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(54) Title: CONTINUOUS CASTING EQUIPMENT

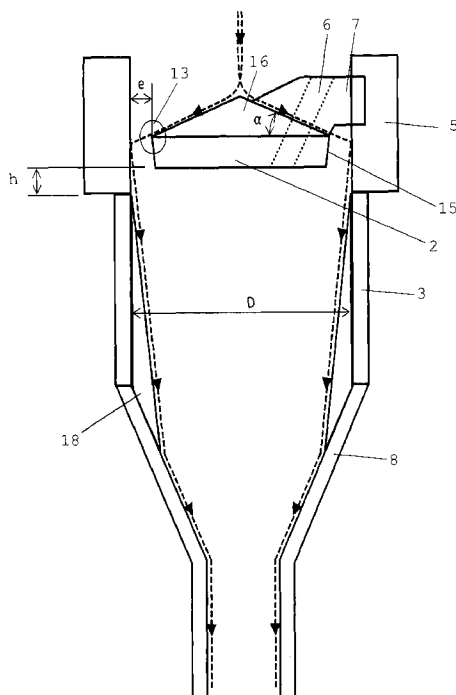


FIG. 2

(57) Abstract: The present invention relates to a continuous casting equipment for a flow of liquid metal from a tundish (1) into a mould (9), said equipment comprising: a vertical duct disposed upstream of the mould (9) with respect to the direction of travel of the liquid metal; said duct comprising from upstream to downstream a refractory ring (5), a copper tube (3) with an internal diameter D and a submerged entry nozzle (8), a dome (2) disposed inside the refractory ring (5) and comprising a sloped upper part (16), said upper part (16) being defined so as to deflect the liquid metal coming from the tundish (1) towards the inner walls of the vertical duct; characterized in that the diameter D of the copper tube (3) ranges between a minimum diameter equals to $Q/3.75$ and a maximum diameter equals to $Q/1.25$, where Q is the nominal liquid metal flow rate of the equipment and is comprised between 200 and 800 kg/min and D the diameter expressed in mm.



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CONTINUOUS CASTING EQUIPMENT

[0001] The invention relates to continuous casting equipment. In particular, the invention relates to continuous casting equipment, called Hollow Jet Nozzle, with an improved new design.

5 [0002] The continuous casting of steel is a well-known process. It consists of pouring a liquid metal from a ladle into a tundish intended to regulate the flow and then, after this tundish, in pouring the metal into the upper part of a water-cooled bottomless copper mould undergoing a vertical reciprocating movement. The
10 solidified semi finished product is extracted from the lower part of the mould by rollers. The liquid steel is introduced into the mould by means of a tubular duct called a nozzle placed between the tundish and the mould.

[0003] Document EP 0 269 180 B1 describes a specific continuous
15 casting equipment called "Hollow Jet Nozzle" (see reference figure 1) in which the liquid metal is poured onto the top of a dome 2 made of a refractory material. The shape of this dome 2 causes the metal to flow towards its periphery, the flow being deflected towards the internal wall of the nozzle or of an intermediate vertical tubular
20 member. Said intermediate vertical tubular member can be a copper tube 3 cooled by a water jacket 4 as illustrated in figure 1 and topped by a refractory ring 5. What is thus created, in the central part of the nozzle beneath the tundish member, is a volume without any liquid metal within which it is possible to carry out additions
25 via an injection channel. One or several support arms are located on the upper part of the dome 2 to secure it to said refractory ring 5. The water-cooled copper tube 3 forms a heat exchanger that extracts heat from the liquid steel. As a consequence, the superheat of the liquid steel is drastically reduced close or even below the liquidus
30 temperature.

[0004] A powder can be injected in the center of the hollow jet created by the refractory dome 2. This injection technique is

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disclosed in the document EP 0 605 379 B1. This powder injection aims to create an additional cooling of the liquid steel by the melting of the metallic powder or to modify the composition of the steel during casting by addition of other metallic elements such as ferro-alloys.

