United States Patent

Schmidt

[54] METHOD OF MAKING A BERYLLIUM TITANIUM COMPOSITE

- [72] Inventor: Richard Schmidt, McLean, Va.
- [73] Assignee: The United States of America as represented by the Secretary of the Navy
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- [21] Appl. No.: 29,597

- 29/480, 482, 472.3

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[45] **June 6, 1972**

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Primary Examiner-John F. Campbell

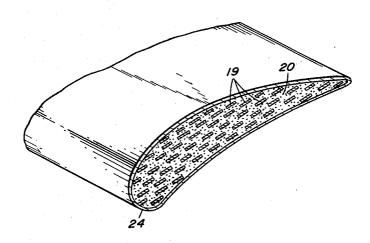
Assistant Examiner-Richard Bernard Lazarus

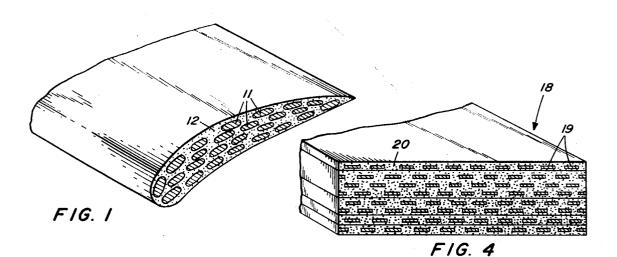
Attorney-R. S. Sciascia and Thomas O. Watson, Jr.

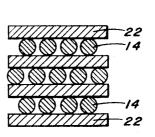
[57] ABSTRACT

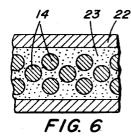
A method of making a beryllium reinforced titanium turbine blade. The method utilizes a preform composed of beryllium rods within a titanium structure. The preform is formed into intricate blading shapes by isothermal forging techniques.

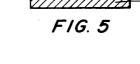
5 Claims, 7 Drawing Figures

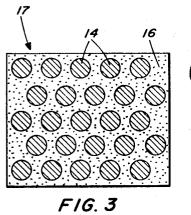


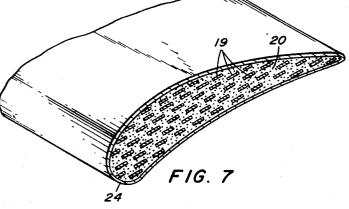












RICHARD SCHMIDT BY I house O. Water).

ATTORNEY

METHOD OF MAKING A BERYLLIUM TITANIUM COMPOSITE

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates generally to reinforced structural shapes and more particularly to beryllium reinforced turbine blading.

etc., use titanium as the major blading material because of its high strength, excellent toughness, and good erosion and corrosion resistance. The major shortcoming of titanium is its relatively low modulus of elasticity which greatly limits the rigidity of the blades and necessitates design compromises. 20 Some designs utilize a mechanical device or "bumper" which appears as a projection of the airfoil surface. These bumpers" are designed to positively affix each blade to its neighbors consequently minimizing bending and torsional stability problems. Other designs utilize an outer shroud to 25 prevent bending of the long blades. The use of these mechanical devices add greately to the weight of the equipment and cause a loss of efficiency due to the restriction of air flow.

In an effort to eliminate external mechanical devices, recent work has been directed toward increasing the modulus of 30 elasticity of titanium by reinforcing it with a high modulus material. This work has included a study of boron, silicon carbide, and beryllium as reinforcing material. These studies have shown beryllium wire composites to be superior to other metal matrix composites employing brittle filaments. In comparison 35 to these brittle filament composites, the beryllium composite is more resistant to foreign object damage and, in a blade configuration, has the capacity to bend plastically when hit without "snapping off." In addition, the ductility of the beryllium allows fabrication procedures to be employed which could 40not be considered for less ductile composite systems. The procedures being used allow fabrication by diffusion bonding alternate layers of thin titanium or aluminum foil and beryllium wire "mat" sections into a solid structure. The term "mat" refers to an evenly spaced array of reinforcing wires held by an 45 organic binder in the form of a thin (one filament diameter) sheet. This process has proven to be highly successful. However, the very high costs of beryllium wire greatly limits its use.

SUMMARY OF THE INVENTION

This invention is directed at a method of producing high strength, high modulus of elasticity, and low density composite blading without the use of high cost wire. Beryllium is the only low density, high modulus of elasticity material that 55 can be fabricated by metallurgical hot working techniques. This invention utilizes beryllium in rod form to produce high strength, high modulus of elasticity, and low density composite blading without the use of high cost wire.

