April 7, 1953 K. M. BARTLETT 2,633,628

METHOD OF MANUFACTURING JET PROPULSION PARTS

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Fig. 1.

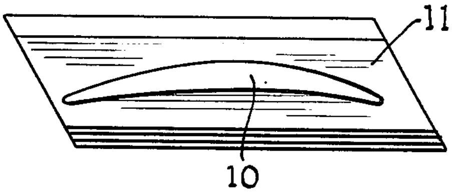


Fig. 2.

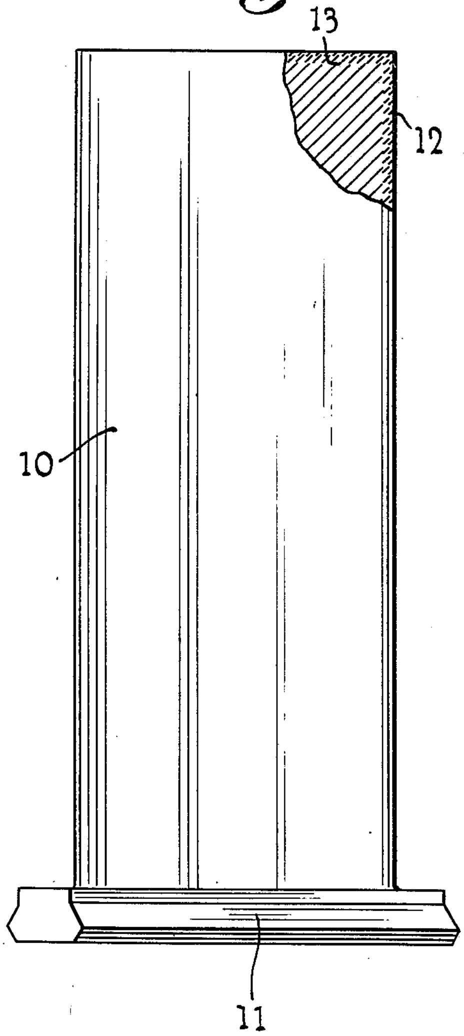
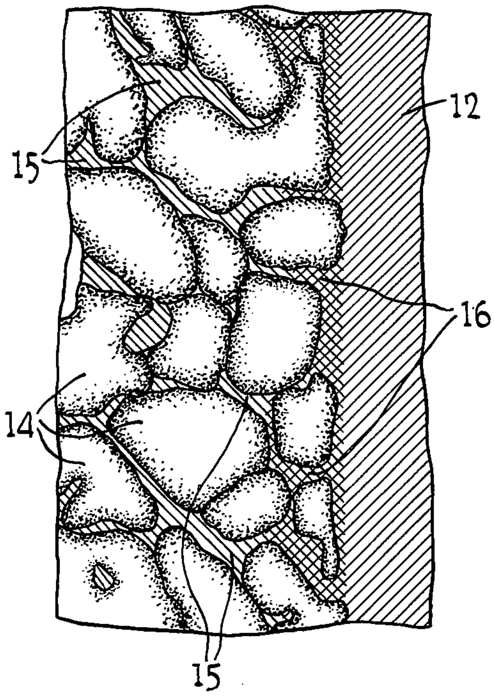


Fig. 3.



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METHOD OF MANUFACTURING JET PROPULSION PARTS

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1 Claim. (Cl. 29—156.8)

This invention relates to the treatment of jet propulsion parts such as compressor blades, turbine buckets, diaphragm blades, and the like vanes for turbo-jet engines for rendering them more resistant to corrosion and scaling.

Specifically the invention is concerned with the production of jet propulsion parts by powder metallurgical and coating processes which form corrosion-resistant covers that are partially diffused into the bodies of the parts and thereby alloyed with the metal of these bodies to form a firm bond therewith.

In accordance with this invention, a shaped part for jet propulsion engines, such as a compressor blade, a turbine bucket, a diaphragm blade, or the like is formed by compacting metallic powder such as of iron or iron admixed with carbon. The compacted porous shape is then infiltrated with copper or a copper alloy to produce the desired dense body structure. If the density of the initially compacted matrix is less than about 85%, the compact is advantageously subjected to a heat treatment and, if required, a high pressure shaping or coining treatment to attain the desired density under preservation of intercommunicating pores therein before it is infiltrated. Since such jet propulsion parts must not only withstand tremendous stresses at operation temperatures, but must also effectively resist corrosion and scaling, in accordance with this invention these parts are covered with a dense and firmly adhering coating of tin or tin alloy which forms its own outer surface resistant to corrosion and scaling. The mainly tin bearing coating can be applied, for instance, by hot dipping, by electroplating followed with a diffusion heat treatment, or by packing the body in the powdered coating metal for subsequent heat treatment. The coating metal in each instance is diffused at least partially into surface layers of the body and thereby alloys to substantial extent with and is absorbed by the infiltrant metal (copper) and the matrix metal (iron), to form particularly solid solution alloys which are sufficiently stable and scale resistant also at elevated temperatures.

