

[54] **REUSABLE MANDREL FOR STRUCTURES HAVING ZERO DRAFT OR RE-ENTRANT GEOMETRIES**

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[58] Field of Search**29/195 P, 191; 249/62**

[56] **References Cited**

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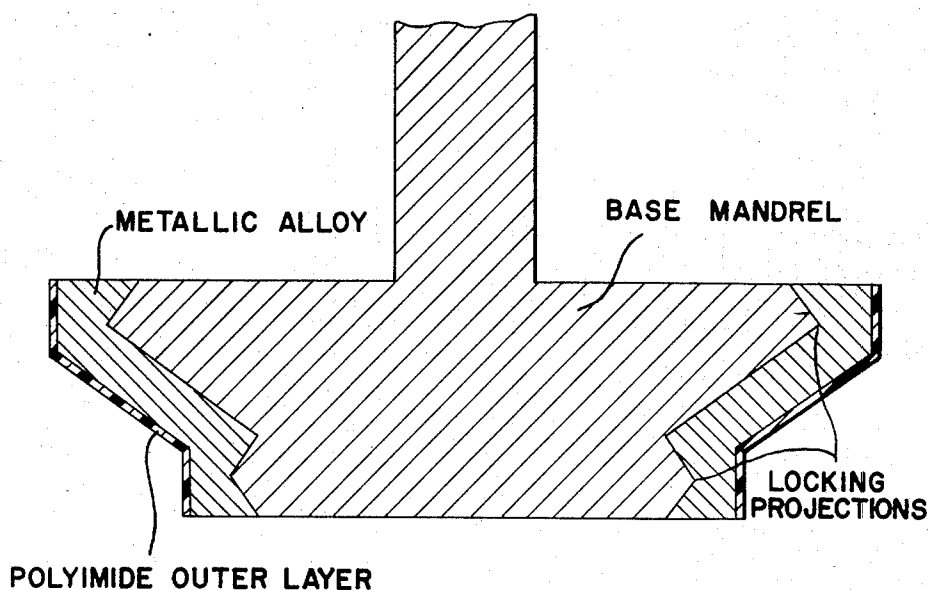
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[57] **ABSTRACT**

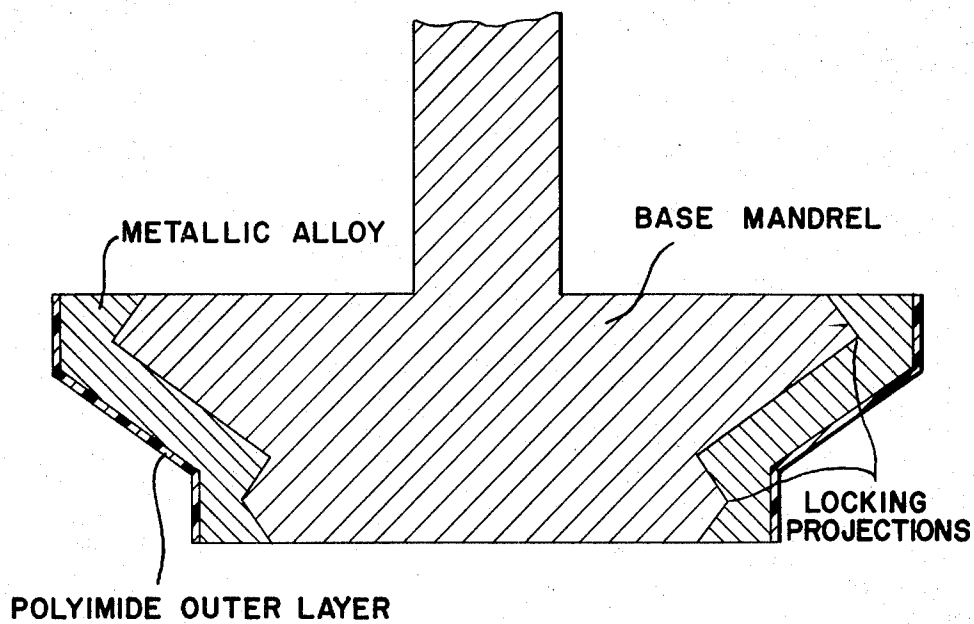
A mandrel, and process therefor, consisting of a high melting temperature base material, such as aluminum, having an undercoating of a low melting temperature metallic alloy and an overcoating of a polyimide material. In casting or plasma deposition applications, the undercoated metallic alloy is removed at an elevated temperature thereby facilitating the removal of the base mandrel.

3 Claims, 1 Drawing Figure



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REUSABLE MANDREL FOR STRUCTURES HAVING ZERO DRAFT OR RE-ENTRANT GEOMETRIES

FIELD OF THE INVENTION

This invention relates to reusable mandrels, and the process therefor, for use in producing plasma-deposited consolidated bodies or castings having zero degree draft or reentrant geometries. Specifically, the mandrel consists essentially of a high-melting-point base mandrel, such as aluminum, having a low-melting-point metallic alloy undercoat and a polyimide overcoat.

