

[54] **METHOD OF FORMING COMPOSITE METAL STRIP**

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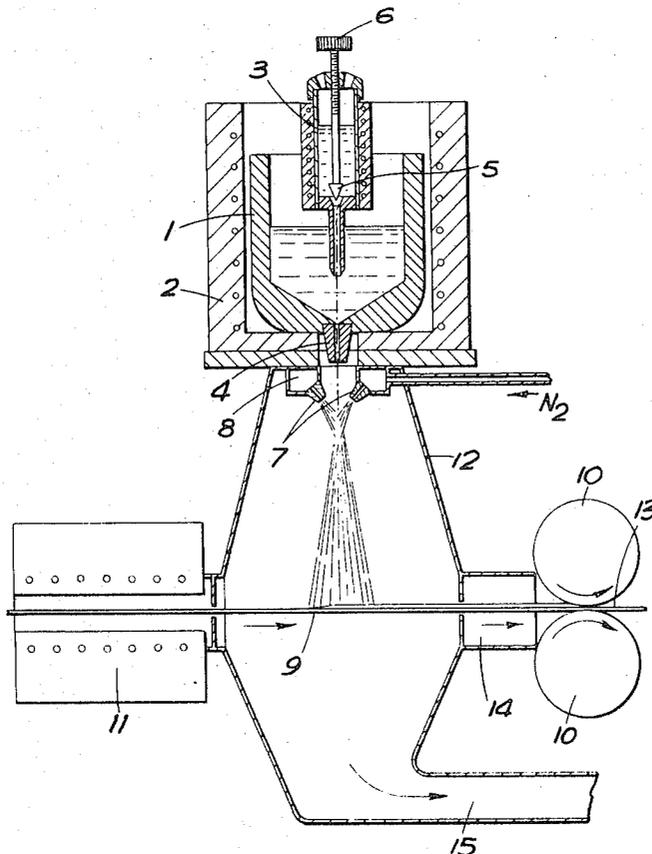
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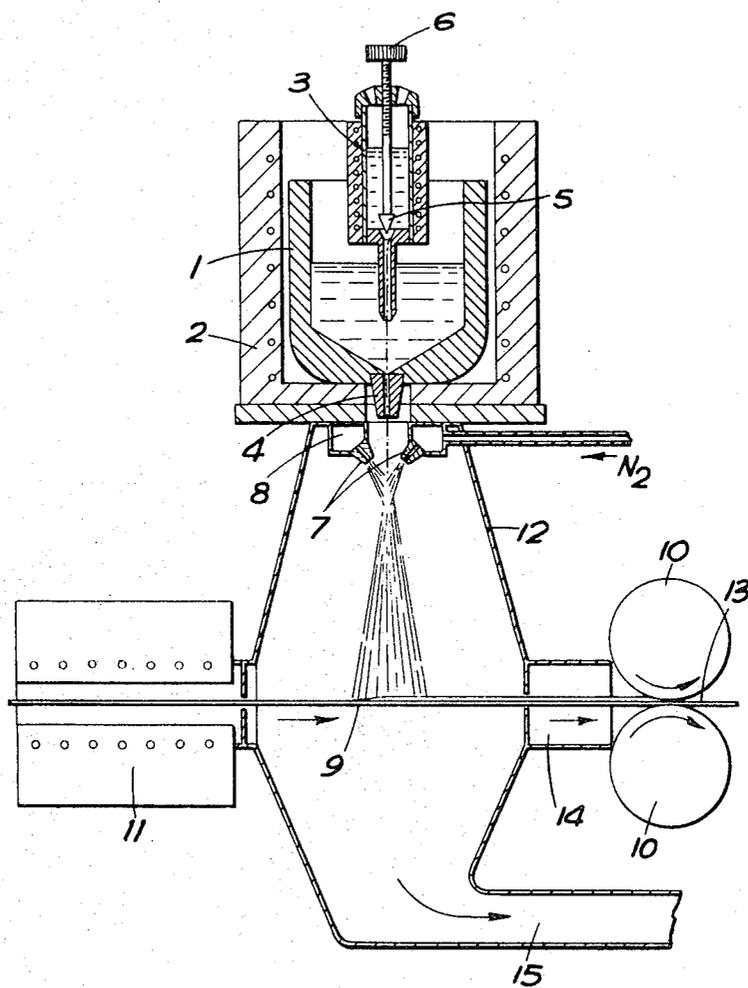
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[57] **ABSTRACT**

