Jan. 28, 1958 C. SCHÖRNER 2,821,357

CONNECTION OF CERAMIC AND METALLIC MACHINE PARTS

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Fig. 1.

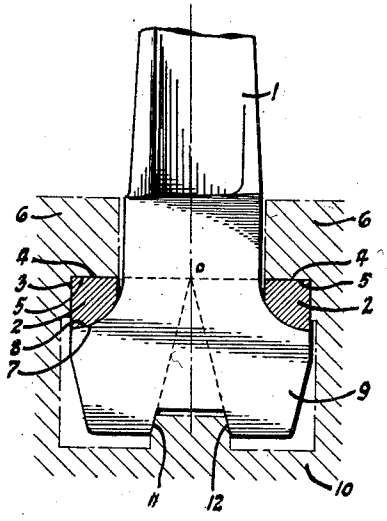


Fig. 2.

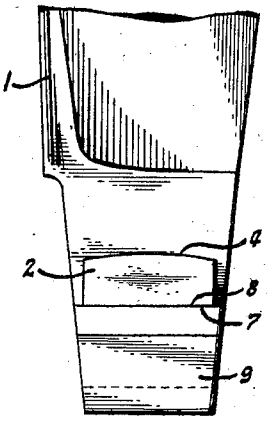
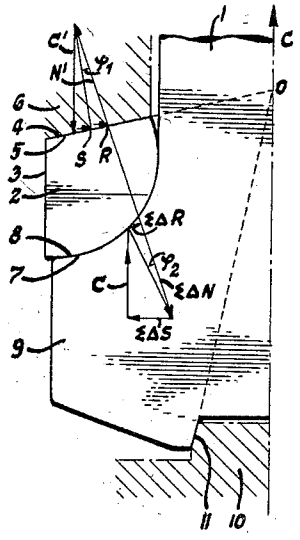


Fig. 3.



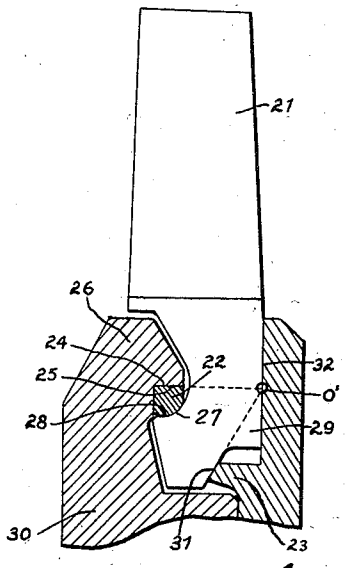


Fig. 4.

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CONNECTION OF CERAMIC AND METALLIC MACHINE PARTS

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7 Claims. (Cl. 253—77)

This invention relates to means for connecting ceramic and metallic machine parts which is adapted to be exposed to heavy temperature stresses.

In highly stressed ceramic constructional parts, such as ceramic blades mounted around the rim of a metallic rotor of turbine engines, it is very important to provide a design and construction in which the rated fatigue limit approaches as much as possible the strength measured on a simple test rod. This is particularly true for the means for fastening the blade in the rotor where a deflection of the forces to be transmitted therethrough is unavoidable. It is not feasible to avoid this difficulty by providing a dovetailed root portion of the blade having a relatively small slope of the seating surface in relation to the blade axis, which may be considered generally as representing the main direction of the load, so as to obtain a very small deflection of forces in the engaged portions of the blade and the rotor rim, because the root of the blade would thus exert too high thrust forces upon the inwardly projecting dovetail portions of the rim supporting the dovetailed root of the blade. The said projecting portions of the rim, while being highly stressed by the turning-over moments exerted by the T-part of the blade, have only a limited stiffness or rigidity at the very high working temperatures which are particularly suitable for the ceramic blades. In fact at these high temperatures the ratio of tensile strength to specific gravity of the ceramic material is superior to that even of high quality steel for elevated temperature service. Cooling of the constructional parts is difficult. Moreover the elastic deformations of the seating surface of the rim work against the required tight engagement of the shoulder of the T-portion of the blade and thus by local compression and unfavorable transmission of forces create additional unfavorable conditions as regards mechanical strength.

