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(54) **Method and apparatus for the treatment of molten metals.**

(57) Apparatus for the treatment of molten metal with a particulate treatment agent and a gas comprises a vessel (21), a rotary device for dispersing particulate treatment agent and a gas in molten metal contained in the vessel and means (23), (51) for supplying the particulate treatment agent and gas to the rotary device, The rotary device comprises a hollow shaft (1) having a discharge end and a hollow rotor (2) attached to the shaft, the rotor having a plurality of vanes (13) each extending from the shaft or from a location adjacent the shaft towards the periphery of the rotor so that the hollow interior of the rotor is divided into a plurality of compartments (10), each compartment having an inlet (11) adjacent the shaft and an outlet (12) adjacent the periphery of the rotor, and the rotor has means for passing the particulate treatment agent and gas from the discharge end of the hollow shaft of the device to the compartments. In a preferred embodiment the discharge end of the shaft opens into a manifold (8) in the rotor and the inlets (11) for the compartments (10) are in the wall (6) of the manifold. For relatively fine particles the means for supplying the particulate treatment agent and gas to the rotary device may be a hopper fitted with gas injection nozzles, or an apparatus (23) in which the particulate treatment agent is fluidised by the gas to produce a dispersion and which is connected by a pipe (33) to the bore of the shaft of the rotary device. For larger particles the means for supplying the particulate treatment agent and gas to the rotary device may be a hopper(51) having a sealed top (52) having a closable inlet (53) for the particles of treatment agent, and an aperture (54) in its base (55) communicating with a tube (61) located inside the bore (62) of the shaft (63) of the rotary device, the sidewall (58) of the hopper adjacent the base having at least one series of apertures spaced apart around its perimeter, each aperture having projecting through it to the inside of the hopper a sliding member (56, 57), and the tube having one or more apertures therein for the introduction of gas.

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FIG. 2

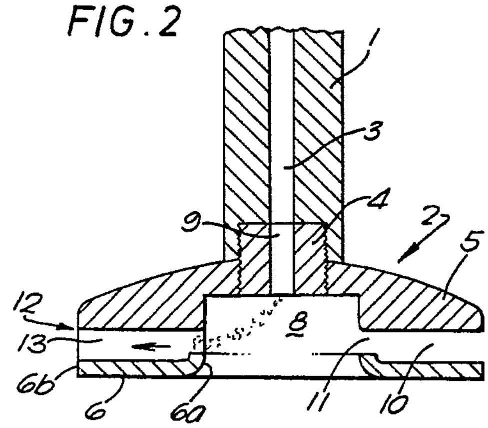


FIG. 3

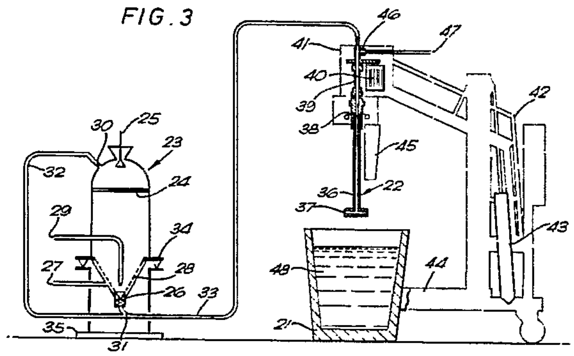
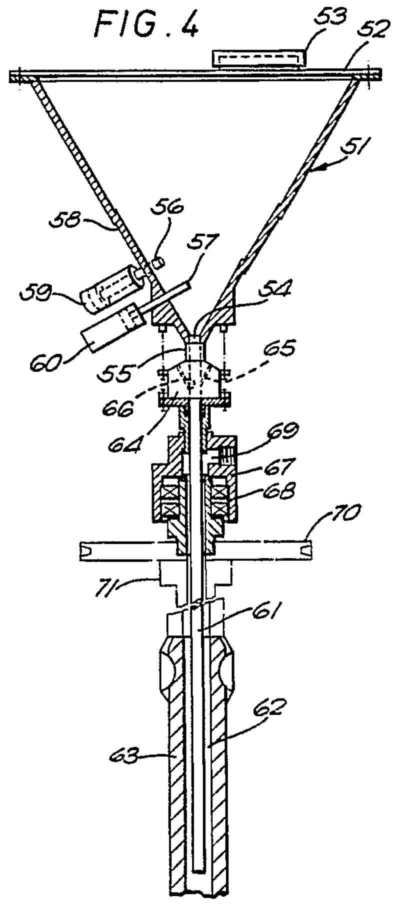


FIG. 4



METHOD AND APPARATUS FOR THE TREATMENT OF MOLTEN METALS

This invention relates to a method and apparatus for the treatment of molten metals.

Various rotary devices have been proposed for introducing gas into molten metal to perform treatments such as the removal of hydrogen from aluminium or aluminium alloys or the removal of alkaline materials from aluminium alloys.

One such device is described in European Patent Application Publication No. 0332292A. The device consists of a hollow shaft and a hollow rotor attached to the shaft. The rotor has a plurality of vanes extending from the shaft towards the periphery of the rotor and dividing the hollow interior of the rotor into a plurality of compartments. Each compartment has an inlet adjacent the shaft and an outlet adjacent the periphery of the rotor. The bottom end of the shaft opens into a manifold in the rotor and the inlets for the compartments are located in the wall of the manifold. When the device is rotated in molten metal molten metal is drawn into the manifold where it breaks up a stream of gas leaving the shaft into very small bubbles. The gas bubbles are dispersed in the molten metal, and the dispersion flows into the compartments through the inlets in the manifold wall, through the compartments and out of the rotor through the peripheral outlets. The gas is thus dispersed through the whole body of molten metal.

