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[54] **METHOD AND APPARATUS FOR MANUFACTURING PRECISION ARTICLES FROM MOLTEN ARTICLES**

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[51] **Int. Cl.** **B22d 11/10**
[58] **Field of Search** 29/527.2, 527.4, 527.5, 29/527.6; 164/46, 76

[56] **References Cited**

UNITED STATES PATENTS

3,397,732	8/1968	Howell	164/46
3,670,400	6/1972	Singer	29/527.5
3,689,987	9/1972	Teague	29/527.2
3,696,502	10/1972	Darling	164/46 X
3,742,585	7/1973	Wentzell	164/46 X

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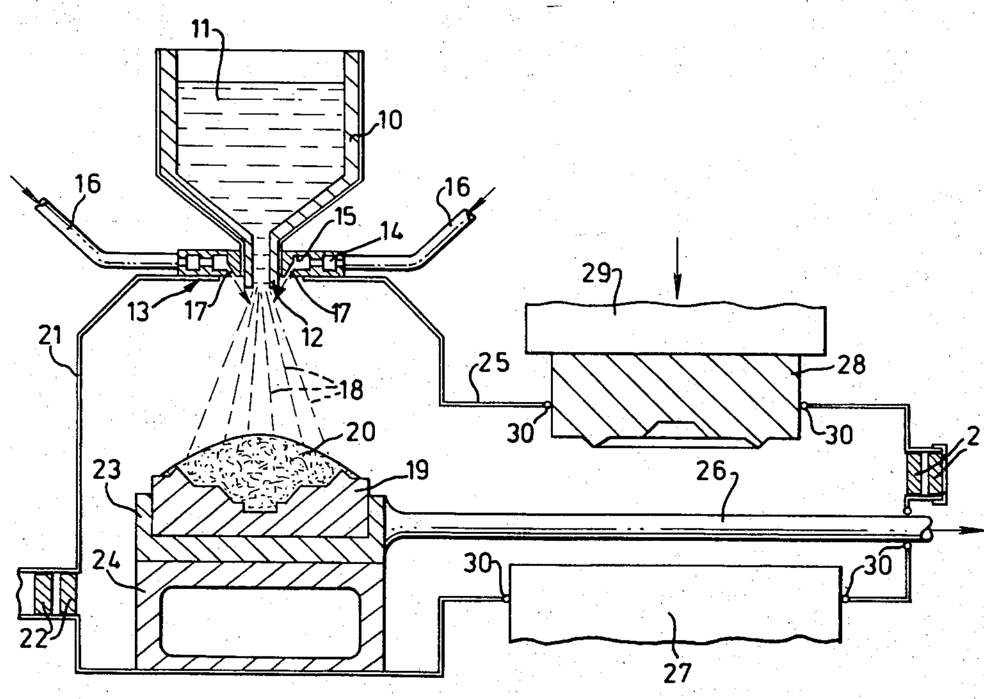
[57] **ABSTRACT**

A method and apparatus for manufacturing shaped precision articles from molten metals (including alloys), which articles may either be effectively nonporous or have a controlled degree of porosity and may be finished (i.e. no further processing is required) or may require a small amount of finish machining (e.g. trimming of flash and/or heat treatment), wherein the method comprises directing a stream of molten metal or molten metal alloy at a collecting surface to form a deposit, and working the deposit by means of a die to form a precision metal or metal alloy article.