In judging the small inclination of the seating surface of the root of the blade in relation to the center axis of the blade, also friction may be of a detrimental influence. This is because, under action of the centrifugal forces, the T-portion of the blade, which is subjected to less expansion in proportion to the steel groove of the wheel body, is drawn into the wedge-shaped groove thereof and may be jammed therein to such an extent, in case of such relatively small slope, which is favorable in regard to the mechanical stresses, that it is not able to return to its original position in case of stoppage of operation and cooling down. An initial state free from tension for a new running period upon restarting the turbine would thus be precluded so that unfavorable clamping conditions with too high preliminary compressive stresses would result in the ceramic blades. Therefore, it is necessary to provide a sufficiently large angle between the shoulders of the dove-tailed root of the blade and the axis of the blade, in which case, on the other hand, the difficulty arises that, owing to a large angle of deflection of the forces, the constructional data as regards the circumferential speed, length of blade, cross section, etc. of

the turbine wheel have to be kept within moderate limits.

Owing to the peculiar manner of manufacture of ceramic materials the receding or inner edge of the shoulder of the dovetail root is biassed by internal tensions and predestined for cracks which may show themselves as cracks on firing but in many instances give rise to damages only on operation, since it is difficult to find them out. The well-tried testing devices and methods for discovering potential weak spots and/or internal distortion in steel parts, for example, are not usable in this case with ceramic parts. These internal tensions which are particularly pronounced at transitional cross sections are amongst others the result of the different shrinkage during firing of the portions of different thickness at the root of the blade. Even by very special measures in the casting operation it is not possible to eliminate such internal tensions completely. In order to keep small the stresses of the root of the blade and of the thickened portion at the rim of the rotor, it is desirable to make the overhang as small as possible. This, normally, necessitates a relatively small rounded surface which, however, is unfavorable with elastic materials such as steel, but is still less permissible in case of a material so brittle as ceramic material which has quite a different and more difficile behaviour under action of external mechanical stresses, excessive local strains being very dangerous in this case.

It is an object of the present invention to provide a construction in which all these difficulties are avoided.

With this and further objects in view, according to the present invention an intermediate member of ceramic material is inserted between the rounded shoulder of the T-part of the blade and the projecting parts of the dovetailed rim of the rotor, said intermediate member on the one side being adapted to the rounding of the shoulder and on the other hand having a cylindrically ground side bearing against the cylindrical inner wall of the inwardly projecting rim of the rotor. Where the blade is fixed in an annular groove of the steel rotor, the circle formed by intersection of the cylindrical surface with the middle plane of the set of blades (plane of center of gravity) is regarded as the line of intersection between the extensions of the supporting surfaces at the lower end of the root of the blade, which are provided in accordance with the rules known per se for a positive fastening system which is independent of changes of temperatures. In case of a straight groove axially worked into the rim of the rotor for engagement with the blades these rules have to be applied mutatis mutandis. In this case the curvature of the seating surfaces becomes infinite.

Other and further objects, features and advantages of the invention will be pointed out hereinafter and appear in the appended claims forming part of the application.

In the accompanying drawing a now preferred embodiment of the invention is shown by way of illustration and not by way of limitation.

Fig. 1 is an axial section of part of the annular rotor,

Fig. 2 is a fragmentary side view of a blade and of an intermediate part,

Fig. 3 is a fragmentary front view, partly in section showing a root portion of a blade and an intermediate part of another type, on a larger scale, and Fig. 4 is a fragmentary view partly in section showing a further embodiment of this invention.

Referring now to the drawings in greater detail, it will be seen that the ceramic blade 1 has a substantially T-shaped root part with a maximum rounding at the transitional cross section leading to the T-shaped root portion of the blade. Seated in the rounded part of the root of the blade is a ceramic insert or intermediate part 2 having approximately the same specific rate of thermal expansion as the material of the blade. This insert 2 forms part of a round bar or rod with flattened portions

3 and 4, the latter being convex so as to conform to the cylindrical inner surface 5 of the projecting part 6 of the rim of the rotor. Two such inserts 2 are arranged one at each of the projecting parts 6 at the rim of the rotor for fastening the blades. To this end, a third surface 7 of each insert 2 conforms to and tightly engages the rounded shoulder surface 8 of the T-root 9 of the blade. In order to maintain the positive engagement of the root 9 of the blade 1 with the cylindrical surfaces 5 disposed coaxially to the center axis of the rotor 10, a bilateral conical surface 11, 12 is arranged in a known manner at the lower end of the blade. As pointed out above, the imaginary line of intersection of the two conical surfaces 11, 12 (projection=point O) is located practically in the imaginary circle of intersection of the said cylindrical surfaces 5 with the middle plane of the set of blades, indicated by the dot and dash line. Thus it is ensured that the blades are seated free from constraint and without play, independently of the temperature conditions of the single parts and their inherent specific thermal expansion. The tight engagement of the shoulders 8 of the T-shaped part 9, via parts 2, with the projecting rims 6 of the rotor is always ensured in spite of the deformation or yielding of rims 6 which may occur at high speeds owing to the turning-over movements due to the radial pull exerted by the blades, because the parts 2 will slip on their seats 8 and thus follow such deformation. Under action of the frictional forces between the parts 2 and the surfaces 5 of the projecting rim, or between the parts 2 and the surfaces 8 of the blade, respectively, the lateral thrust forces caused by the steeper elements of the seating surfaces 8 located towards the main part of the blade are kept within such limits that the tight engagement of the parts 2 at the rounded parts 8 of the T-shaped root 9 is always ensured.

