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POWDER METALLURGY ARTICLE

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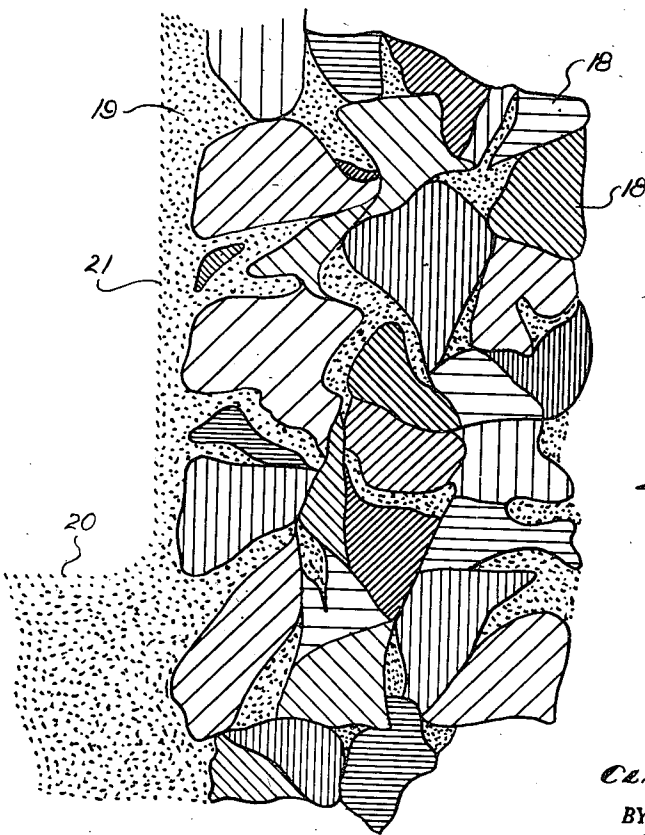
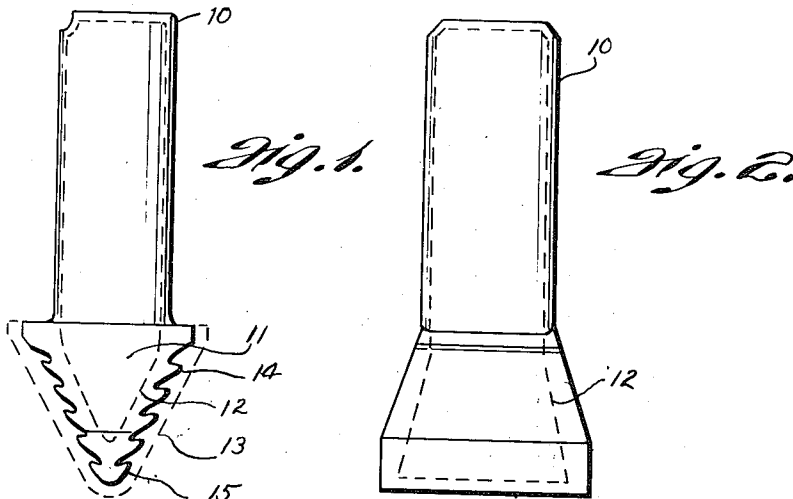


Fig. 3.

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POWDER METALLURGY ARTICLES

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The invention relates to a turbine blade for use at elevated temperatures, which is composed of substances having different melting points, and particularly to a sintered skeleton of a relatively high melting point formed with interconnecting pores substantially throughout its entirety, the pores being permeated with an infiltrant metal, the exterior faces of the turbine blade having a coating thereon of the infiltrant metal.

Heat resistant metallic articles such as blades, buckets, valves and the like for jet engines, rockets, or gas turbines and the like are not satisfactory when made by conventional casting or forging methods. One of the reasons is that the temperature at which the article is formed is near that of the operating temperature of the element in service and it thus is apparent that the element would not be strong and stable in its dimensions under operating conditions. Another difficulty is that the materials which maintain their strength at elevated temperatures under protective atmospheric conditions are subject to corrosion under the conditions of operation of elements such as gas turbine blades, and this tends to impair rapidly their strength.

