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TA32 titanium-alloy thick plate for 550 deg C and its preparation method

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English translation for reference; original Chinese publication controls.

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Translation notes

All 97 description paragraphs and four claims are translated. Numerical values and source inconsistencies are retained, including the Sn range in Example 3, unchanged length/width values in some rolling steps, and the reference to steps five and seven in paragraph [0096]. Rolling campaign (one heat of rolling) is distinguished from an individual pass. The title and reported temperature describe the original research and do not guarantee a TiHubs service rating. Original micrographs and scale bars are reproduced with English captions.

Abstract

The invention relates to titanium-alloy processing and provides TA32 thick plate for 550 deg C and its preparation method. The steps are: (1) heat a TA32 ingot at 1070-1150 deg C, break it down by forging with a finishing temperature no lower than 950 deg C and obtain an intermediate billet; (2) heat the billet at 920-960 deg C and forge a 150-200 mm slab; (3) heat the slab at 920-960 deg C and perform 2-5 successive rolling campaigns with alternating direction to obtain thick-plate stock of 65-12 mm; and (4) anneal, creep-straighten and surface-sand the stock to obtain finished TA32 plate of 60-10 mm for 550 deg C. The resulting plate has a uniform microstructure and excellent room-temperature and elevated-temperature tensile and stress-rupture properties.

Claims

1. A method for preparing TA32 titanium-alloy thick plate for 550 deg C, comprising:

Step 1: hold the titanium-alloy ingot in a furnace at 1070-1150 deg C for 200-240 min, then forge it on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 240-320 mm thick.

Step 2: hold the billet from step 1 at 920-960 deg C for 120-180 min, then forge the intermediate billet to obtain a slab 150-200 mm thick. The slab microstructure is lath-like alpha plus beta, and total deformation in the thickness direction is 35%-38%.

Step 3: hold the slab from step 2 at 920-960 deg C for 100-120 min, then roll it to obtain a billet 100-120 mm thick.

Step 4: hold the billet from step 3 at 930-950 deg C for 100-120 min, then roll perpendicular to the direction in step 3 to obtain a billet 62-65 mm thick.

Step 5: hold the billet from step 4 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 4 to obtain a billet 42-45 mm thick.

Step 6: hold the billet from step 5 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 5 to obtain a billet 22-25 mm thick.

Step 7: hold the billet from step 6 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 6 to obtain a billet 12-15 mm thick.

Step 8: select a billet from steps 4-7 according to the required thickness. Anneal, creep-straighten and surface-sand it to obtain finished plate 10-60 mm thick with acceptable surface quality. Annealing is a double-anneal treatment: first anneal at 880-930 deg C for 60-120 min and cool in air, then anneal at 500-550 deg C for 120-240 min and cool in air.

In steps 3-7, each rolling operation consists of one rolling campaign. Total thickness-direction deformations are respectively 33%-40%, 38%-46%, 30%-32%, 44%-48% and 40%-45%.

2. The method of claim 1, wherein: By weight, the alloy contains Al 5.0%-6.0%, Sn 3.0%-4.0%, Zr 2.5%-3.5%, Mo 0.3%-1.5%, Si 0.1%-0.5%, Nb 0.2%-0.7%, Ta 0.2%-0.7%, Fe <=0.03%, O <=0.15%, H <=0.012% and N <=0.05%, with the balance Ti and unavoidable impurities.

3. The method of claim 1 or 2, wherein: By weight, the preferred composition is Ti-(5.4-5.6)Al-(3.4-3.6)Sn-(2.8-3.2)Zr-(0.8-1.2)Mo-(0.25-0.35)Si-(0.3-0.5)Nb-(0.3-0.5)Ta, with Fe <=0.03%, O <=0.15%, H <=0.012% and N <=0.05%; the balance is Ti and unavoidable impurities.

4. TA32 titanium-alloy thick plate for 550 deg C prepared by claim 1, wherein: The plate has room-temperature tensile strength >=900 MPa, yield strength >=800 MPa and elongation >=8%; at 550 deg C, tensile strength is >=580 MPa and elongation >=8%. Under a stress-rupture test at 550 deg C / 430 MPa, rupture life is at least 100 h.