5 As disclosed in document EP 2 099 576 B1, the powder can be transported via a mechanical screw feeder and is fed by gravity through one of the support arms of the refractory dome and through the refractory dome itself.

[0005] In the present application the term HJN equipment will be
10 understood as describing the elements as described in figure 1 excepting the powder container 10 and the powder feeder 11.

[0006] During casting sequences using the HJN as previously described the equipment has to be frequently stopped because of the irregular flow of the liquid steel from the tundish 1 to the mould 9
15 and/or because of the irregular injection of powder, implying instability of the casting process and which could lead to the clogging of the HJN or to the clogging of the outlet of the powder injector.

[0007] Examples of the invention seek to provide continuous
20 casting equipment allowing a regular and stable casting process.

[0008] The present invention provides continuous casting equipment for a flow of liquid metal from a tundish into a mould, said equipment comprising:

25 a vertical duct disposed upstream of the mould with respect to the direction of travel of the liquid metal; said duct comprising from upstream to downstream a refractory ring, a copper tube with an internal diameter D and a submerged entry nozzle,

30 a dome disposed inside the refractory ring and comprising a sloped upper part, said upper part being defined so as to deflect the liquid metal coming from the tundish towards the inner walls of the vertical duct;

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the diameter D of the copper tube ranges between a minimum diameter equals to $Q/3.75$ and a maximum diameter equals to $Q/1.25$, where Q is the nominal liquid metal flow rate of the equipment and is comprised between 200 and 800 kg/min and D is the diameter expressed in mm,

wherein the slope α of the upper part of said dome ranges from 25 to 15°.

[0009] In further embodiments, taken alone or in combination the equipment may also comprise the following features:

the slope α of the upper part of said dome ranges from 30 to 10°;

said dome further comprises a lateral side extending from the upper part of the dome down to a bottom part of the dome, said lateral side forming at the intersection with the upper part a sharp fillet with a radius of curvature inferior to 2 mm;

the gap e between said sharp fillet and the refractory ring ranges from 10 to 25 mm;

the distance h between the bottom of the dome and the top of the copper tube ranges from 10 to 50 mm;

said upper part of the dome further comprises at least a support arm with a fixing part to secure said dome to the refractory ring, said fixing part having a width C ranging from 10 to 60 mm;

said at least support arm comprises an additional part extending from the fixing part along the lateral side of the dome, said part being designed so that it directs the flow of liquid metal around the support arm and below said arm;

said additional part has converging lateral walls;

the dome is made up of high alumina.

[0010] Examples of the present invention also disclose a continuous casting process of a liquid metal at a nominal flow rate of Q comprised between 200 and 800 kg/min using an equipment as described above including a copper tube with an internal diameter D which has a value ranging between a minimum diameter equal to $Q/3.75$

and a maximum diameter equal to $Q/1.25$.

[0011] The inventors discovered that the perturbations in the casting process are linked to an inappropriate design of the hollow jet nozzle.

5 [0012] The present invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings briefly described below.

Figure 1 is a section view of the continuous casting equipment according to the prior art.

10 Figure 2 is a section view of the continuous casting according to an embodiment of the invention.

Figure 3 is a top view of the dome according to an embodiment of the invention. A section view of the dome according to the axis AA-AA is also represented.

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Figure 4 is a top view of the dome according to another embodiment of the invention. A section view of the dome according to the axis AA-AA is also represented.

Figure 5 is a section view and a side view of the dome
5 according to another embodiment of the invention.