United States Patent No. 4802656 describes an apparatus for dissolving alloying elements and dispersing gas in an aluminium bath. That patent refers in its preamble to known gas dispersers and states that they cannot be used as apparatus for dissolving alloying elements in molten metal. The apparatus described in the patent consists of a vertical shaft pierced along its axis by a duct, and connected to a gas source and a drive motor, and a rotor or disc having the same axis as the shaft. The disc is provided with blades which extend along the generatrices of a right prism of parallelagrammatic section, with its axis passing through the centre of the disc, the ends of which result from the intersection of the said prism with a cylinder of the same axis as that bearing against the side wall of the disc, the large faces of the prism forming an angle of at most 45 degrees to the horizontal and the small faces being disposed respectively in the planes of the upper and lower faces of the disc, and the blades being provided with at least one orifice connected to the duct of the shaft by a tubular passage. In use the disc is immersed in a bath of molten metal and rotated and gas is introduced into the shaft duct. Alloying additions are fed into the molten metal adjacent the shaft from a hopper disposed above the bath.

It has now been found that surprisingly a rotary device similar to that described in European Patent Application Publication No. 0332292A can be used to treat molten metal with a solid treatment agent by entraining particles of treatment agent in a stream of gas passing through the shaft into the rotor

According to the invention there is provided a method for the treatment of molten metal with a particulate treatment agent and a gas the method comprising providing a rotary device comprising a hollow shaft having a discharge end and a hollow rotor attached to the shaft, the rotor having a plurality of vanes each extending from the shaft or from a location adjacent the shaft towards the periphery of the rotor so that the hollow interior of the rotor is divided into a plurality of compartments, each compartment having an inlet adjacent the shaft and an outlet adjacent the periphery of the rotor, and the rotor having means for passing the particulate treatment agent and gas from the discharge end of the shaft to the compartments, immersing the rotary device in molten metal contained in a vessel, rotating the device so that molten metal enters the compartments through the inlets, and supplying a particulate treatment agent for the molten metal and a gas to the shaft so that the particulate treatment agent and gas emerge from the discharge end of the shaft and pass into the compartments, are mixed with the molten metal within the rotor and on emerging from the rotor are dispersed throughout the molten metal contained in the vessel.

According to a further feature of the invention there is provided apparatus for the treatment of molten metal with a particulate treatment agent and a gas comprising a vessel, a rotary device for dispersing particulate treatment agent and a gas in molten metal contained in the vessel and means for supplying the particulate treatment agent and gas to the rotary device, wherein the rotary device comprises a hollow shaft having a discharge end and a hollow rotor attached to the shaft, the rotor having a plurality of vanes each extending from the shaft or from a location adjacent the shaft towards the periphery of the rotor so that the hollow interior of the rotor is divided into a plurality of compartments, each compartment having an inlet adjacent the shaft and an outlet adjacent the periphery of the rotor, and the rotor having means for passing the particulate treatment agent and gas from the discharge end of the hollow shaft of the device to the compartments.

In a preferred embodiment the rotary device may be as described in European Patent Application Publication No. 0332292A and have a rotor having a manifold and inlets for the compartments in the walls of the manifold and a shaft whose lower end opens into the manifold.

The rotor of the rotary device may be formed separately from and be fixed to the shaft or the rotor may be formed integrally with the shaft.

The rotor is preferably circular in transverse cross-section in order to reduce drag in the molten metal when the device rotates and in order that the overall weight of the rotor may be as low as possible.

The rotor may have two or more vanes and hence two or more compartments. At least three vanes and three compartments are preferred and four has been found to be a convenient number in practice, Preferably the vanes extend from the shaft, to which they may be joined or with which they may be integrally formed, to the periphery of the rotor. The vanes may extend radially or be tangential to the shaft.

In use the shaft is connected to drive means, either through a drive shaft or directly at the top of the shaft, or through the base of the rotor at the bottom of the shaft.

When the rotary device is of the type described in European Patent Application Publication No. 0332292A molten metal is drawn into the manifold of the rotor when the device rotates in the molten metal, and in the manifold the metal breaks up the stream of particulate treatment agent and gas leaving the outlet of the shaft. The gas in the form of very small bubbles and the particulate treatment agent are intimately mixed with the molten metal and the dispersion formed flows into the compartments through the inlets in the manifold wall and out through the peripheral outlet, and is dispersed through the whole body of molten metal.

The flow pattern of the molten metal and gas/particulate treatment agent mixture emerging from the rotor into the body of molten metal is determined by the geometry of the interior of the rotor. In practice it is preferred to locate the device as near to the bottom of the vessel as possible and to cause the molten metal, gas and particulate treatment to emerge from the rotor in a substantially horizontal direction. This may be achieved, for example, by making the edge or the whole of the upper surface of the bottom of the rotor, and optionally the edge of the underside of the top of the rotor, horizontal.

The rotary device of the apparatus of the invention provides an efficient means for dispersing a particulate treatment agent and a gas in molten metal and for distributing them throughout a large body of the molten metal.

The rotary device may be made from graphite, silicon carbide or a ceramic material which is inert to the molten metal.