Powder metallurgy methods must be used in order to meet the high temperature requirements in articles in the fields mentioned as well as in many other places. The previously used powder metallurgy processes employing simple pressing and sintering operations with mixtures of powdered ingredients have limitations due to inherent porosity of the article and fine grain size and weak grain boundaries of the resulting structure, all of which contribute to unfavorable hot tensile strength, hot fatigue strength, and resistance to creep at elevated temperatures.

In previously used powder metallurgy techniques involving impregnation of a formed compact, or skeleton, the high melting metal, alloy, or refractory material in a powdered form is usually shaped by compression in a mold and then removed from the forming mold before sintering. After the skeleton has been formed and sintered, a second or auxiliary lower melting metal is brought into contact with the skeleton in a suitable ceramic or metallic vessel and heat applied so as to liquefy the second metal, and cause the second or auxiliary metal to be drawn into the skeleton by capillary action. In such a process, the infiltrant metallic material will not completely cover the exterior face of the body.

In the forming of the skeleton, difficult problems arise when the shape is complex and irregular, due to lack of uniformity in the pressed

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skeleton because the particles of the powdered material will not be distributed evenly within the mold, or distributed in the mold in the desired pattern. In prior impregnation processes, sizing and machining frequently have been necessary following the impregnation step. One reason is the uneven distribution of the second metal on the surface of the skeleton, which is caused by uncontrollable adherence of the second metal to the surface of the skeleton, and non-uniformity thereof.

One of the objects of the invention is to provide a shaped article having improved physical characteristics, including high hot tensile strength, high hot fatigue strength, high resistance to creep at elevated temperatures, and especially high corrosion resistance under conditions of operation.

The shaped article of the present invention comprises a continuous skeleton of high melting point made from powdered materials suitably sintered, the skeleton structure having intercommunicating pores substantially throughout its entirety. The pores of the skeleton are permeated throughout by a network of an infiltrant metallic material, and a layer of corrosion resistant metallic material is formed on the faces of the article, said layer being integrally merged, fused, or joined to the metallic material net work permeating the pores of the skeleton. The layer of metal is formed of sufficient thickness to suitably protect the article from corrosion.

The skeleton is selected from materials so as to have high hot tensile strength, high hot fatigue strength, and high resistance to creep at elevated temperatures. The infiltrant metallic material is selected to have the desired corrosion resistance and to impart the desired physical properties to the skeleton. Preferably the layer of corrosion resistant material is the same as that of the infiltrant metallic material.

The article can be formed efficaciously by performing the impregnation step with the skeleton in a mold and applying pressure to the infiltrant material while the infiltrant is in contact with the skeleton in a pore impregnatable or liquefied condition. The infiltrant metal will completely fill the mold so that the article will be accurately sized, and will form a continuous layer over the faces of the article. The skeleton can be arranged in conjunction with the mold so that there is sufficient clearance to form the desired thickness of the coating layer. The thickness of this layer of the infiltrant material is increased

at the base of the turbine blade for the shaped wheel engaging portions thereof.

The harder and more abrasive types of skeleton materials are difficult to machine and this difficulty normally remains after the pores have been filled with the infiltrated material. It is desirable, therefore, to provide a layer of a skeleton-free infiltrant portion at places where the article is to be machined. This can be accomplished by placing the skeleton in a mold having an increased clearance between the mold walls and the skeleton at areas where there is to be skeleton-free infiltrant metal. The skeleton is impregnated while in said mold, preferably in a pressure differential apparatus, so that the infiltrant completely fills the mold, thus leaving skeleton-free infiltrant metal of the desired thickness in selected areas.