Description - Technical field

[0001] The invention belongs to titanium-alloy processing technology and specifically concerns TA32 thick plate for 550 deg C and its preparation method.

Background

[0002] With the development of near-space hypersonic vehicles, TA32 thick plate has gradually been used extensively in high-temperature structural regions such as fuselages, tail structures and nozzles because of its high specific strength and excellent overall elevated-temperature mechanical properties.

[0003] Patent publication CN104874604A provides a rolling method for wide titanium-alloy thick plate and addresses industrial rolling of wide TC4 plate, but does not consider its elevated-temperature mechanical properties.

[0004] Patent publication CN110961453A provides a method for processing titanium and titanium-alloy thick plate and addresses dimensional accuracy and surface-quality control of 350-500 mm plate, but does not consider mechanical properties.

[0005] Patent publication CN111235504A provides a titanium-alloy thick-plate production process. It does not identify the applicable alloy type and only gives a process for obtaining basketweave microstructure.

[0006] Granted patent CN102441584B provides a method for chamfered titanium-alloy thick-plate billets, focusing on reducing edge folds, reducing trimming losses at the head, tail and sides and improving yield. It does not mention the alloy grade or plate mechanical properties.

[0007] Granted patent CN104651767B provides a method for medical TC4ELI medium/thick plate, focusing on microstructure and room-temperature mechanical properties.

[0008] Granted patent CN105951016B provides a short-process method for TA5 thick plate, focusing on shape control without mentioning mechanical properties.

[0009] Granted patent CN107952794B provides a single-heat rolling method for TC4 thick plate, focusing on microstructure, room-temperature tensile properties and surface quality.

[0010] TA32 is a near-alpha high-temperature titanium alloy. The source states that no domestic or foreign patent had reported a preparation process for 10-60 mm plate of this alloy. Because of its high hot strength and fatigue performance, its hot-deformation resistance exceeds that of alloys such as TC4 and TA5. Excessively high rolling temperatures cause severe surface oxidation and impair final surface quality; excessively low temperatures cause severe deformation cracking and prevent rolling. Rolling reduction and direction also influence microstructural and

property uniformity. Existing patents largely concern dimensions, cost and room-temperature tensile properties of alpha-beta alloys such as TC4. The method for near-alpha TA32 plate for 550 deg C differs significantly from conventional titanium alloys: it must ensure uniform microstructure and texture and consider processing effects on room-temperature tensile, elevated-temperature tensile and high-temperature stress-rupture properties to meet 550 deg C service needs.

[0011] The main problem addressed is therefore to optimize the plate preparation route and appropriately balance room-temperature and elevated-temperature mechanical properties.

Disclosure of the invention

[0012] To fill the preparation-technology gap, the invention provides TA32 thick plate for 550 deg C and a method for producing it. The plate is 10-60 mm thick, with high short-term tensile strength and good long-duration stress-rupture performance at 550 deg C; its stated long-term service temperature, for at least 100 h, can reach 550 deg C.

[0013] The technical solution is as follows:

[0014] A preparation method for TA32 thick plate for 550 deg C comprises:

[0015] Step 1: hold the titanium-alloy ingot in a furnace at 1070-1150 deg C for 200-240 min, then forge it on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 240-320 mm thick.

[0016] Step 2: hold the billet from step 1 at 920-960 deg C for 120-180 min, then forge the intermediate billet to obtain a slab 150-200 mm thick.

[0017] Step 3: hold the slab from step 2 at 920-960 deg C for 100-120 min, then roll it to obtain a billet 100-120 mm thick.

[0018] Step 4: hold the billet from step 3 at 930-950 deg C for 100-120 min, then roll perpendicular to the direction in step 3 to obtain a billet 62-65 mm thick.

[0019] Step 5: hold the billet from step 4 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 4 to obtain a billet 42-45 mm thick.

[0020] Step 6: hold the billet from step 5 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 5 to obtain a billet 22-25 mm thick.

[0021] Step 7: hold the billet from step 6 at 930-950 deg C for 80-100 min, then roll perpendicular to the direction in step 6 to obtain a billet 12-15 mm thick.

[0022] Step 8: select a billet from steps 4-7 according to the required thickness. Anneal, creep-straighten and surface-sand it to obtain finished plate 10-60 mm thick with acceptable surface quality. Acceptable surface quality means a finished surface roughness of 3.2 micrometers or better.

