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(56) Documents Cited:
EP 0510598 A
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(54) Title of the Invention: **A method of forming a composite metal item**
Abstract Title: **A Method of Forming a Composite Metal Item**

(57) A method of forming a composite metal item, the method comprising the steps of: forming a shell having an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed, the outer surface of the shell being larger than the outer surface of the composite metal item to be formed, the shell defining a shell cavity and comprising a first type of metal; providing metal powder within the shell cavity, the metal power comprising a second type of metal that is different to the first type; and consolidating the shell and powder to form the composite metal item. The shell may be formed by superplastic deformation of a titanium alloy.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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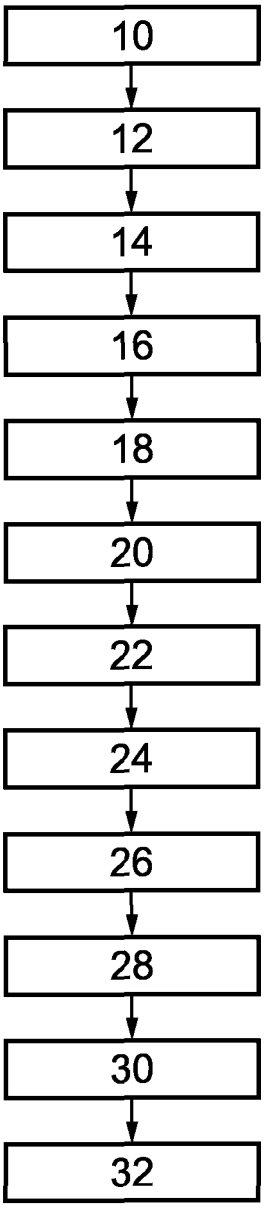

FIG. 1

A Method of Forming a Composite Metal Item

Background

It is known to produce items by moulding. Typically, a mould is formed to define a cavity and the cavity is filled with a material which, once consolidated, forms the item.

Moulded products often require simple external features, to enable the moulded part to be released once consolidated, meaning that it can be difficult to create moulded parts that have complex shapes.

Alternatively, the mould tool may be machined away, or corroded, to leave the moulded part. However, this is wasteful in terms of material and processing time.

Once released from a mould, a part may require secondary machining to arrive at its final form, or "net shape". However, smooth, flowing surfaces may not be easily or economically achieved through mechanised material removal operations. Furthermore, surface features created by material removal operations may create points of weakness in the moulded part, or fatigue and corrosion initiation sites.

Summary

In accordance with a first aspect of the present invention, there is provided a method of forming a composite metal item, the method comprising the steps of:

forming a shell having an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed, the outer surface of the shell being larger than the outer surface of the composite metal item to be formed, the shell defining a shell cavity and comprising a first type of metal;

providing metal powder within the shell cavity, the metal power comprising a second type of metal that is different to the first type; and

consolidating the shell and powder to form the composite metal item.

Thus, the metal shell defines an outer surface of the finished composite metal item. As such, the item may have a near-net shape once consolidated, which may result in less machining being required post-consolidation. The shell is initially larger than the composite metal item to be formed to enable the shell to shrink with the power as it is consolidated. The metal of the shell is different to the metal of the power which may act in synergy with the feature of the shell being initially larger than the composite metal item to be formed because it enables the selection of a metal for the shell that is suitable for the required size change and the selection of a metal for the powder that has advantageous properties, as set out in more detail below.

The first type of metal may have one or more of the following characteristics relative to the second type of metal: better fatigue tolerance; better corrosion tolerance; being easier to machine; and being more amenable to nitriding.

The second type of metal may have one or more of the following characteristics relative to the first metal: being cheaper or more abundant; having a lower density; being harder or stiffer.

The step of forming a metal shell may comprise superplastically forming a metal shell. Thus, "springback" may be reduced due to superplastically forming the metal shell.

The step of forming a shell may comprise:

forming a plurality of shell components each having an outer surface arranged to define part of the net or near-net outer surface of the composite metal item to be formed, the outer surface each shell component being larger than the respective part of the outer surface of the composite metal item to be formed; and

joining the shell components to form the shell.

Prior to the step of consolidating, the method may comprise the step of: providing one or more inserts into the cavity or cavities. The insert or inserts may comprise a rigid element. The rigid element may be hollow, such as tubular. Thus, inserts may be provided to impart different properties to the composite metal item to be formed.

The inserts may comprise a third type of metal. The third type of metal may be different to the first and/or the second type of metal. The third type of metal may have one or more of the following characteristics relative to the first and/or second metal: being cheaper or more abundant; having a lower or higher density; being harder or stiffer.

