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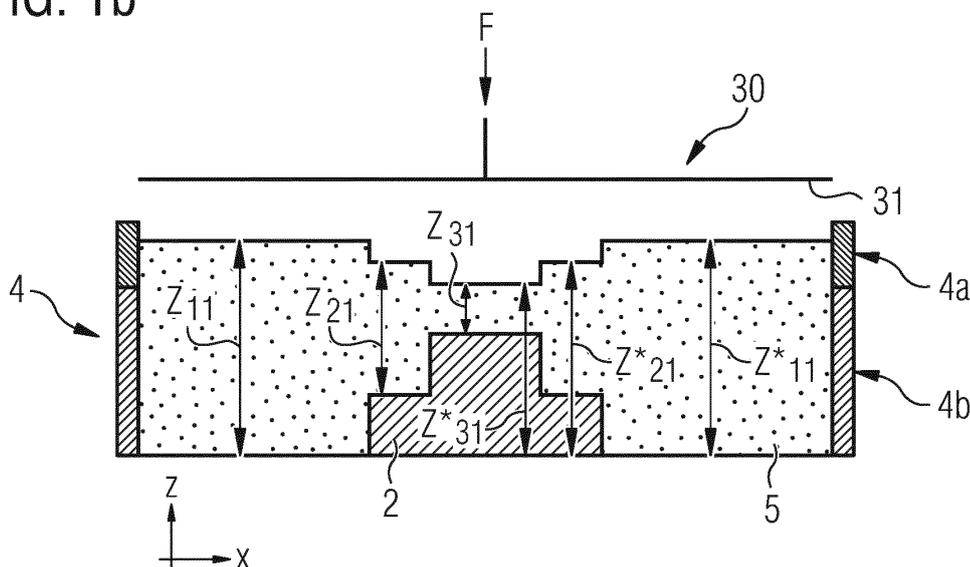
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(54) **METHOD AND MACHINE FOR PRODUCING A MOULD PORTION, MOULDING MATERIAL CONVEYOR SYSTEM**

(57) A method of producing a mould portion comprises the steps of: providing a pattern (2) in a filling box (4), wherein the filling box (4) defines a coordinate system having an x-axis, a y-axis and a z-axis; defining a first matrix (M1), wherein elements of the first matrix (M1) represent surface segments in the filling box (4) in an x-y-plane of the pattern (2) or the filling box (4), and wherein a value of each element of the first matrix (M1) corresponds to an amount of moulding material (5) for the respective surface segment; filling moulding material

(5) into the filling box (4) according to the first matrix (M1), wherein at least two different surface segments in the filling box (4) are filled with different amounts of moulding material (5), such that the filling box (4) comprises at least two different filling heights (z^{*11} , z^{*21} , z^{*31}) of the moulding material (5) at the two different surface segments after completion of filling moulding material (5) into the filling box (4); and compacting the moulding material (5) in the filling box (4), thereby providing a mould portion.

FIG. 1b



Description

[0001] The invention relates to a method and a device for producing at least a portion or a part of a mould, e.g. a cope or a drag of a sand mould for metal casting. Specifically, the invention relates to a method and a machine for an optimized filling of fresh (uncompacted) moulding material into a moulding box in order to reduce the waste of fresh moulding material.

[0002] Sand moulds for metal casting are well known in the art. Typically a model, called pattern, resembling the element, which is to be cast, is used for producing sand moulds. There are two patterns resembling two portions of the element to be cast. Each pattern can then be placed into a filling box and sand is filled into the moulding box so as to cover the pattern. Dosing of the uncompacted sand during the filling into the moulding box is often controlled by volume or by weight of the uncompacted sand.

[0003] The sand is then compacted by a pressing tool until a sufficient strength or stability of the compacted sand is achieved. Afterwards, the pattern is removed leaving a negative of the pattern in the compacted sand. Thereby, a first portion of a mould is produced. These steps are repeated for a second portion of a mould.

[0004] These mould portions are called "cope", which is the upper portion of a mould, and "drag", which is the lower portion of a mould. Cope and drag are assembled to achieve a mould, which comprises a cavity having the same shape or geometry as the sum of the patterns. Gating systems, as known in the art, can be included in the cope and/or drag.

[0005] Typically, the pattern has a non-constant geometry perpendicular to the filling box plane, but sand (moulding material) is usually filled into the filling box such that the filling level of the uncompacted sand is constant, wherein the filling level is typically the highest sand filling level needed for the production of the mould.

[0006] The sand is often compacted by a pressing tool comprising several independently extendable or retractable cylinders such that the relative compaction (sand filling level after compaction divided by sand filling level before compaction at the same area element) is more or less constant over the filling box plane. This leads to a non-constant sand level (height) distribution in the filling box plane after compaction.

[0007] As the surface, at which the pressing tool has come into contact with the sand, is usually needed to be flat, additional compacted sand material is removed (cut or scrapped). This sand material is wasted and would not have been needed to be filled into the filling box as fresh (uncompacted) sand.

[0008] The **problem to be solved** by the invention is to reduce the amount of (uncompacted) moulding material used during the production of a mould portion while maintaining the strength of the mould after compaction of the moulding material.

[0009] **This problem is solved** by a method of pro-

ducing a portion of a mould according to claim 1, by a machine for producing a portion of a mould according to claim 7 or by a moulding material conveyor system according to claim 12.

5 **[0010]** A method of producing a mould portion, e.g. drag or cope, is presented. Within the method a pattern in a filling box is provided. The filling box defines a coordinate system having an x-axis, a y-axis and a z-axis. The x-y-plane of the filling box is parallel to the pattern plate, onto which the pattern is typically mounted. The z-axis stands perpendicularly on the x-y-plane.

10 **[0011]** A first matrix with elements is defined. Elements of the matrix represent surface segments in the filling box in the x-y-plane of the pattern or the filling box. Each value of each element of the first matrix corresponds to an amount of moulding material for the respective surface segment.

15 **[0012]** Moulding material is filled into the filling box such that at least two different surface segments in the filling box are filled with different amounts of the moulding material according to the first matrix. By filling different amounts of filling material into different surface segments, the filling box comprises at least two different filling heights of moulding material at the different surface segments after completion of the filling.

20 **[0013]** The moulding material in the filling box is compacted, e.g. by a compacting head, whereby a mould portion is provided.

25 **[0014]** Generally, surface segments can have different geometrical basic forms. It is preferred that surface segments are rectangles, especially squares.

30 **[0015]** The more surface segments by area are defined the finer the resolution of different moulding material filling heights will be, and consequently the more elements will be present in the first matrix. E.g. at least ten surface segments or at least twenty surface segments, and matrix elements, can be present.

35 **[0016]** Surface segments can be rectangles or squares with a side length between 10 mm and 500 mm, preferably between 50 mm and 200 mm.

40 **[0017]** A filling box can comprise a bolster arrangement, a flask and/or a filling frame. The bolster arrangement can accommodate the pattern and a portion of the uncompacted moulding material. The flask can be positioned on the bolster arrangement and provide a frame for the produced mould portion after compaction of the moulding material. The filling frame can be used to accommodate additional uncompacted moulding material, which is often necessary for the production of a mould portion.

45 **[0018]** Moulding material is often of granular consistency. Therefore, it is clear to the skilled person in the art that a completely constant filling height in a defined surface segment is rarely present, especially if there are different filling heights in other surface segments. E.g., if the filling height in a surface segment differs from the filling height of an adjacent surface segment by a significant amount (e.g. 20 mm), uncompacted moulding ma-

material will typically not allow a sharp-edged transition between the surface segments. A transition between the surface segments with significantly different filling heights is often smooth, while the maximum possible slope depends inter alia on the physical properties of the moulding material. It should be understood that for the determination of a filling height within a surface segment the average filling height over the area of the surface segment should be considered.

[0019] Different filling heights of different surface segments can be considered different if the average filling heights, as explained above, differ by at least 2 mm, preferably 5 mm.

[0020] Generally, the moulding material can comprise sand, especially can comprise green sand.

[0021] Within the method, a second matrix can be determined based on the values of the first matrix. The values of the second matrix represent a filling height of moulding material in the respective surface segment. Moulding material can be filled into the filling box according to the values of the second matrix.

[0022] Preferably, the compactibility of the moulding material is a parameter for the conversion of values from the first matrix to values of the second matrix.

[0023] Values of the first matrix can represent the pattern geometry. Different heights of the pattern in different surface segments can be represented as different values of first matrix elements. Analogous to the moulding material filling height, a constant pattern height over a surface segment is not always present, average height values of the pattern over the respective surface segment can be taken into account for the values of matrix elements.

[0024] Preferably, the filling height of moulding material is larger at a surface segment in the filling box at which the pattern has a lower height than at a surface segment in the filling box at which the pattern has a greater height, after completion of the moulding material filling step.

[0025] Moulding material can be filled into the filling box such that at least two different filling heights of moulding material in the filling box are provided in two different surface segments in (along) the x-axis and two different filling heights of the moulding material are provided in two different surface segments in the y-axis, wherein the different filling heights of the moulding material are present after completion of the filling step.

[0026] At least five different filling heights of moulding material in the filling box can be present after the filling step.

[0027] The moulding material in the filling box can be compacted by compacting head with a flat surface. The moulding material in the filling box can also be compacted by a compacting head with extendable or retractable elements, wherein the elements can be retracted or extended in the z-axis.

[0028] The flat surface of the compacting head can be flat during the filling of the moulding material into the filling

box and/or during the compaction of the moulding material.

[0029] It is preferred that extendable or retractable elements are at least partially extended during and/or after the compacting of the moulding material.

[0030] The extendable or retractable elements of the compacting head can be cylinders.

[0031] Preferably, the filling box comprises a top opening through which the moulding material is filled. The top opening of the filling box extends in a x-y-plane and extends over a large portion of the filling box in the x-y-plane. The top opening can extend over at least 40 % of the extension (area) of the filling box in the x-y-plane during the filling step.

[0032] It is especially preferred that the top opening of the filling box extends over at least 60 %, at least 80 % or even at least 95 % of the area of the filling box in the x-y-plane during the filling step.

[0033] The filling box may be filled with moulding material by a moulding material conveyor directly. The moulding material conveyor can be a belt conveyor.

[0034] The filling box may also be filled with moulding material by a hopper. The hopper may be a dosing hopper.

[0035] Moulding material can be filled into the hopper by the moulding material conveyor.

[0036] For example, the moulding material can be filled into the filling box via a (belt) conveyor (directly) or the moulding material may be filled into the filling box via a hopper which hopper was filled by the (belt) conveyor.

[0037] The moulding material conveyor may transport the moulding material with a height profile in a transport plane of the moulding material conveyor or perpendicular to the running (transport) direction of the moulding material conveyor. At least two different moulding material heights can be transported on the moulding material conveyor as part of the height profile. Preferably, at least three or five different heights of the moulding material are transported on the moulding material conveyor.

[0038] Again, as moulding material typically has a granular consistence different moulding material heights on the moulding material conveyor are usually not sharp-edged, rather the transition between sections of the moulding material flow on the moulding material conveyor or with different heights is usually smooth.

[0039] Heights on the conveyor may be considered different if the average moulding material height over a distance of 50 mm perpendicular to the conveyor transport direction (first section) is different by at least 2 mm, preferably 5 mm, compared to the average height of another section of the moulding material transported on the moulding material conveyor that extends over a distance of 50 mm in a direction perpendicular to the conveyor running or transport direction.

[0040] The moulding material profile on the moulding material conveyor can have at least five different heights.

