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GAS TURBINE NOZZLE VANE AND LIKE ARTICLES

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Fig. 1.

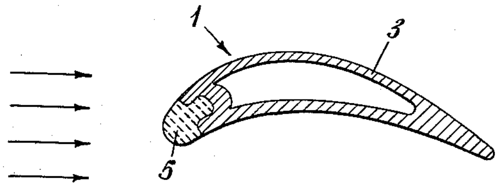
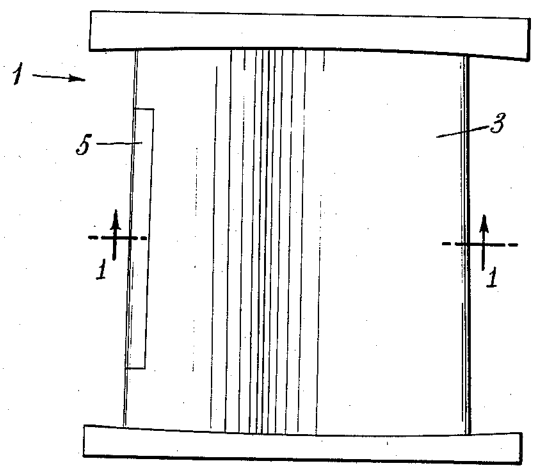


Fig. 2.



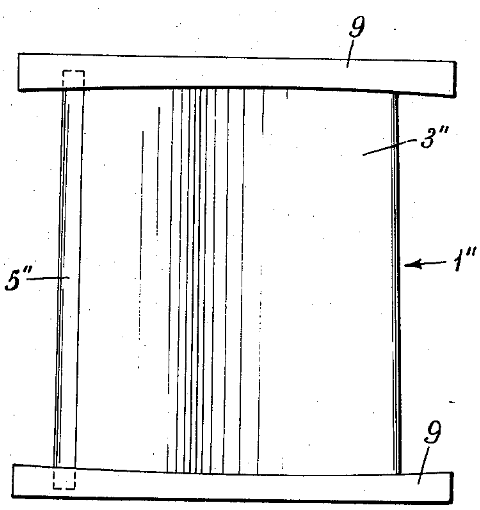


Fig. 4.

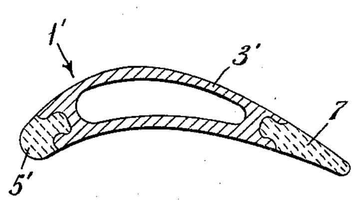


Fig. 3.

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GAS TURBINE NOZZLE VANE AND LIKE ARTICLES

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7 Claims. (Cl. 29—183)

The present invention relates to gas turbine nozzle vanes and like articles and more particularly to a novel composite gas turbine nozzle vane having both improved thermal shock resistance and improved resistance to deformation under high temperature operating conditions.

In the operation of gas turbines and the like, the nozzle vanes of the apparatus are continuously subjected to a very severe and complex environment, e.g. high temperatures, severe thermal gradients, erosion, and forces which tend to deform the nozzle vanes, particularly the trailing portions thereof.

The aforesaid environmental conditions are developed mainly by the high velocity, high temperature effluent of the turbine which continuously impinges on the leading edges of the nozzle vanes and, in its continuous passage, exerts strenuous forces against the thinner trailing edges of the vanes.

The continuous impinging contact of the effluent against the leading edges of the vanes tends to erode these edges and, further, produces severe temperature gradients in the vanes by the devlopment of localized extremely high temperatures at the leading edges and in contiguous sections of the trailing portions of the vanes.

In addition to the severe thermal shock to which the vanes are subjected due to the aforedscribed conditions, the heat which is conducted from the very high temperature regions at the leading portions of the vanes to the thinner trailing portions renders these thinner portions less capable of withstanding the strenuous forces exerted by the turbine effluent.

Consequently, due to the severe temperature gradients and other thermal conditions encountered by the nozzle vanes presently employed in gas turbines and like apparatus, the permissible operational periods and operating temperatures of these apparatus are considerably limited.

It is therefore an object of the present invention to provide a gas turbine nozzle vane having both improved resistance to thermal shock and increased resistance to the deforming forces exerted by the turbine effluent.

Other objects will be apparent from the following description and claims taken in conjunction with the drawing in which:

FIGURE 1 shows a cross section of an embodiment of a composite gas turbine nozzle vane of the present invention.

FIGURE 2 shows the upper surface of the nozzle vane of FIGURE 1.

FIGURE 3 is a cross section of a further embodiment of the present invention and

FIGURE 4 shows a still further embodiment of the present invention.

A gas turbine nozzle vane or like article in accordance with the present invention is a composite article of manufacture comprising a metallic body member and a heat-resistant non-metallic member fixedly joined thereto and forming at least part of an edge surface of the nozzle vane.

The present invention will be more clearly understood by referring to the drawing which shows in FIGURES 1 and 2 a gas turbine nozzle vane **1** having a metal body member **3** and a leading edge member **5** which extends over the portion of the leading edge of the vane at which

the highest temperatures are developed during turbine operation. Body member **3** is shown in the drawing to have a hollow center which can be utilized in providing cooling for the vane. However, hollow construction is not essential to the present invention and solid vanes can also be used.

