

[54] METHOD FOR IMPROVING BOND BETWEEN TRANSPLANTED COATING AND DIE-CASTING

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[56] References Cited

UNITED STATES PATENTS

2,911,708	11/1959	Fike et al.	29/527.3
3,061,525	10/1962	Grazen	204/49
3,083,424	4/1963	Bauer	164/112 X
3,098,270	7/1963	Bauer	164/112 X
3,293,109	12/1966	Luce et al.	204/38 E
3,616,288	10/1971	Snaely	204/26
3,628,237	12/1971	Zeigler	29/527.6
3,640,799	2/1972	Stephan et al.	204/40
3,797,101	3/1974	Bauer	164/46
3,856,635	12/1974	Brown	29/527.3
3,878,880	4/1975	Jones	164/9

FOREIGN PATENTS OR APPLICATIONS

873,012 7/1961 United Kingdom

OTHER PUBLICATIONS

"Bonding Cast Iron to Aluminum Castings," *Light Metal Age*, Oct., 1959, p. 17.

"Aluminum Bonded by Diecasting Process," *Steel*, Nov. 30, 1959, pp. 98-100.

"Transplant Coated Aluminum Cylinder Bores," A. F. Bauer, Paper No. 369C, 1961, Summer Meeting, Society of Automotive Engineers, 485 Lexington Ave., N.Y., N.Y.

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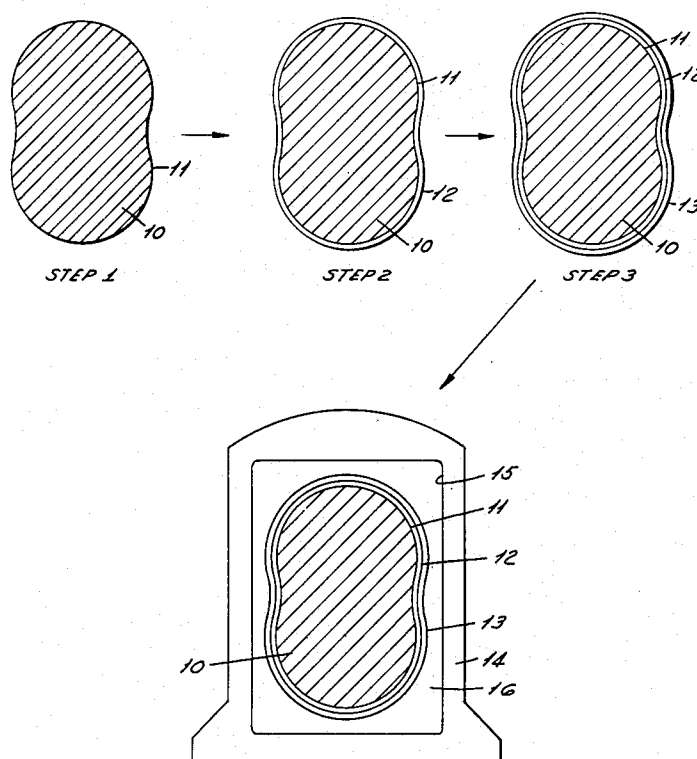
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[57] ABSTRACT

An improved process is disclosed for uniting an electrolytically deposited cermet with a molten cast material such as aluminum. The cermet is deposited on a mandrel so as to provide a smooth inner surface (8-12 r.m.s.) and a controlled rough outer surface at least 250 times more rough than the inner surface. Electrolytically deposited copper is positioned on the cermet and assumes the rough character of said cermet outer surface. The assembly of electrolytic deposits is then placed in a die-cast machine where molten metal, such as aluminum, is cast thereabout to form an integrated composite particularly useful as a rotor housing for a rotary internal combustion engine.

