

(19)



(11)

EP 4 772 293 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.07.2026 Bulletin 2026/28

(51) International Patent Classification (IPC):
B22D 1/00 (2006.01) **C21C 5/48** (2006.01)
F27D 3/16 (2006.01)

(21) Application number: **25150476.7**

(52) Cooperative Patent Classification (CPC):
B22D 1/005; C21C 5/48; F27D 3/16;
F27D 2003/161

(22) Date of filing: **07.01.2025**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(71) Applicant: **Refractory Intellectual Property GmbH & Co. KG**
1100 Wien (AT)

(72) Inventor: **SADUAL, Manas Ranjan**
Rourkela (IN)

(74) Representative: **Eibel, Anna**
RHI Magnesita GmbH
Kranichberggasse 6
1120 Wien (AT)

(54) GAS PURGING PLUG AND METHOD FOR PRODUCING A GAS PURGING PLUG

(57) The present invention discloses a gas purging plug configured to transport gas from a bottom end of the gas purging plug to a top end of the gas purging plug, the gas purging plug comprising a first refractory body, the first refractory body comprising a first end, a second end and a lateral surface, the first end being arranged at the top end of the gas purging plug and the second end being arranged closer to the bottom end of the gas purging plug than the first end; the first refractory body further comprising at least two refractory plates, wherein each refractory plate extends from the first end to the second end of the first refractory body and each refractory plate is adjacent to at least one further refractory plate; the first refractory body further comprising at least one gas channel being arranged between adjacent refractory plates, the at least one gas channel extending from the first end to the second end of the first refractory body; the gas purging plug further comprising a second refractory body, wherein the second refractory body extends from the top end to the bottom end of the gas purging plug, and surrounds the lateral surface of the first refractory body, and is impermeable to gas; wherein each refractory plate is provided in the form of a pressed and sintered refractory plate comprising pores, wherein said pores are at least partly filled with a carbonaceous material.

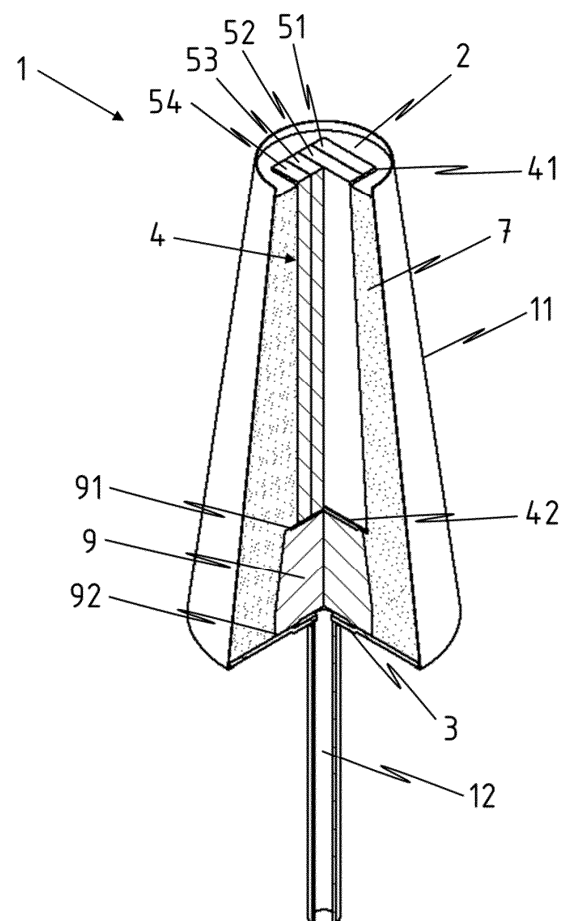


Figure 1

Description

[0001] The invention relates to a gas purging plug and to a method for producing a gas purging plug.

[0002] Gas purging plugs are used for the metallurgical treatment of molten metals, for example in a steel ladle for secondary metallurgical treatment of molten steel.

[0003] A gas purging plug typically has a bottom end and an opposite top end and comprises refractory material through which a gas can be transported. A gas purging plug is designed such that gas can be introduced at the bottom end. The gas then flows through the refractory material and exits the gas purging plug at the top end.

[0004] Herein, the term "refractory material" is used as known from the prior art. The term preferably refers to a material produced from inorganic refractory raw materials which can withstand high temperatures such as at least 1500°C or higher, without softening. A refractory material has preferably a pyrometric cone temperature equivalent ("Kegelfallpunkt") above 1500°C according to ISO 836 and DIN 51060. The pyrometric cone temperature equivalent can be determined according to ISO 528 and DIN EN 993-12.

[0005] A gas purging plug is typically mounted in the bottom region of a metallurgical vessel, such that the top end of the gas purging plug is in direct contact with the metal melt inside the vessel.

[0006] Gas introduced into a molten metal through a gas purging plug can be used, e.g., for homogenizing the composition and temperature of the molten metal, for removing undesired gases from the molten metal and/or for transporting non-metallic contaminations into the slag. This allows a purification of the molten metal.

[0007] Various technologies are known to allow gas to pass through the refractory material in the gas purging plug. According to one technology, the body of the gas purging plug comprises a porous, permeable refractory material through which gas can be passed. Since in this case the gas permeability results from the random, chaotic arrangement of the pore structure in the refractory ceramic material, it is also referred to as "undirected" or "random" porosity.

[0008] According to another technology, gas channels (also called "gas slots" or "gas slits") of a defined geometry are arranged in the refractory material. Such gas channels, which have a defined geometry, are also referred to as "directed" porosity.

[0009] Gas channels for purging plugs with directed porosity may for example be created by burning out (i.e., combusting) a combustible material that has been arranged on the refractory material. Thereby, the remaining burned-out hollow area forms gas channels. For example, an adhesive tape or adhesive film of combustible material, such as plastic or cellulose, may be used for this purpose.

[0010] A refractory ceramic gas purging plug having both undirected porosity and directed porosity is disclosed, for example, in EP 1 101 825 A1. In EP 1 101 825 A1, the gas channels are formed from combustible material. EP 1 101 825 A1 further discloses a "segmented" refractory body, consisting of at least two refractory plates (segments), wherein slot-like channels are formed between corresponding surface sections of adjacent plates. For this purpose, the plates comprise recesses (also called: "grooves") on their surface. According to EP 1 101 825 A1, the gas channels are inserted into a porous refractory material having undirected / random porosity, and therefore, a refractory material having both random and directed porosity is in direct contact with molten metal.

[0011] However, if a refractory material with random porosity is in direct contact with molten metal, the molten metal may infiltrate the pores, which leads to a considerable wear, and thus to a reduced lifetime of the gas purging plug. This results in the necessity to frequently replace the purging plug during operation of the metallurgical vessel, which is (at the same time) dangerous, time-consuming and costly.

[0012] It is an object of the present invention to provide a gas purging plug which shows a higher wear resistance and thus an increased lifetime compared to conventional purging plugs having directed and undirected porosity.

[0013] This object is achieved by a gas purging plug and by a method to obtain a refractory plate for use in a gas purging plug and by a method to obtain a gas purging plug, as defined in the independent claims. Any advantages and embodiments mentioned in connection with the gas purging plug also apply analogously to the methods and vice versa.

[0014] The gas purging plug according to the present invention comprises a first refractory body comprising several refractory plates and may therefore also be referred to as a "segmented gas purging plug". The refractory plates may also be referred to as "refractory segments".

[0015] The core idea of the present invention lies in the provision of a segmented gas purging plug, in which the refractory plates are impregnated with a carbonaceous material, preferably a phenol formaldehyde resin, before being assembled into the gas purging plug. Due to the impregnation, the pores of the refractory plates are filled, thus reducing the apparent porosity of the refractory plates. As a result of the presence of a carbonaceous material inside the pores of the refractory plates, molten metal is prevented from infiltrating the pores of the refractory plates during application of the gas purging plug, which leads to an increased wear resistance and thus to an increased lifetime of the gas purging plug. Herein, the term "wear resistance" encompasses resistance against chemical, mechanical as well as thermal attack, e.g., the resistance against chemical corrosion, the resistance against mechanical abrasion and the resistance against thermal shocks or spalling.

[0016] Further, it has surprisingly been found that the presence of a carbonaceous material, such as a phenol

formaldehyde resin or a thermal degradation product thereof, inside the pores of the refractory plates of a segmented gas purging plug leads to an increased thermal conductivity of the gas purging plug and to a decreased formation of cracks during application, when compared to a conventional segmented gas purging plug. It is assumed that these effects contribute to avoiding discontinuous wear, which is beneficial for increasing the lifetime of the segment purging plug.

[0017] The present invention provides a gas purging plug configured to transport gas from a bottom end of the gas purging plug to a top end of the gas purging plug, the gas purging plug comprising the following features:

- a first refractory body, comprising:

- a first end, a second end and a lateral surface, the first end being arranged at the top end of the gas purging plug and the second end being arranged closer to the bottom end of the gas purging plug than the first end;
- at least two refractory plates,

- each refractory plate extending from the first end to the second end of the first refractory body,
- each refractory plate being adjacent to at least one further refractory plate;

- at least one gas channel being arranged between adjacent refractory plates, the at least one gas channel extending from the first end to the second end of the first refractory body;

- a second refractory body,

- the second refractory body extending from the top end to the bottom end of the gas purging plug,
- the second refractory body surrounding the lateral surface of the first refractory body, and
- the second refractory body being impermeable to gas;

- wherein each refractory plate is provided in the form of a pressed and sintered refractory plate comprising pores, wherein said pores are at least partly filled with a carbonaceous material.

