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(71) Applicants:
- **Motegi, Tetsuichi**
  Chiba-shi, Chiba-ken (JP)
- **Miyazaki, Keiichi**
  Saha-gun, Gunma-ken (JP)
- **Tezuka, Yoshimoto**
  Hachiouzi-shi, Tokyo (JP)
- **Yoshihara, Kiyotaka**
  Fukushima-shi, Fukushima (JP)
- **Seiko Center Co., Ltd.**
  Shinjyuku-ku, Tokyo (JP)

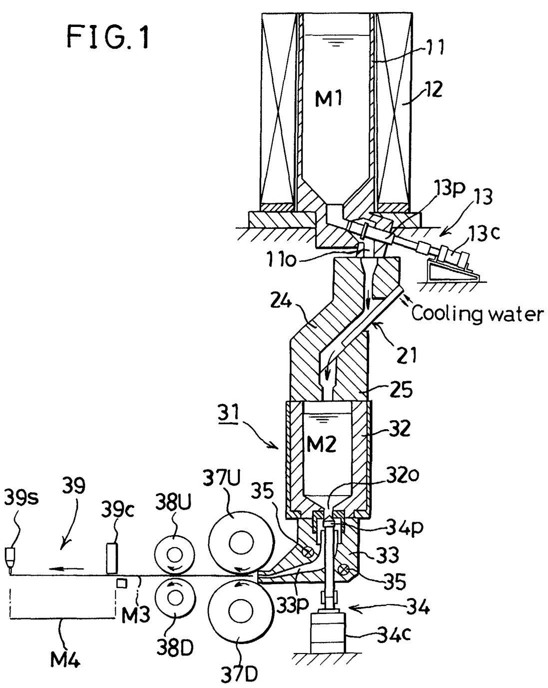
(72) Inventors:
- **Miyazaki, Keiichi**
  Sawa-gun, Gubma (JP)
- **Tezuka, Yoshitomo**
  Hachiouji-shi, Tokyo (JP)
- **Yoshihara, Kiyotaka**
  Fukushima-shi, Fukushima (JP)
- **Motegi, Tetsuichi,**
  Chiba (JP)

(74) Representative: **Smith, Norman Ian et al**
fJ CLEVELAND
40-43 Chancery Lane
London WC2A 1JQ (GB)

(54) Method and apparatus for production of platelike metal material

(57) An apparatus for the production of a platelike metal material includes a cooling unit (21) for cooling a molten metal (M1) to form a metal slurry (M2) containing a solid phase, a pair of coarse rollers (37D, 37U) for cooling the metal slurry and, at the same time, rolling it to thereby give rise to a continuous, solidified, platelike metal material (M3), and a cutting mechanism (39) for cutting the continuous, solidified platelike metal material into platelike metal materials (M4) of a stated length. Thus, platelike metal materials containing numerous uniform spherical crystals are obtained.

FIG.1



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Description

[0001] This invention relates to a method and apparatus for the production of a platelike metal material by effective utilization of the thixotropy inherent in a semiliquid/semisolid metal.

[0002] The thixo-casting method (semiliquid casting method) and rheocasting method (semisolid casting method) have been known as casting methods utilizing the thixotropy inherent in a semiliquid/semisolid metal, namely the property of exhibiting small viscosity and excelling in fluidity.

[0003] These casting methods invariably consist in casting a metal slurry in such a semiliquid/semisolid state formed of an interfused mixture of a liquid-phase metal and a solid-phase metal.

[0004] The thixo-casting method is so adapted as to comprise the steps of heating a solid metal till formation of a metal slurry in the semiliquid state and supplying the formed metal slurry to a metallic mold.

[0005] The rheocasting method is so adapted as to comprise the steps of provisionally melting a solid metal, cooling the resultant molten metal till formation of a metal slurry in the semisolid state containing granular crystals, and subsequently supplying the metal slurry to a metallic mold.

[0006] Since these casting methods are capable of casting a metal having a high solid-phase ratio and exhibiting low viscosity, they are at an advantage in improving the metallic mold in filling capacity, thereby enhancing the yield of casting, enabling formation of a product of a large size, repressing occurrence of a shrinkage cavity, thereby adding to the mechanical strength of the product, and permitting a reduction in the wall thickness of the product.

[0007] Further, they are capable of allaying the thermal load exerted on the metallic mold and, therefore, elongating the service life of the metallic mold.

[0008] With the aim of effectively utilizing the thixotropy of a semiliquid metal and the fluidity of a semisolid metal respectively in the casting methods described above, it is necessary that the semiliquid/semisolid metal should contain non-dendritic crystals, preferably spherical crystals, as fine and uniform as permissible.

[0009] When the solid metal is heated till formation of a semiliquid state and the molten metal is simply cooled till formation of a semisolid state, however, these metals nearly wholly take part in giving rise to dendritic crystals in the semiliquid/semisolid metal and rendering it impossible to obtain the thixotropy of the semiliquid metal and the fluidity of the semisolid metal fully satisfactorily.