4 Claims, 2 Drawing Figures



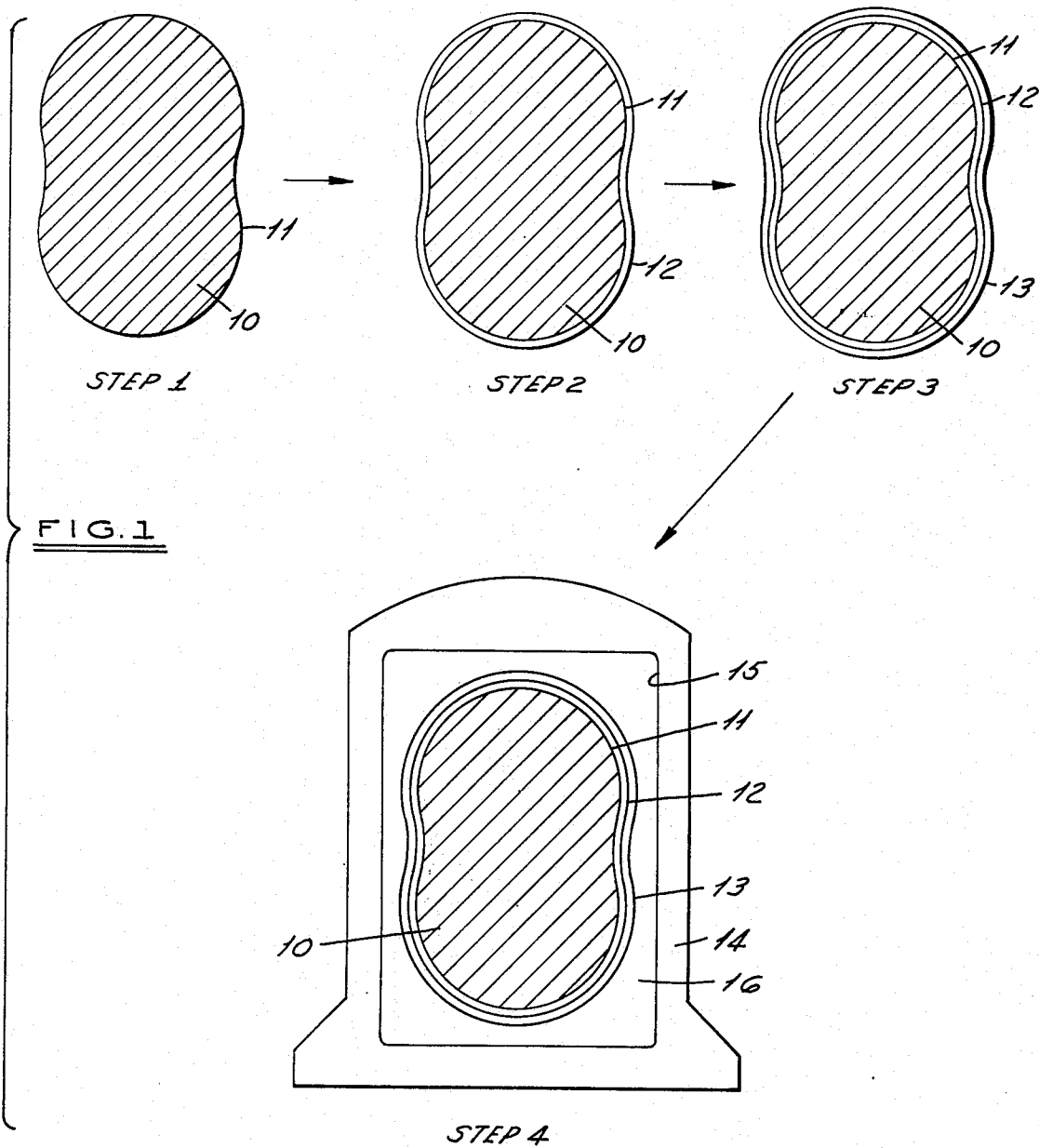
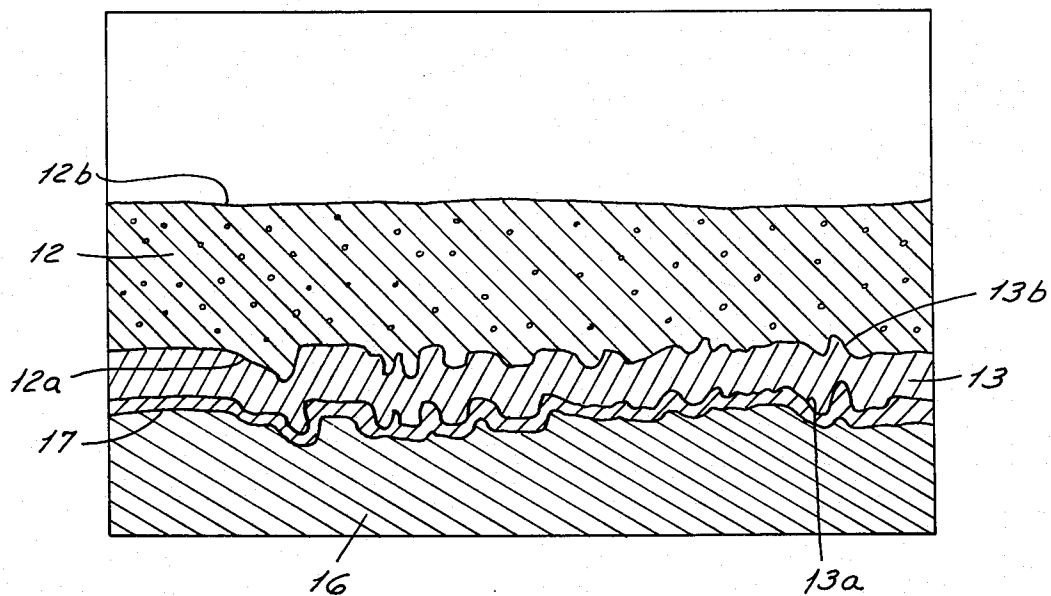


