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(54) Benævnelse: **ANORDNING OG FREMGANGSMÅDE TIL FREMSTILLING AF ET ROTORBLADSBÆLTE**

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Description

The invention relates to an apparatus for producing a rotor blade spar cap for a rotor blade of a wind turbine, comprising a mold, which has a depression like a cavity in cross section, in which material for a rotor blade spar cap can be placed or has been placed, and also a sheet-like mold covering sealing off the depression, wherein the depression has side walls, an opening bounded by the side walls and a base area between the side walls. The invention also relates to a method for producing a rotor blade spar cap for a rotor blade of a wind turbine and also to a rotor blade spar cap that is produced or can be produced by the method.

Rotor blade spar caps have so far usually been produced on molds which either are flat, and thus substantially form the base for the spar cap material, or have a depression that is much deeper than the thickness of the rotor blade spar cap to be produced.

In the case of a planar area without borders, sandwich cores are used for stabilization at the leading edge and the trailing edge of the spar cap and remain in the rotor blade spar cap after demolding.

In the case of a cavity-like mold, that is to say a mold with a depression, the borders are higher than the spar cap material. Sandwich cores are not provided, just unidirectional glass fibers or other fibers. In this case, a vacuum film is placed on the spar cap material for resin infusions, the film standing up slightly at the corners or the borders of the side walls to provide coverage, and so at the corners or borders there form cross-sectional triangles or triangular voids, which during the infusion with the resin material fill with resin and sometimes even take in individual fibers.

In both cases, that is to say with the use of planar areas without borders and with the previously customary cavity-like

molds, it is necessary to laboriously trim the rotor blade spar cap after demolding, since either the cross-sectionally triangular undesired resin and fiber projections have to be removed or the outer edges of the sandwich cores, which are likewise encapsulated irregularly in resin, have to be brought back into the desired form.

An example of a cavity-like mold is offered by EP 2 181 834 A2, wherein a method for producing a fiber-reinforced spar cap of a rotor blade of a wind turbine from a fiber material according to the preamble of Claim 1 is described. The fiber material is arranged in a depression of a mold on a flow promoter, the depression is sealed off on the upper side from the outer surroundings by means of a covering, the sealed-off interior space is subjected to a vacuum and resin is provided on the upper side of the fiber material at at least one location on and/or in the fiber material, so that the resin flows to the flow promoter arranged under the fiber material with the applied vacuum in the interior space.

The invention is therefore based on the object of providing an apparatus and a method with which rotor blade spar caps can be produced efficiently and with a high degree of reliability in terms of the process and a high level of producibility, and also to a rotor blade spar cap that can be produced by the method.

This object is achieved by an apparatus for producing a rotor blade spar cap for a rotor blade of a wind turbine, comprising a mold, which has a depression like a cavity in cross section, in which material for a rotor blade spar cap can be placed or has been placed, and also a sheet-like mold covering sealing off the depression, wherein the depression has side walls, an opening bounded by the side walls and a base area between the side walls, developed in such a way that a height of the side walls corresponds to a height of the sides of the rotor blade spar cap, wherein at least one removable guide body is included for at least one border of the depression.

The use according to the invention of a cavity-like depression in which the side walls are just the same height as the side walls of the spar cap material and the spar cap assembly makes it possible for the first time to seal off the depression with the spar cap material by a sheet-like mold covering, in particular a vacuum-tight film, so as to achieve a flush and well-defined planar mold on which there no longer forms any cross-sectionally triangular fiber and resin flash, in particular no such flash that can contain fibers. There is consequently also no longer the need for laborious trimming. If anything, a few isolated lugs formed by overflowing resin, very minor because of the mold according to the invention, still have to be knocked off, but this does not require anything like the effort involved in full trimming.

Particularly for the case where the fusing together of the rotor blade spar cap in the mold takes place by means of a resin infusion process, it is advantageously provided that the depressed base area has a further-depressed feed channel, which is covered in particular by a sheet-like channel covering permeable to feed material, wherein a suction means, in particular a suction pipe or a suction channel, is arranged or can be arranged between the material for the rotor blade spar cap and the mold covering. Resin is consequently introduced over the entire length of the depression in the feed channel into the base area of the mold. The suction means arranged under the covering, that is to say in particular the vacuum-tight film, generates a negative pressure, which sucks the resin material or feed material introduced through the feed channel upward, and so the spar cap material is impregnated with the feed material, that is to say in particular the resin.

