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EUROPEAN PATENT APPLICATION

21 Application number: 84305738.1

51 Int. Cl.⁴: F 01 D 5/28
 C 23 C 4/00

22 Date of filing: 22.08.84

30 Priority: 29.08.83 US 527606

43 Date of publication of application:
 02.05.85 Bulletin 85/18

84 Designated Contracting States:
 BE CH DE FR GB IT LI NL SE

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54 Combustion turbine blade with varying coating.

57 A turbine blade for a combustion turbine, in which the blade is provided with a hot-end coating, a cooler-end coating, and an intermediate transition zone with a mixture of the two end coatings. The blade has a hot end portion operable at a temperature in excess of 1500°F, a cooler end portion operable at a temperature of less than 1250°F, and an intermediate zone portion operable at between 1250 and 1500°F. The blade with hot end portion is coated with a low creep-type coating which is resistant to high temperature corrosion and oxidation, the cooler end portion is coated with a ductile-type coating which is resistant to sulfide corrosion, and the intermediate portion coated with a mixture of the hot end coating and the cooler end coating.

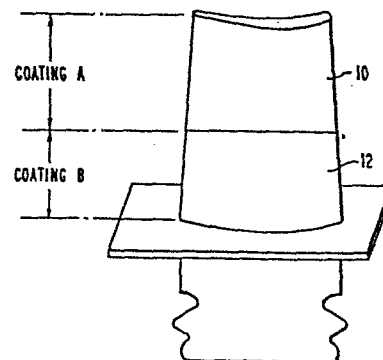


FIG. 1

COMBUSTION TURBINE BLADE WITH VARYING COATING
BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a turbine blade, for a land-based or marine combustion turbine, and in particular to turbine blades provided with coatings for protecting such blades.

5 Land-based or marine-type combustion turbines present difficult problems of blade materials. Near the tip of the blades, the temperatures are often 1700°F or more. Down near the base of the blade (near the shaft), temperatures are much cooler, for example, approximately
10 1000°F. In addition, such turbines are commonly operated with fuels containing corrosive impurities such as sulfur and vanadium. Further, corrosion-causing compounds such as sea salt or fertilizer are often ingested in with the air drawn in by the turbine compressor. Such problems are
15 significantly worse with land-based and marine combustion turbines as compared to aircraft (aircraft turbines are operated with cleaner fuel and significantly less contaminated air).

According to the present invention, a turbine
20 blade, for a combustion turbine, said blade having a hot end portion at least a portion of which is designed to operate at a temperature in excess of 1500°F, a cooler end portion at least a portion of which is designed to operate at a temperature of less than 1250°F, and an intermediate
25 portion at least a portion of which is designed to operate

at between 1250 and 1500°F, said blade comprising: a hot end portion coated with a low creep-type coating which is resistant to high temperature oxidation, a cooler end coated with a ductile-type coating which is resistant to sulfide corrosion, and an intermediate portion, which is coated with a mixture of said hot end coating and said cooler end coating.

Advantageously, it is to be noted that not only must the hotter portion be protected against high temperature oxidation type corrosion, but that the coating on this portion of the blade must be creep resistant. Conversely, the cooler temperature of the blade (especially those portions less than about 1250°F) must be protected against sulfide-type corrosion and must have high coating ductility to prevent crack propagation. Further, it has been found that an intermediate zone, which is a mixture of the two coatings, must be used in order to prevent problems such as abrupt chemical discontinuities in the coating or stress concentrations. Preferably, the coatings are applied by plasma spraying and the intermediate portion is a graded coating giving a smooth transition from the hot end coating to the cooler end coating.

The invention will now be described, by way of example, with reference to the following drawings in which:

Figure 1 is an elevation of a blade showing typical tip intermediate and base temperatures;

Figure 2 is a blade elevation showing three coating zones;

Figure 3 shows a system for applying the coatings of this invention, and

Figure 4 is a graph of typical ductilities for coatings and superalloy base materials at various temperatures.