35 Claims, 5 Drawing Figures



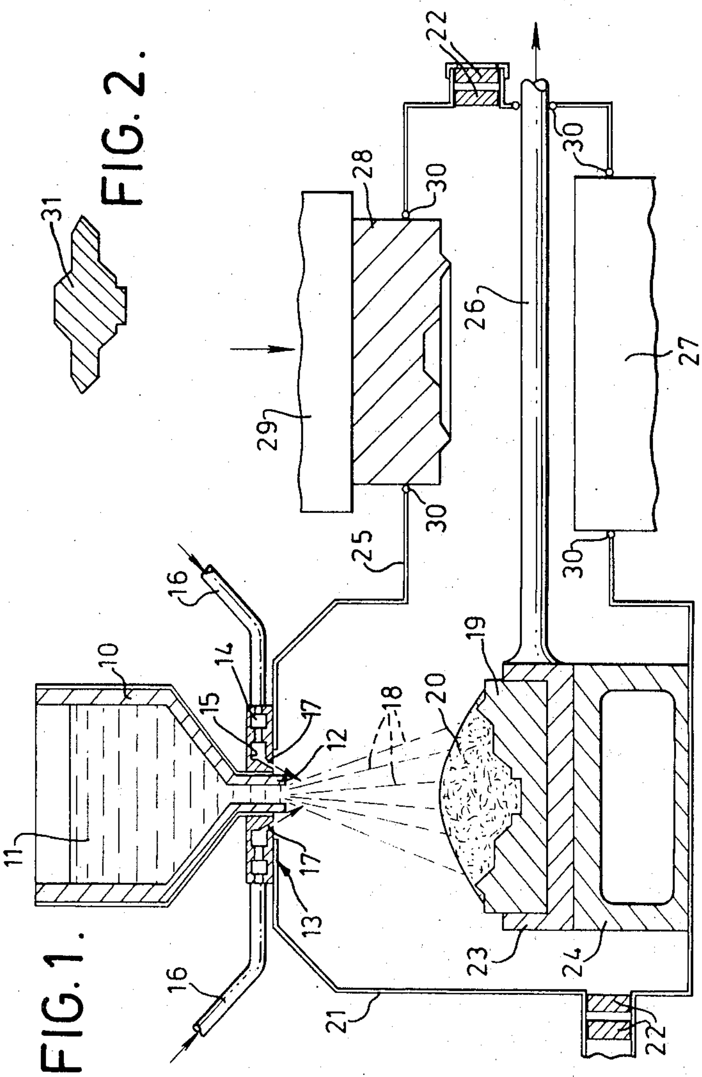


FIG. 1.

FIG. 2.

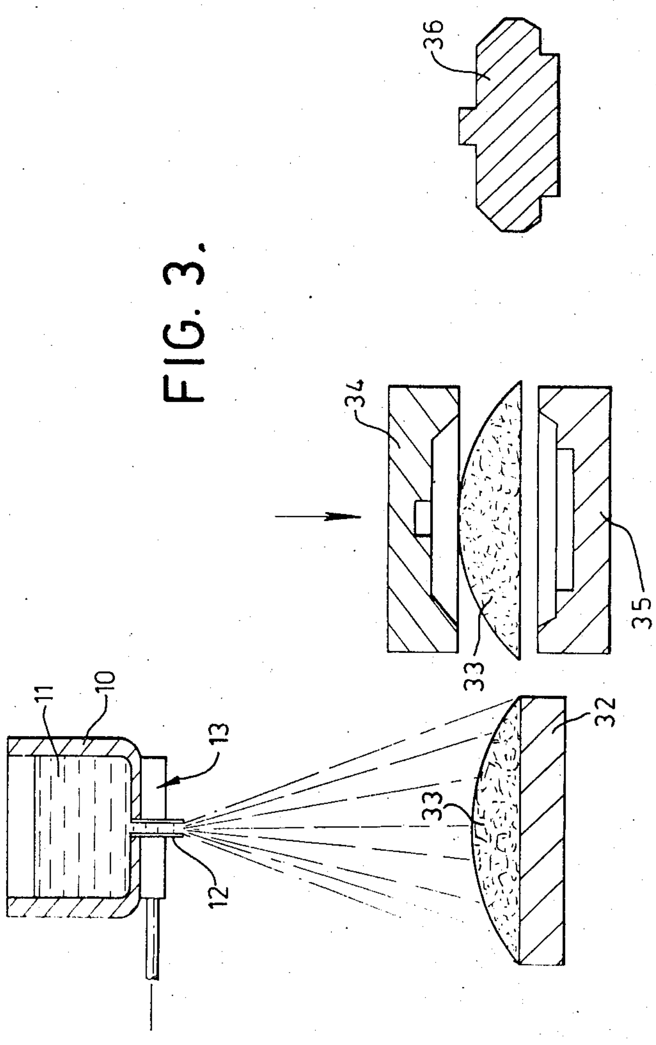


FIG. 3.

FIG. 4.