The refractory materials as employed in this invention have a low coefficient of expansion, usually in the order of $\frac{1}{3}$ to $\frac{1}{2}$ of that of steel, or other metal alloys conventionally used in the construction of components of engines, turbines, and the like. This would result in difficulties if plain refractory compounds were used as structural materials for such elements as turbine blades, buckets, valves and the like.

In the present invention, the skeleton can be made of a refractory material having the low coefficient of expansion and the desired strength characteristics at elevated temperatures. The infiltrant material can be selected having a sufficiently high coefficient of expansion, so that the correct dimensional relationship can be maintained with a supporting part for the composite article at all service temperatures. The thickness of the infiltrant outside layer is increased, as required, at the point of joinder of the blade with the element to which it is to be attached, thus maintaining a fit without regard to temperature of operation.

The difference in coefficients of expansion of the skeleton materials and the infiltrant materials will result in other advantages, such as strengthening of the composite structure, as will be explained hereafter.

These and other features, advantages, and objects of the invention will become apparent from the following description and drawings.

In the drawings:

Fig. 1 shows a side view of one form of a turbine blade of the present invention.

Fig. 2 shows a front view of the blade of Fig. 1.

Fig. 3 shows an enlarged representation of a section of the composite body at the point where the blade body joins the base thereof.

The invention will now be described in conjunction with a turbine blade, such as is generally used in gas turbines.

The blade may have a tip or blade portion 10 and a base portion 11 which is machined to fit accurately into a suitably shaped notch or aperture in the turbine wheel.

It is desirable that the materials and dimensions of the base portion relative to the turbine wheel be chosen so that the blade will remain tightly held under the elevated temperature conditions of operation.

In formation of the blade, the skeleton or high refractory phase dimensions or outline are diagrammatically indicated by the inner dashed lines 12 (Figs. 1, 2). The mold used during impregnation is arranged so that the infiltrant metal or corrosion resistant phase will fill the

the mold and form the outside of the tip portion of the blade and will reach the dashed lines 13 of the base 11. Thus there will be an excess of the infiltrant metal at 14 which can be machined to the desired base shape 15. Such a formation of the composite article with a thickened infiltrant metal portion may be termed "undercasting." As previously mentioned, the layer of infiltrant metallic material can be increased as desired at other points such as where erosion takes place on the blade.

In Fig. 3, the skeleton or high refractory phase is indicated at 18, the particles thereof being formed together with intercommunicating pores therebetween, said phase being continuous.

As an example, the skeleton material may be tungsten, molybdenum, titanium, tantalum, columbium, chromium, zirconium, or their alloys with each other, or with iron, nickel, cobalt, or their compounds of metalloidal character with carbon, boron, silicon, nitrogen, etc. Some examples of the aforementioned compounds of metalloidal character are tungsten carbide (WC), titanium carbide (TiC), molybdenum carbide (Mo_2C), tantalum carbide (TaC), columbium carbide (CbC), chromium carbide (Cr_3C_2), zirconium carbide (ZrC), vanadium carbide (VC), tungsten boride (WB_2), titanium boride (TiB_2), molybdenum boride (MoB), tantalum boride (TaB), columbium boride (CbB), chromium boride (CrB), zirconium boride (Zr_3B_4), vanadium boride (VB_2), thorium boride (ThB_6); also stable refractory materials or compounds such as beryllium oxide, magnesium oxide, aluminum oxide, zirconium oxide, silicon carbide, and boron carbide can be used, these being stable at elevated temperatures.

A typical composition of a homogeneous skeleton material as employed by this invention consists of 70% by weight of tungsten carbide (WC), 25% titanium carbide (TiC), and 5% cobalt (Co), the tungsten carbide (WC) and titanium carbide (TiC) components being combined as a solid solution. Another typical composition of a homogeneous skeleton material as employed by this invention consists of 45% by weight of tungsten carbide (WC), 25% titanium carbide (TiC), 25% chromium carbide (Cr_3C_2) and 5% cobalt (Co), the tungsten carbide (WC) and titanium carbide (TiC) and chromium carbide (Cr_3C_2) components again being combined as a solid solution.