[0010] The thixo-molding method, therefore, generally resorts to a procedure of utilizing a screw-type extruding device popularly used in an injection molding machine and sequentially heating a given solid metal within the barrel of the extruding device while exerting a shearing force thereon till conversion of the solid metal into a metal slurry in a semiliquid state.

[0011] Since the screw-type extruding device is complicated in structure and, accordingly, is expensive, however, the cost for application thereof to the casting equipment is very enormous.

[0012] Since the metal slurry formed within the barrel of the extruding device is fated to be supplied in its unmodified form to the metallic mold, it cannot be confirmed at all whether or not the crystals formed have assumed the state of non-dendritic crystals.

[0013] Further, since the solid metal to be used for supply to the barrel must be prepared in the form of chips, the cost of the raw material is very high.

[0014] Meanwhile, the rheocasting method, as disclosed in JP-A HEI 10-34307, for example, resorts to a procedure of exposing a metal molten in advance within a retaining oven to a cooling means, thereby cooling this molten metal to the solid-liquid coexisting state formed of a solid phase and a liquid phase, and converting this solid-liquid composite into a metal slurry while retaining it in the range of semiliquid temperature within a retaining container.

[0015] The method using this procedure is enabled to obtain an expected metal slurry without requiring use of such an expensive extruding device as is indispensable to the thixo-casting method because numerous crystal nuclei are precipitated at the stage at which the molten metal contacts the cooling means and these crystal nuclei are destined to grow into spheres within the retaining container.

[0016] Moreover, since a mass of metal may be supplied in its unmodified form to the retaining oven, the cost of the raw material can be restrained from being increased.

[0017] This method, further, enables the casting aimed at to be fulfilled by effective utilization of the fluidity of the semisolid metal because it permits easy determination of the question whether or not the metal slurry formed in the retaining container has assumed the expected state of non-dendritic crystals.

[0018] In the rheocasting method, however, the actual construction of a system for mass production makes it necessary to interpose numerous retaining containers between the cooling means serving the purpose of cooling the molten metal and the metallic mold serving as a receptacle for storing the metal slurry being supplied thereto and, at the same time, synchronize the step of causing the molten metal to contact the cooling means with the step of supplying the metal slurry to the metallic mold through such numerous retaining containers. The system, therefore, necessitates extremely complicated control.

[0019] The control is all the more complicated because the metal slurry in each of the retaining containers requires accurate control of temperature till it is supplied to the metallic mold.

[0020] The present inventors, in the light of the actual state of things mentioned above, have proposed a method for casting a metal, which comprises a first production step for forming a metal slurry containing a solid phase by cooling a molten metal, a second production step for forming a solidified metal material by further cooling the metal slurry, and a step for heating the metal material till a semiliquid state and supplying the semiliquid metal material to a metallic mold.

[0021] As a result, this method is enabled to obtain a metal slurry abounding in fluidity and containing non-dendritic crystals without requiring any complicated control and, by supplying this metal slurry to the metallic mold, further enabled to obtain a mass of metal.

[0022] Incidentally, the press working proves advantageous in terms of cost because the productivity thereof is 20 ~ 100 times as high as that of die-casting or injection-molding. Since plates are easy of working, the desirability of materializing manufacture of a platelike metal material by effective utilization of thixotropy has been finding enthusiastic recognition.

[0023] This invention, conceived and perfected with a view to attaining the desire mentioned above, aims to provide a method for the production of a platelike metal material by such effective utilization of thixotropy as to permit manufacture of a product by press working and an apparatus for the production thereof.

[0024] The method contemplated by this invention for the production of a platelike metal material comprises a first production step for cooling a molten metal to form a metal slurry containing a solid phase and a second production step for cooling the metal slurry and rolling it at the same time to form a continuous, solidified, platelike metal material.

[0025] The second production step preferably embraces a cutting work for cutting a continuous, solidified, platelike metal material into pieces of a stated length or a winding work for winding a continuous, solidified, platelike metal material into rolls of a stated diameter.

[0026] The apparatus contemplated by this invention for the production of a platelike metal material comprises a first production means for cooling a molten metal to form a metal slurry containing a solid phase and a second production means for cooling the metal slurry and rolling it at the same time to form a continuous, solidified, platelike metal material.

[0027] The second production means is preferably furnished with a cutting mechanism for cutting a continuous, solidified, platelike metal material into pieces of a stated length or a winding mechanism for winding the continuous, solidified, platelike material formed into rolls of a stated diameter.

[0028] This invention, by dividing the process of operation into two production steps as described above, enables the numerous crystal nuclei precipitated in the metal slurry to attain further growth into spheres and, by subjecting the metal slurry in the ensuing state simultaneously to the treatments of cooling and rolling, makes it possible to render the product fit for press working and to exalt the productivity of the operation itself markedly.