The range of temperatures of many gas turbine blades (as used herein, the term "blades" is used to mean turbine components having airfoil portions whether rotating or stationary, e.g., including the stationary parts which

are sometimes called "vanes") generally exceeds the range of effectiveness of any single type of coating. This is in part due to the chemical/thermal stability of a coating in the various deleterious corrosive environments and partly
5 due to the physical/mechanical properties of the coating itself. This invention enables the use of a multiple composite coating system that enables the designer to maximize coating capabilities without the usual compromises (especially with regard to reduced physical/mechanical
10 properties above or below the ductile/brittle transition temperature which are inherent to any given coating composition).

Referring to the drawings, Figure 1 shows a blade with a portion designated 10 as the hot end part, and a
15 cooler end portion 12.

A gas turbine blade may have an operating temperature profile ranging from about 1000°F at the base of the gas path surface to nearly 1800°F at the outermost tip region. Because the deleterious species and compounds are
20 stable only through certain temperature ranges, application of a singular coating system has inherent limitations. A coating system which is most effective in preventing low temperature class II type corrosion in the range of 1000°F to 1450°F, for example, could be applied through the lower
25 portion of the airfoil and a high temperature corrosion resistant composition applied to the upper portion (away from the center axis) of the airfoil where blade temperatures are highest.

At the hot end of the blade the inherent ductility of most coating systems currently employed for environmental protection is generally equal to or greater than that of the base alloy to which it is applied. Premature failure of the blade due to brittle coating behavior and crack initiation is therefore not likely. Consequently,
30 the coating that exhibits the best environmental protection
35 may be utilized.

At the cooler end 12 of the blade (generally here the end towards the 1000°F temperature), it has been discovered that unusually high ductility for these temperatures is required in addition to resistance to low temperature sulfide-type corrosion. As used herein, the term "ductile-type coating" means coatings which have a ductility of greater than or equal to that of the base metal at a given operating temperature. The correlation of coating and base metal ductility can be demonstrated in Figure 4.

Figure 2 shows three zones of coatings, with a hot-end coating 14 at the top and a cooler-end coating 16 at the bottom, with a transition zone 18 in the intermediate portion, the transition zone 18 being coated with a mixture of hot-end coating and cooler-end coating. This transition zone 18 eliminates a sharp transition between the hot end coating and the cooler end coating. As a variation in the coating in an abrupt manner would result in poor thermal/mechanical properties and the possibility of uncoated areas resulting from less than perfect alignment, the transition needs to be gradual. Generally, this transition zone 18 will be at least $\frac{1}{2}$ inch in height.

Preferably, the coating is applied by plasma spray. If pack cementation techniques were used, additional handling would be required and masking would present difficulties with little or no control over interdiffusion between masked areas. It would be very difficult, therefore, to control the transition from one coating chemistry to the adjacent coating chemistry.

Although any type of plasma spray could be used, a non-oxidizing plasma spray system is thought to be the most practical. As most such coatings require an inert atmosphere or vacuum, such plasma spraying could, for example, be done with an argon flood or low pressure plasma spray.

Although the transition zone could be formed by applying the coating compositions one at a time (e.g., by applying the hot-end coating with its thickness tapering

from full thickness at the top end of the transition zone down to essentially zero thickness at the lower end of the transition zone and then applying the cooler-end coating with a maximum thickness at the lower transition zone and tapering down to near zero at the upper end of the transition zone, preferably followed by appropriate heat treatment), the coating is preferably applied by a system such as shown in Figure 3 where the transition zone 18 is accomplished by spraying a powder premixed by the hopper system. Thus, the hot end coating composition (designated "A") and the cooler end coating (designated "B") are loaded into separate hoppers 20, 22. As the plasma gun 24 traverses the blade airfoil (under programmed computer control to maintain coating thickness profile), the feeding mechanism of the powder hoppers containing A and B compositions can be programmed to deliver the proper powder or powder mixture to the mixing vessel 26 which in turn supplies the gun 24. As the plasma gun 24 moves down the airfoil, the composition is initially 100% A, then an A-rich mixture becoming richer and richer in B, then a B-rich mixture and finally a 100% B coating. Generally all three zones (14, 18, and 16) will have a height of at least $\frac{1}{2}$ inch.

The specification of U.S. Patents Nos. 3,545,944 and 3,020,182 describe similar systems being used for different purposes.

