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(54) TITANIUM-BASED ALLOY

(57) The invention relates to the field of metallurgy and particularly to titanium base alloys used for making high-strength and high-workable articles. The titanium base alloy consists of Aluminum, Vanadium, Molybdenum, Iron, and Oxygen in the following ratio, wt.%: Aluminum 3.5 - 4.4, Vanadium 2.0 - 4.0, Molybdenum 0.1 - 0.8, Iron max 0.4, Oxygen max 0.25, the balance is titanium. The technical objective is to provide a versatile alloy to be used for making of large forgings and die forgings, rolled sheet products and foil having sufficient strength and ductility and structure. 2 tables.

EP 1 783 235 A1

Description

Field of the Invention

[0001] The invention relates to the field of metallurgy and particularly to the field of development of state-of-the-art titanium alloys used for making high-strength and high-workable articles including large articles, i.e. alloys of high versatility.

[0002] Titanium alloys are widely used as aerospace materials, e.g. in airplanes and rockets since the alloys possess tough mechanical properties and are comparatively light.

Prior state of Art

[0003] Known is the most widely used titanium alloy, Ti6A14V alloy (B.A. Kalachyov, I.S. Polkin and V.D. Talalayev. Titanium Alloys of Different Countries. Reference Book. Moscow: VILS, 2000, p. 58-59) - [1]. This alloy was developed in 1950s in the USA. It is characterized by medium strength of 850 up to 1000 MPa and high workability. It is a good material to work by forming: forging, die forging, and extruding. It is widely used in aeronautical and aerospace engineering, shipbuilding, automotive industry, etc., as well as in manufacturing fasteners for various applications. This alloy is good to work by all types of welding including diffusion bonding.

[0004] The disadvantage of Ti6A14V alloy is its insufficient versatility. It is difficult to make rolled sheet products, foil, and tubes thereof since the alloy possesses relatively high resistance to deformation, which in case that the deformation temperature becomes below 800°C leads to the generation of defects such as cracks and shortens the life of working tools or necessitates costly tools.

[0005] Known is a pseudo-α-titanium alloy Grade 9 (Ti-3Al-2,5V), which is highly capable of cold working (see [1], p. 44, 45). The strength of this alloy is intermediate between that of Ti-6Al-4V alloy and titanium (600-800 MPa). This alloy is used as cold-worked and stress annealed; it is characterized by high corrosion resistance in various media including sea water. This alloy is used in making tubes for hydraulics and fuel systems of airplanes, rockets, and submarines.

[0006] The disadvantage of this alloy is also its low versatility since it requires stress relieving in making large structural parts thereof. Therefore, articles have to be annealed which reduces strength of Grade 9 alloy down to 400-500 MPa.

[0007] The most close analogue of the invented alloy is α+β-titanium alloy consisting of 3.0-5.0 Al; 2.1-3.7 V; 0.85-3.15 Mo; 0.85-3.15 Fe; 0.06-0.2 O_2, and inevitable impurities (Japanese application No. 3007214 B2, filed Feb. 7, 2000) - prior art.

[0008] The disadvantage of this alloy is that it is rich in Fe and Mo and, therefore, is prone to segregation process. In order to reduce possibility of segregational heterogeneity it is required to use a special ingot melting technology, then carry out rolling and forging at a small deformation rate in order to exclude decoration of "beta-flecks", which decreases the productivity.

Disclosure of the Invention

[0009] It is an object of the invention to provide a versatile titanium alloy which requires the least manufacturing costs and is capable of making a wide product mix thereof, such as large forgings and die forgings, as well as rolled sheet products and foil having sufficient strength and plastic properties and structure.

[0010] According to the invention an optimum mix of α- and β-stabilizing alloying elements in a semi-finished product is provided.

[0011] According to the invention a titanium base alloy is provided consisting of Aluminum, Vanadium, Molybdenum, Iron, and Oxygen in the following ratio, wt.%:

Aluminum	3.5-4.4
Vanadium	2.0-4.0
Molybdenum	0.1-0.8
Iron	max 0.4
Oxygen	max 0.25
Ti	balance

[0012] High strength and ductility combined in the invented alloy is achieved through targeted selection and experimental evaluation of the alloying ranges. The content of α- stabilizers (Aluminum, Oxygen) and β-stabilizers (Vanadium, Molybdenum, and Iron) was determined so as to meet a goal objective.

[0013] Aluminum is a α-stabilizer for the α +β-titanium alloys, which contributes to the increase of mechanical strength.

However in case that Aluminum content is below 3.5%, sufficient strength aimed in this invention cannot be obtained, whereas in case that Aluminum content exceeds 4.4%, the hot deformation resistance is increased and ductility at lower temperatures is deteriorated, which leads to the lowering of productivity.

