



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:

14.12.2005 Bulletin 2005/50

(51) Int Cl.7: **B22F 1/00, B22F 1/02**

(21) Application number: **05252858.5**

(22) Date of filing: **10.05.2005**

(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 MC NL PL PT RO SE SI SK TR**

Designated Extension States:

AL BA HR LV MK YU

(72) Inventor: **Voice, Wayne Eric**

West Bridgford Nottingham NG2 5JB (GB)

(74) Representative: **Gunn, Michael Alan**

Rolls-Royce plc

P.O. Box 31

Derby DE24 8BJ (GB)

(30) Priority: **12.06.2004 GB 0413135**

(71) Applicant: **ROLLS-ROYCE PLC**

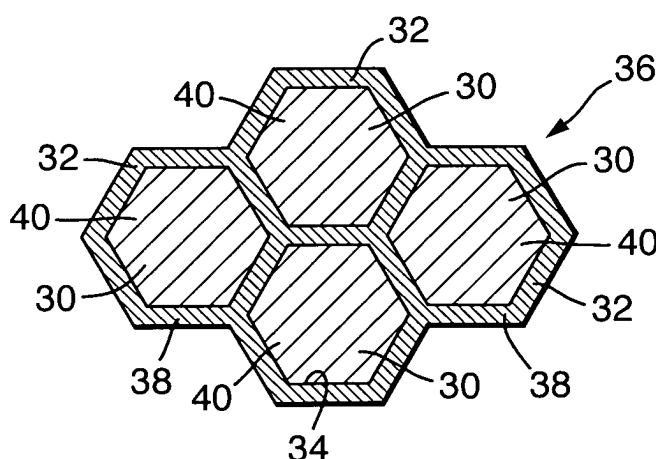
London, SW1E 6AT (GB)

(54) **A method of manufacturing a component with a cellular structure by consolidating a coated metal powder**

(57) A method of manufacturing a component (10,20) by consolidating a metal powder comprises preparing a metal powder, the metal powder comprising metal particles (30). Depositing a coating (32) containing at least one element on the surfaces (34) of the metal particles (30) of the metal powder. Applying heat and

pressure to consolidate the metal particles (30) such that the at least one element of the coating (32) on the surfaces (34) of the metal particles (30) partially diffuses into the metal particles (30) and the coated metal particles (30) are diffusion bonded together to form a cellular structure (36).

Fig.5.



Description

[0001] The present invention relates to a method of manufacturing a component by consolidating a metal powder.

[0002] Conventional alloys have their physical and mechanical properties improved by modifying the microstructure of the alloys by processing and heat treatment of the source ingot material, which is normally cast, though powder billet may be used.

[0003] Near net shape components are manufactured by consolidating metal powder, for example by hot isostatic pressing. In the hot isostatic pressing process a vacuum purge system is used so as to maintain the composition of the metal powder constant throughout the consolidation process. The resulting component thus has a homogeneous composition.

[0004] Accordingly the present invention seeks to provide a novel method of manufacturing a component by consolidating a metal powder in which the microstructure of the metal of the component is modified and the component has improved physical and mechanical properties.

[0005] Accordingly the present invention provides a method of manufacturing a component by consolidating a metal powder comprising the steps of:-

- (a) preparing a metal powder, the metal powder comprising metal particles,
- (b) depositing a coating containing at least one element on the surfaces of the metal particles of the metal powder,
- (c) applying heat and pressure to consolidate the metal particles such that the at least one element of the coating on the surfaces of the metal particles partially diffuses into the metal particles and the coated metal particles are diffusion bonded together to form a cellular structure, the cellular structure comprising a framework of more highly alloyed material located at the boundaries of the diffusion bonded metal particles and the centres of the consolidated metal particles retain their original composition.

[0006] Preferably step (b) comprises oxidising the surfaces of the metal particles.

[0007] Alternatively step (b) comprises nitriding the surfaces of the metal particles.