The specification discloses a method of forming a composite metal strip comprising a backing layer and a layer of two metals which, in liquid form, are immiscible or partially immiscible and having differing densities. The two metals are maintained in molten state in two crucibles each of which has a bottom outlet from which a stream of molten metal issues. The crucible containing the higher density metal is supported within the other crucible so that the stream of higher density metal passes through the lower density metal and issues concentrically with the stream of lower density metal to atomizing gas jets which atomize the streams of metal and direct a spray of the resulting particles onto a backing layer to which the particles adhere.

7 Claims, 1 Drawing Figure





## METHOD OF FORMING COMPOSITE METAL STRIP

The invention relates to a process and apparatus for producing composite metal material.

The invention provides a method of producing composite metal material comprising passing simultaneously to atomising means at least two liquid metals, to form a fine spray consisting of atomised particles of the metals, and directing the spray on to a base material to which the particles adhere.

The liquid metals, before atomisation, may be pre-alloyed with a predetermined proportion of the other metal, the temperature of the alloy being maintained at a level above the point corresponding to said proportion on the miscibility curve for the alloy, whereby said other metal is retained in solution in said one metal.

One of the liquid metals may be passed into the other liquid metal before atomisation and the two liquid metals are then atomised together in a single spray.

The base material may be etched or grit blasted before the said spray of atomised particles is directed on to it.

The base material may be rolled after it has been sprayed with the atomised particles of the metals.

The invention also provides apparatus for performing the above method comprising a container for one of the liquid metals connected to means for atomising the liquid metal in the container, a second container for the other of the liquid metals connected to means for atomising the liquid metal in the second container and means for moving the base material through the region of the atomised particles of the two liquid metals.

Single means may be provided for atomising the liquid metals in said two containers, one of which is connected to pass the liquid metal therein to said single means through the liquid metal in the other container.

Each container may have an outlet through which the liquid metal in the container passes under gravity.

The, or each, atomising means may include a plurality of nozzles each providing a jet of gas which acts on the liquid metal issuing from the respective container.

The gas may be nitrogen.

The nozzles may be arranged in an annular formation and direct the respective jets of gas inwardly towards the axis of the annulus, and towards the base material.

At least one pair of rollers may be provided in the direction of movement of the base material, said rollers being arranged to act on the material after it has been sprayed with the two liquid materials.

Each container may have separate heating means which control the temperature of the liquid metal in the container.

One of the containers may have an outlet portion which extends into the other of the containers.

Said one container may have an adjustable needle valve controlling the opening of the outlet of the container.

Two embodiments will now be described by way of example and with reference to the accompanying drawing which shows a cross-section of a suitable apparatus for producing composite strip suitable for the manufacture of bearings.

In the first embodiment, aluminum alloy is maintained in a molten state in the crucible 1 by the electric holding furnace 2. Lead is maintained in a molten state in a smaller stainless steel heated container 3. The bot-

tom of the crucible is shaped in such a way that it tapers to a nozzle 4 through which the aluminium alloy is delivered to the atomiser in a stream. Molten lead is allowed to run in a thin stream from the container 3 through a needle valve 5 which can be used to control the flow of lead by turning the knob 6. The thin stream of lead falls through the liquid aluminium alloy with which it is immiscible and is directed into the nozzle 4 by the shape of the bottom of the crucible 1 and the positioning of the container 3. The combined streams of metal on issuing from the nozzle 4 are atomised by jets of nitrogen 7 at a pressure of between 60 and 150 p.s.i. issuing from the atomising ring 8. The atomised particles of aluminium alloy and lead are directed on to a prepared steel backing strip 9. The backing strip, which is prepared by cleaning and etching or grit blasting, is drawn continuously by the rolls 10 through a controlled atmosphere electric preheating furnace 11 into the atomising chamber 12 beneath the spray of atomised particles. The atomised spray impinges on the prepared surface of the backing strip 9 to which the particles flatten and adhere tightly. As the strip proceeds through the atomising chamber a thick deposit builds up on the strip which is then rolled in the rolling mill 10 to consolidate the deposit and bond the aluminium alloy tightly to the backing strip. The composite strip issues at 13 and can then be further processed into bearing shells by the usual methods. It will be apparent that in the case of aluminium and certain other alloys, if freedom from oxide is required, air must be excluded from the atomising and deposition chamber. Excess nitrogen from the atomising chamber 12 is allowed to flow into the ancillary chamber 14, so providing protection for the strip up to the nip of the rolls. Used gases and surplus particles are exhausted at 15. After rolling the deposit is no longer porous and can be exposed to air without causing a deterioration of properties. It will be appreciated that the process can be run continuously by feeding metal into the holding furnace 1 and container 3 to maintain constant levels. While, in the drawing, the delivery nozzle of the lead container 3 is placed below the level of the liquid aluminium in order to avoid having the lead encapsulated by aluminium oxide, it is possible to have the nozzle exit above the surface of the liquid metal in some cases. When a high melting point metal, such as copper, is used this procedure is advantageous particularly when the metal surface is protected from oxidation by a protective atmosphere.