By a suitable angle of inclination of the surfaces 5 in accordance with the modification shown in Fig. 3 the conditions of balance with respect to the parts 2 can be influenced in the required manner. As shown by the vectorial triangles shown in Fig. 3, the outer forces $\Sigma\Delta N$, $\Sigma\Delta S$, $\Sigma\Delta R$ occurring at the surfaces 8 as a resultant of the outer forces occurring in the individual surface elements can always be balanced by the reaction forces at the flattened side 4 of the part 2 with due regard to the friction. In the vector diagrams of Fig. 3: N (in the expression "$\Sigma\Delta N$") is the normal force, S is the transverse force, C is the load due to the centrifugal forces developed by the blade, (N' and C' designating these respective forces particularly on surface 4) R is the frictional force and φ is the angle of friction, the subscripts 1 and 2 designating the respective angles for the metal-ceramic and the ceramic-ceramic junctures. By a special condition of the frictional surfaces, for instance, by metal coatings, graphite or glazings, the coefficient of friction can be altered in the required manner so as to produce the frictional forces required for static equilibrium. With a view to the manufacturing process it is very advantageous that the seating surfaces 8 at the root of the blade can be easily worked by clamping a plurality of blades together and using a large profiled grinding disc.

The constructional arrangement according to the invention can also be applied to half of a symmetrical T-shaped root, e. g., to a hook-shaped form of the root of the blade with a lateral plane counter-surface, as illustrated in Fig. 4. In this embodiment, a turbine blade 21 is illustrated having a hook-shaped root 29 including a concave seating surface 27. An insert 22 is provided with a curved seating surface 28 and a substantially flat seating surface 25 for cooperative engagement with a corresponding metal seating surface 24 adjacent the rim portion 26 of the turbine rotor 30. The blade 21 also has a seating surface 31 for engagement with a radially inner rotor projection 23 in the manner of the cooperating parts 10 and 11 in the other embodiments, and the projection of the surfaces 31 and 24 meet at a point O', as indicated by the dotted lines, on the lateral plane side surface 32 of blade 21.

While the invention has been described in detail with respect to a now preferred example and embodiment of the invention it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed is:

1. A differential expansion-compensating mounting for affixing a ceramic turbine blade into a recess in the rim of a metal turbine rotor throughout a range of temperature variations and substantially different thermal expansion characteristics of said ceramic blade and said metal rotor, which comprises in combination metal rim portions in said recess forming annular metal seating surfaces having substantially linear configuration in axial cross section, linear extensions of said linear configuration intersecting the longitudinal mid-plane of said blade at an acute angle a ceramic dovetail root portion on said blade having substantially different thermal expansion characteristics than said metal rotor, ceramic shoulders on said root portion adjacent said metal shoulders in said recess forming rounded concave ceramic seating surfaces, ceramic insert members having substantially the same thermal expansion characteristics as said ceramic root portion, one side of said insert members being convexly rounded for fitting engagement with said rounded ceramic seating surfaces and another side of said insert members being linear in cross section and complementary to said annular metal seating surfaces for fitting engagement therewith, and means in the radially inner portion of said recess for maintaining firm engagement between said insert members and said metal and ceramic seating surfaces throughout said range of temperature.

2. In a gas turbine adapted for high temperature operation, the combination which comprises a metal rotor having a blade-receiving recess in the rim thereof, a metal rim portion in said recess forming a metal seating surface of substantially linear configuration in axial cross section, a ceramic blade mounted in said recess and having substantially different thermal expansion characteristics from said rotor, a ceramic dovetail root on said blade within said recess, radially outer portions of said root forming a rounded concave ceramic seating surface, and a ceramic insert having substantially the same thermal expansion characteristics as said blade, one side of said ceramic insert member being convexly rounded for fitting engagement with said rounded concave seating surface and another side of said insert member being complementary to said metal seating surface for fitting engagement therewith to hold said blade in said rotor against the action of centrifugal and axial forces during differing thermal expansions of said blade and said rotor.

