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STEEL TURBINE ROTORS WITH CERAMIC BLADES

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FIG. 2

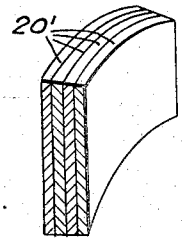
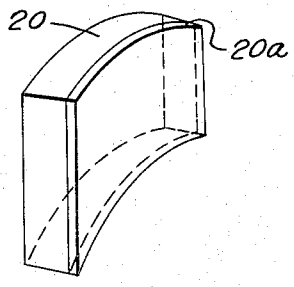


FIG. 3



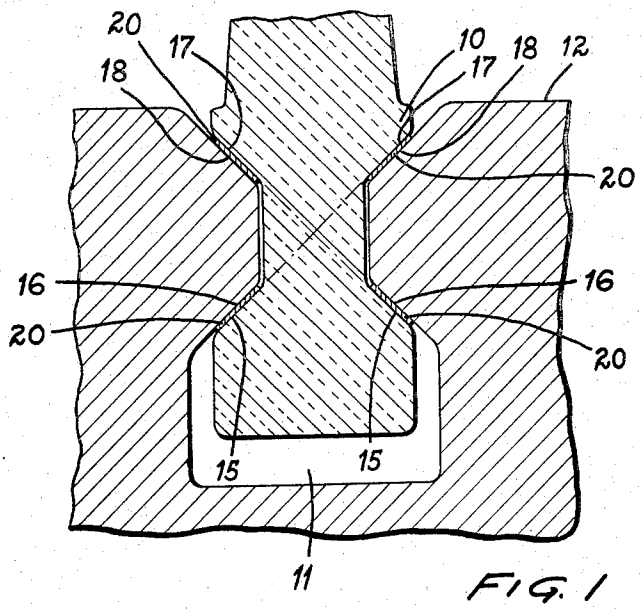


FIG. 1

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STEEL TURBINE ROTORS WITH CERAMIC BLADES

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10 Claims. (Cl. 253—77)

This invention relates to gas turbines and more particularly to high temperature, high speed gas turbine rotors and ceramic turbine blades.

Because of their heat resistance and other thermal properties, many ceramic materials are adapted for use as turbine blades, particularly in high temperature gas turbines. Such materials, however, may not possess mechanical strength properties generally adapted for such use without special consideration being given to the manner in which the ceramic blades are secured around the rim of, for example, a steel turbine rotor.

A satisfactory interlocking joint for securing ceramic blades in the rim of metal turbine rotor includes a dovetail arrangement having a plurality of supporting surfaces on the blade and corresponding surfaces in a blade receiving socket in the rim of the metal rotor. If these supporting surfaces are inclined with respect to the radial axis of the blade or the direction of centrifugal force acting thereon, firm sliding engagement will be maintained notwithstanding widely differing extents of thermal expansion of the ceramic and metal materials. In such an arrangement, however, the mechanical strength properties of the ceramic material may indicate that the angle of inclination between the supporting surfaces and the blade axis should be small, whereas the different friction coefficients between steel and ceramic material indicate that such angles should be large, as does the danger of the blade becoming crushingly wedged in the metal rotor socket, especially during heat expansion of the rotor, and to secure continuously firm clamping of the blades in the rotor throughout heat expansion and contraction of the whole range of operation.

According to this invention, heat resistant inserts or shims are arranged on the supporting surfaces between the ceramic blades and the metal rotor providing for an adequately small angle of inclination confirming with mechanical properties and stability of the ceramic material and heat insulation, while avoiding the structural difficulties which may otherwise be encountered with such an arrangement.

It is accordingly one object of this invention to provide a metal turbine rotor and ceramic turbine blades of the character described having interlocking supporting seating surfaces inclined at an angle of optimum strength according to the mechanical properties of the ceramic.

Another object of this invention is to provide a turbine rotor and blades of the character described having therebetween heat resistant inserts for controlling difficulties of different friction coefficients between ceramic and metal materials.

Still another object of this invention is to provide ceramic turbine blades of the character described having supporting surfaces thereon carrying metal inserts adapted or treated for controlling friction coefficients between the blade and the blade socket of a metal turbine rotor as well as producing heat insulation effects therebetween.

Still another object of this invention is to provide a turbine blade arrangement of the character described having metallic inserts between ceramic blades and the metal turbine rotor providing a machineable surface for close tolerance fitting of said blades in said rotor.

A further object of this invention is to provide a turbine blade arrangement of the character described having metal inserts between ceramic blades and a steel turbine rotor in which the surfaces of the inserts are treated to produce uniform friction relations between the inserts and adjacent surface of the steel rotor.

A still further object of this invention is to provide in a turbine blade arrangement of the character described metal inserts between ceramic blades and the steel turbine rotor with the inserts comprising a plurality of layers for increasing the number of heat transition points between the ceramic blades and the turbine rotor.

Still another object of this invention to is provide in a turbine blade arrangement of the character described metal inserts between the blades and the rotor the surfaces of which inserts are treated for heat and ignition resistance to control and reduce heat transmission.