[0008] Alternatively step (b) comprises vapour depositing a solid solution strengthening element on the surfaces of the metal particles.

[0009] Alternatively step (b) comprises coating the surfaces of the metal particles with a second metal having lower melting point than the metal particles.

[0010] Alternatively step (b) comprises coating the surfaces of the metal particles with particles of a second metal powder having a lower yield strength than the metal particles.

[0011] Preferably the metal particles have an average size of 100 micrometers. Preferably the metal particles have a maximum size of 250 micrometers.

[0012] Alternatively the size of the metal particles may be varied to vary the properties of the component.

[0013] The metal particles may be alloy particles.

[0014] The second metal may be an alloy.

[0015] The second metal particles may be alloy particles.

[0016] Preferably the metal particles are titanium alloy particles. More preferably the titanium alloy particles comprise 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities.

[0017] Preferably the step a) comprises supplying the titanium alloy particles into a container, step b) comprises oxidising the titanium alloy particles, step c) comprises sealing the container and applying heat and pressure.

[0018] Preferably step b) comprises heating to a temperature of 450°C and maintaining at 450°C for 8 hours under a partial pressure of 10^{-1} torr to oxidise the titanium alloy particles and step c) comprises hot isostatic pressing the container at a temperature of 925°C for 2 hours at a pressure of 150MPa.

[0019] Preferably the container is removed by machining or dissolving in a suitable acid. Preferably the container comprises mild steel.

[0020] The present invention also provides a component comprising consolidated metal powder, the metal powder comprising metal particles diffusion bonded together, the surfaces of the metal particles having a coating having at least one element which has partially diffused into the metal particles to form a cellular structure, the cellular structure comprising a framework of more highly alloyed material located at the boundaries of the diffusion bonded metal particles and the centres of the consolidated metal particles retain their original composition.

[0021] Preferably the coating comprising an oxide or a nitride and the at least one element is oxygen or nitrogen respectively.

[0022] Alternatively the coating comprises a solid solution strengthening element on the surfaces of the metal particles.

[0023] Alternatively the coating comprises a second metal having lower melting point than the metal particles.

[0024] Alternatively the coating comprises a second metal powder having a lower yield strength than the metal particles.

[0025] Preferably the metal particles are titanium alloy particles. More preferably the titanium alloy particles comprise 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities.

[0026] Preferably the component is a gas turbine engine component.

[0027] Preferably the component is a fan blade, a part of a fan blade, a compressor blade or a casing.

[0028] The present invention will be more fully described by way of example with reference to the accompanying drawings in which:-

Figure 1 shows a component, which has been manufactured by consolidating a metal powder according to the present invention.

Figure 2 shows a further component, which has been manufactured by consolidating a metal powder according to the present invention.

Figure 3 shows an enlarged cross-sectional view through a portion of the metal powder before the start of the manufacturing process according to the present invention.

Figure 4 shows an enlarged cross-sectional view through a portion of the metal powder at a first stage of the manufacturing process according to the present invention.

Figure 5 shows an enlarged cross-sectional view through a portion of the metal powder at the end of the manufacturing process according to the present invention.

[0029] A component 10, in this example a casing, is shown in figure 1 and a further component 20, in this example a fan blade, is shown in figure 2 are manufactured by consolidating a metal powder according to the present invention.

[0030] The present invention uses a metal powder consolidation process to produce a cellular structure into a component 10 or 20 in which the normal alloy composition is held within a framework of interstitial alloy or solid solution strengthened alloy.

