

[54] CERAMIC TURBINE WHEEL

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[51] Int. Cl. F01d 5/28

[58] Field of Search 416/213, 241; 415/214

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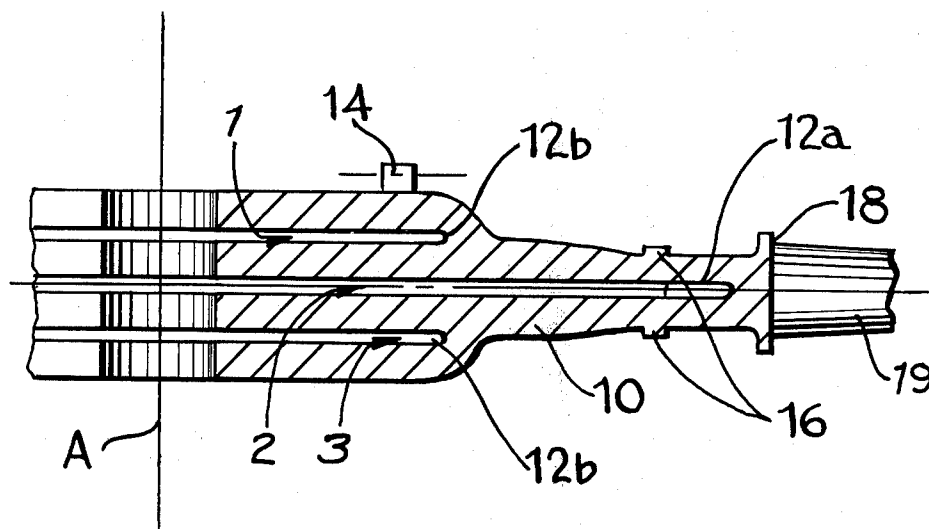
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[57] ABSTRACT

A unitary turbine wheel formed of reaction-bonded silicon nitride in which each portion of the cross-sectional area of the hub-blade assembly has at least one dimension extending between opposing surfaces thereof which is no greater than one-fourth inch.

