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(71) Applicant: **ARCELORMITTAL** [LU/LU]; 24-26, Boulevard d'Avranches, L-1160 LUXEMBOURG (LU).

(72) Inventors: **NAVEAU, Paul**; Allée des fauvettes, 16, 4432 Ans (BE). **PIRLOT, Nicolas**; Rue collée N°10, 4031 Angleur (BE).

(74) Agent: **PLAISANT, Sophie**; ArcelorMittal France, Research & Development, Intellectual Property, 6 rue André Campra, 93200 Saint-Denis (FR).

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(54) **Title:** CONTINUOUS CASTING EQUIPMENT

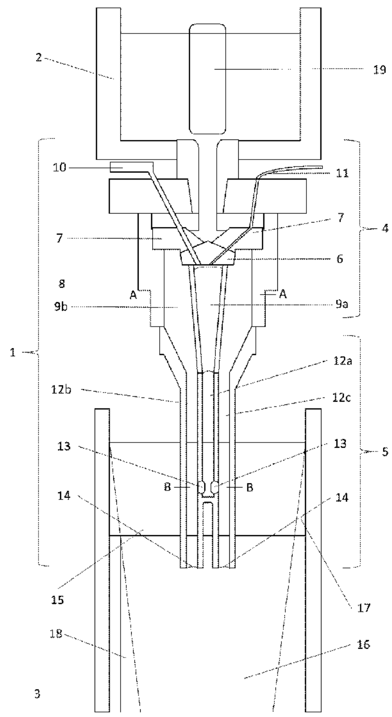

FIG 1

(57) **Abstract:** The invention relates to a continuous casting nozzle for manufacturing a composite metallic product, said nozzle being located between a tundish and a mold, comprising: − an upper part disposed downstream of the tundish, − a dome disposed at the inlet of the upper part comprising means for splitting the initial stream of liquid metal, − an internal wall located below the dome, creating at least two chambers, − means for injecting powder through the dome to allow mixing with the liquid metal, − a lower part composed of at least a central channel and side channels allowing the liquid metal to flow into the mold through at least one outlet for each channel, wherein said side channels are longer than said central channel. The invention also relates to a method of continuously casting, using a continuous casting nozzle related to the invention.

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CONTINUOUS CASTING EQUIPMENT

[0001] The invention relates to a continuous casting equipment. In particular, the invention relates to a continuous casting nozzle, with an improved design, made for manufacturing a composite metallic product.

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

[0003] However, this simple equipment is not suitable for the casting of a composite metallic product. The nozzle being a simple duct, it can only be used as a pouring tool for the liquid metal between the tundish and the mold. Therefore, the nozzle and the method of casting must be modified to allow the casting of a composite metallic product.

[0004] Japanese Patent Application JP11197807 describes a continuous casting nozzle for manufacturing a multilayer cast piece, being formed of a vertical duct having multiple discharge ports in the vertical direction, the duct being divided on the inside by a partition wall creating multiple molten steel flow passages and having one or multiple ports for adding raw material.

[0005] The continuous casting nozzle described allows the injection of two types of molten metals, differing in composition, into the mold at different heights thus creating two pools of liquid metal, an upper pool and a lower pool, differing by their respective composition. The metal located in the upper pool solidifies first, creating a shell having the composition of the upper pool. The metal located in the lower pool solidifies then inside the shell, forming the bulk of the material and having the composition of the lower pool, thus creating a composite metallic product.

[0006] When manufacturing a composite metallic product by continuous casting, to obtain a product of excellent quality, it is necessary to reach a very good stability of the two pools of liquid metal into the mold and the streams of liquid metal coming from the nozzle.

[0007] Japanese Patent Application JP11197807 uses a static magnetic field and injects the different streams of liquid metal above and below the magnetic field to stabilize the two pools.

[0008] However the solution proposed in the prior art does not provide a sufficient solution in terms of stability of the different streams of liquid metal and the specific magnetic field brings complexity to the casting operations.

[0009] The present invention discloses a continuous casting nozzle for manufacturing a composite metallic product with an improved design, allowing better stability of the liquid metal streams with a simple equipment.

[0010] A first object of the invention is a continuous casting nozzle for manufacturing a composite metallic product, said nozzle 1 being located between a tundish 2 and a mold 3, said nozzle 1 comprising:

- an upper part 4 disposed downstream of the tundish 2 with respect to the direction of travel of the liquid metal,
- a dome 6 disposed at the inlet of the upper part 4, said dome 6 comprising means for splitting the initial stream of liquid metal into at least two separate streams,
- an internal wall 8 located below the dome 6, creating at least two chambers 9a, 9b, said separate streams of liquid metal flowing respectively in each of said chambers 9a, 9b,
- means for injecting powder 10 through the dome 6 into at least one of said chambers 9a, 9b, to allow mixing with the liquid metal flowing into said chamber 9a, 9b,
- a lower part 5 composed of at least a central channel 12a and side channels 12b, 12c, extending from the upper part 4 into the mold 3, said channels 12a, 12b, 12c allowing the liquid metal to flow into the mold 3 through at least one outlet 13, 14 for each channel 12a, 12b,

12c, wherein said central channel 12a is connected to one of said chambers 9a, 9b, and said side channels 12b, 12c are connected to at least one other chamber 9b, said side channels 12b, 12c being longer than said central channel (12a).

