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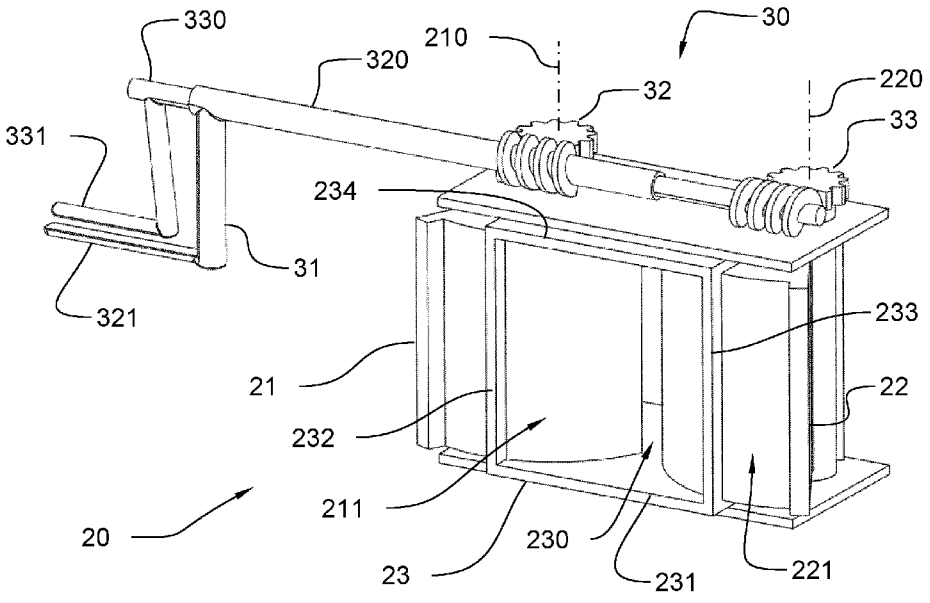

FIG 2

(57) Abstract: Door assembly (20) for closing an inlet or outlet passageway (230) of a furnace (10) for melting a particulate material, the door assembly comprising at least one door wing (21, 22) configured to pivot on a respective hinge axis (210, 220) between an open position in which the door wing at least partially clears the passageway and a closed position in which the door wing at least partially closes the passageway. The door wing comprises a first face (211, 221) configured to form a barrier in the passageway in the closed position and being shaped as a portion of a surface of revolution having the hinge axis as axis of rotation.

WO 2024/251770 A1

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PIVOTING DOOR FOR MELTING FURNACE

Technical field

[0001] The present disclosure is related to pivoting doors for closing passageways through walls of melting furnaces, in particular furnaces for melting particulate material, such as vitrifiable material, e.g. glass, rock material, wastes, or other raw material in powder or granular form. More particularly, the present disclosure is related to pivoting doors for closing charging and/or discharging passageways in such melting furnaces.

Background art

[0002] Melting furnaces have an inlet opening for supplying the raw particulate material, e.g. glass, rock material, or wastes, to a melting chamber. They also comprise an outlet opening from where melt, e.g. for producing glass, glass wool, or rock wool, is discharged. Systems for supplying the raw material to the melting furnace, referred to as charging systems, exist in two types. A first type is configured to supply the particulate material into the melting furnace from an elevated position above the melt. A second type is configured to supply the particulate material to the melt from an inlet positioned below the level of the melt in the furnace. This second type is referred to as submerged charging. Analogously, the outlet opening of the melting furnace can be positioned non-submerged (i.e. most of the time above the level of the melt), or submerged (positioned below the level of the melt).

[0003] Doors are provided to close the inlet and/or outlet openings of the furnace. Such doors are typically sliding doors. US 9394192 B2 (VILLEROY DE GALHAU GREGOIRE et al.) discloses a water-cooled guillotine-type sliding door for the inlet opening of a melting furnace. However, it has been observed that this type of door system has several drawbacks. Firstly, dust from the particulate material easily enters into the guides of the door, increasing friction and causing jamming of the door. Secondly, it happens that larger particulates get trapped in the door opening when closing the door, impeding to fully close the door. This causes a risk that melt may leak out of the door. This can only be overcome by breaking up the larger particulates through exerting a large force on the door, increasing risk of deformation. Thirdly, the door and the walls of the furnace are water cooled to avoid overheating. As a result, a layer of melt solidifies adjacent to the walls, referred to as frozen melt, and adheres to the furnace facing side of the door, which renders opening of the door difficult.

[0004] US 2007/0290420 (WUNSCHE EDGAR R et al.) discloses a sealing apparatus for a slag door of a metallurgical furnace, having a mounting assembly for mounting the apparatus to the furnace, and at least one closure element, moveable from an open position that is exterior of the slag door opening, to a closed position that effectively seals against the slag door and extends into the slag door opening with the rear panel of the closure element(s) being proximally aligned with the interior wall of the furnace. The apparatus may also have at least one wiping component moveable so as to sweep across the lower surface of the slag door to remove obstructions. In particular, US 2007/0290420 discloses a pivoting door for a slag discharge opening of a metallurgical furnace The door comprises an upper door wing that pivots upwards through a hinge mechanism that rotates about horizontal hinge axes and a lower door with two door wings that pivot about vertical hinge axes. The internal sides of the doors are provided with cooling channels through which a coolant fluid flows.

[0005] WO 2011/115919 (PROCESS TECHNOLOGY INTERNATIONAL INC [US]; SHVER VALERY [US]) and EP 2347208 (SMS SIEMAG AG [DE]) disclose other types of pivoting slag doors.

[0006] One drawback of the above mentioned pivoting doors, is that they are not suitable for the inlet openings because they require the supply channel to be freed up from charging material before opening or closing the door, otherwise operation of the door is impeded, or too much effort is required for opening and closing.

Summary

[0007] There is hence a need in the art to provide an improved door assembly or system and a furnace comprising such a door assembly or system that overcomes the problems of the prior art. Particularly, there is a need to provide a door assembly or system for a melting furnace that is easier to operate and/or requires less effort to operate. There is a need in the art to provide a door assembly or system for a melting furnace that reduces risk of malfunction, such as risk of jamming of the door.

[0008] According to a first aspect of the present disclosure, there is therefore provided a door assembly, or a door system, as set out in the appended claims. A door assembly according to the present disclosure is configured to close a passageway through a wall of a furnace for melting a particulate material. The door assembly comprises at least one door wing configured to pivot on a respective hinge axis between an open position in which the door wing at least partially clears the passageway and a closed position in which the door wing at least partially closes the passageway. The at least one door wing comprises a first face configured to form a barrier in the passageway in the closed position and advantageously comprises a second

face, wherein the first face and the second face are configured to face opposite sides of the passageway in the closed position. According to an aspect of the present disclosure, the first face is shaped as a portion of a surface of revolution having the hinge axis as axis of rotation. In particular, the first aspect of the present disclosure concerns a door assembly for closing a passageway through a wall of a furnace for melting a particulate material, the door assembly comprising at least one door wing configured to pivot on a respective hinge axis between an open position in which the door wing at least partially clears the passageway and a closed position in which the door wing at least partially closes the passageway, wherein the at least one door wing comprises a first face, the first face is configured to form a barrier in the passageway in the closed position, and wherein said first face is shaped as a portion of a surface of revolution having the hinge axis as axis of rotation.

[0009] One advantage of the door assembly of the present disclosure is that it allows a pivoting door to be arranged in a closed channel where the door can be easily operated to open and close the channel passageway, even when the channel is filled with material. As will be explained below in more detail, such a door assembly creates less pressure variations and disturbance when closing, and avoids material getting trapped in the channel behind the door when opening.