[0041] The moulding material conveyor can comprise at least two, preferably at least three, more preferably at

least five, height adjustable elements for providing a moulding material flow on the moulding material conveyor, wherein the moulding material flow has a profile in a transport plane of the moulding material conveyor or perpendicular to the running direction of the moulding material conveyor, preferably with at least two, three or five different moulding material heights.

[0042] The height adjustable elements can be controllable. Preferably the height adjustable elements are control plates.

[0043] The height adjustable elements can be repositioned, e.g. in the z-direction, thereby adjusting the height (position) of the elements.

[0044] For example, moulding material can be accommodated in a silo that stores a (large) amount of moulding material. Moulding material from the silo can be dosed and then transported on the moulding material conveyor (belt conveyor). The dosing is often realized by an opening with straight sides (rectangular area), whereby a moulding material flow with constant height is dosed on the moulding material conveyor. By applying height adjustable elements that define the opening, a moulding material flow with a profile (different heights) can be dosed on the moulding material conveyor.

[0045] Moulding material may be deflected by a deflecting device during filling of the moulding material into the filling box or into the hopper in the x-axis or in the y-axis.

[0046] At least two, preferably three or five, deflecting devices may be used for deflecting moulding material during the filling of the filling box or the hopper in the x-axis or in the y-axis.

[0047] The deflecting device(s) can be a guide plate(s).

[0048] A machine for producing a mould portion comprises a pattern, a filling box, a compacting head and a control device. The pattern is positioned in the filling box. The filling box defines a coordinate system with a x-axis, a y-axis and a z-axis. The control device is configured to define a first matrix and elements of the first matrix represent surface segments in the filling box in an x-y-plane of the pattern or the filling box. Values of each element of the first matrix correspond to an amount of moulding material for the respective surface segment. When moulding material is filled into the filling box according to the first matrix, at least two different surface segments in the filling box are filled with different amounts of moulding material. The filling box comprises at least two different filling heights of the moulding material on or in the respective surface segments after the filling of moulding material into the filling box is completed. The compacting head is configured to compact the moulding material in the filling box, thereby a filling box with compacted moulding material as the mould portion is producible.

[0049] The machine can comprise a moulding material conveyor. The moulding material conveyor can be configured to transport moulding material and to define a height profile in a transport plane of the moulding material conveyor or perpendicular to the running or transport di-

rection of the moulding material conveyor to the transportable moulding material (moulding material flow) for filling moulding material into the filling box.

[0050] The height profile can comprise at least two different moulding material heights. Especially, the moulding material flow on the moulding material conveyor can comprise a height profile with at least three or five different heights of moulding material.

[0051] Preferably, the moulding material conveyor comprises at least two, preferably three, more preferably five, height adjustable elements for providing a moulding material flow on the moulding material conveyor with a height profile in a transport plane of the moulding material conveyor or perpendicular to the running or transport direction of the moulding material conveyor.

[0052] It is preferred that the machine comprises a hopper. The hopper can be positioned and can be configured for receiving moulding material from the moulding material conveyor for filling the received moulding material into the filling box.

[0053] Herein disclosed machines can be used in herein disclosed methods and the machines can be configured to execute the herein disclosed method steps.

[0054] A moulding material conveyor system for filling moulding material into a filling box can comprise a belt conveyor, a silo and at least two height (position) adjustable elements. The belt conveyor can comprise a belt and the belt is driven by a motor. The silo comprises moulding material, and the moulding material can be dosed onto to the conveyor belt from the silo. The height adjustable elements can be individually controlled in their positions along a z-axis perpendicular to a transport plane of the conveyor belt. Thereby a moulding material flow on the belt conveyor with a height profile corresponding to the positions of the height adjustable elements is provided.

[0055] The system can comprise at least three height adjustable elements, preferably at least five adjustable elements. Gaps can be present between a lower end of each of the height adjustable elements and the conveyor belt. At least two, preferably three, more preferably five, of the gaps can have different heights.

[0056] For example, the system can comprise at least three height adjustable elements, wherein the three height adjustable elements are positioned at at least two different heights. In this example two height adjustable elements are positioned at the same height and a third height adjustable element is positioned at a different height.

[0057] The lower end of a height adjustable element can be the end of the height adjustable element that faces the conveyor belt.

[0058] The system can comprise a hopper and the hopper can comprise deflecting devices for deflecting moulding material when the moulding material is filled into the filling box.

[0059] The moulding material conveyor system can be used to fill moulding material into a filling box that can be

compacted for producing a portion of a mould.

[0060] Embodiments of the invention are described in more detail with regard to the drawings. The description of the embodiments is not to be construed as to limit the scope defined by the claims. Same reference signs of the figures describe same elements.

Figure 1a shows a step for producing a part of a mould (cope 10).

Figure 1b shows a further step for producing the part of the mould (cope 10).

Figure 1c shows a part of the mould (cope 10).

Figure 2 shows a schematic diagram of a geometry of a pattern 2 and an ideal sand level (filling height of a moulding material 5) in a moulding box 4.

Figure 3a shows a first matrix M_1 of a geometry of a pattern 2 perpendicular to an x-y-plane for a portion of a mould (cope).

Figure 3b shows the geometry of the pattern 2 of figure 3a in a 3D-plot.

Figure 3c shows a second matrix M_2 of an ideal sand level (ideal filling height of moulding material 5) in a filling box 4 based on the geometry of the pattern 2 of figures 3a and 3b.

Figure 3d shows the ideal sand level (filling height of moulding material 5) of figure 3c in a 3D-plot.

Figure 3e shows a matrix of a volume of needed moulding material 5 (sand) for an ideal sand level (filling height of moulding material 5) based on the matrices M_1 and M_2 of figures 3a and 3c.

Figure 3f shows the volume of needed moulding material 5 of figure 3d in a 3D-plot.

Figure 4a shows the volume of needed moulding material 5 in the x-axis with summed up values of the volume in the y-axis (cope), based on the cope pattern geometry shown in Figure 3a.

Figure 4b shows the volume of needed moulding material 5 in the y-axis with summed up values of the volume in the x-axis (cope), based on the cope pattern geometry shown in Figure 3a.

Figure 5 shows a graphic of the ideal volume of needed moulding material 5 in the x-axis (cope), based on the cope pattern geometry shown in Figure 3a comparing the state of the art with the invention.

Figure 6a shows a moulding material conveyor 40 according to the invention in a z-x-plane.

Figure 6b shows the moulding material conveyor 40 of Figure 6a in a z-y-plane.

Figure 7 shows a moulding material conveyor 40 according to the invention in a z-y-plane.

[0061] Figure 1a shows a filling box 4, that comprises

a filling frame 4a and a flask 4b. A bolster or bolster arrangement (not shown) can be positioned under the flask 4b for supporting the pattern 2, which is positioned in the flask 4b. As can be seen from Figure 1a the pattern 2 has different heights in the z-direction. As moulding material 5 are necessary for different pattern 2 height sections. Moulding material 5 can be filled through top opening 7 of the filling box 4. The top opening 7 of the filling box 4 extends substantially over the entire area of the filling box 4 in the x-y-plane reduced by the area of the sidewalls of the filling box 4 in the x-y-plane.

[0062] Uncompacted moulding material 5 can be filled into the filling box 4 such that after compaction of the moulding material 5 a flat upper surface is obtained and every section of moulding material has undergone the same relative compaction.

[0063] This can best be seen when referring to Figures 1b and 1c, wherein Figure 1b shows the filling box 4 with three different filling heights z^*_{11} , z^*_{21} , z^*_{31} . For determination of the respective filling height z^*_{11} , z^*_{21} , z^*_{31} the respective pattern height can be added to the respective relative moulding material height z_{11} , z_{21} , z_{31} .

[0064] At sections within the filling box 4 at which the pattern 2 has a large height, the relative moulding material height z_{31} can be low, wherein at sections at which the pattern 2 has a low (or no) height the relative moulding material height z_{11} is large. The filling height z^*_{11} and the relative moulding material height z_{11} are equal in the example of Figures 1a-1c, since the pattern 2 does not have an extension (height) in z-direction in the section of the filling height z^*_{11} of the moulding material 5 in the filling box 4.

[0065] The relative moulding material heights z_{11} , z_{21} , z_{31} can be determined from the desired filling heights after compaction z'_{11} , z'_{21} , z'_{31} , wherein the compactibility of the moulding material is used as a conversion factor.

[0066] For example, the desired filling height after compaction z'_{31} can be divided by the compactibility of the moulding material (about 45 % for green sand) in order to obtain the relative moulding material height z_{31} . By adding the relative moulding material height z_{31} to the height of the pattern 2 at this position, the filling height z^*_{31} of the moulding material 5 in the filling box 4 can be determined. The relative moulding material heights z_{21} , z_{31} and the filling heights z^*_{21} , z^*_{31} can be determined accordingly.

[0067] After compacting the moulding material 5 by a compacting head 30 with a surface 31 (see Figure 1b) in the filling box 4 the filling frame 4a and the pattern 2 can be removed and a mould portion 10 is provided comprising compacted moulding material 5 in the flask 4b.

[0068] If a compacting head 30 with a flat surface 31 is used, the compacted moulding material top surface 6 can be substantially flat after the compaction step. A compacting head 30 with extendable or retractable elements, such as cylinders, can also be used, which often leads

to a non-flat compacted moulding material top surface 6. The non-flat compacted moulding material top surface 6 can be flattened by removing extra compacted moulding material 5, for example by cutting or scrapping the surface 6. For most mould portions 10 it is desired that the top surface 6 of the compacted moulding material has at least partially substantially the same height as the side walls of the flask 4b with or without an extra moulding material 5 cutting or scrapping step in order to be able to match the mould portion 10 with another mould portion 10 (cope and drag). Parts of the mould portion can protrude above the side walls of the flask 4b as is shown and described with regard to Figures 3a-3f.

[0069] Figure 2 shows an example of an optimal filling height in a filling box based on a specific pattern geometry. The optimal filling height is depicted by the "sand level" curve and the pattern geometry is represented by the "pattern" curve. The broken line overlaying the "sand level" curve shows a technically occurring filling height in a filling box. Due to the physical properties of moulding material, often green sand, sharp edges or high slopes of the filling height curve are typically technically unworkable. Still, an approximation of a moulding material filling height distribution in a filling box prior to compaction to an ideal curve or profile surprisingly leads to a significant reduction of needed uncompacted moulding material, which will also be explained later in more detail.

[0070] An example for the determination of an ideal moulding material distribution for a specific pattern is shown in Figures 3a-3f.

[0071] A cope pattern geometry of a large brake drum is shown in Figure 3b. Obviously, a brake drum is solely an example of an object to be casted in a moulding process and moulding material distribution for any other object to be casted can be determined accordingly, as well for a drag part of the mould. A gating system is not included in the example, but can be included as known in the art.

[0072] A first matrix M_1 can be determined based on the pattern geometry shown in Figure 3b, which matrix M_1 is shown in Figure 3a. A flask with an extension in x-direction of 120 cm, an extension in y-direction of 100 cm and an extension in z-direction of 30 cm is chosen. Surface segments in the x-y-plane of the filling box are chosen to be 10 cm x 10 cm in size. Thus, the matrix M_1 comprises 120 elements with values between 0 and -20. Surface segments with non-constant height of the pattern are averaged.

[0073] Elements of the matrix M_1 with a value of 0 represent the largest height in z-direction of the pattern, whereas the value -20 stands for surface segments in the filling box with the lowest height of the pattern. For obtaining a mould portion with compacted sand, more moulding material is needed at or on surface segments (elements of matrix M_1) with a low value than at surface segments (elements of matrix M_1) with a large value, when assuming the same relative compaction for moulding material over the entire x-y-plane. In this example a

dome-like shaped portion of the mould portion will protrude over the flask's side walls in z-direction.