The step of forming a metal shell may comprise forming a mould tool comprising female mould cavity, enlarging the mould cavity and using the mould cavity to form the metal shell.

The outer surface of the shell may be at least 5%, 10%, 15%, 20% or 25% larger than the outer surface of the composite metal item to be formed.

The outer surface of the shell may be substantially uniformally larger than the outer surface of the composite metal item to be formed.

The mould cavity may be arranged to define one or more of the following: a filling port or ports; sheet metal fixtures; internal locating features for inserts; and flanges to assist with joining two shells together.

The first type of metal may be steel, titanium, or a titanium alloy such as Ti6-4 or Ti-6Al-4V.

The second type of metal may be steel, titanium, or a titanium alloy such as Ti3-2.5.

The third type of metal may be steel, titanium, or a titanium alloy such as Ti6-4 or Ti-6Al-4V.

The step of consolidating the shell and powder to form the composite metal item may comprise hot isostatic pressing the shell and powder.

Brief Description of the Drawings

By way of example only, certain embodiments of the invention will now be described by reference to the accompanying drawings, in which;

Figure 1 is a flow diagram of a method according to an embodiment of the present invention.

Detailed Description

Figure 1 show a flow diagram of a method according to an embodiment of the present invention.

At step 10 a mould is designed having a cavity which substantially matches the final shape a composite metal item to be formed. The cavity may be formed by a plurality of mould parts that each define a sub cavity, the sub cavities together defining the cavity. For example, two moulds may be designed, each defining a semi-spherical cavity such that the moulds, when positioned adjacent one another, together define a spherical cavity. The cavity thus defines substantially the entire outer profile of the composite metal item, although in other embodiments this need not be the case. The cavity may be designed using a CAD program, or by any other suitable means.

At step 12 the cavity is substantially uniformly enlarged. For example, the CAD model of the cavity may be enlarged using standard CAD program features. In one embodiment, the cavity may be enlarged by approximately 15%, as this may generally equates to the green packing density loss on consolidation. The outer surface of the shell may be at least 5%, 10%, 15%, 20% or 25% larger than the outer surface of the composite metal item to be formed.

At step 14 features such as filling ports, sheet metal fixtures, internal locating features for inserts, and/or flanges to assist with joining shell parts together may be included in the mould.

At step 16 a mould is built according to the mould design obtained at step 14. The mould may be built using any suitable conventional means, such as by a CAM process. The

mould may be formed of any suitable material, such as high strength mould tool steel. The mould may comprise one or more individual mould parts that together form the mould.

At step 18 a shell is formed using the mould created at step 16. The shell has an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed. Due to the enlargement at step 12, the outer surface of the shell is larger than the outer surface of the composite metal item to be formed. The shell defines a shell cavity into which metal power may be provided.

The shell may comprise a plurality of shell components that together form the shell. The shell may be superplastically formed. Superplastic forming is a conventional metalworking process and thus for clarity will not be described in any detail. Superplastically forming the shell may enable it to have complex geometries and may reduce spring-back.

The shell is formed of a first type of metal. The first type of metal may be any suitable metal such as steel, titanium, or a titanium alloy of a first type such as Ti6-4 or Ti-6Al-4V.

At step 20 the shell is cleaned using acid etching or any other suitable cleaning process.

At step 22 one or more inserts may optionally be located within the cavity, using the locating features moulded into the shells. An insert may comprise a rigid element, such as a section of metal or metal composite material, which may be hollow, for example tubular. Thus, inserts may be provided to impart different properties to the composite metal item to be formed.

At step 24 the shell cavity is filled with metal power to create an item. The metal powder comprises a second type of metal that is different to the first type. The second type of metal may be any suitable metal such as steel, titanium, or a titanium alloy of a second type which is different to the first type, such as Ti3-2.5. The shell cavity size may be calculated to determine the appropriate amount of powder required for a fully dense fill. When the shell cavity is filled with power, the amount of powder inserted can be determined to enable the fill density to be calculated. In some embodiments further power is compressed

into the shell cavity if the fill density is calculated to be less than 85%, which would be indicative to poor packing or voids.

Metal powder can be added pure or blended with a removable binder arranged to improve flow characteristics and to help bond the green state powder once compacted.

In embodiments where the shell is assembled prior to filling with metal power, the power may be inserted via the filling port or ports. Alternatively, the metal powder may be inserted into cavities of the shell components and thereafter the shell components coupled to form the shell.

The first type of metal may have one or more of the following characteristics relative to the second type of metal: better fatigue tolerance; better corrosion tolerance; being easier to machine; and being more amenable to nitriding.