[0011] The continuous casting nozzle according to the invention may also have the optional features listed below, considered individually or in combination:

- the central channel 12a has at least two outlets 13,
- the central channel 12a has at least four lateral outlets 13 being located on the same horizontal plan,
- the lateral outlets 13 of said central channel 12a have their axis positioned towards a median zone of the faces of the mold 3,
- the dome 6 further comprises at least one mean for injecting gas 11 through the dome 6,
- the dome further comprises support arms 7,
- the means for injecting powder 10 and the means for injecting gas 11 are partly located into said support arms 7.

[0012] A second object of the invention is a method of continuous casting of a composite metallic product, using a continuous casting nozzle 1 according to the invention wherein:

- liquid metal is poured in a tundish 2 located above said continuous casting nozzle 1,
- said liquid metal flows from the tundish 2 into the upper part 4 of said casting nozzle 1 creating an initial stream,
- said initial stream collides onto the dome 6, thus separating it into a defined number of separate streams,
- said separate streams flow into the chambers 9a, 9b of the nozzle 1,
- powder is injected into one of said chambers 9a, 9b, and mixed with the stream of liquid metal flowing into said chamber 9a, 9b, thus modifying its composition,
- said separate streams are then distributed into the channels 12a, 12b, 12c of the lower part of said continuous casting nozzle 1,

- said liquid metal is poured into the mold 3 by the outlets 13, 14 of said channels 12a, 12b, 12c, wherein the liquid metal flowing in the side channels 12b, 12c is poured deeper into the mold 3 than the liquid metal flowing into the central channel 12a, thus forming two distinct pools 14, 15 of liquid metal into the mold 3.

[0013] The method of continuous casting according to the invention may also have the optional features listed below, considered individually or in combination:

- the liquid metal is steel,
- the powder is injected in the chamber connected to the central channel 12a,
- the liquid metal in the upper pool 15 in the mold 3 is composed of the base metal coming from the tundish 2 mixed with the powder injected below the dome 6 and the liquid metal in the lower pool 16 in the mold 13 is composed of the base metal coming from the tundish 2 only,
- the powder is injected in at least one chamber connected to the side channels 12b, 12c,
- the liquid metal in the upper pool 15 in the mold 3 is composed of the base metal coming from the tundish 2 only and the liquid metal in the lower pool 16 in the mold 3 is composed of the base metal coming from the tundish 2 mixed with the powder injected below the dome 6.

[0014] The invention will be described, in a non-limitative way, in reference to the following drawings:

- Fig 1: general view of the nozzle according to the invention, in a usage configuration,
- Fig 2: view of the bottom of the lower part of the nozzle
- Fig 3: dome observed with a view from above for a bulk alloying embodiment
- Fig 4: dome observed with a view from above for a shell alloying embodiment
- Fig 5: cross-sectional view A-A of the upper part of the nozzle below the dome of Fig 1

- Fig 6: cross-sectional view B-B of the lower part of the nozzle into the mold with a representation of the flows
- Fig 7: submerged part of the nozzle with representation of the flows in the mold
- Fig 8: section of the composite metallic product obtained by continuous casting

[0015] Fig 1 shows a nozzle 1 disposed between a tundish 2 and a mold 3. The nozzle is composed of an upper part 4 and a lower part 5.

[0016] A dome 6 is disposed at the inlet of the upper part 4 and closes a part of it. The top of the dome 6 preferably has a slope of a certain angle, higher than 15° for example. The dome 6 also has a lateral side, preferably forming a sharp edge with the slope. The dome 6 is fixed to the upper part 5 by one or more support arms 7.

[0017] An internal wall 8, located below the dome 6, creates at least two chambers 9a, 9b in the upper part 4. In the configuration presented in Fig 1, two chambers are present 9a, 9b.

[0018] A means for injecting powder 10 and a means for injecting gas 11 are also comprised in the upper part 4, each one being partly located in one of the support arms 7 and passing through the dome 6. The means for injecting powder 10 can be an endless screw, for example, linked to a powder tank.

[0019] Fig 3 shows a configuration of the dome 6 having three support arms 7 and having one passage for powder injection 10 located in one of the support arms 7 and two passages for gas injection 11 located in the other two support arms 7.

[0020] Fig 4 shows another configuration of the dome 6 also having three support arms 7 but unlike the one represented in Fig 3, it has two passages for powder injection 10 located in two support arms 7 and one passage for gas injection 11 located in the other support arm 7. In this configuration, the two passages for powder injection 10 can be linked to two different powder injectors, each one having a different type of powder.

[0021] The dome 6 can also have other configurations with less or more support arms. A configuration with four support arms 7, for example, can be considered.

