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(54) **BURNER DECK AND PROCESS OF MANUFACTURING THEREOF**

(57) The invention relates to a burner deck (1) for a gas burner (2) comprising a sheet (3) enclosing a chamber (4) and having at least one protrusion (6) with a through hole (5) fluidically connected with the chamber (4) wherein the protrusion (6) comprises a concave section (8) and a convex section (9).

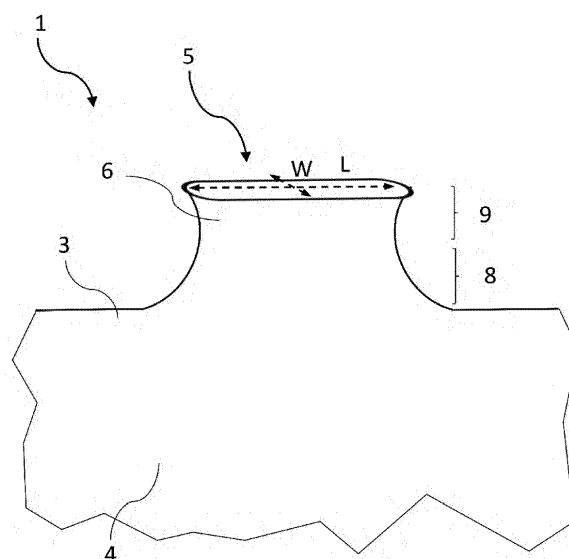


FIG. 2A

Description

[0001] The invention relates to a burner deck for a gas boiler and to a gas burner comprising said burner deck. Additionally, the invention relates to a heating appliance comprising such a burner deck.

[0002] Gas boilers combust fuel gas to e.g. heat water for domestic use and/or central heating system facilities in buildings. Based on the characteristics of the gas mixture, the boiler's efficiency can be differently affected. For example, the position of the flame relative to the burner deck of a gas boiler is strongly affected by the air to fuel gas ratio (A).

[0003] Figures 1A-1C show the position variation of a flame FL relative to a burner sheet BS (or flame holder) of a gas boiler as a function of the gas mixture. In the optimal situation, i.e. with a correct λ (figure 1A), the base of flame FL is located close to the burner sheet BS at a perforation present on the burner sheet BS and extends from the outside face OF of the burner sheet BS. This is a so called normal flame. If the air to fuel gas ratio increases, the flame FL can experience a lift from the burner sheet BS on the outside face OF. On the other hand, in case of a low value of λ , the flame FL can extend back from the inside face IF of the burner sheet BS. This is a so called light back flame or flashback. Flashback and flame lift are opposite phenomena that must be avoided. For example, flashback can lead to combustion instabilities and structural damages due to overheating of machine components.

[0004] In an air and methane combustion environment, as well as in environments comprising natural gas or LPG, due to the properties of the gas, the main problem the burner has to avoid is the flame lift (it happens when the speed, i.e. the maximum adiabatic flame velocity in air, is higher than flame speed) (Fig. 1B). In hydrogen (or any highly reactive gas) and air combustion environment, the main problem is the flashback (Fig. 1C). Consequently, when using hydrogen as fuel gas, the main feature is to avoid the anchoring of the flame near the perforations on the burner.

[0005] In particular, a gas mixture comprising both hydrogen and hydrocarbons (i.e. methane), an increased value in hydrogen could lead to flashback. The flashback is a phenomenon that characterizes hydrogen and/or other fuels due to its high flame speed. The easiest way to avoid any flashback phenomena is to make the speed of the mixture sufficiently high by reducing the area of the perforations of the burner surface. The same quantity of gas mixture passes through a smaller section with a higher speed. However, due to this solution, there is also an increased pressure drop that could make the flame front go in the opposite direction of the gas mixture flow causing flashback. Hence, considering the high flame speed of hydrogen, it is difficult to compensate the flashback with a flame lift by simply reducing the area of burner perforations.

[0006] It is therefore desirable to provide a burner sur-

face that favors a better gas mixture flow, especially for gas boilers using hydrogen as fuel gas, since flame lift phenomenon is secondary with a so reactive mixture.

[0007] US 9,885,476 B2 is directed to providing a surface combustion gas burner with less flashbacks, having a high flame-holding performance, the possibility of using it over a wide power range, an increased burner lifetime, a combustion scheme that is adaptable to burner with a great variety of shapes, and both small and large dimensions, a considerable reduction in pollutant gas emissions and low cost, and discloses a surface-combustion gas burner comprising a combustion grate consisting of a metal sheet pierced with a series of slots. The metal sheet comprises a series of deflectors made in one piece with said metal sheet and protruding on the outer face of same, each deflector extending longitudinally and laterally above the entire surface of a slot. Each deflector comprises a guide portion for guiding the gas flow and a junction portion joining to the metal sheet, the guide portion being spaced from the metal sheet in such a way as to provide therewith at least one lateral gas ejection port. The deflectors are disposed in pairs in such a way that the lateral gas ejection ports of same face each other.

[0008] EP 2 551 590 B1 is directed to overcoming thermoacoustic phenomena and discloses a super-stoichiometric burner with a planar or non-planar surface provided with a multiplicity of through apertures in the form of slots or holes aligned in a horizontal and vertical direction. The burner comprises a plurality of distanced groups of slots, of constant or varying width, forming lines superposed and parallel to each other, between each pair of which circular holes are made in groups of equal or varying diameter.

[0009] WO 2003/062705 A1 is directed to providing a gas burner wherein a sheet of flexible porous and insulating material is not or practically not subject to deformation due to external shocks or problems with the burner operating without calling into question the general structure of existing burners and discloses a gas burner in the form of a case that defines a chamber which receives the air/gas mixture to be burnt and which houses a perforated distribution partition through which said mixture passes. One part of the wall of the case forms the combustion surface. The external face of the combustion surface comprises a layer of flexible, porous, thermally-insulating material, said layer being provided with numerous perforations which are evenly distributed and which are used for the discharge and combustion of the air/gas mixture once it has passed through the distribution partition. The internal face of the combustion surface comprises a perforated support plate which supports the layer. The holes in the plate are disposed opposite a perforation in the layer and are provided with dimensions greater than those of said perforations.

[0010] EP 2 815 181 A1 is directed to providing cylindrical premix gas burners with a perforated inlet disc and that show reduced thermo-acoustic instabilities and discloses a cylindrical premix gas burner comprising a per-

forated metal plate as cylindrical burner deck. The cylindrical premix gas burner is delimited by an end cap. An inlet disc is provided for the supply of a premix of combustible gas and air into the burner. The premix gas is to be burned on the outside of the cylindrical burner deck after the premix gas has flown through it. The inlet disc comprises a plurality of perforations for supplying premix gas supply into the burner. The inlet disc has a center point, which is where the central axis of the cylindrical premix gas burner crosses the inlet disc. The inlet disc is not permeable to premix gas at least within a circle with a diameter of at least 8 mm around the center point.

