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(71) Applicant: **Calderys Ukraine Ltd.**
85721 Vladmirovka (UA)

(72) Inventors:
- **Sergiy, Solvkyh**
  85721 Vladimirovka (UA)
- **Svitlana, Malich**
  85721 Vladimirovka (UA)
- **Volodymyr, Klimov**
  85721 Vladimirovka (UA)

(74) Representative: **Nash, David Allan**
Haseltine Lake LLP
Redcliff Quay
120 Redcliff Street
Bristol
BS1 6HU (GB)

(54) **Metal-flow impact pad and diffuser for tundish**

(57) The invention relates to a diffuser for use in a tundish and made of a refractory material comprising (a) a base portion having a top surface and a bottom surface, wherein said top surface is an impact surface suitable for withstanding the impact of molten metal; and (b) an outer side wall entirely surrounding said base portion and extending from said top surface of said base portion in order to from a substantially bucket-like structure, and characterised in that said outer side wall comprises two or more flow outlets in the form of recesses extending from the edge of said side wall furthest away from said base portion towards but not up to said base portion. The invention further relates to the use of a diffuser in the process of pouring molten metal through a tundish.

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to diffusers for tundishes as well as the use of such diffusers in tundishes and the tundishes comprising said diffusers.

BACKGROUND OF THE INVENTION

[0002] An impact pad is commonly placed on the floor of a tundish to receive an incoming stream of molten metal poured into the tundish from a source such as a metallurgical ladle or the output of a high furnace. The tundish has a distribution and buffering function for the molten metal, but also helps purifying and cleaning the melt.

[0003] Due to the high requirements for steel quality, cleanliness has become one of the main concerns for steel makers. The tundish is considered an important tool in improving the cleanliness of cast steel. Improving the liquid steel flow in the different stages of the steelmaking chain is becoming essential. Uncontrolled flow severely impairs the steel quality through atmosphere contamination with oxygen and nitrogen entrained in the open slag areas around the feeding shroud.

[0004] Slag entrapment and refractory wear due to surface turbulence form large inclusions in the steel product; skull formation zones are also sources of operational problems and quality. Non-metallic inclusions, such as AlO_3, are removed from the steel melt as they float to the top of the melt and collect at the liquid steel to metal-slag interface, due to their lower density compared to the liquid steel. For this process to occur efficiently, convection streams in the steel melt can be encouraged by installation of so-called tundish furniture such as dams, weirs and baffles.

[0005] It is a common problem that the residence time of a steel melt in a tundish is too short for this convection process to occur to a sufficient degree. The flow of the dense and viscous steel melt through the tundish and the arrangement of the tundish furniture lead to a complex dynamic system, the behaviour of which is inherently difficult to predict. In particular, the occurrence of so-called "dead zones" where some liquid metal accumulates and stagnates, and around which the flow of the melt is directed, is problematic. On the one hand the flow of the melt is accelerated by the reduction of the effective volume of the tundish, leading to a reduced residence time of the melt in the tundish. On the other hand, the accumulated stagnating melt is exposed to the atmosphere for prolonged time, leading to the formation of impurities through reaction with atmospheric oxygen and nitrogen. These problems could be avoided by directing the flow of the liquid metal such that a uniform flow velocity and temperature distribution are ensured throughout the molten metal in the tundish during operation.

[0006] Impact pads are generally designed to protect the tundish interior surface from the forces caused by the heavy and hot melt falling onto the tundish floor at the start of the casting process. They are generally formed of a reinforced portion of refractory material, and arranged such that minimal splashing of molten metal occurs upon impact.

[0007] US 5,169,591 discloses an impact pad designed to protect the tundish from said strain, and to reduce the occurrence of surface turbulence on the melt which causes the supernatant solid metal and slag to be dragged into the melt and to negatively affect the purity and quality of the obtained product. The disclosed impact pad comprises a base for receiving an incoming stream of liquid metal and upwardly extending sidewalls with an inner surface having an undercut portion facing the incoming stream. This effectively reduces splashing and surface turbulence within the tundish during operation, but does not direct the flow of liquid metal such that residence time in the tundish may be controlled or dead zones eliminated. Tundish furniture is still required for directing the melt flow.

[0008] DE 197 26 540 A1 and WO 03/061879 A1 propose further impact pad designs for protecting the tundish interior and improving the serviceability or the stability of the impact pad, respectively. None of these designs proposes a method for reducing effective flow velocity and therefore increasing or stabilising the residence time of the melt and avoiding the formation of dead zones in the tundish.

[0009] EP 1 397 221 B1 proposes impact pads for use in molten metal tundishes which help directing the flow of molten metal. These impact pads consist of a base plate and sidewalls having multiple protrusions, with a complex design. They are therefore difficult and expensive to produce and maintain.

[0010] The state of the art therefore constitutes a problem.

