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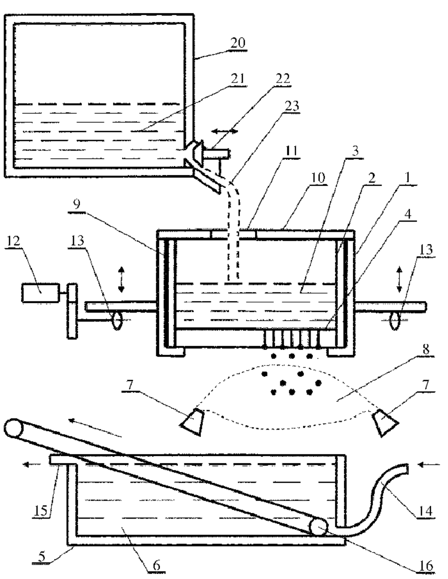

Fig. 1

(57) Abstract: The invention relates to metallurgy, in particular to production of metal shot from a molten metal or alloy by casting. According to the claimed method for producing shot, melt fragments, as obtained by passing a melt through a die which passages consist of two successive sections, are cooled by a spilling flow of an air-droplet mixture and are placed into a cooling liquid. Another aspect of this invention is the device for producing shot from a molten metal or alloy for carrying out the claimed method. Yet another aspect of this invention is a device for cooling melt fragments of a molten metal or alloy, as produced by passing a melt through a die, which comprises one or more nozzles for supplying a sprayed cooling air-droplet mixture as a spilling flow to a space under the crucible. Still another aspect of this invention is a die for producing shot from a molten metal or alloy, which is arranged in the crucible bottom and which passages consist of two sections performing the functions of a dosing passage and an isothermal chamber. The technical effect of the claimed invention is production of shot with a high degree of sphericity and fractional composition.

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A METHOD FOR PRODUCING SHOT FROM MELT, A DEVICE FOR CARRYING OUT SAME, A DEVICE FOR COOLING MELT FRAGMENTS, AND A DIE FOR PRODUCING SHOT FROM MELT

The invention relates to the field of metallurgy, in particular to metal shot production by casting.

Shot made of various metals and alloys is widely used in metallurgical technologies, for example in foundry, is applied for shot blasting and blast cleaning of manufactured articles, surface hardening of parts, etc.

When producing shot by casting, of great importance are such process characteristics as productivity, acceptable material costs, stability of fractional composition of shot produced, proper shot geometry. For example, when injecting shot into a melt for the purpose of alloying or deoxidizing, a depth of shot penetration into a melt volume and, consequently, usage efficiency of an added material depends significantly on shot fractional composition and shape.

A specific process task, i.e., deoxidizing, alloying, refining, etc., as well as a size of shot to be used for it, defines injection parameters, such as transport gas pressure, material feed intensity, shot flow velocity, material line diameter. These parameters define efficiency of material usage and stability of a result to be achieved. If shot used comprises fragments of different fineness grades, it is impossible to set optimal parameters for efficient injection, and a material utilization coefficient declines. The more variable is shot in fineness grades, the lower is a material utilization coefficient.

A shot shape also affects its ability to penetrate into a melt volume. If there are deviations from a spherical shape, a depth of shot penetration into a melt is reduced, a possibility of ricocheting appears, i.e., shot, when interacting with the melt surface does not penetrate into the melt volume, but bounces off its surface. A shot shape is also of importance for transporting by a gas, especially with respect to larger grades. A material consisting of fragments having spherical shapes causes less wear to pipe lines and assists in reducing the effect of a material line blocking.

A various methods for producing metal shot are known, such as spraying a metal jet with air, steam, water; breaking up a metal jet falling onto an inclined surface moistened with water; pouring a metal into water through shower gates; pouring through water sieves. Further, a method of centrifugal graining is known, which is based on fragmenting a melt by the centrifugal force. This method may be realized by means of a rotating perforated cup, spraying from the edge of a rotating disc or cup, spraying of a rotating blank molten layer. Further, there exists an electrical contact method for producing shot or a metal powder, which comprises the action of a rotating conducting disc on a metal, e.g., in the form of a bar or chips, in which the metal melts due to electric current energy.

The above-mentioned methods have, along with their advantages, a number of shortcomings. Thus, they enable to produce shot from various metals in rather large quantities with relatively low costs and satisfactory geometries. However, all the above-mentioned methods may not ensure correct weight dosing in breaking up a metal or alloy into separate fragments, and, consequently, a fractional composition of shot thus produced has unstable fineness. Therefore, it is impossible to select an optimal cooling mode ensuring production of shot having a high sphericity factor for all obtained fineness grades simultaneously. Since shot, as produced by these methods, has different fineness, it should be sieved before use; and, frequently, shot of non-standard fineness grades either should be used for another purpose or returned to the beginning of the production process. Furthermore, if a metal or an alloy with increased affinity to oxygen is processed into shot, its smaller fractions are more subjected to oxygenation when contacting the atmosphere than larger ones, which results in extra loss of a final product.

It seems, that the most preferred method for producing shot of a spherical form is a method based on passing a molten metal or alloy through a die with the subsequent cooling of melt fragments thus obtained.

A method for producing lead pellets is described in GB Patent No. 625941 (published in 7/6/1949; IPC B22F9/08), which comprises passing of molten lead through the crucible perforated bottom and subsequent cooling of pellets thus produced in the atmosphere of an inert gas. Shortcomings of this method consist in that the shape of shot produced is far from spherical as well as a wide spread of shot fineness grades.

A method for producing shot, as described in RF Patent No. 2063305 (published on 07/10/1996; IPC B22F9/06), consists in separating a melt into droplets with the use of a die with an orifice, cooling melt droplets and collection of them. A rosin-and-oil emulsion with a temperature ranging from 100°C to 200°C is used as a cooling medium. This invention enables to produce shot with a rather high degree of sphericity due to the use of a liquid that does not moisten the metal surface as a cooling medium. This solution ensures efficient cooling of melt fragments obtained, but maintains the known shortcomings of the above-mentioned methods; in particular it may not exclude production of shot having different fineness grades, since a stationary die cannot ensure proper separation (break-up) of a metal into fragments having identical weights. Therefore, though this method enables to produce shot with a rather high degree of sphericity, the main shortcoming – production of shot having different weights, i.e., shot having variable fractional composition – is not eliminated.