[0029] The other objects and characteristic features of this invention will become apparent from the detailed description to be given herein below with reference to the annexed drawings, in which:-

Figure 1 is an explanatory diagram schematically depicting the construction of an apparatus for the production of a platelike metal material as one embodiment of this invention,

Figure 2(a) is a schematic longitudinal cross section of a cooling unit for forming a metal slurry in the apparatus of Figure 1,

Figure 2(b) is a section of the cooling unit of Figure 2(a),

Figure 3 is a partially omitted cutaway plan view of the leading end portion of a nozzle in the apparatus of Figure 1,

Figure 4(a) is an explanatory diagram depicting the state in which the metal slurry flows in the direction of the opening at the leading end of the nozzle in the apparatus of Figure 1,

Figure 4(b) is an explanatory diagram depicting the state in which the metal slurry shown in Figure 4(a) is on the verge of emanating from the opening of the nozzle,

Figure 4(c) is an explanatory diagram depicting the operation of cooling and rolling the metal slurry shown in Figure 4(b),

Figure 5 is an explanatory diagram schematically depicting the configuration of a winding mechanism used in the apparatus of Figure 1,

Figure 6(a) is a photomicrograph showing the platelike metal material produced according to the method of the present invention,

Figure 6(b) is a photomicrograph showing the platelike metal material of Figure 6(a) that has been heated again at a solid-liquid coexisting temperature and then quenched in water,

Figure 6(c) is a photomicrograph showing a casting ingot produced by a conventional method.

[0030] Figure 1 schematically illustrates the construction of the apparatus for the production of a platelike metal material as one embodiment of this invention. In this diagram, reference numeral 11 denotes a melting tank for retaining a magnesium alloy represented by the AZ type or the AM type, for example, in a molten state or in a state of liquid phase temperature. This melting tank 11 is furnished around the periphery thereof with a heater 12.

[0031] The melting tank 11 is provided in the lowermost part thereof with a tapping path 11a bent roughly in the shape of a crank and used for discharging the stored molten magnesium alloy M1 downward.

[0032] The tapping path 11 a is provided halfway the length thereof with a switch valve 13 that is composed of a valve plunger 13p so disposed as to produce a forward or backward motion to open or close the tapping path 11a and a valve cylinder 13c serving the purpose of moving the valve plunger 13p forward or backward.

[0033] Below the melting tank 11, a cooling unit 21 is disposed as a first production means. This cooling unit 21, as illustrated in detail in Figures 2(a) and 2(b), is so constructed as to be furnished on the surface thereof with a guide groove 22 and in the interior thereof with a circulating path 23 for cooling water. Though the example of Figure 2 is depicted as using one guide groove 22, it is permissible to use a plurality of such guide grooves.

[0034] This cooling unit 21 is disposed as being slanted in such a state that the guide groove 22 is opposed to the lower end of the tapping path 11a.

[0035] The cooling unit 21 is so disposed in a cover block 24 that this cover block 24 covers the cooling unit 12 while securing a stated intervening space between the opposed surfaces. The empty space on the upper surface of the cooling unit 21 communicates with the lower end of the tapping path 11a.

[0036] The cover block 24 and a storing tank 32 that will be specifically described herein below are jointly provided with a guide block 25 through which they are interconnected.

[0037] A second production means which is denoted by reference numeral 31 comprises the storing tank 32 furnished in the lowermost part thereof with a material path 32a for discharging a stored metal slurry M2 downward, a nozzle 33 disposed on the lower side of the storing tank 32 and furnished with a supply path 33p formed roughly in the shape of the letter L so as to communicate at the upper end thereof with the lower end of the material path 32a, a switch valve 34 for controlling the flow of the metal slurry M2 from the material path 32a to the supply path 33p, an auxiliary heater 35 disposed in the nozzle 33 and adapted to retain the metal slurry in the nozzle 33 at a stated temperature, width regulating guides 36L and 36R disposed on the left and right sides of the leading end of the nozzle 33 as illustrated in Figure 3 and adapted to regulate the width of a continuous, platelike metal material M3, a pair of coarse roller 37D and 37U adapted to cool and roll simultaneously the metal slurry M2 discharged from the nozzle 33, a pair of finishing rollers 38D and 38U for performing a finishing roll on the continuous, platelike metal material M3 which has been rolled by the coarse rollers 37D and 37U, and a cutting mechanism 39 for cutting the continuous, platelike metal material M3 discharged through the gap between the finishing rollers 38D and 38U.

[0038] The switch valve 34 comprises a valve plunger 34p adapted to producing a forward or backward motion to open or close the material path 32a and a valve cylinder 34c adapted to move the valve plunger 34p forward or backward.

