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REINFORCED GAS-TURBINE BLADE OR VANE

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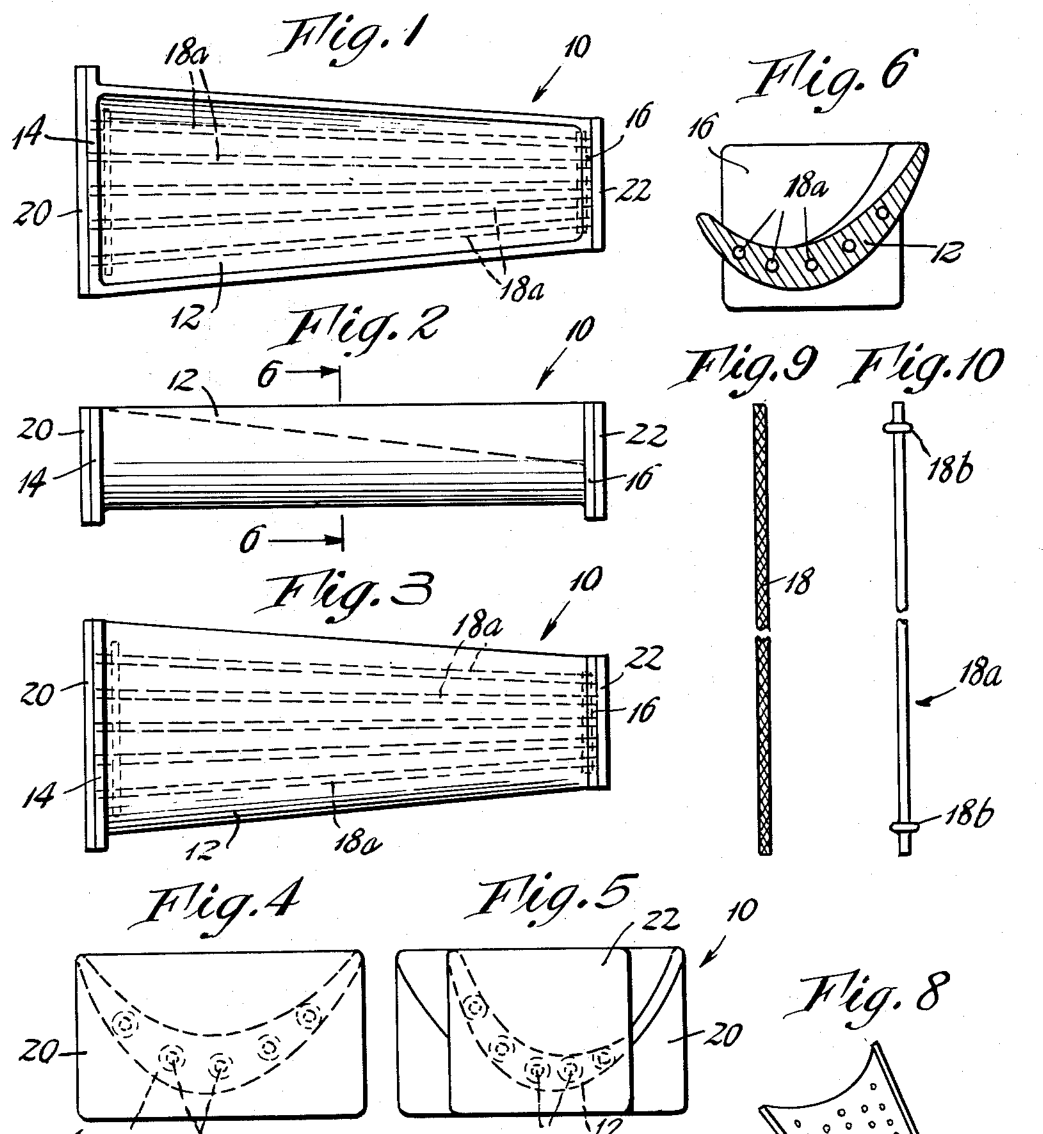