3 Claims, 2 Drawing Figures



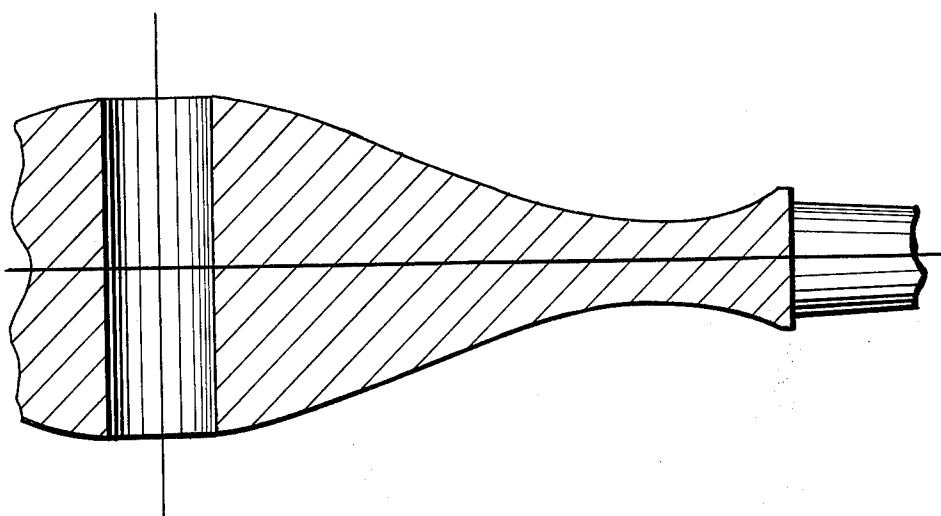


FIG. 1

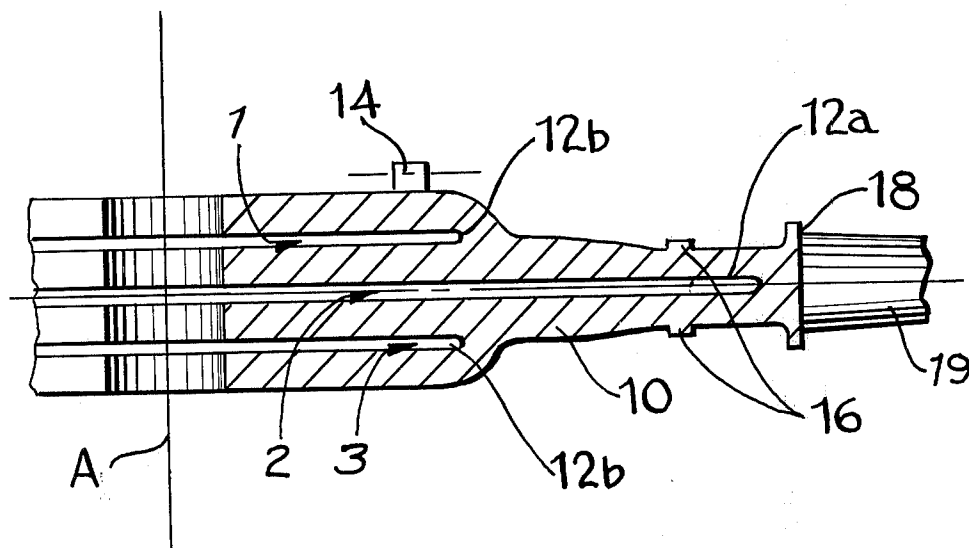


FIG. 2

CERAMIC TURBINE WHEEL

CROSS REFERENCE TO RELATED APPLICATION

This invention pertains to one useful application for silicon nitride produced in the manner described in U.S. patent application Ser. No. 263,578, now abandoned, filed June 16, 1972 by Malcolm E. Washburn, hereby incorporated by reference in this application, in its entirety. Patent application Ser. No. 263,578 has been superceded since by continuation-in-part application Ser. No. 370,745, filed June 18, 1973.

BACKGROUND OF THE INVENTION

Field of Invention

This invention relates to a ceramic turbine wheel and especially to a turbine wheel manufactured from ceramic material ultimately consisting essentially of silicon nitride.

Description of the Prior Art

The copending prior application of Malcom E. Washburn referred to above includes references to several prior patents and several prior publications all relating to methods of manufacturing silicon nitride. The copending prior application of M. L. Torti, Ser. No. 301,472, filed Oct. 27, 1972 describes a composite turbine wheel formed of a sintered silicon nitride rim and a hot-pressed hub.

SUMMARY OF THE INVENTION

The present invention contemplates a turbine wheel initially formed to the desired shape from compacted silicon powder, which is machined to a final shape in which essentially none of the silicon in the hub-blade assembly is more than one-eighth inch from an outside or an inside surface of the shape. The machined shape is then reacted with nitrogen to form a high strength structural unit of the desired configuration composed of substantially continuous silicon nitride material.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the accompanying drawings, in which the respective reference numerals refer to like or corresponding parts, wherein:

FIG. 1 comprises a transverse section extending radially of a typical unitary turbine hub-blade assembly of a suitable configuration for manufacture from a high strength alloy steel, and

FIG. 2 comprises a transverse section extending radially of a unitary turbine hub-blade assembly of a configuration suitable for manufacture from silicon for subsequent conversion to silicon nitride.

DESCRIPTION OF THE PREFERRED EMBODIMENT

If the material used to manufacture a turbine wheel is changed from steel to ceramic, the mass of the wheel is decreased by approximately 60 percent with an attendant substantial saving in weight.

One ideal material for a turbine wheel manufactured from ceramic material is reaction bonded silicon nitride. However, the silicon must first be formed into the final wheel shape and must then be nitrided to form silicon nitride. The problem in this procedure is that the nitrogen will only react the silicon to a depth of approximately one-eighth inch from the nearest surface. At depths greater than one-eighth inch, the reaction

becomes unreliable and may result in low density silicon nitride or even unreacted silicon, if the depth is great enough. Low density or unreacted areas have low or zero strength. Consequently, such low density or unreacted areas must be minimized and, preferably, be eliminated completely in the manufacture of a turbine wheel with extremely high strength requirements.

The turbine hub-blade assembly cross section illustrated in FIG. 1 is a representation of a typical configuration thereof manufactured from steel characterized by a continuous relatively thick cross section not suitable for a turbine wheel to be manufactured from silicon and then nitrided as contemplated by this invention.

The turbine hub-blade assembly cross section illustrated in FIG. 2 shows one configuration thereof suitable for manufacture according to the instant invention with uniformly thin individual cross sections throughout its entire relatively thicker cumulative cross-sectional area provided by incorporating in this cross-sectional area, generally designated by the reference numeral 10 and shown in operative relation to its axis of rotation A, a series of radially extending annular slits 12a and 12b of the proper size and shape to reduce the minimum section of the material in all parts thereof to not more than the maximum thickness acceptable for a fully successful nitriding operation.

