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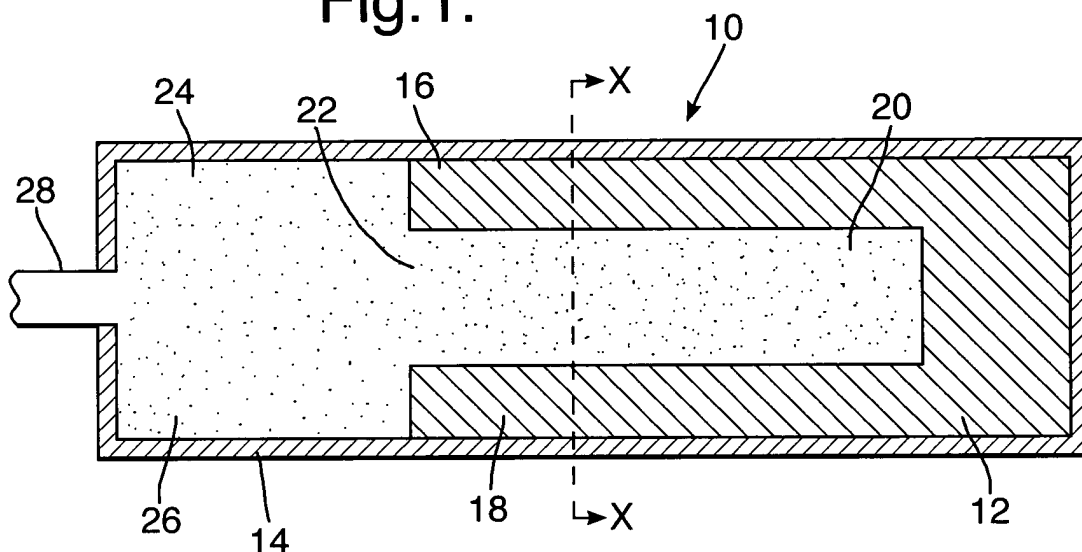
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(54) **An apparatus and a method of manufacturing an article by consolidating powder material**

(57) A method of manufacturing an article by consolidating powder material comprises forming a non-deformable tool (12) and a deformable tool (14). The non-deformable tool (12) comprises a plurality of tool parts (16,18). The non-deformable tool (12) defines a first cavity (20) having an open end (22) and the first cavity (20) corresponds in shape to that of the article. The non-deformable tool (12) is encapsulated in the deformable tool (14) and the non-deformable tool (12) and the de-

formable tool (14) define a second cavity (24) interconnected with the first cavity (20). The first and second cavities are filled with powder material (26). The deformable tool (14) is evacuated and sealed. Heat and pressure are applied to the deformable tool (14) and non-deformable tool (12) to consolidate the powder material (26) to form an article (30) in the first cavity (20) of the non-deformable tool (12). The method is used to make compressor blades, compressor vanes or compressor blisks for gas turbine engines.

Fig.1.



Description

[0001] The present invention relates to a method of manufacturing an article by consolidating powder material, and in particular to a method of manufacturing an article by consolidating metal powder, ceramic powder or a mixture of metal powder and ceramic powder.

[0002] Conventionally metal powder and/or ceramic powder, is consolidated to form an article by placing the metal powder in a consumable/deformable tool. The consumable/deformable tool is evacuated and then hot isostatically pressed such that the consumable/deformable tool deforms and compresses the metal powder and/or ceramic powder to a fully consolidated article.

[0003] However, this method of manufacturing articles requires sophisticated process/computer modelling to predict the shape of the tool required prior to hot isostatic pressing so that the hot isostatic pressing process deforms the tool, and hence the metal powder and/or ceramic powder, to near the net-shape of the article. Furthermore, because the tool is deformed during the hot isostatic pressing process the tool cannot be reused to produce further articles. Also, this method is dependent upon the control of the powder material and requires measurement of the powder flow and consolidation properties.

[0004] Accordingly the present invention seeks to provide a novel method of manufacturing an article by consolidating powder material.