[0023] By weight, the alloy contains Al 5.0%-6.0%, Sn 3.0%-4.0%, Zr 2.5%-3.5%, Mo 0.3%-1.5%, Si 0.1%-0.5%, Nb 0.2%-0.7%, Ta 0.2%-0.7%, Fe <=0.03%, O <=0.15%, H <=0.012% and N <=0.05%, with the balance Ti and unavoidable impurities.

[0024] Preferred technical solutions are as follows:

[0025] By weight, the preferred composition is Ti-(5.4-5.6)Al-(3.4-3.6)Sn-(2.8-3.2)Zr-(0.8-1.2)Mo-(0.25-0.35)Si-(0.3-0.5)Nb-(0.3-0.5)Ta, with Fe <=0.03%, O <=0.15%, H <=0.012% and N <=0.05%; the balance is Ti and unavoidable impurities.

[0026] In step 2, the slab measures (150-200) x 500 x 1000 mm. Its structure is lath-like alpha plus beta. Total thickness-direction deformation is at least 30%, with 35%-38% recommended.

[0027] In step 3, rolling consists of one campaign; total thickness-direction deformation is at least 30%, most preferably 33%-40%.

[0028] In step 4, rolling consists of one campaign; total thickness-direction deformation is at least 35%, most preferably 38%-46%.

[0029] In step 5, rolling consists of one campaign; total thickness-direction deformation is at least 30%, most preferably 30%-32%.

[0030] In step 6, rolling consists of one campaign; total thickness-direction deformation is at least 40%, most preferably 44%-48%.

[0031] In step 7, rolling consists of one campaign; total thickness-direction deformation is at least 40%, most preferably 40%-45%.

[0032] In step 8, Annealing is a double-anneal treatment: first anneal at 880-930 deg C for 60-120 min and cool in air, then anneal at 500-550 deg C for 120-240 min and cool in air.

[0033] TA32 thick plate for 550 deg C prepared by this method has the following properties: The plate has room-temperature tensile strength >=900 MPa, yield strength >=800 MPa and elongation >=8%; at 550 deg C, tensile strength is >=580 MPa and elongation >=8%. Under a stress-rupture test at 550 deg C / 430 MPa, rupture life is at least 100 h.

[0034] The invention has the following advantages over existing technology:

[0035] 1. Intermediate-thickness stock is sufficiently deformed in the two-phase temperature range of 920-960 deg C, while the processing-temperature range is gradually narrowed to 930-950 deg C. This can effectively weaken transformation texture and ensure that mechanical properties consistently meet requirements.

[0036] 2. The resulting TA32 thick plate has a uniform microstructure, excellent room-temperature and elevated-temperature tensile and stress-rupture properties, and stable mechanical performance capable of meeting 550 deg C use requirements.

Description of the drawings

[0037] Figure 1 shows the microstructure of the slab after forging in step 2 of Example 2.

[0038] Figure 2 shows the microstructure of the finished TA32 thick plate for 550 deg C prepared in Example 2.

Detailed embodiments

[0039] The invention is described in further detail below through examples.

Example 1

[0040] Example 1.

[0041] Preparation of 60 mm TA32 thick plate for 550 deg C.

[0042] Step 1: melt a TA32 ingot with target composition Ti-5.6Al-3.4Sn-3.1Zr-0.8Mo-0.35Si-0.4Nb-0.5Ta. Hold it at 1150 deg C for 240 min, then forge on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 320 mm thick.

[0043] Step 2: hold the billet from step 1 at 960 deg C for 180 min and forge it to a 200 x 500 x 1000 mm slab with lath-like alpha plus beta microstructure.

[0044] Step 3: hold the slab from step 2 at 960 deg C for 120 min, then roll to obtain 120 x 500 x 1000 mm stock.

[0045] Step 4: hold the stock from step 3 at 940 deg C for 120 min, then roll perpendicular to the rolling direction in step 3 to obtain 65 mm thick stock.

[0046] Step 5: double-anneal the stock from step 4, first at 930 deg C for 120 min followed by air cooling, then at 550 deg C for 240 min followed by air cooling. Creep-straighten and surface-sand it to obtain 60 mm finished plate with acceptable surface quality.