It can be seen that a coating system similar to Figure 3 can be used to coat more than three zones. For example, if erosion (or corrosion or coating ductility) were a problem on some particular portion of the blade, a third hopper with a "C" type coating composition could be added to apply an erosion resistant coating (or extended corrosion or lower temperature ductility coating, etc.) in this area (preferably using an additional transition zone).

It should be noted that prior-art single coatings can fail mechanically due to insufficient creep strength, but that this problem is generally in the high temperature

regions, above the ductile/brittle coating transition temperature. Failures also can be caused by poor ductility below the brittle/ductile transition temperature of such a single coating. By using different coatings in the high
5 temperature region and the cooler temperature region, a low temperature corrosion resistant coating with good low temperature ductility can be used on the lower portion of the blade airfoil. A high temperature corrosion resistant coating with good high temperature creep resistance is
10 applied to the upper portion of the airfoil. Problems at the interface of the two regions are avoided by using the blended composition in the intermediate zone of the airfoil.

It is felt that current coating systems are
15 compromises in an attempt to perform adequately over a wide range of conditions, and are not optimized for providing either the high temperature corrosion resistance with high creep strength required in the hot end or the low temperature corrosion high ductility required in the cooler end.

20 Generally, it is anticipated that the hot end (designed to operate above about 1500°F) can, for example, use MCrAlY coatings (with M being Ni and/or Co). Similarly, it is anticipated that the cooler end coatings be similar to the MCrAlY (with M being Fe or FeNi or combinations thereof).
25

Figure 4 shows typical ductility variations with temperature for coatings and nickel-based superalloys. The ductility of coating A is equal to or greater than the base metal alloys at temperature above about 1350°F and the
30 ductility of coating B is equal to or greater than the ductility of the base metal alloys above about 1050°F. The corrosion resistance of coating A is greater than that of coating B above about 1400°F while below about 1300°F coating B has a corrosion resistance at least as good as
35 that of coating A. Thus, the coating system of this invention provides improved protection against low coating ductility problems (above e.g. 1000°F) and against corro-

sion problems.

Again, the transition zone which is coated with a mixture of the coatings is to be generally greater than $\frac{1}{2}$ inch in height. The location of the transition zone can vary with various coatings, but at least a portion of this transition zone will be in a portion of the blade which is designed to operate at a temperature of between 1250 and 1500°F. Preferably, at least a portion of the transition zone is to be at a part of the blade which is designed to operate at between 1300 and 1450°F and most preferably at 1350°F.

CLAIMS:

1. A turbine blade, for a combustion turbine, said blade having a hot end portion at least a portion of which is designed to operate at a temperature in excess of 1500°F, a cooler end portion at least a portion of which is
5 designed to operate at a temperature of less than 1250°F, and an intermediate portion at least a portion of which is designed to operate at between 1250 and 1500°F, said blade comprising: a hot end portion coated with a low creep-type coating which is resistant to high temperature oxidation, a
10 cooler end coated with a ductile-type coating which is resistant to sulfide corrosion, and an intermediate portion, which is coated with a mixture of said hot end coating and said cooler end coating.
2. A blade as claimed in claim 1, wherein a
15 mixture of said hot end coating is applied over at least $\frac{1}{2}$ inch of blade height.
3. A blade as claimed in claim 1 or 2, wherein said cooler end coating is chosen from the group consisting of MCrAlY, where M is Fe or FeNi.
- 20 4. A blade as claimed in any one of claims 2 to 3, wherein said coatings are applied by plasma spray.
5. A turbine blade, for a combustion turbine, constructed and adapted for use, substantially as hereinbefore described and illustrated with reference to the
25 accompanying drawings.