[0039] The cutting mechanism 39 comprises a cutter 39c disposed on the downstream side of the finishing rollers 38D and 38U and an end-detecting sensor 39s disposed on the downstream side of the cutter 39c as being separated by a stated length (the length of pieces obtained by cutting) from the cutter 39c and adapted to detect the end (leading end) of the continuous, platelike metal material M3.

[0040] The coarse rollers 37D and 37U are so constructed as to directly contact and suddenly cool the metal slurry M2 by means of a built-in water-cooled cooling unit, for example.

[0041] Incidentally, the leading end of the supply path 33p is diverged in the vertical direction as illustrated in Figure 4 so as to facilitate the emission of the metal slurry M2.

[0042] The pair of coarse rollers 37D and 37U are adapted so as to be synchronously rotated by a drive mechanism omitted from illustration here, with the result that the coarse roller 37D will be rotated counterclockwise and the coarse roller 37U clockwise.

[0043] Then, the pair of finishing rollers 38D and 38U are adapted so as to be synchronously rotated by a drive mechanism omitted from illustration here, with the result that the finishing roller 38D will be rotated counterclockwise and the finishing roller 38U clockwise.

[0044] Now, the operation of the apparatus will be explained. First, by introducing a mass of a magnesium alloy into the melting tank 11 and actuating the heater 12, the melting tank 11 is enabled to retain the molten magnesium alloy M1 and, at the same time, the cooling unit 21 is enabled to admit the flow of the cooling water. Then, the apparatus is readied for operation by setting the coarse rollers 37D and 37U rotating at a stated speed and also setting the finishing roller 38D and 38U rotating at a stated speed.

[0045] In this case, the cooling units in the coarse rollers 37D and 37U are made to allow flow of cooling water therethrough and the auxiliary heater 35 is connected to a power source.

[0046] When the valve cylinder 13c is actuated from the reset state to impart a backward motion to the valve plunger 13p, the tapping path 11a is opened and the molten magnesium alloy M1 stored in the melting tank 11 is supplied via the tapping path 11a to the cooling unit 21.

[0047] The molten magnesium alloy M1 that has been supplied to the cooling unit 21 flows down the guide groove 22 along the inclination of the cooling unit 31 and is then put to temporary storage in the storing tank 32.

[0048] The molten magnesium alloy M1 that flows down the cooling unit 21 is properly cooled by the cooling unit 21 and consequently transformed into the metal slurry M2 having numerous crystal nuclei precipitated therein. In the storing tank 32, the crystal nuclei further gain in growth into spheres and eventually give rise to fine and uniform spherical crystals.

[0049] Then, by actuating the valve cylinder 34 so as to impart a backward motion to the valve plunger 34p and consequently opening the material path 32a, the metal slurry M2 which has been stored temporarily in the storing tank 32 is enabled to be continuously discharged through the supply path 33p of the nozzle 33 to the ambience as illustrated in Figure 4(a).

[0050] The metal slurry M2, while passing through the supply path 33p, is retained at a stated temperature by the auxiliary heater 35.

[0051] Then, the metal slurry M2 containing the spherical crystal nuclei and discharged through the supply path 33p as illustrated in Figure 4(b) is cooled by contacting the coarse rollers 37D and 37U currently in rotation, with the result that it will be continuously discharged in the form of a perfectly solidified plate and eventually enabled to form a continuous, platelike metal material M3 as illustrated in Figure 4(c).

[0052] Thus, the continuous, platelike metal material M3 discharged through the supply path 33p is conveyed as being compressed by the width regulating guides 36L and 36R to a stated width and rolled by the coarse rollers 37D and 37U and subsequently given a finish rolling treatment by the finishing rollers 38D and 38U and advanced through the gap between the cutters 39c.

[0053] Incidentally, the perfectly solidified continuous, platelike metal material M3 is formed by suddenly cooling the metal slurry M2 which still retains thixotropy sufficiently. The latent retention of this thixotropy can be easily confirmed by visual observation of the crystal structure contained in the continuous, platelike metal material M3.

[0054] When the end-detecting sensor 39s detects the leading end of the advancing continuous, platelike metal material M3, the cutter 39c is actuated to cut the continuous, platelike metal material M3 into pieces of a stated length. The cut pieces are conveyed as platelike metal materials M4 by means of a conveyor, for example.

[0055] While the continuous, platelike metal material M3 is being cut into platelike metal materials M4, this continuous, platelike metal material M3 droops and absorbs excess length. When the cutter 39c is opened, the continuous, platelike metal material M3 advances with the elasticity of its own.

[0056] Thereafter, the continuous, platelike metal material M3 is successively cut likewise to give rise to platelike metal materials M4.

[0057] Since this invention is capable of producing platelike metal materials M4 by effectively utilizing thixotropy as described above, the platelike metal materials M4 are enabled by press working to give birth to required products with high productivity as compared with the die-casting or the injection-molding.