[0018] The gas purging plug according to the invention comprises a first refractory body. The first refractory body has a first end, a second end and a lateral surface, the first end being arranged at the top end of the gas purging plug and the second end being arranged closer to the bottom end of the gas purging plug than the first end. Thus, the first refractory body extends from the top end towards the bottom end of the gas purging plug. In some embodiments, the second end of the first refractory body may be arranged at the bottom end of the gas purging plug. During application of the purging plug in a metallurgical vessel, the first end of the first refractory body is in direct contact with molten metal.

[0019] The first refractory body comprises at least two refractory plates and at least one gas channel being arranged between adjacent refractory plates. Preferably, the first refractory body is composed of at least two refractory plates and at least one gas channel being arranged between adjacent refractory plates. Each refractory plate extends from the first end to the second end of the first refractory body. In other words, the height of the refractory plates is equal to the height of the first refractory body. Each refractory plate is adjacent to at least one further refractory plate. In this context, the term "adjacent" means that each refractory plate has at least one direct neighbor plate, to which it is arranged in parallel and to which it preferably abuts. If more than two refractory plates are present in the first refractory body, each middle plate is adjacent to two further refractory plates, i.e., has two direct neighbors, whereas the outer plates have one direct neighbor.

[0020] At least one gas channel is arranged between adjacent refractory plates, the at least one gas channel extending from the first end to the second end of the first refractory body. In other words, the at least one gas channel connects the second end of the first refractory body with the first end, such that gas can be transported through the first refractory body via said at least one gas channel. Thus, due to the presence of said at least one gas channel, the first refractory body has a directed porosity. Preferably, the first refractory body may allow a gas flow of 1 standard liter to 600 standard liters per minute.

[0021] The gas purging plug according to the invention further comprises a second refractory body, which extends from the top end to the bottom end of the gas purging plug. The second refractory body surrounds the lateral surface of the first refractory body.

[0022] Herein, the term "lateral surface" refers to the outer surface of the first refractory body formed by the sum of its side surfaces, excluding the top surface (i.e., the surface where the first end of the first refractory body is located), and excluding the bottom surface (i.e., the surface, where the second end of the first refractory body is located). For example, if the first refractory body has a cuboid shape with a rectangular cross section, the lateral surface is formed by the sum of the four side surfaces.

[0023] Since the second refractory body surrounds the lateral surface of the first refractory body, it does not surround the first end of the first refractory body, nor the second end of the first refractory body. In other words, the second refractory

body does not surround the top surface of the first refractory body, where the first end of the first refractory body is located and where gas is released from the first refractory body, nor the bottom surface of the first refractory body, where the second end of the first refractory body is located and where gas is introduced into the first refractory body.

[0024] Preferably, the first refractory body forms the core of the gas purging plug, and the second refractory body symmetrically surrounds the lateral surface of the first refractory body.

[0025] Herein, the term "surround" refers both to embodiments, in which the second refractory body encloses the lateral surface of the first refractory body directly and entirely (i.e., the second refractory body abuts to the first refractory body) and to embodiments, in which the second refractory body encloses the lateral surface of the first refractory body with a distance, which means that a gap, such as a gas channel, may be present between the first refractory body and the second refractory body.

[0026] Since both the first refractory body and the second refractory body extend from the top end of the gas purging plug towards the bottom end of the gas purging plug, both the first refractory body and the second refractory body are in direct contact with liquid metal at the top end of the gas purging plug, when the gas purging plug is in use.

[0027] According to the invention, the second refractory body is impermeable to gas. Herein, the term "impermeable to gas" means that the second refractory body is not configured to transport gas from the bottom end to the top end of the gas purging plug. Preferably, the gas permeability of the second refractory body is below $0.005 \mu\text{m}^2$, determined according to ISO 8841. The second refractory body is preferably provided in the form of a cast refractory body as described herein.

[0028] According to the invention, each refractory plate is provided in the form of a pressed and sintered refractory plate comprising pores.

[0029] A "pressed and sintered refractory plate" is herein to be understood as a refractory body produced from a batch of refractory raw material, wherein said batch is first pressed into a green body in the shape of a plate, followed by a sintering (firing) step. The sintering step is usually performed at temperatures above 1500°C , preferably above 1550°C , such that the grains of the raw materials are sintered together and ceramically bonded.

[0030] During these production steps, pores are formed inside the material. Therefore, the pressed and sintered refractory plates as described herein comprise pores. The porosity of the pressed and sintered refractory plates can be controlled as known in the art, e.g., by selecting the composition and grain size distribution of the raw material and by selecting the production parameters such as the pressing pressure.

[0031] According to the present invention, the pores of the pressed and sintered refractory plates are at least partly filled with a carbonaceous material. As used herein, the term "carbonaceous material" refers to any material comprising a high amount of carbon, in particular more than 50 wt. % of carbon, preferably more than 60 wt. % of carbon, even more preferably more than 70 wt. % of carbon. The term "carbonaceous material" encompasses both inorganic materials, such as graphite, and organic materials based on saturated, unsaturated or aromatic hydrocarbons, wherein the organic materials may further comprise heteroatoms like oxygen. Examples for carbonaceous materials include synthetic organic polymers, oils, tar, and pitch.

[0032] It has been found that the presence of the carbonaceous material inside the pores of the refractory plates reduces the apparent porosity of the refractory plates. Moreover, the presence of the carbonaceous material leads to an increased thermal conductivity of the gas purging plug and to a decreased formation of cracks during application, when compared to a conventional segmented gas purging plug. These effects result in an increased wear resistance and thus in an increased lifetime of the gas purging plug, when the gas purging plug is applied in a vessel for the treatment of molten metal, as described above.

[0033] Preferably, the carbonaceous material is a phenol formaldehyde resin, or a thermal degradation product of a phenol formaldehyde resin, said thermal degradation product being obtained at a temperature between 300°C and 650°C , preferably at a temperature between 300°C and 550°C . The thermal degradation product of the phenol formaldehyde resin may be obtained due to heat treatment of the pressed and sintered refractory plates and/or due to heat treatment of the gas purging plug, wherein said heat treatment is performed at a temperature between 300°C and 650°C , preferably at a temperature between 300°C and 550°C .

[0034] Preferably, the carbonaceous material is a phenol formaldehyde resin. As known in the art, a phenol formaldehyde resin is a synthetic organic polymer obtained by the reaction of phenol with formaldehyde. In the present invention, it has been found that phenol formaldehyde resins show good infiltration properties into the pores of refractory materials and can easily be handled during production of the gas purging plug, especially during an impregnation step of the pressed and sintered refractory plates. In particular, phenol formaldehyde resins typically show a lower viscosity than other impregnation media such as tar or pitch, and therefore, the impregnation can be performed at lower temperatures, which is beneficial for saving energy. Additionally, phenol formaldehyde resins show a low toxicity, and produce less harmful fumes during heating when compared to other carbonaceous materials, such as tar or pitch. For these reasons, it is advantageous to use a phenol formaldehyde resin as a source for the carbonaceous material.

[0035] Preferably, the phenol formaldehyde resin is a resole or a novolak, even more preferably a resole. As known in the art, a novolak is a phenol formaldehyde resin with a formaldehyde to phenol molar ratio of less than one, while resoles are obtained if a formaldehyde to phenol ratio of greater than one is used during the synthesis.

[0036] The phenol formaldehyde resin is preferably a phenol formaldehyde resole resin. Using a resole is advantageous compared to novolaks, since resoles are known to have a lower viscosity than novolaks. Preferably, the phenol formaldehyde resin, such as the phenol formaldehyde resole resin, has an (apparent) viscosity at 25 °C between 0.35 Pa·s and 1 Pa·s, determined according to ISO 2555:2018. This viscosity is low enough to allow an easy handling of the phenol formaldehyde resin.

[0037] According to the invention, the carbonaceous material can be introduced into the pores of the pressed and sintered refractory plates via an impregnation step. Preferably, such an impregnation step is performed before the gas purging plug is produced, i.e., before the pressed and sintered refractory plates are assembled to form the first refractory body and before the second refractory body is built around the first refractory body. Thereby, it can be assured that the carbonaceous material is only present in the pores of the refractory plates and does not contaminate other parts of the gas purging plug.

[0038] During the production of the gas purging plug, the pressed and sintered refractory plates and/or the gas purging plug may be subjected to one or more heat treatment steps.

[0039] Such a heat treatment step (also called "tempering step") may be performed after impregnating the pressed and sintered refractory plates with the carbonaceous material. This heat treatment step has the advantage that sticky and/or volatile compounds can be removed from the surface of the impregnated refractory plates, which for example allows an easier cleaning of the obtained refractory plates. Such a heat treatment step is preferably performed under a reducing atmosphere and preferably at a temperature between 300 and 650 °C, more preferably between 300 and 500 °C, even more preferably between 350 and 450 °C. The tempering step may also be performed under a neutral (inert) atmosphere, i.e., an atmosphere that is neither reducing nor oxidizing.

[0040] A heat treatment step may also be performed with the obtained gas purging plug, after assembling the first and the second refractory body for the purpose of curing the second refractory body in case the second refractory body is a cast refractory body (i.e., produced from an unshaped refractory mass). This heat treatment step is beneficial to remove water from the cast refractory material. This heat treatment step may preferably be performed at a temperature between 300 °C and 600 °C, more preferably between 300 °C and 550 °C.

[0041] A heat treatment step may also be performed to produce further gas channels from a combustible material inside the gas purging plug, as described herein. Such a heat treatment step is preferably performed under an oxidizing atmosphere and preferably at a temperature between 400 and 650 °C, more preferably between 400 and 550 °C. In this case, the temperature range for the burnout of the combustible material is preferably chosen such that the carbonaceous material inside the pores of the refractory plates is not burnt out.