[0011] US 20200200437 A1 is directed to surface stabilized premix gas burners comprising a woven wire mesh as burner deck and thermal expansion of the same and discloses a premix gas burner comprising a metal plate structure, a burner deck and a shaped distributor plate. The metal plate structure is provided for mounting the premix gas burner in a heating appliance. The burner deck comprises a woven wire mesh on the outer surface of which premix gas is combusted after the premix gas has flown through the woven wire mesh. The shaped distributor plate comprises perforations. When the burner is in use the premix gas flows through the perforations of the shaped distributor plate before the premix gas flows through the woven wire mesh. One or more than one slot or notch shaped opening is provided in the shaped distributor plate. The woven wire mesh comprises a circumferential edge comprising at least one tab. The tab or tabs is/are inserted through a slot or notch shaped opening in the shaped distributor plate.

[0012] EP 3 514 453 A1 is directed to providing a burner plate with which a stable combustion and/or a combustion with low CO emission can be obtained in the case of varying inlet speeds of the gas and discloses a burner plate for a central heating boiler comprising a first pattern of through-holes arranged therein, the through-holes extending between a first, inlet surface and a second, opposite outlet surface of the burner plate. Also, the holes are configured to allow passage of a combustible gas from the inlet surface to the outlet surface and thus form a permeable surface part of the total outlet surface of the burner plate.

[0013] EP 2 815 179 A1 is directed to providing a cylindrical premix gas burner that results in lower emission values, especially of NOX (nitrogen oxides) than known cylindrical premix gas burners and discloses a cylindrical premix gas burner comprising a cylindrical burner deck, which is comprising a perforated metal plate. The cylindrical premix gas burner is delimited by an end cap. At the opposite side of the end cap, an inlet disc with perforations is provided for the supply of a premix of combustible gas and air into the burner and which is to be burnt on the outside of the cylindrical burner deck after the premix gas has flown through it. The inlet disc comprises a plurality of perforations for premix gas supply in a central zone of the plate and a plurality of perforations for premix gas supply in the peripheral zone of the inlet

disc. The porosity of the inlet disc is higher in the central zone than in a peripheral zone. The average surface area of the perforations in the central zone of the inlet disc is less than 20 mm².

[0014] EP 2 805 111 B1 is directed to providing a cylindrical gas premix burner that has high efficiency and low emissions, and that allows the use of a control system via ionization current measurement by means of an ionization pen in a broad range of burner power (or burner load) to control the air to gas ratio of the burner in an efficient way, and especially at low burner loads. In order to achieve said goal, EP 2 805 111 B1 discloses a cylindrical gas premix burner comprising a cylindrical burner deck, wherein the cylindrical burner deck comprises a metal plate, and wherein the cylindrical burner deck has a perforated zone, the perforated zone being the part of the cylindrical burner deck that is foreseen with perforations in the metal plate. The burner also comprises an end cap and an inlet for gas premix at the opposite side of the end cap. The perforated zone comprises at least three sections, wherein a first section at the inlet, a third section located towards the end cap, and a second section located between the first section and the third section. The porosity of the second section of the cylindrical burner deck is at least 50% higher than the porosity of the cylindrical burner deck in the first section and then the porosity in the third section.

[0015] FR 2676269 B3 is directed to providing a gas surface burner in such a way that there can no longer occur known cracks in welds and that the relatively thin and finely perforated sheet which must be the work must be configured with better warping resistance in the area where welds are to be applied and discloses a surface gas burner for heating boilers consisting of at least one symmetrical hollow body of revolution with respectively a finely perforated wall, the longitudinal axis of the burner being oriented essentially in the direction of the influx of the gas and the wall being formed by a cutout piece made of sheet metal made continuous with a weld. The cutout piece made of sheet metal is fashioned without perforations on its edges which are to be connected, in particular on its end edges, and the weld is positioned by being located along the non-perforated edges.

[0016] EP 0 628 146 B1 is directed to providing plates with a controlled uniform gas flow and discloses a porous metal fiber plate, in which a regular pattern of holes has been made which occupy an overall free passage area of 5 % to 35 % of the total surface area of the plate, while each hole has a surface area of between 0.03 mm² and 10 mm². The plate is suitable for use as a membrane in a gas burner device.

[0017] EP 0 774 623 A1 is directed to providing a stable burner deck allowing more flexible arrangement and shaping and discloses a burner for use in a gas-fired burner device, comprising a housing at least partly covered by a burner deck provided with outflow openings for allowing, during use, the passage of a gas or gas/air mixture from the inside of the housing to the environment,

with the circumferential edges of the burner deck being retained so as to be movable relative to the housing, wherein the burner deck comprises a series of burner deck parts arranged next to each other, which burner deck parts each comprise a row of outflow openings in communication with the inside of the housing, while between burner deck parts arranged next to each other bridges are included which are fixedly connected with the housing, in which bridges the proximal edges of the burner deck parts connecting thereto are movably retained. The arrangement is such that during use each burner deck part can deform at least in the plane of the burner deck part in question, independently of the other burner deck parts the housing and the bridges.

[0018] US 20140011142 A1 is directed to providing a burner the thermal load of which is "tuned" on the basis of the form and volumes of the combustion chamber, homogenous temperatures, lower CO and nitrogen oxide (NOx) emissions, and low noise and discloses a gas burner for premixed combustion positioned in a combustion chamber and comprising two components, a first defined by a distributor for a gas and air mixture and the second defining the burner shell. The components are close together but spaced apart. The distributor has a perforated distribution surface through which the gas-air mixture passes directed towards the burner shell, which also has a perforated burning surface on which the flame caused by the combustion of said mixture is generated, to create a thermal load within the combustion chamber. The thermal load in this latter is not uniformly distributed.

[0019] WO 2017/194394 A1 is directed to providing a cylindrical burner deck that can be ignited more easily and at which flame sensing can be done more easily, providing a burner with a large L/D ratio, wherein L is the axial length of the burner deck and D is the internal diameter of cylindrical burner deck, providing an efficient and effective burner comprising a minimal number of parts and discloses a gas premix burner comprising a cylindrical burner deck enclosing a mixing chamber. An inlet device is mounted perpendicularly to the axial direction of the cylindrical burner deck. The inlet device comprises a metal mesh through which, when the burner is in use, premix gas flows into the mixing chamber.

[0020] WO 2021/140036 A1 is directed to providing a gas burner that comprises a surface and is that is suitable for the use of hydrogen as a combustion gas. The surface forms a burner deck comprising burner deck portions and a separation surface. The burner deck portions have holes. The separation surface is arranged to separate the burner deck portions from each other. Less than 5.0% of a surface area of the burner deck is formed by a combined surface area of the holes. The burner deck portions are adapted to define reaction zones extending over the burner deck portions. The holes are adapted to provide gas to be combusted in the reaction zones. The burner deck portions are arranged relative to each other to prevent the reaction zones from extending over the separation surface. Fig. 10 discloses holes having a protruding

edge that extends above the main surface of the surface. The protruding edge protrudes in a direction perpendicular to the surface. The protruding edge may help to improve the flow of hydrogen exiting the hole, as the hydrogen can flow through the hole without being disturbed by any sharp edges that may be present at the boundaries of the hole. In Fig. 10, the protruding edge protrudes in the direction of the reaction zone. Alternatively, the protruding edge protrudes in the opposite direction, i.e., away from the reaction zone.