[0022] As shown on Fig 1, the lower part 5 of the nozzle 1 is composed of three channels 12a, 12b, 12c extending from the chambers 9a, 9b of the upper part 4 and ending into the mold 3, comprising at least one outlet 13 for each channel 12a, 12b, 12c. In this configuration, the side channels 12b, 12c are opened into the mold 3 by means of one bottom outlet 14 for each channel and the central channel 12a is opened into the mold by means of at least two outlets 13. Fig 2 shows an enlarged view of one side of the bottom of the lower part 5 of the nozzle 1 for the configuration shown in Fig 1. The axes of the lateral outlets 13 form an angle β with respect to the horizontal. The angle β is preferably from 0° to 20°. The angle is oriented downwards.

[0023] In the present embodiment, the channels 12a, 12b, 12c are of circular shape. In a preferred embodiment, the side channels 12b, 12c have a triangular section with round angles. In a preferred embodiment, the central channel has an oblong section and has four outlets 13 positioned on the same horizontal plan, two outlets being located on one side of the nozzle and the other two outlets being located on the other side of the nozzle. This configuration causes the axes of the lateral outlets 13 to be positioned towards a median zone of the mold faces. The preferred configuration is shown on Fig 6.

[0024] Fig 5 shows the cross-sectional view A-A of the nozzle 1 in the configuration described in Fig 1. Fig 3 and Fig 4 are disposed with the same orientation than Fig 5. Fig 3 can be superposed with Fig 5 to have a cross-sectional view of the nozzle 1 above the dome 6. The same can be applied to Fig 4 with Fig 5 to obtain the view of another configuration.

[0025] As shown in Fig 5, the internal wall 8 has a V-shape, thus creating two chambers 9a, 9b of different volumes. The chamber located inside the V-shape 9a is linked to the central channel 12a and the chamber located outside the V-shape 9b is linked to the side channels 12b, 12c.

[0026] In other configurations, the internal wall 8 have a different shape and create a different number of chambers. For example, a Y-shape can create three chambers of different volumes, or a simple wall can create two chambers with the exact same volume.

[0027] As shown of Fig 1, the side channels 12b, 12c are longer than the central channel 12a thus opening deeper into the mold 3. In this embodiment, the three channels are aligned, as shown on Fig 5.

[0028] Other configurations can be considered, for example, a third side channel, not aligned with the other channels 12a, 12b, 12c, can be added, thus creating another geometry.

[0029] In a preferred embodiment, the ratio between the lateral outlets 13 diameter and the distance between the lateral outlets 13 and the mold 3 is more than 0.5 and less than 1.

[0030] In a preferred embodiment, the ratio between the lateral outlets 13 diameter and the central channel 12a diameter is more than 1.8 and less than 2.2.

[0031] The invention has two preferred embodiments for its usage named respectively bulk alloying and shell alloying. Only the differences between the two preferred embodiments will be described separately. The invention in a usage configuration is shown in Fig 1.

[0032] A liquid metal of a defined composition is poured from a ladle into a tundish 2. In a preferred embodiment, the liquid metal is steel and the usage of the nozzle 1 will be described with it. The steel flows into the upper part 4 of the continuous casting nozzle 1, thus creating an initial stream. A stopper rod 19 allows the control of the initial flow rate.

[0033] The dome 6, being placed in the trajectory of the steel, forces the initial stream to collide on it. The slope of the dome 6 makes the steel flow towards its edge. The support arms 7 create different areas on the dome 6, dividing the steel into a plurality of separate streams. The number of separate streams is determined by the design of the dome 6 and its support arms 7. In this specific embodiment, the number of separate streams is three.

[0034] The separate streams flow then into the different chambers 9a, 9b. In this configuration, a part of the streams flows into the chamber inside the V-shape 9a and the other part flows into the chamber outside the V-shape

9b. Powder is injected at the same time into one of the chambers 9a, 9b. The design of the chambers allows the steel to be slowed down and to accumulate in the chambers 9a, 9b. In consequence, the powder can be mixed efficiently with the steel into said chamber 9a, 9b to modify its composition, and starts melting.

[0035] The powder injected into the steel can be of various composition, for example, it can be FeSi, Ni, FeAl, FeTi, FeCr, FeNb, FeB, FeCe, FeMo, etc…

[0036] The step of powder addition is different between the two preferred embodiments. For the bulk alloying embodiment, the powder is injected in the chamber outside the V-shape 9a by means of at least one powder injection 10, Fig 3 shows only one injection, whereas for the shell alloying embodiment, the powder is injected in the chamber inside the V-shape 9b by means of at least one powder injection 10, Fig 4 shows two powder injections.

[0037] In both embodiments, the injection of powder is facilitated by a gas injection 11 that creates a gas flow which maintains the steel flowing down the dome 6 towards the exterior of the upper part 4, thus creating a zone below the dome 6 without steel. This hollow zone prevents any contact between the steel and the powder injection 10 thus avoiding potential clogging of the powder injection 10.