[0010] Advantageously, the portion of the surface of revolution is a portion of a right cylindrical surface. Alternatively it can be a portion of a spherical surface. These shapes allow for easy construction and edge sealing to be realized. Particularly, the door assembly can comprise a door frame comprising a first wall and a second wall opposite the first wall and spaced apart from the first wall. The passageway is arranged between the first wall and the second wall and the hinge axis of a first one of the at least one door wing is parallel to the first wall. The first wall comprises an opening and the first one door wing is configured to move through the opening when pivoting between the open position and the closed position. When the first face is shaped as a surface of revolution about the hinge axis, a size of the opening can be made to mate with a (meridional) cross section of the first one door wing in all pivot positions of the door wing.

[0011] Surprisingly, the invention provides an oven door surface which is cylindrical, whereby the center of the cylinder is the rotation axis of the oven door. The technical effect of this difference is, that the door is easy to operate because particles charged into the furnace are not easily trapped in the door, while at the same time a good thermal insulation of the door is ensured. The prior art is silent about providing oven door which can easily be operated and at the same time where a good thermal insulation is ensured. Thus, it is one object of the present invention to provide a designed

mechanically robust door that can be opened and closed with sufficient force such as to crush any particles that might get entrapped.

[0012] Advantageously, the at least one door wing comprises a third face. The second face and the third face extend in radial directions at spaced apart angular positions relative to the hinge axis, particularly defining an angular sector about the hinge axis delimited by the second and third faces. The first face advantageously extends between the second face and the third face, e.g. to span the angular sector. As a result, a pie-shaped door wing is obtained which has excellent mechanical stability and is easy to manufacture. In addition, coolant fluid ports can be arranged on the third face to cool the door wing internally.

[0013] According to a second aspect of the present disclosure, there is provided a furnace for melting a particulate material, as set out in the appended claims. The furnace comprises the door assembly of the present disclosure configured to close a passageway, such as of a feed inlet and/or of a melt outlet. The furnace can be a submerged combustion melting furnace. In particular this second aspect of the present disclosure concerns a furnace for melting a particulate material, the furnace comprising a melting chamber enclosed by a wall, wherein the wall is provided with a passageway through the wall, wherein the furnace comprises the door assembly of the invention configured to close the passageway, preferably wherein the passageway is arranged at a level of the melting chamber configured to be below a level of a melt in the melting chamber.

Brief description of the drawings

[0014] Aspects of the present disclosure will now be described in more detail with reference to the appended drawings, wherein same reference numerals illustrate same features and wherein:

[0015] Figure 1 represents a diagram of a furnace for melting particulate material including a submerged charging system;

[0016] Figure 2 represents a perspective view of a door assembly with two door wings according to aspects of the present disclosure;

[0017] Figure 3 represents a perspective view of a lower half portion of the door assembly of Fig. 2 in an open position;

[0018] Figure 4 represents the lower half portion of the door assembly of Fig. 2 in a closed position;

[0019] Figure 5 represents a diagram of a door assembly with planar faced door wings arranged in a channel section, in a state of opening the door;

[0020] Figure 6 represents a diagram of a door assembly with planar faced door wings arranged in a channel section, in a state of closing the door;

[0021] Figure 7 represents a perspective view of a door assembly with one door wing according to aspects of the present disclosure;

[0022] Figure 8 represents a perspective view of a lower half portion of the door assembly of Fig. 7 in an open position;

[0023] Figure 9 represents the lower half portion of the door assembly of Fig. 7 in a closed position.

Detailed description

[0024] According to a first aspect of the present disclosure, it is provided a door assembly (20, 40) for closing a passageway (230) through a wall (112) of a furnace (10) for melting a particulate material, the door assembly comprising at least one door wing (21, 22) configured to pivot on a respective hinge axis (210, 220) between an open position in which the door wing at least partially clears the passageway and a closed position in which the door wing at least partially closes the passageway, wherein the at least one door wing comprises a first face (211, 221), the first face configured to form a barrier in the passageway in the closed position, and wherein said first face is shaped as a portion of a surface of revolution having the hinge axis as axis of rotation.

[0025] According to a first embodiment, the portion of the surface of revolution is a portion of a right cylindrical surface or a portion of a spherical surface.

[0026] According to another embodiment, the at least one door wing (21, 22) comprises a second face (212, 222), wherein the first face and the second face are configured to face opposite sides of the passageway in the closed position, preferably wherein the first face and the second face join at an edge (214) of the respective door wing.

[0027] According to yet another embodiment, the at least one door wing (21, 22) comprises a second face (212, 222), wherein the first face and the second face are configured to face opposite sides of the passageway in the closed position, and wherein the second face is substantially planar, preferably wherein the at least one door wing is substantially pie-shaped.

[0028] Preferably, the at least one door wing (21, 22) comprises a third face (213, 223), wherein the second face (212, 222) and the third face (213, 223) extend in radial directions at different angular positions relative to the hinge axis (210, 220), and wherein the first face (211, 221) extends between an end (214) of the second face remote from the hinge axis and an end (216) of the third face remote from the hinge axis.

[0029] According to another embodiment of the disclosure, the door assembly further comprises a door frame (23), wherein the door frame comprises a first wall (232) and a second wall (233) opposite the first wall and spaced apart from the first wall, such that the passageway (230) is arranged between the first wall and the second wall, wherein the hinge axis (210) of a first one of the at least one door wing (21) is parallel to the first wall, and wherein the first wall comprises an opening (236), the first one door wing (21) being configured to move through the opening when pivoting between the open position and the closed position, preferably wherein a size of the opening mates with a meridional cross section of the first one door wing (21).

[0030] Preferably, the first one door wing (21) comprises a second face (212), wherein the first face (211) and the second face (212) are configured to face opposite sides of the passageway (230) in the closed position, and wherein the second face (212) is configured to be substantially flush with the first wall (232) in the open position of the first one door wing.

[0031] According to a particular embodiment, the at least one door wing comprises an end stop (218, 219) protruding from the door wing, preferably in a radial direction relative to the hinge axis (210), the end stop configured to abut against a threshold in an extreme position of the respective door wing.

[0032] Preferably the at least one door wing is provided with a duct system configured to receive a flow of coolant fluid for cooling the at least one door wing.

[0033] According to another embodiment, the at least one door wing comprises two door wings (21, 22) having parallel hinge axes (210, 220), preferably wherein the two door wings are configured to be half doors.

[0034] According to yet another embodiment of the disclosure, the door assembly further comprises an actuator configured to drive a pivoting movement of the at least one door wing between the open position and the closed position, preferably wherein the actuator comprises a worm drive system (30).

[0035] Advantageously, the at least one door wing comprises two door wings (21, 22) having parallel hinge axes (210, 220) and the actuator is configured to drive the pivoting movement of the two door wings, wherein the actuator is configured to pivot the two door wings according to a first mode of operation in which the two door wings pivot in unison, and according to a second mode of operation in which the two door wings pivot independently, preferably wherein the actuator comprises a first drive shaft (320) for driving a first one (21) of the door wings and a second drive shaft (330) for driving a second one (22) of the door wings, wherein the first drive shaft and the second drive shaft are coaxial.

[0036] Preferably, the at least one door wing is configured to be secured in at least one intermediate position between the open position and the closed position.

[0037] According to a first aspect of the present disclosure, it is provided a furnace (10) for melting a particulate material, the furnace comprising a melting chamber (11) enclosed by a wall (112), wherein the wall is provided with a passageway (14, 15) through the wall, wherein the furnace comprises the door assembly (20, 40) according to the invention configured to close the passageway, preferably wherein the passageway is arranged at a level of the melting chamber (11) configured to be below a level of a melt (110) in the melting chamber.

[0038] According to one embodiment, the passageway is a charging passageway (14), wherein the furnace further comprises a charging system (16) configured to supply particulate material through the passageway, and wherein the first face (211, 221) of the at least one door wing is facing the charging system in the closed position.