The invention will hereinafter be specifically described in connection with a copper-infiltrated powdered iron compressor blade for a jet propulsion engine, but it should be understood that the invention is not limited to this preferred embodiment, being generally applicable to the protection of jet propulsion parts formed by powder metallurgical processes to render these parts more resistant to corrosion and scaling.

According to the preferred embodiment of the invention the shaped jet propulsion parts are dipped into a bath of the molten, tin bearing coating metal. Since exposure of the molten coating bath to the atmosphere results in the formation of an oxide which floats as a slag or dross on top of the molten bath, a feature of the preferred embodiment of the invention includes the use of a cover for the molten coating bath which will prevent this oxidation. Suitable covers include molten salts floating on top of the bath in the form of a protective flux, suitable inert gases such as dry hydrogen or carbon dioxide in the form of a covering atmosphere for the bath, and the like. Fluxes such as cryolite, zinc chloride, sodium chloride, potassium chloride, and the like can be used.

It is, then, an object of this invention to provide jet propulsion parts capable of resisting corrosion and scale formation by forming the bodies of the parts mainly from powdered metals and by coating the parts with a continuous protective cover of tin or tin alloy at least partially diffused with the metal of the parts.

Another object of the invention is to render metallic shapes produced by combined powder metallurgical and infiltration processes suitable for use in jet propulsion engines by bonding a continuous coating of protective tin or tin alloy onto the parts to increase the corrosion and scale-resisting capacity of the parts.

A specific object of this invention is to provide a shaped jet propulsion part composed of a skeleton substantially of sintered iron or steel powder infiltrated with infiltrant metal of considerably lower melting point than the skeleton material, such as copper or copper alloy, and having a non-porous protective coating of tin or tin alloy bonded thereon and at least partially diffused therewith in alloyed relation with the infiltrant metal and/or iron skeleton (matrix).

A still further object of this invention is to provide a method of protecting jet propulsion parts mainly composed of sintered powdered metal by dipping the parts in a molten bath of tin or tin and alloying constituents which is protected against oxidation by a sealing cover which does not adhere tenaciously to the part passed therethrough.

A still further object of the invention is to protect jet propulsion parts against corrosion by coating the parts with tin or tin alloy that forms its own corrosion resistant surface and by at least partially diffusing this metal into and with the body to form an alloy therewith.

Other and further objects of the invention will be apparent to those skilled in the art from the following detailed description of the annexed sheet of drawings which, by way of a preferred example only, illustrates the article and method of the invention.

On the drawings, Figure 1 is a plan view of a compressor blade for a jet propulsion engine, Figure 2 is a side view of the blade of Figure 1 with parts broken away and illustrating the coating on the body of the blade, and Figure 3 is a greatly magnified fragmentary view illustrating the structure of the blade body and coating to show the manner in which the coating is diffused into the body.

Referring to Figures 1 and 2, the reference numeral **10** designates generally a compressor blade for a jet propulsion engine. The blade **10** has a root **11** for attachment to the compressor body. The blade is coated with a protective metal **12** that forms its own corrosion resistant surface. Suitable coating metals are tin and tin alloys.

The body **13**, as best shown in Figure 3, is composed of particles **14** of iron interconnected to form a porous iron skeleton. The iron preferably contains no carbon, but carbon up to about 1% and alloying constituents of alloy steel can be present. The iron particles **14** have initially an average particle size within the range of about 80 to above 325 mesh. They are compacted under commercial pressures ranging from about 6 to 50 tons per square inch to a briquette in the shape of the desired article such as the blade **10**. A blade having a porosity of about 10 to 35% is thus formed. If the porosity of the briquette exceeds about 15% it is preferably presintered, an iron briquette for instance at temperatures between 900 and 1100° C. for about one half to one hour. The sintered porous shape is next coined, if required, to decrease further its porosity preferably below 15% and to impart to it the final configuration. The porous shape is then contacted on one of its faces with copper in an amount measured to completely fill the pores of the shape. The copper forms conveniently a solid piece and is preferably alloyed, e. g. by melting and quenching, with up to about 5% manganese and 1% silicon, or about 2 to 8% manganese and about 1 to 2% iron. Other alloying constituents, such as .2 to 5% nickel, titanium, phosphorus, chromium and/or sulphur may be added. The porous shapes with the copper or copper alloy thereon are then heated in a clean, dry protective atmosphere at temperatures above the melting point of the copper or copper alloy and preferably between 1125 to 1250° C. This temperature is maintained for a sufficient time to melt the alloy completely and to cause its infiltration into the pores of the shape. Usually 10 to 15 minutes are sufficient for this purpose. When the infiltration of copper is completed, the resulting infiltered body is cooled. In Figure 3 the copper infiltrant is indicated at **15** between the iron particles **14**. This infiltrant extends throughout the entire body of the blade **10** and fills its voids completely. The infiltrated body may be subjected to suitable heat treatments, such as diffusion and precipitation or steel treatments. It can be heat treated particularly to superficially alloy the ferrous skeleton and copper network intimately interlaced therewith. The coating **12** applied in the manner hereinafter described is quite dense, completely covers the body of the blade, and is alloyed with the matrix metal by diffusion preferably to a depth of about 0.003 to 0.004 inch. As indicated, the coating **12** is also alloyed with the copper infiltrant as at **16**. These alloy layers provide a firm bond integrally uniting the coating with the body metals so that it will not peel, flake, or chip off of the blade even when subjected to severe stresses. It forms its own corrosion resistant surface when or before it is exposed to corrosive atmospheres at operation temperatures.