SHORT DESCRIPTION OF THE INVENTION

[0011] The above mentioned problems are solved by the invention according to the appended claims. In particular, the problem is solved by a diffuser for use in a tundish and made of a refractory material, comprising (a) a base portion having a top surface and a bottom surface, wherein said top surface is an impact surface suitable for withstanding the impact of molten metal; and (b) an outer side wall entirely surrounding said base portion and extending from said top surface of said base portion in order to from a substantially bucket-like structure. The said outer side wall comprises two or more flow outlets in the form of recesses extending from the edge of said side wall located furthest from said base portion towards but not up to said base portion. The diffuser may be further characterised in that the opening at the top of the diffuser has a cross-sectional surface greater than or equal to the surface of said base portion not covered by said side wall. The base portion of the diffuser according to the invention may be substantially planar or raised towards its centre.

[0012] In one advantageous embodiment of the invention, the outer side wall of the diffuser comprises exactly two flow outlets, which may be arranged at diametrically opposed portions of said side wall, depending on the shape of the tundish. The flow outlets extend from the edge of the side wall located furthest from the base portion towards the base portion, and may extend for a distance which is substantially half the total distance between said edge of the side wall and said base portion. Each flow outlet may have a different length extension compared to any other of the two or more flow outlets.

[0013] In one advantageous embodiment of the invention, the side wall extends in an outwardly direction from said base portion, such that the top opening of the diffuser has a larger section than the base portion of the diffuser, and the internal volume of the diffuser is increased. For example, the side wall may form an angle of more than 90 degrees with the base portion, such as for example from 92 to 110 degrees, or from 95 to 105 degrees. In a further advantageous embodiment of the invention, said outer side wall may have a varying extension, such that the edge of said side wall which is furthest away from said base portion is at least partially sloped.

[0014] The diffuser according to the present invention may be made of a refractory material which is a cast or pressed refractory material capable of withstanding prolonged contact with molten metal, such as molten steel. In one embodiment, the refractory material may have an alumina content between 55% and 85% by weight. The refractory material may be an alumina-spinel or an alumina-magnesia refractory material. In an alternative embodiment, the refractory material may be a basic refractory material with a magnesia content of between 55% and 95% by weight.

[0015] The diffuser according to the present invention is adapted for use in a tundish for transfer of molten metal. The tundish may be selected from the group consisting of V-shaped tundishes, B-shaped tundishes, T-shaped tundishes, C-shaped tundishes and H-shaped tundishes, and the shape and orientation of the diffuser adapted accordingly.

[0016] Further part of the invention is the use of a diffuser of the invention in the process of pouring molten metal through a tundish.

SHORT DESCRIPTION OF THE FIGURES

[0017] The invention will be further illustrated using the following figures:

Fig. 1a shows an impact pad according to the state of the art;

Fig. 1 b shows the flow of molten metal when pored into the impact pad according to the state of the art of Fig. 1 a

Fig. 2 shows top views of different types of tundishes available;

Fig. 3 shows a cross-section of an exemplary base portion having a non-planar shape of the diffuser according to the invention;

Fig. 4 shows a three-dimensional structure of a diffuser according to the invention in a B-shaped tundish;

Fig. 5a shows 3-dimensional image of a diffuser according to one embodiment of the present invention;

Fig. 5b shows 3-dimensional image of a diffuser according to a further embodiment of the present invention;

Fig. 6a shows the temperature distribution in a V-shaped tundish shortly after the start of the pouring process when an impact pad according to the state of the art is used;

Fig. 6b shows the temperature distribution in a V-shaped tundish shortly after the start of the pouring process when an impact pad according to the present invention is used;

Fig. 7a shows the temperature distribution in a V-shaped tundish one minute after the start of the pouring process when an impact pad according to the state of the art is used;

Fig. 7b shows the temperature distribution in a V-shaped tundish one minute after the start of the pouring process when an impact pad according to the present invention is used;

Fig. 8 shows the velocity distribution of flowing molten metal in a B-shaped tundish at different height levels of the tundish during casting;

Fig. 9 shows the temperature distribution of molten metal in a B-shaped tundish at different height levels of the tundish during casting.

DETAILED DESCRIPTION OF THE INVENTION

[0018] According to the state of the art, impact pads have been used in order to reduce the strain and forces borne by a tundish during operation, and in particular at the start of the casting process. Tundish furniture, such as dams, weirs and baffles are traditionally used for directing flow and avoiding dead zones of the molten metal in the tundish during operation. In continuous casting, it is particularly important that uniform flow and temperature are ensured during operation, and the strain caused by prolonged exposure to high temperatures and abrasion caused by the constant flow of dense and viscous liquid requires high stability and resilience of the equipment used.

