Oct. 13, 1970 G. J. WALKEY ETAL 3,533,271

METAL DIES

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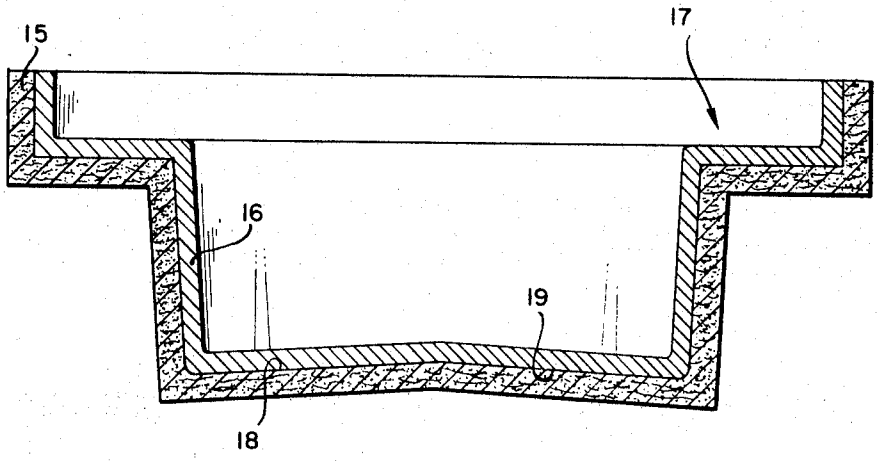


