

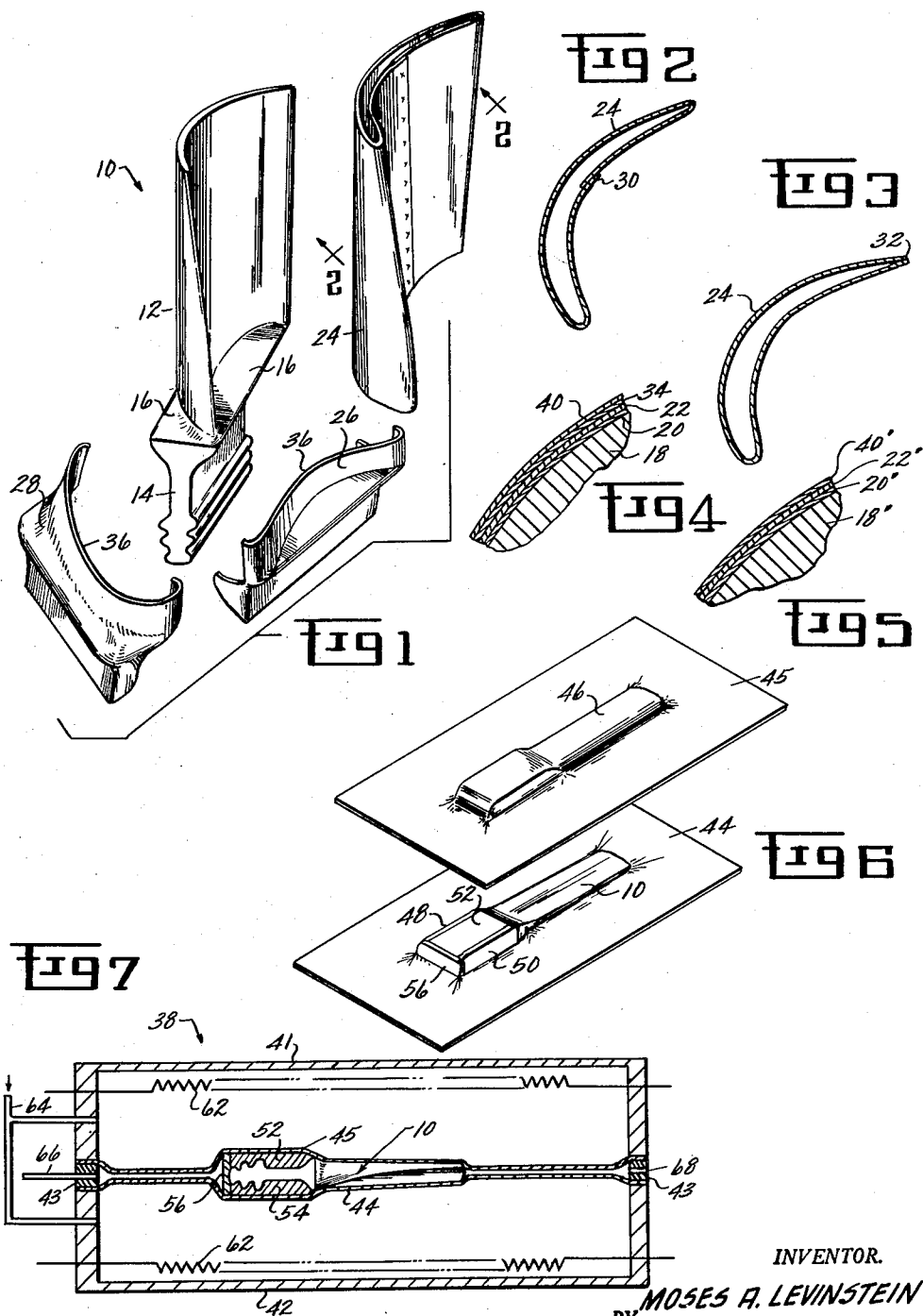
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METAL CLAD BLADE

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METAL CLAD BLADE

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This invention relates to protective surfaces for structural components operating at elevated temperatures and, more particularly, to a method of applying a protective surface to molybdenum and molybdenum base alloys said surface having both oxidation resistance and resistance to impact, abrasion and erosion.