[0042] If one or more heat treatment steps are performed during the production of the gas purging plug, the carbonaceous material inside the pores of the refractory plates may undergo a thermal degradation reaction. Thus, in the final gas purging plug, the carbonaceous material may be present in the form of a thermal degradation product.

[0043] Preferably, the carbonaceous material may be a thermal degradation product of a phenol formaldehyde resin, said thermal degradation product being obtained at a temperature between 300 °C and 650 °C, preferably at a temperature between 300 °C and 550 °C. As described above, the thermal degradation product of the phenol formaldehyde resin may be obtained due to heat treatment of the pressed and sintered refractory plates and/or due to heat treatment of the gas purging plug, wherein said heat treatment is performed at a temperature between 300 °C and 650 °C, preferably at a temperature between 300 °C and 550 °C. Thus, if a phenol formaldehyde resin was originally used to at least partly fill the pores of the refractory plates, a thermal degradation product of said phenol formaldehyde resin may be present in the pores after the production of the gas purging plug is completed. The thermal degradation product may, e.g., comprise a polymeric carbon scaffold resulting from the thermal degradation of the resin.

[0044] Preferably, the refractory plates are produced from a batch of non-basic refractory raw materials. In this context, a "batch of non-basic refractory raw materials" is a refractory batch based on non-basic refractory raw materials. The term "based on" shall refer to the main component of the batch. For example, a batch "based on non-basic refractory raw materials" contains such non-basic refractory raw materials as the main refractory component and may further contain other components such as binders or additives.

[0045] Preferably, the refractory plates are produced from a batch of non-basic refractory raw materials selected from the group consisting of mullite, corundum, chromia, zirconia and mixtures thereof.

[0046] As known in the art, mullite is an aluminum silicate raw material comprising alumina (aluminium oxide, Al_2O_3) and silica (silicon dioxide, SiO_2), having the chemical formula $3\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ or $2\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2$. Corundum is a mineral consisting of alumina. "Chromia" refers to chromium(III) oxide (Cr_2O_3) and "zirconia" refers to zirconium oxide (ZrO_2).

[0047] By using these raw materials, refractory plates having a high refractoriness and high thermal shock resistance can be obtained.

[0048] Thus, preferably, the refractory plates according to the invention comprise alumina and optionally further comprise silica (SiO_2), chromia (Cr_2O_3) and/or zirconia (ZrO_2).

[0049] Preferably, the refractory plates comprise alumina in an amount of at least 80 wt.%, preferably at least 85 wt.%, based on the total weight of the refractory plates. Such an alumina content is advantageous for achieving a particularly high

refractoriness. Herein, the "total weight of the refractory plates" refers to the weight of the pressed and sintered refractory plates excluding the weight of the carbonaceous material present in the pores of said plates.

[0050] It has been found that particularly good properties can be obtained if the refractory plates are produced from a batch based on mullite and corundum, or from a batch based on chromia and corundum, or from a batch based on chromia, corundum and zirconia. If the refractory plates are produced from a batch based on mullite and corundum, refractory plates having a high refractoriness, and a sufficiently high thermal shock resistance can be obtained in a cost-efficient way. If the refractory plates are produced from a batch based on chromia, corundum and zirconia, refractory plates having a high refractoriness, and a particularly high thermal shock resistance can be obtained.

[0051] If the refractory plates are produced from a batch based on mullite and corundum, the refractory plates may have a silica content of 5 to 15 wt.%, and an alumina content of up to 95 wt.%, based on the total weight of the refractory plates.

[0052] If the refractory plates are produced from a batch based on chromia and corundum, the refractory plates may have a chromia content of 2 to 10 wt.% and an alumina content of up to 98 wt.%, based on the total weight of the refractory plates.

[0053] If the refractory plates are produced from a batch based on chromia, corundum and zirconia, the refractory plates may have a chromia content of 2 to 10 wt.%, a zirconia content of 2 to 10 wt.% and an alumina content of up to 96 wt.%, based on the total weight of the refractory plates.

[0054] The contents of alumina, chromia, silica and zirconia may be determined according to ISO 12677.

[0055] Before introducing the carbonaceous material into the pores of the refractory plates, the plates may show an apparent porosity in the range of 14 % to 18 %, determined according to ASTM C-20. After at least partly filling the pores of the refractory plates with the carbonaceous material as described herein, the plates preferably show an apparent porosity in the range of 8 % to 11 %, determined according to ASTM C-20. It has been found that refractory plates having an apparent porosity in the range of 8 % to 11 % show a particularly good wear resistance, due to a combination of a high corrosion resistance and a high thermal spalling resistance.

[0056] The dimensions of each refractory plate may be defined by the height, the width and the thickness of the refractory plate. Preferably, each refractory plate has a height of 100 mm to 700 mm, preferably of 300 mm to 400 mm. Preferably, each refractory plate has a width of 30 mm to 150 mm, preferably 50 mm to 130 mm. Preferably, each refractory plate has a thickness of 8 mm to 25 mm, preferably 10 mm to 15 mm. Preferably, the width of each refractory plate increases along the height of the refractory plate from a first end to a second end of the refractory plate, such that the refractory plate has a trapezoidal shape. Alternatively, the refractory plate may also have a cuboid shape, thus having a constant width along the height of the refractory plate.

[0057] Preferably, the at least one gas channel being arranged between adjacent refractory plates is provided in the form of at least one recess (also called a "groove") pressed into a surface of one of said at least two adjacent refractory plates, said at least one recess being covered by a surface of an adjacent refractory plate.

[0058] If the at least one gas channel comprises two or more gas channels, it is preferred that each of said gas channels is provided in the form of a recess pressed into a surface of one of said at least two adjacent refractory plates, the recesses being covered by a surface of an adjacent refractory plate.

[0059] The recess may be pressed into the front surface or into the back surface of said refractory plate. The terms "front surface" and "back surface" herein refer to those surfaces of the refractory plate that are defined by the width and the height of the refractory plate. Preferably, the surface, in particular the front surface or back surface, of the adjacent refractory plate, which covers the recess, does not comprise a recess.

[0060] By using a refractory plate having a recess on one of their surfaces, a gas channel can easily be obtained between adjacent refractory plates, when the refractory plates are assembled in the first refractory body.

[0061] Advantageously, the dimensions of the at least one gas channel can be adjusted by adjusting the dimensions of the recess. According to the present invention, it is preferred that each recess has a rectangular shape having a width of 5 mm to 50 mm, preferably 15 mm to 20 mm, and a depth of 0.1 mm to 0.5 mm, preferably a depth of not more than 0.3 mm. A depth of maximum 0.3 mm allows to efficiently avoid the infiltration of molten metal into the gas channel.

[0062] Preferably, the at least one gas channel being arranged between adjacent refractory plates comprises at least two gas channels. In other words, it is preferred that at least two gas channels are arranged between adjacent refractory plates, wherein each gas channel extends from the first end to the second end of the first refractory body.

[0063] Preferably, the at least two refractory plates of the inventive gas purging plug comprise at least three, preferably at least four, refractory plates, wherein each of said refractory plates extends from the first end to the second end of the first refractory body, and each of said refractory plates is adjacent to at least one further refractory plate. The at least two refractory plates of the inventive gas purging plug may also comprise at least five or six refractory plates.

[0064] Further preferably, the at least one gas channel comprises at least four, preferably at least six, gas channels, wherein each of said at least four, preferably at least six, gas channels is arranged between adjacent refractory plates, and each of said at least four, preferably at least six, gas channels extends from the first end to the second end of the first refractory body. Each of said at least four, preferably at least six, gas channels may be provided in the form of a recess pressed into a surface of one of said refractory plates, said recess being covered by a surface of an adjacent refractory

plate, as described herein.

[0065] According to a particularly preferred embodiment, the first refractory body comprises, preferably is composed of, at least three, preferably at least four, refractory plates, and at least four, preferably at least six, gas channels. These numbers of refractory plates and gas channels are beneficial for ensuring a uniform and efficient gas flow into the molten metal, when the gas purging plug is in use. Furthermore, a higher number of refractory plates allows to obtain higher gas flow rates.

[0066] The at least four, preferably at least six, gas channels are preferably arranged such that at least one, preferably at least two, gas channels are present between each pair of adjacent refractory plates. This allows for a particularly uniform and efficient gas flow into the molten metal, when the gas purging plug is in use.

[0067] For example, a first refractory body comprising four refractory plates may be provided, wherein a first refractory plate is adjacent to a second refractory plate, the second refractory plate is adjacent to the first refractory plate and to a third refractory plate (i.e., the second refractory plate is located between the first and the third refractory plate), the third refractory plate is adjacent to the second refractory plate and to a fourth refractory plate (i.e., the third refractory plate is located between the second and the fourth refractory plate), and the fourth refractory plate is adjacent to the third refractory plate.

In this case, it is preferred that six gas channels are arranged between the refractory plates such that two gas channels are arranged between the first refractory plate and the second refractory plate, and further two gas channels are arranged between the second refractory plate and the third refractory plate, and further two gas channels are arranged between the third refractory plate and the fourth refractory plate. By this arrangement, a highly uniform gas transfer into a molten metal and high gas flow rates can be achieved.

[0068] Preferably, the second refractory body is provided as a cast refractory body. The term "cast refractory body" refers to a refractory body that is produced from an unshaped mass of a refractory raw material, which mass is poured or cast into a mold to form the second refractory body. The second refractory body may be produced from an unshaped mass of non-basic refractory raw materials such as alumina, alumina spinel, cement or chromia and/or mixtures thereof. The alumina may be provided in the form of fused, tabular or calcined alumina.