[0074] From Matrix M_1 a second matrix M_2 can be determined taking the compactibility of the moulding material into account, which is considered 45 % in this example. As the height (extension in z-direction) of the flask is 30 cm, a filling height of 55 cm in matrix M_2 corresponds to a "0" in matrix M_1 ($55 \text{ cm} * 0.55 = 30 \text{ cm}$). Thus, surface segments of the filling box that have a value of 55 cm in matrix M_2 will have a height of 30 cm after compaction of the moulding material, which height is equal to the height of the flask's side walls of the filling box.

[0075] Surface segments with a value of 91 cm in matrix M_2 will have a height of 50 cm after compaction of the moulding material ($91 \text{ cm} * 0.55 = 50 \text{ cm}$). Thus, these surface segments will have compacted moulding material with a larger height than the flask and will extend over the flask.

[0076] Other surface segments in the filling box will have an accordingly determined height after compaction of the moulding material. The proposed moulding material filling height distribution is graphically depicted in Figure 3d without averaging non-constant heights within a respective surface segment.

[0077] In Figure 3e the volume of moulding material that is needed for the filling height distribution as determined in matrix M_2 is depicted for each surface segment. For example, a surface segment (element in matrix M_2) with a targeted filling height of 55 cm will need 5.5 L of moulding material as the surface segments have an area of 100 cm^2 . The needed moulding material volume for other surface segments of the filling is determined accordingly. The volume of moulding material needed for all surface segments is graphically depicted in Figure 3f, again without averaging non-constant filling heights within a respective surface segment.

[0078] Figure 3e additionally shows the sum of moulding material volume needed along each row and each column of the matrix shown in Figure 3e. For example, values of the first column of the matrix add up to 54.5 L as $\sum y$, which is equal to ten times 5.5 L (including rounding errors).

[0079] Accordingly, the values of the first row of the matrix of Figure 3e is added up to 65.5 L, which is equal to twelve times 5.5 L as $\sum x$ (including rounding errors).

[0080] The values of $\sum y$ and $\sum x$ represent the volume of moulding material needed for rows and columns of the matrix of Figure 3e, i.e. the volume of moulding material needed along the y-axis and along the x-axis of the filling box for a mould with a flat surface and same relative compaction values after compaction according to the first matrix M_1 and the second matrix M_2 .

[0081] The summed moulding material volume needed for the cope along the x-axis is shown in Figure 4a as $\sum y$ in L (liters). The values of $\sum y$ correspond to the matrix of Figure 3e. The plot of Figure 4a shows this graphically and it becomes apparent that the needed (optimal) moulding material volume significantly differs along the

x-axis. Close to the edge regions of the filling box in the x-direction, for example surface segments "10" and "120", 55 L of uncompacted moulding material is needed, whereas at the center of the filling box, for example surface segments "60" and "70" more uncompacted moulding material (84 L) is needed.

[0082] Accordingly, the same applies for the summed moulding material volume needed along the y-axis as shown in Figure 4b as Σx . Close to edge portion of the filling box less material, for example 65 L, is needed than at the center portion of the filling box (91 L).

[0083] Figure 5 depicts a comparison of the calculated needed moulding material volume as "sand real demand". The values shown in the table named "sand real demand" correspond to the values of the table shown in Figure 4a and depict the summed moulding material needed along the x-axis (10, 20, 30, ... 120) Σy with values between 55 L and 84 L.

[0084] Table "state of the art" shows values of used moulding material according to the practice of the state of the art. These values are summed moulding material values along the x-axis (10, 20, 30, ... 120) Σy for the same cope production process, but as it is practiced in the state of the art. The largest volume needed for the mould portion production process, i.e. 84 L in this example, is used for all columns (10, 20, 30, ... 120) as Σy . Thus, a significant volume of uncompacted moulding material is wasted as can be seen in table "excess of sand (dm^3)". For example, in column 10 the summed volume of moulding material according to the invention for the specific cope production is 55 L. The state of the art uses 84 L for the same column 10 (see Figure 5, table "state of the art"). Thus, 29 L of uncompacted moulding material is wasted in this column. Along the x-axis 192 L (see Figure 5, table "excess of sand (dm^3)") of uncompacted moulding material is wasted. Comparing the total moulding material used according to the invention (811 L) to the total moulding material used according to the state of the art (1004 L), moulding material demand is reduced by about 20 % by the invention.

[0085] Therefore, the invention provides the possibility to reduce the use of uncompacted moulding material while maintaining a good mould quality by surprisingly reducing the volume of uncompacted moulding material at portions (surface segments) within the filling box at which the state of the art believed more moulding material to be necessary for the producing of a high quality mould portion.

[0086] Figure 6a depicts a moulding material conveyor 40 as belt conveyor in a z-x-plane and Figure 6b depicts the moulding material conveyor 40 as belt conveyor in a z-y-plane.

[0087] The moulding material conveyor 40 comprises a belt B that is driven by a motor M. Moulding material 5 can be transported on the belt B of the moulding material conveyor 40 as a moulding material flow that travels with a speed v in y-direction. Moulding material 5 can be dosed onto the belt B via a silo 50 that is connected to

the moulding material conveyor 40. An opening O between the silo 50 and the belt B of the moulding material conveyor 40 defines the height of transported moulding material 5 on the moulding material conveyor 40.

[0088] The moulding material conveyor shown in Figures 6a and 6b comprises several height adjustable elements 42a-42f that define the opening O between the silo 50 and the belt B of the moulding material conveyor 40. The height adjustable elements 42a-42f can be adjusted in height such that the height of moulding material 5 transported on the belt B can be adjusted. For example, the height adjustable element 42f can be adjusted such that moulding material 5 with a height h_1 is released from the silo 50 onto the belt B and the height adjustable element 42e can be adjusted such that moulding material 5 with a height h_2 is released from the silo 50 onto belt B. Thus, moulding material 5 transported on the belt B of the moulding material conveyor 40 is transported with different heights as a moulding material flow. The moulding material 5 has a height profile perpendicular to the running direction or the transport direction of the belt B.

[0089] The heights h_1 and h_2 can be different heights. Other height adjustable elements 42a-42d can have other heights such that the belt B transports moulding material 5 with several (at least two, preferably at least three, more preferably at least 5) different heights.

[0090] The height adjustable elements 42a-42f can be controllable in height such that the height of the opening of the respective height adjustable elements 42a-42f can be (automatically) adjusted while moulding material 5 is dosed onto the moulding material conveyor 40.

[0091] The height adjustable elements 42a-42f can be control plates.

[0092] At least two, preferably at least three, more preferably at least five, height adjustable elements 42a-42f can be mounted on the moulding material conveyor 40 or on the silo 50 that define an opening O between the silo 50 and the moulding material conveyor 40 for dosing moulding material 5 stored in the silo 50 onto the moulding material conveyor 40.

[0093] Moulding material 5 can be filled into a filling box 4 (not shown in Figures 6a and 6b) from the moulding material conveyor 40. Moulding material 5 can be filled (directly) into the filling box 4 from the moulding material conveyor 40 or into a hopper, from which hopper the moulding material 5 can be filled into the filling box 4.

[0094] By filling moulding material 5 with a height profile perpendicular to the running direction of the moulding material conveyor 40, moulding material 5 can be filled into the filling box 4 or into the hopper and then into the filling box 4 such that the filling box 4 is filled with different heights of moulding material 5 along the x- or y-axis.

[0095] If the moulding material 5 is filled into the filling box 4 via the hopper, the hopper comprises moulding material 5 with different heights. The hopper typically comprises a discharge mechanism that allows the moulding material 5 with different heights to be transferred from the hopper to the filling box 4.

[0096] The moulding material 5 distribution caused by the opening O can best be seen with reference to Figure 5 again.

[0097] According to the state of the art the opening height between a silo and a moulding material conveyor is constant perpendicular to the running direction of the moulding material conveyor. In Figure 5 the constant height is 23.2 cm for this specific example, which example takes a specific belt speed (60 cm s^{-1}), a specific filling time (6 s) and a specific opening width (120 cm) into account.

[0098] According to the invention moulding material 5 with different heights, i.e. from 15.2 cm to 23.2 cm, is transported by the moulding material conveyor by adjusting height adjustable elements 42a-42f such that the opening between a silo and the moulding material conveyor is adjusted to the respective height.

[0099] The height (position) of the adjustable elements 42a-42f is based on the pattern geometry as corresponding to the first matrix M_1 , the summed moulding material volume along the x-or y-axis $\sum y$ or $\sum x$ (see Figures 3a to 3f) and the moulding material conveyor characteristics (see Figure 5).

[0100] Usually, the position of the height adjustable elements 42a-42f is changed between production of different mould portions, e.g. cope and drag. The position of the height adjustable elements 42a-42f can also be changed during the filling of a mould portion for also allowing a height profile of transported moulding material in a direction parallel to the running direction of the moulding material on the moulding material conveyor.

[0101] Figure 7 shows the moulding material conveyor 40 of Figures 6a and 6b in a z-y-plane that transports moulding material 5. The silo 50 is connected to the moulding material conveyor 40 and an opening (gap) between silo 50 and the moulding material conveyor 40 is defined by height adjustable elements 42a-42f as described above. Moulding material 5 can be transported on the moulding material conveyor 40 in a transport plane 5a.

[0102] Deflecting devices 45a-45c are positioned below the moulding material conveyor 40. Deflecting devices 45a-45c can be baffles, especially metal baffles.

[0103] The deflecting devices 45a-45c can be controllable.

[0104] The deflecting devices 45a-45c are positioned such that moulding material 5 coming from moulding material conveyor 40 is deflected in a direction parallel to the running direction of the moulding material 5 on the moulding material conveyor 40.

[0105] As the moulding material 5 on the moulding material conveyor 40 can have a height profile perpendicular to the running direction and the deflecting devices 45a-45c can deflect the moulding material 5 from the moulding material conveyor 40 parallel to the running direction of the moulding material 5 on the moulding material conveyor, it is possible to fill a filling box with moulding material 5 that has different heights in different surface seg-

ments of the filling box 4 along the x-axis and along the y-axis. This can be done according to the geometry of the pattern as described above.

[0106] Moulding material 5 can be deflected by the deflecting devices 45a-45c such that the moulding material 5 is (directly) filled into the filling box 4. Alternatively, moulding 5 can be deflected by the deflecting devices 45a-45c such that the moulding material 5 is filled into a hopper, from which hopper the moulding material can be filled into the filling box 4.

[0107] The hopper H can comprise the described deflecting devices 45a-45c.

15 Claims

1. Method of producing a mould portion, the method comprising the steps of:

(a) providing a pattern (2) in a filling box (4), wherein the filling box (4) defines a coordinate system having an x-axis, a y-axis and a z-axis;

(b) defining a first matrix (M_1), wherein elements of the first matrix (M_1) represent surface segments in the filling box (4) in an x-y-plane of the pattern (2) or the filling box (4), and wherein a value of each element of the first matrix (M_1) corresponds to an amount of moulding material (5) for the respective surface segment;

(c) filling moulding material (5) into the filling box (4) according to the first matrix (M_1), wherein at least two different surface segments in the filling box (4) are filled with different amounts of moulding material (5), such that the filling box (4) comprises at least two different filling heights (z^*_{11} , z^*_{21} , z^*_{31}) of the moulding material (5) at the two different surface segments after completion of filling moulding material (5) into the filling box (4);

(d) compacting the moulding material (5) in the filling box (4), thereby providing a mould portion.