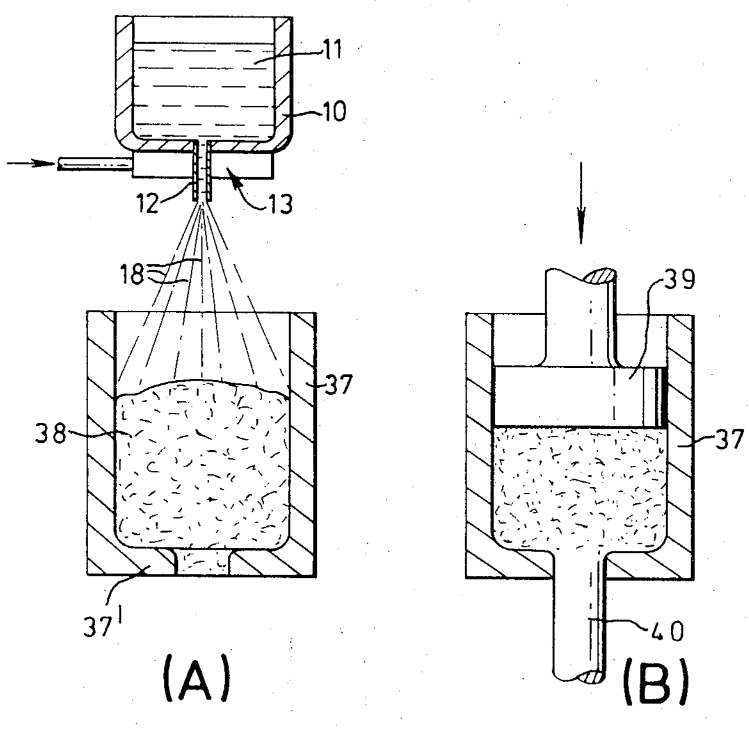
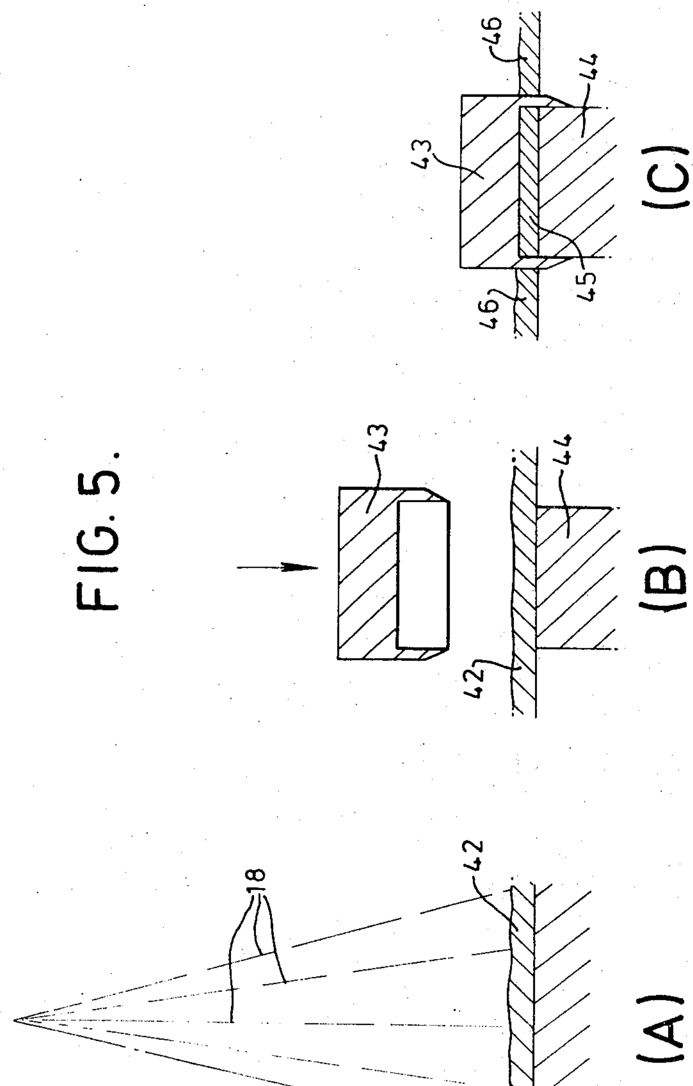


FIG. 5.



METHOD AND APPARATUS FOR MANUFACTURING PRECISION ARTICLES FROM MOLTEN ARTICLES

This invention relates to the manufacture from molten metals (including alloys), of shaped precision articles which may either be effectively non-porous or have a controlled degree of porosity. The articles produced according to this invention may be finished (i.e., no further processing is required) or they may require a small amount of finish machining (e.g., the trimming of flash and/or heat treatment).

Shaped metal articles are usually produced at present by one of three main methods. One known method involves the casting of molten metal into a desired shape; this can be achieved by several different techniques, e.g., sand-casting, die-casting, centrifugal casting, shell-moulting or investment casting. Articles produced by these methods, however, may possess poor mechanical properties mainly as a result of relatively large grain sizes, structural weaknesses and defects arising from the casting process, e.g., shrinkage, segregation (particularly in highly-alloyed metals) and splashings onto the side of the mould.

A second known method involves the casting of molten metal as an ingot, followed by either a hot-working process (e.g., hot-rolling, forging, pressing or extruding) and/or a cold-working process (e.g., cold-rolling, pressing, drawing, coining or spinning). In either case semi-finished products (i.e., plates, billets and bars) often have to be manufactured before subsequent processing to produce finished articles. Such processing may involve re-heating of the semi-finished product at various stages, each time followed by a forming operation which can involve high loads, resulting in considerable wearing of the forming dies. In addition, machining is often needed to obtain the required dimensions of the finished product (e.g., a gear wheel).

By this second method articles of complex shape can be manufactured which can possess mechanical properties generally superior to those articles produced by the first known method already described. Defects in the original ingot, however, can result in a final product of poor quality.