[0039] Referring to Fig. 1, a furnace 10 for melting particulate material 17 generally comprises one or more melting chambers 11 where the particulate material is molten to form a melt 110 in melting chamber 11. The melting chamber 11 is generally defined by a bottom wall 111, one or more upright walls 112 which may have planar or curved horizontal and/or vertical profiles, and a ceiling wall 113 configured to cover the melting chamber 11. A chimney 12 is arranged through the ceiling wall 113 for exhaust of fumes. It will be appreciated that the geometry of the melting chamber and, more generally, of the furnace as a whole, can vary, and the configuration shown in Fig. 1 is merely provided for illustrative purposes. One or more heating elements, such as gas burners 13, can be configured to heat the melting chamber 11. One or more gas burners 13 can be arranged through the bottom wall 111, and these are generally referred to as submerged combustion burners. In addition, or alternatively, one or more burners 131 can be arranged through the ceiling wall 113 and/or the upright walls 112 to ensure any heating function, such as pre-heating or heating the melting chamber 11.

[0040] The furnace 10 comprises a feed inlet 14 for supplying particulate material to the melting chamber. Feed inlet 14 can be arranged at any desired position through the upright wall 112, or alternatively through the ceiling wall 113. Feed inlet 14 can be arranged at a submerged position compared to the level of melt 110 in the melting chamber 11. Alternatively, feed inlet is arranged at an elevated position compared to the level of the melt.

[0041] A melt outlet 15 for discharging the melt can be arranged at any desired position through the upright wall 112, or alternatively through the bottom wall

111. As with the feed inlet, the melt outlet 15 can be arranged at a submerged position, in particular so as to be configured to allow a complete evacuation of the melt 110 from the melting chamber.

[0042] Advantageously, a supply system, such as an auger system 16, is configured to supply the particulate material 17 to the melting chamber 11 through the feed inlet 14. The auger system 16 comprises a helical blade shaft 161, which can be arranged with the longitudinal axis of shaft 161 aligned with, or generally parallel to, an axis of a passageway defined by the feed inlet 14. The helical blade shaft can be driven by any suitable actuator such as an electric motor 162 and can be arranged in a duct. It will be appreciated that other supply systems can be contemplated, such as systems provided with a pusher piston (cylindrical or rectangular) or vibrating supply systems. It will be appreciated that the supply system can be at least in part cooled with a coolant fluid (liquid, such as water, or gas, such as air).

[0043] Referring to Figs. 2-4, a door assembly 20 is advantageously arranged in either one of the feed inlet 14, the melt outlet 15, or both. Door assembly 20 is configured to close a passageway of the feed inlet 14 and/or the melt outlet 15. Door assembly 20 comprises two door wings: a first door wing 21 and a second door wing 22 configured to co-operate to completely close a passageway 230 defined by a door frame 23. Door frame 23 comprises a first upright wall 232 and a second upright wall 233 opposite the first upright wall, and can further comprise a bottom wall 231 and a top wall 234 which both connect the first and second upright walls 232, 233. In some examples, the passageway 230 is a passageway of the feed inlet 14 and/or of the melt outlet 15.

[0044] The first and second door wings 21, 22 are configured to pivot on respective hinge axes 210, 220. Hinge axes 210, 220 are advantageously parallel to, and spaced apart from, one another. Particularly, the hinge axis 210 associated with the first door wing 21 can be positioned adjacent the first upright wall 232 and be parallel to it. The hinge axis 220 associated with the second door wing 22 can be positioned adjacent the second upright wall 233 and be parallel to it. As shown most clearly in Figs. 3-4, by pivoting the first and second door wings 21, 22 on respective hinge axes 210, 220, the passageway 230 can be opened (Fig. 3) and closed (Fig. 4).

[0045] Each of the first and second door wing 21, 22 is formed as a body with a first face 211, 221 respectively and a second face 212, 222 respectively. In the closed position of the door, as illustrated in Fig. 4, the first faces 211, 221 are configured to close the passageway 230 on one side, e.g. an upstream side, and the second faces 212, 222 on another, opposite side, e.g. a downstream side. Particularly, the first faces 211, 221 and the second faces 212, 222 are facing away from one another, or at least

facing towards opposite sides of the passageway in the closed position of the door. The door wings 21, 22, particularly the first face and/or the second face, can extend to span the complete height of passageway 230 (e.g. a size of the passageway parallel to the hinge axis), e.g. from the bottom wall 231 to the top wall 234.

[0046] In one aspect, the first faces 211, 221 of the door wings 21, 22 are shaped as (a portion of a) surface of revolution with the respective hinge axis 210, 220 being the axis of rotation of the surface of revolution (i.e., the axis of revolution). Specifically, the surface of revolution of the first face 211 is obtained by revolving a line (generatrix) about the hinge axis 210 over a sector angle. Advantageously, this surface of revolution is a right cylindrical surface with the respective hinge axis being the axis of the cylinder. Such a cylindrical surface allows an easy sealing at the edges and allows both door wings to easily engage in the closed position, obtaining a complete closure. It will however be appreciated that other kinds of surfaces of revolution can be contemplated, such as spherical surfaces.

[0047] One advantage of forming the first face 211, 221 as a surface of revolution with the hinge axis as the axis of rotation, is that, at the side of the first face, no voids are created when closing the door, e.g. as illustrated when operating the door to turn from the position of Fig.3 to the position of Fig. 4. Likewise, no material needs to be displaced to open the door, e.g. when turning from the position of Fig. 4 back to the position of Fig. 3. This can be easily understood when considering the case of a “standard” planar faced door as illustrated in Figs. 5 – 6. Referring to Fig. 5, when the door wings 91, 92 in a passageway 930 of a channel section 93 are opened, as indicated by the arrows 95, any material present in the areas 94 in front of the door wing 91, 92 must be displaced. If the channel is filled with material – either liquid or solid – at that side, opening of the door can be impeded. With the door wings 21, 22 according to the present disclosure, this is obviated, and the door wings can be opened with greater ease. Likewise, referring to Fig. 6, when the door wings 91, 92 are closed in channel section 93, as indicated by the arrows 97, voids are created in the spaces 96. This may create undesired turbulence or pressure variations in material – either liquid or solid – present in the channel at that side of the door, rendering closing of the door more difficult and/or causing problems to upstream equipment. With the door wings 21, 22 according to the present disclosure, this is obviated and the door can be closed with greater ease. Hence, the door assembly according to aspects of the present disclosure allows a pivoting door to be arranged in a channel section and to be easily operated even when the channel is filled with material.

[0048] Referring again to Figs. 3 and 4, any section line 215 of the first face 211 (i.e., of the surface of revolution) with a plane perpendicular to the axis of rotation (i.e., the hinge axis 210) is a circular arc having the hinge axis as centre, and this circular arc will turn about its centre when the door wing is pivoted. If the passageway 230 is filled with material, such as feed particulate material or melt, at the side 235 facing the first face 211, 221, the door wing will not need to displace any of this material for opening. By so doing, less effort is required to open the door, even if the passageway is filled, and the door can be opened more easily.

[0049] The second face 212, 222 of each door wing 21, 22 respectively, can be shaped as desired. Advantageously, the second face is substantially planar or suitably curved in a plane perpendicular to the hinge axis. The first face 211, 221 and the respective second face 212, 222 advantageously join at an edge 214 of the door wing. In some examples, the second face forms a meridional section of the surface of revolution of the first face. With such a configuration of the door wing, when the door is closed, any material present in the passageway 230 is displaced by the second face in direction of movement, but, as explained previously, no voids are created in the passageway for the displaced material due to the shape of the first face. It will be appreciated that this reduces effort in closing the door, while providing minimal disturbance to the flow of material in the passageway.