FIG_3

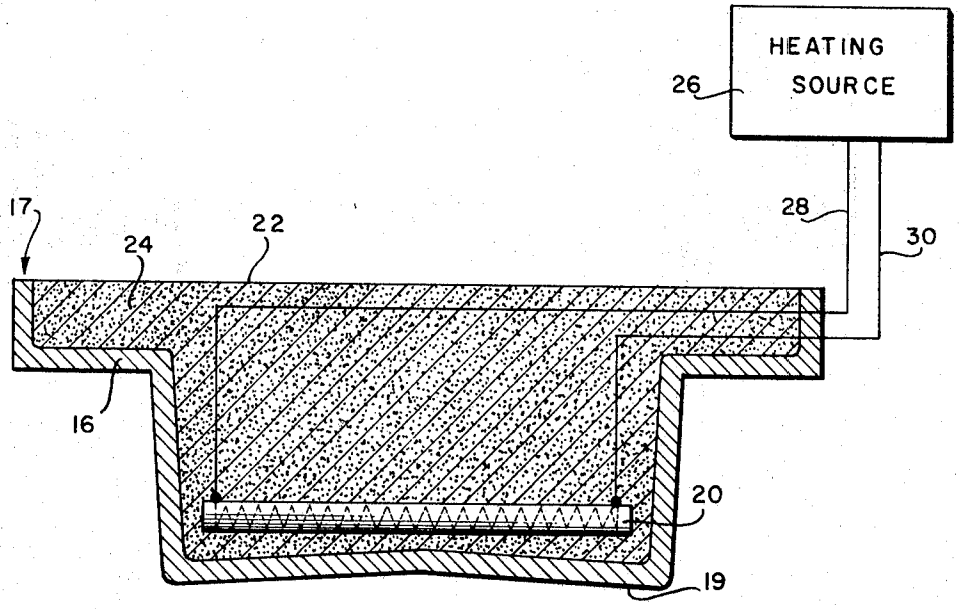


FIG_4

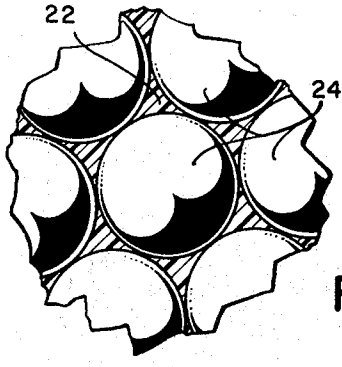


FIG_8

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METAL DIES

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FIG_5

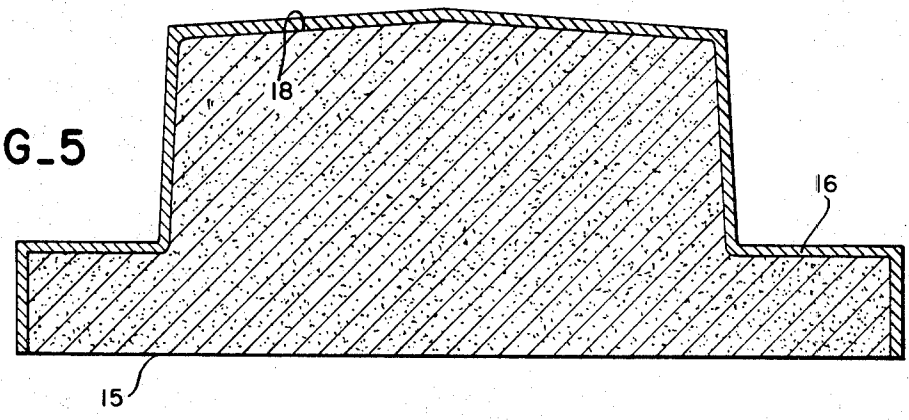
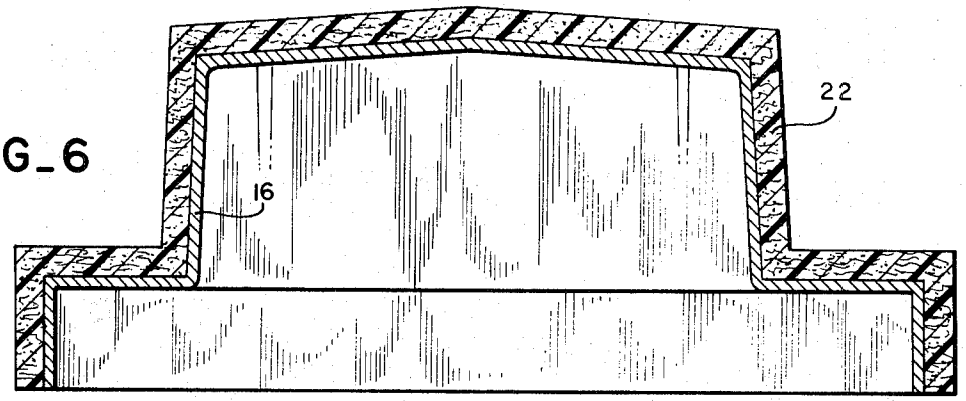