[0069] Preferably, the inventive gas purging plug comprises at least one further gas channel in addition to the at least one gas channel being arranged between adjacent refractory plates, wherein the at least one further gas channel is formed as an interstice between the first refractory body and the second refractory body and wherein the at least one further gas channel ranges from the top end to the bottom end of the first refractory body. In other words, the at least one further gas channel is located between the first refractory body and the second refractory body, i.e., the at least one further gas channel is formed as a gap between the first refractory body and the second refractory body. Therefore, gas can be introduced into a molten metal via said at least one further gas channel. Thus, according to this embodiment, two types of gas channels are present, the first type being the at least one gas channel arranged between adjacent refractory plates of the first refractory body, and the second type being the at least one further gas channel formed as an interstice between the first and second refractory body. This second type of gas channel may additionally contribute to a uniform and efficient gas flow into the molten metal, when the gas purging plug is in use, and may increase the maximum gas flow rate through the gas purging plug.

[0070] Preferably, the at least one further gas channel (i.e., the second type of gas channels) is formed from a combustible material. For that purpose, the combustible material may be arranged on the lateral surface of the first refractory body. The combustible material is preferably provided in the form of an adhesive tape or an adhesive film. The combustible material may be made of any material that burns out (i.e., combusts) upon heating, such as plastic, cellulose, paper or cardboard. Preferably, the combustible material is made of plastic, preferably polyethylene (PE), even more preferably low-density polyethylene (LDPE). To form a gas channel ranging from the top end to the bottom end of the first refractory body, the combustible material is arranged such that the total height of the first refractory body is covered. After arranging the combustible material on the lateral surface of the first refractory body, the second refractory body may be built, e.g., by casting a refractory mass around the first refractory body. Afterwards, the gas purging plug may be subjected to a heat treatment step to burn out (and thus remove) the combustible material, so that a gas channel is formed as an interstice between the first refractory body and the second refractory body. As described above, such a heat treatment step may be performed under an oxidizing atmosphere and preferably at a temperature between 400 and 650 °C, preferably between 400 and 550 °C.

[0071] Preferably, the inventive gas purging plug further comprises a third refractory body,

- the third refractory body having a first end and a second end, the first end being arranged at the second end of the first refractory body, and the second end being arranged closer to the bottom end of the gas purging plug than the first end,
- wherein the second end of the third refractory body is preferably arranged at the bottom end of the gas purging plug;
- wherein the third refractory body is provided in the form of a pressed and sintered refractory body comprising pores,

◦ wherein the pores are configured to transport gas from the second end to the first end of the third refractory body, and

◦ wherein the third refractory body has a higher apparent porosity than the refractory plates of the first refractory body;

- wherein the third refractory body preferably has a different horizontal cross section than the first refractory body.

[0072] The first end of the third refractory body is arranged at the second end of the first refractory body. Accordingly, the bottom surface of the first refractory body (where the second end of the first refractory body is located) may at least partly abut to the top surface of the third refractory body (where the first end of the third refractory body is located). Preferably, the top surface of the third refractory body is provided with a recess, which serves as a gas distribution chamber. From this gas distribution chamber, the gas may flow into the first refractory body.

[0073] The second end of the third refractory body is arranged closer to the bottom end of the gas purging plug than the first end of the third refractory body. If a third refractory body is present, said third refractory body is arranged between the first refractory body and the bottom end of the gas purging plug. Preferably, the third refractory body is arranged at the bottom end of the gas purging plug.

[0074] The third refractory body is provided in the form of a pressed and sintered refractory body comprising pores. The pores of the third refractory body are configured to transport gas from the second end to the first end of the third refractory body, and thus, the third refractory body allows a gas flow via random porosity. The third refractory body has a higher apparent porosity than the refractory plates of the first refractory body to efficiently allow a gas flow via random porosity. Preferably, the apparent porosity of the third refractory body is in the range of 25 % to 35 %, preferably between 29 % to 32 %, determined according to ASTM C-20.

[0075] The third refractory body is preferably made of a non-basic refractory material, such as alumina, alumina spinel, chromia and/or mixtures thereof. These materials are advantageous due to their high refractoriness.

[0076] If a third refractory body is present, the second refractory body preferably surrounds the lateral surface of the third refractory body, such that the second refractory body surrounds both the lateral surface of the first refractory body and the lateral surface of the third refractory body.

[0077] The purpose of installing a third refractory body below the first refractory body is to avoid that the at least one gas channel of the first refractory body directly connects the top end of the gas purging plug with the bottom end of the gas purging plug. Such a direct connection may be disadvantageous, since liquid metal could in this case directly flow through the at least one gas channel from the top end of the gas purging plug down to the bottom end, which might constitute a safety risk. Thus, installing a third refractory body is advantageous for improving the safety of the gas purging plug.

[0078] Preferably, the third refractory body has a different horizontal cross section than the first refractory body. Thereby, the third refractory body may act as a safety indicator. A visible change in the cross section indicates that the first refractory body has been destroyed due to wear, which is an indication that the gas purging plug needs to be replaced.

[0079] Preferably, the first refractory body has a rectangular horizontal cross section, whereas the third refractory body has a circular horizontal cross section. Preferably, the third refractory body has the shape of a truncated cone.

[0080] Preferably, the inventive gas purging plug has the shape of a truncated cone. This shape allows an easy installation and demounting of the gas purging plug at the bottom of a metallurgical vessel. The inventive gas purging plug may have a height of 200 mm to 800 mm, preferably 350 mm to 600 mm, the height of the gas purging plug being defined as the distance from the top end to the bottom end of the gas purging plug.

[0081] Preferably, the second refractory body is covered by a metal casing. A metal casing is advantageous for installing the gas purging plug at the bottom of a metallurgical vessel.

[0082] Gas may be introduced into the gas purging plug via a gas injection system attached to the bottom end of the gas purging plug. After introducing the gas into the gas purging plug, the gas is directed through the third refractory body, in case such a third refractory body is present, and then the gas is directed through the first refractory body, from where it is released into a molten metal.

[0083] The present invention also provides a method for producing a refractory plate for use in a gas purging plug, said method comprising the steps of:

- pressing a batch of refractory raw materials into a green body, said green body having the shape of a plate, wherein at least one recess is pressed into a surface of said green body, such that the at least one recess extends from a first end to a second end of the green body;
- sintering said green body at a temperature above 1500 °C to obtain a pressed and sintered refractory plate comprising pores;
- impregnating said pressed and sintered refractory plate with a carbonaceous material,
- optionally subjecting the impregnated pressed and sintered refractory plate to a heat treatment step.

[0084] As a first step of the inventive method, a batch of refractory raw materials is pressed into a green body in the shape of a plate. Preferably, said refractory raw materials are non-basic refractory raw materials, preferably being selected from

the group consisting of mullite, corundum, chromia, zirconia and mixtures thereof.

[0085] Even more preferably, said refractory raw materials are provided as a mixture of mullite and corundum, or as a mixture of chromia and corundum, or as a mixture of chromia, corundum and zirconia. Thus, preferably, the refractory plate is produced from a batch based on mullite and corundum, or from a batch based on chromia and corundum, or from a batch

[0086] In addition to the non-basic refractory raw materials, the batch may comprise further components such as binders or additives. For example, a lignosulfonate may be used as a binder.

[0087] As known in the art, a "green body" is a shaped non-fired refractory body. In the present invention, the batch is shaped into a green body in the shape of a plate by pressing, which is a simple and precise method for shaping a refractory batch. The pressing step is preferably performed in such a way that a plate having the dimensions (height, width, thickness) as described herein is formed.

[0088] The refractory plate has at least one recess pressed into a surface, such that the at least one recess extends from a first end to a second end of the green body. In other words, the recess extends along the height of the plate. The at least one recess may be pressed into the front surface or into the back surface of the refractory plate. Preferably, the at least one recess is pressed into said surface centrally, such that the remaining surface is arranged symmetrically around the at least one recess. When the refractory plate is installed in a gas purging plug, the at least one recess will form a gas channel, as described herein.

[0089] Preferably, each of the at least one recesses has a rectangular shape having a width and thickness as described herein.

[0090] After forming the at least one recess, the green body is sintered at a temperature above 1500 °C, preferably above 1550 °C. Thereby, the grains of the raw materials are sintered together and ceramically bonded.

[0091] The obtained pressed and sintered refractory plate is then subjected to an impregnation step, wherein a carbonaceous material is used as the impregnation medium. By impregnating the pressed and sintered refractory plate with a carbonaceous material, the pores of the refractory plate are at least partly filled with said carbonaceous material, as described herein. When the refractory plate is used in a segmented gas purging plug, a gas purging plug having an increased wear resistance and an increased lifetime can be obtained, as described herein.

[0092] Preferably, the carbonaceous material used for impregnating the pressed and sintered refractory plate is a phenol formaldehyde resin. Using a phenol formaldehyde resin is advantageous since phenol formaldehyde resins show good infiltration properties into the pores of refractory materials and can easily be handled during the impregnation process. In particular, phenol formaldehyde resins typically show a lower viscosity than other impregnation media such as tar or pitch, and therefore, the impregnation can be performed at lower temperatures, which is beneficial for saving energy. Additionally, phenol formaldehyde resins show a low toxicity, and produce less harmful fumes during heating when compared to other carbonaceous materials, such as tar or pitch.

[0093] Preferably, the phenol formaldehyde resin is a resole or a novolak, even more preferably a resole. Preferably, the phenol formaldehyde resin, such as the phenol formaldehyde resole resin, has a viscosity at 25°C between 0.35 Pa·s and 1 Pa·s, determined according to ISO 2555:2018. This viscosity is low enough to allow an easy handling of the phenol formaldehyde resin. Preferably, the solid content of the phenol formaldehyde resin is between 70 wt.% and 80 wt.% at 180°C.