2. Method according to claim 1, wherein the moulding material (5) in the filling box (4) is compacted by a compacting head (30) with a flat surface (31) or by a compacting head (30) with at least two extendable or retractable elements in the z-axis, wherein the flat surface (31) of the compacting head (30) is flat during the filling of the moulding material (5) into the filling box (4) and/or during the compaction of the moulding material (5) in the filling box (4), or the extendable or retractable elements are at least partially extended during and/or after the compacting of the moulding material (5) in the filling box (4).

3. Method according to any one of claims 1 to 2, wherein the moulding material (5) is filled into the filling box (4) by a moulding material conveyor (40) or by a hopper.

4. Method according to claim 3, wherein the moulding material (5) is transported on the moulding material conveyor (40) with a height profile (h_1, h_2) in a transport plane (5a) of the moulding material conveyor (40) or perpendicular to a running direction (v), preferably the profile comprising at least two different heights of the moulding material (5) on the moulding material conveyor (40), more preferably the profile comprising at least five different heights of the moulding material (5) on the moulding material conveyor (40).
5. Method according to any one of claims 3 or 4, wherein the moulding material conveyor (40) comprises at least two, preferably five, height adjustable elements (42a, ..., 42f) for providing a height profile (h_1, h_2) in a transport plane (5a) of the moulding material conveyor (40) or perpendicular to the running direction (v) for a profiled moulding material (5) flow on the moulding material conveyor (40).
6. Method according to any one of claims 1 to 5, wherein moulding material (5) is deflected in the x-axis or in the y-axis during filling of the moulding material (5) into the filling box (4) or into a hopper (H) by at least one deflecting device (45a, 45b, 45c).
7. **Machine** for producing a mould portion, the machine having a pattern (2), a filling box (4), a compacting head and a control device; wherein
- (a) the pattern (2) is positioned in the filling box (4) and the filling box (4) defining a coordinate system having an x-axis, a y-axis and a z-axis;
- (b) the control device being configured to define a first matrix (M_1), wherein elements of the first matrix (M_1) represent surface segments in the filling box (4) in an x-y-plane of the pattern (2) or the filling box (4), and wherein a value of each element of the first matrix (M_1) corresponds to an amount of moulding material (5) for the respective surface segment;
- (c) such that when moulding material (5) is filled into the filling box (4) according to the first matrix (M_1), at least two different surface segments in the filling box (4) are filled with different amounts of moulding material (5) and the filling box (4) comprises at least two different filling heights ($z^*_{11}, z^*_{21}, z^*_{31}$) of the moulding material (5) on the two different surface segments after completion of filling moulding material (5) into the filling box (4);
- (d) and the compacting head for compacting the moulding material (5) in the filling box (4), to produce a filling box (4) with compacted moulding material (5) as the mould portion.
8. Machine according to claim 7, comprising a moulding material conveyor (40), wherein the moulding material conveyor (40) is configured to transport moulding material (5) and to define a height profile (h_1, h_2) in the transport plane (5a) of the moulding material conveyor (40) or perpendicular to the running direction (v) of the transportable moulding material for filling moulding material (5) into the filling box (4), preferably the profile comprising at least two, more preferably at least five, different heights of the moulding material (5).
9. Machine according to claim 8, wherein the moulding material conveyor (40) comprises at least two height adjustable, preferably controllable, elements (42a, ..., 42f), the elements (42a, ..., 42f) being height adjustable for providing a moulding material (5) flow on the moulding material conveyor (40) with a height profile (h_1, h_2) in the transport plane (5a) of the moulding material conveyor (40) or perpendicular to the running direction (v).
10. Machine according to any one of claims 8 or 9, comprising a hopper, wherein the hopper is positioned and configured for receiving moulding material from the moulding material conveyor (40) for filling the received moulding material into the filling box (4).
11. Machine according to any one of claims 7 to 10, comprising at least one deflecting device (45a, 45b, 45c), the at least one deflecting device (45a, 45b, 45c) being configured to deflect moulding material (5) during filling of the moulding material (5) into the filling box (4) in the x-axis or in the y-axis, preferably into a hopper (H) prior to filling of the moulding material (5) into the filling box (4).
12. **Moulding material conveyor system** for filling moulding material into a filling box (4), the system comprising:
- (a) a belt conveyor, wherein the belt conveyor comprises a belt (B) and the belt (B) is driven by a motor (M);
- (b) a silo (50), wherein the silo (50) comprises moulding material (5), and wherein moulding material (5) is dosable onto to the conveyor belt (B) from the silo (50);
- (c) height adjustable elements (42a-42f), wherein the height adjustable elements (42a-42f) are individually controlled in their positions along a z-axis perpendicular to a transport plane (5a) of the conveyor belt (B), for providing a moulding material flow on the belt conveyor with a height profile (h_1, h_2) corresponding to the positions of the height adjustable elements (42a-42f).
13. System according to claim 12, comprising at least two height adjustable elements (42a-42f), preferably

at least three height adjustable elements (42a-42f), more preferably at least five height adjustable elements (42a-42f).

14. System according to claim 12 or 13, wherein a gap between a lower end of each of the height adjustable elements (42a-42f) and the conveyor belt (B) is present, and wherein at least two of the gaps have a different height. 5
- 10
15. System according to any one of claims 12 to 14, further comprising a hopper (H), wherein the hopper (H) comprises deflecting devices (45a-45c) and for deflecting moulding material during the filling of the filling box (4). 15

