(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 022 582 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
11.02.2009 Bulletin 2009/07

(21) Application number: **07739304.9**

(22) Date of filing: **22.03.2007**

(51) Int Cl.:
B22F 9/08 *(2006.01)* ***C22C 14/00*** *(2006.01)*
C22C 21/00 *(2006.01)*

(86) International application number:
PCT/JP2007/055861

(87) International publication number:
WO 2007/135806 (29.11.2007 Gazette 2007/48)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(30) Priority: **18.05.2006 JP 2006138730**

(71) Applicant: **OSAKA Titanium Technologies Co., Ltd.**
Amagasaki-shi, Hyogo 660-8533 (JP)

(72) Inventors:
- **NISHIOKA, Kazuo**
  Amagasaki-shi
  Hyogo 660-8533 (JP)
- **FUJITA, Makoto**
  Amagasaki-shi
  Hyogo 660-8533 (JP)
- **ARIMOTO, Nobuhiro**
  Amagasaki-shi
  Hyogo 660-8533 (JP)

(74) Representative: **Hartz, Nikolai**
Wächtershauser & Hartz
Weinstrasse 8
80333 München (DE)

(54) PROCESS FOR PRODUCING SPHERICAL TITANIUM ALLOY POWDER

(57) In production of a titanium alloy spherical powder by a gas atomizing method, the difference in alloy composition depending on the product particle size is reduced economically. To achieve this, sponge titanium particles and additive metal element particles are mixed by means of a mixer having a pulverizing function such as a ball mill. The mixed particles are compressed to form a rod-formed raw material for melting. The formed rod-formed raw material for melting is powderized by a gas atomizing method. In the mixing step, the additive metal element particles are pulverized, or ground depending on the kind of particles, and solidly adhered to the surface of the sponge titanium particles, so that uniform mixing is possible.

EP 2 022 582 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a process for producing a spherical powder comprising a titanium alloy such as a Ti-Al alloy (Ti : Al = 64 : 36) or a Ti-6Al-4V alloy (Ti : Al : V = 90 : 6 : 4), and more specifically to a process for producing a titanium alloy spherical powder capable of reducing the difference in alloy composition depending on the product particle size.

BACKGROUND ART

[0002] As one process for producing a titanium alloy spherical powder for use, for example, as powder metallurgical raw materials, a process according to a gas atomizing method is known. In this process, a spherical powder of a titanium alloy is produced by mixing a titanium powder and an additive alloy element powder, compressing the mixed powder to form a raw material for melting (compact), and making a melt obtained by melting the compact be scattered and solidified in fine liquid droplets by a high pressure gas. The step of making the melt obtained by melting the compact be scattered and solidified by a high pressure gas is gas atomizing, which enables stable production of particles having a high degree of sphericity.

[0003] This process for producing a spherical powder is described, for example, in Patent documents 1 to 3, and in the processes described therein, induction heating is utilized to melt the compact, and a melt is continuously formed and flown down by gradually melting a rod-formed compact from downside in a non-contact manner, and the melt flow is directly gas-atomized. This eliminates the necessity of a crucible, and greatly reduces contamination by contact with foreign substances. With this process, a spherical powder of a Ti-6Al-4V alloy (Ti : Al : V = 90 : 6 : 4) is produced in Patent document 1, and a spherical powder of a Ti-Al alloy (Ti : Al = 64 : 36) is produced in Patent documents 2 and 3.

[0004] Patent document 1: Japanese Patent Application Laid-open Publication No. 5-93213
Patent document 2: Japanese Patent Application Laid-open Publication No. 6-116609
Patent document 3: Japanese Patent Application Laid-open Publication No. 2002-241807

[0005] It is known that such a process for producing a titanium alloy spherical powder based on the gas atomizing method has a problem that a difference arises in the alloy composition depending on the product particle size. To be more specific, in the production process of a Ti-6Al-4V alloy powder described in Patent document 1, when classification is conducted after gas atomizing, the additive metal element concentration in a powder of small particle sizes (Al in the Ti-6Al-4V alloy) is higher than the proportion (blending proportion) in the mixed raw material which is a raw material powder. Contrarily, in a powder of large particle sizes, the concentration is lower.