[0094] Preferably, the impregnation step is performed under a pressure of 0.5 MPa to 1.5 MPa. For that, the pressed and sintered refractory plate may be placed into a vacuum chamber and evacuated to remove air from the pores. Afterwards, the impregnation medium (carbonaceous material) may be pressed into the pores of the refractory plates by applying a pressure of 0.5 MPa to 1.5 MPa. Performing the impregnation step under a pressure of 0.5 MPa to 1.5 MPa is advantageous to ensure that the pores are well infiltrated with the carbonaceous material. The impregnation step may preferably be performed at a temperature between 25 °C and 250 °C, preferably between 100 °C and 250 °C.

[0095] After the impregnation, the impregnated refractory plate may optionally be subjected to a heat treatment step (also called "tempering step"). This heat treatment step may be performed to remove sticky and/or volatile compounds stemming from the impregnation medium from the surface of the impregnated refractory plates. This also allows an easier cleaning of the obtained refractory plates. Preferably, the heat treatment step is performed under a reducing atmosphere and preferably at a temperature between 300 and 650 °C, more preferably between 300 and 500 °C, even more preferably between 350 and 450 °C. The tempering step may also be performed under a neutral atmosphere, i.e., an atmosphere that is neither reducing nor oxidizing.

[0096] The impregnated pressed and sintered refractory plate obtained by the inventive method can be used as a refractory plate in the first refractory body of a gas purging plug as described herein.

[0097] The present invention further provides a method for producing a gas purging plug, the method comprising the following steps:

- providing at least two refractory plates obtained from the method described herein,
- assembling said at least two refractory plates to obtain a first refractory body such that:

- each refractory plate extends from a first end to a second end of the first refractory body, and
- each refractory plate is adjacent to at least one further refractory plate, and
- at least one gas channel is formed between adjacent refractory plates;

- optionally assembling a combustible material around the lateral surface of the first refractory body;
- placing the first refractory body into a mold;
- casting a mass of a refractory raw material into the mold, such that a second refractory body being impermeable to gas is formed;
- wherein the placing and casting steps are performed such that:

- a gas purging plug comprising a top end and a bottom end is obtained, wherein the first end of the first refractory body is arranged at the top end of the gas purging plug and the second end of the first refractory body is arranged closer to the bottom end of the gas purging plug than the first end, and

- the second refractory body extends from the top end to the bottom end of the gas purging plug and surrounds the lateral surface of the first refractory body;

- optionally subjecting said gas purging plug to a heat treatment step, preferably at a temperature between 300 °C and 650 °C.

[0098] With the inventive method, a gas purging plug as described herein can be obtained.

[0099] As a first step, at least two impregnated pressed and sintered refractory plates produced as described herein are provided. The plates are then assembled to form a first refractory body, such that each plate extends from the first end to the second end of the first refractory body and each plate is adjacent to at least one further plate and at least one gas channel is formed between adjacent refractory plates. The at least one gas channel is preferably formed from the recess pressed into the surface of one of said at least two refractory plates, the recess being covered by a surface of another one of said at least two refractory plates, as described above.

[0100] Preferably, at least three, more preferably at least four, impregnated pressed and sintered refractory plates produced as described herein are assembled to form the first refractory body. Preferably, each of said refractory plates has at least one recess, more preferably at least two recesses, as described above, so that at least four, more preferably at least six, gas channels being arranged between adjacent refractory plates can be obtained.

[0101] In case at least one further gas channel is to be formed as an interstice between the first and the second refractory body, a combustible material can be arranged around the lateral surface of the first refractory body. The combustible material can be provided as an adhesive tape or adhesive film as described above.

[0102] Afterwards, the first refractory body is placed into a mold, and a mass of a refractory raw material is poured into the mold to surround the lateral surface of the first refractory body to form the second refractory body being impermeable to gas. These steps are performed such that a gas purging plug as described herein is obtained.

[0103] In case the gas purging plug shall comprise a third refractory body as described herein, the third refractory body is placed into the mold together with the first refractory body before the mass of unshaped refractory raw material is cast into the mold. The first and third refractory body are arranged inside the mold such that a gas purging plug is formed in which the first end of the third refractory body is arranged at the second end of the first refractory body, and the second end of the third refractory body is arranged closer to the bottom end of the gas purging plug than the first end of the third refractory body, preferably the second end of the third refractory body is arranged at the bottom end of the gas purging plug.

[0104] According to the inventive method, the materials and shapes of the first, second and third refractory body may be chosen as described above. According to the inventive method, the obtained gas purging plug may optionally be subjected to a heat treatment step, preferably at a temperature between 300 °C and 650 °C, more preferably at a temperature between 300 °C and 550 °C.

[0105] This heat treatment step may be performed to remove water from the cast refractory material of the second refractory body. In this case, the heat treatment may be performed under an oxidizing atmosphere and preferably at a temperature between 300 °C and 600 °C, more preferably between 300 °C and 550 °C.

[0106] If a combustible material was assembled around the lateral surface of the first refractory body, the heat treatment step will be required for the purpose of removing the combustible material to produce one or more further gas channels. Such a heat treatment step is preferably performed under an oxidizing atmosphere and preferably at a temperature between 400 and 650 °C, more preferably between 400 and 550 °C. In this case, the temperature range for the burnout of the combustible material is preferably chosen such that the carbonaceous material inside the pores of the refractory plates is not burnt out.

[0107] The present invention is further illustrated below by exemplary and non-limiting figures and examples.

Figure 1 shows a gas purging plug according to one embodiment of the invention.

Figure 2 shows a top view of the gas purging plug shown in Figure 1.

Figure 3 shows a top view of a gas purging plug according to another embodiment of the invention.

5 Figure 4 shows a refractory plate for use in a gas purging plug according to the invention.

[0108] The gas purging plug 1 shown in Figures 1 to 3 is configured to transport gas from the bottom end 3 to the top end 2 of the gas purging plug 1.

10 **[0109]** The gas purging plug 1 comprises a first refractory body 4, the first refractory body 4 having a first (top) end 41 and a second (bottom) end 42, the first end 41 being arranged at the top end 2 of the gas purging plug, such that the top end 41 is in direct contact with molten metal when the gas purging plug 1 is in use. The second end 42 is arranged closer to the bottom end 3 of the gas purging plug 1 than the first end 41. According to the embodiment shown in Figures 1 and 2, the first refractory body 4 is composed of four refractory plates 51, 52, 53, 54 and six gas channels 61, 62, 63, 64, 65, 66. Each refractory plate extends from the first end 41 to the second end 42 of the first refractory body 4. Therefore, the height h of
15 each refractory plate 51, 52, 53, 54 is equal to the distance from the first end 41 to the second end 42 of the first refractory body 4. Each refractory plate 51, 52, 53, 54 is adjacent to one or two further refractory plates, as shown in Figures 1 and 2.

[0110] Figure 2 shows a top view of the gas purging plug 1 shown in Figure 1. As can be seen from Figures 1 and 2, a first refractory plate 51 is adjacent to a second refractory plate 52, the second refractory plate 52 is adjacent to the first refractory plate 51 and a third refractory plate 53, the third refractory plate 53 is adjacent to the second refractory plate 52
20 and a fourth refractory plate 54, and the fourth refractory plate 54 is adjacent to the third refractory plate 53.

[0111] Six gas channels 61, 62, 63, 64, 65, 66 (not indicated in Figure 1, but shown in Figure 2) are arranged between the refractory plates, such that two gas channels 61, 62 are arranged between the first refractory plate 51 and the second refractory plate 52, and further two gas channels 63, 64 are arranged between the second refractory plate 52 and the third refractory plate 53, and further two gas channels 65, 66 are arranged between the third refractory plate 53 and the fourth
25 refractory plate 54.

[0112] As shown in Figure 2, the gas channels 61 and 62 are formed from recesses pressed into the first refractory plate 51, said recesses being covered by the second refractory plate 52. The gas channels 63 and 64 are formed from recesses pressed into the second refractory plate 52, said recesses being covered by the third refractory plate 53. The gas channels 65 and 66 are formed from recesses pressed into the third refractory plate 53, said recesses being covered by the fourth
30 refractory plate 54. The fourth refractory plate 54 is provided without any recesses. All gas channels 61, 62, 63, 64, 65, 66 extend from the first end 41 to the second end 42 of the first refractory body 4.

[0113] The gas purging plug 1 shown in Figures 1 and 2 further comprises a second refractory body 7 that surrounds the lateral surface 43 of the first refractory body 4. A further gas channel 10 is formed as an interstice between the first refractory body 4 and the second refractory body 7, as can be seen in Figure 2. In the exemplary gas purging plug shown in
35 Figures 1 and 2, the further gas channel 10 is formed along the entire lateral surface 43 of the first refractory body 4.

[0114] Each refractory plate 51, 52, 53, 54 is provided in the form of a pressed and sintered refractory plate comprising pores, wherein the pores are at least partly filled with a carbonaceous material. The carbonaceous material inside the pores may be obtained from impregnating the pressed and sintered refractory plates as described herein. The carbonaceous material is preferably a phenol formaldehyde resole resin. The second refractory body 7 is provided as
40 a cast refractory body being impermeable to gas.

[0115] The gas purging plug 1 further comprises a third refractory body 9, the third refractory body 9 having a first end 91 and a second end 92, the first end 91 being arranged at the second end 42 of the first refractory body 4, and the second end 92 being arranged at the bottom end 3 of the gas purging plug 1, as shown in Figure 1. The third refractory body 9 is provided in the form of a pressed and sintered refractory body comprising pores, wherein the pores are configured to
45 transport gas from the second end 92 to the first end 91 of the third refractory body 9. The third refractory body 9 has a higher apparent porosity than the refractory plates 51, 52, 53, 54 of the first refractory body 4.