[0050] The door wing 21, 22 advantageously further comprises a third face 213, 223. The third face 213, 223 and the second face 212, 222 respectively are arranged at opposite sides of the first face 211, 221. As a result, the body of the door wing is advantageously pie-shaped (e.g., as a right cylindrical sector) with the hinge axis substantially arranged at a centre of the pie (cylinder axis). The third face may form another meridional section of the surface of revolution of the first face. In some examples, the body of a door wing 21 comprises the first face 211 formed as a surface of revolution about the hinge axis 210. The second face 212 extends from one edge 214 of the first face towards the hinge axis 210. The third face 213 advantageously extends substantially from another edge 216 of the first face, opposite the edge 214, towards the hinge axis 210.

[0051] Advantageously, the second face 212, 222 and the third face 213, 223 of the door wings 21, 22 respectively extend substantially in radial directions from the hinge axis 210, 220 respectively. The first face 211, 221 extends over an angle α enclosed between the second face 212, 222 and the third face 213, 223, as measured in a plane perpendicular to the hinge axis 210, 220 respectively. The angle α can be 90° or less, advantageously between about 45° and 90°, advantageously between about 60°

and 85°, or alternatively 90° or more, e.g. between 90° and 105°. Suitable values for the angle α can be between 60° and 100°. It will be appreciated that the first face 211, 221 extends as a surface of revolution over the angle α, hence spanning between the second face and the third face.

[0052] Each of the door wings 21, 22 can be cooled with a fluid coolant, which can be liquid, such as water, or gas, such as air. To this end, the door wing can comprise fluid ports 217, advantageously arranged in the third face 213, 223, configured to provide a flow of a coolant fluid to the interior of the door wing, or to one or more surfaces thereof.

[0053] Advantageously, referring to Figs. 3-4, each door wing is configured to pivot on its hinge axis through an opening in a wall of the door frame 23. By way of example, wall 232 of the door frame 23 comprises an opening 236 and the door wing 21 is configured to pivot through the opening 236. Advantageously, the size of opening 236 is mating with a cross section of the door wing 21. Due to the first face 211 being formed as a surface of revolution about the hinge axis, the opening 236 can be kept in registration with a cross section of the door wing, allowing a complete seal, in all pivot positions of the door wing and no further sealing measures may be necessary.

[0054] It will be appreciated that while in the figures the door wings are illustrated to pivot through the upright walls, this is no necessity and the door wings and door frame can alternatively be disposed with horizontal hinge axes, or in any other suitable orientation. Likewise, assemblies with more than two door wings can be contemplated, e.g. with three or four door wings, two of which forming half doors as in Figs. 2-4 and additionally a third and possibly a fourth door wing having respective hinge axes perpendicular to the hinge axes of the half doors, to further close apertures above and/or below the two half doors.

[0055] Each door wing 21, 22 can be provided with abutments 218, 219 respectively configured to abut against the door frame 23 (or any other suitable threshold) in an extreme or end position of the door wing. The abutments 218, 219 hence act as end stops for the pivoting movement about the hinge axis. Abutments 218, 219 can be shaped as desired. In some examples, they are shaped as protrusions, protruding from an edge of (the first face of) the door wing in a radial direction relative to the hinge axis.

[0056] Referring again to Fig. 2, the door wings can be operated manually, or through an actuator or drive system. Manual operation can be effected through lever handles (not shown) affixed to the respective hinge axes, or worm drive assemblies 30 operated through a respective rotary handle. Long levers allow operators to operate even

the largest door wings with reduced effort. In case there are two or more door wings, it is advantageous to provide both an operation in which the door wings move in unison to open and/or close, and an operation in which the door wings can be moved independently. The latter mode of operation is particularly advantageous when material gets trapped between the door wings during closure, impeding to fully close the door. By allowing to retract one door wing a little while keeping the other door wing static, it becomes possible to easily evacuate the trapped material without effort.

[0057] A worm gear assembly 30 can comprise a first worm drive 32 operably coupled to the hinge axis 210 of the first door wing 21 and a second worm drive 33 operably coupled to the hinge axis 220 of the second door wing 22. The shafts 320, 330 of the worm screws of the first and second worm drives 31, 32 respectively are advantageously coaxial. Particularly, worm screw shaft 320 of the first worm drive 32 is tubular receiving worm screw shaft 330 of the second worm drive 33 therethrough. Handles 321, 331 are connected to the worm screw shafts 320, 330 respectively at a same remote end thereof. As a result, the first and second worm drives 32, 33 can be easily operated both in unison and independently as desired. Furthermore, both door wings can be operated by a single operator. To ease independent rotation of the handles, one handle, e.g. handle 321, can extend remotely (i.e., towards the operator) beyond the other handle, e.g. handle 331. Handles 321, 331 can be replaced with motor drives as known in the art.

[0058] It will be appreciated that door assemblies according to aspects of the present disclosure do not require to be equipped with two or more door wings. Referring to Figs. 7-9, a door assembly 40 is illustrated comprising a single door wing 22 configured to completely close the passageway 230 defined by door frame 23. Door wing 22 can be shaped like any of the door wings described in relation to Figs. 2-4 above. Particularly, door wing 22 comprises a first face 221 shaped as a surface of revolution, particularly as a right cylinder surface, extending over an angle α about the hinge axis 220, between the second face 222 and the third face 223. The angle α can be selected as indicated above for the door wings 21, 22 of Figs. 1-4.

[0059] It will be appreciated that operation modes in which the door wings are configured to be secured in one or more intermediate positions can be contemplated, e.g. by fixing the handles 321, 331 or the shafts 320, 330 in one or more defined angular positions. One advantage of securing the door wing in intermediate positions is that it enables to change the cross section of the inlet or exit port of the furnace. For the melt outlet port, changing the cross section size of the outlet port enables to regulate the melt flow rate. In addition, or alternatively, the size of the outlet port can be varied depending

on the viscosity of the melt: for one melt composition with low viscosity a small outlet opening can be utilized, whereas for a more viscous melt composition, a larger outlet opening is advantageous to maintain a desired flow rate. As a result, doors according to the present disclosure allow utilizing the furnace for a large variety of raw material compositions, making the furnace universally applicable. On the other hand, for the feed inlet port, adapting a size of the inlet opening by pivoting the door wing(s) to assume an intermediate position can be beneficial to increase the flow velocity of the feed stream of raw material thereby creating a sort of plug that avoids melt or hot fumes to enter the duct of the supply system, which may otherwise cause risk of fire in the supply system.

[0060] As indicated, the door assembly 20, 40 will be most advantageous when disposed in a closed channel, such as the channel of the feed inlet 14 in the furnace of Fig. 1. Door assemblies according to aspects of the present disclosure are useful in melting furnaces, such as the furnace 10 described in relation to Fig. 1, either for the feed inlet, the melt outlet, or both. Particularly they will allow for batch operations and for closing the melting chamber in case of warming up or restart after an operational discontinuity, or for regulating the flow of material into, or out of, the furnace. The door assemblies can be arranged such that the first face of each door wing faces towards the melting chamber, or faces away from it.

[0061] Advantageously, door assemblies as described herein are disposed in the feed inlet 14 of the furnace 10. The door assemblies are advantageously arranged such that the first faces 211, 221 of each of the one or more door wings 21, 22 respectively face away from the melting chamber, towards the supply system for supplying the particulate material. This ensures a smoother operation of the supply system, such as auger system 16, since sudden pressure variations in the feed channel just upstream of the door are avoided when the door is closed due the to the peculiar shape of the first face. This avoids large force fluctuations on the end of the helical blade shaft 161 ensuring a longer lifetime. A further particular advantage of the door wings of the present disclosure is that, with the surface of revolution (first face 211 / 221) arranged facing the feed side of the inlet port, in any intermediate position of the door wing, the flow of raw material is always guided, via the first faces, towards the open section of the passageway 230 in a fluid manner and without hindrance, avoiding obstructions or dead zones.