[0006] The nonuniformity of the alloy composition depending on the product particle size of a gas atomizing alloy spherical powder is acknowledged as a problem for the case of a Ti-Al alloy in Patent document 3. In the same document, from the view point that it is essential to uniformize the composition of the melt to eliminate the nonuniformity, use of fine spherical particles having a particle size of not more than 250 μm produced by a gas atomizing method as a raw material powder is proposed as a means for solving the problem. Explanation is given that excellent fluidity and high apparent packing density of such spherical microparticles enable production of a compact in which a raw material powder is uniformly mixed and is effective in uniformizing the composition of the melt.

[0007] As concrete examples, when sponge titanium particles having particle sizes of 0.75 to 12.7 mm and particulate aluminum having particle sizes of 4 to 10 mm are used as raw material powders, a difference in the Al concentration between different product particle sizes is 2% at maximum, whereas when sponge titanium particles having particle sizes of 0. 75 to 12. 7 mm and an aluminum powder having particle sizes of not more than 250 μm are used, the difference in the Al concentration between different product particle sizes is 2.6% at maximum (Comparative Examples 3, 4). In contrast to this, when a gas atomizing Ti powder having particle sizes of not more than 250 μm and an Al powder having particle sizes of not more than 250 μm are used, the difference in the Al concentration is 0.4% at maximum (Example 1). When a gas atomizing Ti powder having particle sizes of not more than 150 μm and an Al powder having particle sizes of not more than 150 μm are used, the difference in the Al concentration is 0.3% at maximum (Example 2).

[0008] However, a gas atomizing Ti powder is very expensive compared to a sponge titanium powder, and the measure of using this as a raw material is not economical, and results in a rise in the price of the product powder.

[0009] In addition to this, when the product is a Ti-6Al-4V alloy powder, the proportion of the additive metal element is as small as 10%. For this reason, such a degree of difference in concentration between different particle sizes that is allowable in the case of a Ti-Al alloy powder (additive metal element proportion 36%) may not be allowed in a Ti-6Al-4V alloy powder, so that it is an especially important technical issue in production of a Ti-6Al-4V alloy powder to uniformize the composition between different product particle sizes.

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0010] It is an object of the present invention to provide a process for producing a titanium alloy spherical powder capable of significantly and economically reducing the difference in alloy composition depending on the product particle size, and effectively reducing the difference in alloy composition depending on the product particle size even when the product is a Ti-6Al-4V alloy powder.

MEANS FOR SOLVING THE PROBLEM

[0011] In order to achieve the above object, inventors of the present application took notice of the kind of the raw material titanium particle and the method in mixing with additive metal element particles. Specifically, to reduce the raw material cost, it is necessary to avoid the use of a gas atomizing titanium powder, and it is essential to use a sponge titanium powder. In light of this, inventors of the present application attempted to produce a sponge titanium powder of as fine size as possible. This is based on the assumption that mixability with an alloy element powder is improved when the particles are fine even in the case of a sponge titanium powder, and the difference in alloy composition depending on the product particle size is eliminated. However, it is difficult to produce a fine sponge titanium powder of the gas atomizing level (not more than 250 μm). For example, in the grain refining step of sponge titanium for expanded materials, typically, a sponge titanium block that is split into large pieces or small pieces is crushed by a jaw crusher, and fine particulate products having particle sizes of 0.75 to 12.7 mm are produced by classification (sieving separation).

[0012] In such a widely used method, it is clearly impossible to produce a fine sponge titanium powder of the gas atomizing level (not more than 250 μm), and even sub-sieve articles which are low quality articles resulting from the classification step have particle sizes of not less than 0.3 mm. In other words, in the case of a sponge titanium powder, it is very difficult to produce a fine sponge titanium powder of the gas atomizing level (not more than 250 μm), however it is easy to produce a powder of not less than 0.3 mm.

