an initial forging temperature of 1050-1150 deg C, a 3 h hold, a finishing temperature above 700 deg C and upsetting/drawing-out deformation of 65%-70%. In the second heat, use two upsetting and two drawing-out operations, an initial temperature of 900-1000 deg C, a 3 h hold, a finishing temperature above 600 deg C and deformation of 60%-65%.

(2) Rolling: grind the forged titanium billet to a metallic luster with no defects visible to the unaided eye, then heat it in a furnace. Use two rolling heats to obtain wire rod. The first heat is at 850-900 deg C with a 2 h hold, a rolling speed of 2 m/s, a final diameter of 60 mm, 13 passes and 75% deformation. The second heat is at 800-850 deg C with a 2 h hold, 10 passes, a final diameter of 10 mm and 97% deformation.

(3) Rotary swaging: first round and peel the wire rod from step (2). Round it by hot drawing at 800 deg C to a diameter of 9.5 mm. Peel it using a centerless grinding lathe to a diameter of 9.0 mm. Then use a rotary swaging machine for seven passes, each reducing the diameter by 0.5 mm, to reduce 9.0 mm wire to 5.5 mm intermediate wire.

(4) Heat treatment: vacuum-anneal the intermediate wire from step (3) at 700-810 deg C, hold for 1-2 h and water cool.

(5) Roller-die drawing: uniformly coat the annealed wire from step (4) with a water-soluble lubricant, then draw it through roller dies. In reducing the diameter from 5.5 mm to 1.8-2.0 mm, successively reduce it to 4.3-4.9 mm, 3.5-3.9 mm and 2.0-2.4 mm. No heat treatment is needed during roller-die drawing.

2. The method of claim 1, wherein hydraulic oil is used for lubrication during rotary swaging in step (3), the swaging rate is no greater than 0.3/min and no heat treatment is needed during rotary swaging.

Description - Technical field

[0001] The invention belongs to titanium-alloy wire preparation technology and specifically concerns improving the mechanical properties of TB13 wire for spectacle frames.

Background

[0002] TB13 (Ti-4Al-22V) is a metastable beta titanium alloy with excellent overall properties. Its high strength, good ductility and excellent cold-workability have led to widespread use in chemical, biomedical, eyewear and automotive industries. As titanium and its alloys are increasingly used for spectacle frames, this alloy can be a preferred material for high-end frame products.

[0003] The traditional TB13 wire process is fixed-die hot drawing, heat treatment, pickling and polishing, commonly delivering coiled rod with a machined surface. Problems include: (1) slow fixed-die drawing, small diameter reductions per pass, a long process chain and low efficiency; (2) heating at 700-800 deg C during drawing, which makes absorption of nitrogen, hydrogen and oxygen from air likely and reduces consistency of properties; (3) high sliding friction between the fixed die and wire, increasing dimensional variation and causing surface scoring and continuous defects; and (4) the need for electrolytic polishing or pickling after drawing to remove graphite or phosphated lubricant, leading to high energy consumption and pollution.

Disclosure of the invention

[0004] To overcome these defects of conventional hot-drawing diameter reduction, including atmospheric uptake of harmful elements, reduced material performance, low efficiency, increased dimensional tolerance, surface scoring, energy consumption and pollution, the invention uses rotary swaging and roller-die drawing for cold reduction and cold drawing of TB13 wire to improve its mechanical properties.

[0005] Cold working is an important route for improving titanium-alloy wire properties. Rotary swaging offers simple die replacement, a smooth cold-worked surface and high dimensional accuracy. Roller-die drawing offers low rolling friction, large deformation per pass, a uniform post-deformation structure, low wire-surface residual stress and excellent finished mechanical properties.

[0006] To achieve these objectives, the invention provides the following preparation method:

[0007] (1) Forging: peel the TB13 ingot and remove the riser to obtain the billet. Break down the billet in two heats. In the first heat, use three upsetting and three drawing-out operations, an initial forging temperature of 1050-1150 deg C, a 3 h hold, a finishing temperature above 700 deg C and upsetting/drawing-out deformation of 65%-70%. In the second heat, use two upsetting and two drawing-out operations, an initial temperature of 900-1000 deg C, a 3 h hold, a finishing temperature above 600 deg C and deformation of 60%-65%.

[0008] (2) Rolling: grind the forged titanium billet to a metallic luster with no defects visible to the unaided eye, then heat it in a furnace. Use two rolling heats to obtain wire rod. The first heat is at 850-900 deg C with a 2 h hold, a rolling speed of 2 m/s, a final diameter of 60 mm, 13 passes and 75% deformation. The second heat is at 800-850 deg C with a 2 h hold, 10 passes, a final diameter of 10 mm and 97% deformation.

