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US-A-1 903 842
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Description

Background of the Invention

This invention relates to aluminium alloys possessing time-stable mechanical, physical and chemical characteristics suitable for their use in nuclear apparatus, in particular in the first wall of nuclear fusion reactors.

The first wall of a nuclear fusion reactor is known to require the use of materials able to withstand very critical operating conditions for a long period of time (up to 10 years), they being subjected to temperatures up to 350—400°C (with a minimum of 120°C), to neutron irradiation and to corrosion in very pure water. Because of its low activity following neutron irradiation, pure aluminium might appear to be a material suitable for this purpose. However, when in the pure state and especially when hot, this material has low mechanical properties and low corrosion resistance, insufficient for its use for the aforesaid application. This deficiency of pure aluminium could be overcome by using its known commercial alloys containing additives such as Si, Zn, Cu, Mg, Fe, Ni, Cr, Mn and Zr.

However, most of said additives are unsuitable for the aforesaid application in that activation problems arise when under neutron irradiation.

The use of hyper-pure alloys containing conventional additives of low activity would leave the problem of hot corrosion resistance in very pure water unsolved.

In connection with the subject matter of the present invention, the following known art is further disclosed.

From the patent US—A—4 043 840 (see table 1 in example 1) are known alloys with the following composition (in % by weight): Mg = 2% or 3%; Fe = 0,07%; Si = 0,05%; V = 0,20%; Al = balance.

Said aluminium alloys exhibit improved resistance weldability and are particularly used for automotive metal working applications.

From the patent US—A—3 236 632 is known an high strength aluminium alloy pellet extrusion formed from a pelletized aluminium alloy consisting essentially of (in % by weight): Mg = 1,2%; Si = 0,8%; V = 2%; Al = balance (see alloy 11 in table 1).

The aforesaid Al-alloys are used by the known art in fields which are very far from the use in nuclear apparatus, in particular in the first wall of nuclear fusion reactors.

Summary of the Invention

The object of the present invention is therefore to provide aluminium alloys having the necessary initial mechanical, physical and chemical characteristics for their use in nuclear apparatus, in particular in the first wall of nuclear fusion reactors, said alloys being also able to maintain said initial characteristics substantially stable with time during their use.

Said object is attained according to the present invention by aluminium alloys containing Mg in a quantity of between 0.2 and 4% by weight, V in a quantity of between 0.1 and 2.0% by weight, possibly Si in a quantity of between 0 and 1% by weight, and conventional impurities (such as Cu, Mn, Cr, Ti, Zn, Ni, B, Fe) in a total quantity of less than 1000 p.p.m. by weight, the balance to 100% being represented by Al.

Said alloys can be prepared by the known typical casting methods for Al alloys (fusion-produced alloys).

In order to obtain the relative required semi-finished products, suitable known cycles are used comprising homogenisation, extrusion and/or rolling, and/or other plastic deformation processes which may be necessary, as known to experts of the art.

Said alloys according to the invention can also be prepared (in particular alloys containing Si) by the known powder technology method.

In this case, a dispersed phase of Al_2O_3 and/or $Al_2O_3.MgO$ type can also be present.

Preferred Embodiments of the Invention

Preferred compositions for the alloys prepared by fusion according to the invention comprise 2.5—3% of Mg, 0.1—0.5% of V, possibly 0.05—0.2% of Si, and less than 150 p.p.m. of conventional impurities, the balance to 100% being Al (quantities expressed by weight). Preferred compositions for alloys prepared by powder metallurgy according to the invention comprise 0.2—1% of Mg, 0.2—1% of Si, 0.5—2% of V, and less than 150 p.p.m. of conventional impurities, the balance to 100% being Al (quantities expressed by weight). Alloys prepared by fusion are particularly suitable for maximum operating temperatures of 150—200°C for the said wall, whereas powder-produced alloys are preferred for temperatures above 200°C and up to 350—400°C.

The examples given hereinafter by way of non-limiting illustration describe the alloys according to the present invention in greater detail.

Example 1

A billet is cast by the semi-continuous method from an Al-Mg-V alloy which on chemical analysis shows the following composition (quantities expressed as % by weight):

Mg 2.69%; V 0.11%; Fe 100 p.p.m.; Si 11 p.p.m.; Cu 10 p.p.m.; Mn 5 p.p.m.; Zn 2 p.p.m.; Ni 3 p.p.m.; Ti less than 1 p.p.m.; Al balance to 100%.

Said billet is homogenised for 15 hours at 400°C and 24 hours at 460°C, and is then extruded at 420°C to a diameter of 14 mm. From the extrusion obtained in this manner, samples of the required size are prepared by known methods for determining tensile, physical and creep behaviour characteristics (by ASTM procedures), these characteristics being shown hereinafter (the known symbols R, Rp 0,2, A and σ being used to indicate respectively the ultimate tensile stress, 0.2% yield strength, ultimate tensile stress, 0.2% yield strength, ultimate elongation and breaking stress):

— Tensile characteristics

Test temperature	R N/mm^2	Rp 0.2 N/mm^2	A %
20°C	171	70	32.6
100°C	173	74	31.8
125°C	162	78	38.6
150°C	152	76	39.5

— Physical characteristics
— Electrical resistivity at −196°C: 1.890 μΩcm
— Coefficient of linear expansion between 20 and 200°C: 26.2 MK^{-1}

— Creep behaviour:
1) — Test temperature: 120°C
— Test duration: 1000 hours
— σ 85 N/mm^2

2) — Test temperature: 200°C
— Test duration: 1000 hours
— σ 62 N/mm^2

Example 2

The procedure of Example 1. is followed, the only difference being that the alloy composition is as follows (quantities expressed in % by weight) Mg 2.68%; V 0.21%; Fe 12 p.p.m.; Si 11 p.p.m.; Cu 10 p.p.m.; Mn 5 p.p.m.; Ni 3 p.p.m.; Zn 2 p.p.m.; Ti less than 1 p.p.m.; Al balance to 100%.