FIG_6



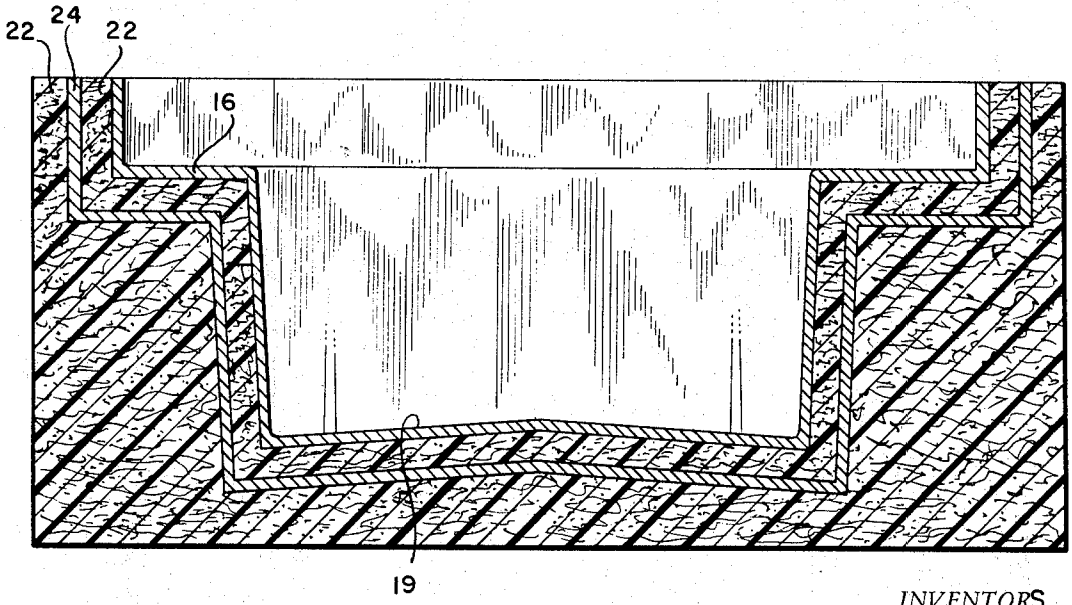


FIG_7

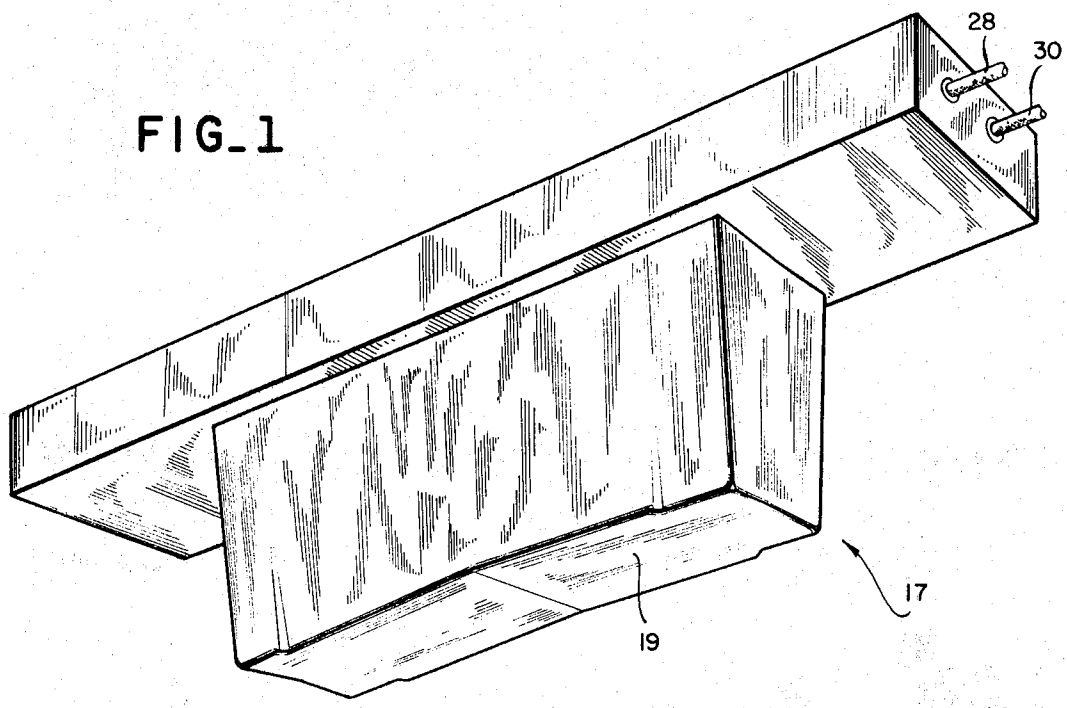
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METAL DIES

Filed July 6, 1967 3 Sheets-Sheet 3

FIG_1



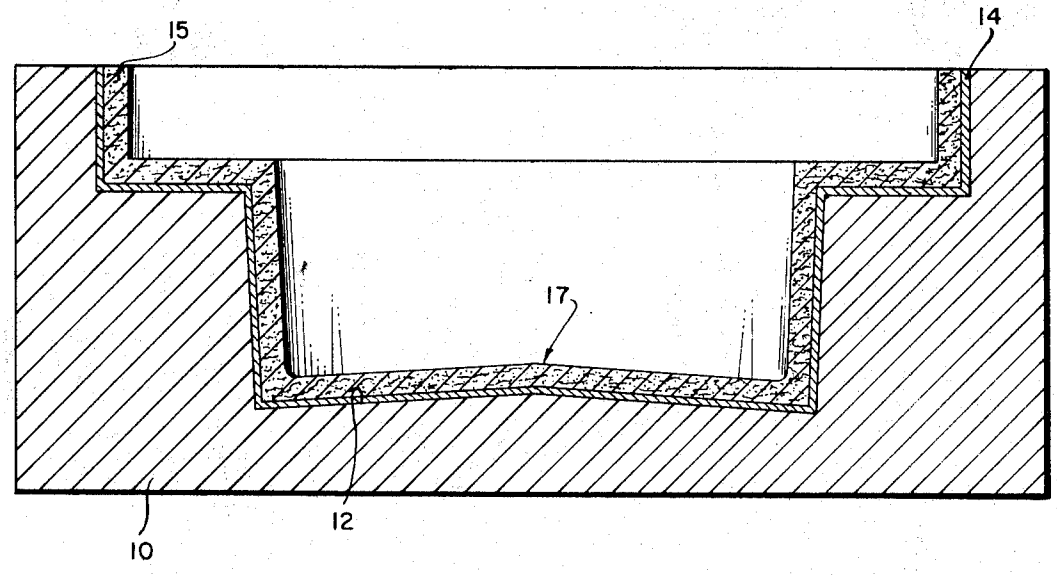


FIG_2

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United States Patent Office 3,533,271 Patented Oct. 13, 1970