The infiltrant metallic material or corrosion resistant phase network is indicated at 19 (Fig. 3), as entirely permeating all of the intercommunicating pores at the skeleton, thus forming a network as equally continuous as the skeleton. At 20 is seen the excess infiltrant metal of sufficient thickness to allow for machining and at 21 is indicated the layer of corrosion resistant metal on the exterior faces of the article integrally merged, fused or joined with the infiltrant metal network permeating the pores of the skeleton. The representation in Fig. 3 corresponds to a single plane as is normally obtained in metallographic procedures, the infiltrant metal being a continuous network throughout the pores of the skeleton, this necessarily resulting from the manner in which the infiltrant metal fills the pores of the skeleton. Depending upon the alloyability between skeleton and infiltrant materials, there may be formed an interphase along the boundaries of the same where they are in contact with each other. This interphase may ma-

terially contribute to the strength of the composite structure.

Again merely by way of example, the impregnating material may be iron, nickel, cobalt, chromium and their alloys with each other, or their alloys with the previously mentioned refractory metals, or metal compounds as minor constituents. It is to be understood that the appropriate infiltrant having a dissimilar lower melting point relative to the skeleton can be used, and that the word "metal" in the claims is to be construed to include the aforementioned. A typical composition of impregnating material employed successfully by this invention comprises an alloy containing 69% by weight of cobalt, 25% chromium and 6% molybdenum. Another example is a material containing 50% by weight of cobalt, 29% chromium, 15% nickel and 6% molybdenum. Still another example is one containing 52% by weight of cobalt, 28% chromium, 11% nickel, and 9% tungsten. Another example contains 60% by weight of nickel, 16% molybdenum, 14% chromium, 5% tungsten and 5% iron, while still another contains 60% by weight of chromium, 25% molybdenum and 15% iron.

As mentioned previously, the coefficient of expansion of the infiltrant phase is usually much higher than that of the skeleton phase. Consequently, because the infiltrant phase is carried out at a much higher temperature than the operating temperature of the article, there will be a shrinkage of the infiltrant phase relative to the refractory phase. The relationship of the coefficients will be such as to create internal stress conditions in the article, so that better elevated temperature strength and creep resistance will be obtained.

It is apparent that details of construction can be varied without departing from the spirit of the invention except as defined in the appended claims.

We claim:

1. A composite material shaped turbine blade having a base portion engageable with a turbine wheel for use at elevated temperatures in corrosive atmospheres, said blade being composed

of substances of different melting points and having a sintered porous skeleton of higher melting point normally corrodible at the temperatures of operation and formed with intercommunicating pores substantially throughout its entirety, the pores thereof being permeated with an infiltrant metal having corrosion resistant properties under the conditions of operation and a substantially continuous controlled layer of said infiltrant metal of predetermined thickness on the exterior faces of said blade to protect the same, said layer being integrally fused with the metal permeating said pores, the layer being thickened at the base portion of the blade for the shaped wheel engaging portions thereof.

2. In a composite material shaped turbine blade according to claim 1, the sintered porous skeleton consisting of titanium carbide.

3. In a composite material shaped turbine blade according to claim 1, the sintered porous skeleton consisting of tungsten carbide.

4. In a composite material shaped turbine blade according to claim 1, the sintered porous skeleton consisting of 70 weight per cent tungsten carbide, 25 weight per cent titanium carbide and 5 weight per cent cobalt.

5. In a composite material shaped turbine blade according to claim 1, the sintered porous skeleton consisting of 45 weight per cent tungsten carbide, 25 weight per cent titanium carbide, 25 weight per cent chromium carbide and 5 weight per cent cobalt.

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