CLAIMS

1. Door assembly (20, 40) for closing a passageway (230) through a wall (112) of a furnace (10) for melting a particulate material, the door assembly comprising at least one door wing (21, 22) configured to pivot on a respective hinge axis (210, 220) between an open position in which the door wing at least partially clears the passageway and a closed position in which the door wing at least partially closes the passageway,

wherein the at least one door wing comprises a first face (211, 221), the first face configured to form a barrier in the passageway in the closed position,

characterised in that:

the first face is shaped as a portion of a surface of revolution having the hinge axis as axis of rotation.

2. Door assembly of claim 1, wherein the portion of the surface of revolution is a portion of a right cylindrical surface or a portion of a spherical surface.

3. Door assembly of claim 1 or 2, wherein the at least one door wing (21, 22) comprises a second face (212, 222), wherein the first face and the second face are configured to face opposite sides of the passageway in the closed position, preferably wherein the first face and the second face join at an edge (214) of the respective door wing.

4. Door assembly of any one of the preceding claims, wherein the at least one door wing (21, 22) comprises a second face (212, 222), wherein the first face and the second face are configured to face opposite sides of the passageway in the closed position, and wherein the second face is substantially planar, preferably wherein the at least one door wing is substantially pie-shaped.

5. Door assembly of claim 3 or 4, wherein the at least one door wing (21, 22) comprises a third face (213, 223), wherein the second face (212, 222) and the third face (213, 223) extend in radial directions at different angular positions relative to the hinge axis (210, 220), and wherein the first face (211, 221) extends between an end (214) of the second face remote from the hinge axis and an end (216) of the third face remote from the hinge axis.

6. Door assembly of any one of the preceding claims, further comprising a door frame (23), wherein the door frame comprises a first wall (232) and a second wall (233) opposite the first wall and spaced apart from the first wall, such that the passageway (230) is arranged between the first wall and the second wall, wherein the hinge axis (210) of a first one of the at least one door wing (21) is parallel to the first wall, and wherein the first wall comprises an opening (236), the first one door wing (21)

being configured to move through the opening when pivoting between the open position and the closed position, preferably wherein a size of the opening mates with a meridional cross section of the first one door wing (21).

7. Door assembly of the preceding claim, wherein the first one door wing (21) comprises a second face (212), wherein the first face (211) and the second face (212) are configured to face opposite sides of the passageway (230) in the closed position, and wherein the second face (212) is configured to be substantially flush with the first wall (232) in the open position of the first one door wing.

8. Door assembly of any one of the preceding claims, wherein the at least one door wing comprises an end stop (218, 219) protruding from the door wing, preferably in a radial direction relative to the hinge axis (210), the end stop configured to abut against a threshold in an extreme position of the respective door wing.

9. Door assembly of any one of the preceding claims, wherein the at least one door wing is provided with a duct system configured to receive a flow of coolant fluid for cooling the at least one door wing.

10. Door assembly of any one of the preceding claims, wherein the at least one door wing comprises two door wings (21, 22) having parallel hinge axes (210, 220), preferably wherein the two door wings are configured to be half doors.

11. Door assembly of any one of the preceding claims, further comprising an actuator configured to drive a pivoting movement of the at least one door wing between the open position and the closed position, preferably wherein the actuator comprises a worm drive system (30).

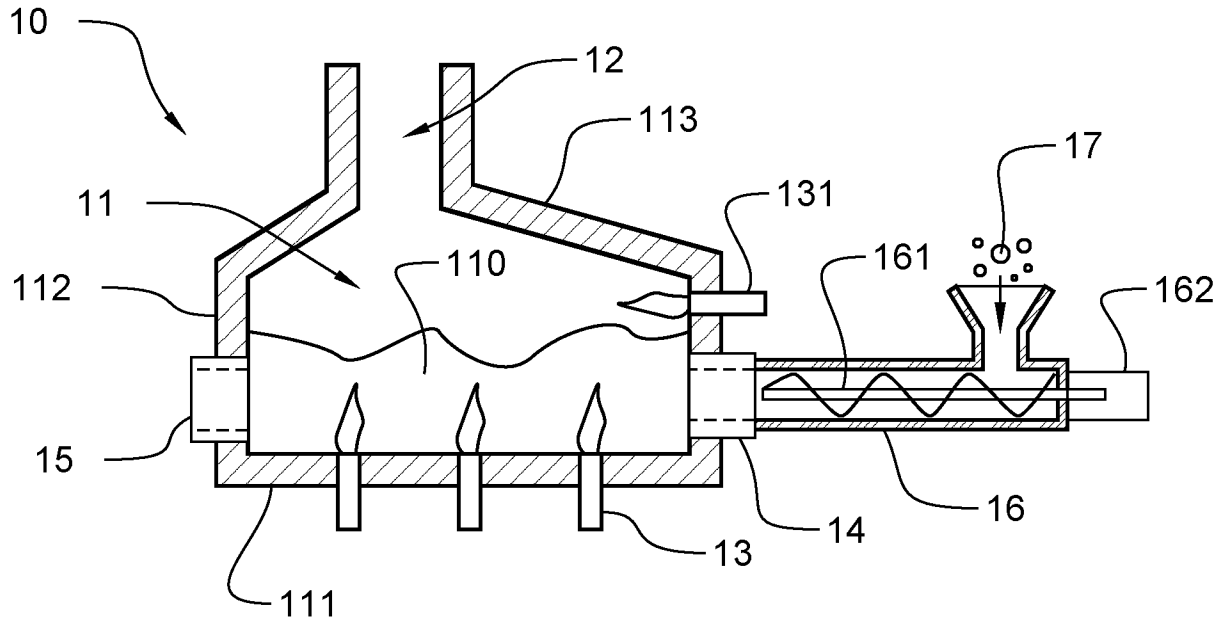
12. Door assembly of the preceding claim, wherein the at least one door wing comprises two door wings (21, 22) having parallel hinge axes (210, 220) and the actuator is configured to drive the pivoting movement of the two door wings, wherein the actuator is configured to pivot the two door wings according to a first mode of operation in which the two door wings pivot in unison, and according to a second mode of operation in which the two door wings pivot independently, preferably wherein the actuator comprises a first drive shaft (320) for driving a first one (21) of the door wings and a second drive shaft (330) for driving a second one (22) of the door wings, wherein the first drive shaft and the second drive shaft are coaxial.

13. Door assembly of any one of the preceding claims, wherein the at least one door wing is configured to be secured in at least one intermediate position between the open position and the closed position.

14. Furnace (10) for melting a particulate material, the furnace comprising a melting chamber (11) enclosed by a wall (112), wherein the wall is provided

with a passageway (14, 15) through the wall, wherein the furnace comprises the door assembly (20, 40) of any one of the preceding claims configured to close the passageway, preferably wherein the passageway is arranged at a level of the melting chamber (11) configured to be below a level of a melt (110) in the melting chamber.