[0005] Accordingly the present invention provides a method of manufacturing an article by consolidating powder material comprising the steps of:-

- (a) forming a non-deformable tool, the non-deformable tool comprising a plurality of tool parts, the non-deformable tool defining a first cavity having an open end, the first cavity corresponding in shape to that of the article,
- (b) encapsulating the non-deformable tool in a deformable tool, the non-deformable tool and deformable tool defining a second cavity interconnected with the first cavity,
- (c) filling the first cavity and second cavity with powder material,
- (d) evacuating the deformable tool,
- (e) sealing the deformable tool,
- (f) applying heat and pressure to the deformable tool and non-deformable tool to consolidate the powder material to form an article in the first cavity of the non-deformable tool.

[0006] Preferably step (e) comprises heating to a temperature of 925°C and applying a pressure of 150MPa and maintaining for 2 hours.

[0007] Preferably the deformable tool is removed from the non-deformable tool.

[0008] Preferably the deformable tool is dissolved from the non-deformable tool.

[0009] Preferably the deformable tool is dissolved using an acid.

[0010] Preferably the deformable tool comprises a deformable vacuum bag.

[0011] Preferably the vacuum bag comprises a metal.

[0012] Preferably the metal comprises mild steel.

[0013] Preferably the non-deformable tool is removed from the article.

[0014] Preferably the non-deformable tool is removed by removing the tool parts.

[0015] Preferably the non-deformable tool comprises at least two tool parts.

[0016] Preferably the non-deformable tool comprises a non-deformable metal.

[0017] Preferably the metal comprises high strength steel.

[0018] The tool parts may be removed from the article and excess consolidated powder is removed from the end of the article, which was adjacent the opening.

[0019] Alternatively excess consolidated powder is removed from the end of the article and non-deformable tool, which was adjacent the opening and then the tool parts are removed from the article.

[0020] Preferably the powder material comprises metal powder, ceramic powder or metal powder and ceramic powder.

[0021] The metal powder may be an alloy powder or an elemental powder. The metal powder may be nickel alloy powder, titanium alloy powder, aluminium alloy powder, cobalt alloy powder or an iron alloy powder.

[0022] Preferably the article is a compressor blade, a compressor vane, a turbine blade, a turbine vane, a compressor disc, a turbine disc, a compressor blisk or a turbine blisk.

[0023] Preferably step (f) comprises hot isostatic pressing or isothermal pressing.

[0024] The present invention also provides an apparatus for manufacturing an article by consolidating powder material comprising a non-deformable tool and a deformable tool, the non-deformable tool comprising a plurality of tool parts, the non-deformable tool defining a first cavity having an open end, the first cavity corresponding in shape to that of the article, the non-deformable tool and deformable tool defining a second cavity interconnected with the first cavity.

[0025] Preferably the deformable tool comprises a deformable vacuum bag.

[0026] Preferably the vacuum bag comprises a metal.

[0027] Preferably the metal comprises mild steel.

[0028] Preferably the non-deformable tool comprises a non-deformable metal.

[0029] Preferably the metal comprises high strength steel.

[0030] The present invention will be more fully described by way of example with reference to the accompanying drawings in which:-

Figure 1 is a cross-sectional view through an appa-

ratus for manufacturing an article by consolidating powder material according to the present invention. Figure 2 is a cross-sectional view in the direction of arrows X-X in figure 1.

Figure 3 is a cross-sectional view through the apparatus shown in figure 1 after consolidation of the powder material.

[0031] An apparatus 10 for manufacturing an article by consolidating powder material, as shown in figure 1, comprises a non-deformable tool 12 and a deformable tool 14. The non-deformable tool 12 comprises a plurality of tool parts 16 and 18 and the non-deformable tool 12 defines a first cavity 20, which has an open end 22. The first cavity 20 corresponds in shape to that of an article to be manufactured. The non-deformable tool 12 is arranged in the deformable tool 14 and the non-deformable tool 12 and deformable tool 14 define a second cavity 24 interconnected with the first cavity 20 via the opening 22. The deformable tool 14 comprises a deformable vacuum bag, a thin walled deformable jacket and the vacuum bag comprises a metal, for example mild steel. The vacuum bag may be formed by welding a number of metal parts together. The non-deformable tool 12 comprises at least two tool parts 16 and 18 and the non-deformable tool 12 comprises a non-deformable metal, for example high strength steel, which does not adhere to the powder material after consolidation.