[0021] The documents that are discussed above provide devices, systems and methods that are not specifically configured to control the flame position on a burner surface when highly reactive gases, such as hydrogen, are employed in the gas mixture.

[0022] The object of the invention is therefore to provide a burner deck configured to maintain the flame front close to the surface of the burner deck but not too anchored on the surface of the burner deck in order to avoid flashbacks.

[0023] The object is achieved by a burner deck for a gas burner comprising a sheet enclosing a chamber and having at least one protrusion with a through hole fluidically connected with the chamber wherein the protrusion comprises a concave section and a convex section.

[0024] Due to this configuration of the protrusion, i.e. the presence of a concave section and a convex section, the flame front is maintained not so far from the burner deck - under the limit of the lift flame - and at the same time not so anchored on the deck surface - over the limit of the back flame. In this way, the burner deck according to the present invention focuses on a reduction of the risk of flashback and facilitates the lift instead of maintaining the flame attached to the burner. This is especially useful when employing a highly reactive gas, such as hydrogen, as fuel gas.

[0025] The concave and convex sections determine a particular aerodynamic of the protrusion and the corresponding through hole. In particular, a sort of Venturi effect is created when the gas mixture passes through the protrusion from the chamber of the burner to outside the gas burner. This aerodynamic helps the mixed flow to pass with a reduced local pressure loss and the flow is guided towards the outside without any recirculation. Additionally, the gas mixture that passes through the through hole of the protrusion maintains the temperature below the auto-ignition of the fuel gas, i.e. hydrogen. There are no local pressure drops that could cause hot spots, like it happens with the thin edge of a natural gas burner deck that has an anchoring effect for the flame. In this way, a flame lifting behavior is prioritized instead of an anchor-feature. Accordingly, using such burner deck, a better fluid dynamic and thermal behavior is obtained when and where the gas expands due to the combustion.

[0026] According to an embodiment, the protrusion protrudes in a direction away from the chamber. In particular, the protrusion comprises a proximal portion close

to the sheet, a distal portion away from the sheet and a middle portion located between the proximal and the distal portion. It is noted that the concave section of the protrusion includes the proximal portion and can include a part of the middle portion, whereas the convex section includes the distal portion and can include another part of the middle portion. Specifically, the transverse cross section of the distal portion, in particular at an end distal to the middle portion, is larger than the transverse cross section of the middle portion, and preferably the transverse cross section of the distal portion, in particular at an end distal to the middle portion, is larger than the transverse cross section of the middle portion and/or proximal portion, in particular at an end distal to the middle portion.

[0027] In the concave section the area of the transverse cross section is decreasing in a direction away from the chamber. In the middle section, the area of the transverse cross section is, in particular essentially, constant in the direction away from the chamber. In the convex section, the area of the transverse cross section is increasing in the direction away from the chamber. The transverse cross section corresponds with a plane that is orthogonal to a central axis of the protrusion.

[0028] Advantageously, the protrusion can have a Venturi shape and/or a double truncated cone shape. This is advantageous for further limiting the flashback. The concave section and the convex section can be arranged coaxially. Additionally, the burner deck is configured such that the gas-air mixture can merely flow out through the protrusion from the chamber to a combustion chamber of the gas burner.

[0029] In a further embodiment, the protrusion can extend over a length comprised between 15% to 25%, preferably 20%, of a thickness value of the sheet of the burner deck. In this way, the risk of flashback is further reduced.

[0030] According to an embodiment, the protrusion can be a slot. In other words, the transverse cross section of the protrusion can have the shape of a slot having a rectangular shape with semicircular ends. Advantageously, the slot-shaped protrusion can have a length comprised between 2.4 and 2.6 mm, preferably 2.5 mm and a width comprised between 0.4 and 0.6 mm, preferably 0.5 mm. These particular dimensions increase the general stability of the flame around the deck and reduce the limit of flashback. It is noted that this shape of the protrusion helps to decrease the local pressure drop in that point and/or help with thermo acoustics problems. So, with the same amount of input energy, the speed of the mixture going outside of the burner is increased.

[0031] According to another embodiment, the protrusion can be circular. In other words, the transverse cross section of the protrusion can have a circular shape. Advantageously, the circular-shaped protrusion can have a diameter comprised between 0.45 and 0.65 mm, preferably 0.55 mm. This particular dimension affects the pressure drop of the mixture on the exit of the through hole of the protrusion and help to stabilize the flame. In other embodiments it is possible that the burner deck compris-

es circular protrusions and protrusions that are a slot.

[0032] To improve the efficiency, the burner deck can have a perforation area with a plurality of protrusions. In particular, the protrusions can be arranged in rows and columns and can be distributed homogeneously on the perforation area. The protrusions can be arranged in rows and columns in a staggered manner, such that the protrusions present in a row are misaligned compared to the protrusions present in the previous and/or subsequent row.

[0033] In order to avoid flashback, the ratio between the perforated area and the total area of the burner deck can be comprised between 3% and 15%, preferably between 3% and 7% or between 5% and 15%. In particular, the ratio between the perforated area and the total area of the burner deck can be 5% or 10%. It has been shown that this ratio achieves the target of avoiding flashback over all the maximum and minimum heat input range and also the modulation phase of a gas boiler. The compromise that has been taken is a perforated area that achieves at minimum and maximum heat input with a normal fan. The focus is to avoid any flashback, especially at minimum heat inputs (below the auto-ignition temperature of the hydrogen) where the flame is supposed to be anchored to the deck of the burner. In particular, the target is to achieve a burner deck design that gives the requested heat input reducing as much as possible the pressure loss and also to have a behavior close to standard burner deck of the natural gas/LPG systems. The above-mentioned ratio of perforated area avoids any flashback and maintains at the same time the speed sufficiently high. In fact, the same flow rate of gas-air mix (l/h) that passes through less area causes an increased speed through the holes.

[0034] In an embodiment, the protrusions can be arranged in rows and columns and each protrusion has a length of $2d$ to $3d$, preferably $2.5d$, and a width of $0.4d$ to $0.6d$, preferably $0.5d$, wherein d is the distance between a protrusion and an immediate neighbor protrusion in the same row. Also, the protrusions can be arranged in rows and columns and the distance between a protrusion and an immediate neighbor protrusion in the same column is between $3d$ to $5d$, preferably $4d$, wherein d is the distance between a protrusion and an immediate neighbor protrusion in the same row. For example, d can be comprised between 0.9 mm and 1.1 mm, preferably equal to 1.0 mm. This particular configuration leads to improvements in terms of flashback limit. It is noted that the present embodiment reduces the radial distance between the protrusions, i.e. between the through holes of the protrusions, of about between 15% and 25%, preferably 20% compared to standard gas burners designs, for example natural gas burners. In fact, the larger the distance between the through-holes, the higher the temperature on the burner deck and the higher the possibility of flashback.