[0038] The gas is preferably non-oxidizing, Ar for example, to prevent any reaction with the steel during casting.

[0039] After the injection, the two chambers 9a, 9b contain two types of steel with different composition.

[0040] The steels flow then into the channels 12a, 12b, 12c of the lower part 5 of the nozzle 1. The steel in the chamber located inside the V-shape 9a flows into the central channel 12a and the steel in the chamber located outside the V-shape 9b flows into the side channels 12b, 12c. The different steels are then poured into the mold 3 through the outlets 13, 14 of the channels 12a, 12b, 12c.

[0041] The steel from the side channels 12b, 12c is poured deeper into the mold 3 due to the side channels 12b, 12c being longer than the central channel 12a. This configuration allows the two types of steels to be poured at different heights into the mold 3, thus creating two pools of steel, an upper pool 15 and a lower pool 16, different in composition. The upper pool 15 is formed by the steel coming from the central channel 12a and the lower pool 16 is formed by the steel coming from the side channels 12b, 12c.

[0042] The outlets 13, 14 of the nozzle 1 are submerged into the different pools of steel during usage. The bottom outlets 14 of the side channels 12b, 12c are submerged into the lower pool 16 and the lateral outlets 13 of the central channel 12a are submerged into the upper pool 15.

[0043] The composition of the pools is different according to the embodiment.

[0044] For the bulk alloying embodiment, the composition of the upper pool 15 is the composition of the steel coming from the tundish 2 only. The composition of the lower pool 16 is the combination of the composition of the steel coming from the tundish 2 and the composition of the powder injected.

[0045] For the shell alloying embodiment, the composition of the upper pool 15 is the combination of the composition of the steel coming from the tundish 2 and the composition of the powder injected. The composition of the lower pool 16 is the composition of the steel coming from the tundish 2 only.

[0046] In both embodiments, in the mold 3, the steel of the upper pool 15 solidifies first thus creating a shell 17. The steel of the lower pool 16 solidifies then inside the shell 17 thus creating the bulk 18 of the material. After full solidification, the material obtained is a composite metallic product with a composition different in its shell than in its bulk, as shown on Fig 8.

[0047] To cast a composite metallic product with sufficient quality, each pool must have a homogeneous composition and the boundary between them has to be stable. These elements are influenced by the behavior of the different streams of liquid metal coming from the nozzle 1.

[0048] The design of the nozzle 1, having at least four side outlets 13 with their axis being positioned towards the median zone of each mold face, allows the flows in the mold to be symmetrical in all directions, as shown in Fig 6, thus assuring the homogeneity of the two pools (15, 16).

[0049] These flows, created by the design of the nozzle, assure the stability of the boundary between the two pools of liquid metal (15, 16).

[0050] For example, in the configuration shown in Fig 7, the streams coming from the lateral outlets 13 create a main ascending flow 20 in the upper pool 15 as it meets the faces of the mold 3 and a secondary descending flow 21 with a smaller flow rate. In the meantime, the streams coming from the bottom outlets 15 create flows in the shape of a vortex 22 in the lower pool 16.

[0051] The design of the outlets can influence the stability of the boundary between the two pools and the homogeneity as they influence the initial direction and speed of the flows. A man skilled in the art will determine the characteristics of the outlets 13, 14 to optimize these parameters. Among the characteristics, the diameter of the outlet with respect to the diameter of the channel, the diameter of the outlet with respect to the distance between the outlets 13 and the mold 3 and the angle β of the outlet axes with respect to the horizontal can be considered.

[0052] In a preferred embodiment, the lateral outlets 13 axes have an angle β with respect to the horizontal between 0° and 20° as it allows to reach an optimum of stability of the two pools.

[0053] In a preferred embodiment, the ratio between the lateral outlets 13 diameter and the distance between the outlets 13 and the mold is more than 0.5 and less than 1.

[0054] In a preferred embodiment, the ratio between the lateral outlets 13 diameter and the central channel 12a diameter is more than 1.8 and less than 2.2.

[0055] In a preferred embodiment, the nozzle 1 is mainly composed of a refractory material surrounded by a metal ring.

[0056] In its usage configuration, the continuous casting nozzle 1 meets the expectations in terms of stability. It allows a stable casting speed and the different streams of liquid metal allow a great stability of the two pools into the mold 3. This stability results in a great quality of the semi-finished products with a well-defined gradient of composition between its shell and its bulk.

