METHOD OF MAKING METALLIC COMPOSITE FOAM COMPONENTS

BACKGROUND OF THE INVENTION

This invention relates generally to metallic components and more particularly to composite components which include a foam as part of their structure.

Certain foams, including particularly foams with ceramic and/or metallic cell walls, have promise as structural materials. In particular, they may be useful for light weight, high-strength, high-temperature capable components for gas turbine engines. It has been proposed to create composite materials from such foams by filling the intracellular spaces of the foam with a metal alloy, for example by introducing molten alloy into the foam and then allowing it to solidify.

However, the high temperature processing required for many metal alloys may cause non-uniform heating and thermal stresses in foam structures. This can result in immediate thermal fatigue failure of the foam, rendering it unusable for the intended purpose.

Accordingly, there is a need for a method of manufacturing a composite metallic component using a ceramic or metallic foam core, while protecting the structural integrity of the foam.

BRIEF SUMMARY OF THE INVENTION

The above-mentioned need is met by the present invention, which according to one aspect provides a method of producing a metallic composite component, including: providing a core comprising a foam material having ceramic or metallic cell walls with intracellular volume therebetween; disposing the core in a mold having a cavity defining the exterior contour of the component; providing a mixture of a metallic powder and a binder; melting the binder and injecting the mixture into the mold so as to penetrate the intracellular volume; removing a majority of the binder from the preform; and heating the preform to remove the remainder of the binder and to sinter the metal powder together to form the finished component.

According to another aspect of the invention, a method of producing a blade for a gas turbine engine having an airfoil with a leading edge, a trailing edge, a tip, a root, and opposed sides includes: providing a core comprising a foam material having ceramic or metallic cell walls with intracellular volume therebetween; disposing the core in a mold having a cavity defining the exterior contour of the airfoil; providing a mixture of a metallic powder and a binder; melting the binder and injecting the mixture into the mold so as to penetrate the intracellular volume; removing a majority of the binder from the preform; and heating the preform to remove the remainder of the binder and to sinter the metal powder together to form the finished blade.

According to another aspect of the invention, a preform for a metallic composite component includes: a core comprising a foam material having ceramic or metallic cell walls with intracellular volume therebetween; the core defining at least a portion of the exterior contour of the component; and a mixture of a metallic powder and a binder disposed in the intracellular volume.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be best understood by reference to the following description taken in conjunction with the accompanying drawing figures in which:

Figure 1 is a perspective view of an exemplary metallic component;

Figure 2 is a partial cross-section taken along lines 2-2 of Figure 1 illustrating the structure of the component of Figure 1 before a metal injection molding process;

Figure 3 is a view illustrating the structure of the component of Figure 1 after a first step in a manufacturing process thereof;

Figure 4 is a view illustrating the structure of the component of Figure 1 after a second step; and

Figure 5 is a block diagram of a manufacturing process carried out in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings wherein identical reference numerals denote the same elements throughout the various views, Figure 1 depicts an exemplary turbine blade 10 for a gas turbine engine. The present invention is equally applicable to the construction of other types of metallic components, non-limiting examples of which include rotating compressor blades, stationary turbine vanes, turbine shrouds, and the like. The turbine blade 10 comprises an airfoil 12 having a leading edge 14, a trailing edge 16, a tip 18, a root 19, and opposed sides 20 and 22. An arcuate inner platform 24 is attached to the root 19 of the airfoil 12. A dovetail 26 extends downward for mounting the blade 10 in a rotor slot.

Figure 5 depicts the process for making the turbine blade 10. Initially, as shown in block 32, a core of foam material is provided. The size and shape of the core can be varied to suit a particular application. In the illustrated example, the core defines the external contours of the turbine blade 10, and thus is similar in appearance to the finished turbine blade 10. Alternatively, the core could be made smaller to form an internal reinforcement member, such as a beam section.

