

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 1 577 409 A1

(12)

EUROPEAN PATENT APPLICATION

published in accordance with Art. 158(3) EPC

(43) Date of publication:

21.09.2005 Bulletin 2005/38

(51) Int Cl.7: **C22C 14/00**

(21) Application number: **03811968.1**

(86) International application number:

PCT/RU2003/000378

(22) Date of filing: **21.08.2003**

(87) International publication number:

WO 2004/048627 (10.06.2004 Gazette 2004/24)

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR**

Designated Extension States:

AL LT LV MK

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(30) Priority: **25.11.2002 RU 2002131488**

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(54) **TITANIUM-BASED ALLOY**

(57) Titanium - base alloy includes the following elements (% of weight): 2,2-3,8 of aluminum; 4,5-5,9 of vanadium; 4,5-5,9 of molybdenum; 2,0-3,6 of chromium; 0,1-0,4 of zirconium; 0,01-0,18 of iron; 0,01-0,25 of carbon; 0,03-0,25 of oxygen; balance - titanium. The alloy is **characterized by** high process ductility in the quenched condition in combination with high strength.

Furthermore, the alloy has a higher range of working temperatures which allows to use it not only for manufacture of bolt heads and coil springs, but also for large-size semi products with the section of up to 60 mm operating at elevated temperatures.

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Description

Field of the invention

[0001] The invention relates to the metallurgical one, and more particularly to creation of the modern titanium alloys used for making high-strength and high-tech items, including the large-sized ones, i.e. alloys having the high genericity.

Prior state of art

[0002] One of the known titanium alloys is the alloy containing, in % by weight: aluminum 2-6, molybdenum 6-9, vanadium 1-3, chromium 0,5-2,0, iron 0-1,5, titanium - balance (Inventor's Certificate USSR No. 180351, Class C22C 14/00, published 1966).

This alloy was proposed for making die-forgings and forgings for the highly loaded structural parts. The significant drawback is its tendency to forming the high density inclusions when melting ingots due to the high content of the refractory element molybdenum (> 6%). The presence of such inclusions in the high-loaded parts leads to destruction of such parts when being in service.

[0003] The other known titanium alloy, containing % by weight: 4,0-6,3 Al; 4,0-5,0 V; 1,5-2,5 Mo; 0,8-1,4 Cr; 0,4-0,8 Fe; 0,01-0,08 Zr; 0,01-0,25 C; 0,03-0,25 O; balance - titanium (Inventor's Certificate USSR No. 555161, Class C22C 14/00, published 1977).

[0004] This alloy has the high strength properties, fine ductility, not disposed to forming the high density inclusions.

[0005] The drawback of this alloy is the impossibility of cold die-forging, caused by insufficient level of the index of the process plasticity as age, such as the degree of cold upsetting (less than 60%).

[0006] The closest to the claimed invention from the technical point is the alloy with the base of titanium, containing % by weight: 2,2-3,8 Al; 4,5-5,9 V; 4,5-5,9 Mo; 2,0-3,6 Cr; 0,2-0,8 Fe; 0,01-0,08 Zr; 0,01-0,25 C; 0,03-0,25 O; Ti - balance (RF Patent No. 2150528, Class C22C 14/00, published 2000) - prototype.

[0007] Alloy has the high level of plasticity as quenched, in this case they achieve the degree of cold upsetting $\geq 75\%$.

[0008] However, the known alloy has the insufficiently high level of the working temperatures, this limits the scope of its application as a structural material for making parts, used at increased temperatures.

Disclosure of the invention

[0009] This invention aims at creation of the titanium alloy with the increased heat-resistance, which ensures the possibility of making the heavy large-sized parts with the high level of the strength and plastic properties, used at increased temperatures.

[0010] The technical result achieved when patent pending is in regulating the optimum combination of α - and β -stabilizing alloying elements in the finished semiproduct.

[0011] The technical result is achieved due to the fact that in the alloy with the base of titanium, containing aluminum, vanadium, molybdenum, chromium, iron, zirconium, carbon, oxygen, according to the invention, the components are taken in the following ratio, weight %:

Aluminum	2,2 - 3,8
Vanadium	4,5 - 5,9
Molybdenum	4,5 - 5,9
Chromium	2,0 - 3,6
Zirconium	0,1 - 0,4
Iron	0,01 - 0,18
Carbon	0,01 - 0,25
Oxygen	0,03 - 0,25
Titanium	balance

[0012] The combination of high strength and plasticity of the proposed alloy is achieved as a result of the task-oriented choice and experimental evaluation of the alloying ranges. Content of the α - stabilizing elements (aluminum, oxygen, carbon) and β -stabilizers (molybdenum, vanadium, chromium, iron) is chosen as required and sufficient for achievement of the set target. Besides, the proposed alloy ensures the possibility to effectively regulate the strength level of the alloy as aged within the wide ranges.

[0013] Balancing aluminum and chromium content in the claimed alloy ensures high alloy ability for cold die forging

(fine rolling to bar) and possibility of alloy strengthening by the thermal techniques obtaining the high level of the strength and plastic properties.

[0014] With aluminum and chromium content below the minimum values the alloy strength is lowered after thermos-trengthening ($\sigma_B < 1400$ MPa), i.e. the problem put is not achieved.

[0015] When aluminum and chromium content exceeds the declared limit the alloy plasticity lowers ($\delta < 8\%$, $\psi < 40\%$) with the high strength level ($\sigma_B \geq 1400$ MPa).