USSR Inventor's Certificate No. 1222417 (published on 04/07/1986; IPC B22F9/08) describes a method for producing metal pellets from a melt, in which a molten metal is passed through openings in the crucible bottom having a diameter from 1 mm to 8 mm and then is cooled in a liquid. For achieving this a positive pressure ranging from 0.01 to 1.0 bar is created by using an inert gas in the chamber under the melt. Pellet sizes are adjusted by changing the opening diameter, gas pressure under the crucible, metal temperature and metal column in the crucible. An alloy level in the crucible is kept constant.

German Patent Application No. 3109909 (published on 03/18/1982, IPC B22F9/08) describes preferred shapes of die openings that enable to avoid solidification of droplets forming at the opening outlets without additional heating of a metal or droplets formed. However, the said application does not disclose influence of die openings on, e.g., shapes of droplets.

RF Patent No. 2117553 (published on 08/20/1998; IPC B22F9/06) discloses a method for producing spherical metal pellets which comprises dispersion of a molten metal, as produced through openings, due to a pressure differential with applying a constant magnetic field to the metal and passing alternating current through it with subsequent cooling of pellets in the air atmosphere, the metal coming out of said openings is passed through an inert gas layer. Droplets obtain a spherical form, mainly, in the inert gas medium.

A method for producing pellets of a metal with a low melting temperature, which comprises passing a liquid metal through a nozzle having a plurality of holes separated by a distance that is at least three hole diameters, is known from JP Patent No. 4259312 (published on 09/14/1992; IPC B22F9/08, B23K35/40). The nozzle is set to vibrations for the purpose of forming separate droplets of a liquid metal. Droplets are spherically shaped during their fall, and solidification of spherical pellets takes place in the cooling area.

The technical solution described in Japan Patent Application No. 62253705 (published on 11/05/1987; IPC B22F9/08) may be taken as the closest art. This application discloses a device and a method for producing metal shot with the use of a crucible having holes and arranged on a vibrating device. Vibration frequency is from 40 to 100 Hz, amplitude is 0.2÷1.5 mm. A molten metal passes through holes and is broken into droplets by vibration action. Droplets thus formed are partially solidified while falling through an atmosphere between a die and a cooling liquid and finally solidified and obtain a spherical form in the said cooling liquid (water).

The arrangement of a crucible on a vibrating device enables to define a separation time of a melt fragment from a hole more correctly, which contributes to uniformity of fractional composition of shot produced. However, it does not ensure that a spherical shape will be imparted to droplets at a time when they separate from a die, which affects a shape of shot produced that may be recognized as spherical only as a rough approximation.

The present invention is aimed at eliminating the shortcomings of the methods and devices for producing shot, as known from the art, and enables to produce spherical shot with stable geometry parameters and physical properties during the whole process of melt movement through a die.

The claimed technical effect is achieved due to the fact that the method for producing shot from a molten metal or alloy comprises forming melt fragments by passing a melt through a die and arrangement of shot thus produced in a cooling liquid, the passages of the said die consisting of two sequential sections – a dosing passage and an isothermal chamber, and, when melt fragments leave the isothermal chamber, they are subjected to cooling in a spilling flow of an air-droplet mixture.

Preferably, a constant level of a melt is maintained in a crucible when a melt is passed through a die.

Also preferably, a temperature of the cooling liquid upper layer is maintained in the range from 45 to 80°C due to a constant supply of the cooling liquid to the basin lower level. For this it is necessary to ensure free overflow of excess cooling liquid via an overflow hole in the upper part of the basin. Water or water-based solutions may be used as a cooling liquid.

The present invention in its another aspect relates to a device for producing shot from a molten metal or alloy, which comprises a crucible, a die arranged in the crucible bottom and intended for producing melt fragments, and a basin with a cooling liquid that is arranged under the crucible. The die passages consist of two conjugate sections performing the functions of a dosing passage and an isothermal chamber, respectively. A means for cooling melt fragments with a spilling flow of an air-droplet mixture is arranged between the crucible bottom and the basin.

The crucible may have a bottom of rectangular shape; its walls are preferably made of stainless steel and are internally coated by a refractory mixture that simultaneously serves both as a lining and as a heat-retention layer. A cover with a filling opening is arranged on the crucible top.

The device for producing shot with a means for cooling melt fragments may comprise a nozzle or a number of nozzles. The row of nozzles is arranged frontally with respect of the crucible wall at the level equal to a half-distance from its bottom to a cooling liquid in the basin. A distance from a nozzle to the vertical plane coinciding with the crucible wall, as well as an angle between the horizontal plane and the nozzle axis are selected so as to ensure that the extremum of the upper branch of a parabolic trajectory for a cooling air-droplet mixture coming from the nozzle coincides with the intersection point of the crucible bottom and its wall.

A distance between the nozzles arranged frontally along the crucible length in the horizontal plane is preferably selected so as to be equal to the double product of the distance from the nozzle to the vertical plane coinciding with the crucible wall and equal to the tangent of a half of the opening angle of the nozzle plume. The crucible width should not exceed the distance from the nozzle to the vertical plane coinciding with the crucible wall.

When a melt is passed through a die, the crucible may perform reciprocal motions at a frequency from 0.5 to 15 Hz in the vertical direction, such vibrations may have different forms, in particular a saw-tooth form.

Preferably, a distance from the crucible bottom to the cooling liquid level in the basin is from 65 to 250 mm.

Another aspect of the present invention is a device for cooling fragments of a molten metal or alloy, as obtained by passing a melt through a die arranged in the crucible bottom. The device for cooling melt fragments comprises at least one nozzle arranged under the crucible bottom and intended for supplying a sprayed cooling air-droplet mixture into the under-crucible space, the nozzle being arranged so as to supply an air-droplet mixture into the under-crucible space as a spilling flow.

The device for cooling melt fragments may comprise several nozzles arranged frontally with respect of the crucible wall at the level equal to a half-distance from the crucible bottom to the cooling liquid level in the basin arranged under the crucible. Preferably, the distance between the nozzle outlet and the vertical plane coinciding with the crucible wall and the angle between the horizontal plane and the nozzle axis will be selected so as to ensure that the extremum of the upper branch of a parabolic trajectory for a cooling air-droplet mixture coming from the nozzle coincides with the intersection point of the crucible bottom and its wall. Also preferably, the distance between the nozzles arranged frontally along the crucible length in the horizontal plane is equal to the double product of the distance from the nozzle to the vertical plane coinciding with the crucible wall and is equal to the tangent of a half of the opening angle of the nozzle plume.