In the present invention, the body member is formed of a suitable high temperature metal or alloy such as the well-known nickel- or cobalt-base super-alloys while the edge material is formed of different material such as a heat-resistant ceramic or metal ceramic material. Heat-resistant metal compounds, and heat-resistant bonded mixtures of metal compounds can also be used for the edge material. The body members and edges are separately formed and can be fabricated by investment casting, extrusion, forging, slip casting or other known techniques. When the separate body and edge members are formed to the proper dimensions, they are fixedly connected to provide an article having a surface which is suitable for a gas turbine nozzle vane or like article. This can be accomplished for example, by the keying joint illustrated in the drawing. It is to be understood, of course, that while the particular manner of mechanically connecting the component parts of the composite turbine blade is not critical, the connection should be such as to provide sufficient strength for the intended use.

The composite gas turbine vane as above described, when in operation, is exposed to the flow of turbine effluent, indicated in the drawing by the arrows, with the result that extremely high temperatures are developed at the leading edge. However, due to what may be termed a "thermal barrier" which is formed at the joint between the separately formed edge member and vane, the conduction of heat from the non-metallic leading edge to the body member and relatively thin trailing portion of the vane is substantially reduced. Also, whatever heat is developed in the body member of the vane tends to be more uniformy distributed so that the temperature gradient in the body member is much less severe than would be expected.

Consequently, by virtue of its composite construction, the nozzle vane of the present invention, in effect, has greatly improved resistance to deformation and thermal shock and can thus be used for longer periods at operating temperatures substantially higher than the maximum permissible with a gas turbine vane of integral construction having the same composition as either the edge or body member of the composite vane.

In a further embodiment of the invention, illustrated in FIGURE 3, a separate edge member **7** can be similarly provided for the trailing portion of the nozzle vane. In this way, the temperature gradients in the body member are further moderated and conduction of heat from the forward portion of the vane to the trailing edge is further reduced. As a result, higher operating temperatures and longer operating times can be used.

In the practice of the present invention, the component parts of the nozzle vane are formed of different materials which are especially suitable for use under the operating conditions encountered at the locations of the respective component parts.

For example, since the composite structure of the present invention in effect divides the nozzle vane into a very high temperature forward region and a lower-temperature trailing portion which is subjected to severe deforming forces, different materials having different properties to accommodate the distinct operating environments can be employed with advantage. In a specific nozzle vane in accordance with the present invention, and in a form similar to that shown in FIGURE 1, the edge member was formed from a metal ceramic material (23 percent alumina; 77 percent chromium) and the vane was formed from a nickel-base alloy (12.5 percent chromium, 4.5 percent molybdenum, 6 percent aluminum, 2 percent columbium plus tantalum and the balance essentially nickel with minor amounts of carbon, boron, zirconium and titanium). It was found that under severe thermal shock testing at temperatures up to about 2100° F. both the metal ceramic leading edge of the vane and the body member were substantially unaffected.

In the manufacture of the composite vanes of this invention from different materials, any suitable technique can be employed for preparing the component parts such as, for example, slip casting, extrusion, and die-forming. Also, any suitable method for joining the component parts can be used provided that a thermal barrier is maintained between the parts and the mechanical strength of the joint is sufficient to withstand the forces encountered in operation. A particularly effective way to accomplish this is to first prepare the edge member from the desired heat-resistant material in a form such as shown in the drawing and then incorporate the edge member as an insert in a wax pattern designed for the body member. The well-known "lost wax" or other technique is then followed to provide a mold in which the metal body member is cast. The resulting article is a composite turbine blade having an edge surface member securely fixed to the vane.

In addition to the materials previously mentioned, a wide variety of substances can be effectively employed in the formation of the component parts of the turbine blade of the present invention. The following table sets forth a selection of materials which can be advantageously employed; however, this tabulation is not to be considered as limitative.

TABLE

Type Material	Component	Specific Example	Nominal Composition, Weight/Percent
Alloy	Body member	Nickel-base alloy	12.5 percent Cr, 4.5 percent Mo, 6 percent Al, 3 percent total of Cb, Ta, B, C, Ti, Zr.
Do	do	Cobalt-base alloy	21.5 percent Cr, 10 percent W, 7.5 percent Ta, 4 percent total of Si, C, Fe, Ni.
Ceramic	Edge	Alumina	Al_2O_3.
Do	do	Beryllia	About 99 percent BeO.
Metal Ceramic	do	Metal Ceramic	23 percent alumina, 77 percent chromium.
Do	do	do	25 percent Cr, 60 percent W, 15 percent alumina.
Do	do	do	59 percent Cr, 20 percent Mo, 19 percent alumina, 2 percent Ti.
Metal Compound	do	Titanium diboride	90 to 99+ percent TiB_2 plus modifying ingredients and impurities.
Do	do	Silicon nitride	Principally Si_3N_4.
Bonded mixture	do	Cemented titanium carbide.	Titanium carbide bonded with about 40 percent Ni or Co.