[0013] As for a mixing method of raw material particles, in production of a titanium alloy by a gas atomizing method, simple mixing by means of a V-type mixer is used for mixing raw material titanium particles and additive metal element particles. Inventors of the present application obtained three kinds of sponge titanium particles having average particle sizes of 0.3 mm, 1 mm and 3 mm by sieving classification from sub-sieve articles and product powder particles in the grain refining and classifying step of sponge titanium. These and Al particles and V particles were simply mixed by means of a V-type mixer, and compressed to form a compact for melting, followed by gas atomizing. However, nonuniformity of the Al concentration depending on the product particle size was not eliminated.

[0014] Also, a gas atomizing Ti alloy powder was produced by simply mixing Al and V master alloy particles with the aforementioned Ti particles by means of a V-type mixer in a similar manner rather than using the Al particles and the V particles separately. Although the nonuniformity of the Al concentration depending on the product particle size was slightly eliminated, it was still not a satisfactory level. Since nonuniformity of the Al concentration is roughly in proportional to nonuniformity of the V concentration, nonuniformity of the concentration of the additive metal element can be represented by nonuniformity of the Al concentration.

[0015] Based on these results, inventors of the present application made reconsideration about a method of eliminating nonuniformity of the concentration of the additive metal element, and finally reached a mixing method of sponge titanium particles and additive metal element particles. In addition, the simple mixing by a V-type mixer conventionally employed was changed to pulverization-mixing by a ball mill. As a result, deviation in the Al concentration depending on the product particle size from the blending proportion was dramatically reduced although three kinds of sponge titanium particles having average particle sizes of 0.3 mm, 1 mm and 3 mm as described above were used as the Ti particles.

[0016] In other words, as for mixing of raw material particles, improvement in uniformity was considered as a principal issue, and trial and error were made about mixing time and the like. However, there was no idea of changing the type of the mixer. Under such a circumstance, inventors of the present application focused on a mixer having a crushing function such as a ball mill, and further discussed from various angles, to finally find that when a mixer having a pulverizing function is used, refining and grinding by pulverization of particles, in particular, of additive metal element particles during mixing, and further daubing of titanium particles by grinding proceed, to lead to the condition as if the microparticles were mixed uniformly. It is also found that as a result of the above, preceding melting of additive metal element particles is effectively suppressed, and eventually an excellent uniform mixing effect comparable to the case where fine spherical particles are used is obtained, even when raw material particles having relatively large diameters of not less than 0.3 mm are used, and nonuniformity in the alloy composition depending on the product particle size is dramatically eliminated.

[0017] A process for producing a titanium alloy spherical powder according to the present invention was accomplished based on the above findings, and includes the steps of: mixing sponge titanium particles and additive metal element particles by means of a mixer having a pulverizing function; compressing mixed particles obtained by mixing by the mixer to form a rod-formed raw material for melting; induction-heating the formed rod-formed raw material for melting in an inert atmosphere to melt it in a non-contact manner; and powderizing an alloy melt obtained by non-contact melting by a gas atomizing method.

[0018] In the process for producing a titanium alloy spherical powder according to the present invention, by using a mixer having a pulverizing function in mixing titanium particles and additive metal element particles, fixation to titanium particles occurs by pulverization (or grinding) of additive metal element particles in the course of mixing although the titanium particles which are amorphous sponge titanium particles and have such large diameters as not less than 0.3 mm are used, and the phenomenon that the additive metal element particles having a lower melting point melt precedingly is prevented. Therefore, an excellent uniform mixing action which is comparable to that of the case of using fine gas atomizing Ti particles is obtained, with the result that the nonuniformity of the alloy composition depending on the product particle size is eliminated markedly and economically.

[0019] More specifically, when the additive metal element particles are soft Al particles, rubbing on the sponge titanium particles occurs solely by grinding, while in the case of fragile Al-V particles, fitting into recess parts on rough surfaces of sponge titanium particles occurs solely by being pulverized finely into micro particles. In both cases, a condition comparable to the condition that titanium particles and additive metal element particles are well mixed with each other is achieved, and a nonuniformity eliminating effect comparable to that obtained by fine spherical particles is realized even though the titanium particles are not fine spherical particles. This is the first feature of the present invention.

[0020] Furthermore, in mixing of titanium particles and additive metal element particles by a mixer having a pulverizing function, alloying by mechanical alloying which is a solid phase reaction may partly proceed to contribute elimination of the nonuniformity of the composition.