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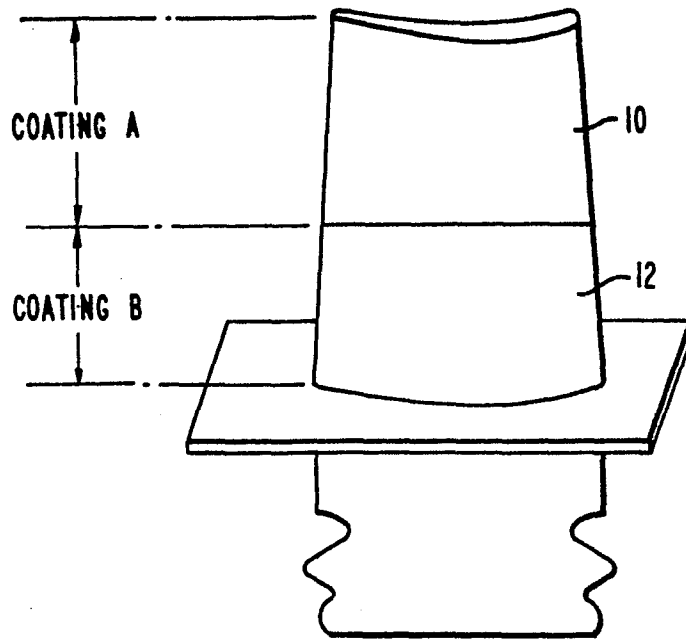