[0031] The method of manufacturing a component 10, or 20, by consolidating a metal powder comprises preparing a metal powder, the metal powder comprising metal particles 30. The metal particles ideally should have a narrow particle size, diameter, range, although this is not essential. For example the metal particles 30 have an average size of 100 micrometers and the metal particles 30 have a maximum size of 250 micrometers. A coating 32 containing at least one element is deposited on the surfaces 34 of the metal particles 30 of the metal powder. Heat and pressure is then applied to consolidate the metal particles 30 such that the at least one element of the coating 32 on the surfaces 34 of the metal particles 30 partially diffuses into the metal particles 30 and the coated metal particles 30 are diffusion bonded together to form a cellular structure 36. During the consolidation of the metal particles 30, the roughly spherical metal particles 30 are deformed to a polyhedral shape. This results in a framework of more highly alloyed material 38 located at the boundaries of the diffusion bonded metal particles 30, or adjacent the original surfaces 34 of the metal particles 30. Because there is only limited diffusion of the at least one element from the coating 32 into the metal particles 30, the centres 40 of the consolidated metal particles 30 retain their original compo-

sition and thus a cellular structure 36 is created.

[0032] The properties of the cellular structure 36 are dependent on the size, diameter, of the metal particles 30 of the metal powder, e.g. the dimensions of the resulting centres 40, and the at least one element in the coating 32. Thus the size, diameter, of the metal particles 30 may be varied to vary the properties of the cellular structure 36 and hence the physical and mechanical properties of the component 10 or 20. The coating 32 for the metal particles 30 may be varied to vary the properties of the cellular structure 36 and hence the physical and mechanical properties of the component 10 or 20.

[0033] The coating 32 may comprise an oxide, which is produced by oxidising the surfaces 34 the metal particles 30 in oxygen or air. Alternatively the coating 32 may comprise a nitride, which is produced by nitriding the surfaces 34 of the metal particles 30. Alternatively the coating 32 may comprise a solid solution strengthening element, which is produced by vapour depositing on the surfaces 34 of the metal particles 30. Alternatively the coating 32 may comprise a second metal, having lower melting point than the metal particles 30. Alternatively the coating 32 comprises a second metal powder having a lower yield strength than the metal particles 30. The metal particles 30 may be alloy particles. The second metal may be an alloy. The second metal particles may be alloy particles. The metal particles may be titanium alloy particles. More preferably the titanium alloy particles comprise 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities.

[0034] The present invention permits modification of the material structure to enhance physical and mechanical properties according to the laws of cellular structures. The present invention produces a cellular structure within a solid metallic component, the cellular structure improves the impact absorption properties, the ductility and the strength of a conventional alloy. In addition physical properties such as the elastic modulus, Poisson's Ratio, friction and damping characteristics are improved.

Example 1

[0035] Titanium alloy particles comprising 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities were prepared. The titanium alloy particles were then filtered to the required titanium alloy particle size, 100 micrometers average size and 250 micrometers maximum size. The titanium alloy particles were poured through an inlet tube into and filled a mild steel container, which defines the shape of the component being produced. The container was heated to a temperature of 450°C and maintained at 450°C for 8 hours under a partial air pressure of 10⁻¹ torr to oxidise the titanium alloy particles. The container was then sealed by welding shut an inlet tube. The con-

tainer was placed in a HIP vessel and hot isostatically pressed at a temperature of 925°C for 2 hours at a pressure of 150MPa. Then the container was removed from the consolidated metal powder component by machining or dissolving in a suitable acid.

[0036] The use of a second metal, or second alloy, which has a lower melting point the metal particles will result in melting or evaporation of the second metal to produce a coating on the metal particles. The use of a second metal powder having a lower yield strength than the metal particles will result in the second metal powder deforming around the metal particles during consolidation to produce the cellular structure.

[0037] The present invention may also be used to infill metal powder particles into an existing hollow metal structure, for example a hollow fan blade or hollow compressor blade, and then to produce the cellular structure within the existing hollow metal structure. Alternatively, it may be possible to infill metal powder between at least two metal workpieces, then to produce the cellular structure between the at least two metal workpieces and to diffusion bond the cellular structure to the at least two workpieces and to diffusion bond the at least two workpieces together, for example a fan blade.