[0021] The daubing effect by grinding of additive metal element particles, and filling and fixing on the surface of titanium particles by fine pulverization are little expected when the raw material titanium particles are spherical gas atomizing particles having a smooth surface, but are much expected by inexpensive amorphous sponge titanium particles having recesses and projections on the surface. That is, there are a large number of recesses and projections on the surface of sponge titanium particles, and in the mixer having a pulverizing function, the additive metal element particles are more effectively fixed. As described above, in the present invention, it is important to combine the mixer having a pulverizing function with inexpensive sponge titanium particles. This is the second feature of the invention.

[0022] The mixer having a pulverizing function is concretely a ball mill, an attritor or a vibration mill, and a particularly preferred mixer is a ball mill that provides a remarkable grinding effect by a pulverizing action and rubbing.

[0023] Particle sizes of the sponge titanium particles used as raw material titanium particles are desirably 0.3 to 5 mm, more desirably 0.4 to 3 mm, and particularly desirably 0.6 to 3 mm on average. This is because sponge titanium particles having particle sizes of smaller than 0.3 mm are difficult to be produced, and as the particle sizes of the sponge titanium particles decrease, the concentration of impurities such as impure metal elements and oxygen in the product powder tends to increase. This is because contamination increases during production of sponge titanium particles as the surface area of the sponge titanium particles increase.

[0024] As the sponge titanium particles of not less than 0.3 mm, sub-sieve materials derived in the refining and classifying step of sponge titanium for expanded materials may be used, and using such materials are rather preferred from the economical aspect. In other words, applicability of sub-sieve materials which are particularly inexpensive among sponge titanium particles is also one feature of the present invention.

[0025] As a production raw material of the gas atomizing alloy spherical powder, refined Ti particles are preferred, however, Ti particles are difficult to be refined because of their high ductility as described above. For this reason, Ti particles refined by a gas atomizing method or an HDH method are used, which leads to running up of production cost and increase in the product price. Since sub-sieve articles which are low-quality articles can be effectively utilized in the present invention, it is possible to reduce the refining cost. This is the third feature of the present invention.

[0026] As for an upper limit of the particle size of the sponge titanium particles, although the feature of the present invention lies in that composition of the product powder can be uniformized even when particle sizes of the sponge titanium particles are large, too large a particle size will make it difficult to obtain the effect of uniformizing the composition. From this point of view, the particle size is preferably not more than 5 mm, and particularly preferably not more than 3 mm.

[0027] The kind of additive metal element particles is appropriately selected depending on the product composition, and for example, when the product is a Ti-Al alloy powder, it is Al particles, while when the product is a Ti-6Al-4V alloy powder, it is Al particles and V particles, or Al-V master alloy particles obtained by smelting Al and V. Using Al-V master alloy particles is more effective in uniformization of the composition than using a mixture of Al particles and V particles. Since Al particles and V particles have largely different melting points, preceding melting of Al particles proceeds also by a daubing action onto the sponge titanium particles. This is disadvantageous in uniformization of the composition.

[0028] The average particle size of the additive metal element particles is desirably 0.2 to 50 mm, and particularly desirably 0.5 to 30 mm. When this particle size is too small, the daubing action onto the sponge titanium particles which is the characteristic action of the present invention, in association with the pulverization or grinding of the additive metal element particles is insufficient, so that the effect of the present invention is insufficient. Contrarily, when the particle size is too large, pulverization efficiency in the early stage of mixing and pulverization is impaired.

[0029] The problem of the difference in alloy composition depending on the product particle size is more significant in production of an alloy having a small proportion of additive metal element as described above. The present invention capable of effectively solving this problem is effective in production of an alloy having a small proportion of additive metal element, concretely in production of an alloy having a proportion of additive metal element of not more than 20%, and is particularly effective in production of a Ti-6Al-4V alloy having this proportion of as small as 10%.