[0035] According to an embodiment, the sheet of the burner deck defines a cylindrical surface with a longitu-

dinal axis. Each protrusion is a slot with a length and a width and the plurality of protrusions is arranged on the sheet such that the length of each protrusion is parallel to said longitudinal axis. In particular, the orientation of the longer part of the slots is parallel on the gas/air mixture flow.

[0036] In an aspect of the invention, a gas burner is provided, the gas burner comprising the burner deck according to any of the preceding embodiments.

[0037] Advantageously, to determine a homogeneous distribution of the air/gas mixture to the burner deck, the gas burner can comprise an internal burner deck located in the chamber and having a perforated area comprising a plurality of internal through-holes. In particular, the internal through-holes can have a circular cross section with a diameter comprised between 1.7 and 1.9 mm, preferably 1.8 mm. It noted that the dimension of the through-holes is intended to be lower than about 25%-40% compared to that of standard internal distributors.

[0038] To control in each moment the temperature reached by the air/gas mixture, the burner deck can comprise at least one and preferably two temperature sensors located between the burner deck and the internal burner deck, wherein preferably the temperature sensors are thermocouples. In particular, the at least two temperature sensors can be fixed on the burner deck. A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of Seebeck effect, and this voltage can be interpreted to measure temperature.

[0039] According to another aspect of the invention a burner deck according to the invention is used in a gas burner.

[0040] According to a further aspect, a process to manufacture a burner deck is provided, The process comprises laying a sheet of material, preferably metallic or refractory material, having a thickness on a die matrix having at least an opening, said opening being laterally limited by a first die surface and a second die surface defining a die length, moving a punch element into the opening to create at least a through hole in the sheet of material, wherein the sheet of material is placed between the matrix and the punch element and the punch element has a diameter smaller than the die length, wherein a clearance is determined between the punch element and the opening, when the punch element is moved inside the opening, the value of the diameter being chosen such that the clearance is between $T/10$ and $T/4$, in particular $T/5$, wherein T is the thickness of the sheet of material.

[0041] According to an additional aspect, a sheet is provided, the sheet being obtained by the process of the previous aspect as well as a burner deck comprising said sheet.

[0042] The burner can be used for combusting fuel gas comprising hydrogen, in particular at least 20 mol% hydrogen, in particular at least 70 mol% hydrogen or at least 90 mol% hydrogen, or pure hydrogen, natural gas or mix-

tures thereof.

[0043] According to an aspect of the invention a heating appliance is provided. The heating appliance comprises an inventive burner deck or an inventive gas burner, a fuel gas inlet adapted to provide fuel gas to the burner deck and an air gas inlet adapted to provide air to the burner deck.

[0044] The heating appliance comprises a control unit adapted to control the fuel gas inlet, in particular by controlling a valve, and/or the air inlet, in particular by controlling a valve, to control a mixture of air to fuel gas before the mixture is at the burner deck. This means the control of the mixture occurs in a timely manner before the mixture flows to the burner deck. The heating appliance can be a gas boiler.

[0045] In the figures, the subject-matter of the invention is schematically shown, wherein identical or similarly acting elements are usually provided with the same reference signs.

Figures 1A-1C show a schematic representation of the flame position relative to the burner surface.

Figures 2A-2B show a schematic representation of a protrusion according to one embodiment in a perspective view (A) and in cross-section (B).

Figure 3 shows a schematic representation of a perforated area with a plurality of protrusions in a front view

Figure 4 shows a schematic representation of a burner deck and an internal burner deck of a gas burner.

Figure 5A-5B show the functioning of an apparatus for creating perforations on a sheet of material and manufacturing a burner deck.

Figure 6 shows a flow chart of a process for manufacturing a burner deck.

[0046] With reference to figure 2A, a detail of a burner deck 1 is shown. The burner deck 1 comprises a sheet 3 enclosing a chamber 4. The protrusion 6 is basically a part of the sheet 3 extending outward and is provided with a through hole 5 that is fluidically connected with the chamber 4. The through hole 5 allows the passage of a combustible gas from the chamber 4 and is configured to hold a flame at the upper edge of the protrusion 6. It is clear that, whereas figure 1A shows a single protrusion 6, the burner deck 1 is provided with a plurality of such protrusions 6.

[0047] The protrusion 6 has a particular configuration. First of all, the transverse cross section of the protrusion

6 has the shape of a slot with a length L and a width W . Also, the protrusion 6 comprises a concave section 8, wherein the transverse cross section gets progressively smaller, and a convex section 9, wherein the transverse cross section gets progressively wider, both along a direction from the chamber 4 towards a combustion chamber 16 of a gas burner 2 comprising said burner deck 1.

[0048] The particular configuration of the protrusion 6 can be better appreciated in figure 2B that shows a cross section along a vertical plane of the protrusion 6 of figure 2A. As mentioned above, the protrusion 6 extends outwards from the base of the sheet 3 and comprises a proximal portion 10 close to the sheet 3, a distal portion 11 far away from the sheet 3 and a middle portion 12 located between the proximal and the distal portion. It is noted that the configuration of the protrusion 6 having a concave section 8 and a convex section 9 results in a variable dimension value at the different portions, i.e. in a variable dimension (i.e. length) of the apertures at the different portions along the through-hole 5. The average value of the aperture length of the through-hole 5 at the distal portion 11 is defined as r_1 , the average value of the aperture length of the through-hole 5 at the middle portion 12 is defined as r_2 , and the average value of the aperture length of the through-hole 5 at the proximal portion 10 is defined as r_3 . In particular, the configuration of the protrusion 6 is such that $r_1 > r_2$ and preferably $r_1 > r_3 > r_2$. In one embodiment, r_1 can be almost equal to r_3 or r_1 can be lower than r_3 . Fig. 2B also shows a central axis of the protrusion.

[0049] As shown in the figures, the protrusion 6 extends in the axial direction and due to the larger edge at the distal portion 11, compared to the protrusions in conventional burner decks, the flame is not anchored and the flashback is less probable. Of course, other aspects, such as the fluid-dynamic of the gas, the heat transfer and the chemistry reaction of the gas mixture should be taken into account to definitely make the flame less anchored. However, the innovative structural geometry of the protrusion 6 is a key factor for reducing the flashback phenomenon.

[0050] The height of the protrusion 6 corresponds approximately to the sum of the proximal portion 10, the distal portion 11 and the middle portion 12 and is about 20% of the thickness T of the burner deck 1, i.e. of the sheet 3. It is noted that, in order to emphasize the configuration of the above-mentioned portions, the relationship between the height of the protrusion 6 and the thickness of the sheet 3 is not in scale in the figures 2A and 2B.