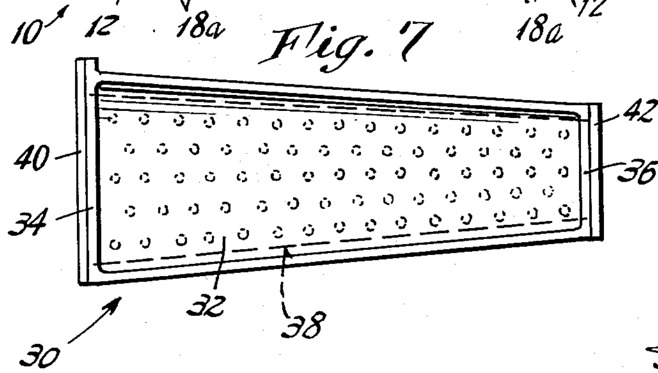

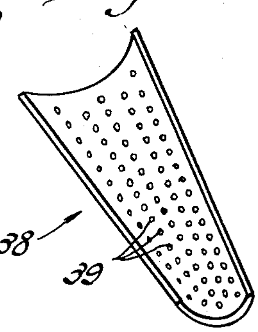

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REINFORCED GAS-TURBINE BLADE OR VANE

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3 Claims. (Cl. 253—77)

This application is a continuation-in-part of my copending applications Serial No. 257,938 filed February 12, 1963, and Serial No. 424,454 filed January 4, 1965, both entitled, "Reinforced Gas-Turbine Blade or Vane," both now abandoned.

This invention relates to turbines intended for high temperature service, such as gas turbines, and more particularly to the blade and vane components of such turbines.

Because of the increased efficiency which is attendant higher operating temperatures, present-day turbines are being designed with the thought of enabling the blades and vanes to withstand increasingly higher temperatures. However, under the severe thermal conditions encountered the blade and vane components despite all efforts to date still tend to fail quickly. To meet this situation, improved alloys are continually being developed and tried, for the purpose of combatting the thermal fatigue which results from elevated operating temperatures, as well as combatting stress rupture, growth and deformation.

A certain measure of success is had with alloys of cobalt or of nickel, wherein various percentages of other metals are present. However, all such alloys have one or more weaknesses, and do not fully successfully meet the complex and demanding requirements of turbine use.

For example, it is known that an alloy which has a satisfactory high temperature strength and which is resistant to deformation under thermal stress will show poor oxidation resistance and fail because of thermal fatigue after a period of apparently successful operation. Alloys which come under this category are those known commercially as Waspaloy, W152 and Stellite 31.

On the other hand, alloys which are developed to show good oxidation resistance and to withstand thermal fatigue quite well, lack mechanical strength and resistance to deformation, which characteristics are important in turbine engines. The SM series of alloys falls in this category.

The above disadvantages and drawbacks of prior turbine blades and vanes fabricated of SM or like alloys are obviated by the present invention, and one object of the invention is to provide an improved reinforced turbine blade or vane structure constituted principally of high-oxidation resistant metal such as SM alloy, which structure also has the necessary mechanical strength and resistance to deformation demanded for high temperature use in gas turbines. In accomplishing this object there is provided by the invention an improved composite blade or vane structure which is cast of SM (Sierra-Metals, division of Martin Marietta Co.) alloys, including cobalt base (manufacturer's "300" series) and nickel base (manufacturer's "200" series), or similar alloys in the desired configuration and which has incorporated in it strategically placed reinforcing wires or members especially constituted of a different alloy comprising molybdenum, tungsten, tantalum or columbium and so selected that the casting temperature (when the reinforcing insert is incorporated in the cast piece) will not seriously reduce the strength of the insert nor adversely alter its properties as a reinforcing means. By such organization an improved composite blade or vane structure is obtained having the necessary oxidation resistance and which will at the same time withstand thermal fatigue sufficiently to meet the exacting requirements of gas turbine use, such composite structure further having the necessary physical strength and resistance to deformation by virtue of the reinforcing elements of different alloy materials.

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The reinforcement means may be constituted as individual wires having various configurations, or such means may be in the form of perforated sheets or strips. In each case the reinforcement means is arranged to be supported in the mold cavities so as to enable the blade or vane structure to be cast in the desired configuration. Further, the reinforcing means preferably has a coefficient of expansion which is less than that of the blade or vane alloy, whereby a prestressing effect is had during the high temperature operation of the composite component.

Preferably also the reinforcement means are coated with either the base metal of the blade alloy or else with one of its alloying additions, whichever is found to be most suitable for protecting the reinforcement while in the mold cavity, and found to be suitable to alloy readily with the blade or vane metal during the casting of the latter. Means are provided for subsequently preventing exposure of the reinforcing means when the composite structure is in use, especially at those locations which experience the highest operating temperature. The prestressing action mentioned above is of considerable advantage in minimizing distortion and combatting thermal shock or fatigue, at such elevated operating temperatures.