[0058] Figure 6(a) is a photomicrograph of the platelike metal material produced by cooling the melt of magnesium alloy (AZ91D magnesium alloy) in the melting tank with the cooling unit into a metal slurry in the storing tank and bringing the metal slurry discharged from the nozzle into contact with the guide rollers.

[0059] It is found from the photomicrograph that numerous crystal nuclei grown to a large size are crystallized in the platelike metal material thus produced.

[0060] Figure 6(b) is a photomicrograph, for comparison with that of Figure 6(a), of the platelike metal material that has been heated again at 570°C, from which it is found that thixotropy emerges because liquid metal exists around the crystals.

[0061] Figure 6(c) is a photomicrograph of a conventional metal material obtained by casting a melt of metal without use of the cooling unit of the present invention, from which it is found that emergence of thixotropy cannot be expected because the crystals have a non-dendritic structure.

[0062] Though the embodiment described above has illustrated the production of platelike metal materials from a magnesium alloy as the raw material, this invention is capable of producing platelike metal materials using aluminum, aluminum alloys, other metals and alloys thereof as the raw materials.

[0063] In Figure 1, the example of furnishing the apparatus with the cutting mechanism (cutting step) for successively cutting the continuous, platelike metal material to produce platelike metal materials has been cited by way of illustration. Since the products of spherical crystals show an increase in strength by about 15% over the products of dendritic crystals, the necessity for furnishing the apparatus with the cutting mechanism may be obviated by providing a winding mechanism (winding step) for winding the continuous, platelike metal material directly around itself or indirectly around a core of a stated diameter. Figure 5 shows the apparatus equipped with the winding mechanism in place of the cutting mechanism, in which the metal slurry M2 containing spherical crystal nuclei that is discharged from the nozzle 33 is brought into contact with the coarse rollers 37D and 37U for cooling, then rolled by the finishing rollers 38D and 38U and wound on a winding drum 40 in the form of the continuous, platelike metal material.

[0064] Incidentally, when the apparatus is furnished with the winding mechanism (winding step), the length of the continuous, platelike metal material which permits the formed roll on the winding drum 40 to acquire a stated diameter may be calculated with a calculating mechanism prior to the cutting work with the cutter 39c.

[0065] When the continuous, platelike metal material that has been finish-rolled by the finishing rollers 38D and 38U is subjected directly to the press working, neither the cutting mechanism nor winding mechanism is required.

[0066] When the continuous, platelike metal material is wound in rolls, the raw material (plate material) for the manufacture of finished products allows easy handling and also allows easy supply of the raw material to the site of manufacture. Thus, the raw material suitable for mass production can be handled and supplied.

[0067] Since this invention is capable of producing platelike metal materials by effectively utilizing thioxtropy as described above, it is enabled by subjecting these platelike metal materials to the operation of press working to give rise to required products with high productivity as compared with die-casting or injection-molding.

Claims

1. A method for the production of a platelike metal material, comprising a first production step for cooling a molten metal (M1) to form a metal slurry (M2) containing a solid phase and a second production step for cooling and, at the same time, rolling said metal slurry to form a continuous, solidified, platelike metal material (M3).

2. A method according to claim 1, wherein said second production step further comprises a cutting step (39) for cutting the continuous, solidified, platelike metal material into pieces (M4) of a stated length.

3. A method according to claim 1, wherein said second production step further comprises a winding step (40) for winding the continuous, solidified, platelike metal material into rolls of a stated diameter.

4. An apparatus for the production of a platelike metal material, comprising a first production means (21) for cooling a molten metal (M1) to form a metal slurry (M2) containing a solid phase and a second production means (31) for cooling and, at the same time, rolling said metal slurry to form a continuous, solidified, platelike metal material (M3).

5. An apparatus according to claim 4, wherein said second production means further comprises a cutting means (39) for cutting the continuous, solidified, platelike metal material into pieces (M4) of a stated length.

6. An apparatus according to claim 4, wherein said second production means further comprises a winding mechanism (40) for winding the continuous, solidified, platelike metal material into rolls of a stated diameter.