Molybdenum possesses certain desirable physical characteristics which make it adaptable for structural components exposed to high temperatures. It has been found that the physical properties of molybdenum at elevated temperatures make it a most useful metal for various gas turbine applications such as buckets, blades, valves, nozzles and the like. Unfortunately, however, molybdenum and its alloys oxidize very rapidly above 1400° F. Temperatures in the range of 1400° F. and above are quite common in gas turbine applications. In order to use molybdenum or its alloys at such high-operating temperatures, it is desirable to coat the surface of the molybdenum with an oxidation resistant material.

Heretofore, various types of coatings have been found which will protect the molybdenum article from oxidation at elevated temperatures under static conditions wherein the coated article is subjected to little, if any, external forces from a flow of gases. However, the same coatings which are found to be satisfactory under static conditions are found to be unsatisfactory when used in certain gas turbine applications. When articles having a satisfactory oxidation resistant coating are installed in a gas turbine operating substantially above 1400° F. it is found that the severe operating conditions encountered by the article due to the high gas velocities and the entrainment of particles in the gases cause failures in certain portions of the oxidation resistant coating. It has been found that these failures are due to the effects of impact, abrasion, and erosion by the particles entrained in the hot gases. These localized failures of the oxidation resistant coating result in oxidation and ultimate destruction of the molybdenum or molybdenum alloy article. It has been found that even a very small failure in the coating is very serious since the slightest exposure of the molybdenum or molybdenum alloy to the atmosphere will cause rapid oxidation of the exposed area. As oxidation progresses an increasingly large area of the molybdenum or molybdenum alloy is exposed resulting in failure of the coated article.

Briefly stated, in accordance with one aspect of my invention, I provide a molybdenum or molybdenum alloy article which is clad by the steps of first forming the oxidation resistant cladding material to conform to the contours of the article, attaching the sheet material to the article and holding the sheet material against the article while the article and sheet material are subjected to high temperature and pressure in order to join the sheet material to the article.

The invention hereinafter described is applicable to any regular or irregularly shaped molybdenum or molybdenum alloy object that is to be protected for operation at elevated temperatures. For purposes of illustration, however, the invention will be described in connection with the coating of a gas turbine bucket since this is a rather typical application for protective surfaces of the type disclosed by this invention. It is to be understood, however, that the protective surface as herein described is applicable to any molybdenum or molybdenum base alloy whether it is a flat sheet or an irregularly shaped object,

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the latter being illustrated by a turbine bucket as herein-after set forth.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, FIGURE 1 is a turbine bucket showing the sheet metal cladding which is to be joined thereto; FIGURE 2 is a cross section along the lines 2-2 of FIGURE 1; FIGURE 3 is a modified form of the cross section shown in FIGURE 2; FIGURE 4 is a portion of the cross section of the clad bucket greatly exaggerated; FIGURE 5 is another portion of a cross section of the clad turbine bucket greatly exaggerated; FIGURE 6 is a perspective view of a pair of pressure plates used to join the cladding material to the bucket; and, FIGURE 7 is a schematic cross-sectional view of the pressure chamber used to join the cladding material to the bucket.

Referring now to the drawing, FIGURE 1 shows a typical turbine bucket 10 comprising a blade or airfoil portion 12 and a shank and dovetail portion 14. The bucket 10 has the platform portions 16 on either side of the airfoil portion 12 which also forms the top of the shank and dovetail portion 14. Before joining the cladding material to the bucket 10, I provide coatings of chromium and nickel over the molybdenum. These coatings are highly resistant to oxidation. The cladding material to be clad over the chromium and nickel coatings is used to protect the oxidation resistant coatings from impact, abrasion and erosion and is also highly oxidation resistant. The coatings of chromium and nickel as applied to the bucket are shown in FIGURES 4 and 5. Referring to these figures, 18 and 18' represent the molybdenum bucket portion, 20 and 20' represent the chromium coating and 22 and 22' represent the nickel coating. The method of applying the chromium and the nickel coatings will be hereinafter set forth.