Another object of the invention is to provide an improved composite reinforced blade or vane structure for gas turbines and the like, which structure is comparatively simple, economical to fabricate, and effective in accomplishing the desired increased strength and resistance to deformation.

A feature of the invention resides in the provision of an improved reinforced blade or vane structure as above set forth, wherein no rigid limitations are placed on the blade configuration nor the casting process, so that full freedom is had in the design and fabrication of the blades.

Another feature of the invention resides in the provision of a reinforced turbine blade or vane structure as above characterized, wherein an effective bond is had between the imbedded reinforcing means and the cast metal of the blade structure.

Other features and advantages will hereinafter appear.

In the drawings accompanying this specification, similar characters of reference are used to designate like components throughout the several views, in which:

FIG. 1 is a top plan view of an improved reinforced blade structure as provided by the invention.

FIG. 2 is a side elevational view of the blade structure of FIG. 1.

FIG. 3 is a bottom plan view of the blade structure of FIGS. 1 and 2.

FIG. 4 is a left end elevational view of the blade structure.

FIG. 5 is a right end elevational view of the blade structure.

FIG. 6 is a transverse section, enlarged, taken on the line 6—6 of FIG. 2.

FIG. 7 is a top plan view of a composite blade structure illustrating a modification of the invention.

FIG. 8 is a perspective view of the reinforcing means incorporated in the blade structure of FIG. 7.

FIG. 9 is a plan view of one type of reinforcing wire element, which may be incorporated in the blade structures of FIGS. 1–3.

FIG. 10 is a plan view of another type of reinforcing wire element, which is incorporated in the blade shown in FIGS. 1–3.

Considering first FIGS. 1–6, the composite blade structure showin therein is designated generally by the numeral **10**. The blade structure **10** comprises a curved body portion **12** having somewhat the shape of an air foil section, such body portion having end plates **14** and **16** which are depicted as being of substantially rectangular configuration. The exact shape of the end plates **14** and **16** is subject to alteration, to adapt the blade to various supporting means as provided in the particular turbines under consideration. The blade **10** is cast of an alloy having high resistance to oxidation and heat, such as the SM series of alloys.

In accordance with the invention, reinforcing stiffening elements **18***a* of a special alloy which is not especially resistant to oxidation but which instead has excellent mechanical strength at high temperatures are incorporated in the blade structure **10**. The elements **18***a* may have any desired configuration. In FIGS. 1–6 they are constituted as straight wires, one such wire being illustrated in FIG. 10. The wire **18***a* in this figure is shown as having a smooth surface and end enlargements **18***b*. Preferably the wire is provided with a protective coating, as by electroplating of a noble metal, aluminum or the nickel series. In place of the wires **18***a*, wires **18** with roughened surfaces as indicated in FIG. 10 may be employed. The wire **18***a* has the enlargements or shoulders **18***b* constituted as anchorage means. The shoulders **18***b* have special utility where the reinforcement wire has a smaller coefficient of expansion, since it will reliably insure a tensional stressing of the reinforcements as the blade temperature increases. This is due to the following action: When the casting initially is solidifying and cooling, the shrinkage of the cast metal in directions laterally of the reinforcement rods causing lateral compression of the rods, takes precedence over shrinkage in longitudinal directions because of the thin or blade-like configuration of the casting and the presence of the anchorage shoulders **18***b*. As a consequence, when the cast composite blade structure becomes hot during use, there is not a direct reversal of such shrinkage but instead the tendency is for the blade structure to elongate longitudinally, and this results in a tensional stressing of the reinforcement rods and a condition wherein the blade structure itself is held under continual longitudinal compression at the operating temperature. Thus, under actual conditions of use where very high temperatures are encountered, the increased stressing of the reinforcement means will tend to minimize distortion, thermal shock or fatigue of the blade structure.

In place of the wire-like reinforcements **18** and **18***a* shown in FIGS. 1–6, 9 and 10, a perforated strip type of reinforcement may be employed, such as the strip **38** shown in FIGS. 7 and 8. Such stiff strip may be of the same alloy specified for the wires **18**, **18***a*, and may be provided with perforations or holes **39**. The holes **39** at the two ends of the strip have surfaces (hereinafter called end portion surfaces in the appended claims) which face toward the center portions of the strip and act as abutting surfaces against the cast blade material, causing longitudinal compression of the blade when the latter is very hot. In FIG. 7 the blade structure **30** is provided with a reinforcement in the form of the stiff plate **38**. The blade **30** has a curved body portion **32** providing stiffness, which is similar in shape to the body portion **12**, and has end plates **34** and **36** similar to the plates **14**, **16**. Imbedment of the reinforcing plate **38** is effected by casting the blade alloy substance about the reinforcing plate, as the latter is suitably supported in a mold.