The metal ceramic materials, in the order in which they appear in the table are disclosed in U.S. Patents 2,698,990, 2,656,596 and 2,783,530, respectively; titanium diboride is disclosed in U.S. Patent 3,003,885. Cemented titanium carbide is sold commercially as Kentanium, a trademark of Kennametal Inc.

In general, a nozzle vane of the present invention formed of any of the above-specified or similar edge materials with any of the specified or similar vane materials will provide an article characterized by superior thermal shock resistance and improved resistance to deforming forces at its trailing portion. However, it is clear that for particular applications certain combinations of material will provide a much better over-all turbine vane than others. Therefore, in the practice of the present invention, the conditions to be encountered at the various portions of the turbine vane are analyzed and the material best suited for operation under a particular condition is used in the construction of the vane component for that portion of the blade.

The following examples are provided to further illustrate the present invention.

Example I

A nozzle vane as shown in FIGURES 1 and 2 was constructed having a metal ceramic leading edge (23 percent alumina; 77 percent chromium) and a nickel-base alloy vane member (12.5 percent chromium, 4.5 percent molybdenum, 6 percent aluminum, 2 percent columbium plus tantalum and the balance essentially nickel with minor amounts of carbon, boron, zirconium and titanium).

The metal ceramic edge member was formed by slip casting and subsequently positioned in a wax pattern die and incorporated as an insert in the wax pattern of a vane for the first-stage nozzle of a gas turbine.

The wax pattern containing the metal ceramic insert was processed by the "lost wax" casting technique to fashion a mold. After the usual additional mold processing, the nickel-base alloy was cast in the mold. After solidification and cooling of the metal, the resultant article was removed from the mold and cleaned. The article thus obtained was a composite turbine vane having a metal ceramic edge joined to a nickel-base alloy body member.

The nozzle vane described in Example I was tested under very severe conditions as described in the following Example II.

Example II

The composite nozzle vane described in Example I was subjected to a continuous test of ten consecutive three-hour cycles. Each of the first six temperature cycles was as follows:

30 minutes soak at 2000° F. followed by
100 counts of 1 minute hot (2000° F.) and
30 seconds cold (quenched to below 400° F.)

Each of the four subsequent cycles was as follows:

30 minutes soak at 2100° F. followed by
100 counts of 1 minute hot (2100° F.) and
30 seconds cold (quenched to below 400° F.)

The above-described test is very severe and it is ordinarily expected that most super alloy nozzle vanes will withstand only 2 to 4 cycles at 1800° F. to 2000° F.

It was found that after testing as in Example II, the composite nozzle vane of the invention was satisfactory in all respects and that all portions of the vane, including the nickel-base alloy trailing edge were substantially unaffected by the severe conditions encountered in the test. The fact that the metallic trailing portion was unaffected was surprising since under the same test conditions, the trailing edge of an integral nickel-base alloy turbine vane of the same composition would have failed.

As to modifications of the present invention, it was found that the leading or trailing edge components of the turbine vane may extend over the entire edge surface or only at a critical portion or portions of the edge surface. Several modifications were successfully made and found to be suitable for service. In one configuration illustrated in FIGURE 4, the forward edge member **5''** extended over the entire leading edge and into the shroud section of the vane **9**. In another, as shown in FIGURE 2, the edge member 5 was positioned in the center of the leading edge covering about 75 percent of the edge section. As regards the trailing portion, it is recommended that the trailing edge components constitute the entire trailing edge of the vane and also a portion of the shroud section of the vane, because of the thinner cross section available to resist the complex stresses usually concentrated at that portion of the turbine vane.

From the above description, it can be seen that the present invention provides a novel turbine vane having increased resistance to thermal shock and increased resistance to deformation at its trailing edge.

While the above description has been directed to particular materials for use in the construction of the composite nozzle vanes of this invention, it is to be understood that other known metals and non-metallic materials which have been used or suggested for use in the manufacture of nozzle vanes and the like can also be employed with advantage in accordance with the present invention.

What is claimed is:

1. A gas turbine nozzle vane and the like comprising a metallic body member and a pre-formed non-metallic forward edge member closely engaged with the body member through a keyed mechanical interlock joint said body member being formed of a material selected from the group consisting of nickel and cobalt base alloys and said edge member being formed of a heat resistant material selected from the group consisting of ceramics and non-metallic metal compounds.

2. An article in accordance with claim **1** wherein the selected non-metallic metal compound is titanium diboride.

3. An article in accordance with claim **1** wherein the selected non-metallic metal compound is silicon nitride.

4. An article in accordance with claim **1** wherein the selected ceramic material has a composition of about 23 percent alumina and about 77 percent chromium.

5. An article in accordance with claim **1** wherein the selected ceramic material has a composition of about 15 percent alumina, about 25 percent chromium and about 60 percent tungsten.

6. An article in accordance with claim **1** wherein the selected ceramic material has a composition of about 19 percent alumina, about 59 percent chromium, about 20 percent molybdenum, and about 2 percent titanium.

7. An article in accordance with claim **1** wherein the selected ceramic material is cemented titanium carbide bonded with about 40 percent of a material selected from the group consisting of nickel and cobalt.

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