Although it is possible to obtain good results using a cold backing strip, it will usually be found advantageous to preheat the prepared backing strip before spraying in order to decrease internal stresses and to increase the strength of the bond.

The above procedures enable composite materials to be produced conveniently, continuously and at low cost, in which a finely divided mixture of two or more constituents is obtained irrespective of their miscibility of density.

It will be appreciated that a similar procedure is equally applicable to many other metallic combinations in which two phases are immiscible in the liquid and of different density.

When the method is used to atomise and spray two immiscible liquid metals it is always found that each individual metal has some slight solubility in the other. The degree of solubility generally rises with tempera-

ture. Thus, if in the above described first embodiment in which the system aluminium-lead is taken as an example, the two metals consisting of 25 percent lead by weight overall the remainder being aluminium are sprayed at a temperature of say 750° C, up to about 3 percent of lead could be in solution in the aluminium and up to about 1 percent of aluminium could be in solution in the lead at 750° C. On atomisation and deposition most of the lead would be rejected from solution either in the liquid or in the solid phase and would therefore appear in the product as extremely fine particles within the aluminium matrix. In addition to the very fine particles of lead rejected from solution there would be a much larger quantity of coarser particles consisting of atomised droplets of lead distributed throughout the aluminium matrix of the product.

While for many applications this structure is entirely satisfactory, it would be an advantage to have full control over the microstructure of the deposited material in such a way that the amount of lead rejected from the solution during cooling as compared with the amount atomised could be varied at will. Such a process has now been developed.

In the second embodiment of the invention, a process similar to the above described first embodiment is conducted using the same apparatus in which a bearing material consisting of particles of lead in an aluminium alloy matrix on a steel backing strip is produced. In this embodiment, the aluminium alloy contained in the crucible 1 shaped in such a way that it tapers to a nozzle 4 at the bottom, is pre-alloyed with approximately the amount of lead that is required to be rejected from solution during cooling to room temperature. To ensure that the lead remains in solution in the molten aluminium alloy, it is necessary to retain the aluminium alloy at a temperature slightly above the miscibility curve at that composition, e.g., if it is required to reject 8 percent lead from solution in the aluminium alloy during cooling of the product to room temperature, a temperature of 900° - 950° C should be maintained in the crucible. The minimum temperature which ensures the retention of the lead in solution in the liquid metal will, in practice, be used because higher temperatures cause further difficulties of refractory dissolution and increased cost. Additional lead required in the product in the form of co-deposited atomised droplets, say 17 percent by weight, is added from the centrally disposed lead container fitted with a needle valve through which the lead is delivered to the atomiser at a controlled rate. The exit point of the delivery nozzle of the lead container is below the level of the molten aluminium alloy at a position near to the tapered exit orifice of the crucible. In this way the stream of lead is in contact with the stream of hot aluminium alloy for a very short period of time, thus reducing to a minimum further solution of lead in the molten aluminium alloy. In the example given the product structure would then consist of approximately 8 percent by weight of very finely distributed lead and 17 percent by weight of solidified atomised droplets of lead in an aluminium alloy matrix. It will be appreciated that the process can be run continuously by feeding pre-alloyed aluminium-lead into the crucible and lead into the container to maintain constant levels.