[0032] An article is manufactured by consolidating powder material by securing, welding, a pipe 28 to the deformable tool 14 such that the pipe 28 is interconnected with the second cavity 24. The first cavity 20 and the second cavity 24 are filled with powder material 26, for example metal powder, ceramic powder or a mixture of metal powder and ceramic powder by supplying the powder material through the pipe 28. The deformable tool 14 is evacuated using the pipe 28 and a vacuum pump (not shown). The pipe 28 is then sealed, using one or more welds, to seal the deformable tool 14.

[0033] The apparatus 10 is then placed in a HIP vessel and heat and pressure are applied to the deformable tool 14 and the non-deformable tool 12 to consolidate the powder material 26 to form an article 30 in the first cavity 20 of the non-deformable tool 12. The heat and pressure applied is preferably hot isostatic pressure.

[0034] During the consolidation process the isostatic pressure on the deformable tool 12 is resisted at those positions where the deformable tool 14 is supported by the non-deformable tool 12. However, at those positions of the deformable tool 14 where the deformable tool 14 is not supported by the non-deformable tool 12, adjacent the second cavity 24, the deformable tool 14 collapses, as shown in figure 2. This results in some of the powder material 26 in the second cavity 24 flowing, being extruded, through the opening 22 in the non-deformable tool 12 into the first cavity 20 in the non-deformable tool 12 to aid the consolidation of the powder material 26, as shown in figure 3. The extrusion of the powder material

26 through the opening 22 reduces the size of potential defects in the article 30.

[0035] After consolidation of the powder material 26, the apparatus 10 is removed from the HIP vessel and the deformable tool 14 is removed from the non-deformable tool 12. The deformable tool 14 is removed from the non-deformable tool 12 by dissolving the deformable tool 14, for example using an acid, for example nitric acid. However, the deformable tool may be removed by machining or it may be removed by a combination of machining and dissolving with acid.

[0036] The non-deformable tool 12 is then removed from the article 30. Either the tool parts 16 and 18 are removed from the article 30 and excess consolidated powder 32 is removed, for example machined, from the end of the article 30 which was adjacent the opening 22 or the excess consolidated powder 32 is removed, for example machined, from the end of the article 30 and non-deformable tool 12 adjacent the opening 22 and then the tool parts 16 and 18 are removed from the article 30. In this example the article 30 is a compressor blade.

[0037] The powder material may comprise a metal powder, a ceramic powder or a metal powder and a ceramic powder.

[0038] The metal powder may be an alloy powder or an elemental powder. The metal powder may be nickel alloy powder, titanium alloy powder, aluminium alloy powder, cobalt alloy powder or an iron alloy powder.

[0039] The first cavity may define the shape of a compressor blade, a compressor vane, a turbine blade, a turbine vane, a compressor disc, a turbine disc, a compressor blisk or a turbine blisk.

[0040] The article may be a compressor blade, a compressor vane, a turbine blade, a turbine vane, a compressor disc, a turbine disc, a compressor blisk, a turbine blisk, a compressor bling or a turbine bling for a gas turbine engine. A blisk is a disc having integral blades and a bling is a ring having integral blades. However, the method may be used to manufacture other suitable articles.

[0041] In the case of titanium alloy, for example a titanium alloy comprising 6wt% aluminium, 4wt% vanadium, powder the heating is to a temperature of 925°C, below the beta transus, and a pressure of 150MPa is applied for about 2 hours. The particular temperature and pressure varies according to the specific alloy. In the case of a gamma titanium aluminide alloy powder the temperature may be up to 1300°C, for example 1260°C.

[0042] The present invention effectively provides an apparatus comprising an open ended non-deformable hollow tool, defining an article shape first cavity, and a deformable hollow tool defining a second cavity with the non-deformable tool such that powder material in the second cavity is extruded into the first cavity due to isostatic pressure applied during consolidation.