Since the nitrogen can only be depended upon to react the silicon to a depth of approximately one-eighth inch from the nearest inner or outer surface of any individual cross section, the minimum cross section in all parts of the turbine hub-blade assembly must not exceed one-fourth inch. That is, some of the cross sections taken in various different directions at any part of the turbine hub-blade assembly may substantially exceed one-fourth inch, as long there is at least one minimum cross section at any such part which does not exceed one-fourth inch. Thus, the reaction of the nitrogen with the silicon to a depth of one-eighth inch from each of the opposing surfaces of the cross section will result in reacting each of the entire minimum cross sections not more than one-fourth inch in thickness.

The silicon employed as a starting material is preferably quite finely powdered, with a maximum particle size of 10 microns and an average particle size on the order of 2 microns or less. This fine silicon powder, is isostatically pressed to a green density on the order of 1.5 grams/cc. It is then sintered under an inert gas atmosphere such as argon. The inert gas sintering furnace is preferably evacuated several times and flushed with argon to remove atmosphere contaminants as completely as possible. The sintering operation is preferably carried out at a temperature on the order of 1100°C., the time depending upon the mass of silicon. This provides a bonded product which has sufficient strength to be readily machined. This sintering operation bonds the silicon particles to each other, thus providing a continuous silicon structure. Evidence that such bonding of silicon occurs is the increased strength of the compact. Also, photomicrographs of this sintered product show bonding of the silicon grains.

The time and temperature required for this first sintering operation are determined by the density and size of the compact, the particle size of the silicon and the strength required in the compact for machining. For example, for low density compacts, it will be necessary to increase the sintering time and/or temperature to ob-

tain sufficient bonding of the silicon particles to achieve a continuous structure and higher density and strength in the final product. When even finer silicon is used, sintering times and temperatures can probably be decreased. While the sintering gives the compact sufficient strength to be machined, it also provides the important step of making a continuous silicon structure, from which a continuous silicon nitride structure is produced by the nitriding operation.

After machining, the silicon mass is nitrided in accordance with standard procedures.

It should be understood that the configuration of a turbine wheel manufactured from ceramic materials according to the teachings of the instant invention can be varied as required to accommodate wheel size and speed of rotation.

The curvic coupling 14 shown in FIG. 2 is a commonly used method of taking power from the wheel to a shaft. Other means for accomplishing this function can also be accommodated in the configuration of a turbine wheel manufactured from ceramic material.

As indicated by the showing in FIG. 2, a turbine wheel manufactured from ceramic material according to the teachings of the instant invention, may conveniently include balancing rings 16, a blade platform 18, and a uniformly spaced series of cantilevered turbine blades 19 all integral with and each extending radially outwardly from the blade platform 18.

Since the configuration of a turbine wheel may necessarily be modified to meet the desired requirements for various different applications, it is to be understood that the description herein and the showing in the accompanying drawings are illustrative rather than limiting, and that this invention is to be limited solely by the scope of the claims appended hereto.

What is claimed is:

1. A turbine wheel comprising a unitary hub-blade assembly formed of reaction bonded silicon nitride so that its radial cross section transversely between opposing surfaces thereof includes a relatively wide cross-sectional area extending substantially more than one-fourth inch between its opposing outside surfaces and including mutually spaced but interconnected individual portions thereof, wherein

the outside and inside surfaces of said relatively wide

cross-sectional area are so shaped and relatively disposed that every part of each individual portion of the relatively wide cross-sectional area has at least one transverse dimension extending between the opposing surfaces thereof which is no greater than one-fourth inch.

2. A turbine wheel including a unitary hub-blade assembly made from reaction sintered silicon nitride, with an annular hub having a radially extending transverse cross-sectional area wider than one-fourth inch between opposing outside surfaces thereof and including at least two spaced individual portions of the cross-sectional area, wherein

the cross-sectional area includes at least one generally radially extending annular slit of the size and shape necessary to reduce the minimum cross section of every part of each individual portion of the cross-sectional area of the hub so that at least one transverse dimension extending between the opposing surfaces thereof is not more than one-fourth inch in thickness.

3. A method of manufacturing a unitary hub-blade assembly comprising a turbine wheel from ceramic material including the sequential steps of

compacting a quantity of fine silicon powder to a suitable external annular configuration for a hub-blade assembly comprising a turbine wheel including an annular portion thereof having a cross section from side to side thereof substantially in excess of one-fourth inch in thickness,

providing in the hub-blade assembly of the turbine wheel at least one internally disposed radially extending annular recess of the necessary size and shape in relation to the size and shape of the respective sides of said annular portion to reduce the minimum cross section of the compacted silicon powder so that at every point on said annular portion at least one transverse dimension extending from surface to surface thereof does not exceed one-fourth inch,

exposing the compacted silicon powder to a nitrogen atmosphere at a temperature and for a time sufficient to convert all of the compacted silicon powder to silicon nitride.

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