FIG. 2

METHOD FOR IMPROVING BOND BETWEEN TRANSPLANTED COATING AND DIE-CASTING

BACKGROUND OF THE INVENTION

Electrolytic deposition creates a non-porous dense material by the inherent characteristic of electrolytic deposition which deposits the coating atom by atom. However, it is difficult to adhere another different material to the electrolytic deposit of material because of such density and non-porosity. This has not been a severe problem heretofore since electrolytically deposited metals have rarely been used as functional parts, but rather as decorative outer coatings. However, it has been found that in a rotor housing for a rotary internal combustion engine, an electrolytic layer of considerable thickness can impart certain desirable characteristics, the most important of which is wear resistance.

Under the present state of art, there is a tendency for an electrolytic coating to become disunited from a different substrate during severe service it will receive in a rotary engine. The typical bond that may exist between thin decorating electrolytic coatings and substrates, does not exist when dealing with thicker functional coatings. The environment of such an engine imparts stress as well as heat fatigue, requiring a strong adherency between the exposed electrolytically deposited coating and the supporting cast material. Because a typical rotor housing has an intricate configuration such as an epitrochoid, there is no opportunity to apply a combination of heat and pressure to achieve a conventional metallurgical bond. Also, the molten aluminum is not sufficient to wet a cermet (such as nickel and silicon carbide) which under other circumstances would provide a metallurgical bond by heat alone.

SUMMARY OF THE INVENTION

The primary object of this invention is to provide an improved union between differential materials which are particularly used in forming a composite for a rotor housing of a rotary internal combustion engine.

A particular object of this invention is to provide a method which firstly controls the surface roughness of an electrolytically deposited cermet and secondly utilizes an electrolytically deposited intermediate metal to assume a mirror image of the rough surface cermet while responding to the heat of molten material thereabout to effect a mutually soluble metallurgical bond.

A specific feature of the inventive method comprises use of an electrolytically deposited copper-based strike which is interposed between an electrolytically deposited cermet material (such as nickel-silicon carbide) and a molten cast material (such as aluminum or aluminum-based alloys).

SUMMARY OF THE DRAWINGS

FIG. 1 is a schematic flow diagram of the steps involved in a preferred method embodiment; and

FIG. 2 is a schematic illustration of a section of a composite coated assembly comprising the constituents of this invention and illustrating the view solidification structure.