[0051] Figure 3 illustrates a portion of the perforated area 7 of the burner deck 1. The perforated area 7 comprises a plurality of protrusions 6, i.e. through-holes 5, arranged in rows and columns in a staggered manner. The figure shows three rows of through-holes, wherein the first row is aligned in column with the third row and the second row is shifted by a shift value comprised between W and $2W$, wherein W is the width of the single protrusion 6 or through-hole 5. It is noted that if the dis-

tance between a protrusion 6 and the immediate neighbor protrusion 6 in the same row is d , the distance between a protrusion 6 and an immediate neighbor protrusion 6 in the same column is $4d$. According to this, each single protrusion 6 has a width W equal to $0.5d$ and a length L equal to $2.5L$.

[0052] Figure 4 shows a gas burner 2 comprising a burner deck 1 and an internal burner deck 13, wherein the burner deck 1 covers the internal burner deck 13 in circumferential and radial direction. The internal burner deck 13 is located at a certain distance from the burner deck 1 in the chamber 4 and serves to make the distribution of the air/gas mixture to the burner deck 1 homogeneous. The internal burner deck 13 comprises a perforated area 14 with a plurality of internal through-holes 15. The internal through-holes 15 are distributed uniformly and have a circular cross-section. On the other hand, the burner deck 1 comprises a perforated area 7 with a plurality of slot-shaped through holes 5. From the figure 4 is clear that the sheet 3 of the burner deck 1 defines a cylindrical surface with a longitudinal axis LA and the plurality of protrusions 6 is arranged on the sheet 3 such that the length of each protrusion 6 is parallel to said longitudinal axis LA .

[0053] Figure 5A shows an apparatus 25 for producing perforations on a sheet of material 19. In particular, this apparatus 25 can be used to manufacture a burner deck 1 as described above. The apparatus 25 essentially comprises a die matrix 17 having at least an opening 18 and a punch element 20 movable inside the opening 18. A sheet of material 19, for example a metallic material, with a thickness T can be placed between the die matrix 17 and the punch element 20. The movement of the punch element 20 inside the opening 18 determines a perforation in the sheet of material 19. The punching occurs by moving the punch element 20 exerting a force F on the sheet of material 19 at the opening 18. The punch element 20 can advantageously have a cylindrical/elliptical shape with a diameter dm . The die matrix 17 comprises a first die surface 22 and a second die surface 23 separated by a die length DL . In other words, these two die surfaces define the aperture 18. It is noted that the die length DL is greater than the diameter dm of the punch element 20 so that the punch element can move inside the opening 18. According to Fig. 5A, the distance between the points B and D is greater than the distance between the points A and C. In particular, when the punch element 20 is moved inside the opening 18 a clearance 21 is determined. The punch element 20 is advantageously coaxial to the opening 18 so that the clearance 21 is uniformly present between the punch element 20 and the opening 18.

[0054] Figure 5B illustrates the functioning of the apparatus 25 and the effect of the clearance 21 on the edges 24 of the sheet of material 19 punched by the punch element 20. In other words, Fig. 5B shows the different profile of the edges 24 based on the dimension of the clearance 21. In particular, the value of the clearance 21

must be selected in order to obtain a suitable profile of the edges 24. If the value of the clearance 21 is correctly selected, the edge cut is regular and smooth without distortions (situation (i) in the figure, wherein the resulted edge 24 is shown in the right figure). If the value of the clearance 21 is too small, the edge profile is not regular and a step-like profile can occur (situation (ii) in the figure, wherein the resulted edge profile is shown in the right figure). On the other hand, if the clearance is too big, a distorted profile and a conical shape can be present (situation (iii) in the figure, wherein the profile is shown in the right figure). It has been observed that an optimal value of the clearance can be determined by the thickness value T of the sheet of material 19. In particular, the value of the diameter dm of the punch element 20 is chosen such that the clearance 21 is T/5. If this condition is respected, the edges 24 of the perforations have a regular profile as in the situation (i) of figure 5B.

[0055] It is noted that this apparatus 25 can be used to create perforations or through holes 5 to form protrusions 6 on the sheet 3 of the burner deck 1 as described above. In particular, the apparatus 25 can be used to obtain protrusions 6 comprising a concave section 8 and a convex section 9 as mentioned above. This particular configuration of the protrusions 6 can be obtained if the above condition regarding the value of the clearance 21 is respected.

[0056] Figure 6 illustrates a flow chart of a process (100) for manufacturing a burner deck 1. At step S101, the process 100 comprises the step of laying a sheet of material 19 having a thickness T on a die matrix 17 having at least an opening 18. At step S102, the process 100 comprises moving a punch element 20 into the opening 18 to create at least a through hole 5 in the sheet of material 19. Based on the fact that the clearance 21 formed between the punch element 20 and the opening 18 is between T/10 and T/4, in particular T/5, the through hole 5 has a protruding profile having a concave section and a convex section as shown for example in Figs 2A and 2B.

Reference Signs

[0057]

1	burner deck
2	gas burner
3	sheet
4	chamber
5	through-hole
6	protrusion
7	perforated area (burner deck)
8	concave section
9	convex section
10	proximal portion
11	distal portion
12	middle portion
13	internal burner deck

14	perforated area (internal burner deck)
15	internal through-hole
16	combustion chamber
17	die matrix
5 18	opening
19	sheet material
20	punch element
21	clearance
22	first die surface
10 23	second die surface
24	sheet edge
25	apparatus
dm	diameter of the punch element
DL	die length
15 FL	flame
BS	burner sheet
OF	outside face
IF	inside face
d	distance
20 C	Central axis of the protrusion
T	thickness
W	width
L	length
LA	longitudinal axis

Claims

1. Burner deck (1) for a gas burner (2), the burner deck (1) comprising a sheet (3) enclosing a chamber (4) and having at least one protrusion (6) with a through hole (5) fluidically connected with the chamber (4) wherein the protrusion (6) comprises a concave section (8) and a convex section (9).
2. Burner deck (1) according to claim 1, **characterized in that** the protrusion (6) protrudes in a direction away from the chamber (4).
3. Burner deck (1) according to claim 1 or 2, **characterized in that**
 - a. the protrusion (6) has a Venturi shape and/or **in that**
 - b. the protrusion (6) has a double truncated cone shape and/or **in that**
 - c. the concave section (8) is arranged distant to the chamber (4) and/or **in that**
 - d. the concave section (8) and the convex section (9) are arranged coaxially to each other.
4. Burner deck (1) according to any one of claims 1 to 3, **characterized in that** the protrusion (6) extends over a length comprised between 15% to 25%, preferably 20%, of the thickness value of the sheet (3) of the burner deck (1).
5. Burner deck (1) according to one of the claims 1 to