[0116] The first refractory body 4 has a rectangular cross section, whereas the third refractory body 9 has a circular cross section. Thereby, the third refractory body 9 acts as a safety indicator. If a change in the cross section of the inner part of the gas purging plug 1 is observed during operation, this is an indication that the first refractory body 4 has already been
50 destroyed due to wear and the gas purging plug 1 needs to be replaced.

[0117] The gas purging plug 1 shown in Figures 1 and 2 further comprises a metal casing 11 surrounding the second refractory body 7, the metal casing 11 thus forming the outermost surface of the gas purging plug 1.

[0118] Figure 1 further shows a gas injection system 12 being attached to the bottom end 3 of the gas purging plug 1. The gas injection system 12 allows to introduce gas into the bottom end 3 of the gas purging plug 1. In the gas purging plug 1
55 shown in Figure 1, the gas enters the third refractory body 9 via the second end 92 and is then transported through the third refractory body 9 until it exits the third refractory body 9 at the first end 91. The top surface of the third refractory body 9, i.e., the surface where the first end 91 of the third refractory body 9 is located, may be provided with a recess, which serves as a gas distribution chamber (not shown). From this gas distribution chamber, the gas may flow into the first refractory body 4.

The gas enters the first refractory body 4 at the second end 42 of the first refractory body 4 and then flows through the gas channels 61, 62, 63, 64, 65, 66 until exiting the first refractory body 4 at the first end 41. Thereby, gas can be injected into a molten metal.

[0119] Figure 3 shows a top view of a gas purging plug 1 according to another embodiment of the present invention. This embodiment differs from the embodiment shown in Figures 1 and 2 in the number of refractory plates and gas channels. According to the embodiment shown in Figure 3, the first refractory body 4 is composed of only two adjacent refractory plates 51, 52 and two gas channels 61, 62. The two gas channels 61, 62 are arranged between the refractory plates 51, 52. As shown in Figure 3, the gas channels 61, 62 are formed from recesses pressed into the first refractory plate 51, said recesses being covered by the second refractory plate 52. In the embodiment shown in Figure 3, the second refractory plate 52 is provided without any recesses.

[0120] Both gas channels 61, 62 extend from the first end 41 to the second end 42 of the first refractory body 4 (not shown). Figure 3 further shows a second refractory body 7 that surrounds the lateral surface 43 of the first refractory body 4. A further gas channel 10 is formed as an interstice between the first refractory body 4 and the second refractory body 7. The further gas channel 10 is formed along the entire lateral surface 43 of the first refractory body 4. Figure 3 also shows a metal casing 11 surrounding the second refractory body 7.

[0121] Figure 4 shows a refractory plate 51 obtained from the inventive method.

[0122] The refractory plate 51 comprises a first end 511 and a second end 512. The dimensions of the refractory plate 51 are defined by the height h , the width w and the thickness t . The height h of the refractory plate 51 corresponds to the distance from the first end 511 to the second end 512 of the refractory plate 51, as can be seen from Figure 4. When the refractory plate 51 is arranged in a first refractory body 4 as described herein, the first end 511 is located at the first end 41 of the first refractory body 4, and the second end 512 is located at the second end 42 of the first refractory body 4.

[0123] The refractory plate 51 may have a height h of 100 mm to 700 mm, preferably 300 mm to 400 mm, and a width w of 30 mm to 150 mm, preferably 50 mm to 130 mm. The refractory plate 51 may have a thickness t of 8 to 25 mm, preferably 10 mm to 15 mm. In the exemplary refractory plate 51 shown in Figure 4, the width w of the refractory plate 51 increases along the height h from the first end 511 to the second end 512. Therefore, the refractory plate has a trapezoidal shape.

[0124] Figure 4 further shows the front surface 513 of the refractory plate 51, the front surface 513 having the width w and the height h . Two recesses 61', 62' are pressed into the front surface 513 of the refractory plate 51. As shown, the recesses 61', 62' have a rectangular shape. Each recess 61', 62' may have a width of 5 mm to 50 mm, preferably 15 mm to 20 mm, and a depth of not more than 0.3 mm. The back surface (not shown) of the refractory plate 51, i.e., the surface opposite to the front surface 513, does not comprise any recesses.

[0125] The refractory plates 52, 53 and 54 may be identical to the refractory plate 51 shown in Figure 4. Alternatively, the refractory plates 52, 53 and 54 may be provided without any recesses. For example, if the first refractory body 4 is composed of two refractory plates, namely a first refractory plate 51, and a second refractory plate 52, then the second refractory plate 52 may be provided without any recesses. If the first refractory body 4 is composed of three refractory plates, namely a first refractory plate 51, a second refractory plate 52 and a third refractory plate 53, then the third refractory plate 53 may be provided without any recesses. If the first refractory body 4 is composed of four refractory plates, namely a first refractory plate 51, a second refractory plate 52, a third refractory plate 53 and a fourth refractory plate 54, then the fourth refractory plate 54 may be provided without any recesses.

Example:

[0126] A gas purging plug 1 as shown in Figures 1 and 2 was produced.

[0127] First, four refractory plates 51, 52, 53, 54 were produced from a refractory batch based on mullite and corundum. The batch was pressed into green bodies in the shape of plates, as described herein. The first refractory plate 51 had two recesses 61', 62' pressed into the front surface 513, as shown in Figure 4. The second refractory plate 52 and the third refractory plate 53 were produced in an identical way to the first refractory plate 51. The fourth refractory plate 54 was provided without any recess on its surfaces. The green bodies of the refractory plates 51, 52, 53, 54 were then sintered at 1550 °C. Afterwards, the pressed and sintered refractory plates 51, 52, 53, 54 were impregnated with a phenol formaldehyde resole resin. The impregnation was performed at a temperature of 200 to 250 °C at a pressure of 1.2 MPa under inert gas for 2 hours. The impregnated refractory plates 51, 52, 53, 54 were then tempered at a temperature of 400 °C under a reducing atmosphere.

[0128] Afterwards, the four refractory plates 51, 52, 53, 54 were assembled to form a first refractory body 4 with six gas channels 61, 62, 63, 64, 65, 66, as shown in Figure 2. An adhesive tape made of low-density polyethylene (LDPE) was assembled around the lateral surface 43 of the first refractory body 4. Additionally, a third refractory body 9 was provided, the third refractory body 9 having the shape of a truncated cone made of alumina and chromia, the third refractory body 9 having an apparent porosity of approximately 30 %.

[0129] Afterwards, the first refractory body 4 was placed into a mold together with the third refractory body 9 and an unshaped mass of refractory raw material based on alumina and alumina spinel was cast around the first and third

refractory body to form the second refractory body 7. Thereby, a gas purging plug 1 was obtained.

[0130] Afterwards, the obtained gas purging plug 1 was subjected to a heat treatment step to burn out the adhesive tape made of low-density polyethylene (LDPE) in order to obtain a gas channel 10, as shown in Figure 2. This heat treatment step was performed at a temperature of ca. 500 °C under an oxidizing atmosphere.

[0131] Additionally, a comparative gas purging plug 1' was produced, the comparative gas purging plug 1' being identical to the gas purging plug 1, with the exception that the impregnation step of the refractory plates with the phenol formaldehyde resole resin was omitted.

[0132] Both gas purging plugs 1 and 1' were then applied to introduce gas into molten steel in a steel ladle. Table 1 compares the lifetime, the left-over thickness (LOT), the purging duration and outer appearance of the gas purging plugs after their application.

[0133] The lifetime is indicated as the number of "heats", i.e., the number of treatment cycles of molten steel, which could be performed with the gas purging plug before the gas purging plug had to be replaced due to wear. As can be seen in Table 1, the gas purging plug 1 according to the invention could be used for a higher number of heats, i.e., it had a longer lifetime compared to the comparative gas purging plug 1'.

[0134] The purging duration refers to the cumulative time (in minutes) during which the gas purging plug could be used for introducing gas into molten steel. Table 1 shows that a significantly higher purging duration could be obtained with the inventive gas purging plug compared to the comparative gas purging plug. This again indicates that the inventive gas purging plug needs to be replaced less frequently than the comparative gas purging plug.

[0135] The left-over thickness (LOT) refers to the remaining height of the gas purging plug after its application in a metallurgical vessel, i.e., at the end of its lifetime. As outlined herein, the height of the gas purging plug is reduced during its application due to wear. The left-over thickness is determined by measuring the height of the gas purging plug after its application. Table 1 shows that a higher LOT was obtained for the inventive gas purging plug compared to the comparative gas purging plug.

[0136] Table 1 further compares the outer appearance of the gas purging plugs after its application. For the comparative gas purging plug 1', a deep cavity was observed. The formation of this cavity is most likely a result of oxygen lancing steps, which had to be performed with the comparative gas purging plug 1' between the heats (treatment cycles of molten steel) to reopen the gas channels of the first refractory body, which had been infiltrated with molten steel. In contrast to that, the inventive gas purging plug shows less infiltration with molten steel, which means that also less oxygen lancing steps were required to reopen the gas channels. Thus, the inventive gas purging plug 1 shows a better outer appearance after its application.

Table 1: Comparison of test results of the comparative gas purging plug 1' and the gas purging plug 1 according to the invention.

	Comparative gas purging plug 1'	Gas purging plug 1 according to the invention
Lifetime (Heats)	24	31
Purging duration	1751 min	3115 min
LOT	100 mm	120 mm
Outer appearance	Deep cavity observed	Only a small cavity observed

[0137] In summary, the inventive gas purging plug shows significantly improved properties compared to the comparative gas purging plug.