[0019] Tundishes for distributing and buffering metal melts are available in different configurations, according to the requirements of the specific metals, processes and conditions. The diffusers according to the present invention may be employed in tundishes for different ferrous and non-ferrous metal melts. They are particularly useful in steel making. Fig. 2 shows top views of a range of different tundishes available. Most commonly used are the B-shaped (boat-shaped) tundish with a substantially rectangular base, and the V-shaped tundish with a corresponding V-shaped base. Also available for different applications are T-, C- and H-shaped versions. The tundishes may have varying numbers of strands or outlets, such as for example 1, 2, 4, 6 or 8 strands, depending on the size and shape of the tundish. Further to the shape of the tundishes, the insertion zone of the molten material and the positions of the one or more strands may vary. The flow characteristics of a metal melt in these different tundishes is of course influenced by all these factors. As mentioned above, it is an object of the invention to provide systems allowing the production of cast material of superior and uniform quality by ensuring that the flow velocity and temperature within the tundish during operation is as uniform as possible, with increased residence time, reduced surface turbulence and avoidance of dead zones.

[0020] The diffusers according to the present invention act as both impact pads and flow controllers for molten metal in the tundishes.

[0021] Impact pads according to the state of the art, such as described in US 5,169,591 (see Fig. 1a and 1b), are very effective in reducing and distributing the forces acting on the tundish during operation and in particular at the start of the casting process, and in reducing surface turbulence. However, they are not suitable for directing the flow of molten metal within the tundish during operation, in order to obtain controlled residence times and flow velocities and to avoid dead zones. Various tundish furniture items (dams, weirs and baffles) need to be used in order to control metal flow. The actual flow obtained is difficult to predict prior to starting a casting operation, and it is not convenient to change the positioning of the tundish furniture once installed, since the process has to be stopped and the equipment cooled down before any adaptations can be made.

[0022] The diffusers according to the present invention serve both as impact pads and for directing flow in the tundish during operation. It has been found that diffusers having the specific shapes according to the present invention are efficient and predictable in their operation, in that they direct the flow of molten metal within a tundish such that flow direction and velocity, as well as residence times in the tundish can be controlled. Furthermore, surface turbulence is avoided.

[0023] The diffusers according to the present invention are made of a refractory material and comprise (a) a base portion having a top surface and a bottom surface, wherein said top surface is an impact surface suitable for withstanding the impact of molten metal; and (b) an outer side wall entirely surrounding said base portion and extending from said top surface of said base portion in order to from a substantially bucket-like structure; and the said outer side wall comprises two or more flow outlets in the form of recesses extending from the edge of said side wall which is furthest away from said base portion towards but not up to said base portion. They may be characterised in that the opening at the top of the diffuser has a cross-sectional surface greater than or equal to the surface of said base portion not covered by said side wall. In other words, there is no overhang at the top of the side wall, as is shown e.g. in the prior art diffuser to of Figs. 1 a and 1 b.

[0024] Said base portion of the diffuser may be substantially planar or have a shape that is slightly raised towards the centre of the base portion, as shown in Fig. 3. In general, the shape of the base portion may be adapted to the overall shape of the diffuser and tundish, in order to improve the flow characteristics in the tundish.

[0025] The size and exact configuration of the diffuser may be adapted to the tundish it is to be used in, but always within the structural features as described above. In most common applications, the diffuser has exactly two flow outlets, though diffusers with more than two flow outlets may be considered for more complex applications.

[0026] In particular, the positioning of the flow outlets in the side wall depends on the shape of the tundish. For example, in the case of a B- (boat)-shaped tundish with a central insertion point for the melt and outlets along a central line parallel to the longitudinal sides of the tundish, the two flow outlets of the diffuser may be arranged at diametrically opposed ends of the side wall, in order to direct the flow along said outlets in the tundish (see Fig. 4 and 5a). On the other hand, in tundishes with non-symmetrical base shapes, such as V-shaped tundishes, the flow outlets of the diffuser may be arranged also non-symmetrically along the side wall (see an exemplary embodiment in Fig. 5b).

[0027] The flow outlets of the diffuser according to the invention may have different sizes and shapes and need not be identical for the flow outlets in any given diffuser. They may be rectangular or angled or have any other shape deemed suitable. The flow outlets extend from the edge of the side wall furthest from the base portion of the diffuser (the "top edge") down towards the base portion. They may however not extend all the way down to the base portion of the diffuser, such as to form a gap in the side wall. In that case, splashing of molten metal would occur outside of the diffuser at the start of the casting process, and small puddles of molten metal would form in the tundish in the initial stages of the process, and therefore increasing surface area and exposure to the atmosphere of the molten metal, leading to the formation of further impurities in the melt. Instead, the recesses may extend to substantially half the distance between the top edge of the outer wall and the base portion of the diffuser, such as a distance between 20% and 80% between the top edge of the outer wall and the base portion of the diffuser, or a distance between one third and two thirds between the top edge of the outer wall and the base portion of the diffuser. According to the present invention however, any length of the flow outlets may be considered, as long as they do not extend up to the base portion of the diffuser.