The vessel used to carry out the method of the invention may be for example a ladle which may be used for the treatment of the molten metal by a batch process or the vessel may be a special construction in which the molten metal may be treated by a continuous process for example as described in a European Patent No. 0183402.

The means used for supplying the particulate treatment agent and gas to the rotary device will depend on the particle size of the particulate treatment agent being used.

For relatively fine particles of the order of 1 mm or less the means may be a hopper fitted with gas injection nozzles. However for such particles the preferred means is an apparatus in which the particulate treatment agent is fluidised by the gas to produce a dispersion, and which is connected by a pipe to the bore of the shaft of the rotary device.

Such an apparatus may comprise a container having a closable inlet at its top end for admitting the particulate treatment agent, a primary inlet for introducing a gas such as argon or nitrogen adjacent its bottom end, such as a plurality of jets, through which the gas passes in order to fluidise the particulate treatment agent, and a valve at its bottom end through which the dispersion passes into the pipe connecting the apparatus with the rotary device. The apparatus may also have a secondary inlet for gas which is introduced into the dispersion so as to reduce the concentration of particulate treatment agent in the dispersion, and an outlet adjacent the top end through which excess gas leaves the container and which is connected to the pipe connecting the apparatus with the rotary device. The flow rate of particulate treatment agent may be controlled by the flow rate of gas passing through the secondary inlet and can be controlled by locating the container on a weighing device on a platform.

The particulate treatment agent preferably consists of particles of a size less than 1 mm, and more preferably particles of a size 0.15 mm to 0.8 mm.

The length to width ratio of the particles is preferably no more than 2.0:1, and is more preferably from 1:1 to 1.75:1. Particles of the desired shape and size may be made by forming tablets of the treatment agent and milling the tablets.

For certain types of treatment agent for example alloys such as so-called master alloys which are used for grain refining aluminium and its alloys the production of particles of the above shape and size is difficult and inconvenient. It is therefore desirable to use such treatment agents in the form of larger particles of a size greater than 5 mm, preferably of the order of 6 - 10 mm, and having a droplet like shape.

The means used for introducing these relatively large particles into the rotary device is preferably a hopper of special construction connected to the bore of the shaft of the rotary device.

The hopper which is mounted above the rotary device which preferably has the shape of an inverted cone has a sealed top having a closable inlet for the particles of treatment agent, and an aperture in its base communicating with a tube having one or more apertures therein for the introduction of gas and located inside the bore of the shaft of the rotary device. The sidewall of the hopper, adjacent the base, has at least one series of apertures spaced apart around its perimeter, and each aperture has projecting through it into the inside of the hopper a sliding member connected to means such as compressed air cylinders located outside the hopper to cause the member to slide forwards and backwards towards and away from the vertical axis of the hopper. The hopper preferably has two or more series of apertures and sliding members spaced apart around the perimeter of the hopper, and the apertures and sliding members are preferably located so that the apertures and sliding members in one series are positioned above and between the apertures and sliding members of another series. Preferably each series consists of three apertures and sliding members. In use the sliding members are operated in such a manner that each series operates in succession so that they alternatively open and close the space above and below each sliding member. As a result they accelerate the large particles of treatment agent so that the particles always enter the rotor one at a time. The frequency of operation of the sliding members can be varied depending on the size or density of the particles being used.

In a preferred embodiment the tube connected to the base of the hopper passes through a block beneath on the base of the hopper into the bore of the shaft of the rotary device. The block has a plurality of ducts preferably angled downwardly towards the rotary device, and the ducts communicate via apertures in the wall of the tube with the inside of the tube. In use gas is injected into the tube via the ducts and the effect of the gas is to produce a positive pressure which prevents molten metal entering the rotor of the rotary device and ensures that the particles of treatment agent always fall into a gas pocket.

The apparatus also has means for introducing and controlling the flow of gas into the shaft of the rotary device in the space surrounding the tube from the hopper, and means such as a wheel driven by a fan belt for driving the shaft of the rotary device either directly or via a drive shaft.

When the rotary device is rotated in molten metal the metal is pumped through the rotor and particles of treatment agent and gas are mixed with the metal inside the rotor.

The method and apparatus of the invention may be used to treat a variety of molten metals with a particulate treatment agent, for example aluminium and its alloys, magnesium and its alloys, copper and its alloys, or ferrous metals such as iron or steel.

The gas which is used in conjunction with the particulate treatment agent may be inert or it may be reactive to the metal being treated. Examples of gases which may be used are chlorine, argon and nitrogen.

Examples of treatment agents which may be used in particulate form include fluxing agents, such as mixtures of alkali metal chlorides and simple or complex alkali metal fluorides, for treating aluminium or aluminium alloys, grain refiners, such as mixtures of potassium borofluoride and potassium titanium fluoride salts or alloys for refining the grain structure of aluminium or its alloys, alloying additions for ferrous or non-ferrous metals, desulphurising agents such as a mixture of lime and calcium carbide or magnesium for desulphurising iron, or calcium silicide for desulphurising steel, and compositions to modify the structure of graphite in cast iron, such as compositions to produce spheroidal graphite iron or to produce vermicular graphite iron.

The method and apparatus are particularly useful for adding grain refiners or modifying agents to aluminium or aluminium alloys, and enable materials which would not normally be useful in other processes to be used as treatment agents. For example strontium metal, milled to particulate form, can be used as a modifying agent instead of the commonly used strontium containing alloys, and alloys containing higher concentrations of titanium and boron than are normally used for example, 15% by weight titanium and 2% by weight boron, can be used as grain refiners.