15. Furnace of the preceding claim, wherein the passageway is a charging passageway (14), wherein the furnace further comprises a charging system (16) configured to supply particulate material through the passageway, and wherein the first face (211, 221) of the at least one door wing is facing the charging system in the closed position.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110
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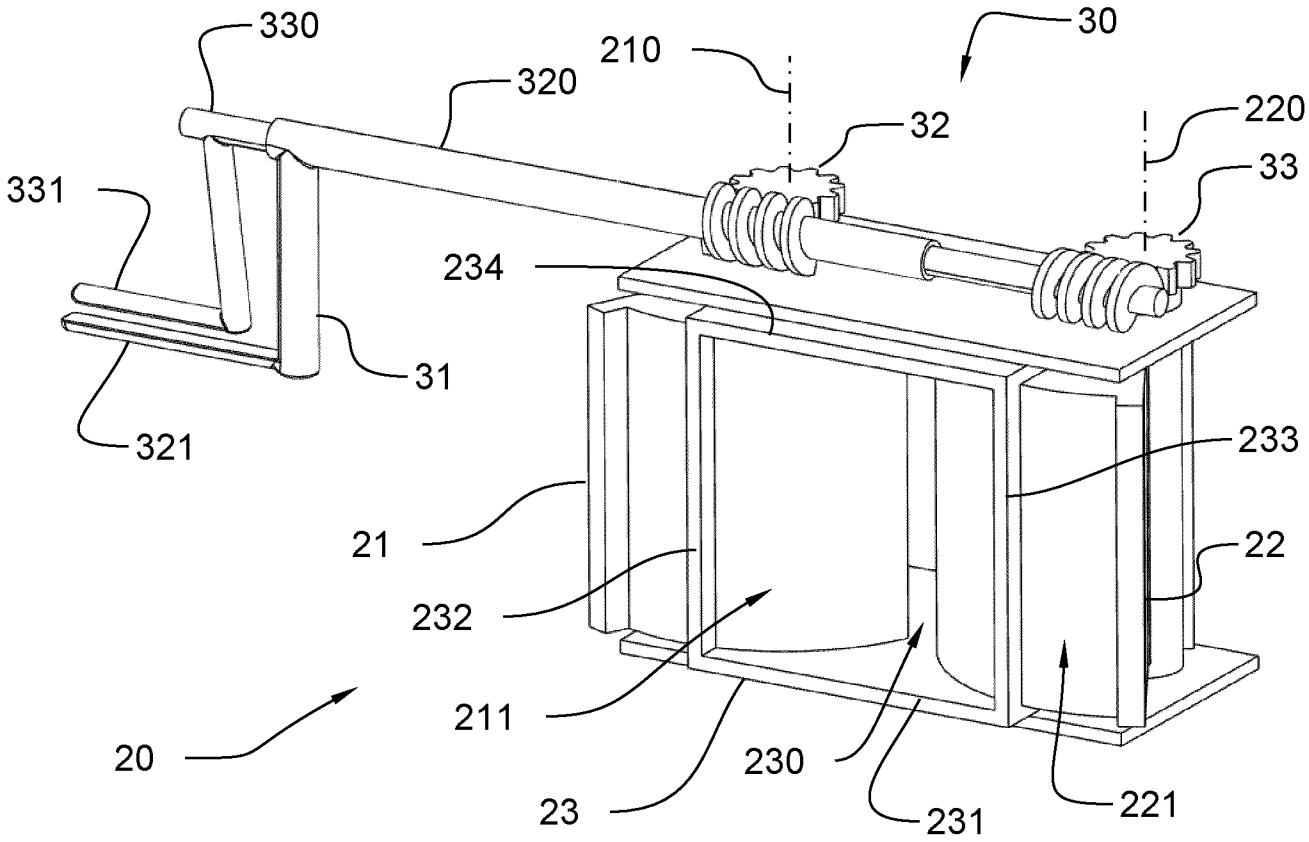
111

FIG 1


330
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230
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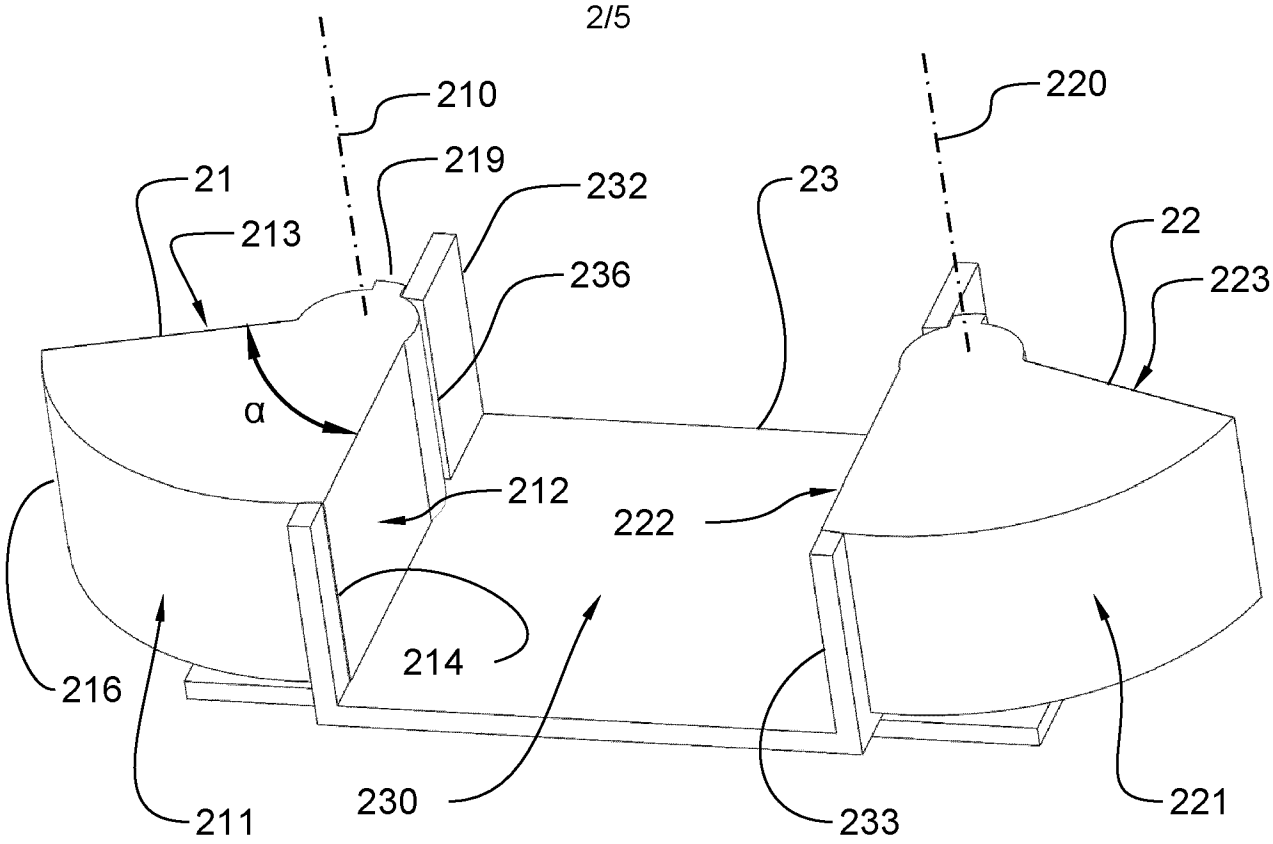
221

FIG 2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α
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230
233
221