[0028] The flow outlets may furthermore have a total width at the top edge of the side wall which is no more than 30% of the total width of the side wall, or a width which is no more than 20, or no more than 10% of the total width of the side wall.

[0029] The side wall of the diffuser may be arranged such that it extends in an outwardly direction from said base portion, meaning the side wall and the base portion form an angle of 90 degrees or higher, such as 92 to 110 degrees, or 95 to 105 degrees or 100 degrees or the like. This further reduces splashing of the molten metal at the start of the pouring process and helps avoid the formation of reaction products from unnecessary exposure to the atmosphere. Even if the side wall extends in an outwardly direction from said base portion, according to the present invention, it need not comprise an overhang at its top edge.

[0030] The outer wall of the diffuser according to the present invention may have varying length, such that its edge furthest away from the base portion of the diffuser is sloped in various portions. An exemplary embodiment of a diffuser with a sloped edge is shown in Fig. 5b. The slope may help direct the flow of molten metal in the tundish in the desired direction.

[0031] The diffusers may be formed from a cast or pressed refractory composition capable of withstanding continuous contact with molten metal, in particular molten steel such as is used in continuous casting operations. Usually a standard medium-to-high alumina refractory with an alumina content in the range of about 55% to 85% by weight is desirable. In case of long sequence or high aggressive steel grades, alumina-spinel or alumina magnesia are suitable. Where a basic refractory is preferred because of steel chemistry, a magnesia-based refractory composition may be utilised, with MgO in the range of about 55% to 95% by weight. In general, any refractory material known by the skilled person in the art may be used for the diffusers according to the invention.

[0032] The diffusers are installed in the tundishes simply by placing at the bottom of the tundish in the designated position. Alternatively, a region may be provided in the wear lining on the floor of the tundish, which is adapted to receiving the impact pad. This may be in the form of an indentation corresponding to the shape of the base of the impact pad. The mass of the impact pad is generally sufficient to hold it in place at the bottom of the tundish.

[0033] The diffusers may have a total height (the distance between the base portion and the end of the side wall furthest from said base portion) which is adapted to the size and height of the tundish they are intended for use in. For example, the height shall be sufficient to avoid splashing or spilling of the molten metal out of the diffuser at the start of the pouring process. However, the impact pad shall not be so high as to create turbulence at the surface of the liquid metal during operation, since this could lead to the creation of vortexes in the liquid and the formation of impurities therein. In general, the impact pad may have a height which is substantially between 20% and 80% of the height of the tundish, or between one third and two thirds of the height of the tundish.

EXAMPLE 1

[0034] A diffuser according to the present invention as shown in Fig. 5b was installed in a V-shaped tundish and an impact pad according to the state of the art as shown in Fig. 1a was installed in an identical V-shaped tundish. Molten steel was poured into both tundishes and the temperature distribution within the tundishes was recorded using temperature imaging equipment. Figs. 6a (state of the art) and 6b (invention) show the temperature distribution in the V-shaped tundishes shortly after the start of the pouring, and Figs. 7a (state of the art) and 7b (invention) show the temperature distribution in the same tundishes exactly 1 minute after the start of the pouring process.

[0035] Figs. 6a and 6b clearly show that at the start of the process, the temperature dissipation within the tundish occurs at a much faster rate when the diffuser according to the invention is used, compared to the impact pad of the state of the art. Also, after 1 minute of operation, it is clearly apparent that a uniform temperature distribution is established in the tundish using the diffuser according to the invention (Fig. 7b), while the temperature differences throughout the tundish are notably larger in the tundish using the impact pad according to the state of the art (Fig. 7a).

[0036] These observations show two different advantages of the present invention. On the one hand, the molten material flows more smoothly through the tundish, as is shown by the wider distribution of the high-temperature zone shortly after the start of the process, showing that that the cast material is distributed quicker throughout the tundish, therefore creating more uniform flow and less surface turbulence caused by pressure variations within the melt. Furthermore, as can be seen in Figs. 7a and 7b, the temperature distribution during operation is much more uniform, leading to an overall flow of liquid that is not disturbed by temperature variations in different parts of the tundish. A uniform flow of material may be easily controlled and avoid the occurrence of dead zones and reduction of effective volume of the tundish.

EXAMPLE 2

[0037] Molten steel was poured at approximately 1510 to 1570°C through boat-shaped tundishes and the distributions of velocity and temperature within the tundish at different height levels was measured. The tundish had previously been equipped with a diffuser according to Fig. 5a.

[0038] Figs. 8 and 9 show flow velocity and temperature distributions within the B- (boat)-shaped tundish during operation, when a diffuser according to Fig. 5a is used. The different section images in each figure describe the situation at different heights in the tundish during operation (heights indicated in mm). As can be seen, the velocity and temperature distributions are very uniform at all heights throughout the tundish, showing that there is a uniform flow pattern of the molten metal through the tundish, avoiding the creation of turbulences and vortexes at the liquid surface and of dead-zones where there is stagnant liquid metal. This leads to an overall improvement of the efficiency of the pouring process, and of the quality of the final product. Due to the reduced splashing and surface turbulence of the liquid metal, as well as the uniform flow and temperature pattern, a homogenous distribution of the metal between separate strands (outflows) in the tundish is guaranteed. This leads to more consistent product quality and reliability.