3,533,271

METAL DIES

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Filed July 6, 1967, Ser. No. 657,720
Int. Cl. B21k 5/20
U.S. Cl. 72—476 4 Claims

ABSTRACT OF THE DISCLOSURE

A die and the method of fabricating it utilizing the technique of thermal spraying. A matrix of predetermined strength is initially cast over a pattern to a desired thickness. After the matrix hardens it is separated from the pattern, heated, and a metal or other die material sprayed over its formed surface. The combination is then cured and allowed to cool, causing the matrix, but not the die, to crack and facilitating easy separation. The resulting die shell may then be filled with a mixture of reinforcing material and binder and heated, causing the binder to liquefy. Upon cooling the binder solidifies around the reinforcing material, giving great structural integrity to the die shell and producing a tough, high temperature die.

BACKGROUND OF THE INVENTION

The ever-increasing use of high strength substances such as titanium in many of today's products has greatly intensified the need for an inexpensive method of fabricating dies. Aircraft and spacecraft, for example, are requiring larger amounts of high strength materials than ever before. However, because only a few parts may be needed and produced from a single die, the conventional hot stamping process commonly used becomes prohibitively expensive.

Many industries have turned to other techniques such as the Shaw process or the Keller method to at least partially alleviate this high cost.

The Shaw process uses a conventional casting technique with a special sand matrix manufactured from Bakelite and resin. While close tolerances are obtainable by this process it is economically unsatisfactory in high temperature applications with hard materials.

The Keller method, on the other hand, is a pantographic-like process and initially entails the making of the finished article as a master. A machine is then slaved, by conventional means such as a stylus bearing against the outer surface of the master, to produce the desired copies. While this method may be utilized for hard materials, it is very slow, comparatively expensive and completely unsuited for tracing complex shapes.

As a consequence of the various disadvantages of the above methods, one approach has been to fabricate dies by means of various thermal spray process. These processes generally involve the deposition of a metallic layer on a plaster casting to produce a die shell. The use of such processes indeed offer several important advantages in that the time required to produce the die as well as the finished article, is much less than by normal maching methods. In addition, complexity of shape is not an important factor as it is in the Keller method.

However, metal spray techniques in the past have been severely limited to low strength, low temperature melting metals such as zinc or tin. One reason for this has been the natural tendency of the sprayed metal as it cooled to contact, such shrinkage causing it to separate from the patterned surface. This tendency produced cracks and spalling, apparently due to the uneven thermal stresses produced in the metal when sprayed onto the

pattern. Consequently, it has heretofore been very difficult to spray an accurate negative or mold having sufficient strength or rigidity for practical use.

While such dies are suitable for forming low strength materials and for operating at low temperatures, they cannot be used to form strong materials at high temperatures. Thus, titanium, for example, which must be formed at a high-temperature because of its tendency to "spring-back" or return to its original shape, could not until now, be formed on a die manufactured by the thermal spray method.

It is, therefore, a purpose of this invention to provide a method of fabricating a strong, high temperature die wherein a substrate or matrix of predetermined strength is deposited upon a pattern to a desired thickness. After being heated and cured, to remove excess water, the matrix is separated from the pattern and is again heated to a temperature compatible with that of the metal to be subsequently deposited thereon. The combination is thereafter placed in a preheated oven and allowed to slowly cool, at which time, the substrate will crack because of its differences in predetermined strength, thickness, and thermal coefficient of expansion as compared with those of the metallic layer. Upon having the matrix thoroughly removed from its surface, the resulting metal shell or die is filled with a selected mixture of reinforcing material and binder and heated, causing the binder to liquefy. As the mixture cools, the binder hardens and adheres the reinforcing material to the die shell.