The second type of metal may have one or more of the following characteristics relative to the first metal: being cheaper or more abundant; having a lower density; being harder or stiffer.

The inserts described above at step 22 may comprise a third type of metal. The third type of metal may be different to the first and/or the second type of metal. The third type of metal may have one or more of the following characteristics relative to the first and/or second metal: being cheaper or more abundant; having a lower or higher density; being harder or stiffer.

At step 26 the item is out-gassed. In some embodiments the out-gassing may comprise a vacuum hot out-gassing step, which may remove some oxide, contamination diffusible gasses such as hydrogen in titanium or binder materials. In other embodiments where no materials require out-gassing, the out-gassing may comprise a evacuating to remove air and any gas or vapours and thereafter sealing the shell under vacuum, such as by electron beam welding.

At step 28 the sealed item is consolidated. The item may be consolidated by hot isostatic pressing, sintering, or by hot pressing, all of which will be well understood by a skilled person. When the first, second and/or third metal comprise titanium, hot isostatic pressing is preferred as this avoids a molten step and may provide a more uniform consolidation.

The composite metal item to be formed may be any suitable part or component, such as an actuator rod lug end.

Once consolidated, the part may be substantially fully dense and may have shrunk in size in line with the anticipated green state density. Should any distortions occur, the mould design at steps 10 to 14 may be modified to account for this.

At step 30 the consolidated part may be machined to remove any sealing flanges and to drill any required holes. The fact that the metal shell defines an outer surface of the finished composite metal item means that the consolidated part may have a near-net shape once consolidated, which may result in less machining being required post-consolidation.

At step 32, the part may optionally be acid etched to de-scale any non-machined parts, or those parts may be media blasted or ground and polished.

As will be appreciated by a skilled person, a number of the above mentioned steps are optional and in embodiments of the invention there is provided a method of forming a composite metal item, the method comprising the steps of: forming a shell having an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed, the outer surface of the shell being larger than the outer surface of the composite metal item to be formed, the shell defining a shell cavity and comprising a first type of metal; providing metal powder within the shell cavity, the metal power comprising a second type of metal that is different to the first type; and consolidating the shell and powder to form the composite metal item. One or more of the above mentioned steps may be combined with this method.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be capable of designing many alternative

embodiments without departing from the scope of the invention as defined by the appended claims. In the claims, any reference signs placed in parenthesis shall not be construed as limiting the claims. The word "comprising" can mean “including” or “consisting of” and therefore does not exclude the presence of elements or steps other than those listed in any claim or the specification as a whole. The singular reference of an element does not exclude the plural reference of such elements and vice-versa. Parts of the invention may be implemented by means of hardware comprising several distinct elements, and/or by means of a suitably programmed computer. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. A method of forming a composite metal item, the method comprising the steps of:

forming a shell having an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed, the outer surface of the shell being larger than the outer surface of the composite metal item to be formed, the shell defining a shell cavity and comprising a first type of metal;

providing metal powder within the shell cavity, the metal power comprising a second type of metal that is different to the first type; and

consolidating the shell and powder to form the composite metal item.

2. A method according to claim 1, wherein the first type of metal has one or more of the following characteristics relative to the second type of metal: better fatigue tolerance; better corrosion tolerance; being easier to machine; and being more amenable to nitriding.

3. A method according to any preceding claim, wherein the second type of metal has one or more of the following characteristics relative to the first metal: being cheaper or more abundant; having a lower density; being harder or stiffer.

4. A method according to any preceding claim, wherein the step of forming a metal shell may comprises superplastically forming a metal shell.

5. A method according to any preceding claim, wherein the step of forming a shell comprises:

forming a plurality of shell components each having an outer surface arranged to define part of the net or near-net outer surface of the composite metal item to be formed, the outer surface each shell component being larger than the respective part of the outer surface of the composite metal item to be formed; and

joining the shell components to form the shell.

6. A method according to any preceding claim comprising the step of: providing one or more inserts into the cavity or cavities.

7. A method according to claim 6, wherein one or more of the inserts comprise a rigid element.

8. A method according to claim 7, wherein one or more of the rigid elements is hollow.

9. A method according to any of claims 6 to 8, wherein the inserts comprise a third type of metal.

10. A method according to claim 9, wherein the third type of metal has one or more of the following characteristics relative to the first and/or second metal: being cheaper or more abundant; having a lower or higher density; being harder or stiffer.

11. A method according to any preceding claim, wherein the step of forming a metal shell comprises forming a mould tool comprising female mould cavity, enlarging the mould cavity and using the mould cavity to form the metal shell.