EFFECT OF THE INVENTION

[0030] The process for producing a titanium alloy spherical powder of the present invention is able to provide a product alloy powder with such high uniformity of an alloy composition as is comparable to that obtained by using expensive fine spherical titanium particles by a gas atomizing method, without using such expensive fine spherical titanium particles by using a mixer having a pulverizing function for mixing the particles in mixing sponge titanium particles and additive metal element particles and producing a titanium alloy spherical powder from a rod-formed raw material for melting by a gas atomizing method. Therefore, it is possible to produce an alloy spherical powder of high quality much more economically than in the past. In addition, particularly inexpensive sub-sieve articles can be used as the sponge titanium particles, and economic efficiency can be improved also from this point.

BEST MODE FOR CARRYING OUT THE INVENTION

[0031] In the following, exemplary embodiments of the present invention will be explained. First, production of a Ti-Al alloy spherical powder will be explained.

[0032] As a raw material powder, sponge titanium particles that are relatively rough particles having an average particle size of not less than 0.3 mm are prepared. As these sponge titanium particles, sub-sieve materials and products (super-sieve articles) resulting from the refining and classifying step by a jaw crusher of sponge titanium for expanded materials are used after classification. As the additive metal element particles, relatively large Al particles having an average particle size of not less than 0.2 mm, and desirably not less than 0.5 mm are prepared.

[0033] After preparing the raw material powders, the sponge titanium particles and the Al particles are mixed in a weight ratio of 64 : 36 by means of a ball mill as a first step. The ball mill has not only the mixing function but also the pulverizing function, and finely pulverizes the Al particles, in particular, in the course of mixing, while grinding relatively soft Al particles by mutual pushing of particles, to rub them on the surface of the sponge titanium particles. As a result, the Al particles are solidly fixed onto the surface having recesses and projections of the sponge titanium particles, so that a condition as if the micro particles were uniformly mixed is established.

[0034] After mixing of the sponge titanium particles and the Al particles ends, the mixed particles are compressed into a rod-formed raw material for melting as a second step. As a compression molding method, well-known methods such as die press and cold isostatic press may be used.

[0035] After the rod-formed raw material for melting is formed, a Ti-Al alloy spherical powder is produced by a gas atomizing method as a third step. Concretely, a rod-formed raw material for melting is set vertically in an inert gas chamber, and is supplied from top to bottom inside a circular induction heating coil that is also placed vertically. As a result, the melt raw material sequentially melts from bottom in a non-contact manner, and a Ti-Al alloy melt is successively formed and flows downward. Then an inert gas is blown to the melt flow from circumference to make the melt be finely scattered and solidified, whereby a Ti-Al alloy spherical powder is produced.

[0036] When simple mixing by means of a V-type mixer is employed in the first step, the Al particles having a lower melting point melts earlier in the third step, which may result in variation in alloy composition. However, in the present exemplary embodiment, since Al particles are almost coated and solidly fixed on the surface of the sponge titanium particles in the first step as described above, preceding melting of Al is prevented, and the difference in alloy composition is eliminated. As the induction heating coil, a spiral coil having a diameter gradually reducing from top to bottom as shown in Patent document 3 is preferred.

[0037] Next, production of a Ti-6Al-4V alloy spherical powder will be explained.

[0038] As the raw material powder, sponge titanium particles that are relatively rough particles having an average particle size of not less than 0.3 mm are prepared. As these sponge titanium particles, sub-sieve materials and products (super-sieve articles) resulting from the refining and classifying step by a jaw crusher of sponge titanium for expanded materials are used after classification. As the additive metal element particles, relatively large Al-V alloy particles (master alloy particles in which Al : V = 6 : 4) having an average particle size of not less than 0.2 mm, and desirably not less than 0.5 mm are prepared.

[0039] After preparing the raw material powders, the sponge titanium particles and the Al-V alloy particles are mixed in a weight ratio of 9 : 1 by means of a ball mill as a first step. The ball mill has not only the mixing function but also the pulverizing function. Since the Al-V master alloy particles are more fragile than Ti, they are particularly finely pulverized in the course of mixing, and solidly embedded in recess parts on the rough surface of the sponge titanium particles. This leads to the condition as if the micro spherical particles were uniformly mixed.

[0040] After mixing of the sponge titanium particles and the Al-V alloy particles ends, the mixed particles are compressed into a rod-formed raw material for melting as a second step. As a compression molding method, well-known methods such as die press and cold isostatic press may be used.