Claims

1. Diffuser for use in a tundish and made of a refractory material comprising
a base portion having a top surface and a bottom surface, wherein said top surface is an impact surface suitable for withstanding the impact of molten metal; and
an outer side wall entirely surrounding said base portion and extending from said top surface of said base portion in order to from a substantially bucket-like structure; **characterised in that**
said outer side wall comprises two or more flow outlets in the form of recesses extending from the edge of said side wall which is located furthest from said base portion towards but not up to said base portion.

2. Diffuser according to claim 1, wherein the opening at the top of the diffuser has a cross-sectional surface greater than or equal to the surface of said base portion not covered by said side wall.

3. Diffuser according to claim 1 or claim 2, wherein the base portion is substantially planar or wherein the base portion is raised towards its centre.

4. Diffuser according to any one of the previous claims, wherein the outer side wall comprises exactly two flow outlets.

5. Diffuser according to claim 4, wherein the two flow outlets are arranged at diametrically opposed portions of said side wall.

6. Diffuser according to any one of the previous claims, wherein the flow outlets each extend to points at substantially half the distance between said base portion and the edge of said side wall which is located furthest from said base portion.

7. Diffuser according to any of the previous claims, wherein the side wall extends in an outwardly direction from said base portion, such that the top opening of the diffuser has a larger section than the base portion of the diffuser, and the internal volume of the diffuser is increased.

8. Diffuser according to claim 7, wherein the side wall forms an angle of 92 to 110 degrees with said base portion.

9. Diffuser according to any of the previous claims, wherein the extension of the outer side wall varies such that the edge of said side wall which is furthest away from said base portion is at least partially sloped.

10. Diffuser according to any of the previous claims, wherein the refractory material is a cast or pressed refractory material capable of withstanding prolonged contact with molten metal, such as molten steel.

11. Diffuser according to any of the previous claims, wherein the refractory material has an alumina content between 55% and 85% by weight.

12. Diffuser according to any of the previous claims, wherein the refractory material is an alumina-spinel or an alumina-magnesia refractory material.

13. Diffuser according to any of claims 1 to 10, wherein the refractory material is a basic refractory material with a magnesia content of between 55% and 95% by weight.

14. Diffuser according to any of the previous claims wherein the diffuser is for use in a tundish selected from the group consisting of V-shaped tundishes, B-shaped tundishes, T-shaped tundishes, C-shaped tundishes and H-shaped tundishes.

15. Use of a diffuser according to any of the previous claims in the process of pouring molten metal through a tundish.

16. Use according to claim 15, wherein flow of molten metal in the tundish is directed by the flow outlets in the diffuser.

17. Use according to claim 16 wherein the tundish does not include furniture items other than the said diffuser to control metal flow.