FIG. 1

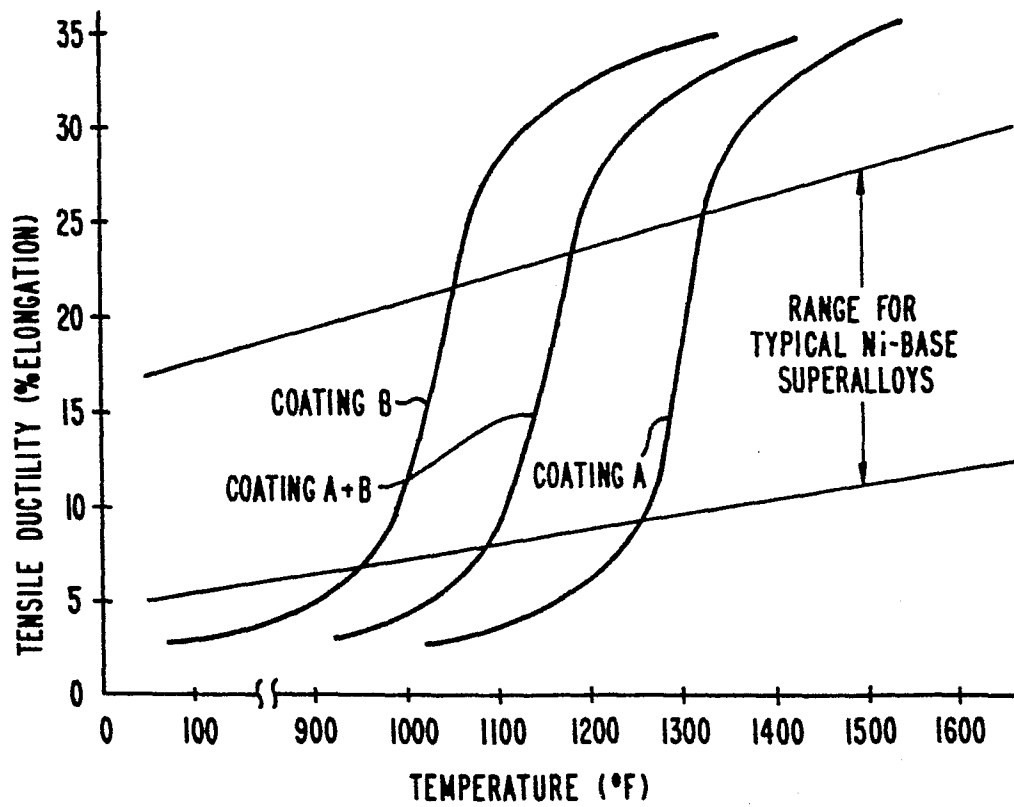


FIG. 4

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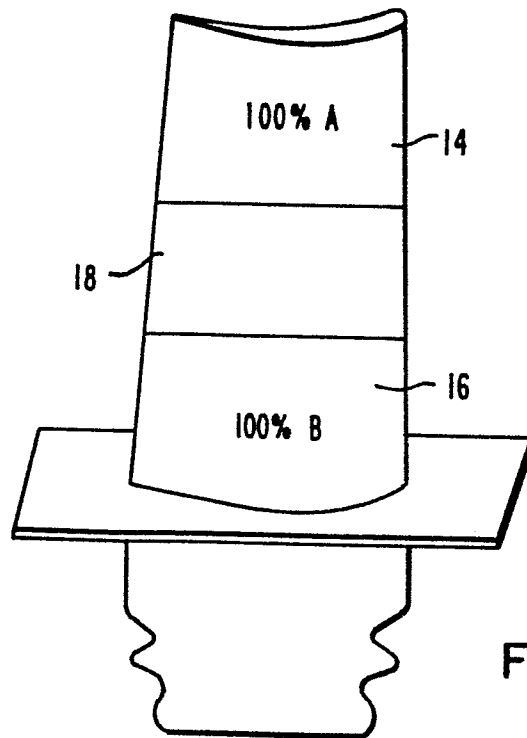


FIG. 2

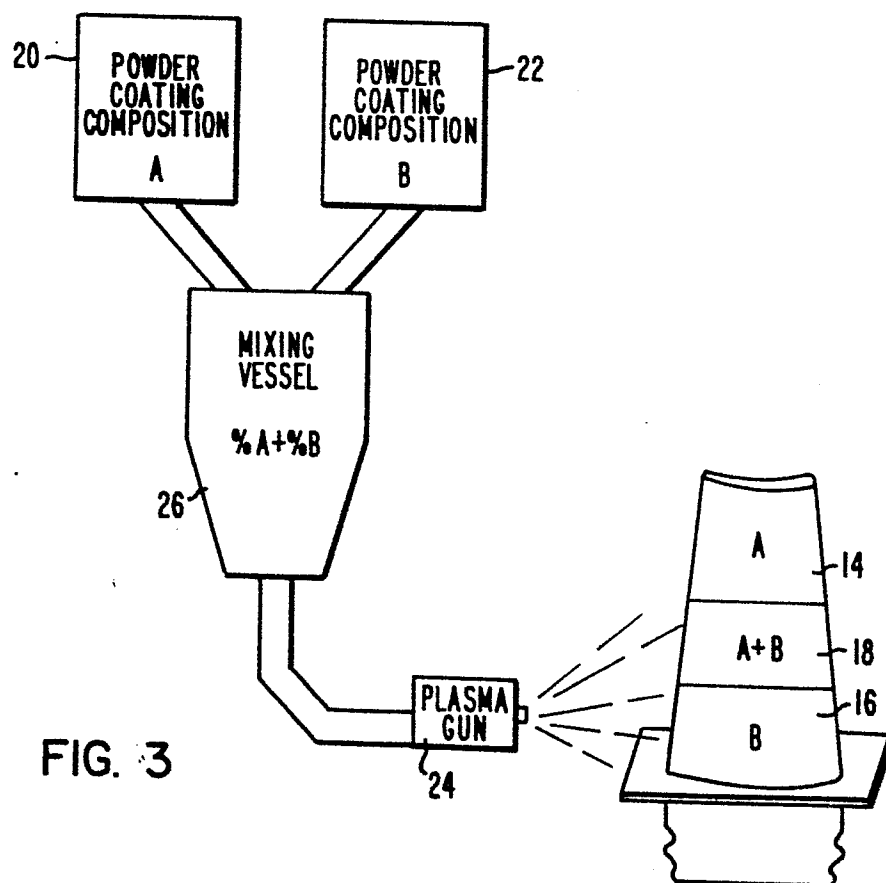


FIG. 3



European Patent
Office

EUROPEAN SEARCH REPORT

0139396

Application number

EP 84 30 5738

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	US-A-2 431 660 (GAUDENZI) * whole document *	1,2	F 01 D 5/28 C 23 C 4/00
A	GB-A- 696 715 (METRO-CUTANIT) * whole document *	1,2	
A	GB-A- 616 432 (POWER-JETS) * whole document *	1	
A	FR-A-2 406 000 (UNITED TECHNOLOGIES) * claims 1,2 *	1,3	
A	FR-A-2 367 833 (BBC)		
A	GB-A-2 046 369 (ROLLS-ROYCE)		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
			F 01 D F 02 C C 23 C 4/00
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-12-1984	Examiner IVERUS D.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	