Legend:

- (1) Tundish
- (2) Refractory dome
- 10 (3) Copper tube
- (4) Water cooling jacket
- (5) Refractory ring
- (6) Feeding tube
- (7) Support arm
- 15 (8) Submerged entry nozzle
- (9) Mould
- (10) Powder container
- (11) Powder feeder
- (12) Additional part
- 20 (13) Fillet of the refractory dome
- (14) Fixing part of the support arm
- (15) Lateral side of the dome
- (16) Upper part of the dome
- (17) Bottom part of the dome
- 25 (18) Skull

[0013] As previously explained, and as can be seen on figure 2, the principle of the Hollow Jet Casting process lies notably on the fact that the water-cooled
30 copper tube 3 extracts the heat from the liquid steel. This heat extraction creates a layer of solidified steel on the copper tube; this layer is called the skull 18. The liquid steel then flows inside the nozzle along this solidified skull 18 (the flow of the liquid steel is represented in

dotted lines). This solidified skull is essential for the process but must not be too large compared to the diameter D of the copper tube 3 because of a risk of clogging of the nozzle which would disturb the liquid steel flow.

5 [0014] In order to maximize the heat extracted by the copper tube and to reduce the risk of clogging of the nozzle, the inventors discovered that said diameter D has to be chosen in function of the nominal steel flow rate of the continuous casting equipment. An adequate ratio between the nominal steel flow rate and the diameter D
10 ensures a stable formation of a homogeneous and thin layer of liquid steel along the copper tube. According to examples of the invention, the diameter D has to be selected between a minimum diameter of $Q/3.75$ and a maximum diameter of $Q/1.25$ ($Q/3.75 \leq D \leq Q/1.25$), where Q is the nominal steel flow rate in kg/min comprised between 200 to
15 800 kg/min and D the diameter in mm. For example, a diameter D of 195 mm can be selected for a nominal steel flow rate of 400 kg/min. As a result, the average heat flux extracted by the heat exchanger is of 0.9 MW/m^2 for a steel superheat in the tundish of 30°C .

[0015] A major improvement is already observed when the diameter
20 D respects the above mentioned range, but in addition, one or several of other criteria can be fulfilled to further improve the regularity of the liquid flow and of the powder injection in the continuous casting equipment according to examples of the invention.

[0016] As illustrated in figure 3 the dome 2 includes an upper
25 part 16 with a slope α which receives and deflects the liquid steel towards the wall of the copper tube to create the hollow jet, a bottom part 17 which allows to inject the powder as close as possible to the center of said hollow jet, and one or several support arms 7 designed to secure the dome 2 to the refractory ring.

30 [0017] The slope α of the refractory dome 2 is designed in order to ensure a good and stable impact of the liquid steel jet on the vertical refractory ring 5 and to reduce the perturbation of the

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liquid steel over the dome 2. According to examples of the invention, the slope ranges from 30 to 10°, preferably from 25 to 15° and, more preferably, the slope is of 20°.

[0018] In addition, the fillet 13, as illustrated in figure 3, formed by the junction of the upper part 16 and the lateral side 15 of the bottom part 17 of the dome 2 is preferably sharp to insure a rectilinear and straight steel flow when the liquid metal flows out of the upper part of the dome and to ensure thereby a good impact of the steel on the refractory ring. Preferably, the curvature radius of the fillet 13 is inferior to 2 mm and, more preferably, to 1 mm. The material of the dome has to be strong enough so as to keep this fillet sharp during the whole casting sequence. Preferably, the dome 2 is made up of high alumina material.

[0019] The gap e, as illustrated in figure 2, between the dome 2 and the vertical refractory ring 5 has also an impact over the liquid flow. This gap e must be large enough to avoid the formation of steel plugs between the dome 2 and the vertical refractory ring 5 but not too large. If this gap is too large, the liquid steel cannot reach the refractory ring 5. According to examples of the invention, the gap e between the fillet 13 of the dome 2 and the vertical refractory ring 5 ranges from 10 to 25 mm, preferably from 13 to 20 mm and, more preferably, the gap is of 15 mm.

[0020] It is also advantageous to foresee a minimum distance h, as illustrated in figure 2, between the bottom

of the refractory dome 2 and the top of the copper tube 3 in order to avoid problems of clogging at the exit of the gap between the dome 2 and the refractory ring 5 and to avoid problems of non desired solidification of liquid steel below the dome 2 which could disrupt the good injection of the powder in the centre of the nozzle. This distance h ranges from 10 to 50 mm, preferably from 15 to 35 mm, and, more preferably, is of 30 mm.