I apply the chromium coating by first cleaning, rinsing and then electro-polishing the bucket for a short period of time, for example, in a strong solution of sulfuric acid. After removal from the acid, the bucket is rinsed, cleaned, rinsed again, then dipped in a weaker solution of sulfuric acid and then rinsed. These steps are conventional and are taken merely to assure a thorough cleaning. Next the bucket is chromium plated in a conventional bath with a bath temperature of about 130-170° F. and using a current of approximately 2 amperes per square inch until about .0005 to .002 inch of chromium have been deposited.

The chromium coating is deposited to prevent the diffusion of subsequently deposited nickel into the molybdenum. At elevated temperatures, nickel diffuses into molybdenum and forms a brittle inter-metallic compound at the interface. Unless the chromium coating is sufficiently thick, the objectionable diffusion will rapidly take place to form the brittle intermetallic compound. Therefore, the first coat of chromium must be at least .0005 inch thick. A coat of chromium of less than this thickness will not sufficiently retard the diffusion at elevated temperatures. Also, the coefficients of expansion of molybdenum and nickel are such that separation due to thermal stress occurs between the two during heating when nickel is plated directly on molybdenum, whereas the chromium coating with its more desirable coefficient of expansion provides a graded seal effect, thus lessening the thermal stress between the multiple coats during thermal change and resulting in better bonding between the coats.

After the bucket has been chromium plated, it is rinsed, cleaned, and rinsed again. It is then electro-polished in a strong solution of sulfuric acid for a short period of time, rinsed, cleaned, re-rinsed, then dipped in

a weak solution of sulfuric acid for a short period of time and then re-rinsed. Again these steps are taken merely to assure a thorough cleaning and are given merely by way of showing one method of cleaning the bucket properly. The bucket is now given a nickel strike, for example, in a high chloride bath for a short period of time such as one minute. The nickel strike is carried out using a current of approximately 1 ampere per square inch.

After the nickel strike, the bucket is dipped in running water and rinsed. Next, the bucket is coated with a low stress nickel plate for a sufficient length of time to give the desired thickness preferably by use of a mechanical rotating fixture. The two coats of nickel which form a composite nickel coating are deposited to a depth of .001 to .004 inch and lend ductility to the coating. It has been found that better coating adhesion is obtained by the use of two separate nickel coatings, such as a nickel strike followed by a low stress nickel coat as disclosed above. The nickel plating is carried out for 15 minutes with a current of approximately $\frac{1}{6}$ to $\frac{2}{5}$ ampere per square inch and a bath temperature of 130–150° F. The nickel plating is carried out in a modified Watts bath to obtain low stress as plated nickel.

After the chromium and nickel coatings have been deposited the bucket is rinsed and then is subjected to a heat treatment cycle in a reducing atmosphere. The heat treatment is carried out in a hydrogen atmosphere and is accomplished by slowly bringing the bucket for a period of approximately $\frac{1}{2}$ hour up to a temperature of 1400° F. The bucket is held at 1400° F. for two hours and then the temperature is raised to 1600° F. for an additional two hours. Following this operation the bucket is furnace cooled. Following this heat treatment, the bucket is ready for cladding.