Other objects and advantages of this invention will be apparent from the following description, the accompanying drawing, and the appended claims.

In the drawing:

Fig. 1 shows a section through the root portion of a ceramic turbine blade secured according to the invention in a blade receiving socket in the rim of a metal turbine rotor;

Fig. 2 is a more detailed showing of a portion of an insert or shim according to this invention made up of a plurality of layers; and

Fig. 3 is an insert or shim according to this invention having a surface coating thereon.

Referring to the drawing, the root portion of a ceramic turbine blade is shown at **10** affixed in the blade receiving socket **11** at the rim of a metal turbine rotor **12**. The root portion of the blade **10** has a pair of inclined supporting surfaces **15** for engagement with a corresponding pair of supporting surfaces **16** on the metal rotor. These cooperating surfaces **15, 16** secure the blade against radial movement due to centrifugal forces acting thereon during rotation of the rotor. The root portion of the blade **10** also has a second pair of supporting surfaces **17** cooperating with a second pair of supporting surfaces **18** on the metal rotor. This second pair of surfaces **17, 18** is oppositely directed from the first pair **15, 16** to secure the blade against other forces acting thereon and to maintain the first pair of seating surfaces **15, 16** in continuously firm engagement.

The reciprocal inclination of the surfaces provides an interlocking joint which is substantially independent of temperature and thermal expansion movement. That is, as the rotor **12** and/or the blade root **10** expand or contract with changing temperatures, such expansion movement at the supporting surfaces results in the surfaces sliding one over the other while still maintaining firm contact notwithstanding widely differing extents of thermal expansion of the materials and without subjecting the ceramic material to crushing or compression forces during heat expansion movement of the surrounding metal socket.

Metal inserts or shims **20** are carried between the cooperating supporting surfaces. The differing friction coefficients between the ceramic and metal surfaces have a controlling effect upon the angles of inclination thereof if the desired sliding engagement of the surfaces is to be maintained. Considering such frictional effects

alone, a relatively flat inclination of seating surfaces may be prescribed for optimum sliding engagement during heat expansion movements. Such continually firm sliding engagement provides for secure fastening of the blades without relaxation which may give rise to vibration at lower temperatures and without excessive compressing forces which may damage the ceramic at high temperatures and great heat expansion.

The mechanical properties of the ceramic are such however, that an optimumly large angle, from the point of view of sliding engagement and friction effects, may exceed the angle of optimumly structural strength for the desired form of ceramic blade.

The metallic inserts **20** permit using a smaller angle of inclination as desired providing greater mechanical and structural stability of ceramic blade while yet avoiding concomitant disadvanages of wedging and friction differences encountered with such a small angle without the inserts. For example, it is not of critical importance if the friction coefficients differ widely between the ceramic surfaces **15**, **17** and the metal inserts **20** because uniform friction effects are present between the inserts **20** and the metallic surfaces **16**, **18** thereby permitting unhindered relative movement therebetween during heat expansion, etc., to an extent which can be determined and, consequently, safely controlled. Similarly the surfaces of the inserts **20** adjacent the rotor surfaces **16**, **18** can be finely machined or otherwise treated to provide both close tolerance fitting in the rotor and controlled friction relationship, although the ceramic surfaces **15**, **17** of the blade do not lend themselves, because of the nature of the ceramic materials and the internal structure and stability thereof, to machining operations.

A further advantage of the invention lies in the fact that, by increasing the interfaces through which heat transmission occurs between the blade root **10** and the rotor **12**, heat conduction from the blade into the metal rotor is reduced. That is, a single layer sheet metal insert **20** increases the heat transmission interfaces to at least two—i. e., that between the ceramic blade and the sheet metal insert and that between the sheet metal insert and the steel rotor—thereby reducing heat transfer directly from the ceramic blades and the steel rotor as well as helping to control the temperature thereof which, under many operating conditions, is sufficiently high to disadvantageously effect the creep strength of the steel rotor material. If the sheet metal inserts **20** are themselves made up of a plurality of layers of material (Fig. 2), this heat transfer controlling effect is increased by further increasing the number of heat transmission interfaces.

Similarly the outer surfaces of the inserts **20** and/or the surfaces of separate layers thereof may also be treated in such a way that heat transmission therethrouth is reduced as, for example, by oxydizing the surfaces of the sheet metal inserts **20** or by glacing their surfaces in a known manner (Fig. 3).

Heat conduction is further controlled, with the use of multiple layer inserts **20**, by using various different sheet metal materials for forming the various layers **20'** of inserts **20**. For example, satisfactory results have been secured according to this invention by forming the inserts **20** of a plurality of alterinative layers **20'** of austenitic and ferritic steels.

The inserts **20** may also be treated to control the above mentioned friction effects for example by covering the surfaces of the sheet metal inserts **20** with a coating **20***a* of graphite or solutions of graphite in oil.

Especially with high temperature turbines, high ignition resistance is advantageous for the metal turbine rotor as well as high heat resistance and high creep strength at elevated temperature. With metallic materials, all of these properties decrease very rapidly with increasing temperature especially in the high ranges encountered with gas turbine operation, and moreover, may not be present

to equal extents in all rotor materials available. According to the invention, these properties may be substantially distributed over both the rotor materials and the insert materials thereby obtaining satisfactory results with, for example, a rotor material which would not alone and without the heat transmission controlling effect of the inserts adequately possess the thermal stability and ignition resistance required.