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FIG. 1a

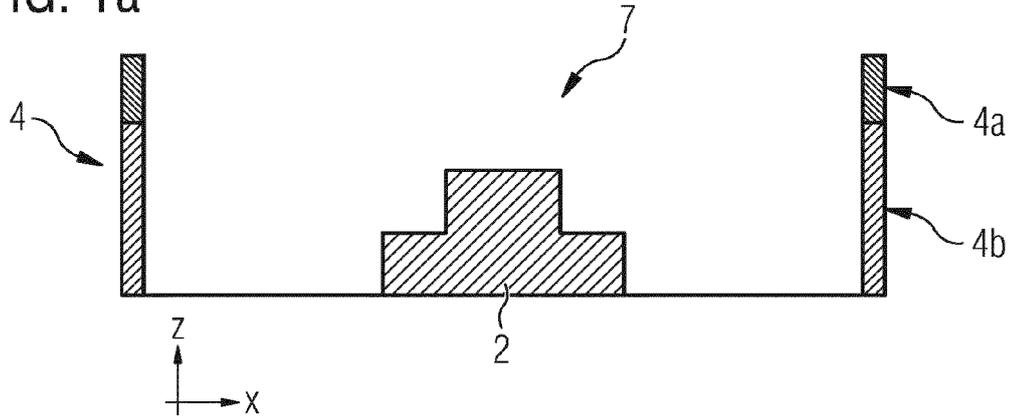


FIG. 1b

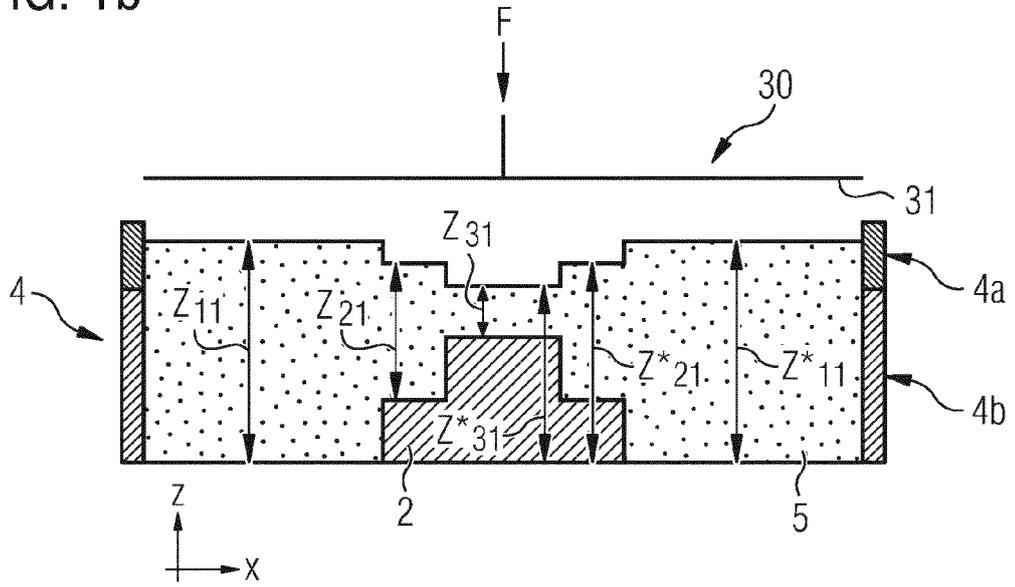


FIG. 1c

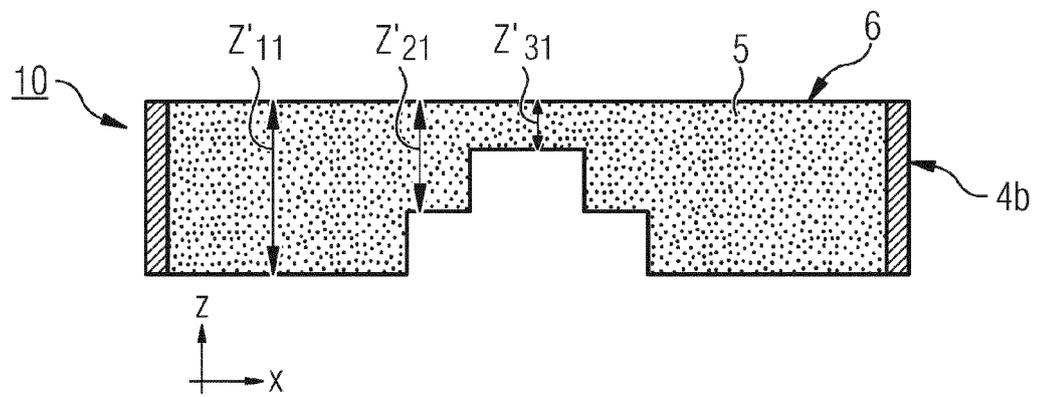


FIG. 2

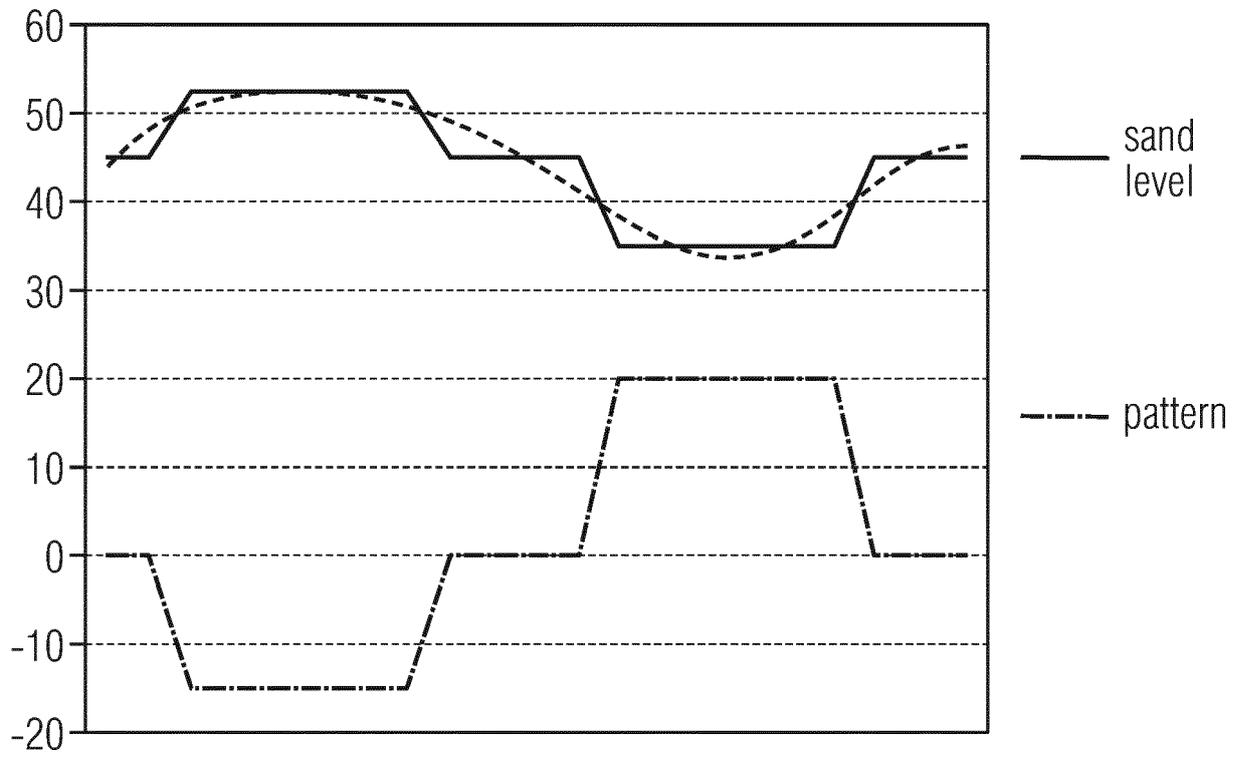


FIG. 3a

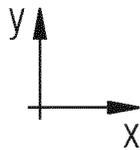
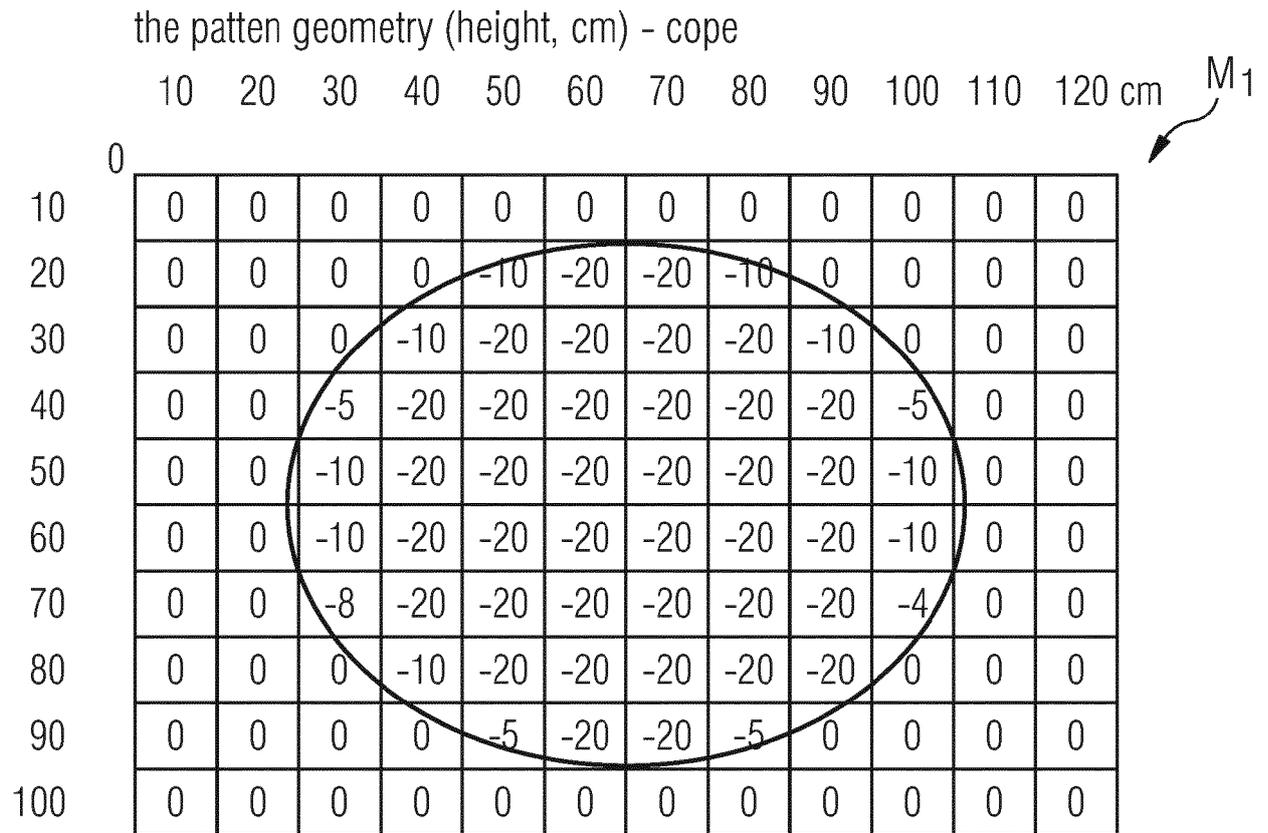