A further aspect of this invention is a die for producing shot from a molten metal or alloy, which is arranged in the crucible bottom. The crucible passages consist of two sections, where the passage section facing inside the crucible performs the function of a dosing passage, and the passage section facing outside the crucible performs the function of an isothermal chamber, and the isothermal chamber diameter is six to ten times greater than that of the dosing passage.

According to one preferred embodiment of the die, the isothermal chamber length is selected so as to ensure a spherical form of a melt fragment during movement of the said melt fragment therein, and the isothermal chamber diameter is selected so as to ensure a minimum gap between the chamber wall and the said melt fragment, in order to exclude any contact between them.

The dosing passage diameter, its length, and the isothermal passage diameter depend on a melt temperature in the crucible, the melting temperature of a metal or alloy, the melt surface tension coefficient, the melt specific weight and the melt level in the crucible.

Hereinafter the invention will be described in more detail with reference to the accompanying drawings and exemplary embodiments of the invention.

Fig. 1 shows a general view of the device for producing shot from a melt.

Fig. 2 shows a side view of the device for cooling fragments of a molten metal or alloy.

Fig. 3 shows a top view of the device for cooling fragments of a molten metal or alloy.

Fig. 4 shows a view of a die passage.

A general view of the device for producing shot from a melt is shown in Fig. 1. The device for producing shot comprises a crucible (1), which body is provided with a cup (2) for placing a melt (3) of a metal or alloy, a die (4) that is arranged in the bottom of the crucible (1), and a basin (5) with a cooling liquid (6), which is arranged under the crucible (1). A device (7) for cooling melt fragments, which forms a cooling flow (8) of an air-droplet mixture, is arranged between the crucible (1) and the basin (5).

Preferably, a heat insulating layer (9) is arranged between the body of the crucible (1) and the cup (2). The body of the crucible (1) is made, for example, of stainless steel, and the heat insulating layer (9) represents a layer of refractory mixture that simultaneously fulfills the functions both of a lining and a heat insulator. Furthermore, in order to ensure better heat insulation and uniform temperature of a melt (3), a cover (10) with a filling device (11) may be arranged on the crucible (1).

According to a preferred embodiment, the bottom of the crucible (1) has a rectangular shape. For this, it is advisable that the width of the crucible (1) does not exceed the distance B from the device (7) for cooling melt fragments to the vertical plane coinciding with the wall of the crucible (1) (Distance D is shown in Figs. 2, 3).

The crucible (1) may be connected with a rocking mechanism (12) via the actuator (13) of the rocking mechanism in order to ensure reciprocal motion of the crucible (1) in the vertical direction. Preferably, a vibration frequency is in the range from 0.5 to 15 Hz. Vibrations may have different forms, for example a saw-tooth form.

The device (7) for cooling melt fragments may represent a nozzle or a number of nozzles arranged frontally with respect to the wall of the crucible (1). Preferably, the nozzles are at the level C equal to a half-distance B from the crucible (1) to the level of a cooling liquid (6) in the basin (5). Also preferably, the distance B from a nozzle to the vertical plane coinciding with the wall of the crucible (1) and the angle β between the horizontal plane and the nozzle axis are selected so as the extremum of the upper branch of a parabolic trajectory for a cooling air-droplet mixture flow (8) coming from the nozzle coincides with the intersection point of the bottom of the crucible (1) and its wall, as shown in Fig. 2.

The distance A between the nozzles frontally arranged along the length of the crucible (1) in the horizontal plane (see Fig. 3) is preferably defined from the relation:

$$A = 2 \cdot B \cdot tg(\alpha/2),$$

where: α – opening angle of the nozzle plume, B – distance from the nozzle to the vertical plane coinciding with the wall of the crucible (1).

The basin (5) has a filling opening (14) and an overflow opening (15). A conveyor (16) may be installed in the basin (3). A distance from the bottom of the crucible (1) to the level of a cooling liquid (6) in the basin (5) depends on a metal or alloy used for producing shot and may be from 65 to 250 mm.

Passages (17) are made in the die (4) (Figs. 2, 3), where a melt (3) of a metal or alloy is separated into fragments. Each passage consists of two conjugate sections (Fig. 4). The first section facing inside the crucible (1) is intended for passing a melt through a die in doses – this is the dosing passage (18). The second section facing outside the crucible (1) is intended for maintaining the conditions necessary for forming fragments of a spherical form in the area without great temperature differences and heat flows – this is the isothermal chamber (19). Preferably, the diameter of the isothermal chamber (19) is six to ten times greater than the diameter of the dosing passage (18).

A length of the isothermal chamber (19) is selected so as to provide a spherical shape to melt fragments during their movement therein, and a diameter of the isothermal chamber (19) is selected so as to ensure a minimum gap between the wall of the isothermal chamber (19) and said fragments, which excludes any contact between them.

Preferably, the diameter of the dosing passage (18) has a value from X to 15·X, where the X value is determined by the relation:

$$X = (T - Tm)\cdot\sigma / (\rho^2\cdot K),$$

where: T – temperature of melt in the crucible, °C;

Tm – melting temperature of a metal or alloy, °C;

σ – melt surface tension coefficient, N/m;

ρ – specific weight of melt, kg/m^3;

K – dimensionless coefficient having a value from 5.5 to 8.5, depending on a melt level in the crucible.

The X value is the diameter of the dosing passage (in millimeters) for some ideal conditions taking into account a melt level in the crucible, melt temperature and form of crucible vibrations. However, it is also influenced by a surface tension value which, in its turn, depends on chemical composition of a melt and may be varied greatly. It is for this reason that X comprises a correction coefficient that, for the purpose of approaching to a real value of the dosing passage diameter, may be reduced from 15 to 7.5.

According to another preferred embodiment, the dosing passage (18) has a length from 4·X to 16·X, and the length of the isothermal passage (19) is from 16·X to 90·X.

The device for producing shot is operated as follows.

After a stop device (22) is opened, a basic material (21) is fed from a melting furnace (20) as a jet (23) into the cup (2) of the crucible through the filling device (11).

A melt (3) in the crucible passes through the passages (17) of the die (4), where it is separated into fragments. Preferably, when the melt (3) is passed through the die, a constant level of the melt is maintained in the crucible (1).

Then fragments go into the cooling flow area of an air-droplet mixture (8) formed by means of the device (7) for cooling melt fragments.