The characteristics of said alloy are as follows:

— Tensile characteristics:

Test temperature	R N/mm^2	Rp 0.2 N/mm^2	A %
20°C	172	74	30.1
100°C	170	80	28.9
125°C	161	80	34.0
150°C	146	76	40.5

— Physical characteristics:
— Electrical resisitivity at −196°C: 2.110 μΩcm
— Coefficient of linear expansion between 20 and 200°C: 25.2 MK^{-1}
— Creep behaviour:
— Test temperature: 120°C
— Test duration: 1000 hours
— σ 75 N/mm^2

Example 3

Powdered Al (purity 99.99%), Mg, Si and V were used (in weight proportions of Mg 0.97%, V 1.1%, Si 0.71, Al balance to 100%) to prepare by the known powder metallurgy method a Al—Mg—Si—V alloy in the form of a billet of size 80 mm diameter × 200 mm, using the following main basic parameters: sintering temperature 580°C; sintering time 24 hours; hot compacting at 580°C with a pressure of 550 N/mm^2; billet extrusion at 450°C to a diameter of 10 mm; solution heat-treatment for 2 hours at 520°C; rapid quenching followed by ageing at 150°C for 15 hours.

On chemical analysis, said extruded billet shows the following composition (% by weight): Mg 0.66%; V 1.07%; Si 0.65/; Fe 80 p.p.m.; Cu 12 p.p.m.; Mn 7 p.p.m.; Zn 3 p.p.m.; Ni 2 p.p.m.; Ti less than 1 p.p.m.; Al balance to 100%.

The characteristics of said alloy are as follows:

— Tensile characteristics:

Test temperature	R N/mm²	Rp 0.2 N/mm²	A %
20°C	377	351	11
200°C	194	187	14
300°C	77	74	24

— Physical characteristics:

— Density: 2.71 Mg M^{-3}

— Electrical resistivity at −196°C: 1.530 µΩcm

The mechanical and physical characteristics of the three alloys described heretofore by way of example satisfy — as is apparent to an expert of the art — the requirements for their use in the primary wall of nuclear fusion reactors.

Moreover, said alloys have good resistance to corrosion in a moist environment, both at room temperature and under hot conditions (100—150°C), and in addition have excellent weldability by all the typical methods for aluminium, and good workability for producing semi-finished products, even of complex form.

From the aforegoing description and examples, the alloys according to the invention are suitable for use in nuclear apparatus components, in particular in the first wall of nuclear fusion reactors, in accordance with the objects of the invention itself.

Claims

1. Use of aluminium alloys having the following composition (% by weight):

— Mg from 0,2 to 4,0%

— V from 0,1 to 2,0%

— possibly Si from 0 to 1%

— other possible elements: total quantity less than 1000 ppm

— Al balance to 100%

in components of apparatus which are subjected to neutron irradiation during their operation, in particular in the first wall of nuclear fusion reactors.

2. Aluminium alloys characterized by the following composition (% by weight):

— Mg from 0,2 to 1%

— V from 0,5 to 2%

— Si from 0,2 to 1%

— other possible elements: total quantity less than 150 ppm

— Al balance to 100%

3. Use of aluminium alloys as claimed in claim 2, in components of apparatus which are subjected to neutron irradiation during their operation, in particular in the first wall of nuclear fusion reactors.

Patentansprüche

1. Verwendung von Aluminiumlegierungen mit der folgenden Zusammensetzung (Gew.—%):

Mg von 0,2 bis 4,0%,

V von 0,1 bis 2,0%,

gegebenenfalls Si von 0 bis 1%.

gegebenenfalls andere Elemente in einer Gesamtmenge von weniger als 1000 ppm, und

Rest Al bis zu 100%

in Komponenten von Vorrichtungen, welche während ihres Einsatzes einer Neutronenstrahlung unterworfen sind, insbesondere in der ersten Wand von Kernfusionsreaktoren.

2. Aluminiumlegierung, gekennzeichnet durch die folgende Zusammensetzung (Gew.—%):

Mg von 0,2 bis 1%,

V von 0,5 bis 2%,

Si von 0,2 bis 1%,

gegebenenfalls andere Elemente in einer Gesamtmenge
von weniger als 150 ppm, und
Rest Al bis zu 100%.

3. Verwendung der Aluminiumlegierungen nach Anspruch 2 in Komponente von Vorrichtungen, die während ihres Einsatzes einer Neutronenstrahlung unterworfen sind, insbesondere in der ersten Wand von Kernfusionsreaktoren.

Revendications

1. Utilisation d'alliages d'aluminium présentant la composition suivante (% en poids):
Mg de 0,2 à 4.0%
V de 0,1 à 2,0%
éventuellement Si de 0 à 1%
d'autres éléments présents: quantité totale inférieure à 1000 ppm, dans des éléments constitutifs d'appareils qui sont exposés à une irradiation neutronique pendant leur fonctionnement, et notamment dans la première paroi d'un réacteur à fusion nucléaire.

2. Alliages d'aluminium, caractérisés par la composition suivante (% en poids):
Mg de 0,2 à 1%
V de 0,5 à 2%
Si de 0,2 à 1%
d'autres éléments éventuellement présents: quantité totale inférieure à 150 ppm
Al quantité suffisante pour totaliser 100%

3. Utilisation d'alliages d'aluminium tels que ceux revendiqués dans la revendication 2, dans des éléments constitutifs d'appareils qui sont exposés à une irradiation neutronique pendant leur fonctionnement, et notamment dans la première paroi d'un réacteur à fusion nucléaire.