FIG. 3b

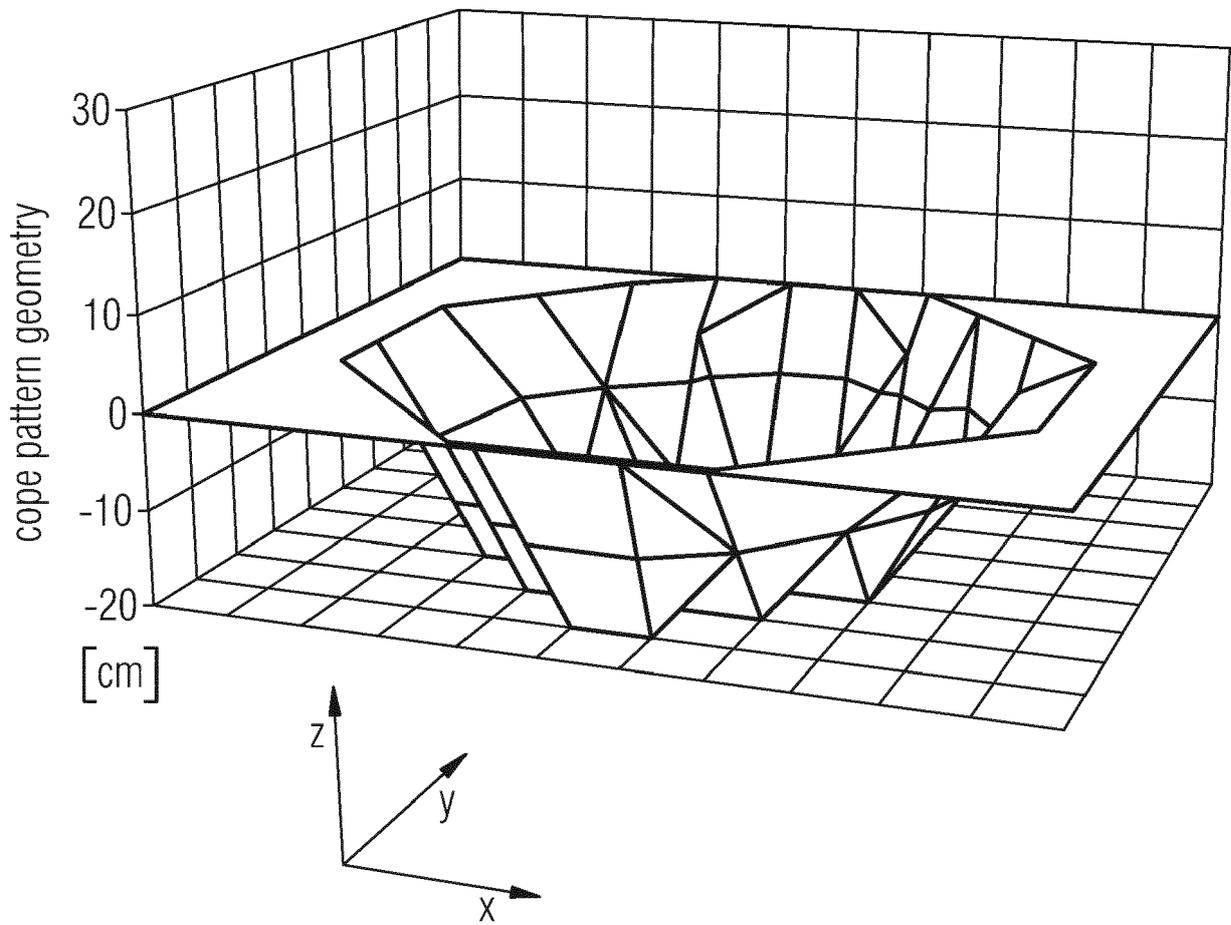


FIG. 3c

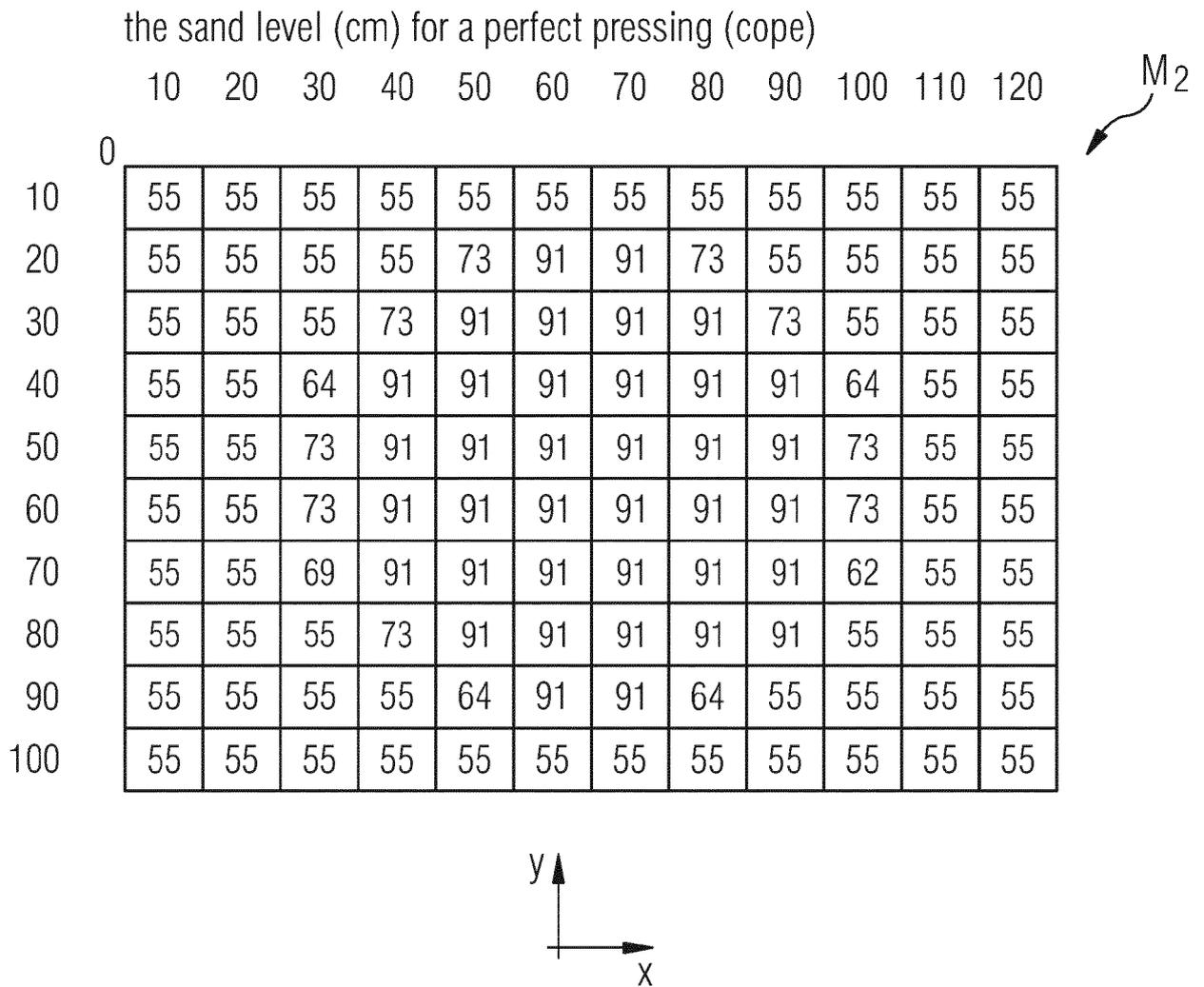


FIG. 3d

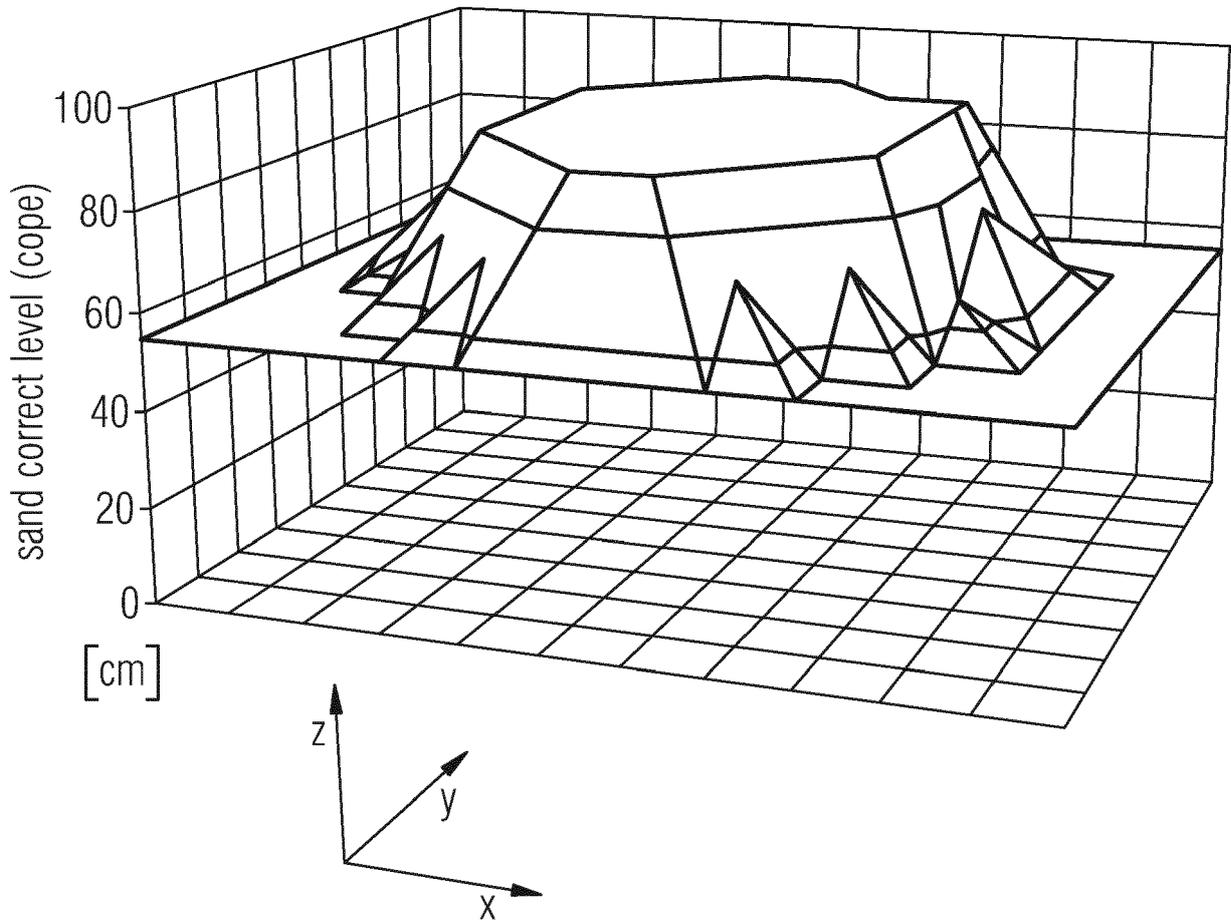


FIG. 3e

in liters for each 10 x 10cm block (100cm²) - cope

	10	20	30	40	50	60	70	80	90	100	110	120	Σ_x
0	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	65,5
10	5,5	5,5	5,5	5,5	7,3	9,1	9,1	7,3	5,5	5,5	5,5	5,5	76,4
20	5,5	5,5	5,5	7,3	9,1	9,1	9,1	9,1	7,3	5,5	5,5	5,5	83,6
30	5,5	5,5	6,4	9,1	9,1	9,1	9,1	9,1	9,1	6,4	5,5	5,5	89,1
40	5,5	5,5	7,3	9,1	9,1	9,1	9,1	9,1	9,1	7,3	5,5	5,5	90,9
50	5,5	5,5	7,3	9,1	9,1	9,1	9,1	9,1	9,1	7,3	5,5	5,5	90,9
60	5,5	5,5	6,9	9,1	9,1	9,1	9,1	9,1	9,1	6,2	5,5	5,5	89,5
70	5,5	5,5	5,5	7,3	9,1	9,1	9,1	9,1	9,1	5,5	5,5	5,5	85,5
80	5,5	5,5	5,5	5,5	6,4	9,1	9,1	6,4	5,5	5,5	5,5	5,5	74,5
90	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	65,5
100	Σ_y	54,5	54,5	60,5	72,7	79,1	83,6	83,6	79,1	74,5	59,8	54,5	811

FIG. 3f

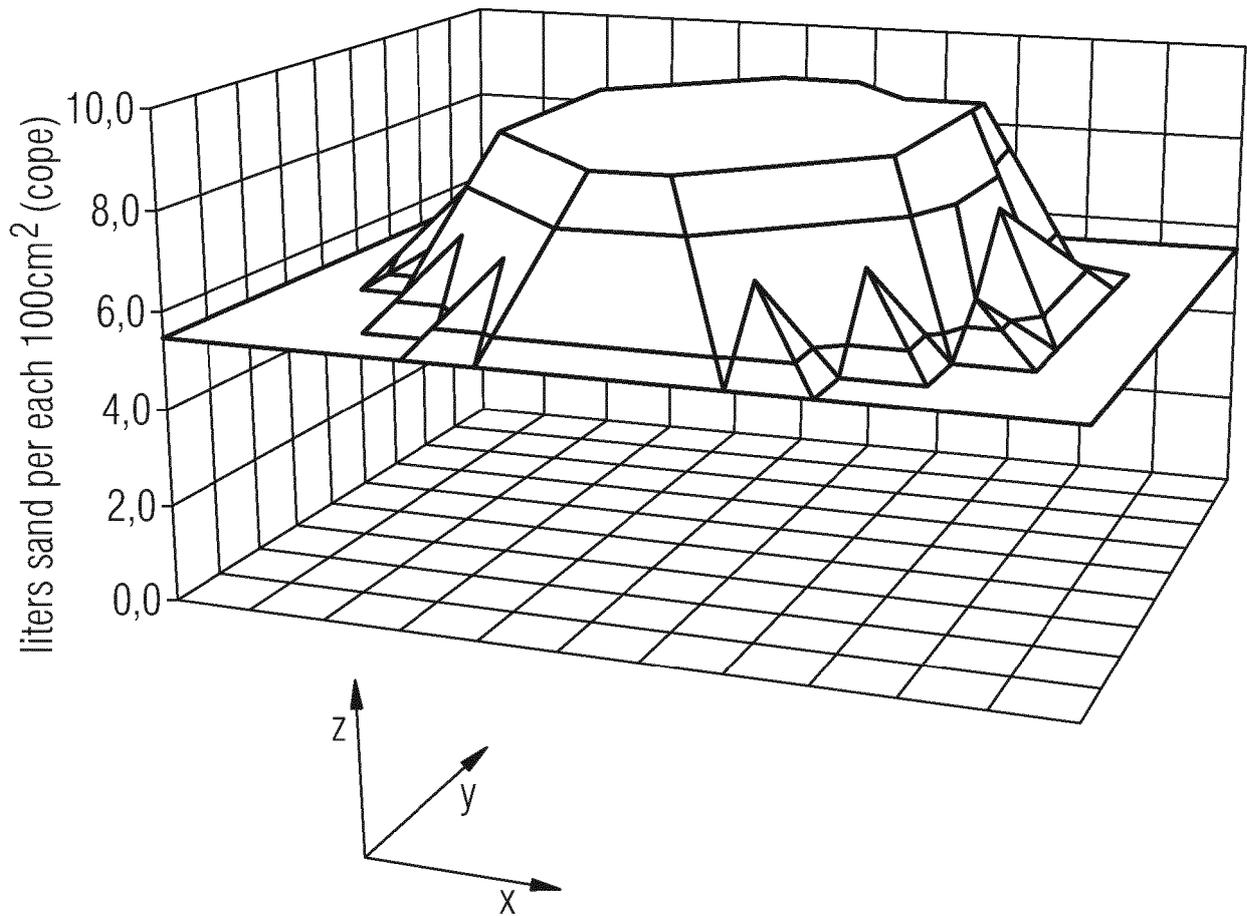


FIG. 4a

X axis	10	20	30	40	50	60	70	80	90	100	110	120
Σ_y (cope)	55	55	61	73	79	84	84	79	75	60	55	55

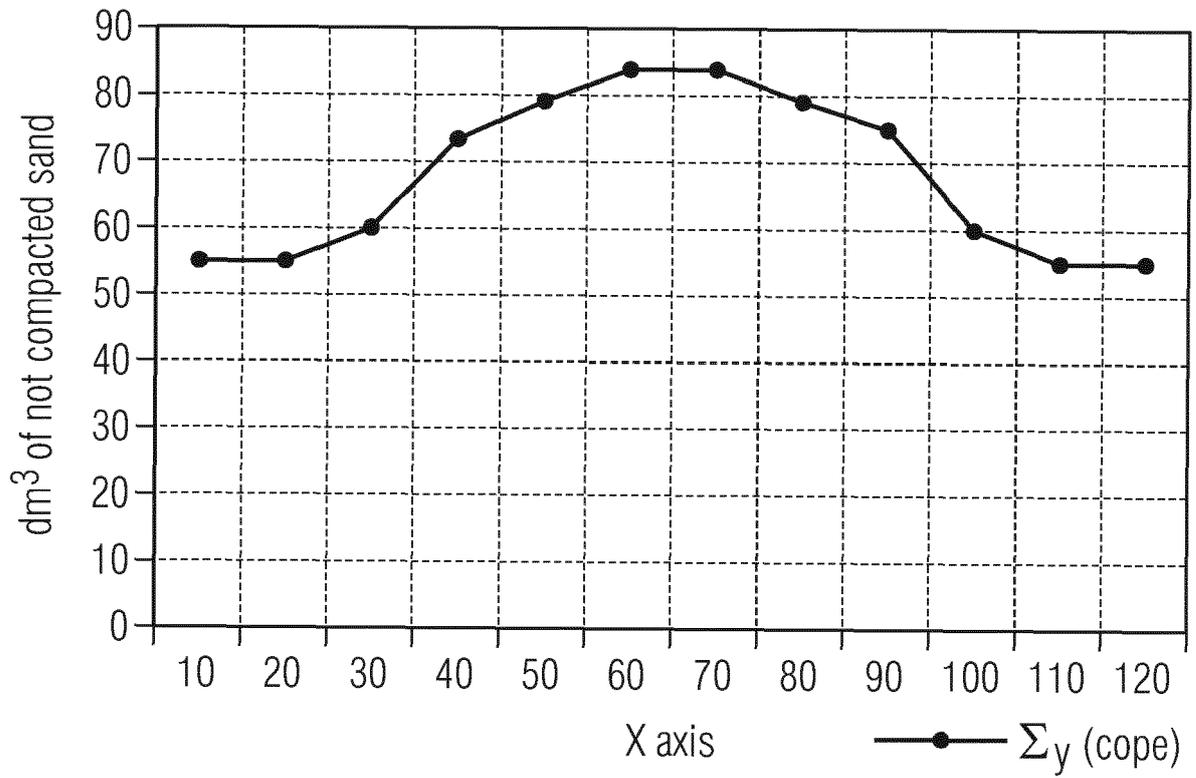


FIG. 4b

Y axis	10	20	30	40	50	60	70	80	90	100
$\Sigma_X(\text{cope})$	65	76	84	89	91	91	89	85	75	65