[0047] The 60 mm TA32 plate has a uniform microstructure. At room temperature, tensile strength is 929 MPa, yield strength 864 MPa and elongation 13.0%. At 550 deg C, tensile strength is 602 MPa and elongation 15.0%. In the stress-rupture test at 550 deg C / 430 MPa, the specimen had not ruptured after more than 101 h.

Example 2

[0048] Example 2.

[0049] Preparation of 40 mm TA32 thick plate for 550 deg C.

[0050] Step 1: melt a TA32 ingot with target composition Ti-5.5Al-3.5Sn-3.0Zr-0.8Mo-0.3Si-0.4Nb-0.4Ta. Hold it at 1100 deg C for 220 min, then forge on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 280 mm thick.

[0051] Step 2: hold the billet from step 1 at 950 deg C for 150 min and forge it to a 180 x 500 x 1000 mm slab with lath-like alpha plus beta microstructure (Figure 1).

[0052] Step 3: hold the slab from step 2 at 950 deg C for 110 min, then roll to obtain 110 x 500 x 1000 mm stock.

[0053] Step 4: hold the stock from step 3 at 950 deg C for 110 min, then roll perpendicular to the rolling direction in step 3 to obtain 62 mm thick stock.

[0054] Step 5: hold the stock from step 4 at 930 deg C for 90 min, then roll perpendicular to the rolling direction in step 4 to obtain 42 mm thick stock.

[0055] Step 6: double-anneal the stock from step 5, first at 900 deg C for 80 min followed by air cooling, then at 500 deg C for 180 min followed by air cooling. Creep-straighten and surface-sand it to obtain 40 mm finished plate with acceptable surface quality.

[0056] The 40 mm TA32 plate has a uniform microstructure (Figure 2). At room temperature, tensile strength is 989 MPa, yield strength 926 MPa and elongation 14.0%. At 550 deg C, tensile strength is 629 MPa and elongation 17%. In the stress-rupture test at 550 deg C / 430 MPa, the specimen had not ruptured after more than 101 h.

Example 3

[0057] Example 3.

[0058] Preparation of 20 mm TA32 thick plate for 550 deg C.

[0059] Step 1: melt a TA32 ingot with target composition Ti-5.4Al-(3.4-3.6)Sn-2.8Zr-1.0Mo-0.25Si-0.3Nb-0.3Ta. Hold it at 1120 deg C for 200 min, then forge on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 240 mm thick.

[0060] Step 2: hold the billet from step 1 at 940 deg C for 160 min and forge it to a 150 x 500 x 1000 mm slab with lath-like alpha plus beta microstructure.

[0061] Step 3: hold the slab from step 2 at 940 deg C for 100 min, then roll to obtain 100 x 500 x 1000 mm stock.

[0062] Step 4: hold the stock from step 3 at 930 deg C for 120 min, then roll perpendicular to the rolling direction in step 3 to obtain 62 mm thick stock.

[0063] Step 5: hold the stock from step 4 at 930 deg C for 100 min, then roll perpendicular to the rolling direction in step 4 to obtain 42 mm thick stock.

[0064] Step 6: hold the stock from step 5 at 930 deg C for 100 min, then roll perpendicular to the rolling direction in step 5 to obtain 22 mm thick stock.

[0065] Step 7: double-anneal the stock from step 6, first at 880 deg C for 80 min followed by air cooling, then at 530 deg C for 120 min followed by air cooling. Creep-straighten and surface-sand it to obtain 20 mm finished plate with acceptable surface quality.

[0066] The 20 mm TA32 plate has a uniform microstructure. At room temperature, tensile strength is 989 MPa, yield strength 926 MPa and elongation 14.0%. At 550 deg C, tensile strength is 629 MPa and elongation 17%. In the stress-rupture test at 550 deg C / 430 MPa, the specimen had not ruptured after more than 101 h.

Example 4

[0067] Example 4.

[0068] Preparation of 10 mm TA32 thick plate for 550 deg C.

[0069] Step 1: melt a TA32 ingot with target composition Ti-5.5Al-3.5Sn-3.0Zr-1.2Mo-0.35Si-0.5Nb-0.5Ta. Hold it at 1070 deg C for 200 min, then forge on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 240 mm thick.