CLAIMS

1. Continuous casting nozzle (1) for manufacturing a composite metallic product, said nozzle (1) being located between a tundish (2) and a mold (3), said nozzle (1) comprising:
   - an upper part (4) disposed downstream of the tundish (2) with respect to the direction of travel of the liquid metal,
   - a dome (6) disposed at the inlet of the upper part (4), said dome (6) comprising means for splitting the initial stream of liquid metal into at least two separate streams,
   - an internal wall (8) located below the dome (6), creating at least two chambers (9a, 9b), said separate streams of liquid metal flowing respectively in each of said chambers (9a, 9b),
   - means for injecting powder (10) through the dome (6) into at least one of said chambers (9a, 9b), to allow mixing with the liquid metal flowing into said chamber (9a, 9b),
   - a lower part (5) composed of at least a central channel (12a) and side channels (12b, 12c), extending from the upper part (4) into the mold (3), said channels (12a, 12b, 12c) allowing the liquid metal to flow into the mold (3) through at least one outlet (13, 14) for each channel (12a, 12b, 12c), wherein said central channel (12a) is connected to one of said chambers (9a, 9b), and said side channels (12b, 12c) are connected to at least one other chamber (9b), said side channels (12b, 12c) being longer than said central channel (12a).
2. Continuous casting nozzle (1) according to claim 1, wherein said central channel has at least two outlets (13).
3. Continuous casting nozzle (1) according to claim 2, wherein said central channel has at least four lateral outlets (13) being located on the same horizontal plan.
4. Continuous casting nozzle (1) according to claim 3, wherein said lateral outlets (13) of said central channel (12a) have their axis positioned towards a median zone of the faces of the mold (3).

5. Continuous casting nozzle (1) according to any one of the preceding claims, wherein said dome (6) further comprises at least one mean for injecting gas (11) through the dome (6).
6. Continuous casting nozzle (1) according to any one of the preceding claims, wherein said dome further comprises support arms (7).
7. Continuous casting nozzle (1) according to claim 4 or 5, wherein the means for injecting powder (10) and the means for injecting gas (11) are partly located into said support arms (7).
8. A method of continuous casting of a composite metallic product, using a continuous casting nozzle (1) according to any one of the preceding claims wherein:
   - liquid metal is poured in a tundish (2) located above said continuous casting nozzle (1),
   - said liquid metal flows from the tundish (2) into the upper part (4) of said casting nozzle (1) creating an initial stream,
   - said initial stream collides onto the dome (6), thus separating it into a defined number of separate streams,
   - said separate streams flow into the chambers (9a, 9b) of the nozzle (1),
   - powder is injected into one of said chambers (9a, 9b) and mixed with the stream of liquid metal flowing into said chamber (9a, 9b) thus modifying its composition,
   - said separate streams are then distributed into the channels (12a, 12b, 12c) of the lower part of said continuous casting nozzle (1),
   - said liquid metal is poured into the mold (3) by the outlets (13, 14) of said channels (12a, 12b, 12c), wherein the liquid metal flowing in the side channels (12b, 12c) is poured deeper into the mold (3) than the liquid metal flowing into the central channel (12a), thus forming two distinct pools (15, 16) of liquid metal into the mold (3).
9. A method according to claim 8, wherein the liquid metal is steel.
10. A method according to claim 8 or 9, wherein the powder is injected in the chamber connected to the central channel (12a).

11. A method according to claim 10, wherein the liquid metal in the upper pool (15) in the mold (3) is composed of the base metal coming from the tundish (2) mixed with the powder injected below the dome (6) and the liquid metal in the lower pool (16) in the mold (13) is composed of the base metal coming from the tundish (2) only.
12. A method according to claim 8 or 9, wherein the powder is injected in at least one chamber connected to the side channels (12b, 12c).
13. A method according to claim 12, wherein the liquid metal in the upper pool (15) in the mold (3) is composed of the base metal coming from the tundish (2) only and the liquid metal in the lower pool (16) in the mold (3) is composed of the base metal coming from the tundish (2) mixed with the powder injected below the dome (6).