The size of rotor, the rotor speed and the gas flow rate will usually be as described in European Patent Publication No. 0332292A and the flow rate of the particulate treatment agent will usually be from about 0.5 kg to 2 kg per minute depending on the size of the vessel containing the metal to be treated.

The invention is illustrated by way of example with reference to the accompanying drawings in which

Figure 1 is a bottom plan view of a rotor for a rotary device for use in the method and apparatus of the invention

Figure 2 is a vertical section through the rotor of Figure 1 in assembly with a shaft

Figure 3 is a diagrammatic view of apparatus according to the invention for treating molten metal with gas and relatively small particles of treatment agent and

Figure 4 is a diagrammatic vertical section through part of an apparatus according to the invention for introducing gas and relatively large particles of treatment agent into molten metal.

Referring to Figures 1 and 2 a rotary device for treating molten metal with a dispersion of a particulate treatment agent in a gas comprises a shaft 1 and a rotor 2. The shaft 1 has a throughbore 3 and is internally threaded to receive a longitudinal portion of a threaded tubular connection piece 4 which has external threads. The rotor 2 comprises a generally disc- or saucer-like body having an annular top 5 from which extends an underlying circular wall 6. The centre of the top 5 contains an internally threaded socket 7 to receive a threaded length of the lower part of the connection piece 4. The area below the socket 7 is open to define a manifold chamber 8 and the connection piece 4 has a bore 9 whose diameter is the same as that of the shaft bore 3 and which opens into the manifold 8. The wall 6 contains four compartments 10 which extend from the inside of the wall 6A to the outside of the wall 6B which defines the rim of the rotor body. Each compartment 10 has an inlet aperture 11 in the wall 6A and an outlet in the form of an elongate slot 12 at the rim of the rotor. Adjacent compartments 10 are separated by vanes 13. The wall 6 defines the wall of the manifold chamber 8. The shaft 1 is connected to the lower end of a hollow drive shaft (not shown) whose upper end is connected to drive means, such as an electric motor (not shown) and the bore 3 is connected through the hollow drive shaft to a source of gas and particulate treatment agent (not shown).

In use the rotary device is located inside a ladle or other vessel containing molten metal. The device is rotated and particulate treatment agent and gas are passed down the bore 3 of the shaft 1 to emerge via the bore 9 at the top of the manifold 8. As the device rotates molten metal is drawn into the manifold 8 through the lower open mouth and in the manifold 8 the metal breaks up the stream of particulate treatment agent and gas leaving the shaft 1 so that very small gas bubbles and particles of treatment agent are intimately mixed with molten metal. The dispersion formed flows into the compartments 10 via the inlets 11, through the compartments 10 and out of the peripheral outlet 12, and is dispersed through the whole body of the molten metal.

Referring to Figure 3 an apparatus for treating molten metal with a dispersion of particulate treatment agent in a gas consists of a ladle 21, a rotary device 22 and apparatus 23 for producing and providing the dispersion of particulate treatment agent in a gas.

The apparatus 23 consists of a pressurised container 24 having a closable inlet 25 at its top end for admitting the particulate treatment agent and at its bottom end a valve 26 and a primary inlet 27 for a gas such as argon or nitrogen. A plurality of jets 28 are arranged around the container 24 adjacent its inner surface at its bottom end. A secondary inlet for gas consists of a pipe 29 and the container 25 also has an outlet 30 adjacent its top end. The valve 26 and the outlet 30 are both connected by pipes 31 and 32 to pipe 33 which is in turn connected to the rotary device 22. The container 24 is located on a weighing device 34 on platform 35.

The rotary device 22 consists of a hollow shaft 36 and a rotor 37 which may be for example of the type shown in Figures 1 and 2. The top of the hollow shaft 36 is connected by means of a snap lock system 38 to the lower end of a hollow drive shaft 39 whose inner diameter corresponds to the inner diameter of pipe 33. The drive shaft 39 is driven by electric motor 40 housed in housing 41. The rotary device 22, drive shaft 39 and motor housing 41 are lifted by a lever system 42 and lowered into the ladle 21 by a chain or screw driven cylinder 43, all located on a movable platform 44, In order to prevent vortex formation when the rotary device 22 is rotated in molten metal a buffer plate 45 is fixed to the bottom of the housing 41 parallel to the shaft 36. A three way spinning valve 46 connects the pipe 33 and a drive shaft 39 and also another pipe 47 which can be connected to a source of gas to enable the apparatus to be used for degassing alone.

In use the rotary device is lowered into molten metal 48, for example molten aluminium alloy, in the ladle 21 and rotated so that molten metal is pumped through the rotor 37. Particulate treatment agent is introduced into the pressurised container 24 through the inlet 25 and the inlet is closed. Gas, such as nitrogen or argon from a source not shown is introduced into the container 24 through inlet 27 and passes through the jets 28 so as to fluidise the particulate treatment agent, and additional gas is also introduced into the container 24 through inlet pipe 29. Excess gas leaves the container 24 through outlet 30 and passes through pipe 32 into pipe 33, together with the fluidised dispersion of particulate treatment agent which passes through the valve 26 and pipe 31 into pipe 33. The dispersion then flows through the valve 46, the drive shaft 39 and the shaft 36 of the rotary device into the rotor 37 where it is mixed with the molten metal being pumped through rotor 37.