[0038] The present invention may also be used to produce a hollow fan blade of a hollow compressor blade. The mild steel container was provided with one or more removable cores in the mild steel container to define one or more chambers in the hollow fan blade, or hollow compressor blade. The titanium alloy particles were poured into the mild steel container to fill the space in the mild steel container around the one or more removable cores. The container was heated to 450°C and maintained at 450°C for 8 hours under a partial air pressure of 10^{-1} torr to oxidise the titanium alloy particles. The container was then sealed by welding shut the inlet tube. The container was placed in a HIP vessel and hot isostatically pressed at a temperature of 925°C for 2 hours at a pressure of 150 MPa. Then the container was removed from the consolidated metal powder hollow fan blade, or hollow compressor blade, by machining or dissolving in a suitable acid. Then the removable cores were removed. The removable cores may comprise an inert metal, for example lead or other metal with large atoms which are too large to diffuse into the titanium particles, having a lower melting point than the titanium alloy particles such that the hollow fan blade, or hollow compressor blade, is heated to a temperature at which the inert metal melts and is run out of the hollow fan blade, or hollow compressor blade. Remnants of the metal, may be removed from the hollow fan blade or hollow compressor blade, using a suitable solvent or a suitable acid. The removable cores may comprise mild steel which may be removed with a suitable acid.

[0039] Alternatively, the hollow fan blade, or hollow compressor blade may be produced by ensuring that the container defines one or more chambers in the hollow fan blade or hollow compressor blade. The chambers

are arranged to be pressurised during the hot isostatic pressing.

[0040] The present invention may also entail machining a consolidated metal powder solid fan blade or solid compressor blade to final shape.

[0041] The present invention is also applicable to titanium alloy particles comprising 6wt% aluminium, 2wt% tin, 4wt% zirconium, 2wt% molybdenum and the balance titanium, minor additions or incidental impurities.

[0042] In the case of oxidising and nitriding the metal particles, or alloy particles, the oxygen or nitrogen partially diffuses into the metal particles, or alloy particles, to form interstitials in the metal, or alloy and the normal, or original, alloy composition at the centres of the consolidated metal particles, or alloy particles, is arranged within a framework of more highly alloyed, interstitial alloy, material located at the boundaries of the diffusion bonded metal particles, or alloy particles.

[0043] Although the present invention has been described with reference to titanium alloys, the invention is equally applicable to aluminium alloys, iron alloys, nickel alloys, cobalt alloys and to intermetallics, for example nickel aluminides, titanium aluminides.

Claims

1. A method of manufacturing a component (10,20) by consolidating a metal powder comprising the steps of:-
 - (d) preparing a metal powder, the metal powder comprising metal particles (30),
 - (e) depositing a coating (32) containing at least one element on the surfaces (34) of the metal particles (30) of the metal powder,
 - (f) applying heat and pressure to consolidate the metal particles (30) such that the at least one element of the coating (32) on the surfaces (34) of the metal particles (30) partially diffuses into the metal particles (30) and the coated metal particles (30) are diffusion bonded together to form a cellular structure (36), the cellular structure (36) comprising a framework of more highly alloyed material (38) located at the boundaries of the diffusion bonded metal particles (30) and the centres (40) of the consolidated metal particles (30) retain their original composition.
2. A method as claimed in claim 1 wherein step (b) comprises oxidising the surfaces (34) of the metal particles (30).
3. A method as claimed in claim 1 wherein step (b) comprises nitriding the surfaces (34) of the metal particles (30).