BRIEF DESCRIPTION OF THE DRAWING

The procedure of the present invention as applied to the production of a die is illustrated by the accompanying drawing, wherein:

FIG. 1 is a perspective view of a heated die configuration manufactured in accordance with the invention;

FIG. 2 is a longitudinal section through a mold pattern after the substrate or matrix has been deposited thereon;

FIG. 3 is the matrix of FIG. 2 after it has been removed from the mold pattern and a layer of die material deposited thereon;

FIG. 4 is similar to FIG. 1 and illustrates the die material separated from the matrix with a mixture of reinforcing material and binder in reinforcing relationship therewith;

FIG. 5 illustrates an alternate embodiment of the matrix with a layer of die material deposited thereon;

FIG. 6 is the die material layer of FIG. 5 separated from the matrix with a binder deposited thereon;

FIG. 7 is the die of FIG. 6 with additional layers of die material deposited thereon; and

FIG. 8 is an enlargement of the mixture of reinforcing material and binder of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1–4 and 8, there is depicted a mold **10** having a surface **12** dimensionally contoured to a desired configuration and smoothness. In contrast to the molds used in prior art processes, particularly where sintering procedures are used, mold **10** may be fabricated from an inexpensive material such as plastic, plaster or wood. This economy is possible since the mold **10** and the surface **12** are not subject to deterioration as a result of subsequent spraying steps.

The surface **12** is first coated with a parting agent to provide a parting coating **14**. The function of the coating **14** is to facilitate removal of the molded refractory skeleton from the mold **10**. In the practice of this invention, the parting agent may be applied in any suitable fashion such as by spraying or pouring. Although several layers of wax material will faciiltate the separation of the skele-

ton from the mold **10**, sprayed Teflon, molybdenum disulfide or lacquer may also be used as the parting agent.

Once the mold **10** has been coated with a parting agent, an inorganic matrix or substrate **15** is deposited thereover and over the coated surface **12** by conventional means such as spraying, ladling or the like. The inorganic matrix **15** is fabricated from an aluminide or beryllide such as aluminum oxide or beryllium oxide or from a cement. The matrix **15** is of such a strength, thickness and substance that it is compatible with die material **16** to be sprayed thereon at a subsequent time. It is of primary importance that the substance used for the matrix **15** be of a strength sufficient to withstand the heat during the preheating procedures and the internal pressures of handling which are produced during the process. For high temperature applications and the ability to withstand internal stresses, a high strength cement has been found to be generally superior to plaster of paris or dental plaster.

(38) Hoffmaster–43965 — Elec. Ptg.—day — 9/18/70

The resulting strength of the deposited matrix **15** is a critical consideration since the matrix **15** must have a compressive strength which is less than the yield strength of the die material **16** which is subsequently deposited thereon. Were it otherwise, die **17** would crack during the cooling process. After a predetermined thickness is reached, the matrix **15** is oven or air cured, depending upon the type of die **17** to be fabricated and the die material to be used.

Highly acceptable results have been obtained by providing a matrix **15** of the high strength cement commercially known as "Glass-Rok" cured in an oven at 300–400° F. for a period of approximately two hours. The curing time is, of course, dependent upon the characteristics of the specific material being cured and the curing temperature, but it is required that the water contained within the matrix **15** be completely removed since during the heating cycle any water remaining in the matrix **15** turns to steam, forming internal bubbles, thereby cracking the matrix **15** or deforming the matrix surface **18**.

After the matrix **15** cools, it is separated from the mold **10**, such removal being facilitated by cracking of mold **10** which usually occurs during the cooling cycle. If the mold **10** does not crack, it may be removed from matrix **15** by use of conventional means (e.g., hammer and chisel). Upon being removed, the matrix **15** is ready to be preheated to a temperature compatible with the die material **16** to be subsequently deposited thereon. The die material **16** itself is usually a metal or metal alloy but may comprise other types of inorganic materials such as plastic, cement or plaster. Thus, while a metallic material is referred to hereinafter, it is to be noted that this is for illustrative purposes only. In addition, an organic which, upon being heated, becomes an inorganic (e.g. calcium lactate into calcium oxide), may be used.

In order to obtain such temperature compatibility of the matrix **15**, it is required that the preheat temperature be approximately that which results in a 50% yield strength of the sprayed metal. While some latitude may be taken with regard to this temperature, the above has been found to be generally satisfactory. In handling aluminum materials, for example, a requirement exists that the temperature of the preheated matrix **15** be approximately 800° F., while in handling steel or steel alloys the heating requirement is approximately 1500° F.