Referring to Figure 4 a hopper 51 for introducing relatively large particles (i.e greater than 1 mm) of treatment agent into a rotary device has a sealed top 52 having a closable inlet 53 for adding the particles to the hopper 51 and an aperture 54 at its base 55. The hopper 51 has adjacent the base 55 two series of three sliding members 56, 57 passing through apertures in the sidewall 58 and driven by compressed air in cylinders 59, 60. The sliding members 56, 57 in each of the series are equally spaced apart around the perimeter of the hopper 51, and sliding members 56 are above and midway between sliding members 57.

The aperture 54 at the base 55 of the hopper 51 is connected to a tube 61 which extends downwardly inside the bore 62 of drive shaft 63. The tube 61 passes through a block 64 mounted underneath the hopper 51 and the block 64 has a plurality of ducts 65 which communicate with the inside of the tube 61 via apertures 66. The block 64 is connected to a three way sealed spinning valve 67 which contains a bearing and washer 68 for shaft 63 and which has an aperture 69 for admitting gas into the bore 62 of the shaft 63. The drive shaft 63 is driven by a wheel 70 connected by a fan belt (not shown) to an electric motor (not shown) and at its bottom end is connected to the shaft (not shown) of a rotary device for example as shown in Figures 1 and 2.

In use the rotary device is lowered into molten metal in a vessel and the hopper 51, block 64, three way spinning valve 67 and wheel 70 are supported on the top of the vessel by means of support 71 which is located on a frame (not shown). Particles of treatment agent are introduced into the hopper 51 through the inlet 53 and the inlet 53 is sealed. Gas from a source not shown is passed through the ducts 65 in block 64 into tube 61. The sliding members 56, 57 are operated alternately so that they move forwards and backwards towards and away from the vertical axis of the hopper 51 and so that they accelerate the particles in the hopper 51 and cause them to fall one by one into the tube 61. Gas from a source not shown is passed into the bore 62 of the drive shaft 63 through the aperture 69 in the valve 67.

When the electric motor is switched on the rotary device is caused to rotate by wheel 70 and molten metal is pumped through the rotor and is mixed with gas and particles of treatment agent entering the rotor from the drive shaft 63 and tube 61.

The following examples will serve to illustrate the invention:-

EXAMPLE 1

Apparatus similar to that shown in Figure 3 but with the ancillary equipment for the rotary device supported by the ladle was used to modify an aluminium-silicon alloy containing 10% magnesium. The rotor used was of the type shown in Figures 1 and 2.

The modifying agent used was particles of a size less then 1 mm produced by milling bonded tablets of sodium carbonate and magnesium containing approximately 50% of each component.

80g of the particles were injected in argon gas into 20kg of the molten alloy held at 790 °C at a flow rate of 10g per minute, and with the rotor rotating at 400 rpm.

Samples of the modified alloy were taken at various times and examined by a standard thermo-analysis technique for assessing modification in which a depression parameter in °K is measured. Using this technique the higher the depression parameter then the finer is the crystal size of the silicon in the alloy and hence the greater the degree of modification.

The results obtained were as follows:-

Time Elapsed	Depression Parameter
2 Minutes	9 °K
10 Minutes	9 °K
30 Minutes	8.5 °K
60 Minutes	7.5 °K

In a comparison test the same alloy was modified at the same temperature using an equivalent amount of the same sodium carbonate-magnesium modifying agent by plunging a tablet of the modifying agent. A sample taken 2 minutes after modification had a depression parameter of 7.5 °K and a sample taken 10 minutes after modification had a depression parameter of 7 °K.

EXAMPLE 2

Using the same apparatus, aluminium-silicon alloy and modifying agent as in Example 1, 40g of the particles were injected into 20kg of the alloy held at 770 °C at a flow rate of 8g per minute, and with the rotor rotating at 400 rpm.

A sample taken 2 minutes after modification treatment had a depression parameter of 6.5 °K and a sample taken after 10 minutes had a depression parameter of 7 °K.

In a comparison test in which a tablet of the modifying agent was plunged into the alloy as described in Example 1, a sample taken after 2 minutes had a depression parameter of 3.5 °K and a sample taken after 10 minutes had a depression parameter of 3 °K.

The above Examples indicate that the process of the invention is superior to the commonly used plunged technique in terms of both the degree of modification achieved and the rate of fading i.e. increases in silicon crystal after modification has taken place.

EXAMPLE 3

Apparatus of the type shown in Figure 4 and a rotary device as shown in Figures 1 and 2 was used to modify an aluminium-silicon alloy containing 9% silicon and 3% copper. 350kg of the alloy which contained 2 parts per million sodium were degassed with nitrogen at 780 °C with the apparatus operating at a rotor speed of 600 rpm and a nitrogen flow rate of 25 litres per minute, and droplet shaped particles of modifying agent containing approximately 50% by weight sodium carbonate were added over a period of 2 minutes at a rate of 642 grams per minute. This treatment increased the sodium content of the alloy to 71 parts per million and gave a depression parameter measured by thermo-analysis of 7 °K.

If the modification process had been carried out using the conventional method of immersing tablets of modifying agent in the molten alloy under the same conditions an addition rate of 2.5kg/tonne of modifying agent would have been needed to achieve a sodium content of 100 parts per million.

However using the apparatus of the invention to perform the modification only 1284g of modifying agent were used and 71% of the efficiency was achieved, representing a total of 138.2% of the efficiency of the modifying tablets.