The cladding material may be any high temperature oxidation resistant sheet material such as a composition having 20% chromium, 80% nickel; 25% chromium, 20% nickel, 55% iron; or, 19.5% chromium, 10% nickel, 51% cobalt, 14.5% tungsten, and 2.5% iron. Good results have been obtained by using a cladding material approximately .005 to .010 inch thick. The high temperature cladding material is formed in three sections. The sections comprise a boot section 24 for the blade or airfoil portion 12 of the bucket 10, a formed concave platform section 26 for the concave platform contour of the bucket 10 and a formed convex platform section 28 for the convex platform contour. The boot section 24 and the concave and convex platform sections 26 and 28 are fabricated so their contours conform substantially to the corresponding portions of the bucket being clad. The boot 24 for the airfoil section is made from a pattern prepared either from perimetral measurements of the airfoil between the tip and the junction of the airfoil with the platform 16 or by covering the surface of the airfoil 12 with masking tape, making a longitudinal cut and peeling the tape from the surface. Since the coefficient of expansion of the cladding material is greater than the base molybdenum and since some stretching of the cladding material will take place in forming, the boot 24 is formed so that its perimeter is .015–.020 inch less per inch of perimeter of the molybdenum airfoil section 12. The boot 24 may be formed with an overlap as shown at 30 in FIGURE 2 along the face of the concave side or it may have an overlap 32 as shown in FIGURE 3 along the trailing edge whichever may be preferable. The concave and convex platform sections 26 and 28 are formed on suitable dies.

Before joining the boot 24 and the platform sections 26 and 28 to the bucket 10 a suitable brazing alloy is applied to the nickel coating 22 as shown at 34 in FIGURE 4. Any suitable brazing alloy will be satisfactory for this application and the only limitation on selection of a proper brazing alloy is the ultimate operating temperature of the bucket itself. I have obtained satisfactory results by using a brazing alloy having 92% nickel,

4½% silicon, 2% boron with the balance impurities. With this type of brazing alloy the bucket can be operated satisfactorily up to 2065° F. The brazing alloy may be flame sprayed on the nickel coating 22. It is desirable that the spraying take place in a reducing flame. The spraying apparatus may be of any conventional type for spraying the coating 34 to the desired thickness. It was found that a thickness of approximately .004–.005 inch is satisfactory. After spraying the brazing alloy on the bucket, the bucket is heat treated in order to fuse the sprayed composition to the nickel coating 22. The heat treatment is preferably carried out in a reducing atmosphere such as dry hydrogen. The heat treatment process is best carried out in three steps, viz. preheating, fusing and cooling. Preheating is carried out below the fusing temperature of the sprayed coating; for example, the range between 1500° F. and 1900° F. During such preheating, a partial sintering takes place between the particles of the sprayed coating. After preheating, the bucket is moved into the fusing or hot zone of the furnace. This zone is maintained at a temperature at or above the fusing temperature. In the case of the brazing alloy discussed above, the temperature in the fusing zone is approximately 2100° F. When the bucket is placed in the fusing zone, the sprayed coating melts, fuses and forms a metallurgical bond between the brazing alloy 34 and the nickel coating 22. The bucket is then ready for the application of the cladding material.

I next assemble the sheet metal portions to the bucket.

The concave and convex platform sections 26 and 28 are first placed over the platform portions 16 of the bucket 10. The boot section 24 is next placed over the blade or airfoil section 12 of the bucket 10 in such a way that it overlaps the upper portion 36 of both the concave and convex platform sections 26 and 28. The overlap is approximately $\frac{1}{8}$ inch. The bucket with the assembled sheet metal portions is then placed in a rubber die having the shape of the bucket and squeezed to give the sheet metal cladding a slight pre-set.

The bucket with the sheet metal cladding in place is put into a pressure chamber 38 as shown in FIGURE 7 in order to permanently join the cladding 40 to the bucket as shown in FIGURE 4. The pressure chamber 38 comprises a pair of gas tight chambers 41 and 42, a spacer member 43 and the pressure plates 44 and 45. The pressure plates 44 and 45 are pre-formed so as to substantially conform to half of the assembled bucket. Pressure plate 44 conforms to the concave face of the bucket and pressure plate 45 conforms to the convex face of the bucket as shown at 46. FIGURE 6 shows the assembled bucket 10 lying in the pressure plate 44. In order to prevent the sharp edges of the shank and dovetail portion 14 of the bucket 10 from damaging the pressure plates 44 and 45 when the pressure plates are placed under pressure in the pressure chamber 38, a pair of end inserts 48 and 50 are placed alongside the end portion of the shank and dovetail portion 14, a pair of side inserts 52 and 54 are placed along the longitudinal faces of the shank and dovetail portion 14 and a bottom insert 56 is placed along the bottom of the shank and dovetail portion 14. As aforesaid, these inserts merely serve as protection for the pressure plates 44 and 45 from the sharp edges of the shank and dovetail portion 14.