DETAILED DESCRIPTION

Turning now to the schematic flow diagram of FIG. 1, a preferred sequence is illustrated. In Step 1, a mandrel 10 is prepared from a suitable core material capable of being machined to a very exact complex configuration,

such as an epitrochoid surface 11. The epitrochoid surface is required by the internal wall of a rotor housing for a rotary internal combustion engine. The epitrochoid surface 11 is a mirror image of the resultant epitrochoid surface to be structured on the rotor housing of the engine. A suitable material for this purpose is a chrome-bearing steel having a chromium content in the range of 3-25 percent. The chrome content enables the material to be passivated thereby facilitating non-adhesion between the mandrel and the material to be deposited thereover. In addition, the mandrel may be tapered in a direction from one end to the other to facilitate stripping subsequent to Step 4. The surface 11 must have a surface roughness of 4-12 r.m.s. which may be imparted by machining and polishing.

In Step 2, the mandrel is placed in an electrolyte for the purpose of electrolytically depositing a cermet coating consisting of nickel with carbide particles. The cermet may also be constituted of a base material selected from either iron or a copper alloy and containing ceramic particles selected from the group consisting of silicon carbide, tungsten carbide, oxides of aluminum or iron and diamond. The resultant electrolytic coating will define a sleeve 12 about the mandrel. The composition of the electrolyte for depositing the nickel-based cermet is not critical, however, the following range of ingredients has been found to be conveniently controlled: Ni So_4 —7 H_2O in the range of 150-300 grams per liter, Ni Cl_2 —6 H_2O in the range of 30-70 grams per liter, and H_3Bo_4 in the range of 20-40 grams per liter. Silicon carbide, being among the hardest materials, is preferred because it combines high hardness with low cost in a most desirable manner. The hard particles are introduced to the electrolyte in an amount in the range of 100-150 grams per liter and in a particle size range of 0-10 microns; the particles are held dispersed in the electrolyte by agitation. A PH value for the electrolyte is selected according to other process variables and may be between 1 and 7 in a conventional manner. The temperature of the electrolyte may be about 160°F. The current density is sequentially staged to be in the range of about 50-100 amps per square foot for a few starting moments of the deposition step and then eventually raised to 500-1000 amps per square foot for the remainder of Step 2. Electrolytic nickel is the preferred anode material.

The deposited coating 12 is in the thickness range of 0.01-0.04 inches, preferably 0.025 inch, and has a porosity of substantially zero. This is in high contrast to the characteristic porosity of a spray coating which has a minimum of 5 percent. The porosity of a spray coating is detrimental to heat transfer and forms a barrier at the very location in the rotor housing where heat must be transmitted. The lack of porosity and the denser material affords a greater heat transfer. The outer surface 12a has a roughness controlled to be at least 250 times more rough than the mandrel surface 11 and thereby also the inner side 12b. More particularly, the roughness may be characterized by projections of a height of at least 0.030 inches and concentrated so as to number 5-100 per square cm.

The eventual casting of aluminum directly about such a coating 12 encounters certain problems. The surface tension of aluminum is considerably high and must be lowered to effectively wet or metallurgically adhere to the non-porous coating 12. One technique used by the prior art is to use sand blasting to lower such surface tension by creating a highly rough surface

for the coating. However, this has not proved successful because of cost and lack of control. A principal feature of this invention is to utilize an intermetallic strike 13 over the coating 12 which not only acts as a more satisfactory wetting agent for the aluminum (since it is selected to be mutually soluble at casting temperatures with aluminum) but also effects a limited degree of alloying with the cermet material. The intermetallic strike should have a melting temperature below the cast metal, be mutually soluble in the cast metal, be easily electroplated, and have a coefficient of thermal expansion slightly less (differ by only 4 micro-inches) than the cast metal.

In Step 3, the mandrel and sleeve coating 12 is placed in another electrolyte to preferably receive coating 13 of elemental copper. The electrolyte bath may be constituted of (a) copper sulphate in the concentration of about 28 ozs. per gallon, (b) concentrated sulphuric acid in a concentration of about 7 ozs. per gallon. The bath is maintained at a temperature in the range of 70°-75°F and a current density is applied to the electrolyte in the range of 40-60 amps per square foot and preferably 50 amps per square foot. The layer or coating 13, being a copper base constituent, is mutually soluble with aluminum which is to subsequently cast thereabout. Coating 13 at both sides 13a and 13b assumes the controlled rough surface contours of side 12a to enhance the wetting characteristic of the aluminum against the upper coating. The copper coating is deposited uniformly but becomes a mirror image of the rough cermet surface 12a. The copper coating is deposited in the thickness range of 0.0005 to 0.002 inches, preferably 0.0005 inches.