EXAMPLE 4

Apparatus of the type used in Example 3 was used to grain refine the alloy used in Example 3 with grain refining droplet-like particles of 6 mm diameter during degassing of the alloy. 350kg of the alloy with 8 parts per million boron were degassed with nitrogen at 780 °C with the apparatus operating at a rotor speed of 600 rpm and a nitrogen flow rate of 25 litres per minute. The grain refiner particles which contained 5% titanium and 1% boron were added over a period of 7 minutes at a rate of approximately 136 grams per minute. This treatment increased the boron content of the alloy to 29 parts per million. Thermo - analysis showed a shortening in primary solidification from 11.5 to 6.5 time units. This is a standard technique for assessing grain refinement of aluminium and indicates approximately the grain size of the primary crystals of aluminium. Using the technique the higher the primary solidification time the larger is the grain size of the primary crystals of aluminium. During the treatment the hydrogen content of the alloy was reduced from 0.25 parts per million to less than 0.05 parts per million.

If a master alloy containing 5% titanium and 1% boron in the form of pieces of wire had been added by hand under the same conditions to grain refine the alloy 10 pieces weighing 100g each would have been needed to achieve a boron content of approximately 27 parts per million in the alloy.

However using the apparatus of the invention only 925g of grain refining alloy were added and 110.5% of the efficiency was achieved, representing a total of 116.1% of the efficiency of the master alloy wire addition.

Claims

1. A method for the treatment of molten metal with particulate treatment agent and a gas characterised in that the method comprises providing a rotary device comprising a hollow shaft (1) having a discharge end and a hollow rotor (2) attached to the shaft, the rotor having a plurality of vanes (13) each extending from the shaft or from a location adjacent the shaft towards the periphery of the rotor so that the hollow interior of the rotor is divided into a plurality of compartments (10), each compartment having an inlet (11)

adjacent the shaft and an outlet (12) adjacent the periphery of the rotor and the rotor having means for passing the particulate treatment agent and gas from the discharge end of the shaft to the compartments, immersing the rotary device in molten metal contained in a vessel, rotating the device so that molten metal enters the compartments through the inlets, and supplying a particulate treatment agent for the molten metal and a gas to the shaft so that the particulate treatment agent and gas emerge from the discharge end of the shaft and pass into the compartments, are mixed with the molten metal within the rotor and on emerging from the rotor are dispersed throughout the molten metal contained in the vessel.

2. Apparatus for the treatment of molten metal with particulate treatment agent and a gas characterised in that the apparatus comprises a vessel, a rotary device for dispersing particulate treatment agent and gas in molten metal contained in the vessel and means for supplying the particulate treatment agent and gas to the rotary device, wherein the rotary device comprises a hollow shaft (1) having a discharge end and a hollow rotor (2) attached to the shaft, the rotor having a plurality of vanes (13) each extending from the shaft or from a location adjacent the shaft towards the periphery of the rotor so that the hollow interior of the rotor is divided into a plurality of compartments (10), each compartment having an inlet (11) adjacent the shaft and an outlet (12) adjacent the periphery of the rotor, and the rotor having means for passing the particulate treatment agent and gas from the discharge end of the hollow shaft of the device to the compartments.

3. Apparatus according to Claim 2 characterised in that the discharge end of the shaft (1) opens into a manifold (8) in the rotor and the inlets (11) for the compartments (10) are in the wall (6) of the manifold.

4. Apparatus according to Claim 2 or Claim 3 characterised in that the means for supplying the particulate treatment agent and gas to the rotary device is a hopper with gas injection nozzles.

5. Apparatus according to Claim 2 or Claim 3 characterised in that the means for supplying the particulate treatment agent and gas to the rotary device is an apparatus (23) in which the particulate treatment agent is fluidised by the gas to produce s dispersion and which is connected by a pipe (33) to the bore of the shaft of the rotary device.

6. Apparatus according to Claim 5 characterised in that the apparatus in which particulate treatment agent is fluidised comprises a container (24) having a closable inlet (25) at its top end for admitting the particulate treatment agent, a primary inlet (27) for introducing the gas which fluidises the particulate treatment agent adjacent its bottom end, and a valve (26) at its bottom end connected to the pipe (33).

7. Apparatus according to Claim 6 characterised in that the container has a secondary inlet (29) for gas for reducing the concentration of particulate treatment in the dispersion.

8. Apparatus according to Claim 6 characterised in that the container has a gas outlet (30) adjacent its top end and connected to the pipe (33).

9. Apparatus according to Claim 2 characterised in that the means for supplying the particulate treatment agent to the rotary device comprises a hopper (51) having a sidewall (58), a sealed top (52) having a closable inlet (53) for the particles of treatment agent, and an aperture (54) in its base (55) communicating with a tube (61) located inside the bore (62) of the shaft (63) of the rotary device, the sidewall (58) of the hopper adjacent the base having at least one series of apertures spaced apart around its perimeter, each aperture having projecting through it to the inside of the hopper a sliding member (56, 57), and the tube having one or more apertures therein for the introduction of gas.

10. Apparatus according to Claim 9 characterised in that the hopper (51) has two or more series of apertures and sliding members (56, 57) in its sidewall (58).

11. Apparatus according to Claim 10 characterised in that the apertures and sliding members (56) in the sidewall (58) of the hopper (51) are located so that the apertures and sliding members of one series are positioned above and between the apertures and the sliding members (57) of another series.

12. Apparatus according to any one of Claims 9 to 11 characterised in that each series consists of three apertures and three sliding members (56, 57).

13. Apparatus according to any one of Claims 9 to 12 characterised in that the hopper (51) has the shape of an inverted cone.