[0014] Vanadium is added to titanium as a β-stabilizer for the α +β-titanitun alloys, which contributes to the increase of mechanical strength without forming brittle intermetallic compounds with titanium. Presence of Vanadium in the alloy impedes formation of α_2-superstructure in α-phase as β-phase stabilizes, and contributes to the increase of both strength and ductility. In case that Vanadium content is below 2%, sufficient strength aimed in this invention cannot be obtained, whereas in case that Vanadium content exceeds 4.0%, the superplastic elongation is decreased by exceedingly lowering of the beta transus. Vanadium content within the range of 2.0-4.0% in this alloy has the merit in which the scrap of the most used Ti6A14V can be utilized.

[0015] Molybdenum is added to titanium as a β-stabilizer for the α +β-titanium alloys. In case that Molybdenum is added within the range of 0.1-0.8% this contributes to its full dissolution in α-phase, which enables to obtain the sufficient strength properties without deteriorating plastic properties. In case that Molybdenum content exceeds 0.8% this contributes to the increase of the specific weight of the alloy due to the fact that Molybdenum is a heavy metal and the plastic properties of the alloy are deteriorated. In case that Molybdenum content is below 0.1%, Molybdenum does not contribute to the alloy properties in full.

[0016] Iron added to the alloy up to 0.4% contributes to increase of the volume ratio of β-phase decreasing resistance to deformation in hot working of this alloy which leads to evading of the generation of such defects as cracking. In case that Iron content exceeds 0.4%, this generates a segregation phase with beta-flecks in melting and solidifying of the alloy, which leads to heterogeneity of mechanical properties, especially ductility.

[0017] Oxygen contributes to the enhancement of mechanical strength by constituting a solid solution mainly in α-phase. In case that Oxygen content exceeds 0.25%, the alloy ductility may be deteriorated.

[0018] The alloy may contain up to 0.1% of carbon and up to 0.05% of nitrogen as inevitable impurities; the total quantity of impurities shall not exceed 0.16%.

Embodiment of the invention

[0019] To evaluate the properties of the claimed alloy ingots were melted by the method of double vacuum arc remelt, having the following chemical composition (Table 1).

Table 1

Alloy	Chemical Composition, wt.%				
	Al	V	Mo	Fe	O
1	3.9	2.2	0.2	0.13	0.17
2	4.3	2.8	0.3	0.24	0.23
3	4.3	3.3	0.6	0.32	0.20

Table 2

Alloy		Heat Treatment	Mechanical Properties			
			σ_B, MPa	$\sigma_{0.2}$, MPa	δ, %	ψ, %
1		W/o annealing	810	735	15.2	38.2
		750°C 1 hour, air	780	693	13.2	32.0
2		W/o annealing	960	840	14.2	33.1
		750°C 1 hour, air	920	845	13.6	32.5
3	α+β	710°C 3 hours, air	900	835	15	33.0
	β	710°C 3 hours, air	870	800	14	28.0

[0020] Bars with the diameter of 50 mm were made of each ingot by hot working. Part of the bars was heat treated by annealing at 750°C, soaking for 1 hour and cooling in the air. The mechanical properties at room temperature were evaluated on the bars heat treated and on those not heat treated. The evaluation results are given in Table 2. In addition, the mechanical properties of β-upset workpieces were evaluated, which were heat treated at 710°C, soaked for 3 hours and cooled in air. The results of mechanical test of workpieces upset in α+β and β-field are given in Table 2.

Commercial practicability

[0021] In comparison with the known alloys the invented alloy is highly versatile, economically beneficial and has lower cost due to the fact that scrap of widely known alloys, such as Ti6Al4V, can be used for its production. This alloy possesses required and sufficient mechanical properties and can be utilized for making a wide range of products, such as large forgings and die forgings, thin sheets and foil, by working in both α+β-field and β-field.

Claims

1. A titanium base alloy consisting of Aluminum, Vanadium, Molybdenum, Iron, and Oxygen in the following ratio, wt.%:

Aluminum	3.5-4.4
Vanadium	2.0-4.0
Molybdenum	0.1-0.8
Iron	max 0.4
Oxygen	max 0.25
Titanium	balance

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2005/000381

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)

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	WO 2003/095690 A1 (TITANIUM METALS CORPORATION) 20.11.2003	1
A	RU 2039111 C1 (NAUCHNO-PROIZVODSTVENNOE OBIEDINENIE "KOMPOZIT") 09.07.1995	1
A	US 5332545 A (RMI TITANIUM COMPANY) 26.07.1994, the abstract	1
A	DE 2719324 A (KOBE STEEL et al) 10.11.1977, the claims	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 September 2005 (07.09.05)	29 September 2005 (29.09.05)
Name and mailing address of the ISA/ Facsimile No.	Authorized officer Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3007214 B **[0007]**

Non-patent literature cited in the description

- **B.A. KALACHYOV ; I.S. POLKIN ; V.D. TALALAYEV.** Titanium Alloys of Different Countries. *VILS,* 2000, 58-59 **[0003]**