[0021] The support arm(s) of the dome can also disrupt the liquid flow under the dome, what can lead to a non desired solidification of liquid steel below the dome. This uncontrolled solidification can interfere with the injected powder and disrupt the powder supply in the hollow jet. The number, the dimensions and the shape of said support arms have to be chosen to avoid these problems.

[0022] The number of arms can vary between one as shown in figure 4 and six (not represented) always to insure a good flow of the liquid steel from the tundish to the copper tube. The preferred configuration is the configuration with three arms. In this configuration, the liquid flow is symmetrically deflected by the dome and the load on the arms is well distributed.

[0023] As illustrated in the section view of figure 3 the support arm 7 is disposed on the upper part 16 of the dome 2. It extends from the center of this upper part up to an area outside of the dome 2. The support arm 7 comprises a fixing part 14 disposed in the area outside of the dome 2 and defined to secure the support arm 7 to the refractory ring of the vertical duct.

[0024] This fixing part 14 has a width C which has to be kept as small as possible in order to maximize the steel flow area along the copper tube circumference while keeping a good support function. The width C can vary between 10 and 60 mm depending on the number of arms. For

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example, in a configuration with three arms like in figure 3, the width C of the arm is of 40 mm. These arms are separated by an arc length S always equal between two arms in order to insure a symmetrical flow of the liquid steel. The steel flow area is then equals to three times the arc length S separating two arms.

[0025] In figures 3 and 4, the support arm 7 only extends on the upper part 16 of the dome 2. In this configuration, the steel flow is disturbed by the arm 7 and an area without liquid steel is formed below the arm 7. To direct the flow of liquid steel around the arm 7 and below this arm as shown in figure 5, the support arm 7 can comprise an additional part 12 extending from the fixing part 14 along the lateral side 15 of the dome 2. The shape of this additional part 12 is designed so that the liquid metal flowing around the arm tends to converge below the arm. Preferably, this additional part 12 has converging lateral walls. This design improves the homogeneity of the liquid steel flow along the copper tube circumference and maximizes the heat extracted by the heat exchanger.

[0026] The present invention has been illustrated for continuous casting of steel but can be extended to casting of other metals or metal alloys, such as copper.

[0027] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0028] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common

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general knowledge in the field of endeavour to which this specification relates.

[0029] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Continuous casting equipment for a flow of liquid metal from a tundish into a mould, said equipment comprising:

a vertical duct disposed upstream of the mould with respect to the direction of travel of the liquid metal; said duct comprising from upstream to downstream a refractory ring, a copper tube with an internal diameter D and a submerged entry nozzle,

a dome disposed inside the refractory ring and comprising a sloped upper part, said upper part being defined so as to deflect the liquid metal coming from the tundish towards the inner walls of the vertical duct;

the diameter D of the copper tube ranges between a minimum diameter equals to $Q/3.75$ and a maximum diameter equals to $Q/1.25$, where Q is the nominal liquid metal flow rate of the equipment and is comprised between 200 and 800 kg/min and D is the diameter expressed in mm,

wherein the slope α of the upper part of said dome ranges from 25 to 15°.

2. Continuous casting equipment according to claim 1, wherein said dome further comprises a lateral side extending from the upper part of the dome down to a bottom part of the dome, said lateral side forming at the intersection with the upper part a sharp fillet with a radius of curvature inferior to 2 mm.

3. Continuous casting equipment according to claim 2, wherein the gap e between said sharp fillet and the refractory ring ranges from 10 to 25 mm.

4. Continuous casting equipment according to claims 2 or 3, wherein the distance h between the bottom of the dome and the top of the copper tube ranges from 10 to 50 mm.