14. Apparatus according to any one of Claims 9 to 13 characterised in that the tube (61) located inside the bore (62) of the shaft (63) of the rotary device passes through a block (64) beneath the base of the hopper (51) and the block has one or more ducts (65) communicating via the aperture or apertures in the wall of the tube (61) with the inside of the tube.

15. Apparatus according to any one of Claims 9 to 14 characterised in that the apparatus has means (69) for introducing gas into the bore of the shaft around the tube.

FIG. 1

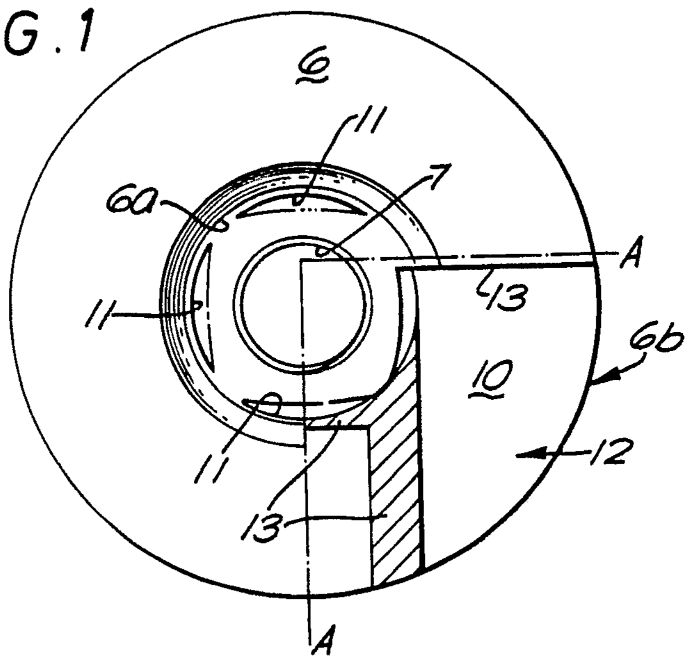
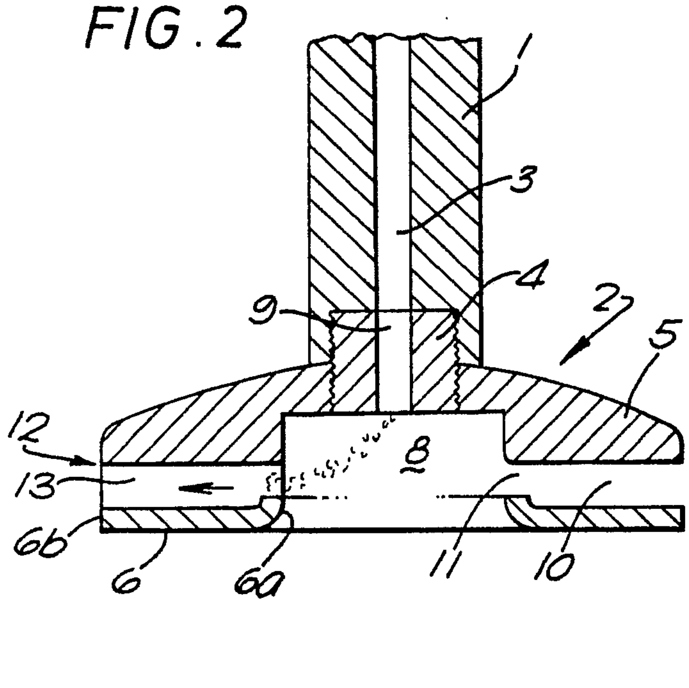