[0009] (3) Rotary swaging: first round and peel the wire rod from step (2). Use a hot-drawing machine at 800 deg C for rounding, removing surface ear defects and producing a diameter of 9.5 mm. Use a centerless grinding lathe for peeling to remove oxide scale and surface defects, producing a diameter of 9.0 mm. Then use a rotary swaging machine for seven passes, reducing the diameter by 0.5 mm per pass from 9.0 mm to 5.5 mm to obtain intermediate wire. Lubricate with hydraulic oil; the swaging rate is no greater than 0.3/min, and no heat treatment is needed during swaging.

[0010] (4) Heat treatment: the intermediate wire from step (3) is work hardened. To facilitate subsequent roller-die drawing, vacuum-anneal it at 700-810 deg C, hold for 1-2 h and water cool.

[0011] (5) Roller-die drawing: uniformly coat the annealed wire from step (4) with a water-soluble lubricant, then draw it through roller dies. In reducing 5.5 mm wire to 1.8-2.0 mm, successively reduce it to the following diameters:

[0012] 4.3-4.9 mm, 3.5-3.9 mm and 2.0-2.4 mm. No heat treatment is required during roller-die drawing.

[0013] Compared with the prior art, the invention has the following beneficial effects:

[0014] Large deformation and relatively low processing temperatures are used for billet breakdown and rolling, helping break up coarse structure and improve the internal microstructure. The complete wire process avoids pickling and electrolysis, with no increase in hydrogen, oxygen or nitrogen and high compositional purity. Rotary swaging and roller-die drawing are cold-working processes. The resulting wire has excellent, stable mechanical properties: for diameters of 2.0-4.9 mm, tensile strength can be maintained continuously and stably at 720-880 MPa, yield strength at 570-700 MPa, elongation at 16%-28% and reduction of area at 45%-65%.

Detailed embodiments

[0015] The invention is further described through specific examples below, without limiting it in any way. Unless otherwise stated, raw materials in the examples are commercially available and methods are conventional.

Example 1

[0016] Example 1.

[0017] A method for improving the mechanical properties of TB13 titanium-alloy wire for spectacle frames comprises the following steps:

[0018] (1) Use a compositionally uniform 300 mm diameter TB13 ingot and a 2000 t hydraulic press for billet breakdown. In the first heat, the initial forging temperature is 1050 deg C, holding time 3 h, finishing temperature 750 deg C and upsetting/drawing-out deformation 65%. In the second heat, the initial temperature is 950 deg C, holding time 3 h, finishing temperature 650 deg C and deformation 60%.

[0019] (2) After surface treatment of the forged billet, use a reciprocating rolling mill. The first heat is at 850 deg C, held for 2 h, with a rolling speed of 2 m/s, final diameter 60 mm, 13 passes and 75% deformation. The second heat is at 800 deg C, held for 2 h, with 10 passes, final diameter 10 mm and 97% deformation.

[0020] (3) Round and peel the wire rod. Use a hot-drawing machine at 800 deg C to remove surface ear defects and round it to 9.5 mm diameter. Peel it on a centerless grinding lathe to remove oxide scale and surface defects, producing 9.0 mm diameter. Rotary-swage it in seven passes, reducing diameter by 0.5 mm per pass from 9.0 to 5.5 mm. Lubricate with hydraulic oil. The swaging wire-feed rate is 0.3/min, and no heat treatment is needed during swaging.

[0021] (4) Vacuum-anneal the intermediate wire from step (3) at 800 deg C for 1.5 h, then water cool.

[0022] (5) Uniformly coat the annealed wire with a water-soluble lubricant and perform roller-die drawing. Use a continuous roller-die drawing machine to reduce 5.5 mm wire to 4.92 mm in one pass(es), with 19.9% deformation.

[0023] Mechanical testing of the 4.92 mm diameter as-drawn TB13 wire from Example 1 is shown in Table 1. The results show excellent and stable mechanical properties.

[0024] Table 1. Mechanical test results for 4.92 mm diameter as-drawn TB13 wire.

[0025] Test results:

Table 1 - Example 1

Property	Point 1	Point 2	Point 3	Point 4	Point 5
Tensile strength (MPa)	721	747	738	736	729
Yield strength (MPa)	629	599	575	611	609
Elongation (%)	23.5	27.5	22.3	27.0	21.2
Reduction of area (%)	62	65	60	61	59

Example 2

[0026] Example 2.

[0027] A method for improving the mechanical properties of TB13 titanium-alloy wire for spectacle frames comprises the following steps:

[0028] (1) Use a compositionally uniform 350 mm diameter TB13 ingot and a 2000 t hydraulic press for billet breakdown. In the first heat, the initial forging temperature is 1150 deg C, holding time 3 h, finishing temperature 780 deg C and upsetting/drawing-out deformation 68%. In the second heat, the initial temperature is 1000 deg C, holding time 3 h, finishing temperature 680 deg C and deformation 63%.