[0043] Additionally it may be possible, in some geo-

metric arrangements of the article, to use a unidirectional pressure, or load, such as an isothermal press rather than an isostatic pressure.

[0044] The advantage of the present invention is that it eliminates the need for sophisticated process modelling techniques to determine the pre-consolidation shape of a deformable tool. Additionally, the non-deformable tool may be re-used to produce further articles.

[0045] Furthermore, measurement of powder flow and consolidation properties are not required. Also, it successfully consolidates powder material to a near net-shape article no matter how the powder material is packed in the tool and is therefore suitable for powder material with poor flowing characteristics, such as powder material produced by electrochemical/chemical or electro-de-oxidation powder production techniques. The properties of the consolidated powder article are improved due to the relatively high degree of work applied by the powder extrusion during the hot isostatic pressing process. The extrusion of the powder material during the consolidation process breaks up potential defects in the powder material, by braking up the defects and spreading the remnants of the defects so as to reduce their size.

Claims

1. A method of manufacturing an article by consolidating powder material comprising the steps of:-
 - (a) providing a non-deformable tool (12), the non-deformable tool (12) comprising a plurality of tool parts (16,18), the non-deformable tool (12) defining a first cavity (20) having an open end (22), the first cavity (20) corresponding in shape to that of the article,
 - (b) encapsulating the non-deformable tool (12) in a deformable tool (14), the non-deformable tool (12) and deformable tool (14) defining a second cavity (24) interconnected with the first cavity (20),
 - (c) filling the first cavity (20) and second cavity (24) with powder material,
 - (d) evacuating the deformable tool (14),
 - (e) sealing the deformable tool (14),
 - (f) applying heat and pressure to the deformable tool (14) and non-deformable tool (12) to consolidate the powder material to form an article in the first cavity (20) of the non-deformable tool (12).
2. A method as claimed in claim 1 wherein step (f) comprises heating to a temperature of 925°C and applying a pressure of 150MPa and maintaining for 2 hours.
3. A method as claimed in claim 1 or claim 2 comprising removing the deformable tool (14) from the non-deformable tool (12).
4. A method as claimed in claim 3 comprising dissolving the deformable tool (14) from the non-deformable tool (12).
5. A method as claimed in claim 4 comprising dissolving the deformable tool (14) using an acid.
6. A method as claimed in any of claims 1 to 5 wherein the deformable tool (14) comprises a deformable vacuum bag.
7. A method as claimed in claim 6 wherein the vacuum bag comprises a metal.
8. A method as claimed in claim 7 wherein the metal comprises mild steel.
9. A method as claimed in any of claims 1 to 8 comprising removing the non-deformable tool (12) from the article.
10. A method as claimed in claim 9 comprising removing the non-deformable tool (12) by removing the tool parts (16,18).
11. A method as claimed in claim 10 wherein the non-deformable tool (12) comprises at least two tool parts (16,18).
12. A method as claimed in any of claims 1 to 11 wherein the non-deformable tool (12) comprises a non-deformable metal.
13. A method as claimed in claim 12 wherein the metal comprises high strength steel.
14. A method as claimed in claim 9 or claim 10 comprising removing the tool parts (16,18) from the article and removing excess consolidated powder from the end of the article, which was adjacent the open end (22).
15. A method as claimed in claim 9 or claim 10 comprising removing excess consolidated powder from the end of the article and non-deformable tool (12), which was adjacent the open end (22) and then removing the tool parts (16,18) from the article.
16. A method as claimed in any of claims 1 to 15 wherein the powder material comprises metal powder, ceramic powder or metal powder and ceramic powder.
17. A method as claimed in claim 16 wherein the metal powder is an alloy powder or an elemental powder.