- 4, **characterized in that**
- a. the protrusion (6) is a slot having a rectangular shape with semicircular ends; and/or
 - b. the protrusion (6) is a slot having a length comprised between 2.4 and 2.6 mm, preferably 2.5 mm, and a width comprised between 0.4 and 0.6 mm, preferably 0.5 mm.
6. Burner deck according to one of the claims 1 to 5, **characterized in that**
- a. the protrusion (6) is circular; and/or
 - b. the protrusion (6) is circular having a diameter comprised between 0.45 and 0.65 mm, preferably 0.55 mm.
7. Burner deck (1) according to one of the claims 1 to 6, **characterized in that** the burner deck (1) has a perforation area (7) with a plurality of protrusions (6).
8. Burner deck (1) according to claim 7, **characterized in that**
- a. the protrusions (6) are arranged in rows and columns; and/or
 - b. the protrusions (6) are arranged in rows and columns in a staggered manner, such that the protrusions (6) present in a row are misaligned compared to the protrusions (6) present in the previous and/or subsequent row.
9. Burner deck (1) according to claim 7 or 8, **characterized in that** the ratio between the perforated area (7) and the total area of the burner deck (1) is comprised between 3% and 15%, preferably 5% or 10%.
10. Burner deck (1) according to one of the claims claim 7 to 9, **characterized in that**
- a. the protrusions (6) are arranged in rows and columns, wherein each protrusion (6) has a length in the range of 2d to 3d, preferably 2.5d, and a width of about 0,4d to 0,6d, preferably 0,5d, wherein d is the distance between a protrusion (6) and an immediate neighbor protrusion (6) in the same row; and/or
 - b. the protrusions (6) are arranged in rows and columns, wherein the distance between a protrusion (6) and an immediate neighbor protrusion (6) in the same column is about 3d to 5d, preferably 4d, wherein d is the distance between a protrusion (6) and an immediate neighbor protrusion (6) in the same row.
11. Burner deck (1) according to any one of claims 7 to 10, **characterized in that** the sheet (3) defines a cylindrical surface with a longitudinal axis (LA) and each protrusion (6) is a slot with a length and a width and the plurality of protrusions (6) is arranged on the sheet (3) such that the length of each protrusion (6) is parallel to said longitudinal axis (LA).
12. Gas burner (2) comprising a burner deck (1) according to any one of claims 1 to 9 and an internal burner deck (13) located in the chamber (4) and having a perforated area (14) comprising a plurality of internal through-holes (15).
13. Gas burner (2) according to claim 12, **characterized in that** the internal through-holes (15) have a circular cross section with a diameter comprised between 1.7 and 1.9 mm, preferably 1.8 mm.
14. Gas burner (2) according to any one of claims 12 to 14, **characterized in that** the burner (2) further comprises
- a. at least one temperature sensor, in particular two temperature sensors, located between the burner deck (1) and the internal burner deck (13), wherein preferably the temperature sensor is a thermocouple; and or
 - b. the at least one temperature sensor is fixed on the burner deck (1).
15. Process (100) to manufacture a burner deck (1) according to one of the claims 1 to 11 comprising:
- laying (S101) a sheet of material (19), preferably metallic or refractory material, having a thickness (T) on a die matrix (17) having at least an opening (18), said opening (18) being laterally limited by a first die surface (22) and a second die surface (23) defining a die length (DL), moving (S102) a punch element (20) into the opening (18) to create at least a through hole (5) in the sheet of material (19), wherein the sheet of material (19) is placed between the matrix (17) and the punch element (20) and the punch element (20) has a diameter (dm) smaller than the die length (DL), wherein a clearance (21) is determined between the punch element (20) and the opening (18), when the punch element (20) is moved inside the opening (18), the value of the diameter (dm) being chosen such that the clearance (21) is between T/10 and T/4, in particular T/5, wherein T is the thickness of the sheet of material (19).
16. Burner deck (1) obtained by the process according to claim 15.
17. Use of a burner deck (1) according to one of the claims 1 to 11 or 16 in a gas burner (2), in particular

wherein the fuel gas to be combusted comprises hydrogen, in particular at least 20 mol%, in particular at least 70 mol% or at least 90 mol%.

18. Heating appliance comprising

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a burner deck according to one of the claims 1 to 11 or a gas burner according to one of the claims 12 to 14,

a fuel gas inlet adapted to provide fuel gas to the burner deck (1) and

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an air gas inlet adapted to provide air to the burner deck (1).

19. Heating appliance according to claim 18, **characterized in that** the heating appliance comprises a control unit adapted to control the fuel gas inlet and/or the air inlet to control a mixture of air to fuel gas before the mixture flows to the burner deck (1).

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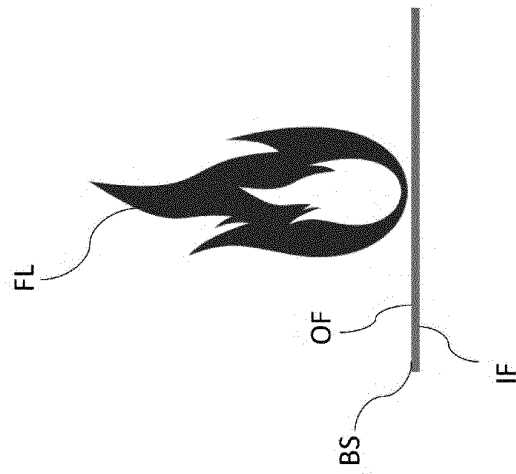