DESCRIPTION OF PRIOR ART

Cast structures and component parts having various complex configurations are presently being fabricated with the aid of mandrels. Simple hollow configurations having a draft or taper angle of at least 2° can be easily cast with removable and reusable mandrels. However, the fabrication of complex configurations having zero draft or re-entrant geometries presents a problem to the casting industry. Multi-segmented mandrels, which can be removed in pieces after a particular structure is cast, have been employed with some success in certain applications. A drawback to this technique, however, is that a misalignment of any of the segments of the mandrel during casting will be reflected in the fabrication of a distorted structure.

Another technique employed by the casting industry is to prepare low-melting-point mandrels for use in the fabrication of high-melting-point structures. The cast unit, upon completion, can be heated to a temperature below that of the structure but above that of the mandrel so that the latter can be removed in the liquid phase. This type mandrel in addition to having the disadvantage of being non-reusable, is also limited to casting applications that do not exceed the melting point of the mandrel and to the casting of only high-melting-point structures.

Recently mandrels have been successfully employed in the fabrication of plasma consolidated free-standing shapes having draft or taper angles sufficient to allow removal of the mandrels without effecting such shapes. However, mandrels can not be successfully used when the desired plasma-consolidated shapes have either zero draft or re-entrant geometries. Thus, this limitation of mandrel usage to the fabrication of relatively simple tapered shapes has forced industry to resort to complex and costly techniques to produce shapes or structures having zero draft angles or re-entrant geometries.

The primary purpose of this invention is to overcome the limitation inherent in conventional type mandrels by providing a new removable type mandrel that will be admirably suited for use in the casting and plasma-deposition of various structures having as low as zero draft or re-entrant geometries.

SUMMARY OF THE INVENTION

Broadly stated, this invention relates to a mandreling technique admirably suited for the production of various shaped structures. Specifically, a mandrel is composed by coating a low-melting-point metallic alloy on a high-melting-point base mandrel and then overcoat-

ing the alloy with a polyimide layer. The undercoated alloy layer has to be sufficiently thick so that after a structure is coated or sprayed onto or into the mandrel, the assembly can be heated to the melting point of the alloy so that it can be removed in the liquid state leaving a space between the structure and the mandrel sufficient to allow the mandrel to be easily removed.

The base mandrel can be cast or otherwise fabricated using a high-melting-point material selected from at least one of the groups consisting of aluminum, brass, steel, and copper. The material selected in addition to having a melting point higher than that of the metallic alloy to be coated thereon, shall be sufficiently strong so as to be reusable and should also be substantially non-reactive with the particular alloy coating selected. Likewise, the metallic alloy coating should have a low-melting point with reference to the base mandrel, and also with reference to the structure to be cast or plasma deposited. The thickness of this metallic alloy coating is variable and depends on the configuration, material and size of the structure being cast. Generally a thickness between about one-sixteenth inch and about 1 inch is sufficient with a thickness about one-eighth inch being preferable for general applications. Metallic alloys having a melting point below 300° C. are generally suitable for this application. However, the selected base mandrel material and structure material dictate the limitations on the characteristics required of this metallic alloy coating. Metallic alloys such as bismuth, lead, tin, cadmium, indium, and antimony in any and all proportions are suitable for use in this invention.

The primary purpose for applying an overcoat on the alloy layer is to substantially eliminate any reaction between the structure to be cast or plasma deposited and the alloy layer. Therefore this overcoating need only be applied to the portion of the coated mandrel that the structure will contact. In addition to preventing any reaction, this outer layer must have a higher melting point than the alloy, be easily separable from the cast or plasma deposited structure and be non-reactive with the deposited structure. The exact thickness of this outer coating is not critical but a layer of between about 0.002 inch and about 0.010 inch is deemed sufficient for most applications. Polyimide coatings are admirably suited for this overcoat layer. Polyimides are a relatively recently developed type of polymer with especially good resistance to heat deterioration. A typical example of a polyimide is that derived from pyromellitic dianhydride and an aromatic diamine and having the following basic structure unit: $[-(\text{CO})_2\text{C}_6\text{H}_2(\text{CO})_2\text{NC}_6\text{H}_4\text{OC}_6\text{H}_4-]_n$. The actual polymer, however, has a more complex structure due to cross linking.

The preferred method for implementing this invention is to initially fabricate a base mandrel from a high-melting-point material such as aluminum. The contour of a male or female type mandrel, in addition to substantially conforming to the configuration of the desired structure, has to be produced with radial dimensions smaller or larger, respectively, than the structure so as to allow for a dual coating buildup. Usually a one-fourth to one-half inch dimension discrepancy is adequate for this purpose.

An alloy having a melting point below about 700° C., preferably about 250° C., is then deposited on the mandrel by any conventional technique such as by spraying, brushing, casting, painting or the like. The thickness of this coated layer is somewhat variable and depends primarily on the complexity of the structure desired, that is, the draft angle or any other re-entrant geometries such structure has. The purpose of this layer is to provide a certain dimensional buildup on the mandrel which can then be easily removed in a liquid state at an elevated temperature after the desired structure is cast or plasma-deposited thereon. The space created between the mandrel and the structure by such alloy removal, will then be sufficient to allow the mandrel to be manipulated and then easily removed thereby leaving a free standing body. A metallic alloy layer of between about one-sixteenth inch and about 1 inch is usually sufficient for most complex structures.