The foam material of the core, shown in Figure 2, is an open-cell solid foam made of cell walls 28 having intracellular volume 30 therebetween. The cell walls 28 are continuous through the volume of the foam. As is implicit in the term "open-cell", the intracellular volume 30 is also continuous. That is, the foam material is formed of two interpenetrating, continuous regions: the cell walls 28 and the intracellular volume 30. In one embodiment, the cell walls 28 occupy at least about 60 volume percent of the foam material, and may occupy from about 60 to about 80 volume percent of the foam material. The intracellular volume 30 occupies the remainder of the foam volume.

The cell walls 28 may be made of a ceramic material or a metallic material, or mixtures thereof. If ceramic is used for the cell walls 28, any operable ceramic may be used. An exemplary ceramic material is aluminum oxide ("alumina"). Aluminum oxide is of particular interest because of its low density. The ceramic material may be a mix of

ceramics, with the ceramic that is present in the largest volume fraction being the "base ceramic".

One or more modifying ceramics may be mixed with the base ceramic to alter its properties. For example, the modifying ceramic may be a ceramic material that is more abrasive than the base ceramic. Examples of abrasive-modifying ceramics that are more abrasive than aluminum oxide and may be mixed with the aluminum oxide base ceramic are cubic boron nitride and sol gel alumina. The modifying ceramic may be a ceramic material that is less abrasive-that is, more abradable-than the base ceramic. Some examples of abradable modifying ceramics that are more abradable than aluminum oxide and may be mixed with the aluminum oxide base ceramic include silicon nitride and silicon carbide. The relative amounts of the modifying ceramics are selected according to the amount of modification desired.

The ceramic foam materials noted above and their construction are described in U.S. Patent 6,435,824 issued to Schell et al. and assigned to the assignee of the present invention.

If a metal is used for the cell walls 28, any alloy which is suitable for the intended operating conditions may be used. Examples of alloys known to be suitable for turbine engine components include aluminum, titanium, iron, cobalt, and nickel alloys. Particular examples of alloys useful for turbine components include Ti-6Al-4V, nickel-based alloys such as INCO 718, UDIMET 720, and Rene 195, and iron-based alloys such as A286.

The metallic foam materials noted above are described in U.S. Patent 6,443,700 issued to Grylls et al. and assigned to the assignee of the present invention.

Continuing at block 34 of Figure 5, the core is placed inside a mold (not shown) which has a cavity defining a negative form of the external contours of the turbine blade 10. If necessary the core may be located inside the mold with appropriate fixturing.

A metallic powder and a suitable binder are provided for injection into the mold. The metallic powder may be a single alloy or it may be a mechanical mixture of more than

one alloy. As used herein the term "powder" refers to any generally free-flowing dry form of a metallic alloy, and is not limited to any particular shape or size of grains. Non-limiting Examples of known alloys suitable for constructing turbine blades include titanium alloys such as Ti-6Al-4V, nickel-based alloys such as INCO 718 or UDIMET 720, Rene 195, and iron-based alloys such as A286.

The binder may be any material which is chemically compatible with the metallic powder and which allows the required processing (e.g. mixing, injection, solidification, and leaching). Examples of known suitable binders include waxes and polymer resins. The binder may be provided in a powder form.

The binder and the metallic powder are thoroughly mechanically mixed together. The mixture is then heated to melt the binder and create a fluid with the metallic powder coated by the binder. Next, the mixture is formed into the shape of the turbine blade 10 at block 36, by using a known injection-molding apparatus to extrude the mixture into the cavity of the mold. The mold may optionally be heated to avoid excessively rapid solidification of the binder which would result in a brittle preform. During the injection process, the binder and metal powder flow around and through the core and fill the intracellular volume 30 of the core. The mixture is at a relatively low temperature, for example about 150^0 C (300^0 F). Accordingly, thermal stresses on the core are minimized. Once the mixture has solidified, the mold is opened and the resulting uncompacted or "green" preform with the core inside is removed (block 38). Figure 3 illustrates the physical structure of the "green" preform with the binder 40 and the metal powder 42 disposed in the intracellular volume 30.