In effecting the support of the insert pieces **18**, **18***a* or **38** in the mold, the latter may be supported at either one end or at both ends. By virtue of such support, the insert piece will have a projecting portion when the cast blade structure is removed from the mold. Such projecting portion may be removed by any suitable machining

process, as by milling, grinding, etc. This will leave an exposed surface of the insert means, at one or both ends of the blade structure. Such exposed surface is not an especially serious consideration at the end plate **16** comprising the base end of the blade **10**, or at the end plate **36** comprising the base end of the blade **30**. Such base ends operate at a lower temperature than the other or hot ends of the blades, whereby oxidation of the reinforcement means does not represent a serious problem. However, in accordance with the invention, end cover plates **20**, **22** may be welded or otherwise secured to the end plates **14–16** respectively of the blade structure, thereby to cover any exposed ends or portions of the reinforcement means. In FIGS. 7 and 8, cover plates **40**, **42** are secured to the end plates **34**, **36** respectively, for this purpose. Thus, with the completed blade structures illustrated in FIGS. 1–5, and 7, no exposed portions of the insert members are had.

The reinforcement means as provided by the invention is stiff and continuous and unbroken throughout virtually the full length of the casting and is resistant to bending forces applied to it adjacent the ends of the casting; thus such means greatly strengthens the blade structures, tending to minimize distortion under the effects of heat and mechanical stress. By virtue of the insert members having a different composition especially chosen to provide great mechanical strength without regard to the adverse effects of oxidation, the composite blade structure is greatly superior to purely monolithic structures involving but a single alloy. The blade structure as provided herein may be economically fabricated, and the increased cost is more than offset by the extended life interval of the blade, whereby the servicing period for the gas turbine is appreciably lengthened.

Variations and modifications may be made within the scope of the claims, and portions of the improvement may be used without others.

I claim:

1. A composite reinforced turbine blade structure comprising, in combination:
   (a) an elongated casting of a refractory metallic alloy of the SM series known to be deficient in mechanical strength as compared with known structural metals,
   (b) said alloy having high oxidation and thermal fatigue resistance,
   (c) said casting having a curved cross section,
   (d) all exposed surfaces of said casting being constituted of the said refractory metallic alloy of high oxidation and thermal fatigue resistance,
   (e) reinforcement and stiffening insert means cast within said casting and bonded thereto,
   (f) said insert means comprising a metal alloy of the group of metals including tantalum, molybdenum, columbium and tungsten and being less refractory but mechanically stronger than the said alloy of the SM series,
   (g) said insert means being coated with a metallic substance of the group of metals including noble metals, aluminum, and the nickel series, by which the insert means is bonded to the casting,
   (h) said insert means having a lesser coefficient of expansion than that of the alloy of the casting,
   (i) said insert means being continuous and unbroken throughout virtually the full length of the casting and comprising stiff elongate elements each resistant to bending forces applied to it adjacent the ends of the casting and each extending longitudinally of and for the full length of the casting and having surfaces at their end portions which surfaces are adjacent the ends of the casting and which face toward the center portions of the elements,
   (j) said casting including integral portions disposed between and on opposite sides of said elongate ele-

ments at all points between the extremities of the latter,

(k) said elongate elements being under continual lateral compression from the casting when cold,

(l) said casting being under continual longitudinal compression from the said end-portion surfaces of the elongated elements when the casting is at operating temperature,

(m) said casting including supporting formations at its ends,

(n) the said end-portion surfaces of the said elongate reinforcing elements being disposed adjacent the said supporting formations of the castings, thereby to maintain major portions of the casting under longitudinal compression.

2. A composite reinforced turbine blade structure as in claim **1**, wherein:

(a) the reinforcement insert means comprises a plurality of separate stiffening rods.

3. A composite reinforced turbine blade structure as in claim **1**, wherein:

(a) the reinforcement insert means comprises a perforated stiffening metal strip of curved cross section, interiorly disposed in the blade and having longitudinally extending rows of perforations, some of said perforations comprising the said end-portion surfaces.

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