It is preferably provided that the feed channel in the base area is arranged on one side of the depression and the suction means is arranged or can be arranged on a side of the depression that lies diagonally opposite the feed channel in

the cross section of the depression. The diagonal arrangement in the cross section of the depression is particularly advantageous since the lateral offsetting of the suction means in relation to the feed channel has the effect that the liquid feed material, that is to say in particular the resin, is also distributed uniformly in the lateral direction. This is more favorable than when there is a central arrangement of both the feed channel and the suction means, in which the lateral regions of the spar cap assembly are impregnated less with resin than the central region arranged directly between the feed channel and the suction means.

Advantageously included is a flow promoter, which is arranged on the base area of the depression, on the sheet-like channel covering in the direction of the opposite side wall, wherein further material layers, in particular peel plies, perforated films and/or absorbent nonwovens, are arranged or can be arranged under and/or over the material of the rotor blade spar cap. The flow promoter helps here to distribute feed material uniformly on the underside. Further material layers provide a uniform distribution both of the feed material and of the applied vacuum and provide that the resin material is not sucked away by the suction means. The sheet-like channel covering for the feed channel preferably consists of a perforated plate or a perforated film.

According to the invention, at least one removable guide body is included for at least one border of the depression. In this case, the guide body can be removed after the fusing together of the rotor blade spar cap, thereby facilitating the demolding of the rotor blade spar cap. Such a guide body may comprise part of a side wall or an entire side wall.

Preferably included is a semipermeable membrane, which is arranged under the mold covering, wherein the membrane is sealed off with respect to the mold covering and the membrane and the mold covering enclose the suction means between them. Consequently, the vacuum that is introduced by the suction

means can act through the semipermeable membrane and suck in resin or feed material, but the feed material cannot penetrate through the semipermeable membrane into the suction means.

The object on which the invention is based is also achieved by a method for producing a rotor blade spar cap for a rotor blade of a wind turbine that is distinguished by the fact that fiber material and/or fiber-reinforced material for a rotor blade spar cap is placed in a cavity-like depression of a mold of a previously described apparatus according to the invention such that the material finishes flush with side walls of the depression with respect to its height, the depression is sealed off by the sheet-like mold covering, the material is fused together to form the rotor blade spar cap and then the rotor blade spar cap is removed from the mold, wherein at the leading edge and/or the trailing edge of the rotor blade spar cap, bodies of a core material, in particular of balsa or foam, are first inserted into the depression, and then the fiber material and/or the fiber-reinforced material is placed between said bodies.

In the case of this method, the trimming step can be omitted, since the rotor blade spar cap already has its final form and there is no flash that could in particular contain fiber material.

The fiber material and/or fiber-reinforced material preferably comprises dry fiber fabrics, prepreg fiber materials and/or pultruded rods of fiber-reinforced material. All of these materials, including the already preimpregnated prepregs and pultruded rods, can also be fused together by means of resin infusion. Thermal fusion, in which the resin material of the resin matrix softens and joins together with the resin material of the neighboring prepregs or rods, is also possible. Pultruded rods have the advantage that in them the fibers are already optimally aligned in parallel and waves cannot form in the spar cap material as a result of exothermic reactions during the setting of the resin. However, the method

according to the invention can be carried out with all three types of material mentioned in such a way as to achieve the advantages according to the invention.

It is likewise provided within the scope of the method according to the invention that, at the leading edge and/or the trailing edge of the rotor blade spar cap, bodies of a core material, in particular of balsa or foam, are first inserted into the depression, and then the fiber material and/or the fiber-reinforced material is placed between said bodies. In this case, a composite rotor blade spar cap, which likewise no longer has to be trimmed, can be produced. The bodies of the core material also lie against the side walls of the depression, and so the form of the rotor blade spar cap is once again determined by the depression and there is no need for subsequent trimming. The flush finish with respect to the height of the side walls and the thickness of the spar cap material in the region of the side walls of the depression mean that the other problems with respect to upwardly projecting flash also do not occur.

The fusing together of the fiber material or of the fiber-reinforced material in the depression preferably takes place by means of resin infusion, which flows in through a feed channel in the base area of the depression, in particular on one side of the base area.

Likewise advantageously, material layers that remain as an outer layer of the rotor blade spar cap after demolding of the rotor blade spar cap following its production are finally placed in the depression, flush with the side walls.

Finally, the object on which the invention is based is achieved by a rotor blade spar cap for a rotor blade of a wind turbine that is produced or can be produced in a previously described method according to the invention.