There are several routes that may be taken to end up with 60 the required properties for composite beryllium-titanium blading. The important considerations are:

1. The volume fraction of the beryllium reinforcement;

2. The size of the reinforcement;

3. The mechanical properties of both the titanium and 65 beryllium after fabrication of the blade; and

4. The bond strength and degree of reaction (alloying) between the beryllium and titanium.

For this invention, the volume fraction of the beryllium should be between 25 and 75 percent. Anything less than 25 70 percent will not give the required reinforcement and over 75 percent will result in a brittle composite blade. The size of the beryllium reinforcements should be as small as economically practical for optimum fracture toughness. A good rule would be to end up with a composite that has a minimum of approxi- 75 beryllium rods 14 into the holes.

mately six layers of reinforcement for good impact resistance. The fabrication temperature should not exceed 1,400° F to minimize loss of strength of beryllium and to reduce the reaction between these reactive materials.

5 With these considerations in mind, the present invention begins with a titanium-beryllium preform and, through a process known as isothermal forging, successfully forms these preforms into intricate shapes at relatively low temperatures and pressures. This involves the use of forging dies which are 10 heated to the forging temperature so that the piece being forged can remain at temperature for a longer period of time. Through a flow process known as creep, the preform readily flows into the shape of the hot die. This process allows Modern jet engines, steam turbines, aircraft, propellers, 15 processing of the forging preform at a temperature below that which causes reaction between the titanium and beryllium. It has been established that a temperature between 1,200° and 1,300° F is satisf story to cause equal flow of both the beryllium and titanium without excessive reaction.

OBJECTS OF THE INVENTION

Accordingly, it is an object of the present invention to eliminate the use of external mechanical devices from blading structures.

Another object is to provide a method of making a titanium based composite blade having a modulus of elasticity exceeding that of pure titanium.

A further object of the invention is the provision of a relatively inexpensive beryllium reinforced titanium blade.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cross section of a blade made according to the method of the present invention;

FIG. 2 shows a preform used in practicing the present invention:

FIG. 3 shows another preform utilized in the practice of the present invention;

FIG. 4 shows a composite beryllium titanium sheet;

FIG. 5 is a preform used to make the composite of FIG. 4;

FIG. 6 shows another preform used to make the composite of FIG. 4: and

FIG. 7 shows a second blade made under the method of the present invention and utilizing the preform of FIG. 4.

DETAILED DESCRIPTION OF THE PREFERRED **EMBODIMENTS**

The invention is illustrated, but not limited, by the following specific examples of the preparation of a beryllium reinforced titanium blade. Wherever possible, alternative modes of preparation are discussed but it is to be recognized that various additional modifications can be made without deviating from the scope of the invention. FIG. 1 shows a creep forged blade 10 made under a preferred method of the present invention. The cross section shows the distribution of the beryllium 11 within the titanium matrix 12.

The first step in producing the creep forged blade 10 of FIG. 1 is the production of beryllium rods by extrusion, drawing or machining from block. To obtain the preform 13 of FIG. 2, the beryllium rods 14 are then clad with titanium as indicated by reference numeral 15. The cladding may be done by many methods such as slipping the rods into extruded or drawn titanium tubing, forming tubing from sheet, vapor depositing or electroplating titanium onto the rod, etc. The composite beryllium titanium rods are then bundled and are the first blade preform 13 as shown in FIG. 2. A second method of producing a suitable blade preform is to drill accurately spaced holes in a titanium block 16 (see FIG. 3) and place

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The volume fraction of beryllium to titanium should be maintained between 25 and 75 percent. Less than 25 percent beryllium will not give sufficient reinforcement and more than 75 percent beryllium will result in a brittle composite blade. The volume fraction of the beryllium reinforcement, in the two illustrated preforms, is controlled by the thickness of the cladding in the preform of FIG. 2 and the spacing of the drilled holes in the preform of FIG. 3.

The size of the beryllium reinforcements should be as small as economically practical for optimum fracture toughness. Good impact resistance requires that a minimum of approximately six layers of reinforcement be present in the final blade form and consequently in the initial preform structure.

Dependent on the requirement in the final blade form (see discussion below) the next step in the fabrication can be to directly preform the clad beryllium rod preform 13 of FIG. 2 or the drilled block preform 17 of FIG. 3 into the blade shape. This involves the use of forging dies which are heated to the forging temperature so that the piece being forged can remain at temperature for longer periods of time. This process allows processing of the forging preform at a temperature which will be below that which causes reaction between titanium and beryllium. It has been established that temperatures ranging between approximately 1,200° and 1,300° F are satisfactory to cause equal flow of both the beryllium and titanium without 25 excessive reaction.