Claims

1. A gas purging plug (1) configured to transport gas from a bottom end (3) of the gas purging plug (1) to a top end (2) of the gas purging plug (1), the gas purging plug (1) comprising the following features:

1.1. a first refractory body (4), comprising:

1.1.1. a first end (41), a second end (42) and a lateral surface (43), the first end (41) being arranged at the top end (2) of the gas purging plug (1) and the second end (42) being arranged closer to the bottom end (3) of the gas purging plug (1) than the first end (41);

1.1.2. at least two refractory plates (51, 52),

1.1.2.1. each refractory plate (51, 52) extending from the first end (41) to the second end (42) of the first refractory body (4),

1.1.2.2. each refractory plate (51, 52) being adjacent to at least one further refractory plate (51, 52); and

1.1.3. at least one gas channel (61, 62) being arranged between adjacent refractory plates (51, 52), the at least one gas channel (61, 62) extending from the first end (41) to the second end (42) of the first refractory body (4);

1.2. a second refractory body (7),

1.2.1. the second refractory body (7) extending from the top end (2) to the bottom end (3) of the gas purging plug (1),

1.2.2. the second refractory body (7) surrounding the lateral surface (43) of the first refractory body (4), and

1.2.3. the second refractory body (7) being impermeable to gas;

1.3. wherein each refractory plate (51, 52) is provided in the form of a pressed and sintered refractory plate (51, 52) comprising pores, wherein said pores are at least partly filled with a carbonaceous material.

2. The gas purging plug (1) according to claim 1, wherein said carbonaceous material is a phenol formaldehyde resin or a thermal degradation product of a phenol formaldehyde resin, said thermal degradation product being obtained at a temperature between 300 °C and 650 °C.

3. The gas purging plug (1) according to claim 2, wherein said phenol formaldehyde resin is a resole or a novolak, preferably a resole.

4. The gas purging plug (1) according to any one of claims 1 to 3, wherein the refractory plates (51, 52) comprise alumina and optionally further comprise silica, chromia and/or zirconia, wherein said refractory plates (51, 52) preferably comprise alumina in an amount of at least 80 wt.%, based on the total weight of the refractory plates (51, 52).

5. The gas purging plug (1) according to any one of claims 1 to 4, wherein the refractory plates (51, 52) have an apparent porosity in the range of 8 % to 11 %, determined according to ASTM C-20 after at least partly filling the pores of the refractory plates (51, 52) with the carbonaceous material.

6. The gas purging plug (1) according to any one of claims 1 to 5, wherein said at least one gas channel (61, 62) being arranged between adjacent refractory plates (51, 52) is provided in the form of at least one recess (61', 62') pressed into a surface (513) of one of said at least two adjacent refractory plates (51), said at least one recess (61', 62') being covered by a surface of an adjacent refractory plate (52).

7. The gas purging plug (1) according to claim 6, wherein said at least one recess (61', 62') has a rectangular shape having a width of 5 mm to 50 mm and a depth of 0.1 mm to 0.5 mm, preferably a depth of not more than 0.3 mm.

8. The gas purging plug (1) according to any one of claims 1 to 7, wherein said at least one gas channel comprises at least two gas channels (61, 62).

9. The gas purging plug (1) according to any one of claims 1 to 8, wherein:

9.1. said at least two refractory plates comprise at least three, preferably at least four, refractory plates (51, 52, 53, 54), wherein each refractory plate (51, 52, 53, 54) extends from the first end (41) to the second end (42) of the first refractory body (4), and wherein each refractory plate (51, 52, 53, 54) is adjacent to at least one further refractory plate (51, 52, 53, 54); and

9.2. said at least one gas channel comprises at least four, preferably at least six, gas channels (61, 62, 63, 64, 65, 66), wherein each of said at least four, preferably at least six, gas channels (61, 62, 63, 64, 65, 66) is arranged between adjacent refractory plates (51, 52, 53, 54), and each of said at least four, preferably at least six, gas channels (61, 62, 63, 64, 65, 66) extends from the first end (41) to the second end (42) of the first refractory body (4),

9.3. preferably wherein said at least four, preferably at least six, gas channels (61, 62, 63, 64, 65, 66) are arranged such that at least one, preferably at least two, of said gas channels (61, 62, 63, 64, 65, 66) are present between each pair of adjacent refractory plates (51, 52, 53, 54).

10. The gas purging plug (1) according to any one of claims 1 to 9, wherein the gas purging plug (1) comprises at least one further gas channel (10),

10.1. wherein said at least one further gas channel (10) is formed as an interstice between the first refractory body (4) and the second refractory body (7), and

10.2. wherein said at least one further gas channel (10) ranges from the top end (41) to the bottom end (42) of the first refractory body (4).

11. The gas purging plug (1) according to any one of claims 1 to 10, further comprising a third refractory body (9),

11.1. the third refractory body (9) having a first end (91) and a second end (92), the first end (91) being arranged at the second end (42) of the first refractory body (4), and the second end (92) being arranged closer to the bottom end (3) of the gas purging plug (1) than the first end (91),

11.2. wherein the second end (92) of the third refractory body (9) is preferably arranged at the bottom end (3) of the gas purging plug (1);

11.3. wherein the third refractory body (9) is provided in the form of a pressed and sintered refractory body comprising pores,

11.3.1. wherein the pores are configured to transport gas from the second end (92) to the first end (91) of the third refractory body (9), and

11.3.2. wherein the third refractory body (9) has a higher apparent porosity than the refractory plates (51, 52) of the first refractory body (4);

11.4. wherein the third refractory body (9) preferably has a different horizontal cross section than the first refractory body (4).

12. A method for producing a refractory plate (51) for use in a gas purging plug (1), said method comprising the steps of:

12.1. pressing a batch of refractory raw materials into a green body,

12.1.1. said green body having the shape of a plate (51), wherein at least one recess (61', 62') is pressed into a surface (513) of said green body, such that the at least one recess (61', 62') extends from a first end (511) to a second end (512) of the green body;

12.2. sintering said green body at a temperature above 1500 °C to obtain a pressed and sintered refractory plate (51) comprising pores;

12.3. impregnating said pressed and sintered refractory plate (51) with a carbonaceous material,

12.4. optionally subjecting the impregnated pressed and sintered refractory plate (51) to a heat treatment step.

13. The method according to claim 12, wherein said refractory raw materials are non-basic refractory raw materials, preferably being selected from the group consisting of mullite, corundum, chromia, zirconia and mixtures thereof, wherein even more preferably said refractory raw materials are provided as a mixture of mullite and corundum, or as a mixture of chromia and corundum, or as a mixture of chromia, corundum and zirconia.

14. The method according to claim 12 or 13, wherein said carbonaceous material is a phenol formaldehyde resin, even more preferably a resole or a novolak, even more preferably a resole.

15. A method for producing a gas purging plug (1), said method comprising the following steps:

15.1. providing at least two refractory plates (51, 52) obtained from the method according to any one of claims 12 to 14,

15.2. assembling said at least two refractory plates (51, 52) to obtain a first refractory body (4) such that:

15.2.1. each refractory plate (51, 52) extends from a first end (41) to a second end (42) of the first refractory body (4), and

15.2.2. each refractory plate (51, 52) is adjacent to at least one further refractory plate (51, 52), and

15.2.3. at least one gas channel (61, 62) is formed between adjacent refractory plates (51, 52);

15.3. optionally assembling a combustible material around the lateral surface (43) of the first refractory body (4);

15.4. placing the first refractory body (4) into a mold;

15.5. casting a mass of a refractory raw material into the mold, such that a second refractory body (7) being impermeable to gas is formed;

15.6. wherein the steps 15.4 and 15.5 are performed such that:

5 15.6.1. a gas purging plug (1) comprising a top end (2) and a bottom end (3) is obtained, wherein the first end (41) of the first refractory body (4) is arranged at the top end (2) of the gas purging plug (1) and the second end (42) of the first refractory body (4) is arranged closer to the bottom end (3) of the gas purging plug (1) than the first end (41), and

10 15.6.2. the second refractory body (7) extends from the top end (2) to the bottom end (3) of the gas purging plug (1) and surrounds the lateral surface (43) of the first refractory body (4);

15.7. optionally subjecting said gas purging plug (1) to a heat treatment step, preferably at a temperature between 300 °C and 650 °C.