The features, properties and advantages mentioned in relation

to the individual subjects of the invention, that is to say the apparatus, the method and the rotor blade spar cap, also apply to the other subjects of the invention respectively, since they relate to one another.

Further features of the invention are evident from the description of embodiments according to the invention together with the claims and the accompanying drawings. Embodiments according to the invention may implement single features or a combination of a number of features.

The invention is described below on the basis of exemplary embodiments with reference to the drawings, without restricting the general concept of the invention, reference being expressly made to the drawings with respect to all details according to the invention that are not explained more specifically in the text. In the drawings:

figure 1 shows a schematic cross-sectional representation through a first apparatus,

figure 2 shows a schematic cross-sectional representation of details of the apparatus according to the invention,

figure 3 shows details of a third apparatus in schematic cross section,

figure 4 shows details of a fourth apparatus in schematic cross section,

figures 5a), 5b) and 5c) show schematic cross-sectional representations through details of the apparatuses, and

figure 6 shows a schematic cross-sectional representation of a mold.

In the drawings, elements and/or parts that are the same or

similar are in each case provided with the same reference numerals, and so they are not described from the beginning each time.

In Figure 1, a first apparatus 1 is schematically shown in cross section. A mold 11 has a cross-sectionally rectangular depression 16, in which the fiber material 7 of a rotor blade spar cap 6 has been placed. The surface of the fiber material 7 finishes flush with side walls 23 of the depression 16. The base area 22 of the depression has on one side, which is shown on the left in figure 1, a feed channel 30, through which feed material, in particular a resin, can be introduced into the depression 16. The feed channel 30 extends lengthwise through the depression 16. It is covered likewise over its full length by a channel covering 31, which may be a perforated plate or a perforated film. Placed on the channel covering 31 is a flow promoter 34, which helps to distribute liquid feed material in the direction of the other side, i.e. the side that lies opposite the feed channel 30.

Arranged diagonally opposite on the upper side of the fiber material 7 of the rotor blade spar cap 6 is a suction means, to be specific a suction pipe 32, at which a vacuum is applied. By means of the suction pipe 32, in the depression 16 as a whole there is an applied vacuum, the gradient of which is directed toward the suction pipe 32. Consequently, the liquid feed material is sucked from the feed channel 30 to the suction pipe 32. To ensure the negative pressure in the depression 16, the latter is covered by a mold covering 21, in particular a vacuum-tight film. Sealing is laterally ensured in this case by so-called “tacky tape” 35, a vacuum-tight adhesive film or adhesive roll.

In order to prevent resin or feed material being sucked into the suction pipe 32 and clogging it, the suction pipe 32 is protected by a semipermeable membrane 33, which is permeable to air, but not to the feed material. This semipermeable membrane 33 is sealed with respect to the mold covering 21,

once again by “tacky tape” 35.

In this way, a pressure gradient that extends through the width and thickness of the depression 16 is produced when liquid feed material enters through the feed channel 30 and when a vacuum or negative pressure is created in the suction pipe 32. Assisted by the flow promoter 34, feed material is sucked up both against the underside of the fiber material 7 and through the fiber material 7 itself over the full width, and so the fiber material 7 is impregnated completely and uniformly.

In comparison with figure 1, in figure 2 there is shown an inventive embodiment of an apparatus 2, in which the depression 17 has side walls 23 that are partly formed by removable guide bodies 24. Together with the mold 12, these define the depression 17. After producing the rotor blade spar cap in this mold 12, the guide bodies 24 can be removed, thereby facilitating the demolding of the rotor blade spar cap produced.

In figure 3, a further exemplary embodiment is represented. The apparatus 3 has a mold 13 with a depression 18, the side walls 23 of which are slightly beveled. Arranged on the left-hand side of the base area 22 of the depression 18 is a suction channel 30 with a channel covering 31, which is formed as a perforated plate. Placed on the entire base area is a first fiber layer 36, on which a core material or sandwich material 8 of balsa wood or a foam has been placed respectively at the leading and trailing edges of the spar cap. The outer side walls of said material are flush with the side walls 23 of the depression 18. The fiber material 7, which may consist of dry fiber fabrics, prepregs or of pultruded rods with fiber-reinforced resin material, has been introduced between the bodies of sandwich materials 8. Applied to the bodies of sandwich material 8 and the body of fiber material 7 is a final fiber layer 36, which finishes flush with the side walls 23 of the depression 18. The other

constituent parts of the apparatus 3 are not shown in figure 3. The ensemble of fiber layers 36, sandwich material 8 and fiber material 7 forms the rotor blade spar cap 6.