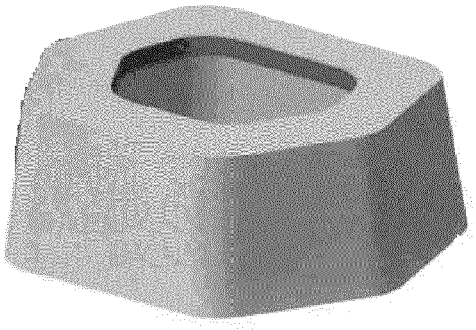

Fig. 1a

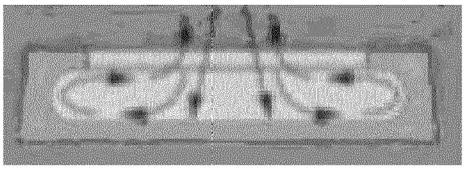

Fig. 1b

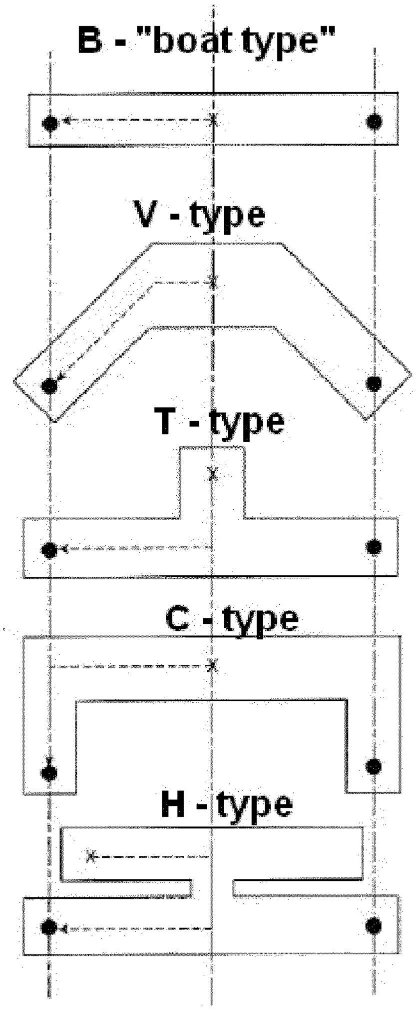

Fig. 2

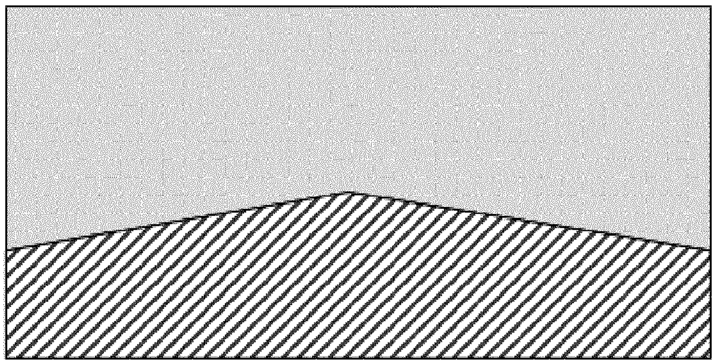

Fig. 3

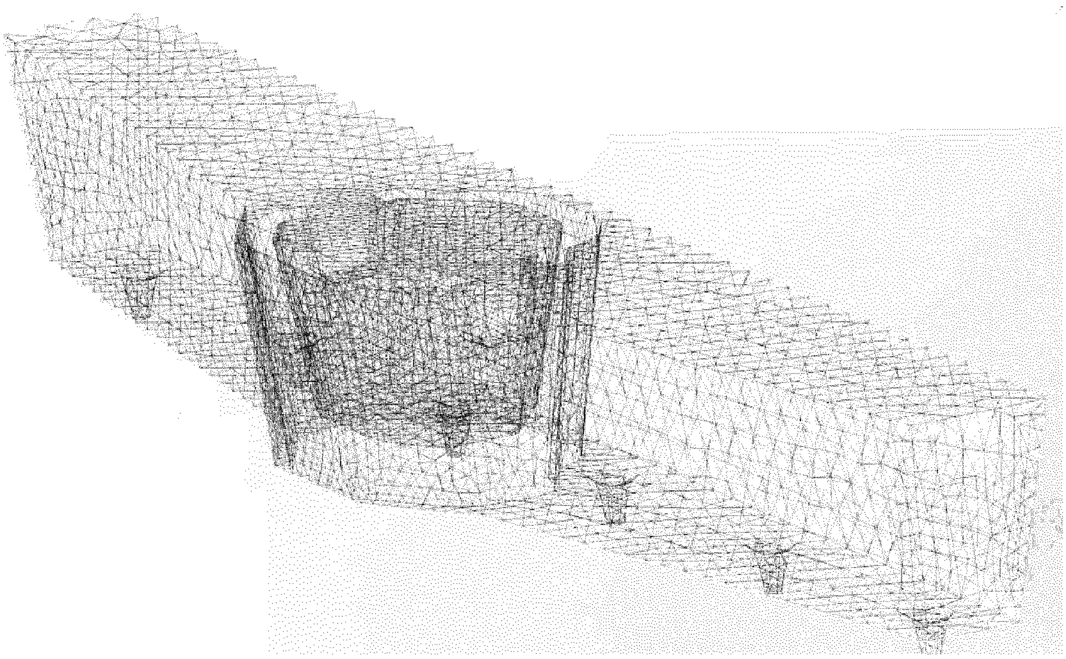