[0070] Step 2: hold the billet from step 1 at 960 deg C for 120 min and forge it to a 150 x 500 x 1000 mm slab with lath-like alpha plus beta microstructure.

[0071] Step 3: hold the slab from step 2 at 960 deg C for 100 min, then roll to obtain 100 x 500 x 1000 mm stock.

[0072] Step 4: hold the stock from step 3 at 950 deg C for 100 min, then roll perpendicular to the rolling direction in step 3 to obtain 62 mm thick stock.

[0073] Step 5: hold the stock from step 4 at 940 deg C for 100 min, then roll perpendicular to the rolling direction in step 4 to obtain 42 mm thick stock.

[0074] Step 6: hold the stock from step 5 at 940 deg C for 90 min, then roll perpendicular to the rolling direction in step 5 to obtain 22 mm thick stock.

[0075] Step 7: hold the stock from step 6 at 930 deg C for 80 min, then roll perpendicular to the rolling direction in step 6 to obtain 12 mm thick stock.

[0076] Step 8: double-anneal the stock from step 7, first at 910 deg C for 70 min followed by air cooling, then at 500 deg C for 180 min followed by air cooling. Creep-straighten and surface-sand it to obtain 10 mm finished plate with acceptable surface quality.

[0077] The 10 mm TA32 plate has a uniform microstructure. At room temperature, tensile strength is 999 MPa, yield strength 940 MPa and elongation 14.0%. At 550 deg C, tensile strength is 654 MPa and elongation 19%. In the stress-rupture test at 550 deg C / 430 MPa, the specimen had not ruptured after more than 101 h.

Comparative example 1

[0078] Comparative example 1.

[0079] Preparation of 60 mm TA32 thick plate for 550 deg C.

[0080] Step 1: melt a TA32 ingot with target composition Ti-5.6Al-3.4Sn-3.1Zr-0.8Mo-0.35Si-0.4Nb-0.5Ta. Hold it at 1170 deg C for 240 min and forge on a forging machine, finishing at no less than 950 deg C, to obtain a 120 x 500 x 1000 mm slab.

[0081] Step 2: hold the slab at 940 deg C for 120 min and roll it to 62 mm thick stock.

[0082] Step 3: double-anneal the stock from step 2, first at 930 deg C for 120 min followed by air cooling, then at 550 deg C for 240 min followed by air cooling. Creep-straighten and surface-sand it to obtain 60 mm finished plate with acceptable surface quality.

[0083] The 60 mm TA32 plate has room-temperature tensile strength 880 MPa, yield strength 800 MPa and elongation 12.0%; at 550 deg C, tensile strength is 550 MPa and elongation 16.0%. Rupture life under 550 deg C / 430 MPa is 89 h.

[0084] Compared with the slab preparation in steps 1-3 of Example 1, the temperature and number of rolling operations differ significantly in step 1 of Comparative example 1. Cross-rolling is also absent. Consequently, the final mechanical properties differ significantly and do not meet this application's thick-plate requirements.

Comparative example 2

[0085] Comparative example 2.

[0086] Preparation of 10 mm TA32 thick plate for 550 deg C.

[0087] Step 1: melt a TA32 ingot with target composition Ti-5.5Al-3.5Sn-3.0Zr-1.2Mo-0.35Si-0.5Nb-0.5Ta. Hold it at 1070 deg C for 200 min, then forge on a forging machine, finishing at no less than 950 deg C, to obtain an intermediate billet 240 mm thick.

[0088] Step 2: hold the billet from step 1 at 960 deg C for 120 min and forge it to a 150 x 500 x 1000 mm slab.

[0089] Step 3: hold the slab from step 2 at 960 deg C for 100 min, then roll to obtain 100 x 500 x 1000 mm stock.

[0090] Step 4: hold the stock from step 3 at 950 deg C for 100 min and roll it to 62 mm thick stock.

[0091] Step 5: hold the stock from step 4 at 940 deg C for 100 min, then roll in the same direction as step 4 to obtain 42 mm thick stock.

[0092] Step 6: hold the stock from step 5 at 940 deg C for 90 min, then roll in the same direction as step 5 to obtain 22 mm thick stock.