In a third known method, metal powders (produced, for example, by gas or water atomisation of molten metal, mechanical pulverisation or chemical reduction of ore) often have to be mechanically handled, graded and heat treated, prior to forming operations. In many instances a brittle "compact" has to be made, usually by cold-pressing powdered metal in a die before sintering and other forming operations can be carried out to produce an article of finished shape. By powder metallurgical techniques it is possible to produce finished articles of complex shape which do not require any machining.

Advantages of this third method of manufacturing articles over the other two known methods described previously include the elimination of problems arising from liquid/solid shrinkage and segregation and the capability of producing articles from a mixture of metals which are not mutually soluble in the liquid state. Non-metallic substances, which would be insoluble in the liquid alloy, can also be added to powder-metallurgical products such that they will be evenly distributed throughout the structure. In addition, products with a controlled degree of porosity can be produced by this third method.

One of the main disadvantages in the manufacture of articles by powder metallurgical methods is the high cost of powdered metal which can be used in such methods. In addition, the subsequent forming and sintering operations necessary to produce articles are expensive.

It is an aim of the present invention to provide a simplified and more economic method for manufacturing shaped precision articles which possesses most of the advantages of the third mentioned method described previously and/or by which articles can be obtained having mechanical properties similar to those produced by the known methods described above.

With these aims in view this invention provides a method for manufacturing shaped precision articles from molten metal or molten metal alloy, comprising directing an atomised stream of molten metal or molten metal alloy at a collecting surface to form a deposit, and working the deposit by means of a die to form a precision metal or metal alloy article.

The invention also provides an apparatus for manufacturing shaped precision articles from molten metal or molten metal alloy, comprising a chamber having means for atomising a stream of molten metal or metal alloy and for directing the atomised stream onto a collecting surface so as to form a deposit on said surface, a die movable by operating means for effecting working of the deposit to form a precision metal or metal alloy article, and means for removing the precision metal or metal alloy article from the chamber.

The collecting surface can be in the form of a deposition second die which can be of any suitable shape or contour; for instance, it can contain an impression of a gear wheel, or a connecting rod for an automobile. The collecting surface may also simply be a plain surface.

The stream of molten metal or metal alloy may be atomised into a spray of hot, metal particles by the impingement of high velocity gas jets. By these means a spray of fine, molten metal particles can be produced from which heat is extracted in flight by the relatively cold gas jets so that the metal particles can be either solid, partly-solid/partly-liquid or liquid at the moment of impacting the deposition die. On impacting the die surface the particles deform, coalesce and build up to form a coherent, hot mass of deposited metal which has a finely divided grain structure.

After deposition heat can be added, if necessary, to the sprayed deposit of metal particles before the forming operation is carried out, but the preferred method is to shape and simultaneously work (i.e., forge or press) the metal deposit without the addition of heat after the deposition operation. This forming operation is normally carried out as soon as the required mass of metal has been deposited onto the die so that the deposit is hot-worked but, when necessary, the sprayed deposit can be cold formed after it has been cooled, e.g., to form a highly porous article.

Generally, if the metal is sprayed onto a deposition die, the die acts as the lower die of a die set; the upper die block, which is also suitably contoured, then shapes the top portion of the sprayed deposit when the dies are loaded against each other. Any surplus metal can be forced out of the die cavity into suitably designed 'flash' gutters. In this way shaped, hot-worked precision metal articles can be manufactured. Alternatively the hot, sprayed deposit in the deposition die may be removed from the die, for instance by an ejection mechanism, and transferred rapidly into another suitably shaped die block which may be the lower die of a die set. The subsequent forming of the hot metal can then be rapidly completed by loading the shaped top die against the bottom die and a hot-worked, shaped precision metal article is produced.

For the production of extruded articles, metal particles can be sprayed into a container, into the base of which an appropriately shaped orifice die is located. When the required mass of metal has been sprayed into the container the hot deposit of metal particles can then be forced through the die by the application of pressure (by means of, for instance, an hydraulically driven ram) to produce an extruded product of the same cross-section as that of the orifice die. Alternatively, extruded articles can be produced by indirect extrusion, the shaped orifice die being located in the ram instead of in the base of the container.

By the method of the invention shaped precision metal articles can be rapidly produced from molten metal and metal alloys and, therefore, the invention is particularly well suited to mass-production methods.