[0041] After the rod-formed raw material for melting is formed, a Ti-6Al-4V alloy spherical powder is produced by a gas atomizing method as a third step. Concretely, a rod-formed raw material for melting is set vertically in an inert gas chamber, and is supplied from top to bottom inside a circular induction heating coil that is also placed vertically. As a result, the melt raw material sequentially melts from bottom in a non-contact manner, and a Ti-6Al-4V alloy melt is successively formed and flows downward. Then an inert gas is blown to the melt flow from circumference to make the melt be finely scattered and solidified, whereby a Ti-6Al-4V alloy spherical powder is produced.

[0042] Also in this exemplary embodiment, since the Al-V alloy particles which are additive metal element particles are finely pulverized into micro particles in the first step as described above, and solidly fixed onto the surface of the sponge titanium particles by mechanical fitting, preceding melting of the additive metal element is prevented, and the difference in alloy composition is eliminated. As the induction heating coil, a spiral coil having a diameter gradually reducing from top to bottom as shown in Patent document 3 is preferred.

EXAMPLES

[0043] In producing a Ti-6Al-4V alloy spherical powder according to the aforementioned method, average particle sizes of sponge titanium particles and Al-V alloy particles were varied in various ways. As the sponge titanium particles, sub-sieve materials and products (super-sieve articles) resulting from the refining and classifying step by a jaw crusher of sponge titanium for expanded materials were used after classification. As the mixer, a ball mill was used. The Al concentration, Fe concentration and O concentration of the produced Ti-6Al-4V alloy spherical powder were examined. The product particle size is not more than 45 μm. For comparison and reference, a similar examination was made for the case where a V-type mixer was used as a mixer. The results are shown in Table 1.

[0044] When the average particle size of the sponge titanium particles is 0.3 mm, deviation in the Al concentration from the blending proportion (6.0%) is as small as 0.05% (the deviation rate is 0.05/6 = about 1/100) (Example 4). This owes to the use of the ball mill as a mixer, because when the V-type mixer is used as a mixer, deviation in the Al concentration from the blending proportion (6.0%) is as large as 0.5% (the deviation rate is 0.5/6 = about 1/10) although other conditions are the same (Comparative Example 2). However, since the surface of the titanium particles is rough, and the particle size thereof is small and the surface area is large, the concentration of impurities is somewhat high.

[0045] Even when an average particle size of the sponge titanium particles is as large as 3 mm, deviation in the Al concentration from the blending proportion (6.0%) is as small as 0.2% (the deviation rate is 0.2/6 = 1/30) (Example 3). The concentration of impurities is suppressed to a low level because the sponge titanium particles have large particle sizes and a small surface area.

[0046] As for the case where the average particle size of the sponge titanium particles is 1 mm, the results are shown for the case where the average particle size of Al-V alloy particles is 10 mm which is the same size as above, and the case where it is 0.5 mm which is smaller than that. When the average particle size of Al-V alloy particles is 10 mm which is same size as above, deviation in the Al concentration from the blending proportion (6.0%) is as small as 0.05% (the deviation rate is 0.05/6 = about 1/100) (Example 2) which is the same with the case where the average particle size of the sponge titanium particles is 0.3 mm. The concentration of impurities is controlled to such a low level that is comparable to that of the case where the average particle size of the sponge titanium particles is 3 mm because the particle size is larger and the surface area is smaller compared to the case where the average particle size of the sponge titanium particles is 0.3 mm.

[0047] When the average particle size of the Al-V alloy particles is 0.5 mm, deviation in the Al concentration from the blending proportion (6.0%) is slightly increased to 0.1% (the deviation rate is 0.1/6 = 1/60) (Example 1). This is because pulverizing of Al-V alloy particles was not sufficiently proceeded by mixing with the ball mill. The concentration of impurities is as same as that in Example 2 because it is dominated by the average particle size of the sponge titanium particles.