FIG. 1

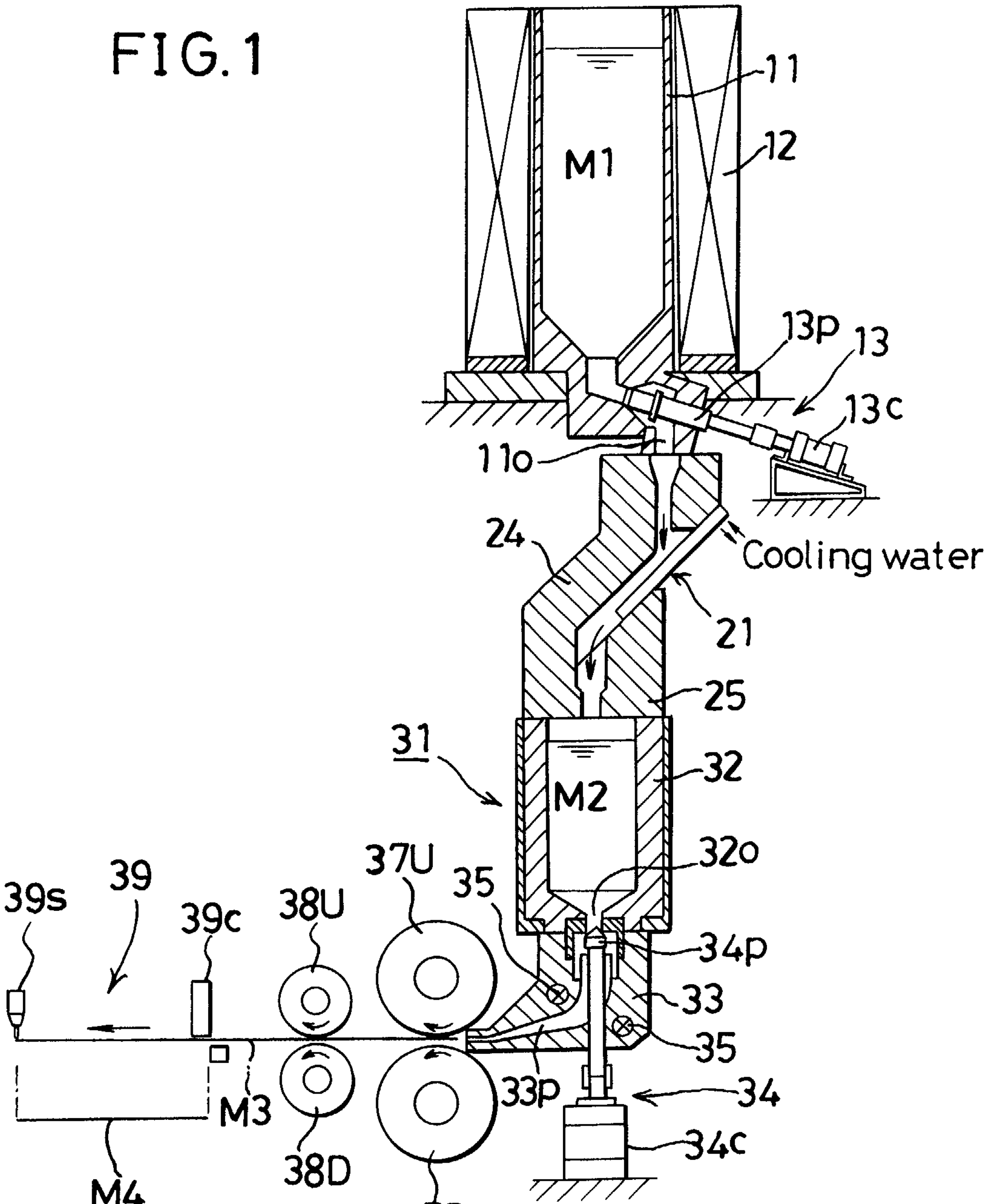

M1
11
12
13p
13
13c
11o
24
Cooling water
21
25
31
32
M2
32o
39s
39
39c
38U
37U
35
34p
33
35
33p
34
M3
34c
M4
38D
37D

FIG.2(a)

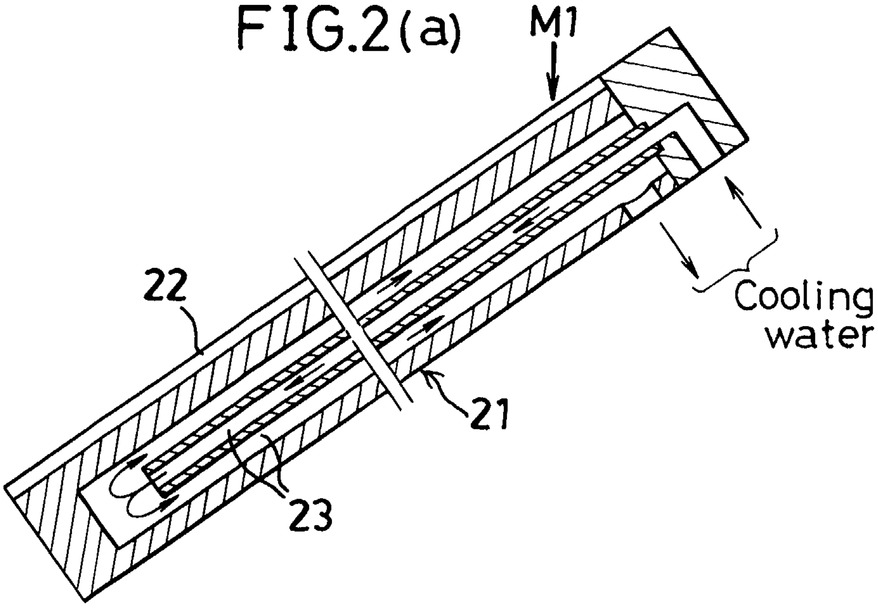


FIG.2(b)