Fig. 4

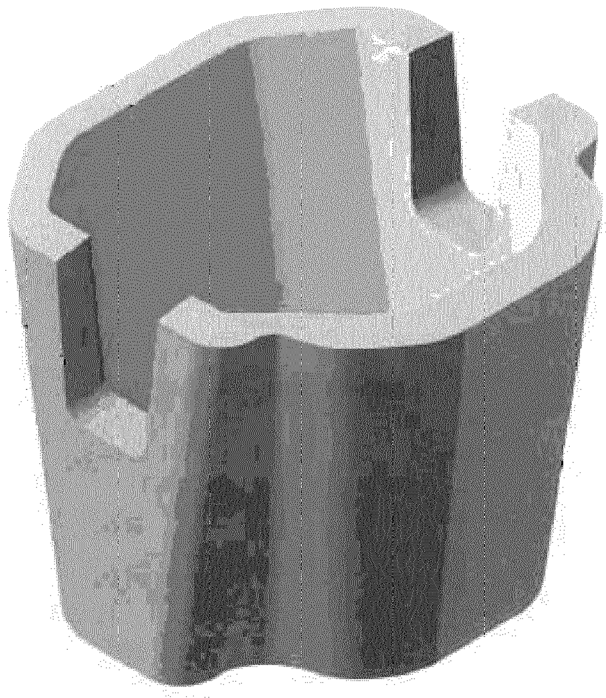

Fig. 5a

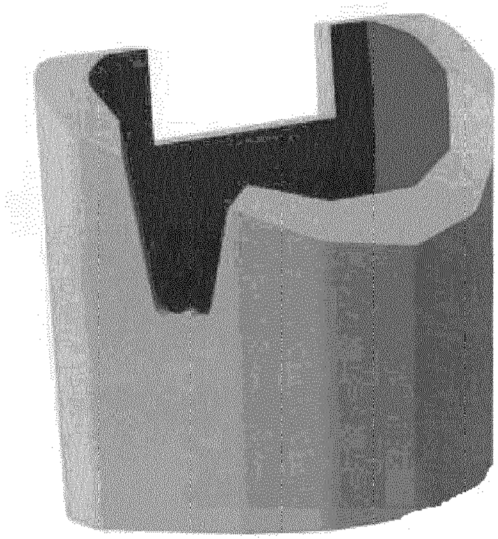

Fig. 5b

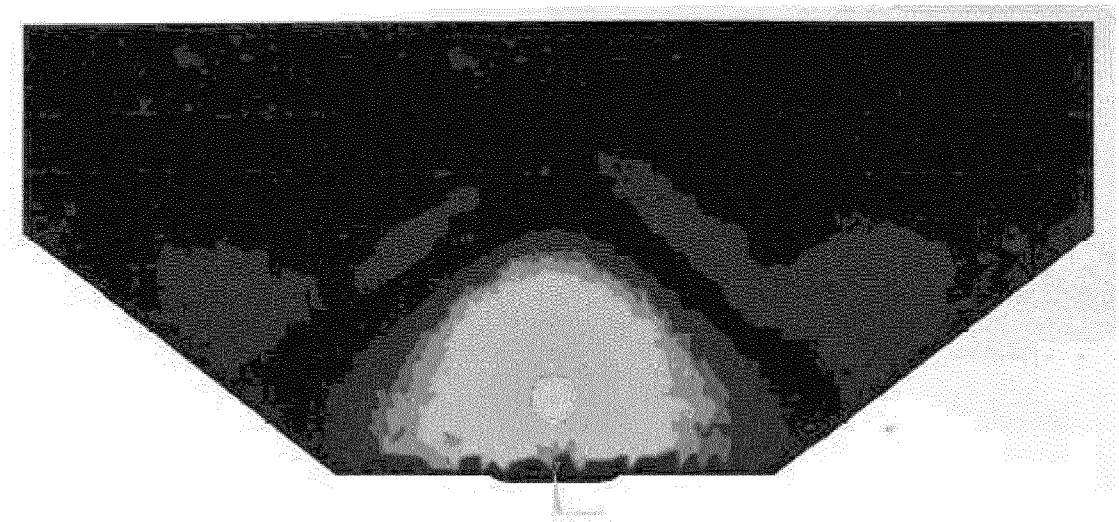

Fig. 6a

Fig. 6b

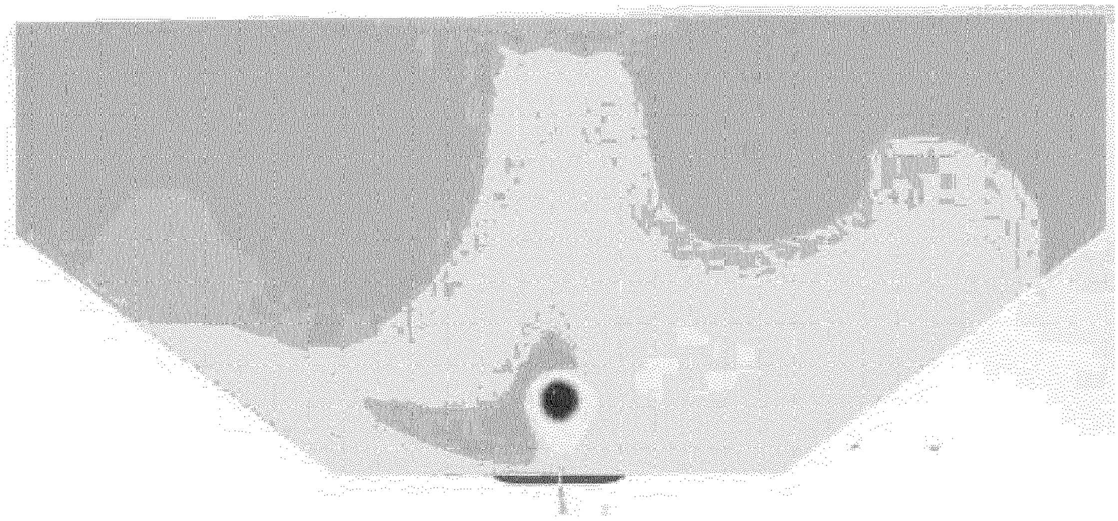