In the event a smaller cross-section of reinforcement is desired and/or a preform shape is needed for ease in forging, the clad rod bundle 13 of FIG. 2 or drilled block preform 17 of FIG. 3 can be extruded to the desired preform size and shape. 30 This extruded composite can then serve as a creep forging blank or a rolling blank for additional processing. The ribbon reinforced composite 18 of FIG. 4 is typical of that obtained following extrusion and/or hot rolling.

FIGS. 5 and 6 illustrate additional preforms that may be 35 used in manufacture of the composite 18 of FIG. 4. FIG. 5 shows a plurality of beryllium rods 14 in spaced parallel relation, separated by titanium plates 22. These plates may be grooved to provide means of spacing and aligning the rod or the rods may be held in place by adhesive, tack welding or any 40 other suitable means. The preform shown in FIG. 5 is passed through a hot rolling mill, the temperature of which is sufficient to cause the covering metal plates to flow and form a matrix and soften the beryllium wires so that they may be flattened into ribbons. In the rolling operation, end pieces may be 45 applied to shape the composites into slabs or sheets having flat parallel tops and bottom faces and square and parallel edges. The rolling operation is carried out at temperatures that metallurgically cold work the wire from a round cross-section to a flat strip or ribbon while diffusion bonding the reinforcing 50 ture comprises a block having accurately drilled holes therein ribbons 19 into the titanium matrix 20.

The preform of FIG. 6, shows a plurality of beryllium rods 14 covered by a powdered metal 23. Upper and lower titanium plates 22 may be added to the powdered titanium preform. The rods are secured together by spot welding or other means 55 so that they may be sent through a hot rolling mill to produce the composite 18 shown in FIG. 4. A more complete discussion of the production of the composite of FIG. 4 may be found in applicant's copending application Ser. No. 819,287 filed Apr. 25, 1969, now U.S. Pat. No. 3,609,855.

FIG. 7 shows a diffusion bonded blade made from the com-

posite of FIG. 4. To form this composite into a blade form, the composite is taken in sheet form and cut to the required width. To avoid beryllium extending to the surface, this cut sheet is covered with an envelope 24 of titanium. The covered composite is then diffusion bonded into the blade form as shown in FIG. 7.

The fact that this invention utilizes a "ductile" reinforcement enables one to fabricate complex shapes by modern metallurgical practices and also permits changes in design 10 shapes by simple additional hot deformation. Use of these fabrication methods will greatly reduce the fabrication cost of composite blades and will also result in a superior product in regard to modulus of elasticity, density, and ductility over that obtained through the use of brittle reinforcements such as 15 boron, silicon carbide, aluminum oxide, etc.

An important advantage over other composite approaches is that you do not start with high cost wire. During the fabrication of the composite blade, the reinforcing material is reduced in situ and formed to the desired diameter and shape. 20 Depending on the direction and degree of deformation, the reinforcement may end up in the form of wire, ribbons, oval rods, hexagonal rods, rectangular rods, etc. This invention has been illustrated as using beryllium rods as the starting reinforcing material. However, the preform consisting of alternate layers of sheet or strip that will permit a preform similar to

FIG. 4 in distribution of the reinforcement is also applicable. Obviously many modifications and variations of the present

invention are possible in the light of the above teachings. I claim:

1. A method of producing titanium structural shapes reinforced with beryllium comprising the steps of:

- forming beryllium into rods having a diameter of 0.125 inches or greater and a substantially circular cross-section:
- incorporating the beryllium rods into a titanium metal structure to form a preform, the volume fraction of beryllium to titanium being in the range of 25 to 75 percent;
- shaping the preform to convert the rods into ribbons having a substantially rectangular cross-section to form a ribbon reinforced composite;
- and subsequently shaping the composite into final form using heated forging dies in an isothermal forging operation at a temperature higher than 1,200° F but no higher than 1,400° F such that both the titanium and beryllium flow at an equal rate with negligible alloying.

2. The method of claim 1 wherein the step of incorporating comprises cladding the titanium to the beryllium rods and then forming the clad rods into bundles.

3. The method of claim 1 wherein the titanium metal strucand the step of incorporating comprises placing the beryllium rods into the drilled holes.

4. The method of claim 1 wherein the titanium metal structure comprises sheets and the step of incorporating comprises placing the titanium sheets and beryllium rods in alternating layers.

5. The method of claim 1 wherein the metal structure comprises powdered titanium having upper and lower covering plates and the step of incorporating comprises placing the 60 beryllium rods within the powdered metal.

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