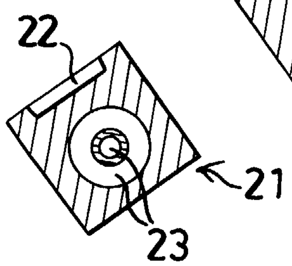


FIG.3

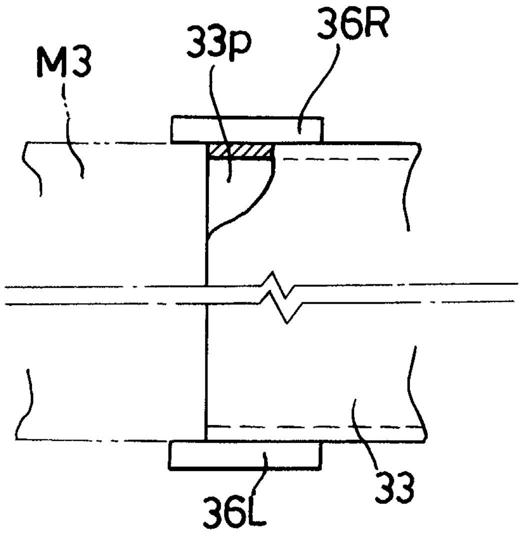


FIG.4(a)

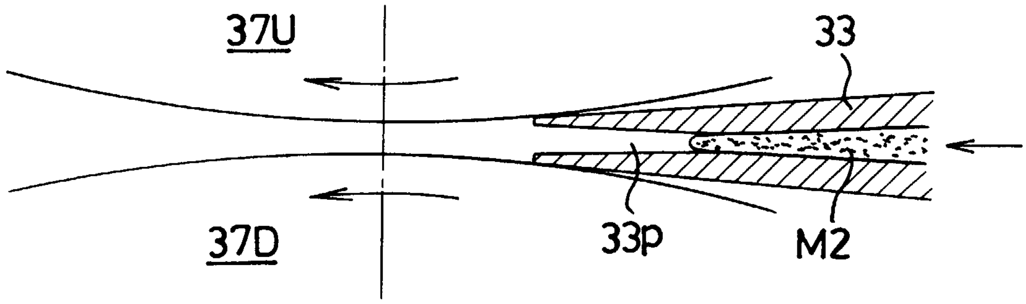


FIG.4(b)

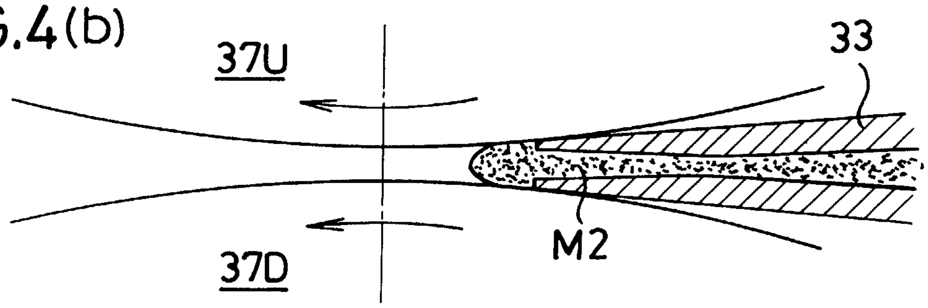


FIG.4(c)