After spraying the deposit of metal particles is not solid, the degree of porosity being a function of several factors, notably the temperature, mass and velocity of the metal particles on deposition. Values of these factors, in turn, can depend on one or more of the process parameters; namely, the geometry of the atomising system, the temperature of the molten metal prior to atomisation; the distance which the particles have to travel before being deposited (hereinafter termed the "spray distance"); the mass ratio of atomising gas to metal being atomised; the relative velocity between the gas jets and the molten metal stream; the temperature and pressure of the atomising gas; and the temperature of the deposition die. In addition, the degree of porosity of the sprayed deposit can be reduced simply by densification or compaction; this can be achieved, for instance, by applying pressure to the deposit by means of an hydraulically operated ram or top die. Therefore, metal articles may be fabricated in a wide range of porosity by the method of the invention. For instance, articles can be produced with a porosity of approximately 50 percent or they can be produced with a porosity effectively equal to zero, or they can have a porosity of any value between these two values. The actual value of the porosity depends primarily on the temperature, size and velocity of the particles on deposition and on the nature and loading of the subsequent forming operation (if this is required).

Articles can be produced in accordance with the invention in most ferrous or non-ferrous metals or alloys which can be melted and atomised; e.g., carbon steels, alloy steels, aluminium, aluminium alloys, brasses, and phosphor bronzes. In addition, articles can be fabricated from a mixture of metals which are not mutually soluble in the liquid state as is the case with some of the existing powder metallurgical methods.

In utilising the method of the invention, the mixing of the different metals can be achieved by spray depositing dissimilar metals either simultaneously, so that mixing of the particles occurs whilst they are in flight, or one after the other so that a sprayed deposit is produced with a structure which consists basically of layers of dissimilar metals. If desired, metallic and/or non-metallic powders, fibres, filaments or whiskers can be incorporated in the sprayed deposit during the deposition operation.

In a preferred method of the invention, the molten metal (or alloy) stream is atomised by the impingement on it of one or more gas jets and generally the greater the velocity and flow rate of the gas jets the finer are the particles produced. Alternatively, any means of breaking up the molten metal stream can be used in conjunction with gas jets which serve to comminute further the molten metal particles and to extract heat from them; for instance, a rotating disc atomiser in conjunction with peripheral gas jets can be used. Any suitable gas may be used to atomise the stream of molten metal, but it is often desirable to use nitrogen or argon or some other inert or reducing gas, so that oxidation of the metal particles is minimised. If oxidation of the particles is not undesirable, compressed air can be used as an atomising medium. To preserve a controlled atmosphere during the deposition process (if required) and for safety reasons the deposition die is disposed within a spray chamber which can be fitted with suitable filters which allow the expanding gas to exhaust but which prevents loss of metallic powders. Any particles which do not adhere to the deposition die (i.e., over-sprayed particles) can be collected from the bottom of this chamber and subsequently re-melted for further spraying and deposition processes. Thus, any oversprayed particles of metal can be re-used in this process (or could be used as a powdered metal product) and as no expensive operations have been performed on this metal (it has only been atomised) the financial loss incurred by overspraying is minimal. The chamber can be constructed simply of welded mild steel panels which may have water-cooled jackets fitted where necessary to remove surplus heat and so maintain the surfaces of the spray chamber at temperatures low enough for safe working during operation. If desired, an inert or reducing atmosphere can be maintained up to, for example, the forging press and also during any subsequent forging (or other forming) operation.

The collecting surface onto which the hot metal particles are deposited can be of a suitable shape and if the surface also acts as the lower die of a die set in, for instance, a forging operation it must be capable of withstanding the stresses involved. In addition it must be resistant to wear that may occur during the deposition of hot metal particles and the subsequent forming operation. Typically, dies are made from nickel-chromium-molybdenum steel for the production of forged steel articles or chromium-molybdenum-vanadium steel for the forging of non-ferrous alloys or for steel forgings where lower temperatures are encountered. Alternatively, nickel based alloys or metallic carbides can be used to make the dies.

One or more sprays of hot, metal particles may be employed in order to obtain the required rate of deposition and/or the required area of deposition. In those cases which involve several sprays, they may be employed to act either simultaneously, or consecutively to produce the required shape and mass of the sprayed deposit. These objectives may also be achieved by relative movements between the deposition die and the spray (or sprays) of hot, metal particles. These movements can occur in any suitable plane (e.g., laterally or axially) and can be of any suitable form (e.g., rotary or oscillatory).

To prevent deposition occurring on selected areas of the deposition die a suitably shaped masking plate may be used; sprayed metal particles being deposited onto this in preference to the deposition die block. When required the masking plate or plates can be removed before the metal deposited into the die cavity is forged or pressed. For example, such masking plates can be used at the edges of the deposition die so that metal is deposited only in the shaped section of the die, i.e., metal which normally would overspray the shaped die is deposited onto the masking plates. The masking plate or plates can be arranged to move away from deposition die at a rate similar to that at which the thickness of the deposit builds up. Over-spraying of the deposition die can also be reduced by modifying the shape of the spray by suitable changes in the arrangement and geometry of the atomising gas-jets. Alternatively, or additionally, any surplus metal that has been deposited on the die block can be removed by other mechanical means, for example, by means of a suitably shaped trimming tool or cutter. This is normally carried out before the subsequent forming operation.