It will accordingly be seen that the invention provides a satisfactory interlocking joint for securing ceramic turbine blades around the rim of a metal turbine rotor with a firm and substantially vibrationless joint clamping the blades and vibrationlessly, yet free of crushing or compressing effects of heat expansion movement and independently of widely differing heat expansion and frictional characteristics of ceramic and metallic materials. Furthermore, the invention provides in such a joint control of frictional effects and heat transmission enabling the use of less expensive steel for the rotor having lower or less exacting heat stability and ignition resistance at high temperatures. The invention also provides such a joint in which the inclination of the supporting surfaces can be adequately small within the limits of mechanical strength considerations of the ceramic material without the otherwise concomitant disadvantages inherent in such inclination.

While the forms of apparatus herein described constitutes preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In a gas turbine of the character described having a metal turbine rotor and means in the rim of said rotor receiving and securing a plurality of turbine blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in and in interlocking engagement with said receiving and securing means on said rotor, and separate metallic inserts on said supporting surfaces of said blade separating said surfaces from said means in the rim of said metal rotor for reduction and control of friction effects between said ceramic blade and said metal rotor, said inserts being permanently affixed to neither said rotor nor said blades.

2. In a gas turbine of the character described having a metal turbine rotor and means in the rim of said rotor receiving and securing a plurality of turbine blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in interlocking engagement with said receiving and securing means on said rotor, and separate heat resistant non-scaling metallic shims on said blade supporting surfaces, but not affixed thereto for separating said blade supporting surfaces from said receiving and securing means on said rotor.

3. In a gas turbine of the character described having a metal turbine rotor and means in the rim of said rotor receiving and securing a plurality of turbine blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in and in interlocking engagement with said receiving and securing means on said rotor, and separate metallic heat resistant inserts separating said blade supporting surfaces from said receiving and securing means on said rotor, the surface of said inserts adjacent said rotor being machined for close tolerance fitting in said blade securing means on said rotor and said inserts being separate from both said blade supporting surfaces and said rotor providing for relative heat expansion movement therebetween along both opposite surfaces of said inserts.

4. In a gas turbine having a metal turbine rotor and socket means in the rim thereof receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on

said blade inserted in interlocking engagement with said socket means on said rotor, and separate heat resistant shims on said blade supporting surfaces separating said surfaces from said receiving and securing means in said metal rotor, said shims including a plurality of layers for reduction of heat transmission therethrough between said blade and said rotor.

5. In a gas turbine having a metal turbine rotor and socket means in the rim thereof receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in interlocking engagement with said socket means on said rotor, and separate heat resistant shims on said blade supporting surfaces separating said surfaces from said receiving and securing means in said metal rotor, said shims including a plurality of layers and heat insulating material thereon for control of heat transmission between said blade and said rotor.

6. In a gas turbine having a metal turbine rotor and socket means in the rim thereof receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in interlocking engagement with said socket means on said rotor, and separate metallic shims on said blade supporting surfaces separating said surfaces from said socket means in said metal rotor, said shims including a plurality of layers having friction reducing material thereon.

7. In a gas turbine having a metal turbine rotor and socket means in the rim thereof receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in interlocking engagement with said socket means on said rotor, and separate metallic shims on said blade supporting surfaces separating said surfaces from said socket means in said metal rotor, said shims having a surface layer of heat insulating material thereon.

8. In a gas turbine having a metal turbine rotor and socket means in the rim thereof receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, supporting surfaces on said blade inserted in interlocking engagement with said socket means on said rotor, and separate metallic shims on said blade supporting surfaces separating said surfaces from said socket means in said metal rotor, said shims having a surface layer of friction reducing material thereon.

9. In a gas turbine having a metal turbine rotor and socket means in the rim of said rotor receiving and securing a plurality of blades therein, the combination which comprises a ceramic turbine blade, means including supporting surfaces on said blade inserted in interlocking engagement in said rotor socket means, and separate sheet metal inserts fitted between and separating said blade supporting surfaces and said socket means in said rotor, said inserts being rigidly affixed to neither said blades nor said rotor.

10. In a high temperature high speed gas turbine having ceramic blades mounted around the rim of a metal turbine rotor, the combination which comprises socket means in the rim of said rotor receiving said blades, a plurality of supporting surfaces in said socket means reciprocally inclined to the radius of said rotor, a root portion on each of said ceramic blades inserted into said socket means, supporting surfaces on said root portion reciprocally inclined to the radius of said rotor in cooperating engagement with said supporting surfaces in said socket means, and heat resistant metal shim inserts separate from both said socket means and said blade supporting surfaces and positioned therebetween separating said blade supporting surfaces from said supporting surfaces in said socket means for close tolerance fitting of said blades in said socket means and for presenting opposite contact surfaces with respect to which both said blades and said rotor are free to move during heat expansion thereof.

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