The "green" preform comprises metal powder particles 42 suspended in the solidified binder 40 in the intracellular volume 30. The preform is not suitable for use as a finished component, but merely has sufficient mechanical strength to undergo further processing. At block 44 of Figure 5, the preform is leached to remove the majority of the binder 40, creating a so-called "brown" preform (see Figure 4). This may be done by submerging or washing the preform with a suitable solvent which dissolves the binder but does not attack the metallic powder 42.

Next, at block 46, the "brown" preform is sintered. The preform is placed in a chamber which includes means for creating a suitable atmosphere to prevent undesired oxidation of the preform or other reactions during the sintering process. In the illustrated example a supply of inert gas such as argon is connected to the interior of the chamber. The sintering could also be performed under a vacuum.

The preform is heated to a temperature below the liquidus temperature of the metallic powder 42 and high enough to cause the metallic powder particles 42 to fuse together and consolidate, for example about 700^0 C (1300^0 F). The high temperature also melts and drives out any remaining binder. The preform is held at the desired temperature for a selected time period long enough to result in a consolidated turbine blade 10. The heating rate is selected depending on variables such as the mass of the preform and the desired cycle time of the sintering process. The metallic powder 42 will provide a support for the foam material during the initial sintering cycle, preventing the immediate thermal fatigue failure that normally occurs, and allowing the foam material to then become an integral part of the structure. The presence of the foam can then supply either stiffness or other mechanical property improvements to the turbine blade 10.

When the sintering cycle is complete, the turbine blade 10 is removed from the chamber and allowed to cool. When required, the turbine blade 10 may be subjected to further consolidation using a known hot isostatic pressing ("HIP") process to result in a substantially 100% dense component. If desired, the turbine blade 10 may be subjected to additional processes such as final machining, coating, inspection, etc. in a known manner.

The foregoing has described a manufacturing process for metallic composite foam components. While specific embodiments of the present invention have been described, it will be apparent to those skilled in the art that various modifications thereto can be made without departing from the spirit and scope of the invention. Accordingly, the foregoing description of the preferred embodiment of the invention and the best mode for practicing the invention are provided for the purpose of illustration only and not for the purpose of limitation, the invention being defined by the claims.

CLAIMS:

1. A method of producing a metallic composite component, comprising:

   providing a core comprising a foam material having ceramic or metallic cell walls with intracellular volume therebetween;

   disposing the core in a mold having a cavity defining the exterior contours of the component;

   providing a mixture of a metallic powder and a binder;

   melting the binder and injecting the mixture into the mold so as to penetrate the intracellular volume;

   removing a portion of the binder from the preform; and

   heating the preform to remove the remainder of the binder and to sinter the metal powder together to form the finished component.

2. The method of claim 1 further comprising performing a hot isostatic pressing treatment on the component after the heating step.

3. The method of claim 1 or 2 wherein the core defines at least a portion of the exterior contours of the component.

4. The method of any one of the preceding claims wherein the core is smaller than the component and defines an internal reinforcement member.

5. The method of any one of the preceding claims wherein the cell walls are ceramic.

6. The method of claim 5 wherein the cell walls consist essentially of alumina.

7. The method of any one of the preceding claims wherein the component is an airfoil for a gas turbine engine.

8. A preform for a metallic composite component, comprising:

a core comprising a foam material having ceramic or metallic cell walls with intracellular volume therebetween; the core defining at least a portion of the exterior contour of the component; and

a mixture of a metallic powder and a binder disposed in the intracellular volume.

9. The preform of claim 8 wherein the core is smaller than the component and defines an internal reinforcement member.

10. The preform of claim 8 or 9 wherein the cell walls consist essentially of alumina.