To provide good securement of the metallic alloy to the base mandrel, at least one locking type groove or projection may be designed into the base mandrel so as to prevent the base mandrel from sliding out of, or otherwise being removed from, the coated metallic alloy layer prior to the latter being removed in the liquid state. When this securement means is employed, the metallic alloy layer will usually require a machining operation to conform its surface to the contour of the desired structure to be produced. Thus, complex curvilinear structures can be fabricated using this mandreling technique.

Although this simple alloy coating would suffice in some applications, an interaction generally occurs between this low melting alloy coating and the deposited structure thereby greatly limiting its utility. To prevent this detrimental interaction, an outer layer of a neutral type plastic composition, having a curving temperature below the melting temperature of the alloy coating, is deposited by any conventional technique on the metallic alloy layer. This outer layer need only be applied to that portion of the metallic coated mandrel that will be contacted by the structure to be cast or plasma-sprayed thereon. This outer coating need only be between about 0.002 inch and about 0.010 inch thick, and be capable of being easily removed from the structures formed. For example, a 0.005 inch layer of DuPont "Pyralin" Type 5081 polyimide (15.2 percent gravimetric solids, 50-70 poises viscosity) will be sufficient to prevent chemical and/or physical interaction between an alloy such as 4 percent Bismuth, 55.5 percent Lead, 40.5 percent Tin (commercially available as Cerro 400-1 alloy) and a plasma-deposited material such as beryllium. To improve the adhesive of plasma deposited materials on a polyimide coated mandrel, the cured polyimide coating can be given a moderate grit blast to roughen the surface. A moderate roughening of the surface may be described as one of 120-200 micron inch RMS surface roughness.

The fully cured dual coated mandrel is then ready for use in casting or plasma-deposition application. Once the selected material is deposited on the mandrel by conventional techniques to produce the desired structure, the unit is placed in a heated environment where the temperature is elevated above the melting point of the alloy undercoat. The liquid state alloy then flows from the unit leaving a space between the mandrel and

the film adhering structure thereby allowing the mandrel to be easily withdrawn. The neutral type polyimide film can then be peeled from the structure leaving a free standing body.

The following examples will serve to illustrate the mandreling technique according to this invention.

EXAMPLE I

An aluminum base mandrel as shown in the drawing was coated with a 4 percent Bismuth, 55.5 percent Lead, 40.5 percent Tin alloy (commercially available as Cerro Type 400-1 alloy) having a melting point range of 170° to 198°C. The coated mandrel was machine finished leaving a smooth alloy layer of about one-fourth inch thick on the aluminum base. The surface of the coated mandrel was overcoated with a DuPont "Pyralin" Type 5081 polyimide precursor solution, 15.2 percent Gravimetric Solids, 50-70 poises viscosity, (commercially available as DuPont Pyralin 5081 polyimide) using an air brush spraying technique. A layer of approximately 0.001 inch thick was applied and then the N-Methyl Pyrrolidone and xylene solvent in the coating was extracted by oven heating the coated mandrel to approximately 125° C. for 15 minutes. This procedure was repeated until a 0.004 inch layer was built up whereupon the coated mandrel was cured at an elevated temperature of 150° C. for 16 hours.

The coated cured mandrel was then given a light grit blast of aluminum oxide to roughen the surface thereof so as to provide a better adhering surface for a plasma deposition of beryllium.

The roughened surface coated mandrel as shown in the drawing was plasma-sprayed with beryllium using the following:

Powder Lot	Beryllium (commercially available as Brush V-1684-P)
Powder Size	325 Tyler mesh size and finer
Non-transfer-Arc Torch	Union Carbide's AT9 model
Electrode Gas	60 CFH Argon
Powder Carrier Gas	80 CFH Argon and 40 CFH Argon + 15% Hydrogen
Shield	Not used
Current	195 amps.
Voltage	58 volts
Torch Pressure	31 PSIG
Dispenser Pressure	36 PSIG
Coating Time	9 minutes
Coating Thickness	0.035" - 0.045"
Torch Standoff	1 inch to 1 1/4 inches
Powder Feed Rate	13 grams per minute

After the plasma deposition of beryllium, the coated mandrel was placed in an oven and heated to 210° C. whereupon the Cerro Alloy melted and flowed from between the base mandrel and the polyimide film-coated beryllium structure leaving a space which enabled the mandrel to be easily removed. The polyimide film was then peeled from the structure leaving a free standing beryllium body having a contour identical to the mandrel shown in the drawing.

EXAMPLE II

A 13 UNC threaded rod, measuring one-half inch in diameter and 24 inches long, was coated with 1.0 inch layer of Cerro Alloy 400-1 as in Example I, for a length of 19 inches. The surface of the Cerro layer was machined to a smooth finish yielding a final rod diameter of 1.92 inches. The smooth surface was then coated

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