15

20

25

30

35

40

45

50

55

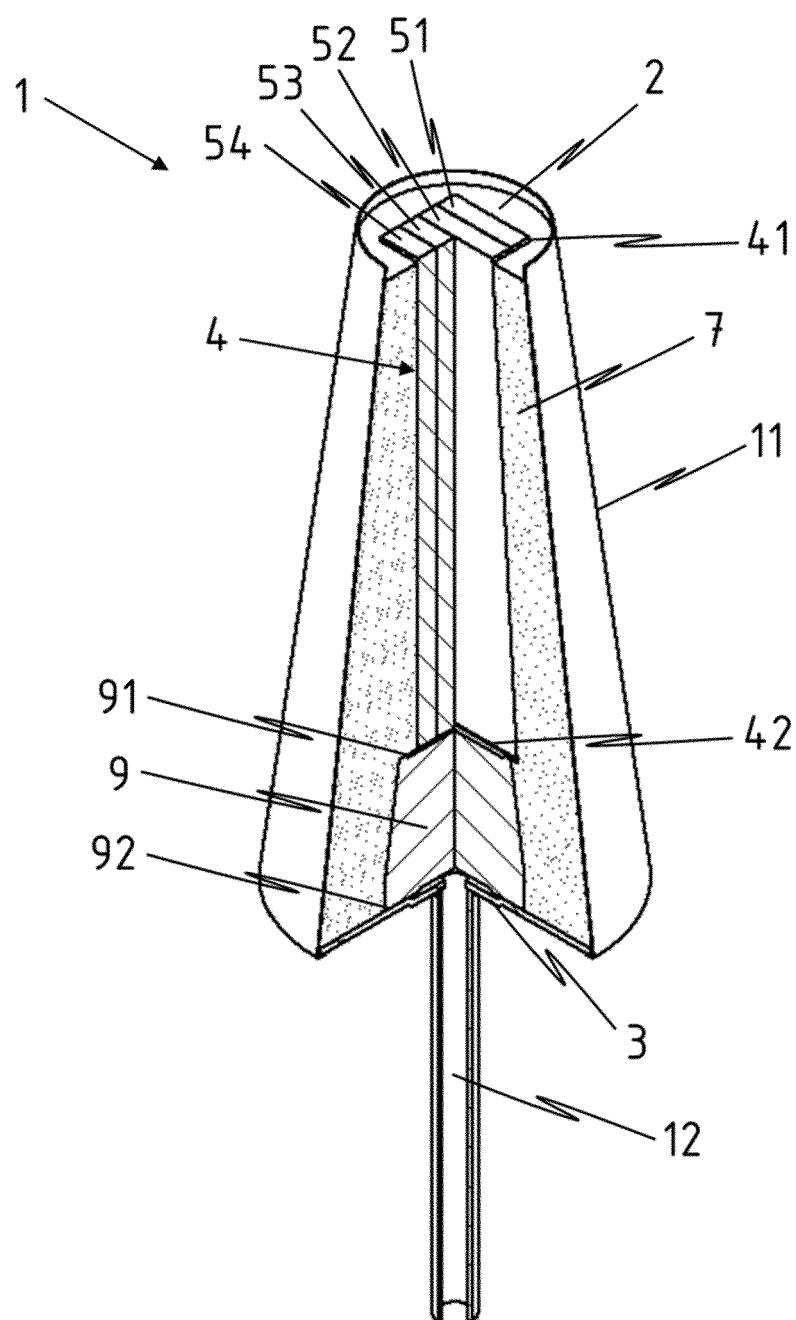


Figure 1

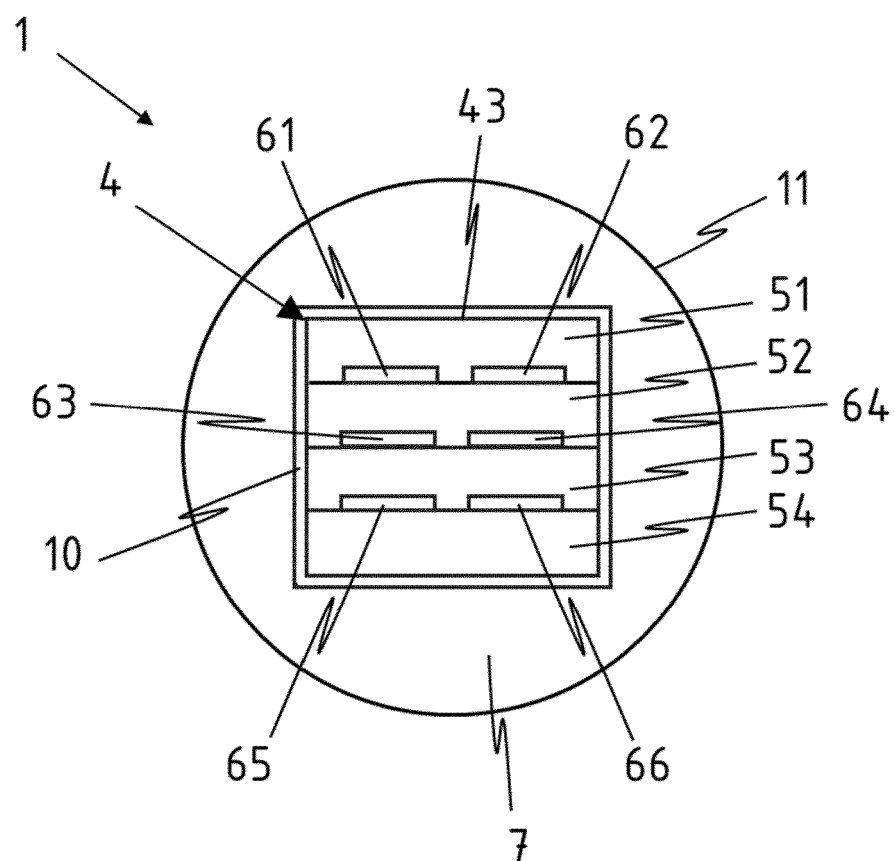


Figure 2

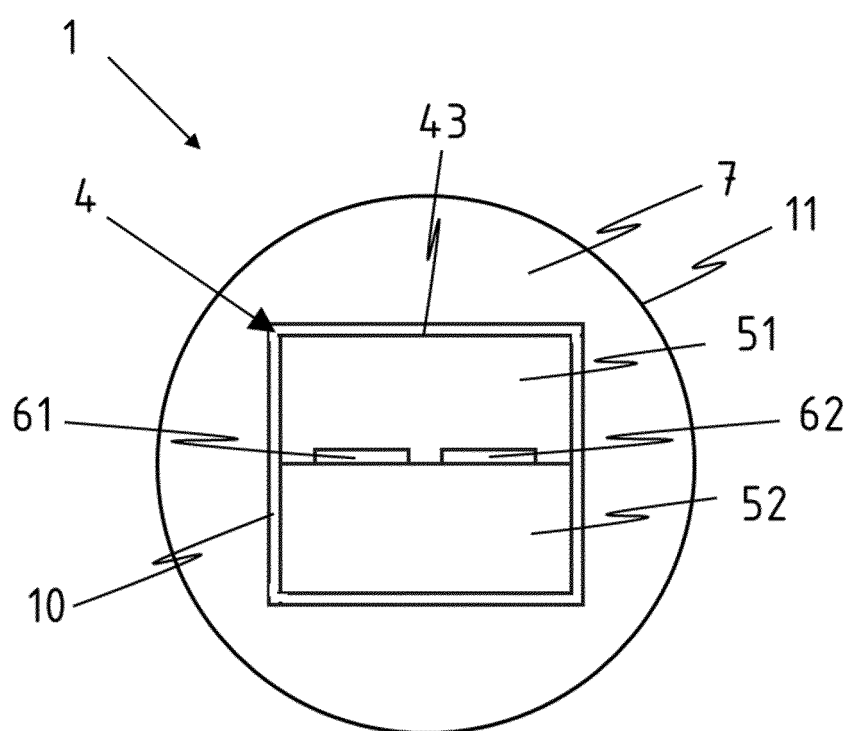


Figure 3

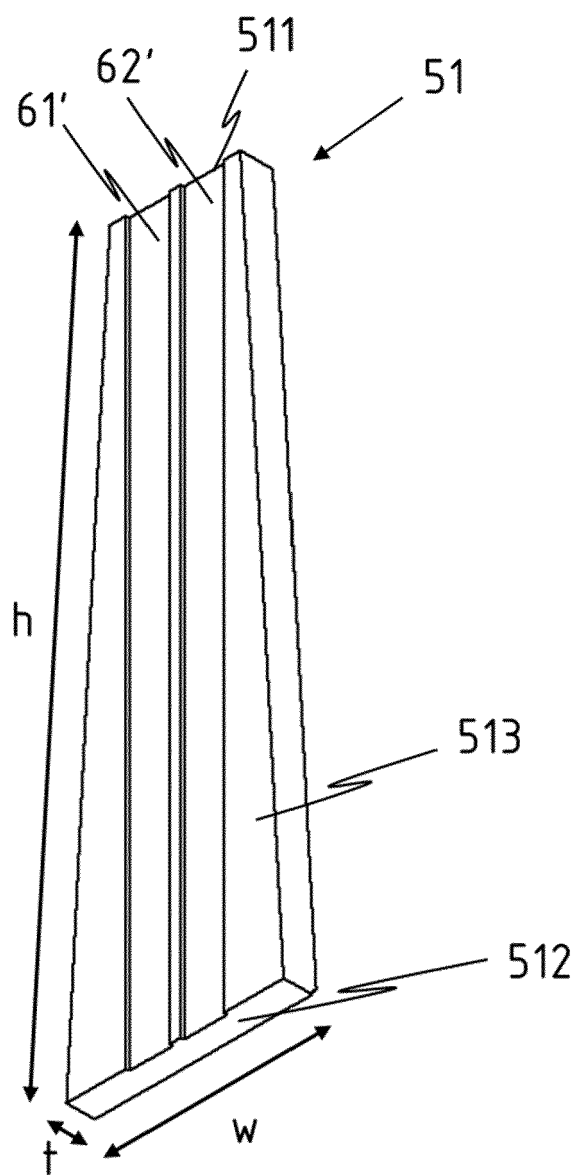


Figure 4



EUROPEAN SEARCH REPORT

Application Number

EP 25 15 0476

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 101 825 A1 (VEITSCH RADEX GMBH [AT]) 23 May 2001 (2001-05-23) * paragraphs [0025], [0034] - [0045]; claims 1-3,6-10; figures 1-4 * -----	1-15	INV. B22D1/00 C21C5/48 F27D3/16
			TECHNICAL FIELDS SEARCHED (IPC)
			B22D C21C F27D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		24 June 2025	Momeni, Mohammad
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P34C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 25 15 0476

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-06-2025

10

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 1101825	A1	23-05-2001	AT	E245202 T1	15-08-2003
			DE	19954918 A1	31-05-2001
			EP	1101825 A1	23-05-2001
			ES	2201981 T3	01-04-2004

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 1101825 A1 [0010]