When the desired preheat temperature is reached, the die material **16** is sprayed on the matrix **15** to form a die **17** of predetermined yield strength, and of thickness compatible with the compressive strength of the matrix **15**. During the metal spraying process, the preheat temperature is maintained by conventional and suitable means such as a gas burner or oxyactylene flame (not shown) until such time as the desired thickness of the sprayed metal is achieved. Again it is to be noted that the matrix **15** must be sufficiently thin that its compressive strength is less than the yield strength of the die **17**. As an example, based upon the reported structural properties of a mild steel, such as S.A.E. 1010 (30,000 p.s.i. tensile strength at 1000° F.) and a high strength cement such as "Glass-Rok" (4,000 to 6,000 p.s.i. compressive strength), a cement matrix **15** having a thickness within the approximate range of 7/16" to 9/16" has been found to fail under the compressive load applied by the thermal contraction of a ¼" mild steel coating at room temperature.

The matrix surface **18** need not be coated with a parting agent as taught by the prior art of metal spraying since the matrix **15** will resist spalling on die surface **19** without the requirement of a coating therebetween because of the preheating of the matrix **15** and the preselected strength of the materials used.

After the layer of die material **16** has been deposited upon the preheated matrix **15**, the combination is placed in a preheated oven (not shown) and allowed to slowly cool for a length of time precalculated to result in failure of the matrix **15**. The temperature of the preheated oven should be approximately that to which the matrix **15** was heated prior to the deposition of die material.

During the cooling process, the die **17** and the matrix **15** cool and contract at different rates because of their different coefficients of thermal expansion. The usual result is a severe cracking of the matrix **15**. However, as previously indicated, this cooling process does not always cause the cracking of the matrix **15**. In such case it can be subsequently removed by suitable conventional means, as by hammer and chisel or by grit blasting it with 40 mesh chilled iron grit at 80 p.s.i. A clean metallic surface has been produced by each of the noted removal methods, no apparent damage to die surface **19** having resulted. The die **17** can, by the aforementioned procedure, be produced to any thickness desired, but because of its "shell-like" configuration would be somewhat limited in strength and thus substantially unsuited for high temperature forming of high strength materials but could, however, be utilized for forming lower strength materials such as plastic and thin aluminum sheet.

Although under normal circumstances the matrix **15** cracks, it is to be noted that the materials used for the die **17** and the matrix **15** may be chosen of materials having nearly identical thermal coefficients of expansion thereby contracting at almost the same rate. While under these circumstances neither material will crack during the cooling period, this procedure is generally very costly and is therefore economically unsatisfactory over the method previously discussed.

It is of course apparent that in performing the above steps dimensional control, surface hardness and other metallurgical properties of the materials used for the matrix **15** and die **17** should be determined prior to the initiation of the process. This provides the fabricator with the ability to predict and control critical dimensions required to assure that the yield strength of the die **17** is greater than the compressive strength of the matrix **15**.

After the combination has cooled the matrix **15** is separated from the die **17** and excess overspray, if any, is removed by conventional means such as by sawing, grinding, or the like, until the desired finished dimensions are obtained. Since the finished dimensions are unaffected by excess overspray, it is not mandatory that it be removed. However, it has been found beneficial in that a more compact, easier handling and lighter weight die can be achieved if the additional material is removed.

When the desired finished dimensions have been achieved, a mixture of binder material **22** (FIG. 4) and reinforcing material **24** (the combination being sometimes referred to as reinforcing mixture) such as epoxy resin and metal shot, respectively, are deposited by pouring, ladling or the like, within a cavity formed in the die **17** opposite its surface **19**. The ingredients of the reinforcing mixture are carefully chosen to pro-

vide the desired strength of the finished die **17** and in view of temperatures involved in forming the material of the ultimate product for which the die of this invention is provided. After this mixture has been deposited the combination is oven heated to a temperature sufficient to liquefy the binder material **22** which, upon cooling, adheres the reinforcing material **24** to the die **17**, thereby forming one continuous, solid, die mass. If a hot forming die is desired to be fabricated, a heating member **20** may be located within the die **17** and surrounded by the reinforcing mixture. The heating member **20** may be of any conventional means such as a high resistance wire or heating rod electrically connected to a heating source **26** by wires **28** and **30** as best illustrated in FIG. 4. The usage of a heating member **20** located within the die serves the dual purpose of heating the reinforcing mixture, thereby eliminating the requirement for oven heating and also permits the finished die to be integrally heated for the purpose of hot forming materials such as titanium. The temperature to which the reinforcing mixture is heated should approximate that to which the matrix **15** and die **17** were previously preheated. The binder material **22** is selected such that it will liquefy at or near the preheat temperature and when cooled cause the reinforcing material **24** to adhere to the interior portion of the die surface **19**.