[0029] (2) After surface treatment of the forged billet, use a reciprocating rolling mill. The first heat is at 900 deg C, held for 2 h, with a rolling speed of 2 m/s, final diameter 60 mm, 13 passes and 75% deformation. The second heat is at 850 deg C, held for 2 h, with 10 passes, final diameter 10 mm and 97% deformation.

[0030] (3) Round and peel the wire rod. Use a hot-drawing machine at 800 deg C to remove surface ear defects and round it to 9.5 mm diameter. Peel it on a centerless grinding lathe to remove oxide scale and surface defects, producing 9.0 mm diameter. Rotary-swage it in seven passes, reducing diameter by 0.5 mm per pass from 9.0 to 5.5 mm. Lubricate with hydraulic oil. The swaging wire-feed rate is 0.2/min, and no heat treatment is needed during swaging.

[0031] (4) Vacuum-anneal the intermediate wire from step (3) at 810 deg C for 1.0 h, then water cool.

[0032] (5) Uniformly coat the annealed wire with a water-soluble lubricant and perform roller-die drawing. Use a continuous roller-die drawing machine to reduce 5.5 mm wire to 3.92 mm in one pass(es), with 49.2% deformation.

[0033] Mechanical testing of the 3.92 mm diameter as-drawn TB13 wire from Example 2 is shown in Table 2. The results show excellent and stable mechanical properties.

[0034] Table 2. Mechanical test results for 3.92 mm diameter as-drawn TB13 wire.

[0035] Test results:

Table 2 - Example 2

Property	Point 1	Point 2	Point 3	Point 4	Point 5
Tensile strength (MPa)	809	821	833	806	819
Yield strength (MPa)	645	636	609	611	633
Elongation (%)	20.2	21.5	19.7	22.0	19.2
Reduction of area (%)	53	52	50	51	49

Example 3

[0036] Example 3.

[0037] A method for improving the mechanical properties of TB13 titanium-alloy wire for spectacle frames comprises the following steps:

[0038] (1) Use a compositionally uniform 400 mm diameter TB13 ingot and a 2000 t hydraulic press for billet breakdown. In the first heat, the initial forging temperature is 1150 deg C, holding time 3 h, finishing temperature 800 deg C and upsetting/drawing-out deformation 70%. In the second heat, the initial temperature is 1050 deg C, holding time 3 h, finishing temperature 700 deg C and deformation 65%.

[0039] (2) After surface treatment of the forged billet, use a reciprocating rolling mill. The first heat is at 900 deg C, held for 2 h, with a rolling speed of 2 m/s, final diameter 60 mm, 13 passes and 75% deformation. The second heat is at 850 deg C, held for 2 h, with 10 passes, final diameter 10 mm and 97% deformation.

[0040] (3) Round and peel the wire rod. Use a hot-drawing machine at 800 deg C to remove surface ear defects and round it to 9.5 mm diameter. Peel it on a centerless grinding lathe to remove oxide scale and surface defects, producing 9.0 mm diameter. Rotary-swage it in seven passes, reducing diameter by 0.5 mm per pass from 9.0 to 5.5 mm. Lubricate with hydraulic oil. The swaging wire-feed rate is 0.1/min, and no heat treatment is needed during swaging.

[0041] (4) Vacuum-anneal the intermediate wire from step (3) at 700 deg C for 2 h, then water cool.

[0042] (5) Uniformly coat the annealed wire with a water-soluble lubricant and perform roller-die drawing. Use a continuous roller-die drawing machine to reduce 5.5 mm wire to 2.43 mm in three pass(es), with 80.4% deformation.

[0043] Mechanical testing of the 2.43 mm diameter as-drawn TB13 wire from Example 3 is shown in Table 3. The results show excellent and stable mechanical properties.

[0044] Table 3. Mechanical test results for 2.43 mm diameter as-drawn TB13 wire.

[0045] Test results:

Table 3 - Example 3

Property	Point 1	Point 2	Point 3	Point 4	Point 5
Tensile strength (MPa)	867	879	845	862	859
Yield strength (MPa)	698	669	672	661	683
Elongation (%)	17.2	16.9	18.3	17.9	18.0
Reduction of area (%)	48	45	46	50	49

[0046] A person skilled in the art may use the disclosed technical content to make numerous changes and modifications, or equivalent embodiments, without departing from the technical solution. Any simple modifications, equivalent changes and alterations to the examples based on the technical substance of the invention, without departing from its content, remain within the scope of protection of the technical solution.