Melt fragments are completely cooled in a cooling liquid (6) in the basin (5), from where shot produced may be removed by, e.g., a conveyor (16). An upper layer temperature of a cooling liquid (6) should be maintained within the range from 45 to 80°C by, for example, a constant inflow of a cooling liquid (6) into the lower layer in the basin (5) via the filling opening (14), and, for this, free overflow of excess cooling liquid (6) should be ensured via the overflow opening (15) in the upper part of the basin (5). Water or water-based solutions may be used as the cooling liquid (6).

When testing the claimed method, scrap aluminum is used as the basic material that is fed and melted in a melting furnace (20). After melting and heating to the predetermined temperature, the melt is poured to the crucible (1) via the filling device (11) in the cover (10). The aluminum temperature in the crucible is 700÷750°C, the metal level from the bottom inner surface is 70÷90 mm. The level is controlled visually through the quartz window and adjusted by a speed of feeding the metal from the melting furnace.

Simultaneously with feeding liquid aluminum to the crucible (1) during pre-heating of the crucible and the die, the actuator (13) of the rocking mechanism is started at a frequency from 0.5 to 2.0 Hz which ensures a minimum discharge of the melt (3) through the passages (17) of the die (4) for the purpose of reducing the amount of process waste before entering the operating mode. After pre-heating of the crucible (1), the die (4) and the cooling liquid (6) in the basin (5) for one and a half minutes the unit is put into the operating mode by setting the optimal values of the vibration amplitude and frequency of the crucible (1), which ensures proper dosing of the melt (3) for fragments that are separated from the lower edge of the dosing passage (18) of the die (4) at the time when the movement direction of the crucible (1) is changed from "down" to "up". For the period of being in the isothermal chamber (19), which function is to protect melt fragments from dynamic action of convective flows and a cooling air-droplet mixture, fragments take a spherical shape under the action of surface tension forces and then are cooled in two stages.

Melt fragments in the form of shaped spheres go to the area of primary cooling by the cooling flow (8) of the air-droplet mixture, which flow is formed so as the air-droplet mixture comes to the space under the crucible (1) along a lofted trajectory, as shown in Fig. 2, without creating turbulence and, correspondingly, without changing the geometry of spherical fragments.

Due to the cooling action fragments crystallize, their surface obtains initial hardness, and they do not deform while contacting the surface of the cooling liquid (6) in the basin (5) arranged at the distance D from the bottom of the crucible (1), which is equal to 175 mm. The arrangement of the nozzles at the first cooling stage corresponds to that shown in Figs. 2 and 3.

After approximately one and a half minutes from the unit start time the cooling liquid (6) in the basin (5) is heated to a temperature in the range from 65 to 85°C, its temperature is controlled with a temperature-sensitive element. After the pre-determined temperature is achieved, a cooling liquid with a lower temperature is fed to the lower level of the basin (5) via a tube of the filling opening (14), which is cut in the basin bottom, thus ensuring constant temperature in the surface layer of the liquid.

In order to determine quality parameters, shot is taken that is produced after the unit enters the operating mode.

The produced shot had the following characteristics: sphericity degree – not less than 97%, deviation from nominal weight for shot in the pre-determined size range from 4 to 8 mm – not more than 1.0% on weight basis.

Example 1.

Aluminum shot is produced with the parameter values indicated for the above-described test of the claimed method, but the basin (5) is arranged in such a way that the distance D between the bottom of the crucible (1) and the level of the cooling liquid (6) is less than 65 mm. Hollow shot is formed in these conditions, and the fraction of such shot is increased with decreasing the distance between the level of the cooling liquid (6) in the basin (5) and the bottom of the crucible (1).

Example 2.

Aluminum shot is produced with the parameter values indicated for the above test of the claimed method, but the basin (5) is arranged in such a way that the distance D between the bottom of the crucible (1) and the level of the cooling liquid (6) is more than 200 mm. As a result of interaction with the surface of the cooling liquid (6) melt fragments are deformed, and shot takes the form of a flattened out sphere.

Example 3.

Aluminum shot is produced with the parameter values indicated for the above test of the claimed method, but the length of the dosing passage (18) is reduced to a value less than 4·X. This results in a sharp decrease in the dosing accuracy, the melt flows practically as a solid jet, the shot produced has improper form and, frequently, sticks together. When the length of the dosing passage (18) is increased, the output of fragments from the die is obstructed or stopped completely.

Example 4.

Aluminum shot is produced with the parameter values indicated for the above test of the claimed method, but the ratio of the diameters of the isothermal chamber (19) and the dosing passage (18) is reduced to a value less than 5. In this case fragments are deformed against the wall of the isothermal chamber (19) and take an oblong shape. When the diameter of the isothermal chamber (19) is increased to a value greater than 10·X, no visible improvements in the product quality are identified. The necessity of unnecessary increase in the bottom of the crucible (1) appears in order to arrange the same number of passages (17) of the die (4).

Example 5.

Aluminum shot is produced with the parameter values indicated for the above test of the claimed method, but the level of the melt (3) in the crucible (1) is lowered. As in Example 3, when the length of the dosing passage (18) is increased, the output of fragments from the die is obstructed or stopped completely in a certain time. When the level of the melt (3) in the crucible (1) is increased, uncontrolled outflow of the melt (3) starts, shot is produced with long tails, or "wire" is formed.

Example 6.

Aluminum shot is produced with the parameter values indicated for the above test of the claimed method, but the die (4) is turned by 180°, i.e., the isothermal chamber (19) faces the melt (3) in the crucible (1). Shot with "tails" is obtained. When the passages (17) of the die (4) are arranged in such a way, the melt fragments are immediately acted upon by the cooling atmosphere under the bottom of the crucible (1), especially in the "tail" area having more developed surface. Furthermore, as a result of interaction with the atmospheric oxygen, a rigid oxide film is formed on the fragment surface, which precludes formation of a spherical surface restricting the fragment volume.

Thus, when the passages (17) of the die (4) are arranged correctly, i.e., the isothermal chamber (19) down, during the time for which a fragment is in the isothermal chamber (19) the process of "tail retraction" is completed. The behavior of this process is much better in the conditions of the isothermal chamber (19), since no crystallization takes place, especially of a "tail" itself having a developed surface, and, correspondingly, no intensive cooling occurs. A fragment has enough time for taking a spherical shape, surface vibrations caused by the fragment separation from the lower edge of the dosing passage (18) of the die (4) decay.

The novelty of the claimed invention consists in the presence of the isothermal chamber (19), which length is calculated so as the process of forming a sphere is completed for the time during which a melt fragment passes through it. A diameter of the isothermal chamber is selected so as, when a melt fragment passes through it, the fragment may not contact the wall of the isothermal chamber (19).