[0093] Step 7: hold the stock from step 6 at 930 deg C for 80 min, then roll in the same direction as step 6 to obtain 12 mm thick stock.

[0094] Step 8: double-anneal the stock from step 7, first at 910 deg C for 70 min followed by air cooling, then at 500 deg C for 180 min followed by air cooling. Creep-straighten and surface-sand it to obtain 10 mm finished plate with acceptable surface quality.

[0095] For the 10 mm TA32 plate, one tensile specimen was taken at each of two plate locations. Specimen 1 had room-temperature tensile strength 950 MPa, yield strength 850 MPa and elongation 10.0%; specimen 2 had tensile strength 890 MPa, yield strength 800 MPa and elongation 12.0%. At 550 deg C, specimen 1 had tensile strength 550 MPa and elongation 15%, while specimen 2 had tensile strength 590 MPa and elongation 13%.

[0096] Compared with Example 4, the rolling direction was not changed in steps 5 and 7 of Comparative example 2. The plate tensile strength therefore could not consistently meet this application's thick-plate requirements.

[0097] The examples illustrate only the technical concept and features of the invention, enabling persons familiar with the technology to understand and implement it. They do not limit its scope of protection. Equivalent changes or modifications made according to its spirit and substance are included within that scope.

Drawing

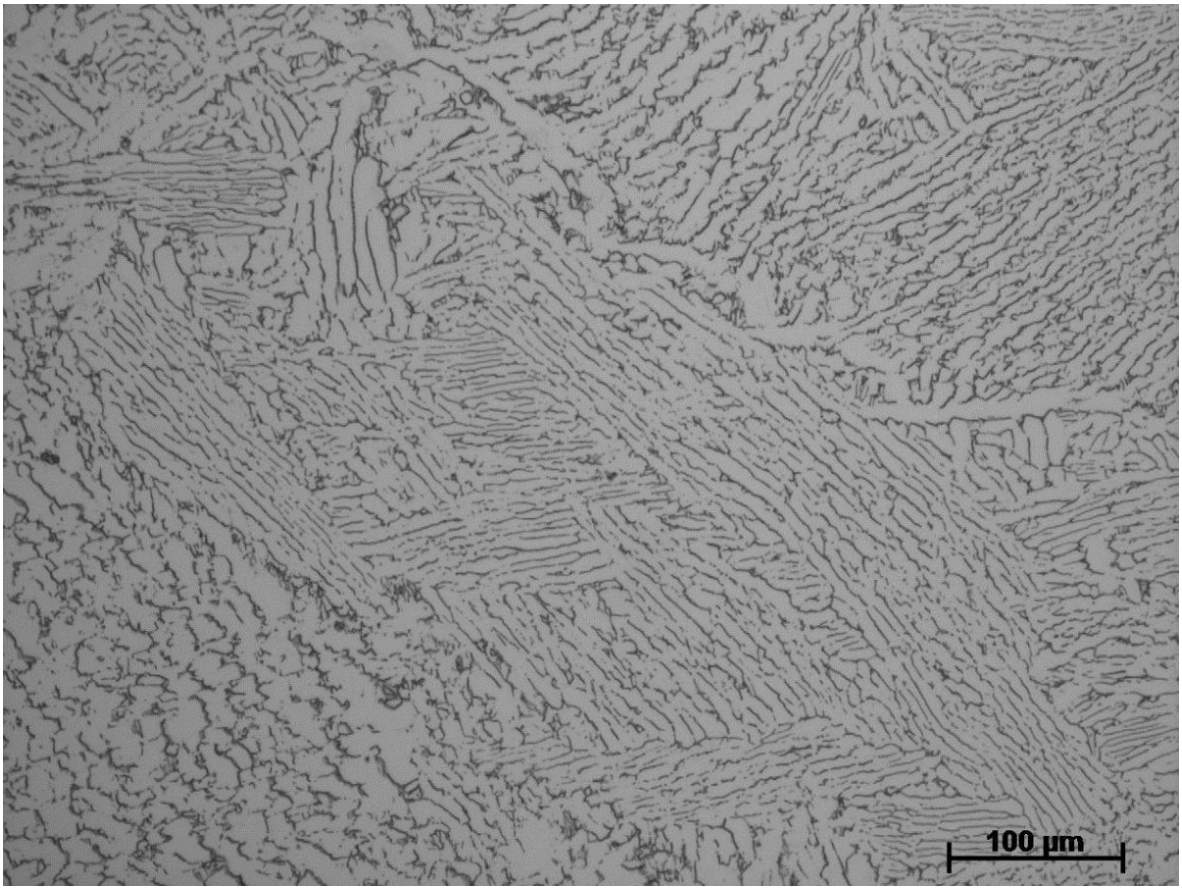


Figure 1. Microstructure of the slab after forging in step 2 of Example 2. Original micrograph; scale bar: 100 micrometers.