[0016] To ensure the required strength (≥ 1150 MPa) as quenched and aged, as well as to perform quenching in the air, not in water, the content of V and Mo is set as $\geq 4,5\%$.

[0017] V and Mo content is accepted 5,9% max due to the hazard of significant growth of segregation non-uniformity and occurrence of defects when using the hard master alloys.

[0018] As the increase of V and Mo content, as already said, is not recommended to be above 5,9%, then for the subsequent (above 1150 MPa) increase of the strength properties (as quenched and aged) they introduce the moderate additions of Cr (2,0-3,6%) and Fe (to 0,18%) within the limits, which do not bring to the occurrence of the visible dendritic or zonal segregation.

[0019] In the proposed alloy, as compared to the prototype, the iron content with the value of the distribution number is decreased. ($K = \frac{C_{\text{solid phase}}}{C_{\text{liquid phase}}}$) is significantly below one, and this predetermines the iron tendency to segregation, which is aggravated with the increase of the ingot and item size.

[0020] Amount of zirconium in the alloy from 0,1 to 0,4% ensures increase of the tensile strength without lowering of the metal processibility during hot (not increases the flow stress) and cold (not decreases the plasticity resource) deformation. In this case stabilizing the α -phase, zirconium increases creep resistance and high-temperature strength.

[0021] Introduction of zirconium exceeding 0,4% significantly lowers the alloy processing plasticity during cold strain.

[0022] Ranges of alloying with zirconium and iron are selected on the base of experimental evaluation of the alloy mechanical properties in the proposed composition range. Content of zirconium from 0,1 to 0,4% and iron to 0,18% ensures the increase of the ultimate strength of the alloy in the as quenched and aged condition.

[0023] The proposed combination of the components of the alloy and their % ratio in complex ensures the possibility of the alloy deformation in the greater temperature range and obtaining parts by cold die forging.

Embodiments of the invention

[0024] For the evaluation of the alloy properties the double-melt ingots were vacuum arc remelting melted with the following alloy compositions (Table 1).

Table 1

Alloy	Alloy chemistry, % by weight								
	Al	V	Mo	Cr	Fe	Zr	C	O ₂	Ti
1	2,2	4,5	4,5	2,0	0,1	0,1	0,01	0,03	balance
2	3,0	5,2	4,8	2,8	0,15	0,2	0,2	0,2	balance
3	3,8	5,9	5,9	3,6	0,18	0,4	0,25	0,25	balance

[0025] The bars were made of each ingot with the diameter of 50 mm. The bars were heat-treated to obtain the high strength. The mechanical properties of bars at room temperature are show in Table 2.

Table 2

Alloy	Rate of deformation when cold upsetting ϵ , %	Mechanical properties				
		Ultimate Strength σ_B (MPa)	Yield Strength $\sigma_{0,2}$ (MPa)	Elongation δ (%)	Reduction of Area ψ (%)	Resistance to shear τ_{cp} (MPa)
1	77	1425	1370	11	48	915
2	75	1470	1385	10	43	945

Table 2 (continued)

Alloy	Rate of deformation when cold upsetting ϵ , %	Mechanical properties				
		Ultimate Strength σ_B (MPa)	Yield Strength $\sigma_{0,2}$ (MPa)	Elongation δ (%)	Reduction of Area ψ (%)	Resistance to shear τ_{cp} (MPa)
3	72	1515	1455	9	41	975
Required level of properties	70	1400	1300	8	40	900

[0026] Test results show that the declared items (bars with dia 50 mm) from titanium-base alloy have the high processing plasticity level as quenched, in this case they achieve the degree of cold upsetting $> 75\%$ in combination with high strength obtained as a result of the subsequent ageing ($\sigma_B > 1500$ Mpa).

Commercial practicability

[0027] The claimed alloy has the higher range of the working temperatures (10-15°C higher than the alloy - prototype has), this gives the possibility to use it not only when making the bolt heads through cold heading, in cold threading, in production of coil springs, and for making large semis up to 60mm in section, with the high level of strength and plastic properties, used at increased temperatures.

Claims

1. Alloy with the base of titanium, containing aluminum, vanadium, molibdenum, chromium, iron, zirconium, carbon, oxygen, differing in the fact that the alloy components are taken in the following ratio of the % by weight.

Aluminum	2,2-3,8
Vanadium	4,5-5,9
Molibdenum	4,5-5,9
Chromium	2,0 - 3,6
Zirconium	0,1 - 0,4
Iron	0,01-0,18
Carbon	0,01-0,25
Oxygen	0,03-0,25
Titanium	balance

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 03/00378

A. CLASSIFICATION OF SUBJECT MATTER C22C 14/00 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) C22F 1/00, 1/16, 1/18, C22C 14/00 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)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RU 2150528 C1 (OAO VERKHNESALDINSKOE METALLURGICHESKOE PROIZVOSTVENNOE OBEDINENIE) 10.06.2000, the abstract	1
A	SU 555161 A (KHOREV, A.I. et al.) 24.05.1977, the claims	1
A	EP 0396236 A1 (TITANIUM METALS CORPORATION OF AMERICA) 07.11.1990, the abstract	1
A	EP 0870845 A1 (OREGON METALLURGICAL CJRPORATION) 14.10.1998, the claims	1
☐ 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 09 December 2003 (09.12.2003)		Date of mailing of the international search report 25 December 2003 (25.12.2003)
Name and mailing address of the ISA/ RU Facsimile No.		Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)