FIG 3

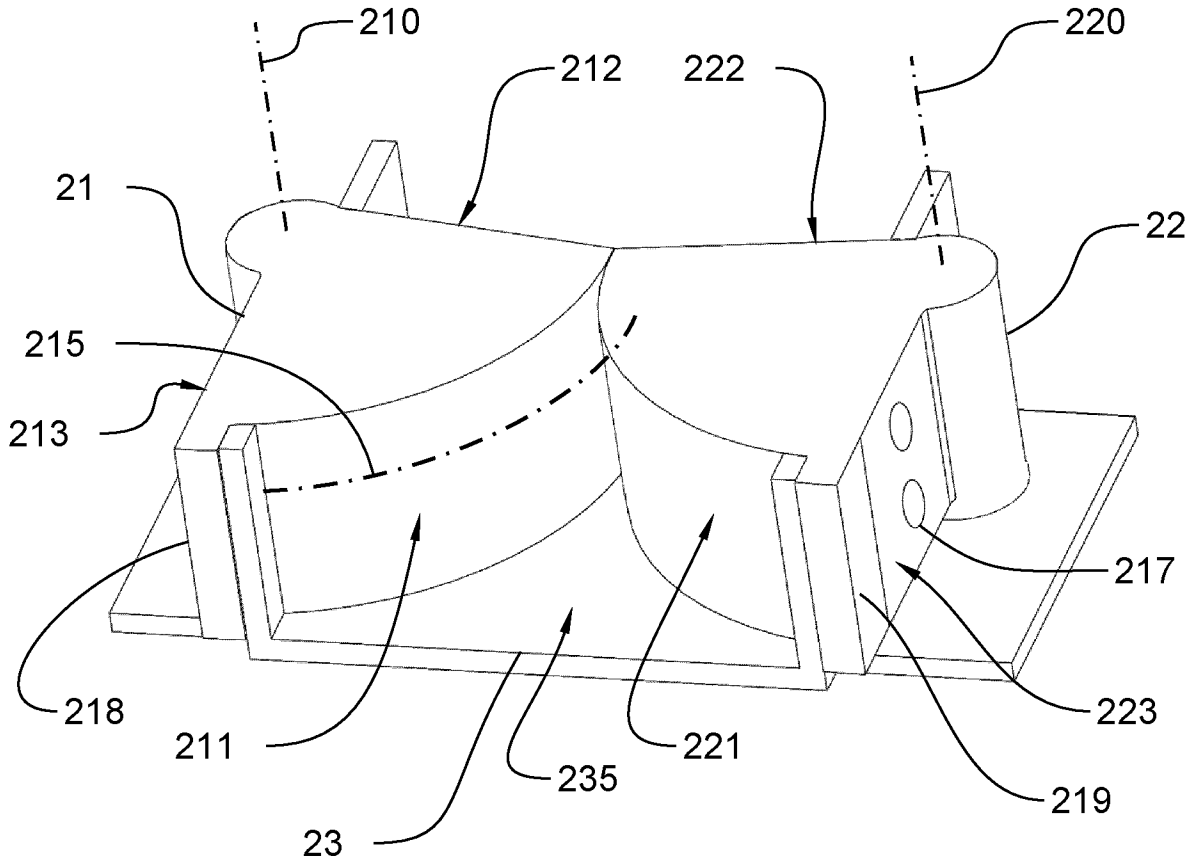
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FIG 4