With prior methods which employ the spray depositing of metal particles to form certain semi-finished products, e.g., metallic strip electrodes for condensers, or metal shapes of long length and relatively thin section (e.g., strip material) it is essential that the thickness of the sprayed deposit is uniform or substantially uniform across the width of the deposit, particularly when a rolling operation is employed, as non-uniformities in the thickness of the deposit can result in cracking of the strip during the rolling operation. This is not the case in the present invention as greater variations in the thickness of the deposit can be tolerated. Surplus material flows out between the shaped dies during the forging, pressing or like forming operation and can then be removed, for example, by the shearing action of the two suitably designed dies as they are loaded against each other. In addition, the deposition surface of the die cavity does not usually require special treatment to ensure optimum adhesion prior to deposition, as the surface finish of the formed component conforms to the surface finish of the dies. In certain instances, however, the application of a suitable releasing agent to the surfaces of the dies aids the ejection of the formed component from the dies.

Under certain circumstances, it is desirable that the porosity of the coherent mass of deposited metal particles is minimal. To achieve this requirement the temperature, size, velocity and degree of solidification of the metal particles have to be such that on impacting the die surface they readily flatten, coalesce and build-up to form a coherent deposit which has a fine grain structure (this is essential to reduce segregation problems particularly in highly alloyed materials).

It has been mentioned previously that the condition of the deposit can depend to a large extent on the temperature, size and velocity of the hot particles on impacting the deposition die and as these factors can be altered by variations in the process parameters; for example, the temperature of the deposit can be increased simply by increases in the temperature of the deposition die, the molten metal prior to atomising and the flow-rate of the molten metal; alternatively reductions in the spray height, the flow-rate and the velocity of the atomising gas also result in an increase in the temperature of the mass of particles in the deposition die. This facility to vary the conditions of the sprayed deposit by simple variations in one, or several, of the many operational parameters is highly desirable and is indicative of the flexibility in operation of the invention.

EXAMPLE

Operational conditions for the production of a typical forged or pressed non-porous aluminium (or aluminium alloy) precision component in accordance with the invention are given below:

The metal to be atomised is heated to between 100° and 200°C above its melting point and then poured through a nozzle (between 3 and 7 mm bore), at the exit of which the stream of molten metal is atomised by means of high velocity jets of nitrogen gas. The atomising gas is fed to an annular atomising system which is located at the periphery of the molten stream. Generally gas is supplied to the atomiser at pressures greater than approximately 30 lb/in^2 gauge; the actual value depending on the design of the atomiser, the required temperature of deposition, the diameter of the molten metal stream, etc. A typical gas pressure for atomising a 3 mm diameter stream of molten aluminium is 60 lbs/in^2 gauge, the atomiser comprising 12 outlet holes each 1 mm in diameter, on a pitch circle diameter of 15 mm. The temperature of the atomising gas can be varied over a considerable range, but is usually at room temperature (i.e., about 20°C) and the gas consumption is generally greater than 700 ft^3/ft^3 of metal sprayed. By these means a spray of hot metal particles of median size between 100 and 200 microns can be obtained.

The resultant spray of hot metal particles is directed into a deposition die, which is placed at such a distance from the atomising system so that most of the particles, on impacting the die are at the solidus temperature of the metal or are just solid. Typical values of the distance between the atomising system and the surface of the deposition die (i.e., the spray distance), for the production of an aluminium (or aluminium alloy) component, are in the range of 20 cm to 45 cm.

On impacting the die the particles flatten and build up to form a coherent mass at a temperature suitable for the subsequent hot-forming operation which can be performed without the addition of heat. The approximate hot-working temperature for aluminium and/or its alloys is typically 450°C. The die can be held at a desired temperature; e.g., between 100° and 200°C, to prevent drastic cooling of the initially deposited layers of particles.

The pressure required for hot-working depends primarily on the alloy used and its temperature. In the case of a forged or pressed aluminium or aluminium alloy component the pressure applied to the deposited metal, between the deposition and top dies, can be up to 13 $tons/in^2$ of face area of the component. Generally the sprayed deposit should be transferred and hot formed in an inert gas atmosphere (e.g., in a nitrogen atmosphere). After completion of the hot-forming operation the shaped component can be ejected from the dies.

It has been mentioned above that shaped precision metal products containing a controlled degree of porosity can also be manufactured by the process of this invention. In this way aluminium (or aluminium alloy) parts, having a porosity of approximately 50 percent, can be produced for use as impact energy absorbers as, for example, during collisions involving automobiles. In this instance, it is desirable that the rigid cabin which contains the driver and passengers is protected in front and at the rear by respective crumpling zones formed from deformable parts having a high energy absorption capacity. Spray-formed, porous parts of this nature may also be used as energy absorbing liners in the protective covers of highspeed grinding wheels.