By altering the temperature of the aluminium alloy together with the percentage of lead held in solution and by controlling the supply of liquid lead to the ato-

misising nozzle, it is thus possible to obtain final products having structures covering the whole range from the one extreme of all the lead being present as an extremely fine deposit because it has been rejected from solution during cooling, to the other extreme of all the lead being present as atomised droplets. Such a range of product structure enables the most suitable product to be used for any particular engineering design.

It will be appreciated that even though the simple apparatus described gives an axi-symmetric distribution of particles of spray, it is possible to modify the shape of the spray from a cone to a thick curtain of particles. This is best achieved by positioning the holes or slots through which the atomising gas is delivered in such a way as to bring about a flattening of the jet of sprayed particles. Further modification of the shape of the jet of sprayed particles can be carried out by allowing secondary jets of gas to impinge upon it after the primary atomisation.

While the detailed description is concerned with the preparation of a bearing material consisting of particles of lead in an aluminium alloy matrix, it will be realised that a similar procedure is equally applicable to many other metallic systems such as, for instance, copper-lead, in which two partially miscible or immiscible liquids are found above the melting point.

The apparatus can also with advantage be used where it is desired to obtain a material in strip form having very fine particles of one phase rejected by the very rapid cooling of a homogeneous liquid. In such a case the container for the second liquid metal is discarded and the equipment then enables the liquid to be chilled by atomising and deposition on a cooler base metal in a very short time interval, frequently only a fraction of a second. Such a procedure is particularly beneficial with, for instance, aluminium-tin alloys which can in this way be fabricated in the form of a composite strip on a steel base in a single inexpensive operation.

It is sometimes desirable to pre-coat a steel base strip before depositing a sprayed layer in order to increase the adhesion to the base. A metal coating should be chosen which is compatible with the deposit and preferably does not form a thick, brittle interface with the steel. In the example given above, a pre-coated steel base strip could be prepared by dip coating or powder coating with aluminium or an aluminium alloy or by spraying on to it a very thin layer of aluminium prior to the application of the main alloy deposit.

I claim:

1. A method of forming a composite metal strip comprising a backing layer and a layer of two metals which, in liquid form, are immiscible or partially immiscible and are of differing densities, said method comprising the steps of:

- a holding a supply of the metal of lower density in molten state;
- b allowing a stream of said molten metal to fall under gravity from said supply;
- c holding a supply of the metal of higher density in molten state;
- d allowing a stream of the molten metal of higher density to fall under gravity from said supply through the supply of molten metal of lower density to the stream of lower density metal issuing therefrom to form a concentric stream within the stream of low density metal; and

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e directing at least one gas jet onto said concentric stream to form a spray of particles of the metals which is directed onto a backing layer to form a layer of said particles adhering to the backing layer.

2. A method as claimed in claim 1 and where the two metals are partially immiscible, wherein a proportion of the metal of higher density is included in the supply of metal of lower density and the temperature of the supply is maintained at a level at which the proportion of metal of higher density is miscible with the supply of lower density metal.

3. A method as claimed in claim 1 wherein the concentric streams of metals are atomized by a number of jets of gas arranged in an annulus concentric with the stream, said jets being directed inwardly and downwardly of the annulus to direct a spray of particles from said concentric streams onto a backing layer located below the annulus.

4. A method as claimed in claim 1 wherein the strip is rolled after said spraying to compact the layer of metals sprayed onto the backing.

5. A method of forming a composite metal strip comprising a backing layer and a layer of two metals which are partially immiscible and are of differing densities,

said method comprising:

a holding a supply of the metal of lower density in molten state with a proportion of the metal of higher density;

b maintaining the temperature of said supply at a level at which the proportion of metal of higher density is miscible with the supply of metal of lower density;

c allowing a stream of said metals to fall under gravity from said supply; and

d directing at least one gas jet onto said stream to form a spray of particles of the metals which is directed onto a backing layer to form a layer of said particles adhering to the backing layer.

6. A method as claimed in claim 5 wherein the stream of metals is atomized by a number of jets of gas arranged in an annulus concentric with the stream, said jets being directed downwardly of the annulus to direct a spray of particles from said stream onto a backing layer located below the annulus.

7. A method as claimed in claim 5 wherein the strip is rolled after said spraying to compact the layer of metals sprayed onto the backing.

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