An inert gas is fed in the space under a crucible in the methods known from the art for the purposes of preventing a rigid oxide film from forming on the surface of a fragment of a molten aluminum and facilitating the process of "tail retraction". This approach does not allow to solve the problem completely, since a protective gas flow has a dynamic and cooling effect on the fragment surface, thus precluding formation of a sphere. Moreover, this approach introduces additional technical problems that are not present in the claimed invention.

The technical effect of the claimed invention is production of shot with a high degree of sphericity and fractional composition.

CLAIMS

1. A method for producing shot from a molten metal or alloy, comprising formation of melt fragments by passing said melt through a die and subsequent placement of produced shot into a cooling liquid, characterized in that the die passages are made as two successive sections – a dosing passage and an isothermal chamber, and when melt fragments exit the isothermal chamber, they are cooled by a spilling flow of an air-droplet mixture.

2. The method for producing shot according to Claim 1, characterized in that a constant level of a melt is maintained in the crucible when a melt is passed through the die.

3. The method for producing shot according to Claim 1, characterized in that, when passing melt through a die, reciprocal motions with frequency from 0.5 to 15 Hz in the vertical direction are imparted to the crucible.

4. The method for producing shot according to Claim 3, characterized in that reciprocal motions have a saw-tooth form.

5. The method for producing shot according to Claim 1, characterized in that a cooling liquid is placed in a basin with the possibility of changing a distance from the crucible bottom to the cooling liquid level in the basin from 65 to 250 mm.

6. The method for producing shot according to Claim 5, characterized in that a temperature of the upper level of the cooling liquid is maintained in the range from 45 to 80°C due to a constant inflow of the cooling liquid into the lower level of the basin, for this free overflow of excess cooling liquid via an overflow opening in the upper part of the basin is provided.

7. The method for producing shot according to Claim 1, characterized in that water or a solution on its basis is used as a cooling liquid.

8. A device for producing shot from a molten metal or alloy, comprising a crucible, a die arranged in the crucible bottom and intended for producing melt fragments, and a basin with a cooling liquid arranged under the crucible, characterized in that the die passages consist of two conjugate sections performing, respectively, the functions of a dosing passage and an isothermal chamber that ensure production of shot having substantially a spherical shape, and a means for cooling melt fragments with a spilling flow of an air-droplet mixture is arranged between the crucible bottom and the basin.

9. The device for producing shot according to Claim 8, characterized in that the crucible has a bottom of a rectangular shape.

10. The device for producing shot according to Claim 8, characterized in that the crucible comprises a heat-insulating layer from a refractory mixture, and a cover with a filling device is arranged on the crucible top.

11. The device for producing shot according to Claim 8 or 9, characterized in that the means for cooling melt fragments is at least one nozzle intended for supplying a cooling medium.

12. The device for producing shot according to Claim 11, characterized in that the means for cooling melt fragments is a row of nozzles arranged frontally with respect to the crucible wall at a level equal to half a distance from its bottom to a cooling liquid in the basin, and a distance B between a nozzle and the vertical plane coinciding with the crucible wall and an angle β between the horizontal plane and the nozzle axis are selected so as the extremum of the parabolic trajectory upper branch of a flow of a cooling air-droplet mixture from a nozzle coincides with the intersection point of the crucible bottom and the crucible wall.

13. The device for producing shot according to Claim 12, characterized in that a distance A between the nozzles arranged frontally in the horizontal plane is determined from the relation:

$$A = 2 \cdot B \cdot tg(\alpha/2),$$

where: α is an opening angle of the nozzle plume,

B is the distance from the nozzle to the vertical plane coinciding with the crucible wall.

14. The device for producing shot according to Claim 12, characterized in that a crucible width does not exceed the distance B from the nozzle to the vertical plane coinciding with the crucible wall.

15. The device for producing shot according to Claim 8, characterized in that the crucible is installed with the possibility of performing reciprocal motions with a frequency from 0.5 to 15 Hz in the vertical direction.

16. The device for producing shot according to Claim 8, characterized in that a distance from the crucible bottom to the level of the cooling liquid in the basin is from 65 to 250 mm, depending on a metal or alloy used for producing shot.

17. A device for cooling fragments of a molten metal or alloy, which are produced by passing a melt through a die arranged in the crucible bottom, comprising at least one nozzle arranged under the crucible bottom and intended for supplying a cooling air-droplet mixture into the space under the crucible, characterized in that the nozzle is arranged with the possibility of supplying an air-droplet mixture as a spilling flow into the space under the crucible.

18. The device for cooling melt fragments according to Claim 17, characterized in that it comprises several nozzles arranged frontally with respect the crucible wall at a level equal to half a distance from the crucible bottom to the cooling liquid level in the basin arranged under the crucible, and the distance B from the nozzle outlet to the vertical plane coinciding with the crucible wall and the angle β between the horizontal plane and the nozzle axis are selected so as the extremum of the parabolic trajectory upper branch of a flow of a cooling air-droplet mixture from a nozzle coincides with the intersection point of the crucible bottom and the crucible wall.

19. The device for cooling melt fragments according to Claim 18, characterized in that a distance A between the nozzles arranged frontally in the horizontal plane is determined from the relation:

$$A = 2 \cdot B \cdot tg(\alpha/2),$$

where: α is an opening angle of the nozzle plume,

B is the distance from the nozzle to the vertical plane coinciding with the crucible wall.

20. A die for producing shot from a molten metal or alloy, which is arranged in the crucible bottom and which is characterized in that the die passages consist of two sections, the passage section facing inside the crucible performing the function of a dosing passage, and the passage section facing outside the crucible performing the function of an isothermal chamber, the isothermal chamber diameter is 6÷10 times greater than the diameter of the dosing passage, and the dosing passage has a length from 4·X to 16·X, and the isothermal passage has a length from 16·X to 90·X, where the X value is determined from the relation:

$$X = (T - Tm) \cdot \sigma / (\rho^2 \cdot K),$$

where: T is melt temperature in the crucible, in °C;

Tm is the melting temperature of a metal or alloy, in °C;

σ is melt surface tension coefficient, in N/m;

ρ is specific weight of the melt, in kg/m^3;

K is dimensionless coefficient taking a value from 5.5 to 8.5, depending on a melt level in the crucible.