Products having a relatively high value of porosity (50 percent) may be produced by a spray of coarse, metal particles which, at the moment of deposition are moving slowly and have solidified or are mostly solid. On impacting the deposition die these particles do not deform readily and a shaped, coherent deposit with large interparticulate voids is formed.

The degree of porosity of spray-formed precision articles can be controlled easily by variations in the process parameters, as discussed above, so that shaped, metal articles can be manufactured over a wide range of porosities. In this way, porous bearings, filters and the like can be manufactured simply by spraying the metal particles at the appropriate conditions into a suitably shaped die. If necessary the sprayed deposit can be pressed to obtain the required value of porosity and/or a suitable shape.

The invention will be described further, by way of example, with reference to the accompanying diagrammatic drawings, in which:-

FIG. 1 is a section through an apparatus for making shaped precision articles in accordance with the invention;

FIG. 2 is a sectional view of the article produced by the apparatus shown in FIG. 1;

FIG. 3 shows a section through an apparatus in which the sprayed deposit is removed from the collecting surface before being worked;

FIG. 4 shows two stages in producing an extruded article in accordance with the invention; and

FIG. 5 shows the stages involved in die-stamping a strip of sprayed metal.

FIG. 1 shows an apparatus for making shaped precision articles according to the invention, such apparatus comprising a tundish **10** filled with molten metal or molten metal alloy **11**. The tundish is formed into a nozzle **12** at its lower end which is surrounded by an annular gas atomiser **13** having outer and inner gas galleries **14, 15** respectively. Gas is supplied through delivery pipes **16** to issue through angled jets **17** connecting with the inner gallery **15**. Gas from the jets **17** serves to break up the stream of molten metal issuing from the nozzle into a spray **18** which is directed at a collecting surface in the form of a deposition die **19**, where the sprayed particles form a hot, coherent deposit **20**. The waste atomising gas leaves the atomising chamber **21** through dust filters **22**.

The die **19** is mounted on a die block **23** which is itself suitably supported on a die block support **24**. Inert gas cover is maintained in a press chamber **25** connected to the atomising chamber **21**, and an operating arm **26** is attached to the die block **23** for transferring the deposit **20** in the die **19** into the press chamber **25**. The chamber **25** is provided with a fixed lower die holder **27** and a top die **28** mounted on a top die block **29** which is movable, for example, mechanically, hydraulically or pneumatically. Seals **30** prevent the ingress of air into the chamber **25**.

When the deposition die **19** is in position on the lower die holder **27**, the top die block is operated to close the top die **28** onto the die **19**, thus hot-forming a shaped precision article **31**, as illustrated in FIG. **2**, which can be removed for the cycle to be repeated.

FIG. **3** shows a similar apparatus to that illustrated in FIG. **1**. However, in this instance, the hot metal particles are sprayed onto a flat collecting surface **32** to form an unshaped deposit **33** which is ejected from the surface **32** to be hot-worked between shaped top and bottom dies **34, 35** respectively under the action of a press (not shown) thereby producing a shaped precision article **36**.

In FIG. **4**, an apparatus is illustrated which is suitable for forming an extruded precision article according to the invention. In this case, the metal spray **18** is directed into a cylindrical container **37** provided with an extrusion die **37'**, to form a hot, coherent deposit **38**. The extrusion die **37** is then transferred to a position wherein a piston **39** of an extrusion press (not shown) can co-operate with the container **37** to extrude a precision metal article **40** (see FIG. 4B).

Referring finally to FIG. **5**, the spray of metal **18** is directed onto a moving collecting surface **41** to form a hot, coherent layer **42** which is transferred to a die-stamping press comprising a top die **43** which co-operates with a bottom die **44** to stamp out a hot-worked product **45** (see FIG. 5B and FIG. 5C). The waste deposit **46** is returned to the tundish **10** to be recycled.

The invention is not limited to the precise details of the foregoing examples and variations may be made thereto within the scope of the appended claims. For example, the deposit may be cold worked by the die when, for instance it is desired to form a highly porous article.

In the FIG. 5 embodiment, instead of a die-stamping press, a forging press may be used to produce articles from a continuous layer of sprayed deposit.

I claim:

1. A method for manufacturing shaped precision articles from molten metal or molten metal alloy, comprising directing an atomised stream of molten metal or molten metal alloy onto a collecting surface to form a solid deposit, then directly working the deposit on the collecting surface by means of a die to form a precision metal or metal alloy article of desired shape, and subsequently removing the precision shaped article from the collecting surface.