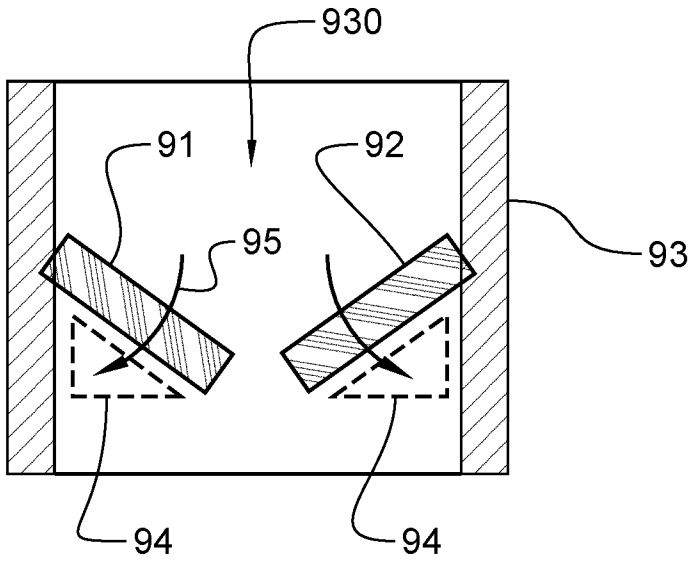

FIG 5

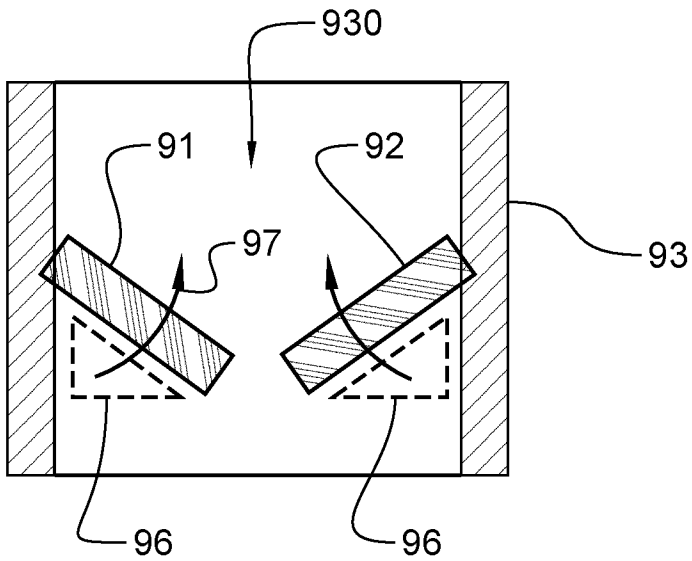

FIG 6

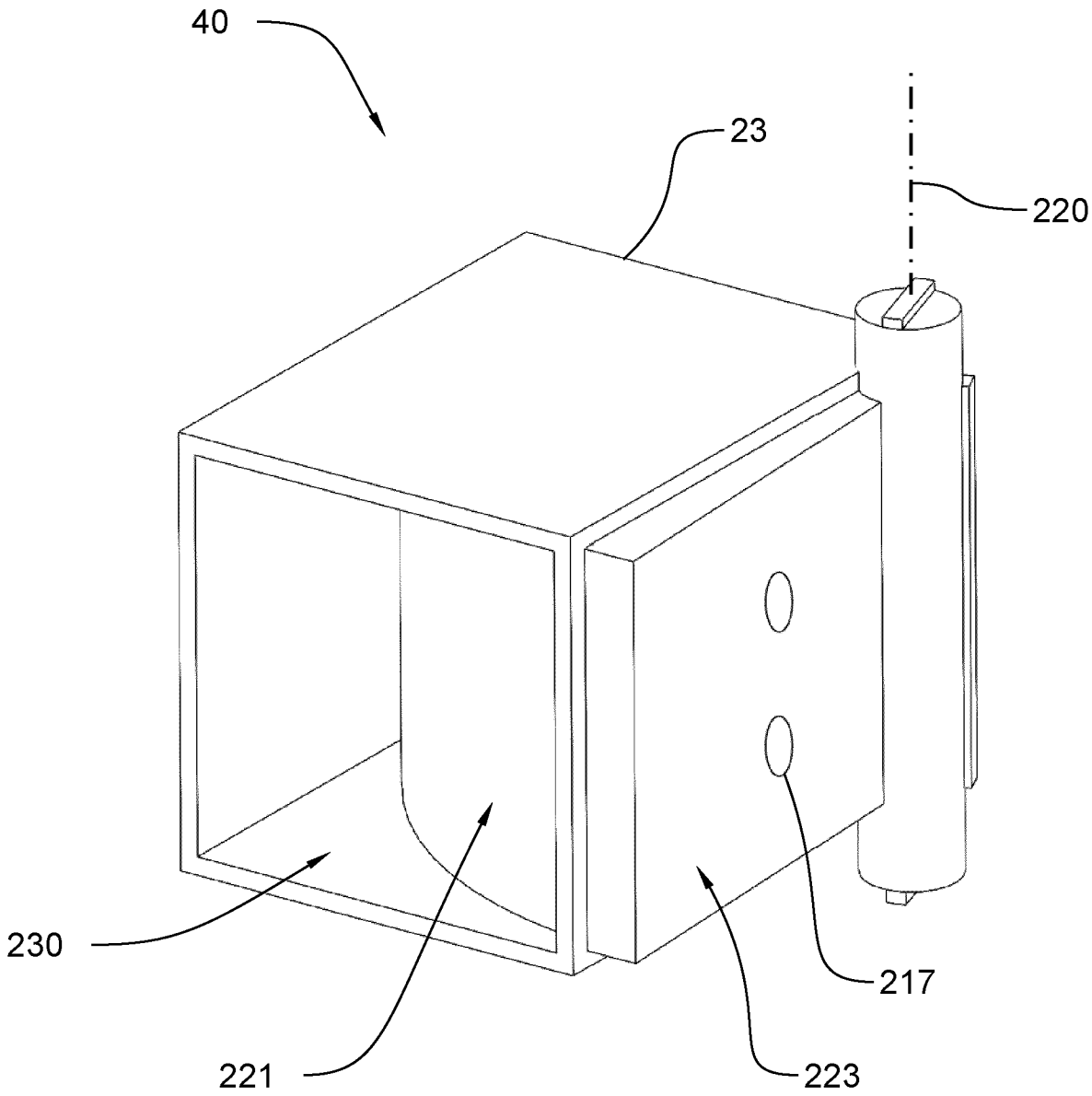

FIG 7

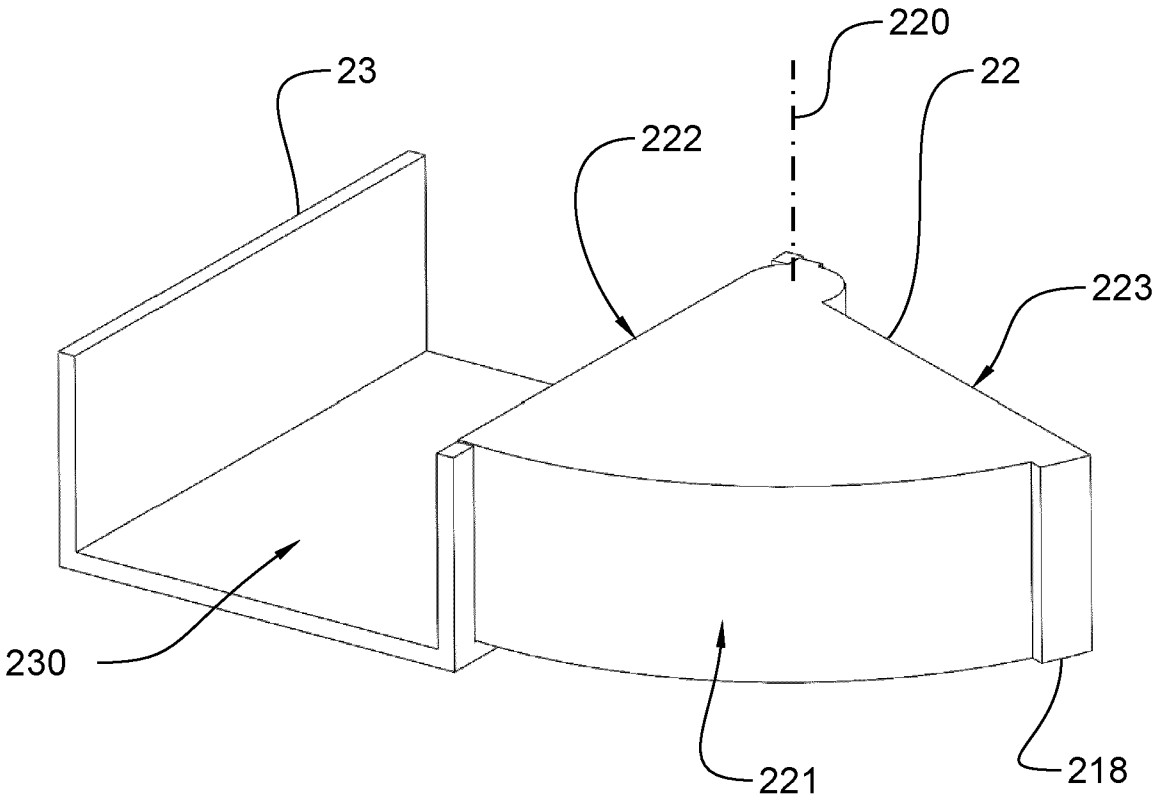

FIG 8

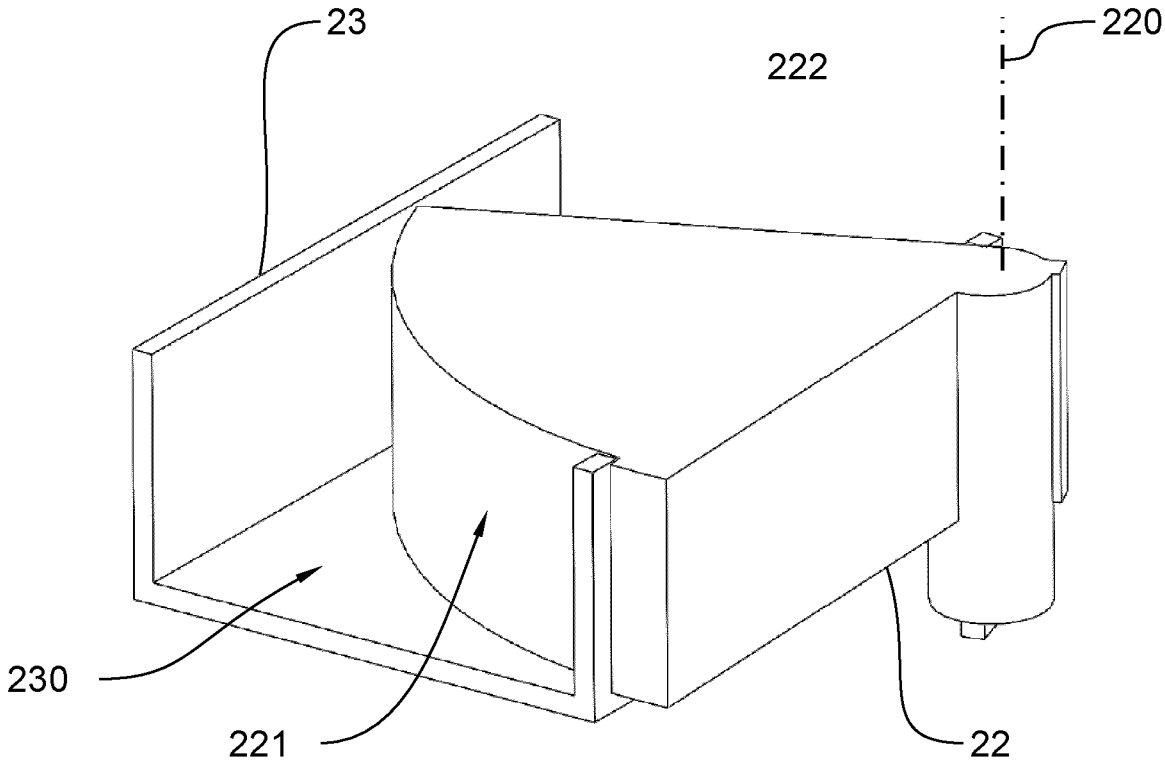

FIG 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/065396

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03B5/16 C10B25/06 C10B25/12 F27D1/18
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)
C03B C04B F27B F27D C21D C10B E05B E05C

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.
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A	EP 2 347 208 A1 (SMS SIEMAG AG [DE]) 27 July 2011 (2011-07-27) figure 1	1-15
A	WO 2014/198977 A1 (FIVES STEIN BILBAO S A [ES]) 18 December 2014 (2014-12-18) figures 8, 9	1-15
A	US 2006/049641 A1 (BARKDOLL MICHAEL P [US] ET AL) 9 March 2006 (2006-03-09) figure 9	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

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"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
20 August 2024	30/08/2024

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	Flügel, Alexander

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

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