18. A method as claimed in claim 17 wherein the metal powder is nickel alloy powder, titanium alloy powder, aluminium alloy powder, cobalt alloy powder or iron alloy powder. 5
19. A method as claimed in any of claims 1 to 18 wherein the article is a compressor blade, a compressor vane, a turbine blade, a turbine vane, a compressor disc, a turbine disc, a compressor blisk or a turbine blisk. 10
20. A method as claimed in any of claims 1 to 19 wherein step (f) comprises hot isostatic pressing or isothermal pressing. 15
21. An apparatus for manufacturing an article by consolidating powder material comprising a non-deformable tool (12) and a deformable tool (14), the non-deformable tool comprising a plurality of tool parts (16,18), the non-deformable tool (12) defining a first cavity (20) having an open end (22), the first cavity (20) corresponding in shape to that of the article, the non-deformable tool (12) and deformable tool (14) defining a second cavity (24) interconnected with the first cavity (20). 20 25
22. An apparatus as claimed in claim 21 wherein the deformable tool (14) comprises a deformable vacuum bag. 30
23. An apparatus as claimed in claim 22 wherein the vacuum bag comprises a metal.
24. An apparatus as claimed in claim 23 wherein the metal comprises mild steel. 35
25. An apparatus as claimed in any of claims 21 to 24 wherein the non-deformable tool comprises a non-deformable metal. 40
26. An apparatus as claimed in claim 25 wherein the metal comprises high strength steel. 45
- 50
- 55

Fig.1.

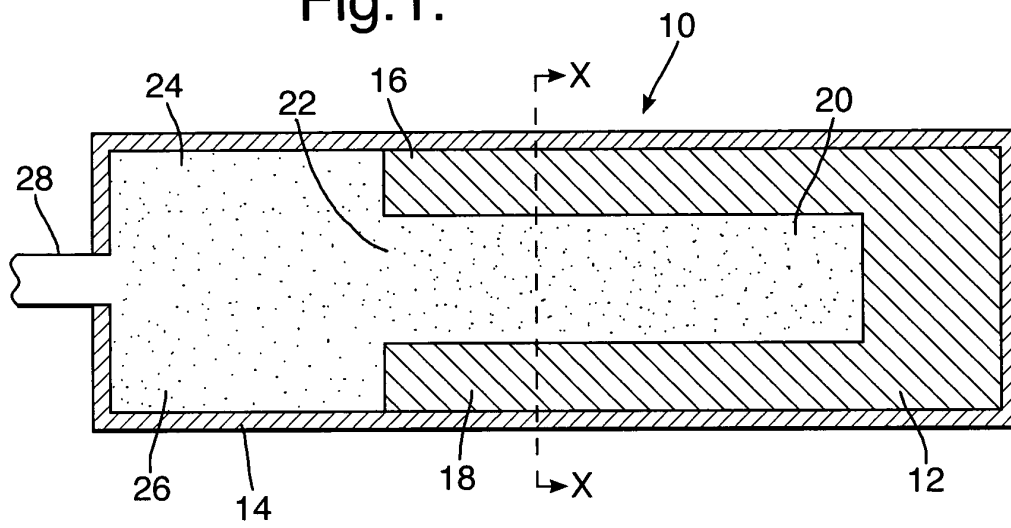


Fig.2.

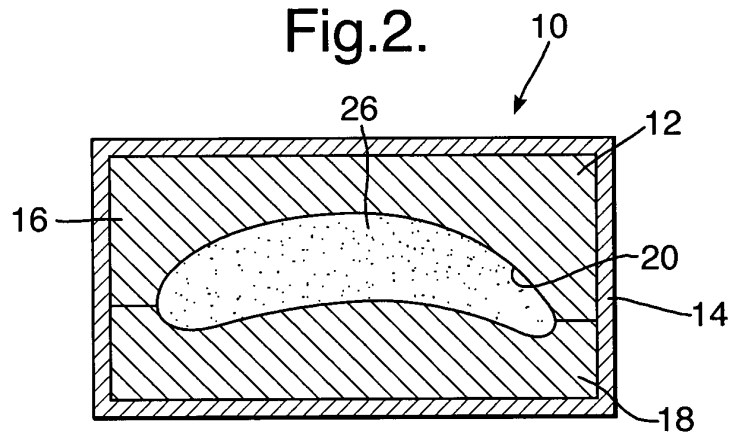


Fig.3.