Referring to FIGS. 5–7, a modified embodiment of the present invention is depicted wherein a matrix **15** having a surface **18** of dimensionally contoured shape and smoothness has a die material **16** deposited thereon. The matrix **15** in the modified embodiment may be of standard composition and for this purpose plaster of paris has been found to be generally satisfactory. The die material **16** sprayed upon the contoured surface **18** need not be heated in the modified embodiment since it has been found that preheat is required only when a thick coating of die material **16** is deposited. In this regard coatings of 3/16 inch and under do not require the die material to be heated since the internal stress determines the necessity for preheat and is a function of thickness. After the die material **16** has set, a fiber glass binder **22** is deposited over the die material **16** to a thickness of approximately ½ inch. After air curing for about three and one-half hours at room temperature, copper reinforcing material **24** is deposited on the binder **22** at room temperature to a thickness of ⅛ inch. Finally an additional layer of epoxy impregnated fiber glass binder **22** is deposited over the copper layer. By such construction a composite die **17** may be formed for many useful purposes, such as filament winding or "lay up" of plastic parts or for the forming of aluminum of thicknesses of .060 inch or less

The following examples are generally illustrative of the process:

EXAMPLE 1

A wooden mold **10** of the character illustrated in FIG. 2 and having a desired dimensionally contoured surface **12** was coated with a .005 inch layer of paste wax to form a parting coating **14** over its surface **12**. An inorganic matrix **15** of high strength cement was thereafter deposited at room temperature upon the waxed surface **12** until the matrix **15** was ½ inch thick. The matrix **15** was deposited by spraying it over the surface **12** and was precalculated to be of a thinness sufficient to crack during the subsequent cooling steps. The matrix **15** was then oven cured at a temperature of 350° F. for two hours and the mold **10** separated therefrom after it had cooled to room temperature. The matrix **15** was next preheated to 1500° F. and S.A.E. 1010 steel sprayed thereon to a thickness of ¼ inch. Upon obtaining the desired thickness, the combination was placed in a preheated oven at 1500° F. and allowed to furnace cool for a period of four hours. The matrix **15** cracked for the reasons previously enumerated and the die surface **19** was cleaned of the residue matrix material by grit blasting with 40 mesh chilled iron grit at 80 p.s.i. A heating rod **20** connected to a heat source **26** and a mixture of 10% sodium silicate binder material **22** and 90% iron shot reinforcing material **24** were then placed within the cavity of the die **17** opposite the die surface **19**. The mixture was then heated to a temperature of 1500° F. and allowed to air cool until it reached room temperature. This die was found to be suitable for both cold and hot forming of titanium and other high strength materials at temperatures of 1450° F. and above.

EXAMPLE 2

A wooden mold **10** having a desired dimensionally contoured surface **12** was coated with molybdenum disulfide to form a parting coating **14** of .004 inch thickness. An inorganic matrix **15** of beryllium oxide was then deposited upon the coating **14** to a thickness of ¼ inch, air cured at a temperature of 350° F. and then allowed to cool for 24 hours to room temperature. Upon cooling, the matrix **15** separated from the mold **10** and was then preheated to 800° F. Aluminum was thereafter sprayed on the matrix **15** while the matrix **15** was maintained at 800° F. by a gas burner. A metal die shell of a 17½ inch thickness in length was formed and the combination thereafter placed in an oven preheated to 800° F., the oven then being turned off and the die allowed to cool for four hours. Upon removal of the die from the oven, the matrix **15** was found to be cracked. The die surface **19** was cleaned by grit blasting with 40 mesh iron grit at 80 p.s.i. A mixture of 5% epoxy resin binder material **22** and 95% chopped fiber glass reinforcing material **24** was then deposited within the die **17** opposite the die surface **19**. The combination was then oven cured at a temperature of 150° F. and subsequently allowed to air cool for a period of 24 hours. The die was found suitable for cold forming low strength metals.

EXAMPLE 3

A plastic mold **10** having a predetermined contoured surface **12** was coated with molybdenum disulfide to a thickness of .002 inch to form a parting coating **14** over its surface **12**. A plaster of paris matrix **15** was then deposited, at room temperature, over the parting coating **14**. The matrix **15** was then oven cured at a temperature of 350° F. for four hours and thereafter removed from the mold **10**. Aluminum was next sprayed over the matrix **15** to a thickness of ⅛ inch. The matrix **15** and the aluminum were not preheated during this step since the resultant internal stresses determine the preheating requirement and are a function of the thickness of the material. Epoxy impregnated fiber glass was then deposited over the aluminum at room temperature to a thickness of ½ inch. The combination was then air cured for three and one-half hours at room temperature. Upon reaching room temperature a ⅛ inch layer of copper was deposited at room temperature on the fiber glass. The die **17** was then filled with epoxy impregnated fiber glass reinforcing material **24** and air cured for 3½ hours. The die was found to be suitable for filament winding and forming aluminum of thickness of .060 inch or less.