4. A method as claimed in claim 1 wherein step (b) comprises vapour depositing a solid solution strengthening element on the surfaces (34) of the metal particles (30).
5. A method as claimed in claim 1 wherein step (b) comprises coating the surfaces (34) of the metal particles (30) with a second metal having lower melting point than the metal particles (30).
6. A method as claimed in claim 1 wherein step (b) comprises coating the surfaces (34) of the metal particles (30) with particles of a second metal powder having a lower yield strength than the metal particles (30).
7. A method as claimed in any of claims 1 to 6 wherein the metal particles (30) are alloy particles.
8. A method as claimed in claim 5 wherein the second metal is an alloy.
9. A method as claimed in claim 6 wherein the second metal particles are alloy particles.
10. A method as claimed in claim 7 wherein the metal particles (30) are titanium alloy particles.
11. A method as claimed in claim 10 wherein the titanium alloy particles (30) comprise 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities.
12. A method as claimed in claim 11 wherein step a) comprises supplying the titanium alloy particles (30) into a container, step b) comprises oxidising the titanium alloy particles (30), step c) comprises sealing the container and applying heat and pressure.
13. A method as claimed in claim 12 wherein step b) comprises heating to a temperature of 450°C and maintaining at 450°C for 8 hours under a partial pressure of 10^{-1} torr to oxidise the titanium alloy particles (30) and step c) comprises hot isostatic pressing the container at a temperature of 925°C for 2 hours at a pressure of 150MPa.
14. A method as claimed in claim 12 or claim 13 wherein the container is removed by machining or dissolving in a suitable acid.
15. A method as claimed in claim 12, claim 13 or claim 14 wherein the container comprises mild steel.
16. A method as claimed in any of claims 1 to 15 wherein the metal particles (30) have an average size of 100 micrometers.
17. A method as claimed in any of claims 1 to 16 wherein the metal particles (30) have a maximum size of 250 micrometers.
18. A method as claimed in any of claims 1 to 15 wherein the size of the metal particles (30) is varied to vary the properties of the component (10,20).
19. A component (10,20) comprising consolidated metal powder, the metal powder comprising metal particles (30) diffusion bonded together, the surfaces (34) of the metal particles (30) having a coating having at least one element, which has partially diffused into the metal particles (30) to form a cellular structure (36), the cellular structure (36) comprising a framework of more highly alloyed material (38) located at the boundaries of the diffusion bonded metal particles (30) and the centres (40) of the consolidated metal particles (30) retain their original composition.
20. A component as claimed in claim 19 wherein the coating (34) comprising an oxide or a nitride and the at least one element is oxygen or nitrogen respectively.
21. A component as claimed in claim 19 wherein the coating comprises a solid solution strengthening element on the surfaces of the metal particles (30).
22. A component as claimed in claim 19 wherein the coating (34) comprises a second metal having lower melting point than the metal particles (30).
23. A component as claimed in claim 19 wherein the coating (34) comprises a second metal powder having a lower yield strength than the metal particles (30).
24. A component as claimed in any of claims 19 to 23 wherein the metal particles (30) are titanium alloy particles.
25. A component as claimed in claim 24 wherein the titanium alloy particles (30) comprise 6wt% aluminium, 4wt% vanadium and the balance titanium, minor additions and incidental impurities.
26. A component as claimed in any of claims 19 to 25 wherein the component (10,20) is a gas turbine engine component.
27. A component as claimed in claim 26 wherein the component is a fan blade (20), a part of a fan blade, a compressor blade or a casing (10).

Fig.1.

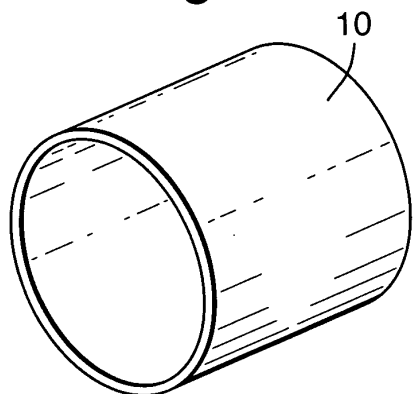


Fig.2.



Fig.3.