FIG. 1A

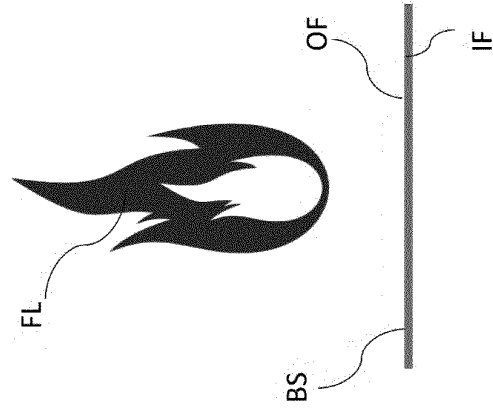


FIG. 1B

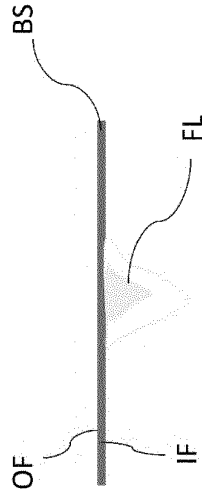


FIG. 1C

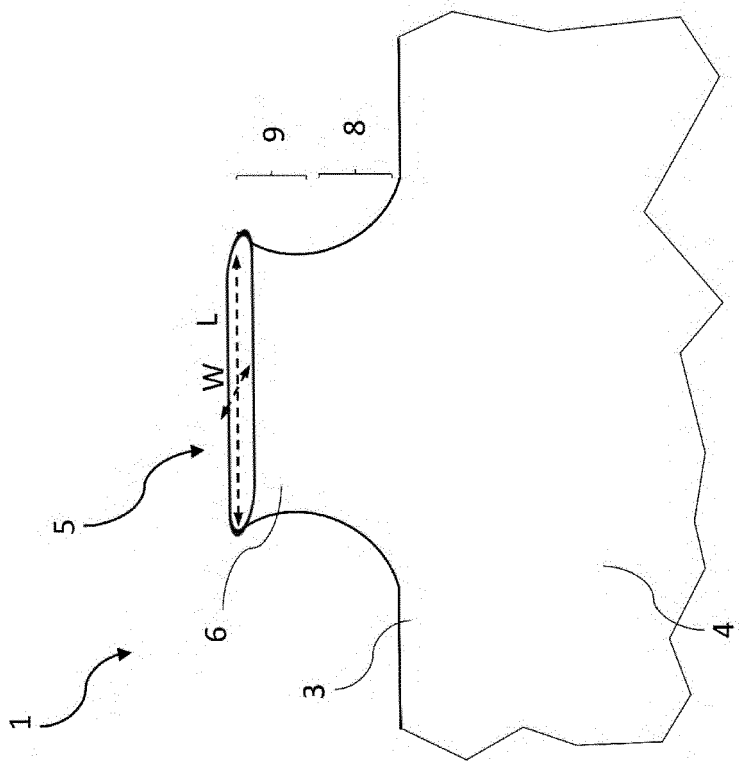


FIG. 2A

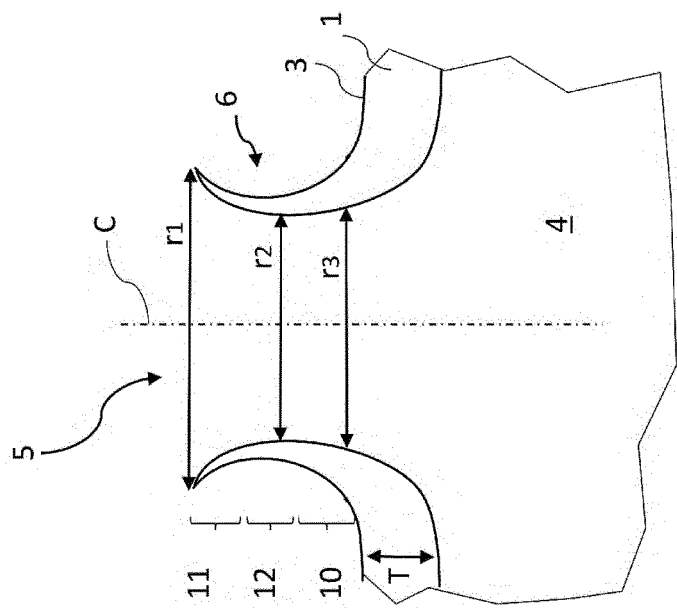


FIG. 2B

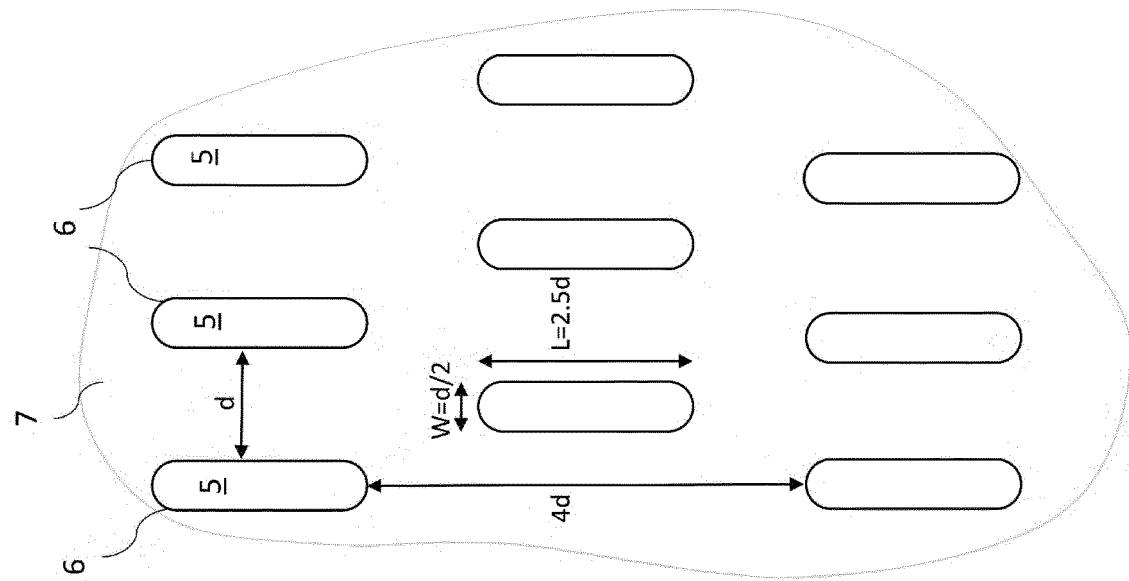


FIG. 3