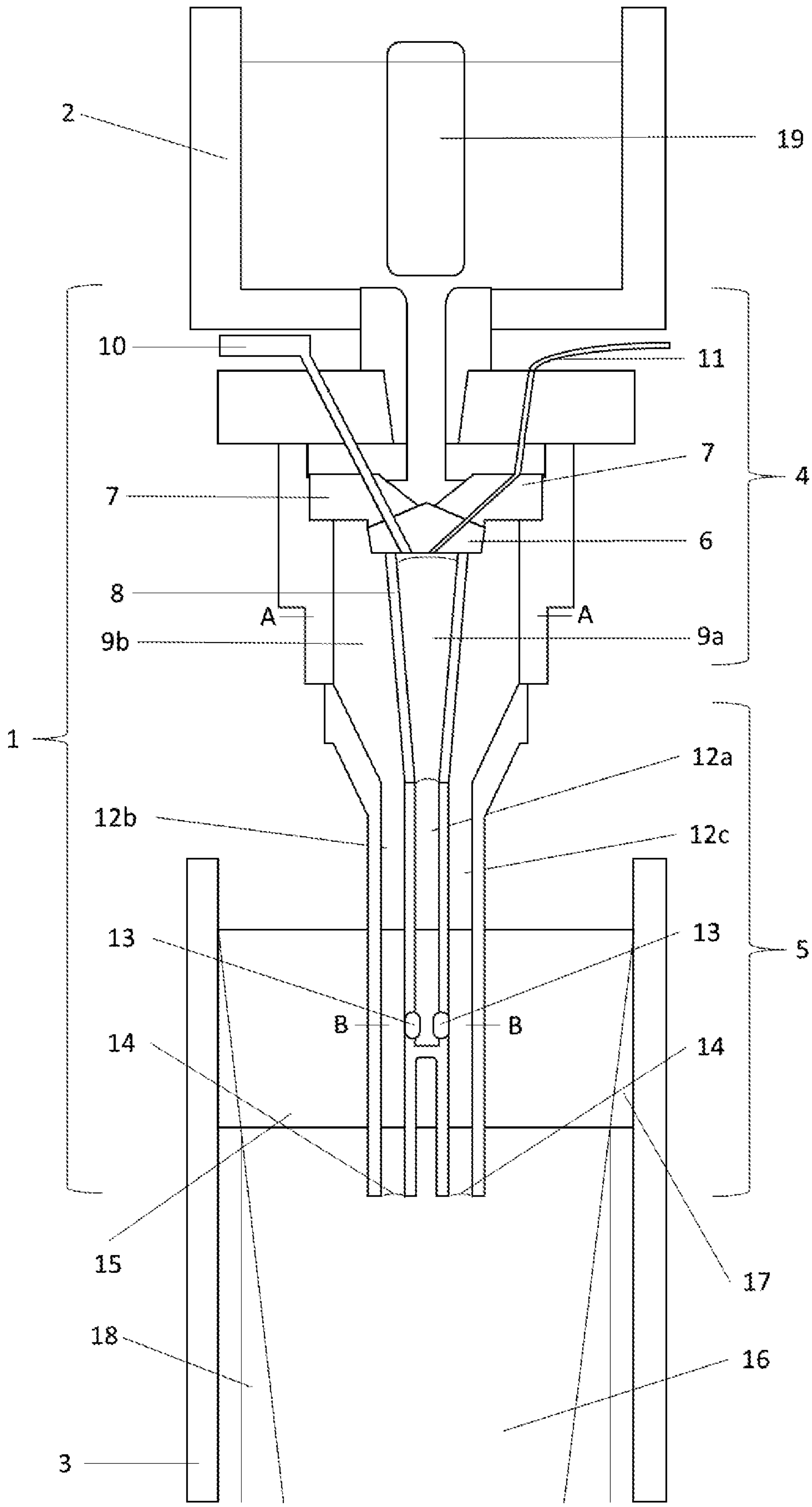

FIG 1

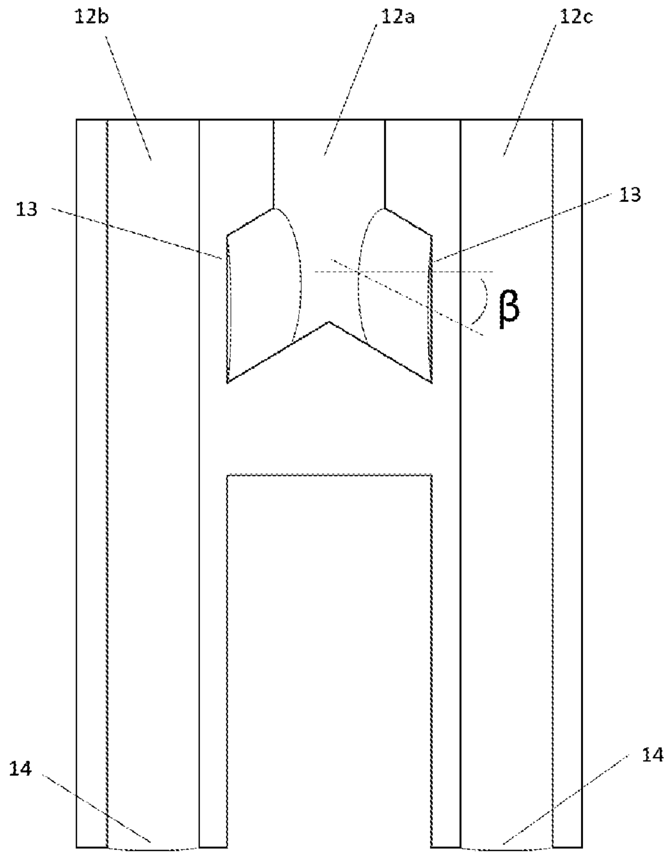

FIG 2

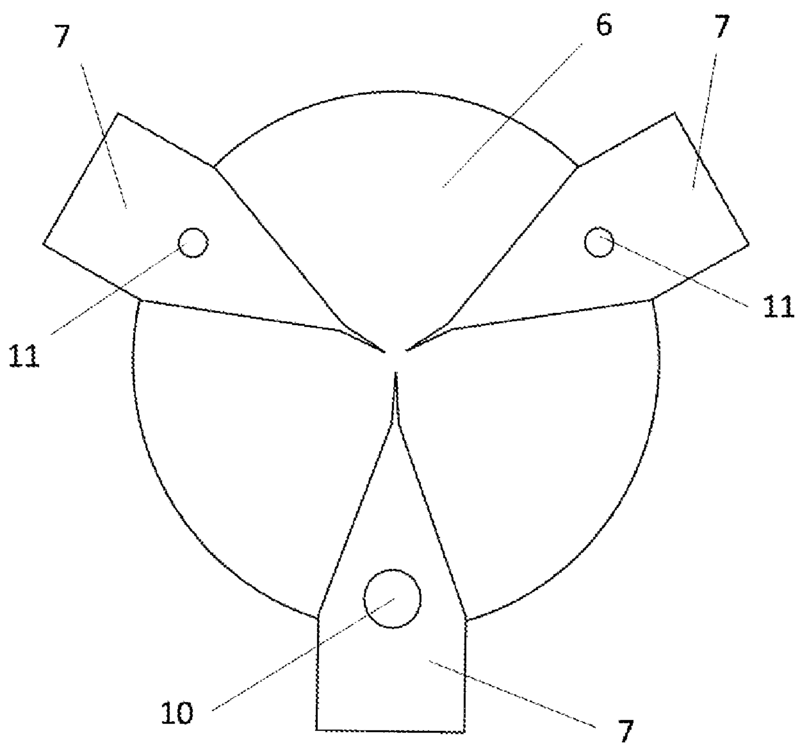

FIG 3

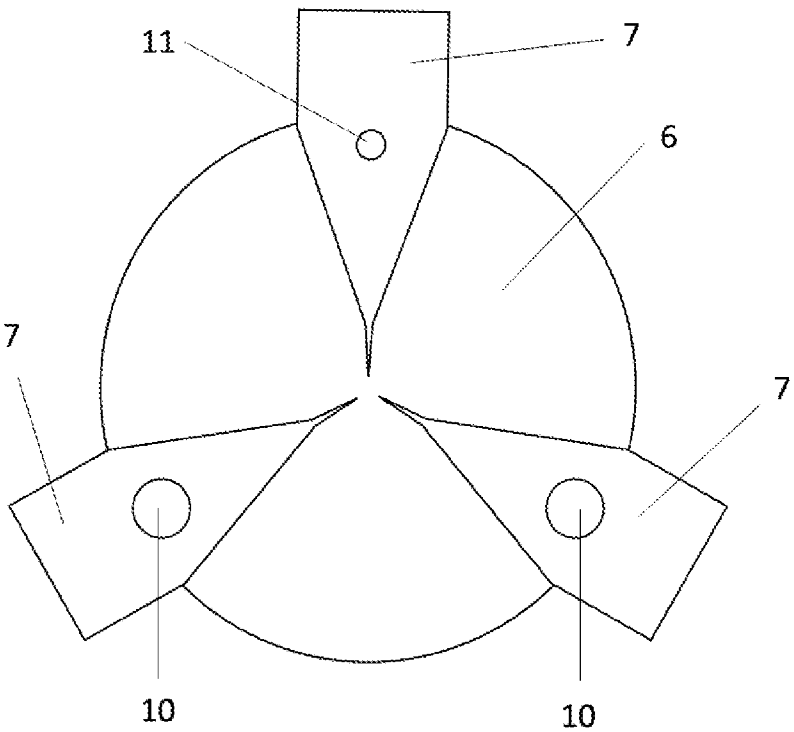

FIG 4

A-A

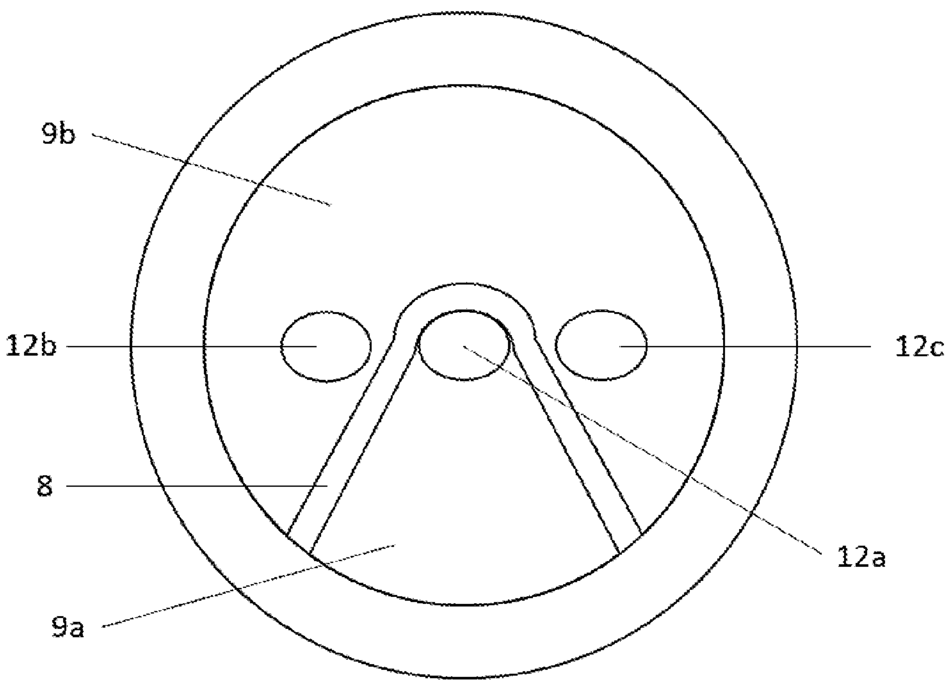

FIG 5

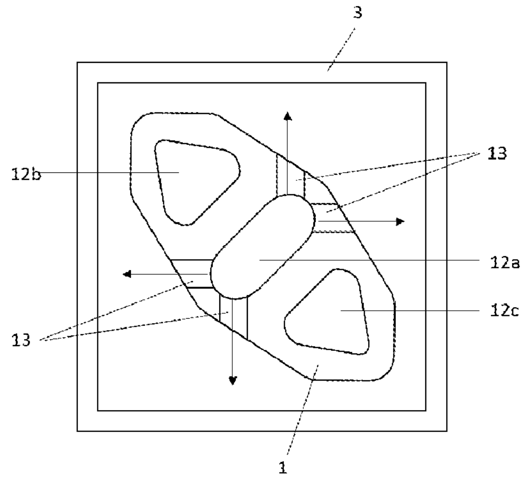

FIG 6

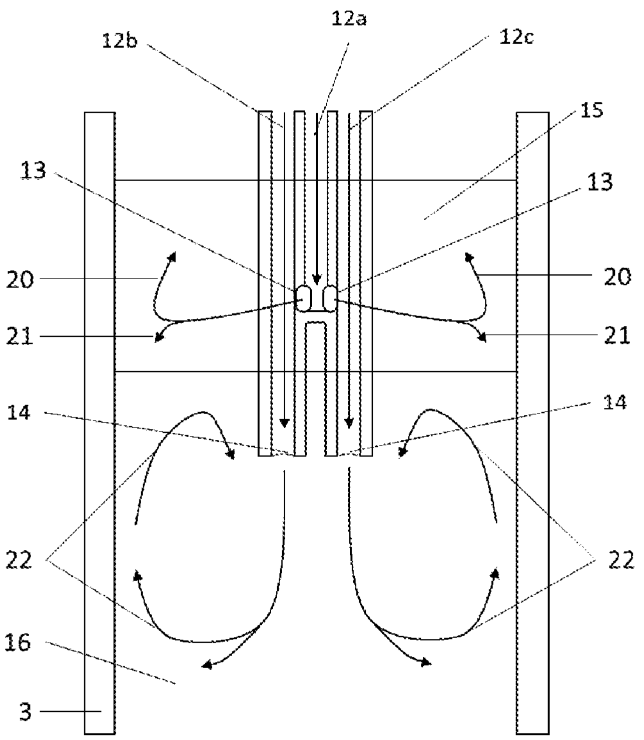

FIG 7

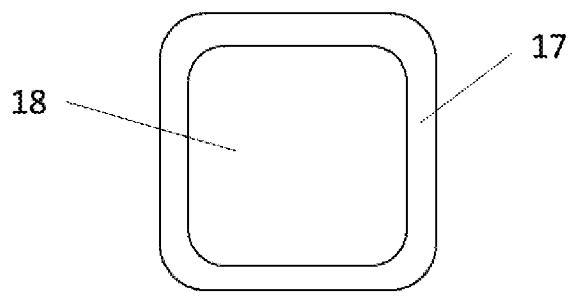

FIG 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/050839

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22D11/108 B22D41/50 B22D41/52 B22D41/58
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)