21. The die for producing shot according to Claim 20, characterized in that a length of the isothermal chamber is selected so as to ensure a spherical shape of a melt fragment during movement of the said melt fragment therein, and the isothermal chamber diameter is selected

so as to ensure a minimum gap between the chamber wall and the said melt fragment, in order to exclude any contact between them.

22. The die for producing shot according to Claim 20, characterized in that the dosing passage diameter has a value from X to 15·X.

AMENDED CLAIMS
received by the International Bureau on 22 August 2013 (22.08.2013)

1. A method for producing shot from a molten metal or alloy, comprising formation of melt fragments by passing a melt through a die arranged in a bottom of a crucible and having die passages and subsequent placement of produced shot into a cooling liquid, characterized in that the die passages are made as two successive sections – a dosing passage facing inside the crucible and an isothermal chamber facing outside the crucible, and when melt fragments exit the isothermal chamber, they are cooled by a spilling flow of an air-droplet mixture.

2. The method for producing shot according to Claim 1, characterized in that a constant level of the melt is maintained in the crucible when the melt is passed through the die.

3. The method for producing shot according to Claim 1, characterized in that, when passing the melt through the die, reciprocal motions with frequency from 0.5 to 15 Hz in the vertical direction are imparted to the crucible.

4. The method for producing shot according to Claim 3, characterized in that the reciprocal motions have a saw-tooth form.

5. The method for producing shot according to Claim 1, characterized in that the cooling liquid is placed in a basin at a distance from the crucible bottom to a cooling liquid level in the basin from 65 to 250 mm.

6. The method for producing shot according to Claim 5, characterized in that a temperature of an upper level of the cooling liquid is maintained in the range from 45 to 80°C due to a constant inflow of the cooling liquid into a lower level of the basin, and for this free overflow of excess of the cooling liquid via an overflow opening in an upper part of the basin is provided.

7. The method for producing shot according to Claim 1, characterized in that water or a water solution is used as the cooling liquid.

8. A device for producing shot from a molten metal or alloy, comprising a crucible, a die having die passages and arranged in a crucible bottom and intended for producing melt fragments, and a basin with a cooling liquid arranged under the crucible, characterized in that the die passages consist of two conjugate sections of a dosing passage facing inside the crucible and an isothermal chamber facing outside the crucible that ensure production of shot having substantially a spherical shape, and a means for cooling melt fragments with a spilling flow of an air-droplet mixture arranged between the crucible bottom and the basin.

9. The device for producing shot according to Claim 8, characterized in that the crucible bottom is of a rectangular shape.

10. The device for producing shot according to Claim 8, characterized in that the crucible comprises a heat-insulating layer made of a refractory mixture, and a cover with a filling device is arranged on a crucible top.

11. The device for producing shot according to Claim 8 or 9, characterized in that the means for cooling melt fragments being at least one nozzle intended for supplying a cooling medium.

12. The device for producing shot according to Claim 11, characterized in that the means for cooling melt fragments is a row of nozzles arranged frontally with respect to a crucible wall at a level equal to half a distance from the crucible bottom to the cooling liquid in the basin, and a distance B between the nozzle and the vertical plane coinciding with the crucible wall and an angle β between the horizontal plane and the nozzle axis are selected so as the extremum of the parabolic trajectory upper branch of the flow of the cooling air-droplet mixture from the nozzle coincides with the intersection point of the crucible bottom and the crucible wall.

13. The device for producing shot according to Claim 12, characterized in that a distance A between the nozzles arranged frontally in the horizontal plane is determined from the relation:

$$A = 2 \cdot B \cdot tg(\alpha/2),$$

where: α is an opening angle of a nozzle plume,

B is the distance from the nozzle to the vertical plane coinciding with the crucible wall.

14. The device for producing shot according to Claim 12, characterized in that a crucible width does not exceed the distance B from the nozzle to the vertical plane coinciding with the crucible wall.

15. The device for producing shot according to Claim 8, characterized in that the crucible is installed with the possibility of performing reciprocal motions with a frequency from 0.5 to 15 Hz in the vertical direction.

16. The device for producing shot according to Claim 8, characterized in that a distance from the crucible bottom to a level of the cooling liquid in the basin is from 65 to 250 mm, depending on a metal or alloy used for producing shot.

17. A device for cooling fragments of a molten metal or alloy,said fragments being produced by passing a melt through a die arranged in a crucible bottom and having substantially the form of shaped spheres, the device comprising at least one nozzle arranged under the crucible bottom and intended for supplying a cooling air-droplet mixture into the space under a crucible, characterized in that the nozzle is arranged with the possibility of supplying an air-droplet mixture as a spilling flow into the space under the crucible.

18. The device for cooling melt fragments according to Claim 17, characterized in that it comprises several nozzles arranged frontally with respect a crucible wall at a level equal to half a distance from the crucible bottom to a cooling liquid level in a basin arranged under the crucible, and a distance B from a nozzle outlet to the vertical plane coinciding with the crucible wall and an angle β between the horizontal plane and a nozzle axis are selected so as the extremum of the parabolic trajectory upper branch of the flow of the cooling air-droplet mixture from the nozzle coincides with the intersection point of the crucible bottom and the crucible wall.

19. The device for cooling melt fragments according to Claim 18, characterized in that a distance A between the nozzles arranged frontally in the horizontal plane is determined from the relation:

$$A = 2 \cdot B \cdot tg(\alpha/2),$$

where: α is an opening angle of a nozzle plume,

B is the distance from the nozzle to the vertical plane coinciding with the crucible wall.

20. A die for producing shot from a molten metal or alloy, which is arranged in a crucible bottom and characterized in that die passages consist of two sections, the passage section facing inside the crucible and performing the function of a dosing passage, and the passage section facing outside the crucible and performing the function of an isothermal chamber, the isothermal chamber having a diameter 6÷10 times greater than a diameter of the dosing passage, and the dosing passage having a length from 4·X to 16·X, and the isothermal passage having a length from 16·X to 90·X, where the X value is determined from the relation:

$$X = (T - Tm) \cdot \sigma / (\rho^2 \cdot K),$$

where: T is a melt temperature in the crucible, in °C;

Tm is a melting temperature of a metal or alloy, in °C;

σ is a melt surface tension coefficient, in N/m;

ρ is a specific weight of the melt, in kg/m^3;

K is a dimensionless coefficient having a value from 5.5 to 8.5, depending on a melt level in the crucible.