The bucket is next placed in the pressure chamber 38. The bucket with the assembled cladding material and inserts 48, 50, 52, 54, 56 is first placed between the pressure plates 44 and 45 with the spacer member 43 separating the pressure plates 44 and 45 about their periphery. The gas tight chambers 41 and 42 are next placed in a suitable press and positioned on either side of the pressure plates 44 and 45 and held in a rigidly assembled position as shown on the drawing. The gas tight chambers 41 and 42 are provided with suitable heating coils 62. The apparatus is now ready for brazing the cladding material to the bucket.

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The gas tight chambers 41 and 42 are first flushed out with argon by means of the conduit 64 and the pressure within the chambers 41 and 42 is held at 5 p.s.i.g. A moderate flow of dry hydrogen having a dew point of -40° F. or lower is introduced at the conduit 66 and flows between the pressure plates 44 and 45 to be burned off at the conduit 68. The hydrogen flow is adjusted until a flame approximately 2 inches long is produced. Next, the electric current is turned on and the bucket is brought up to the re-fusing temperature which is 2115-2135° F. for the particular brazing alloy previously mentioned. When this temperature is attained the argon pressure within the gas tight chambers 41 and 42 is increased to approximately 300-450 p.s.i.g. It is to be understood, of course, that the re-fusing temperature may be different if other types of brazing alloys are used. The temperature and pressure are maintained in the pressure chamber 38 for approximately five minutes and the current to the heating coil 62 is then turned off. The bucket is cooled in the pressure chamber and upon removal it has the cladding material permanently joined to the bucket.

In some cases it may be desirable to join the cladding material directly to the nickel coating by diffusion welding. This is shown in FIGURE 5 wherein the cladding material 40' is joined to the nickel coating 22'. In this type of process, the step of applying the brazing alloy is, of course, eliminated. The cladding material is placed on the bucket immediately after the nickel coating is applied and the process is carried out in the pressure chamber 38 in exactly the same manner as previously explained for the brazed type of cladding. The only difference being that in applying the coating by diffusion welding, the temperature in the pressure chamber is not critical and may be anywhere between 2000° F. and the recrystallization temperature of the molybdenum for 15-30 minutes. Higher argon pressures may be used in the gas tight chambers 41 and 42.

While particular embodiments of the invention have been illustrated and described, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention and it is intended to cover in the appended claims all such changes and modifications that come within the true spirit and scope of the invention.

What I claim is:

1. A molybdenum alloy blade including a platform and an airfoil and having an outer cladding of a nickel and

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chromium bearing sheet metal including at least one other element selected from the group consisting of iron, cobalt and tungsten, said outer cladding comprising a first platform section secured to about one-half of the platform, a second platform section secured to substantially the other half of the platform and a boot section secured to the blade airfoil, said first and second platform sections being secured one to the other and each to the boot section whereby said platform sections and said boot section cooperate to form a continuous oxidation resistant and particle impact resistant cladding over the blade airfoil and platform.

2. A molybdenum alloy blade including a platform and an airfoil and having an outer cladding of a nickel and chromium bearing sheet metal including at least one other element selected from the group consisting of iron, cobalt and tungsten, said outer cladding comprising a first platform section hot pressure welded to about one-half of the platform, a second platform section hot pressure welded to substantially the other half of the platform and a boot section hot pressure welded to the blade airfoil, said first and second platform sections being hot pressure welded one to the other and each to the boot section whereby said platform sections and said boot section cooperate to form a continuous oxidation resistant and particle impact resistant cladding over the blade airfoil and platform.

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