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5. Continuous casting equipment according to any one of the preceding claims, wherein said upper part of the dome further comprises at least a support arm with a fixing part to secure said dome to the refractory ring, said fixing part having a width C
5 ranging from 10 to 60 mm.

6. Continuous casting equipment according to claim 5, wherein said at least support arm comprises an additional part extending from the fixing part along the lateral side of the dome, said part being
10 designed so that it directs the flow of liquid metal around the support arm and below said arm.

7. Continuous casting equipment according to claim 6, wherein said additional part has converging lateral walls.
15

8. Continuous casting equipment according to any one of the preceding claims, wherein the dome is made up of high alumina.

9. Continuous casting process of a liquid metal at a nominal flow rate of Q comprised between 200 and 800 kg/min using an equipment
20 according to claims 1 to 8 including a copper tube with an internal diameter D which has a value ranging between a minimum diameter equal to $Q/3.75$ and a maximum diameter equal to $Q/1.25$.

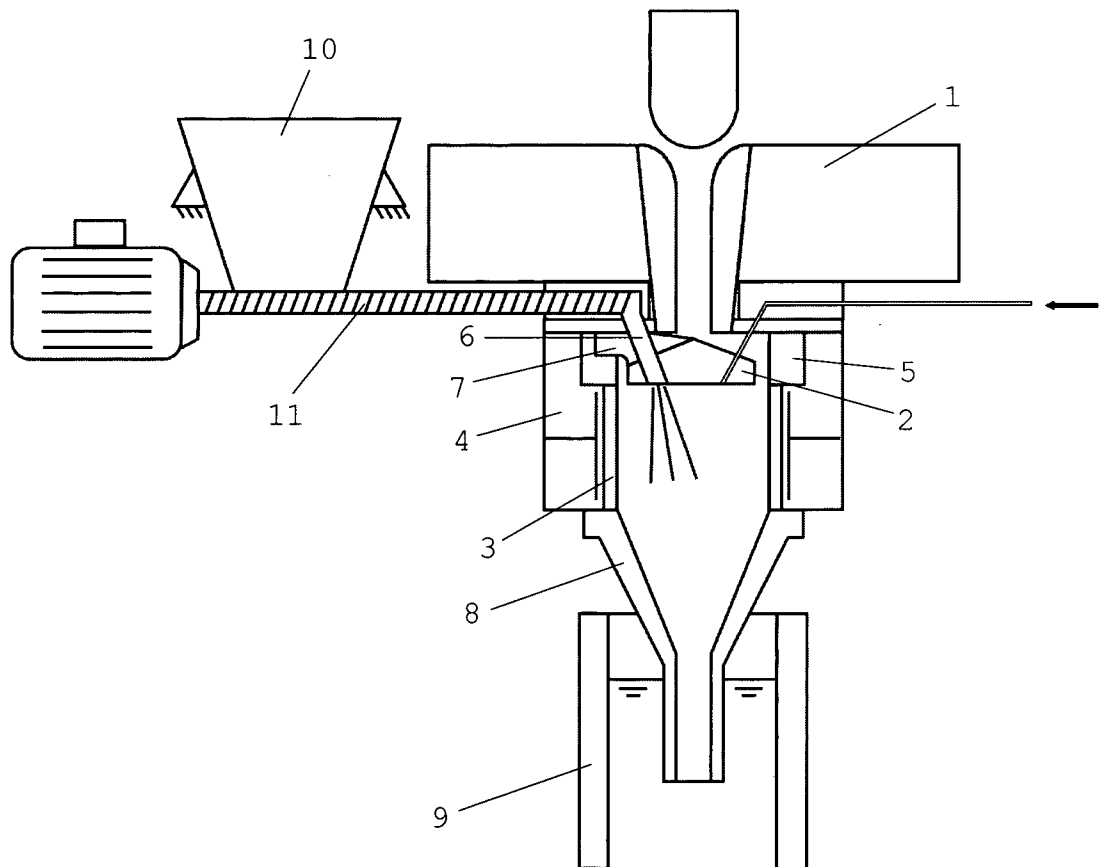


FIG. 1

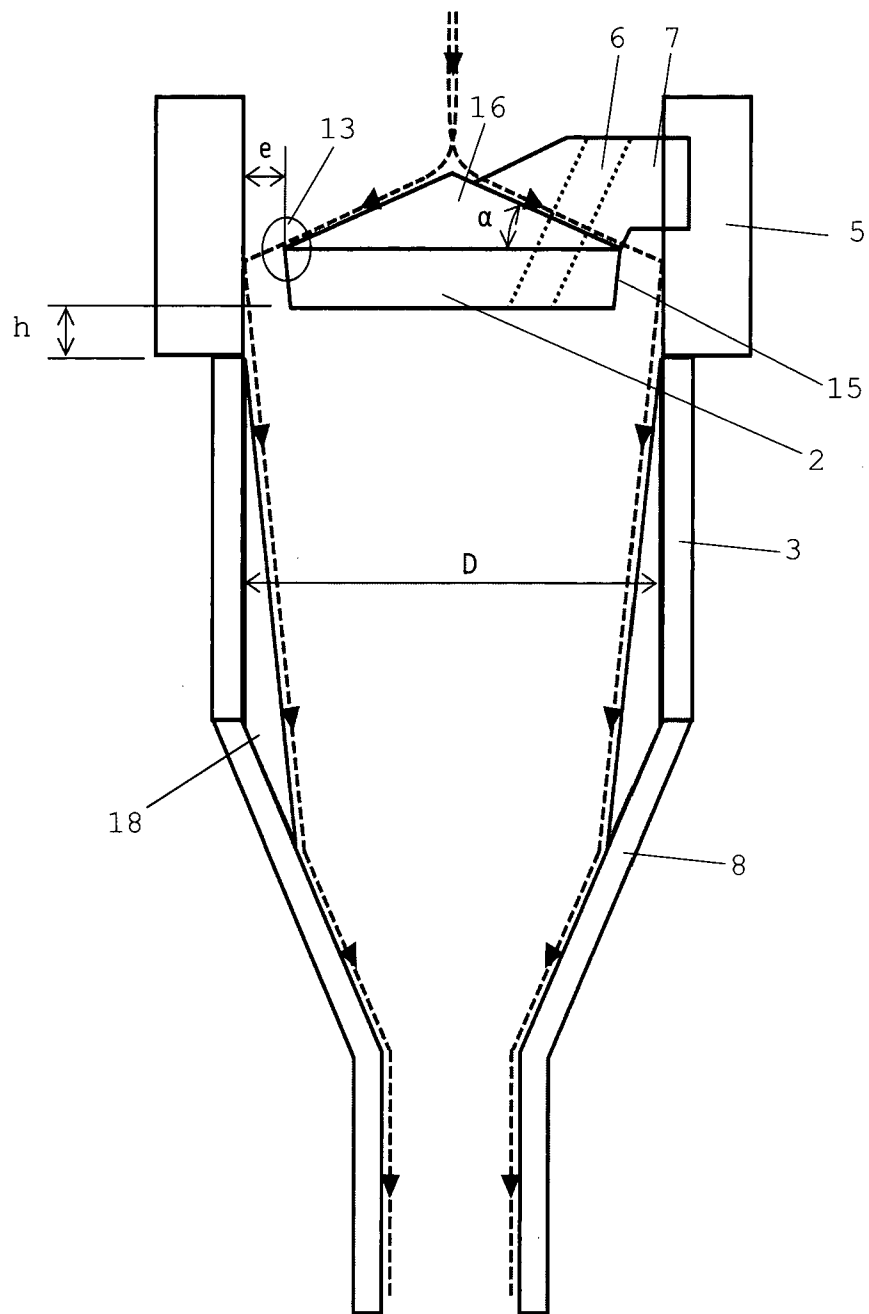


FIG. 2

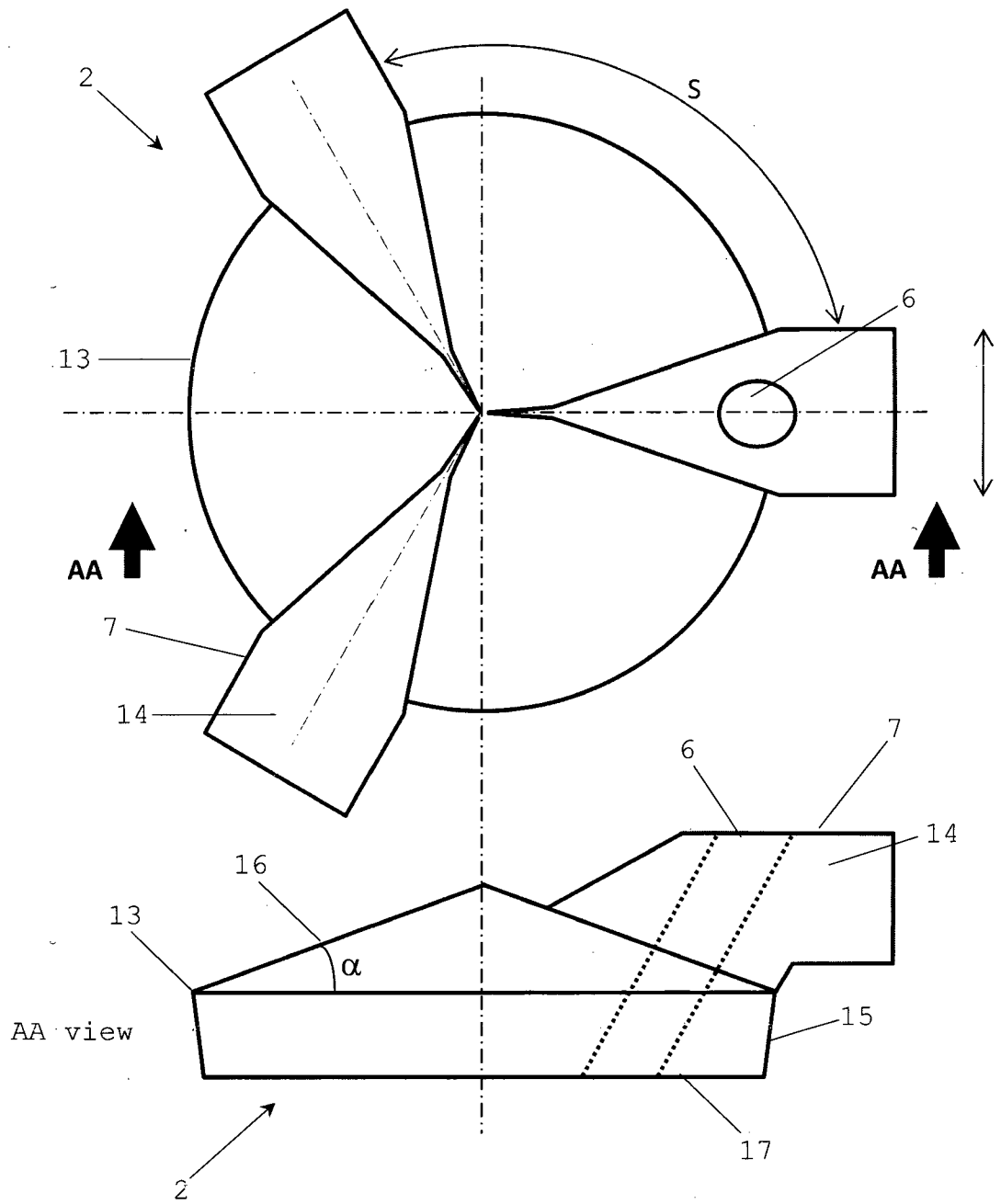


FIG. 3