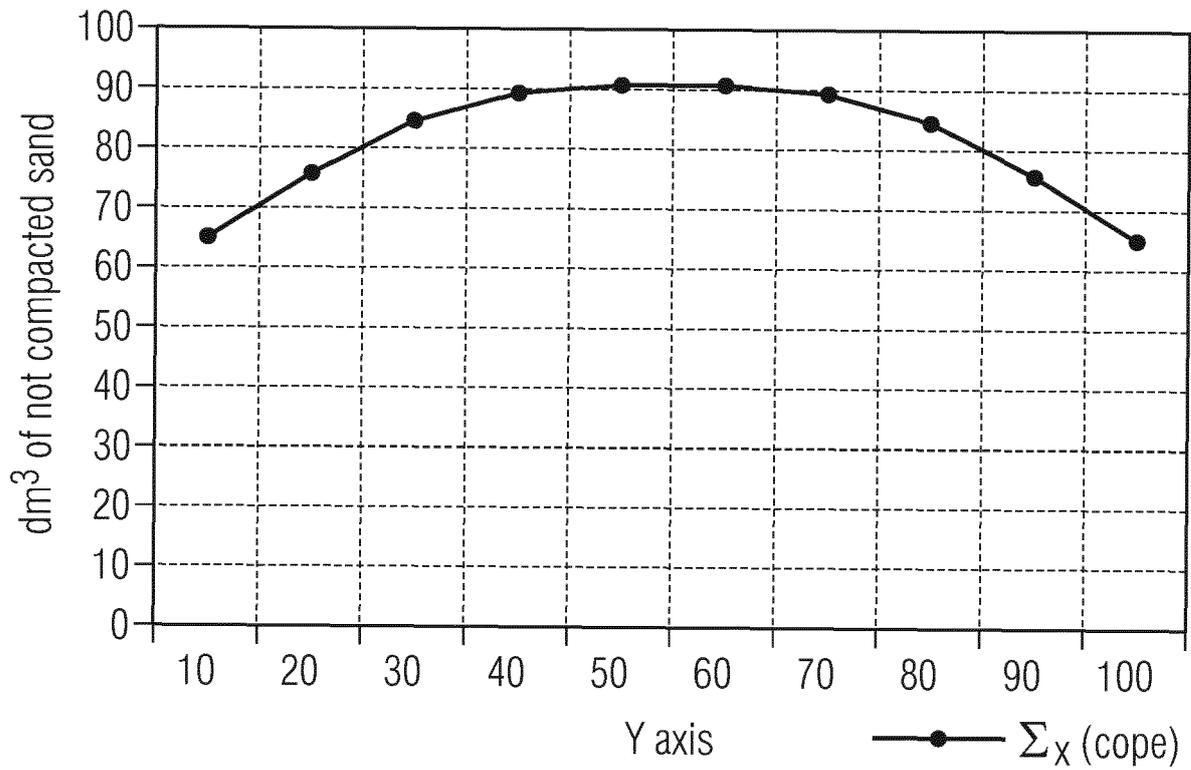


FIG. 5

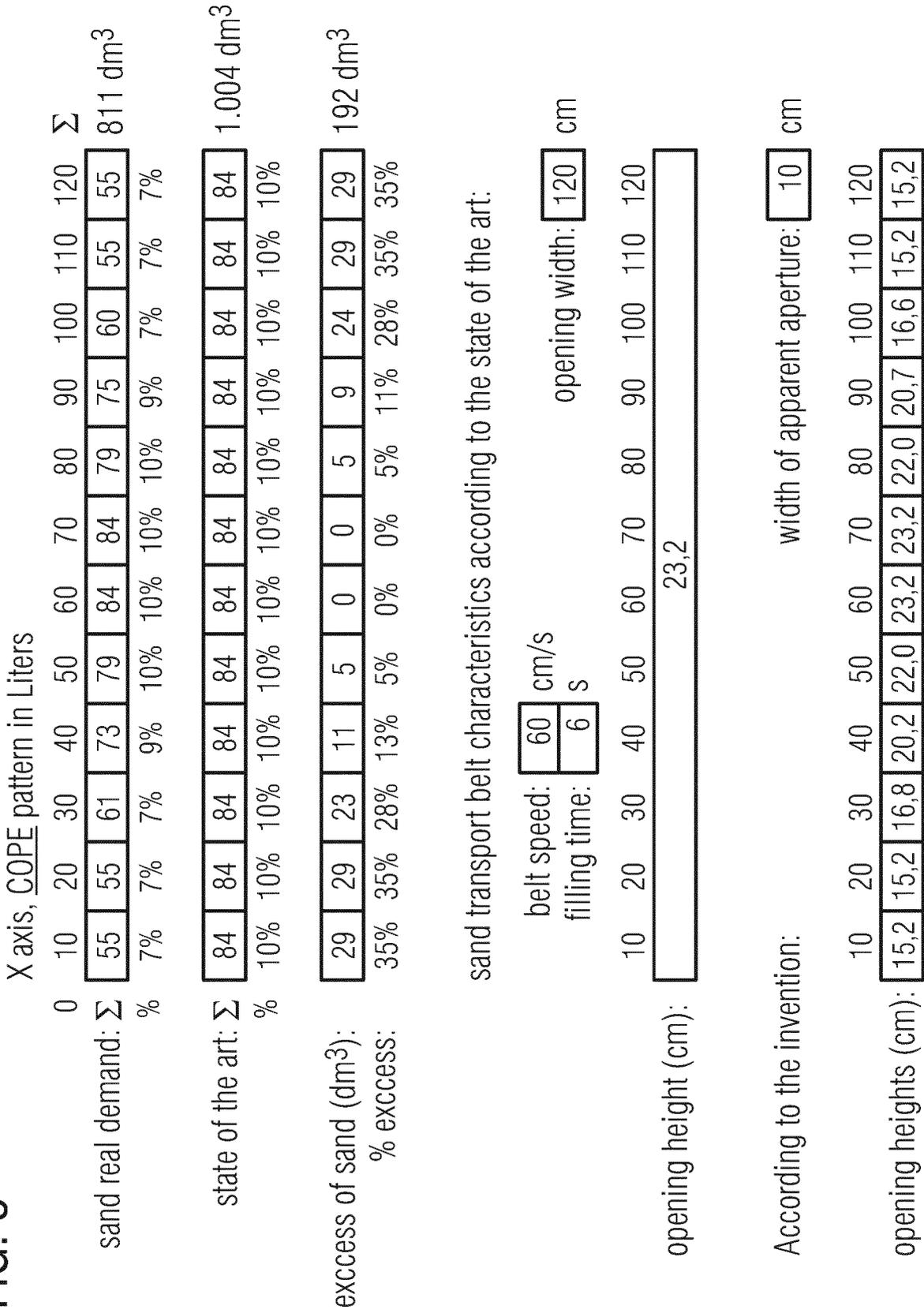


FIG. 6a

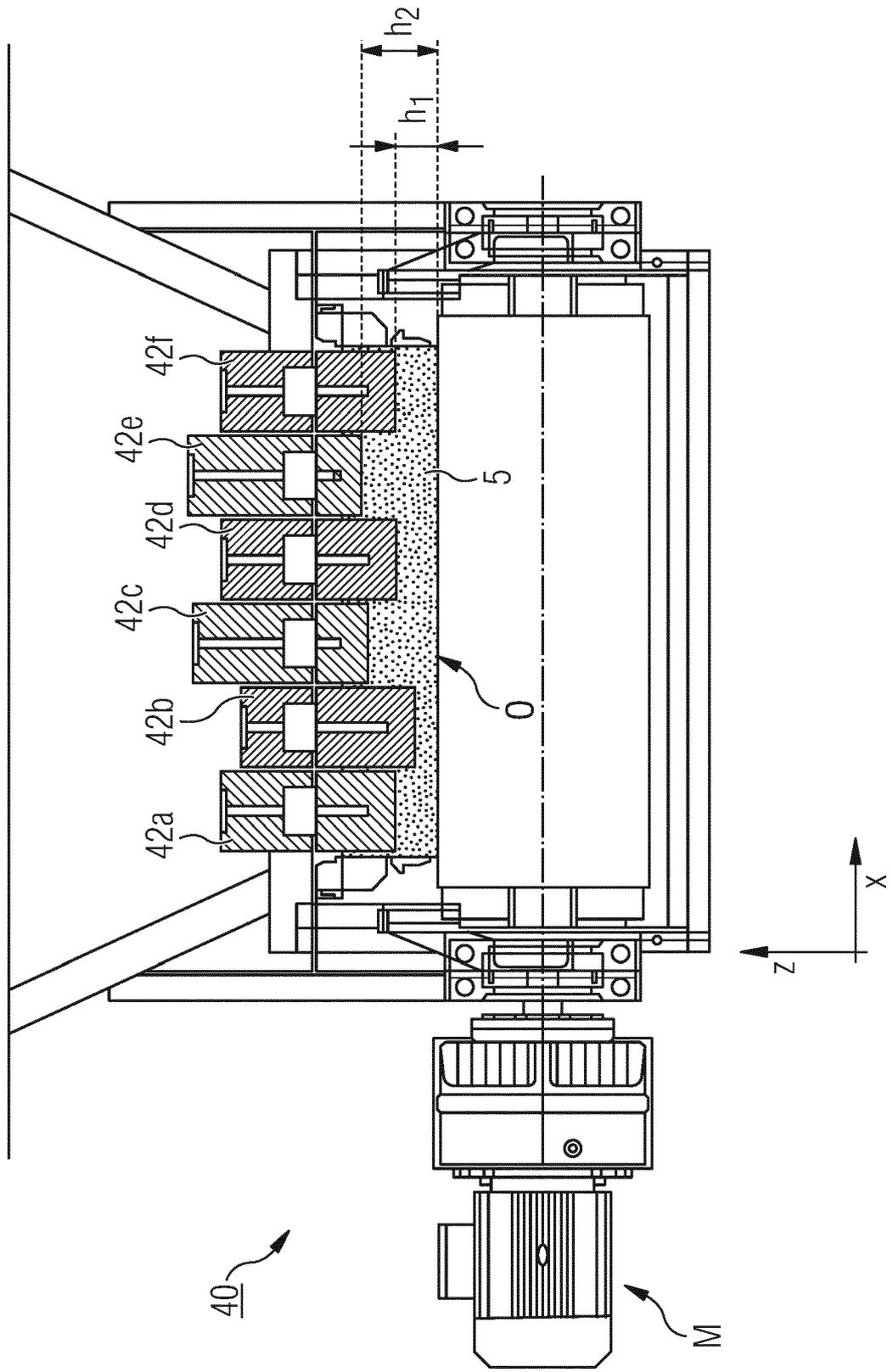


FIG. 6b

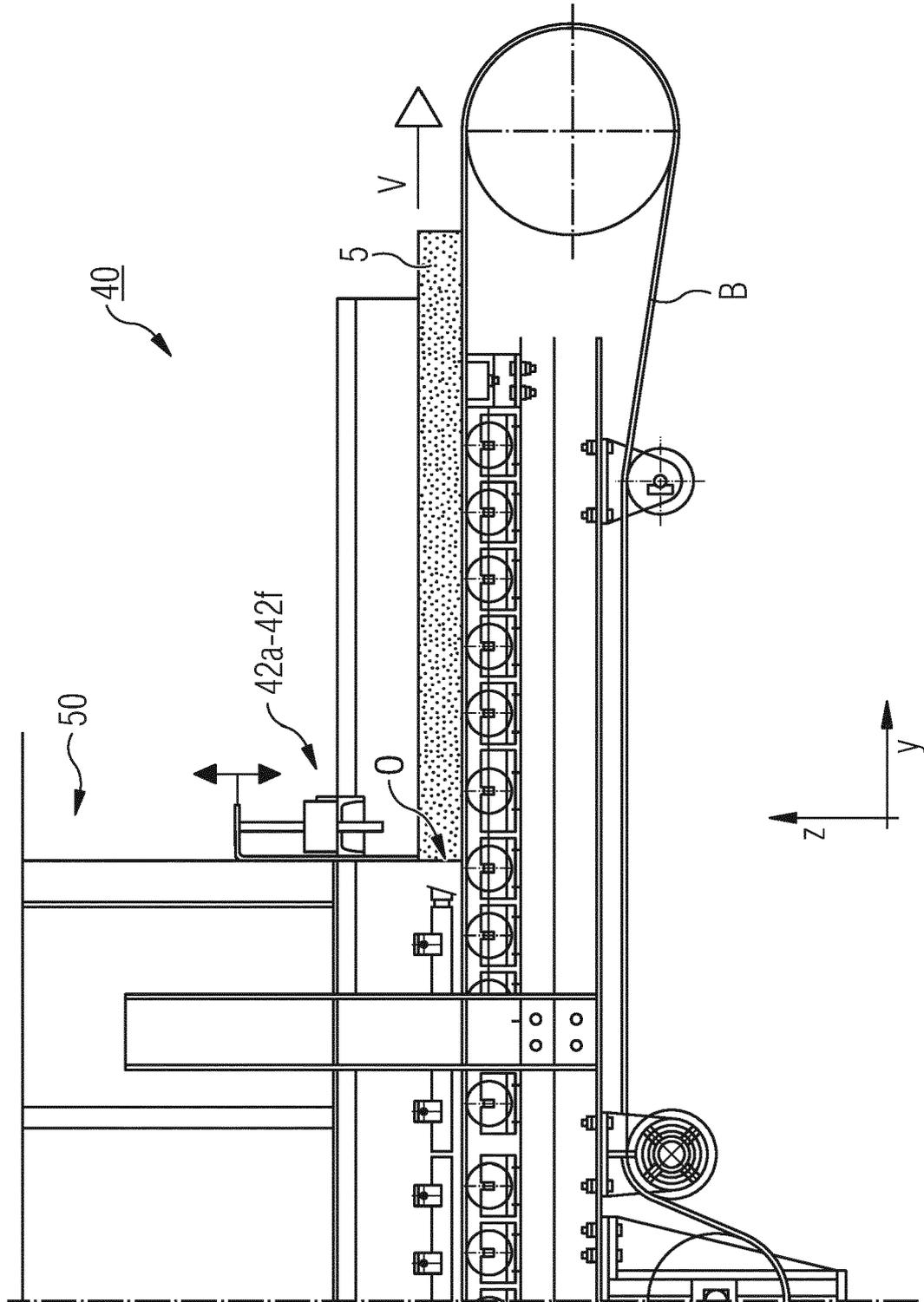
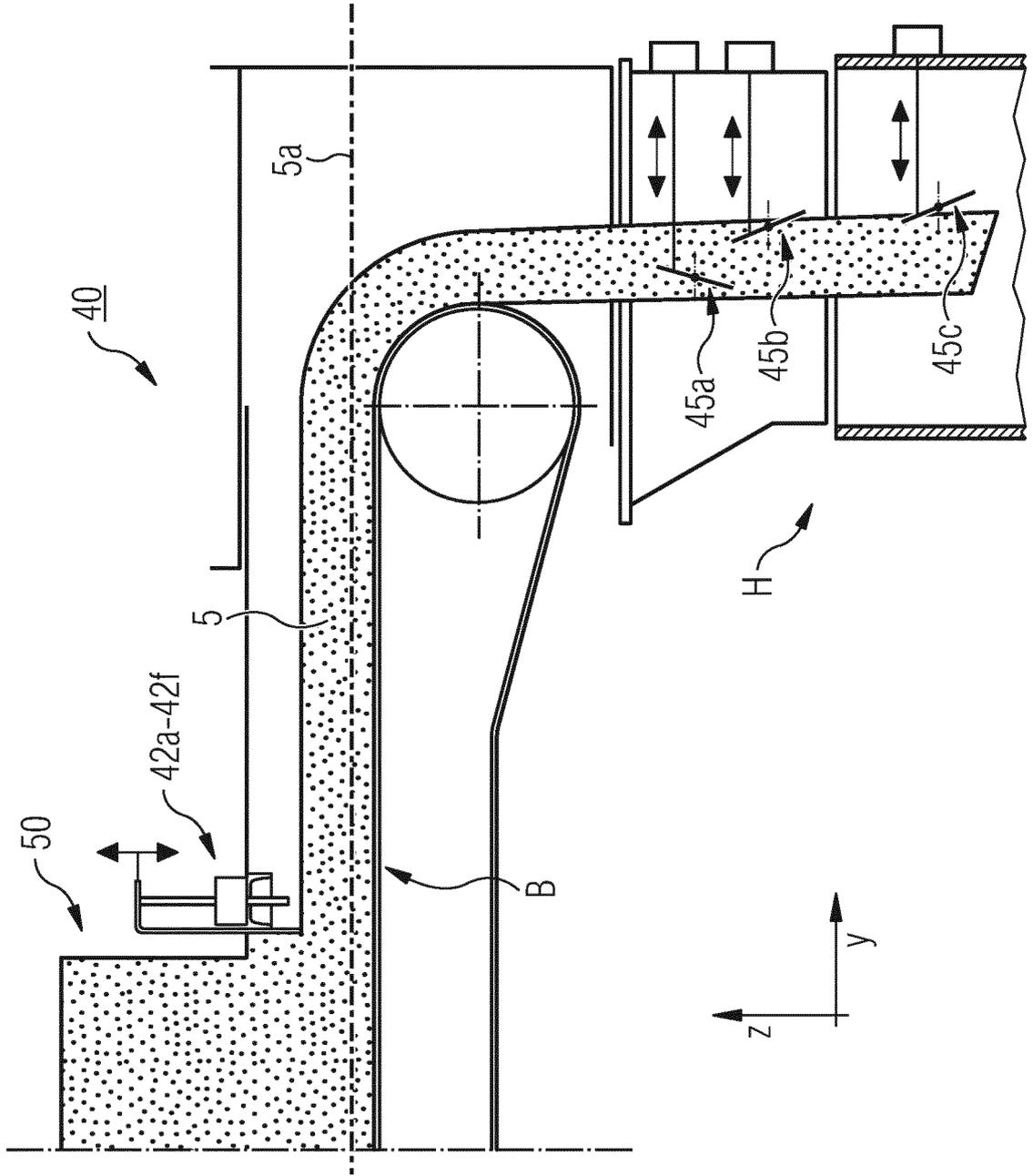


FIG. 7





EUROPEAN SEARCH REPORT

Application Number
EP 19 16 5185

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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	US 2016/303646 A1 (KATO MUNETSUGU [JP]) 20 October 2016 (2016-10-20)	1,7	INV. B22C5/12 B22C5/14 B22C11/00 B22C15/02 B22C19/04
Y	* paragraph [0004] - paragraph [0006] * * paragraph [0051] - paragraph [0053] * * paragraph [0068] - paragraph [0073] * * paragraph [0083] - paragraph [0085] * * figures 1-4 * * paragraph [0096] *	2-6,8-11	
X	GB 2 199 777 A (FOUNDRY DESIGN CORP EUROP) 20 July 1988 (1988-07-20)	1,3,6,7, 10,11	
Y	* page 2, paragraph 2 - page 3, paragraph 3 * * page 6 - page 7 * * figures 1-3 *	2,4-6,8, 9,11,15	
X	US 4 971 135 A (BAILEY FRANCIS V [US] ET AL) 20 November 1990 (1990-11-20)	1	
Y	* column 2, line 58 - column 4, line 25 * * figures 1-9 *		
X	DE 37 17 221 A1 (WAGNER HEINRICH SINTO MASCH [DE]) 8 December 1988 (1988-12-08)	1,2,6,7, 12-14	TECHNICAL FIELDS SEARCHED (IPC) B22C
Y	* column 2, line 65 - column 4, line 15 * * figures 1-2 *	3-5, 8-10, 12-15	
Y	US 2007/137829 A1 (KNUDSEN SOREN E [DK]) 21 June 2007 (2007-06-21)	12-15	
X	DE 11 65 813 B (GRAUE GMBH) 19 March 1964 (1964-03-19)	12-15	
	* paragraph [0011] * * figures 1-2 *		
----- -/--			
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 21 August 2019	Examiner Desvignes, Rémi
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 03.02 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 19 16 5185

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 4 915 159 A (DAMM NORBERT [DE] ET AL) 10 April 1990 (1990-04-10) * figures 1-7 * -----	2	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 21 August 2019	Examiner Desvignes, Rémi
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 (P04/C01)



Application Number

EP 19 16 5185

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

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Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

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No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