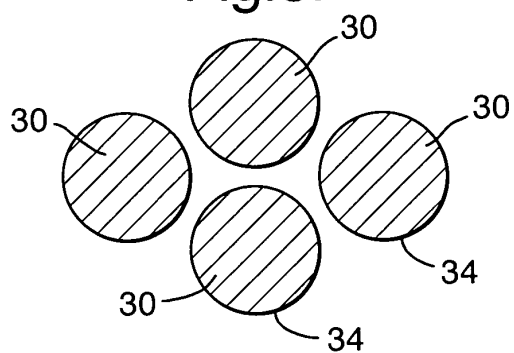


Fig.4.

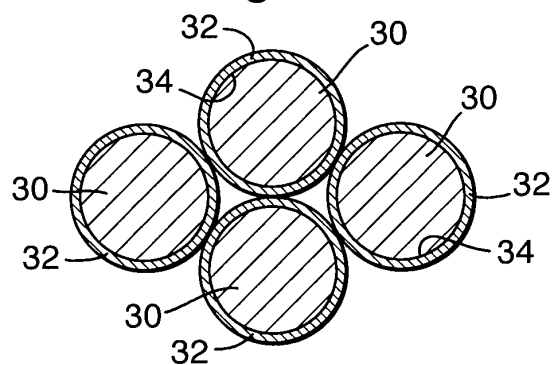
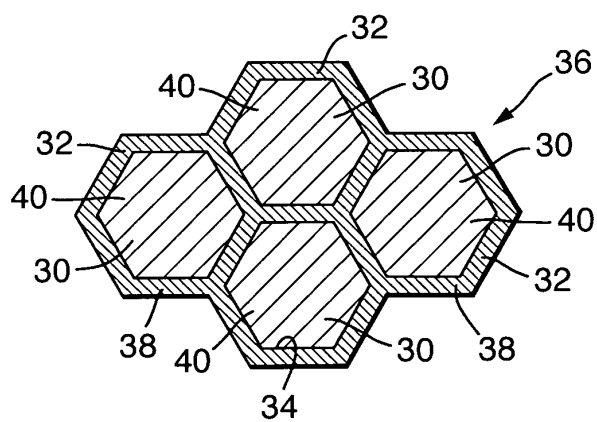


Fig.5.





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 25 2858

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 024 984 A (COMMISSARIAT A L'ENERGIE ATOMIQUE ETABLISSEMENT DE CARACTERE SCIENTIFI) 11 March 1981 (1981-03-11) * page 3, line 16 - page 6, line 7 * -----	1-25	B22F1/00 B22F1/02
A	GB 2 157 711 A (* SINTERMETALLWERK KREBSOGE GMBH) 30 October 1985 (1985-10-30) * page 1, line 66 - page 2, line 26; claim 1 * -----	1,19	
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 507 (M-1327), 20 October 1992 (1992-10-20) & JP 04 187704 A (DAIDO SANSEI KK), 6 July 1992 (1992-07-06) * abstract *	2,3,12, 20	
A	US 6 024 915 A (KUME ET AL) 15 February 2000 (2000-02-15) * examples 1,6,7,14,15,21 *	6-9,22, 23	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	US 6 162 497 A (BEANE ET AL) 19 December 2000 (2000-12-19) * column 4, line 65 - column 5, line 22; claims 1,5,12 * -----	1,19	B22F
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 27 September 2005	Examiner Schruers, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 2
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 05 25 2858

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-09-2005

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0024984	A	11-03-1981	DE 3069828 D1	31-01-1985
			FR 2464112 A1	06-03-1981
			US 4381942 A	03-05-1983

GB 2157711	A	30-10-1985	DE 3412565 A1	24-10-1985
			IT 1184133 B	22-10-1987

JP 04187704	A	06-07-1992	WO 9208560 A1	29-05-1992
			JP 2868889 B2	10-03-1999

US 6024915	A	15-02-2000	NONE	

US 6162497	A	19-12-2000	NONE	