2. A method as claimed in claim **1**, wherein the collecting surface is in the form of a second die.

3. A method as claimed in claim **2**, wherein the molten metal or metal alloy is atomised in an inert atmosphere.

4. A method as claimed in claim **1**, wherein the molten metal or metal alloy is atomised in a reducing atmosphere.

5. A method as claimed in claim **1**, wherein the molten metal or metal alloy is atomised by compressed air.

6. A method as claimed in claim **1**, wherein several atomised streams of different molten metals or alloys are provided, which streams are simultaneously mixed in flight or are sprayed consecutively.

7. A method as claimed in claim 6, wherein metallic and/or non-metallic powders, fibres, filaments or whiskers are incorporated in the sprayed deposit during deposition.

8. A method as claimed in claim 2, wherein the second die is transferred to a press chamber to enable working to be carried out.

9. A method as claimed in claim 1, wherein the collecting surface is in the form of a container provided with an extrusion die, and working of the deposit is carried out by a ram which extrudes the deposit through the die to form a precision metal article.

10. A method as claimed in claim 1, wherein the collecting surface is in the form of a container and working is carried out by a ram having an extrusion die through which the article is extruded.

11. A method as claimed in claim 1, wherein the collecting surface moves relative to the atomised stream of molten metal or metal alloy so that a continuous layer of metal or metal alloy is deposited on the collecting surface.

12. A method as claimed in claim 1, wherein a masking plate or plates is mounted in the atomised steam of molten metal or metal alloy to ensure that metal or metal alloy is only deposited on desired areas of the collecting surface.

13. A method as claimed in claim 1, wherein any surplus metal or metal alloy deposited on the collecting surface is removed by a suitably shaped trimming or cutting tool.

14. A method as claimed in claim 1, wherein a release agent is applied to the collecting surface to facilitate release of the sprayed deposit therefrom.

15. A method as claimed in claim 1, wherein the die or dies are made from nickel-chromium-molybdenum steel, chromium-molybdenum-vanadium steel, nickel based alloys or metallic carbides.

16. A method as claimed in clam 1, wherein the deposit is cold worked.

17. A method as claimed in claim 1, wherein the deposit is cold worked.

18. An apparatus for manufacturing shaped precision articles from molten metal or molten metal alloy, comprising a chamber having means for atomising a stream of molten metal or metal alloy and for directing the atomised stream onto a collecting surface so as to form a solid deposit on said surface, a die movable by operating means for effecting working of said deposit on said surface in order to form a precision metal or metal alloy article, and means for removing the precision metal or metal alloy article from the chamber.

19. An apparatus as claimed in claim 18, wherein the atomising means is an annular gas atomiser which surrounds a nozzle through which molten metal or metal alloy is fed from a tundish.

20. An apparatus as claimed in claim 18, wherein the collecting surface is in the form of a second die which is movable between a depositing position, and a working position wherein it cooperates with said first die.

21. An apparatus as claimed in claim 18, wherein an inert gas atmosphere is maintained in the chamber.

22. An apparatus as claimed in claim 18, wherein the collecting surface is in the form of a container provided with an extrusion die, and a piston is provided for extruding the deposit from the die.

23. An apparatus as claimed in claim 18, wherein the collecting surface is in the form of a container and working is carried out by a ram having an extrusion die through which the article is extruded.

24. An apparatus as claimed in claim 18, wherein means are provided for moving the collecting surface relative to the atomised spray so that a continuous layer of metal or metal alloy is deposited on said surface, press means being provided for forming the worked article from the layer of metal or metal alloy.

25. An apparatus as claimed in claim 18, wherein an inert gas atmosphere is maintained in the chamber.

26. An apparatus as claimed in claim 18, wherein a reducing atmosphere is maintained in the chamber.

27. An apparatus as claimed in claim 18, wherein the molten metal or metal alloy is atomised by compressed air.

28. An apparatus as claimed in claim 18, wherein the atomising means is arranged to atomise several streams of different molten metals or metal alloys, which streams are simultaneously mixed in flight or are sprayed consecutively.

29. An apparatus as claimed in claim 28, wherein means are provided for incorporating metallic and/or non-metallic powders, fibres, filaments or whiskers in the sprayed deposit.

30. An apparatus as claimed in claim 18, wherein the die is made from a material selected from the group consisting of chromium-molybdenum steel, chromium-molybdenum-vanadium steel, nickel based alloys and metallic carbides.

31. An apparatus as claimed in claim 18, wherein a release agent is applied to the collecting surface to facilitate release of the sprayed deposit therefrom.

32. An apparatus as claimed in claim 18, wherein any surplus metal or metal alloy deposited on the collecting surface is removed by a suitably shaped trimming or cutting tool.

33. An apparatus as claimed in claim 18, wherein a masking plate or plates is mounted in the atomised stream of molten metal or metal alloy to ensure that metal or metal alloy is only deposited on desired areas of the collecting surface.

34. An apparatus as claimed in claim 18, wherein the deposit is hot worked.

35. An apparatus as claimed in claim 18, wherein the deposit is cold worked.

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