FIG. 2



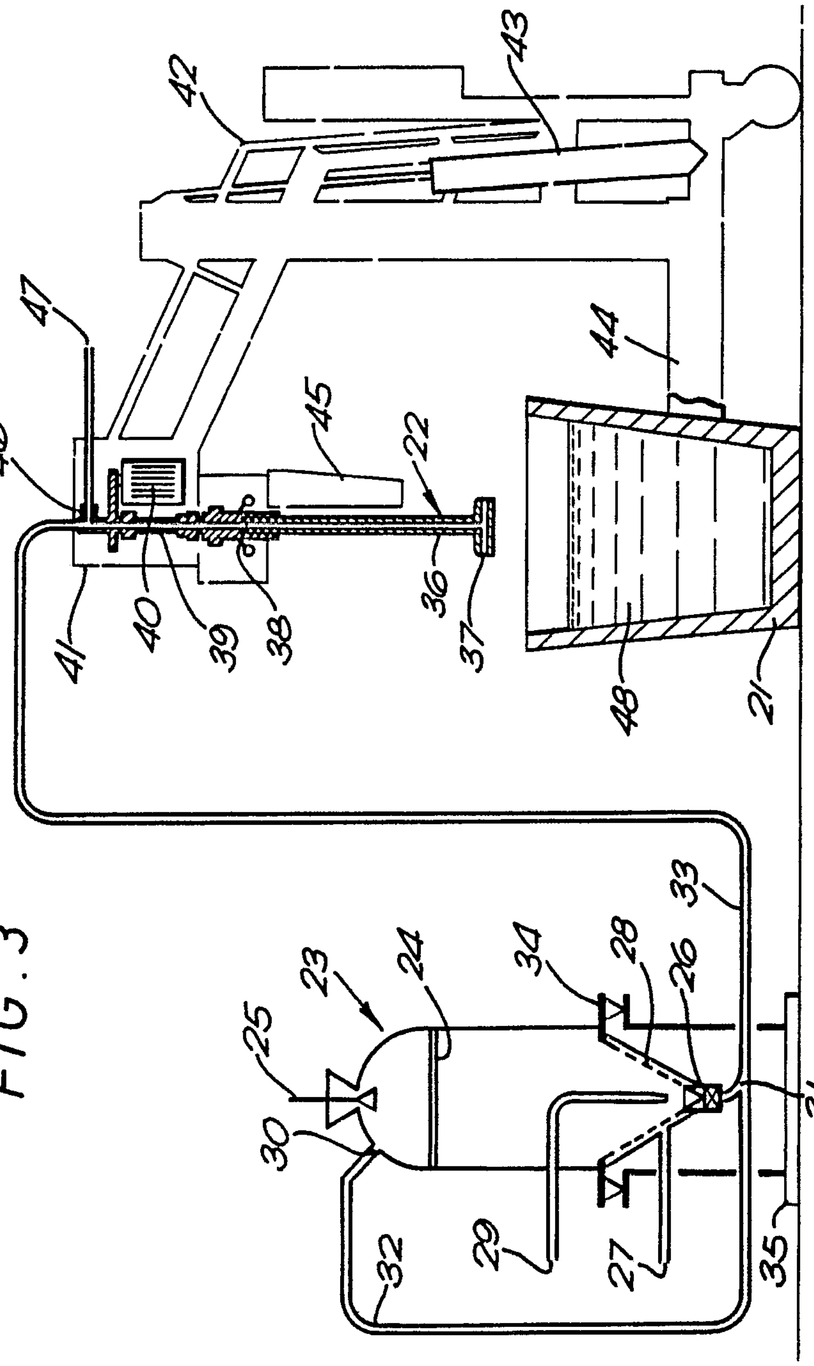

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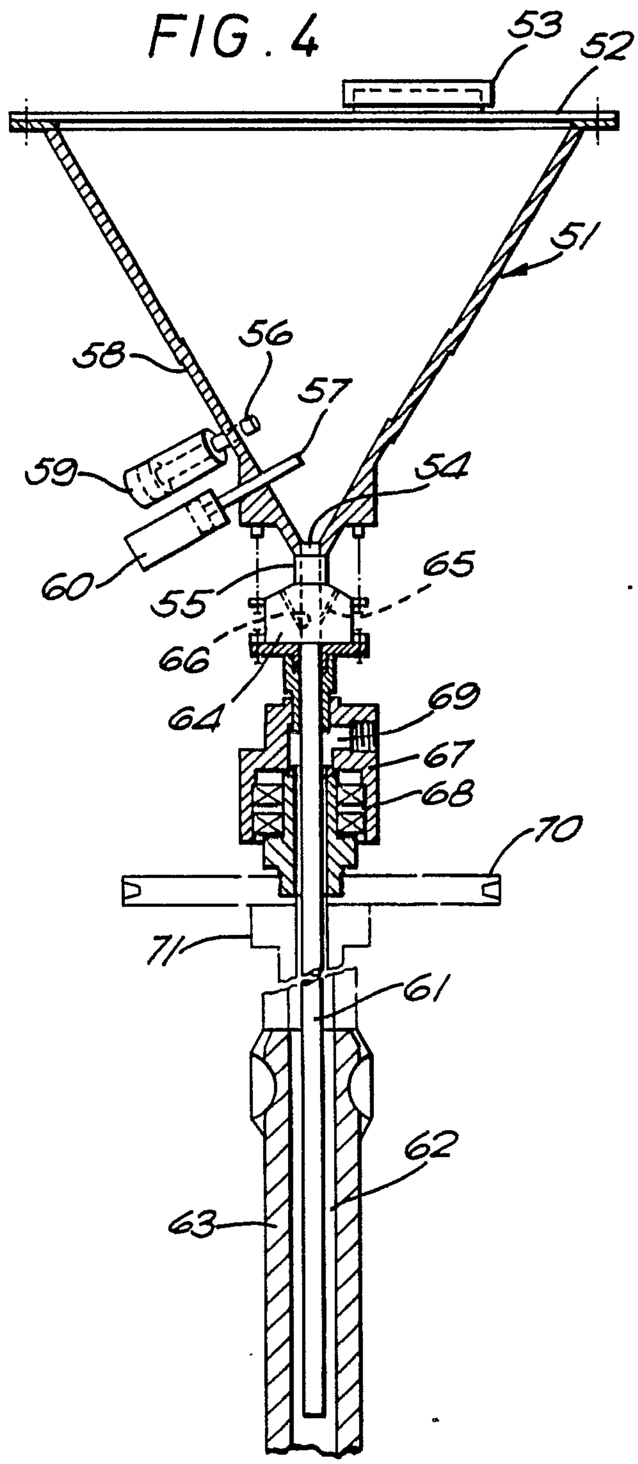
FIG. 3

FIG. 4



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EUROPEAN SEARCH REPORT

Application Number

EP 90 30 3889

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X,P D	EP-A-0 332 292 (FOSECO INTERNATIONAL LTD) * Whole document * ---	1-15	C 22 B 9/05 C 22 B 21/06 C 21 C 7/00
A,D	EP-A-0 183 402 (FOSECO INTERNATIONAL LTD) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 22 B C 21 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-07-1990	JACOBS J.J.E.G.

CATEGORY OF CITED DOCUMENTS

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