21. The die for producing shot according to Claim 20, characterized in that a length of the isothermal chamber is selected so as to ensure a spherical shape of a melt fragment during movement of said melt fragment in the isothermal chamber, and the isothermal chamber diameter is selected so as to ensure a minimum gap between an isotermal chamber wall and said melt fragment, in order to exclude any contact between them.

22. The die for producing shot according to Claim 20, characterized in that the dosing passage diameter has a value from X to 15·X.

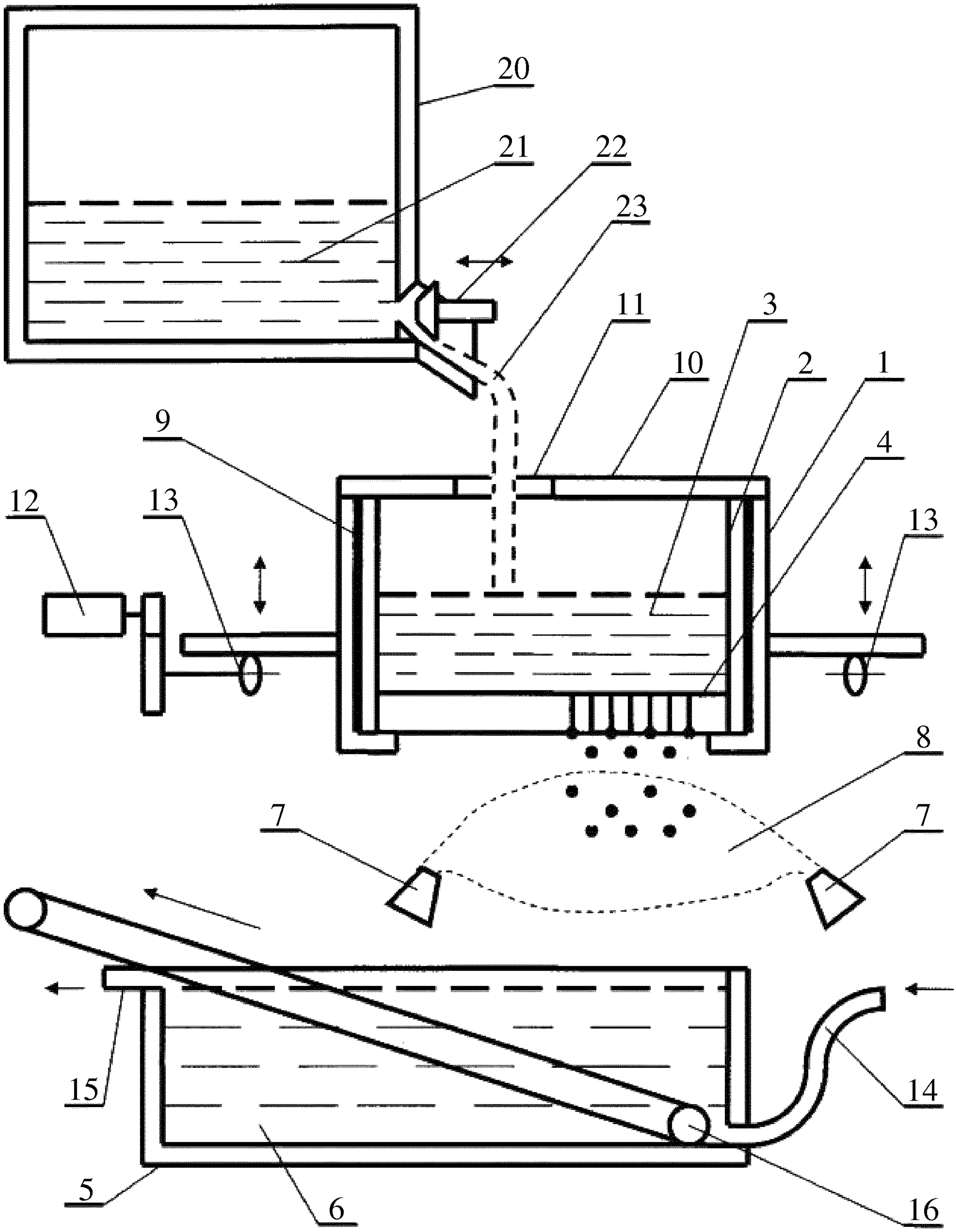

Fig. 1

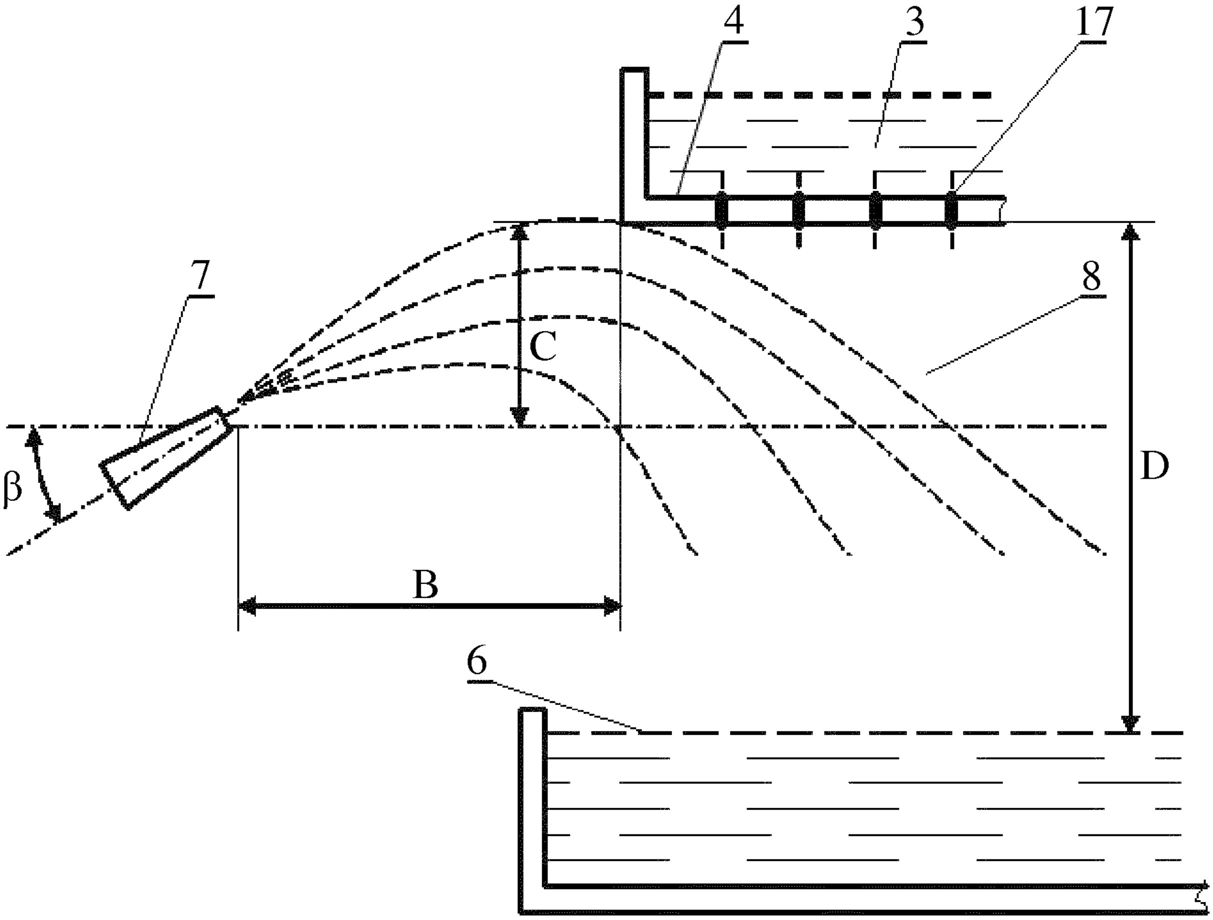

Fig. 2

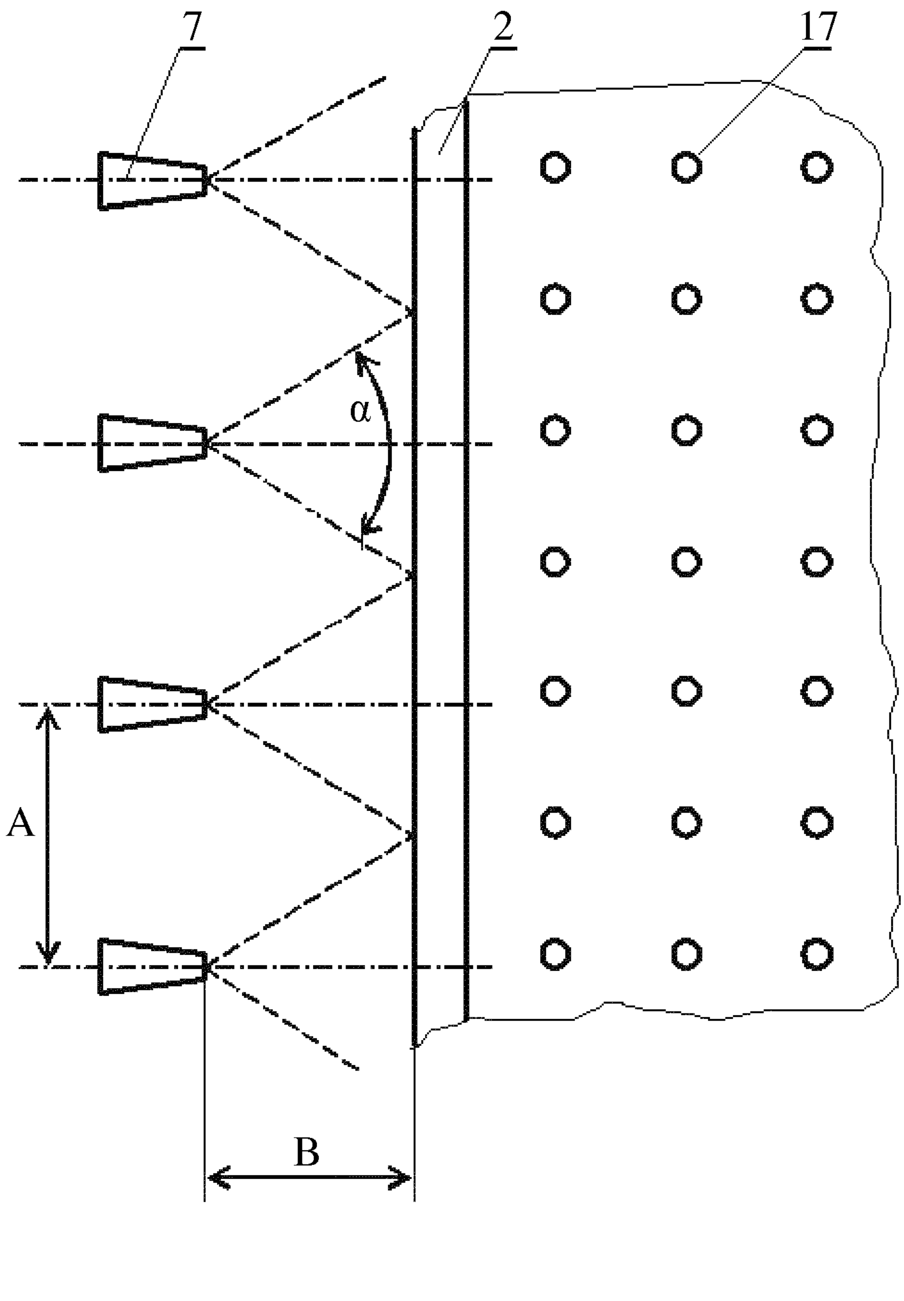

Fig. 3

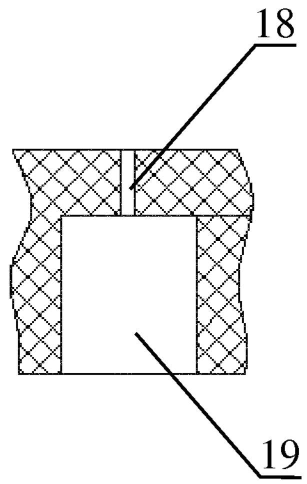

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/056297

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F9/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 31 09 909 A1 (KOPPATZ RUDOLF) 18 March 1982 (1982-03-18) cited in the application the whole document	1-22
A	JP S62 253705 A (MITSUBISHI HEAVY IND LTD; RYOMEI ENG CORP LTD) 5 November 1987 (1987-11-05) abstract	1-22
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A	SU 1 186 395 A1 (CHUKALIN YURIJ A [SU]) 23 October 1985 (1985-10-23) the whole document	1-22

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 June 2013	24/06/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Swiatek, Ryszard

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 349 548 B1 (ARANA DAVID [US]) 26 February 2002 (2002-02-26) column 4, line 47 - column 4, line 51 -----	17-19

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/056297

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