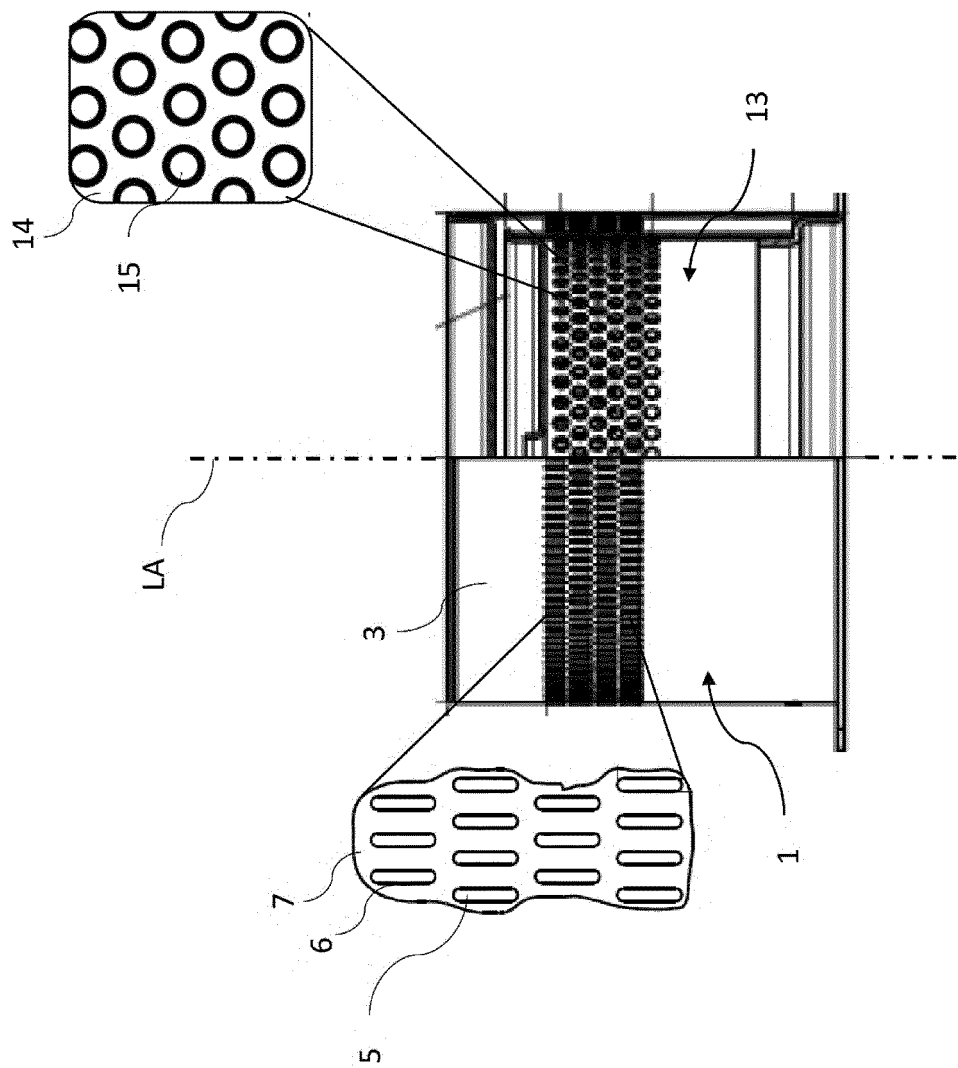


FIG. 4

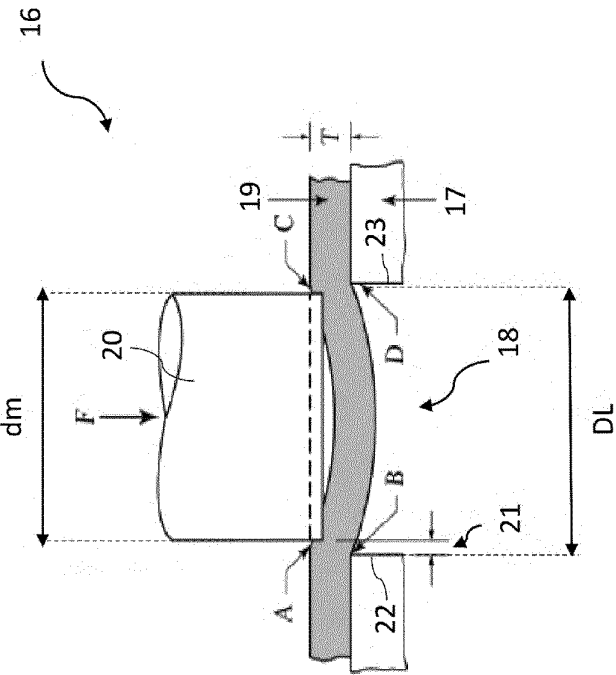


FIG. 5A

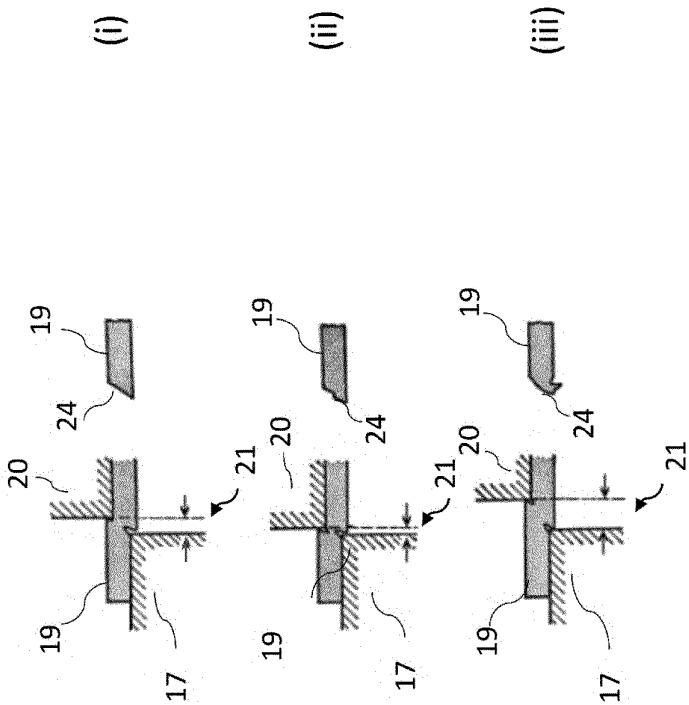


FIG. 5B

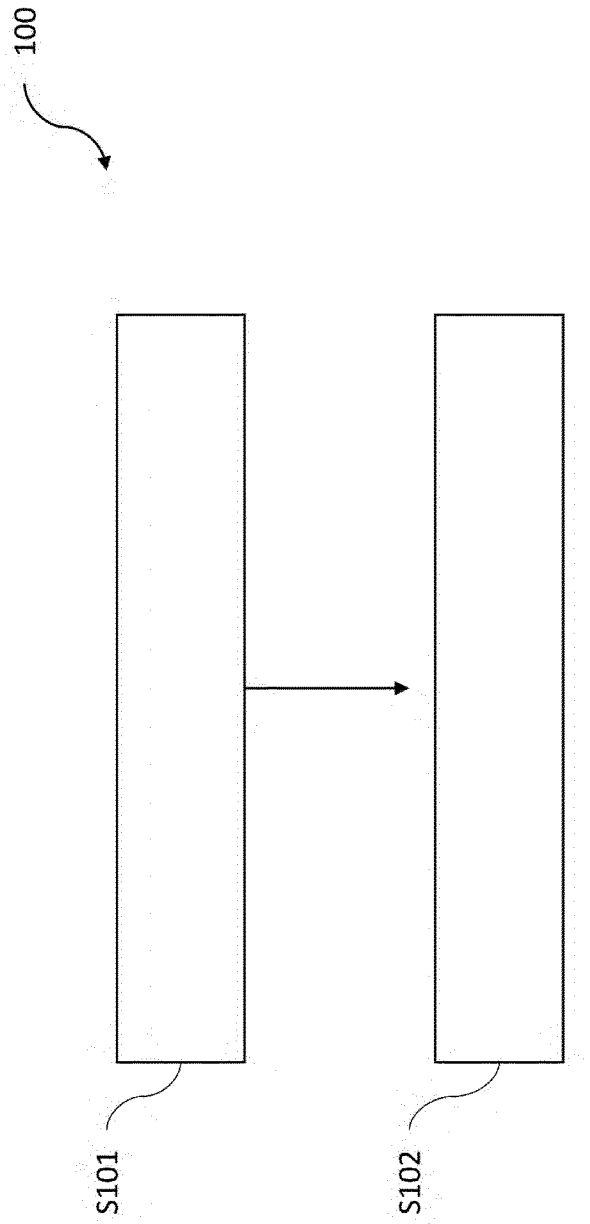


FIG. 6



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