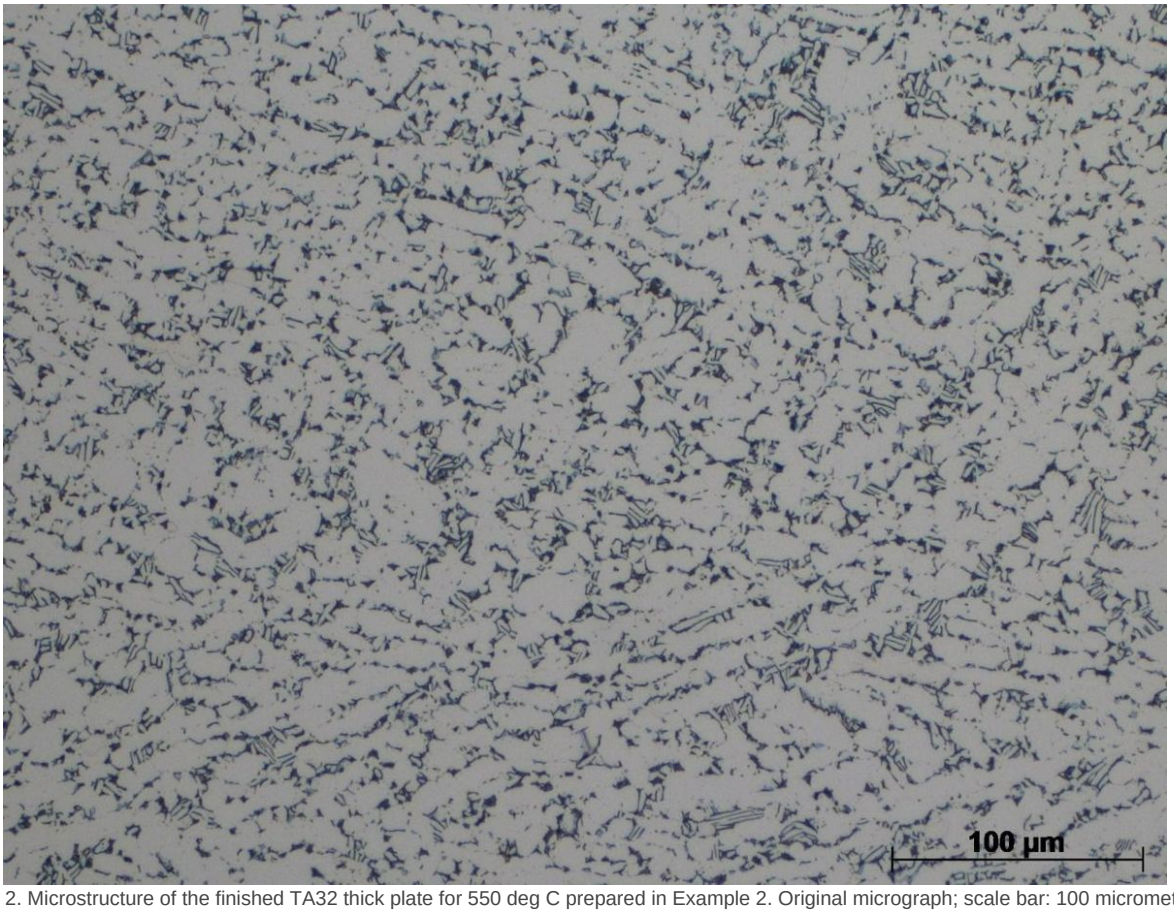


Figure 2. Microstructure of the finished TA32 thick plate for 550 deg C prepared in Example 2. Original micrograph; scale bar: 100 micrometers.