The coating **12** is preferably formed by hot dipping the body **10**. On the illustrated blade, a tin coating is formed by dipping the blade into a molten bath of tin maintained at temperatures well above the melting temperature of tin and preferably around 800° C. The tin coating diffuses to substantial degree into the blade to alloy with the outer layers of the body metal of the blade. It is preferred sometimes to add to and dissolve in the molten tin bath copper, from 1 to 3% up to about 10% by weight of the tin and/or other alloying constituents in small amounts, such as zinc. The tin bath is covered, e. g., with a flux consisting of cryolite, a compound having the composition 3 $NaFAlF_3$ or Na_3AlF_6. This flux will not combine with tin or its alloying constituents in the molten state, nor will it combine with or adhere tenaciously to the ferrous metal or copper forming the body of the blade. After the hot dipping operation, the coated blade **10** may be subjected to a diffusion heat treatment preferably at temperatures around 200° C. if a coating of practically pure tin has been applied, and at higher temperatures if a coating of a tin alloy of higher melting point than tin has been applied. Thereby the tin or tin alloy is caused to further alloy with the superficial layers of the body of the blade. The temperature of the diffusion treatment may be increased in some cases with progressing alloy formation. The heat treatment is continued until the desired penetration depth is obtained. The tin or tin alloy readily alloys with the copper infiltrate and iron matrix. Substantial amounts of tin can be held by copper and alpha-iron in solid solution at room temperature; since the tin is not precipitated from those solvents upon heating in the solid state, a firm bond is established over the applicable range of operation temperatures. If the coated blade is for use at operation temperatures exceeding 230 to 260° C., the thickness of the coating deposited on the blade body and the ensuing diffusion treatment can be controlled so that the resulting coating consists substantially of tin alloyed with the body metal and exhibits a correspondingly higher melting point. This diffusion or alloying heat treatment can be effected in contact with the air and the outer layer of the tin bearing coating will become oxidized to form its own dense oxide cover preventing a corrosion on the coated blade also at higher operation temperatures.

Instead of hot dipping the article to form the protective coating layer thereon, the article can be packed in the powdered coating metal. If tin or tin alloy powder is used, the pack is heated to about 200° to 280° C. for about three or four hours. The packing treatment simultaneously forms the tin or tin alloy coating and the desired diffused alloy with the copper and iron matrix, at least to large extent, and can be followed by a further diffusion treatment, if desired.

In a further embodiment of the invention the coating can be applied by electroplating followed by a subsequent diffusion heat treatment as described herein previously.

From the above descriptions and drawings it will be understood that the invention provides a jet propulsion part prepared by powder metallurgy and protected with a continuous metal coating of a metal that forms its own surface layer more resistant to corrosion and scale formation than the body of the part. The metal coating is at least partially diffused into the body to alloy therewith and form a bond that will effectively resist separation of the coating and body metals.

It should be understood that the invention is not limited to any exemplifications hereinbefore described but is to be derived in its broadest aspects from the appended claim.

What I claim is:

A method of forming a shaped fluid guiding body, such as a gaseous fluid guiding blade of a gas turbine having high hot-strength properties and an operative surface which in operation is exposed to oxidizing gases at high temperatures, which method comprises compacting and forming ferrous particles into a shaped sintered porous skeleton having intercommunicating pores and a porosity in the range of about 10% to 35%, infiltrating said skeleton with a cuprous infiltrant containing at least about 90% copper while said infiltrant is in molten condition, thereafter maintaining the infiltrated skeleton at a temperature below the melting temperature of said infiltrant while coating the exterior of said infiltrated body with a coating metal selected from the group consisting of tin and tin alloys, and thereafter maintaining said coated body at an elevated temperature in the range of about 200° to 280° C. for at least one hour for causing the metal of said coating to diffuse and penetrate through surface layers of said infiltrated body and thereby firmly bond said coating to said layers, and to cause constituents of said body to penetrate and diffuse throughout substantially the entire thickness of said coating and thereby render said coating into a continuous impervious heat and oxygen resisting enclosure tightly adhering to the exterior of said body and having a melting temperature materially higher than the melting temperature of said coating metal.

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