B22D

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.
Y	WO 02/30598 A1 (CT DE RECH S METALLURTGIQUES A [BE]; NAVEAU PAUL [BE]) 18 April 2002 (2002-04-18) figures 1, 2 page 1, line 5 - line 10 page 2, line 32 - page 3, line 27 page 6, line 30 - page 8, line 25 -----	1-13
Y	JP H11 197807 A (KAWASAKI STEEL CO) 27 July 1999 (1999-07-27) figures 1-3 paragraph [0001] paragraph [0005] - paragraph [0008] paragraph [0009] - paragraph [0018] -----	1-13

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

[x] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 May 2023	31/05/2023

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 2008/070935 A1 (CT RECH METALLURGIQUES ASBL [BE]; NAVEAU PAUL [BE] ET AL.) 19 June 2008 (2008-06-19) figure 3 paragraph [0001] paragraph [0007] - paragraph [0011] paragraph [0023] - paragraph [0029] -----	1-13
A	EP 2 830 793 A1 (ARCELORMITTAL INVESTIGACIÓN Y DESARROLLO SL [ES]) 4 February 2015 (2015-02-04) figures 1-5 paragraph [0001] - paragraph [0002] paragraph [0007] - paragraph [0008] paragraph [0013] - paragraph [0027] -----	1-13

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