In Step 4, the two electrolytic coatings and the mandrel are placed as an assembly into a die-cast machine 14 having a suitable cavity 15 which is complimentary in shape to the outer coating 13. An aluminum-based alloy is injected into the molding cavity about the assembly to form a casting 16 which is metallurgically bonded to the coating 13. The heat of the casting material penetrates the coating 13 to effect alloying between the copper and nickel-silicon carbide coating. The aluminum-based alloy may contain an amount of silicon (4-16 percent, preferably 10% Si and 3% copper). The cast metal is selected from the group consisting of aluminum or aluminum alloys, iron and magnesium.

Turning now to FIG. 2, there is shown a schematic of the solidification structure of the resultant composite. Cast aluminum 16 is metallurgically bonded to the copper strike or coating 13 by the mechanical interlock of the mating rough interfaces and by the alloying zone 17 where substantial amounts of aluminum and copper became mutually soluble. The copper strike has rough sides 13a and 13b due to being uniformly deposited on rough surface 12a of the cermet 12. The inner surface 12b of the cermet has an extremely smooth (4-12 r.m.s.) wear-resistance surface because it deposited against the polished mandrel surface.

I claim as my invention:

1. A process for uniting an electrolytically deposited cermet with a die-cast metal, said cermet being comprised of a material selected from the group consisting of titanium carbide, tungsten carbide and aluminum

oxide, said die-cast metal being selected from the group consisting of aluminum, iron and magnesium, the process consisting of electroplating said cermet in a thickness range of 0.010-0.040 inches, and having a controlled surface roughness at one side, said cermet being electrolytically deposited with a current density above 400 amps/ft² during a substantial portion of the time of said deposition, and electroplating a uniform deposit of a copper-base constituent onto said one side of said cermet in a thickness range of 0.0005-0.002 inches to form an electrolytic-metallurgical bonded assembly, and subsequently die-casting said molten metal about said assembly whereby the heat of said molten metal is effective to create an alloy metallurgical bond between said copper-base constituent and the roughness of said constituent creates a mechanical lock therebetween.

2. A process for uniting an electrolytically deposited cermet on a mandrel with a die-cast molten material, said cermet having a thickness in the range of 0.010-0.040 inches, the improvement in said process consisting of electroplating a copper-based constituent onto said cermet-mandrel assembly and subsequently casting said molten metal about said assembly, said constituent and die-cast molten material each having coefficients of thermal expansion which differ by no greater than 4 microinches/in./in./°F, said copper-based constituent having a controlled surface roughness at both sides thereof at least 250 times the surface roughness of the cermet surface facing said mandrel, the resultant structure having both a mechanical and metallurgical bond between said copper and cast material as well as between the copper and electrolytically deposited cermet.

3. A method of uniting an electrolytically deposited cermet with a cast metallic material, said union being particularly useful in a coated rotor housing of a rotary internal combustion engine, the process comprising:

- defining a conductive mandrel having an outer surface complimentary to the resultant inner surface of the union and having a surface roughness no greater than 12 r.m.s.,
- electrolytically depositing a thin coating of a composite particle wear-resistant material on to said mandrel, the current density applied to promote said deposition, being above 400 amps/ft² during a substantial portion of the time of said deposition,
- electrolytically depositing a coating of a copper-base constituent on to said wear-resistant material having a thickness less than said wear-resistant material,
- casting a molten metallic material about said assembly, the molten material having a coefficient of thermal expansion greater than the thermal expansion of said cermet, and
- stripping said mandrel from said casting and inner coatings to expose the inner surface of said wear-resistant material.

4. The method as in claim 3, in which the cermet material is comprised of nickel with uniformly and finely dispersed particles of silicon carbide, and the molten cast material consists of an aluminum-based alloy.

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