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LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

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see sheet B

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All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

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As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

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Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

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None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

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The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number
EP 19 16 5185

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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

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1. claims: 1-15

All searchable inventions

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1.1. claims: 1-11

Method and machine for producing a mould

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1.2. claims: 12-15

Moulding material conveyor system

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Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

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

EP 19 16 5185

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.

21-08-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016303646 A1	20-10-2016	CN 106041001 A	26-10-2016
		DE 102016106423 A1	20-10-2016
		JP 6235524 B2	22-11-2017
		JP 2016203189 A	08-12-2016
		US 2016303646 A1	20-10-2016

GB 2199777 A	20-07-1988	CH 671895 A5	13-10-1989
		DE 3743667 A1	30-06-1988
		GB 2199777 A	20-07-1988

US 4971135 A	20-11-1990	DE 4005483 A1	30-08-1990
		GB 2229947 A	10-10-1990
		GB 2260286 A	14-04-1993
		IT 1239802 B	15-11-1993
		JP H02299745 A	12-12-1990
		US 4971135 A	20-11-1990

DE 3717221 A1	08-12-1988	NONE	

US 2007137829 A1	21-06-2007	CN 1842383 A	04-10-2006
		EP 1753562 A1	21-02-2007
		US 2007137829 A1	21-06-2007
		WO 2005113176 A1	01-12-2005

DE 1165813 B	19-03-1964	NONE	

US 4915159 A	10-04-1990	DE 3740185 A1	08-06-1989
		EP 0295472 A2	21-12-1988
		ES 2028178 T3	01-07-1992
		JP S645642 A	10-01-1989
		JP H0771721 B2	02-08-1995
		US 4915159 A	10-04-1990