Fig. 7a

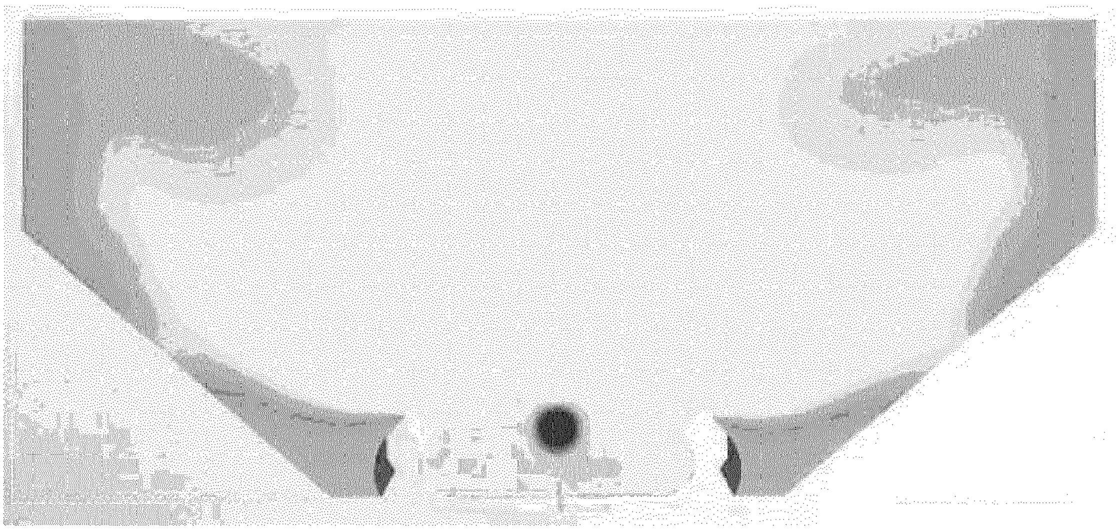

Fig. 7b

Fig. 8

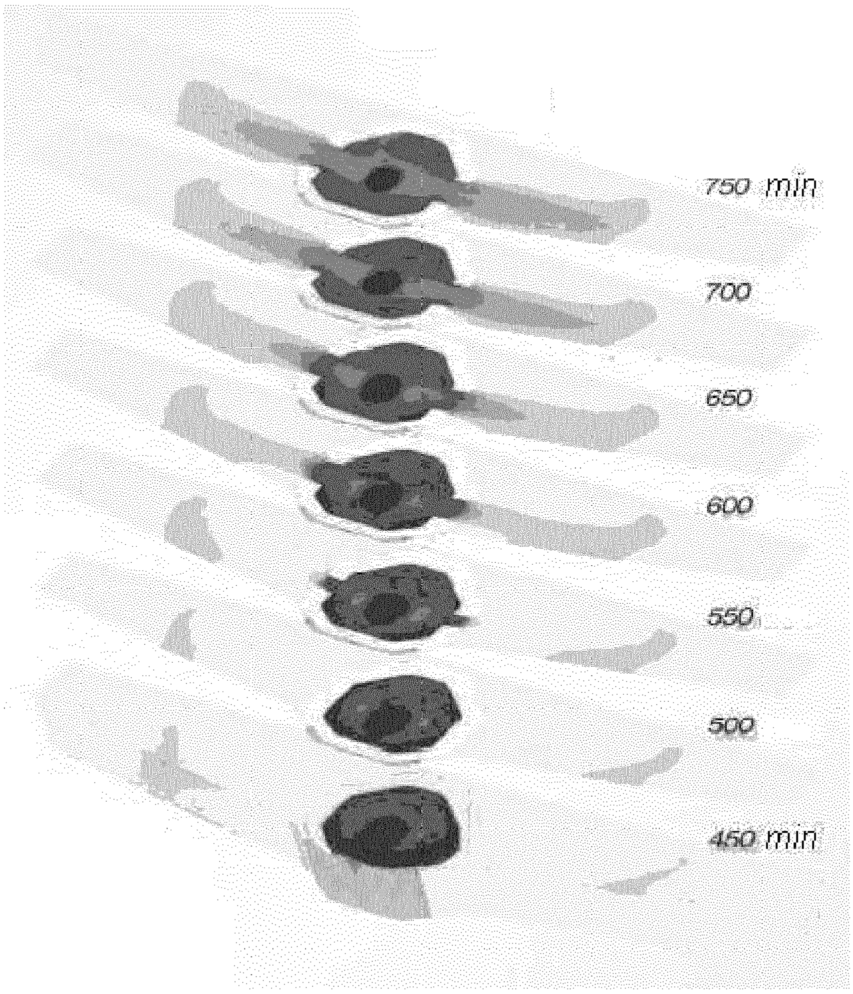

Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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