3. In a gas turbine adapted for high temperature operation, the combination which comprises a metal rotor having a blade-receiving recess in the rim thereof, a metal rim portion in said recess forming a metal seating surface of substantially straight-line configuration in axial cross section, a ceramic blade mounted in said recess and having substantially different thermal expansion characteristics from said rotor, a ceramic dovetail root portion on said blade within said recess, radially outer portions of said root forming a concave ceramic seating surface, and a ceramic insert member having substantially the same thermal expansion characteristics as said blade, the cross section of said insert member being substantially a sector of a circle, the rounded side of said ceramic insert member being convexly rounded for fitting engagement with said rounded concave seating surface and one of the other sides of said insert member being complementary to said metal seating surface for fitting engagement there-

with to hold said blade in said rotor against the action of centrifugal and axial forces during differing thermal expansions of said blade and said rotor.

4. In a gas turbine having a metal rotor and a ceramic blade mounted in a blade-receiving recess in the rim of said rotor, said blade having substantially different thermal expansion characteristics from said rotor, the combination which comprises a metal rim portion in said recess forming an axially disposed metal seating surface having substantially linear configuration in axial cross section, a metal projection in said recess disposed radially inwardly of said rim portion and forming a second metal seating surface having substantially linear configuration in axial cross section, extensions of said linear configurations of said seating surfaces meeting substantially in the longitudinal mid-plane of said blade, a dovetail ceramic root portion on said blade for insertion into said recess, a shoulder on said root portion forming a rounded concave ceramic seating surface, a second shoulder on said root portion forming a ceramic seating surface complementary to said second metal seating surface for engagement therewith, a ceramic insert member having substantially the same thermal expansion characteristics as said blade, one side of said insert member being convexly rounded for fitting engagement with said concave ceramic seating surface and another side of said insert member having substantially linear configuration in cross section and complementary to said first metal seating surface for fitting engagement therewith to hold said blade in said rotor against action of centrifugal and axial forces.

5. In a gas turbine adapted for high temperature operation, the combination of a metal rotor having a blade-receiving recess at the periphery thereof, metal rim portions forming in said recess axially disposed seating surfaces having substantially straight-line configuration in axial cross section, a ceramic blade with substantially different thermal expansion characteristics than said rotor mounted in said recess, a dovetail root portion on said blade for locking said blade into said rotor, ceramic shoulders on said root portion forming concavely rounded seating surfaces, and ceramic insert members for said blade having substantially the same thermal expansion characteristics as said blade, one side of each said insert member being convexly rounded for fitting engagement with said rounded ceramic seating surfaces and another side of each said insert member being substantially straight-line in cross section and complementary to said metal seating surfaces for holding said blade in said rotor against action of centrifugal, radial, and axial forces.

6. In a gas turbine adapted for high temperature operation, the combination of a metal rotor having a blade-receiving recess at the periphery thereof, metal shoulders forming seating surfaces having substantially straight-line configuration in axial cross section in said recess, a

ceramic blade with substantially different thermal expansion characteristics than said rotor mounted in said recess, dovetail root portions on said blade for locking said blade into said rotor, ceramic shoulders on said root portions forming circularly rounded concave seating surfaces, ceramic insert members for said blade having substantially the same thermal expansion characteristics as said blade, one side of each said insert member being circularly rounded and convex for fitting engagement with said rounded ceramic seating surfaces and another side of each said insert member being substantially linear in cross section and complementary to said seating surfaces of said rotor recess for engagement therewith to hold said blade in said rotor against action of centrifugal, radial, and axial forces, and a coating on said ceramic surfaces for altering the coefficients of friction thereof to produce static equilibrium among said interfitting parts.

7. In a gas turbine adapted for high temperature operation, the combination of a metal rotor having a blade-receiving recess at the periphery thereof, metal shoulders forming seating surfaces having substantially linear configuration in cross section in said recess, a plurality of ceramic blades with substantially different thermal expansion characteristics than said rotor mounted in said recess, dovetail root portions on said blades for locking said blades into said rotor, ceramic shoulders on said root portions forming concavely rounded seating surfaces, and ceramic insert members for each blade having substantially the same thermal expansion characteristics as said blades, one side of each said insert member being convexly rounded for fitting engagement with said rounded ceramic seating surfaces and another side of each said insert member being linear in cross section and complementary to said seating surfaces of said recess for engagement therewith to hold said blade in said rotor against action of centrifugal, transverse, and axial forces, the resultant of centrifugal, transverse and frictional force components along said rounded root portion surfaces being substantially balanced in static equilibrium by forces acting between said insert and said metal seating surfaces throughout thermal expansion and operational movements of said blade with respect to said rotor.

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