12. A method according to any preceding claim, wherein the outer surface of the shell is at least 5%, 10%, 15%, 20% or 25% larger than the outer surface of the composite metal item to be formed.

13. A method according to any preceding claim, wherein the outer surface of the shell is substantially uniformally larger than the outer surface of the composite metal item to be formed.

14. A method according to any preceding claim, wherein the mould cavity is arranged to define one or more of the following: a filling port or ports; sheet metal fixtures; internal locating features for inserts; and flanges to assist with joining two shells together.

15. A method according to any preceding claim, wherein the first type of metal comprises one or more of steel, titanium or titanium alloy of a first type.

16. A method according to any preceding claim, wherein the second type of metal comprises one or more of steel, titanium or titanium alloy of a second type.

17. A method according to any preceding claim, wherein the step of consolidating the shell and powder to form the composite metal item comprises hot isostatic pressing of the shell and powder.

18. A method substantially as herein described with reference to the accompanying drawings.

Amendments to the claims have been made as follows:

Claims

1. A method of forming a composite metal item, the method comprising the steps of:

forming a shell having an outer surface arranged to define a net or near-net outer surface of the composite metal item to be formed, the outer surface of the shell being larger than the outer surface of the composite metal item to be formed, the shell defining a shell cavity and comprising a first type of metal;

providing metal powder within the shell cavity, the metal powder comprising a second type of metal that is different to the first type; and

consolidating the shell and powder to form the composite metal item.

2. A method according to claim 1, wherein the first type of metal has one or more of the following characteristics relative to the second type of metal: better fatigue tolerance; better corrosion tolerance; being easier to machine; and being more amenable to nitriding.

3. A method according to any preceding claim, wherein the second type of metal has one or more of the following characteristics relative to the first metal: being cheaper or more abundant; having a lower density; being harder or stiffer.

4. A method according to any preceding claim, wherein the step of forming a metal shell may comprise superplastically forming a metal shell.

5. A method according to any preceding claim, wherein the step of forming a shell comprises:

forming a plurality of shell components each having an outer surface arranged to define part of the net or near-net outer surface of the composite metal item to be formed, the outer surface each shell component being larger than the respective part of the outer surface of the composite metal item to be formed; and

joining the shell components to form the shell.

6. A method according to any preceding claim comprising the step of: providing one or more inserts into the cavity.

7. A method according to claim 6, wherein one or more of the inserts comprise a rigid element.

8. A method according to claim 7, wherein one or more of the rigid elements is hollow.

9. A method according to any of claims 6 to 8, wherein the inserts comprise a third type of metal.

10. A method according to claim 9, wherein the third type of metal has one or more of the following characteristics relative to the first and/or second metal: being cheaper or more abundant; having a lower or higher density; being harder or stiffer.

11. A method according to any preceding claim, wherein the step of forming a metal shell comprises forming a mould tool comprising female mould cavity, enlarging the mould cavity and using the mould cavity to form the metal shell.

12. A method according to any preceding claim, wherein the outer surface of the shell is at least 5%, 10%, 15%, 20% or 25% larger than the outer surface of the composite metal item to be formed.

13. A method according to any preceding claim, wherein the outer surface of the shell is substantially uniformally larger than the outer surface of the composite metal item to be formed.

14. A method according to any preceding claim, wherein the mould cavity is arranged to define one or more of the following: a filling port or ports; sheet metal fixtures; internal locating features for inserts; and flanges to assist with joining two shells together.

15. A method according to any preceding claim, wherein the first type of metal comprises one or more of steel, titanium or titanium alloy of a first type.

16. A method according to any preceding claim, wherein the second type of metal comprises one or more of steel, titanium or titanium alloy of a second type.

17. A method according to any preceding claim, wherein the step of consolidating the shell and powder to form the composite metal item comprises hot isostatic pressing of the shell and powder.

18. A method substantially as herein described with reference to the accompanying drawings.

Application No:	GB1117459.6	**Examiner:**	Tony Martin
Claims searched:	All Claims	**Date of search:**	30 January 2012

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	Not Applicable	WO00/58554 A Valmet see claim17
A	" "	EP0510598 A Hitachi see claim 5
A	" "	JP56152908 A Kobe Steel see abstract
A	" "	US3780418 A Alcoa see claim 1
A	" "	US4602952 A Cameron Iron see claim 1
A	" "	US5053284 A Hitachi see abstract
A	" "	JP53090110 A Yoshizaki see abstract

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B23F

The following online and other databases have been used in the preparation of this search report

On line databases WPI,EPPDOC

International Classification:

Subclass	Subgroup	Valid From
None		