[0048]

[Table 1]

	Mixing method	Average particle size before mixing (mm)		Atomizing powder (-45 μm)				Overall Evaluation	Remarks
		Sponge Ti	Al-V master alloy	Al concentration (%)	Deviation from Al blending value 6.0% (%)	Fe concentration (%)	O concentration (%)		
Example 1	Ball mill	1	0.5	6.10	0.10	0.12	0.15	⊙	Deviation from target blending value of alloy concentration is small, and concentration of impurities is low.
Example 2		1	10	6.05	0.05	0.12	0.15	⊙	
Example 3		3	10	6.20	0.20	0.10	0.12	⊙	
Example 4		0.3	10	6.05	0.05	0.28	0.36	○	Concentration of impurities is high because sponge particle size is small.
Comparative Example 1	V-type mixer	3	0.25	6.60	0.60	0.10	0.12	×	Deviation from target blending value of alloy concentration is large because mixing is not associated with pulverization.
Comparative Example 2		0.3	0.25	6.50	0.50	0.28	0.35	×	

[0049] In the above examples, particle sizes of the Ti-6Al-4V alloy spherical powder which is a product are as small as not more than 45 μm. In this case, the concentration of the additive metal element (herein, represented by the Al concentration) is higher than the mixing proportion in the raw material mixed powder, and the present invention contributes to eliminate the deviation in concentration. However, in the case where the product particle size is large, the concentration of the additive metal element (here, the Al concentration) is lower than the mixing proportion in the raw material mixed powder in contrast to the case of fine particles. It goes without saying that the present invention is effective for eliminating the deviation in concentration in this case.

[0050] That is, the present invention is able to reduce the difference in alloy composition depending on the product particle size significantly and economically.

Claims

1. A process for producing a titanium alloy spherical powder comprising the steps of:

mixing sponge titanium particles and additive metal element particles by means of a mixer having a pulverizing function;
compressing mixed particles obtained by mixing by the mixer to form a rod-formed raw material for melting;
induction-heating the formed rod-formed raw material for melting in an inert atmosphere to melt it in a non-contact manner; and
powderizing an alloy melt obtained by non-contact melting by a gas atomizing method.

2. The process for producing a titanium alloy spherical powder according to claim 1, wherein said additive metal element powder is a master alloy obtained by smelting a plurality of metal elements.

3. The process for producing a titanium alloy spherical powder according to claim 2, wherein said master alloy is AlV (Al : V = 6 : 4), and a Ti-6Al-4V spherical powder is produced using the same.

4. The process for producing a titanium alloy spherical powder according to claim 1, wherein said sponge titanium particles have an average particle size of 0.3 to 5 mm.

5. The process for producing a titanium alloy spherical powder according to claim 1, wherein said sponge titanium particles are sub-sieve materials derived in a refining and classifying step of sponge titanium for expanded materials.

6. The process for producing a titanium alloy spherical powder according to claim 1, wherein said mixer is a ball mill, an attritor or a vibration mill.

7. The process for producing a titanium alloy spherical powder according to claim 1, wherein said additive metal element powder has an average particle size of 0.2 to 50 mm.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/055861

A. CLASSIFICATION OF SUBJECT MATTER
B22F9/08(2006.01)i, *C22C14/00*(2006.01)i, *C22C21/00*(2006.01)i

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)
B22F1/00-9/30, C22C14/00, C22C21/00-21/18, C22B34/10-34/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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	JP 2002-339006 A (Sumitomo Titanium Corp.), 27 November, 2002 (27.11.02), (Family: none)	1-7
A	JP 05-093213 A (Sumitomo Sitix Corp.), 16 April, 1993 (16.04.93), (Family: none)	1-7
A	JP 05-098368 A (NKK Corp.), 20 April, 1993 (20.04.93), (Family: none)	2,4,5
A	JP 05-239571 A (Sumitomo Light Metal Industries, Ltd.), 17 September, 1993 (17.09.93), (Family: none)	2,4,7

☒ 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
"E" earlier application or patent but published on or after the international filing date
"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)
"O" document referring to an oral disclosure, use, exhibition or other means
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 08 June, 2007 (08.06.07)	Date of mailing of the international search report 19 June, 2007 (19.06.07)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/055861

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 02-263947 A (Tokuden Co., Ltd.), 26 October, 1990 (26.10.90), (Family: none)	6

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 5093213 A **[0004]**
- JP 6116609 A **[0004]**
- JP 2002241807 A **[0004]**