EXAMPLE 4

A plastic mold **10** was coated with lacquer to form a parting coating **14** of a thickness of .003 inch. Dental plaster was then deposited on the coating **14** to a thickness of ¼ inch and the combination oven cured at 225° F. for two hours. The matrix **15** was then removed from the mold **10** and preheated to 800° F. Zinc was then sprayed at 300° F. upon the matrix **15** to form the die **17**. The layers were then allowed to cool to 100° F. requiring two hours. After the combination had cooled the matrix **15** was removed from the die surface **19** and a mixture of 10% plaster of paris binder material **22** and 90% aluminum reinforcing material **24** was deposited within the die **17** opposite the die surface **19**. The combination was then

oven cured at 250° F. for three hours and allowed to air cool for 24 hours, at which time room temperature was achieved. A die was produced suitable for forming plastics and filament winding.

EXAMPLE 5

A wooden mold **10** was coated with a paste wax .004 inch thick. A matrix **15** composed of finely powdered portland cement was deposited on the mold **10** to a thickness of ⅜ inch and thereafter cured at a temperature of 175° F. for four hours. That matrix **15** was removed from the mold **10** and then sprayed with a ½ inch layer of copper at room temperature. The matrix **15** was then removed from the copper die **17** by means of grit blasting and a "Cerro-Bend" deposited within the die **17** opposite and die surface **19**. Cerro-Bend is a well known low temperature melting (185° F.) alloy of bismuth and lead, used in die work, and is readily available from a number of manufacturers. The mixture was then allowed to set for approximately four hours producing a die suitable for forming plastics.

The products produced in relation to these examples, while suitable for the indicated uses, may obviously be found readily acceptable for other applications as well.

The various features and advantages of the invention are thought to be clear from the foregoing description. Other advantages not specifically enumerated will undoubtedly occur to those skilled in the art as well as other modifications of the preferred embodiment illustrated. The following claims measure the invention in a die as illustrated by the above Examples 1, 3, 4 and 5, respectively.

We claim:

1. A die for cold and hot forming a high strength material at temperatures at and above 1450° F. and having a solid continuous mass formed from (a) and (b) below and comprising in combination,

(a) a S.A.E. 1010 sprayed steel forming a shell and a die surface thereon,

(b) a mixture formed of substantially 90% iron shot and 10% sodium silicate deposited in said shell and heated to a temperature of 1500° F.

the combination of (a) and (b) then being air cooled to produce said die.

2. A die for filament winding, and forming aluminum, and the like, of .060 inch or less thickness, comprising in combination,

(a) sprayed aluminium forming a shell and a die surface thereon,

(b) epoxy impregnated fiber glass deposited at room temperature within said shell, the combination of (a) and (b) then being air cooled at room temperature for approximately 3½ hours,

(c) a layer of copper deposited at room temperature on said fiber glass, and

(d) additional epoxy impregnated fiber glass filling said shell, being air cured thereto, to produce said die.

3. A die for forming a plastic article and filament winding, comprising in combination,

(a) sprayed zinc formed into a shell and a die surface thereon for said die at 300° F. and cooled to 100° F. in substantially 2 hours,

(b) a reinforcing material deposited within said shell and formed substantially of 90% aluminum and 10% plaster, said material and shell being oven cured at substantially 250° F. for 3 hours,

the combination of (a) and (b) then being air cooled for substantially 24 hours.

4. A die for forming plastics comprising in combination,

(a) a sprayed copper layer forming a die surface and shell for said die,

(b) a low temperature melting alloy of bismuth and lead deposited within said shell,

the combination of said copper layer and alloy producing said die upon setting for approximately 4 hours.

References Cited

UNITED STATES PATENTS

1,835,916	11/1933	Ragsdale	76—107
3,015,292	1/1962	Bridwell	72—342
3,125,974	3/1964	Toulmin	76—107
3,195,341	7/1965	Zunich	72—475
3,422,663	1/1969	James et al.	76—107

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U.S. Cl. X.R.

76—107