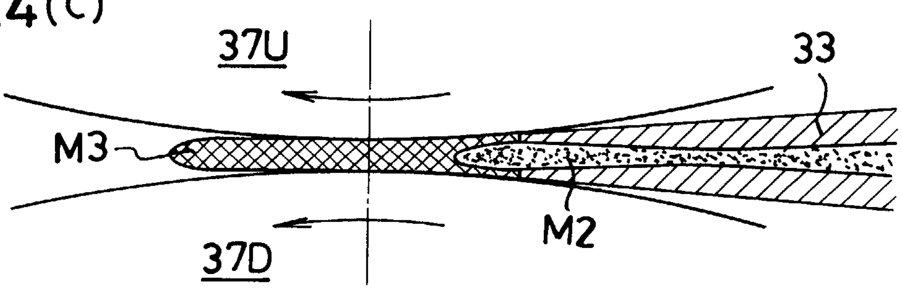


FIG. 5

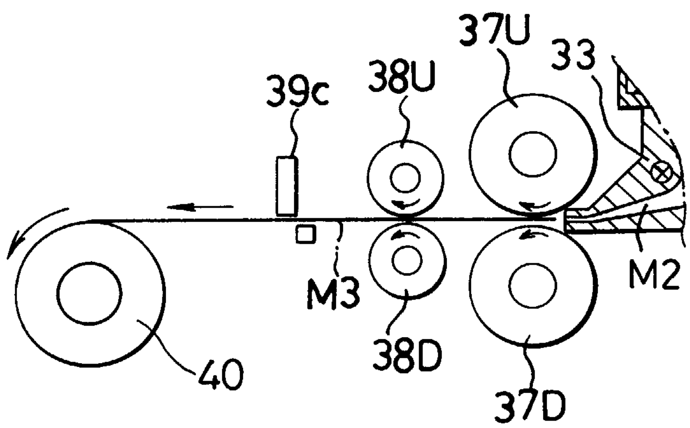


FIG. 6(a)

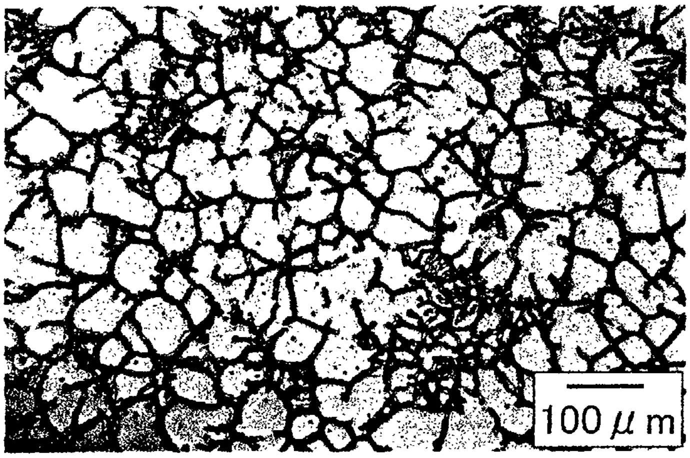


FIG. 6(b)

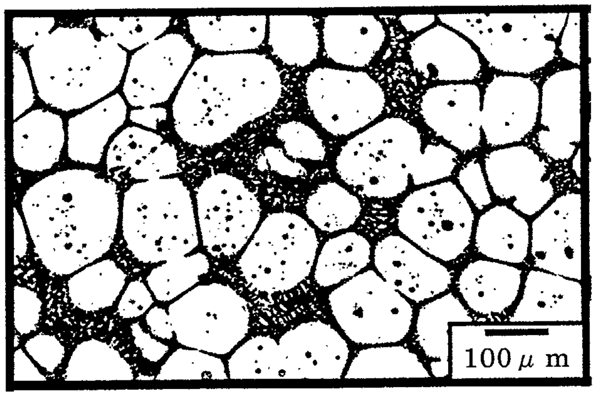
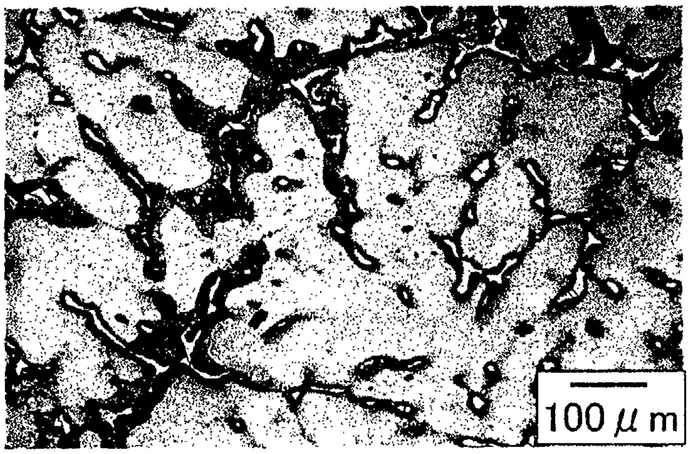


FIG. 6(c)



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EUROPEAN SEARCH REPORT

Application Number
EP 02 25 2063

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.7)
P,X	WO 02 13993 A (BRUNEL UNIVERSITY) 21 February 2002 (2002-02-21) * page 14, line 9 - page 15, line 15; figures 1,6 * * page 16, line 26 - page 17, line 16 *	1,4	B22D11/10 B22D11/06 B22D23/00
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 458 (M-880), 17 October 1989 (1989-10-17) & JP 01 178303 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD), 14 July 1989 (1989-07-14) * abstract *	1-6	
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 103 (M-0941), 26 February 1990 (1990-02-26) & JP 01 309760 A (FURUKAWA ELECTRIC CO LTD:THE), 14 December 1989 (1989-12-14) * abstract *	1,4	
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 392 (M-865), 30 August 1989 (1989-08-30) & JP 01 138044 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD), 30 May 1989 (1989-05-30) * abstract *	1,4	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B22D
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 July 2002	Mailliard, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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05-07-2002

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