Figure 4 shows in schematic cross section a fourth exemplary embodiment of an apparatus 4, in which the depression 19 is substantially similar to the depression 18 from figure 3. The other elements that are represented in figure 4 also correspond to those from figure 3. As a difference from the exemplary embodiment from figure 3, in figure 4 there is shown a rotor blade spar cap 6 that is flattened or tapered toward the borders, that is to say toward the side walls 23 of the depression 19. The total thickness of the rotor blade spar cap 6 at its center is consequently greater than the depth of the depression 19. Nevertheless, the upper fiber layer 36 finishes flush with the side walls 23.

In figures 5a) to 5c, three different possible ways of forming side walls 23 are shown. In figure 5a), a lower part of the side wall 23 is formed by part of the mold 11, on which there has been placed a removable guide body 24, which continues the side wall 23 up to its full height. In figure 5b), the mold 11 merely forms the base area 22 and the side wall 23 is completely formed as a side area of a removable guide body 23. In figure 5c), the entire side wall 23 is part of the mold 11 and no removable guide body is provided.

In figure 6, a more complete representation of the apparatus 4 according to figure 4 is shown. In this case, a flow promoter 34 has been laid on the base area 22 of the depression 19, over the entire width, and then the first or lower fiber layer 36 has been placed on top. The flow promoter 34 provides a uniform distribution of the liquid feed material from the feed channel 30 into the depression 19. On the lower fiber layer 36 there have been laid the two bodies of sandwich material 8 and also the central body of fiber material 7. This layer is terminated by an upper fiber layer 36, which finishes flush both with the side of the bodies of sandwich material 8 and

with the side walls 23 of the depression 19. Further layers of material, which after the demolding of the rotor blade spar cap 6 do not remain with it, however, have been placed on the fiber layer 36. These are firstly a perforated film 40, instead of which a peel ply for example may also have been arranged. On the side represented on the right in figure 6 there is shown an absorbent nonwoven 42, which may also contain a semipermeable membrane and serves for propagating the vacuum that is introduced into the depression 19 through a suction channel 32'. Forming the termination is the sheet-like mold covering 21, which covers the entire depression 19 and part of the rest of the mold.

The way in which the method according to the invention is carried out can be shown by the example of the apparatus 4 in figure 6. The spar cap itself consists, according to choice, of dry fabrics of glass fibers, carbon fibers, basalt fibers or natural fibers, which after placing in the mold according to the invention are impregnated with a resin matrix, for example by vacuum infusion, or of prefabricated, cured elements, which consist of a glass-, carbon-, basalt- or natural-fiber-reinforced resin matrix and, after being deposited in the mold according to the invention, are impregnated with a resin matrix, for example by vacuum infusion. Such prefabricated, cured elements may be pultruded rods.

In the case of the variant according to figure 6, a resin matrix is introduced by vacuum infusion. For this purpose, the apparatus 4 is supplied with feed material, that is to say in particular resin, through the resin feed channel 30 under one of the sandwich portions 8 of the spar cap assembly, which is bounded by a suitable resin-permeable element as a channel covering 31 in such a way that a flush termination with the remaining surface of the mold is obtained. A flow promoter 34, for example a so-called "continuous mat" or "green mesh" is laid over the feed channel 30 on the surface of the mold, extends in the direction of the opposite border of the mold

and may possibly also reach right up to it. Once all the materials have been placed in the mold and on the flow promoter 34, the material placed in is covered by a vacuum construction, which may consist of a peel ply, a perforated film, an absorbent medium (for example a nonwoven or a green mesh) and also a semipermeable membrane and at least one vacuum film. The suction channel 32′ is placed between the semipermeable membrane and the at least one vacuum film. In this case, the suction channel 32′ is positioned in the vicinity of the border of the mold lying opposite the feed channel 30 and the semipermeable membrane extends from the border of the mold lying close to the vacuum channel 32′ significantly in the direction of the opposite border of the mold.

List of reference numerals

1 – 4	apparatus
6	rotor blade spar cap
7	fiber material
8	sandwich material
11 - 14	mold
16 – 19	depression
21	mold covering
22	base area
23	side wall
24	removable guide body
30	feed channel
31	channel covering
32	suction pipe
32′	suction channel
33	semipermeable membrane
34	flow promoter
35	tacky tape
36	fiber layer
40	perforated film
42	absorbent nonwoven

Patentkrav

1. Anordning (1 - 4) til fremstilling af et rotorbladsbælte (6) til et rotorblad til et vindenergianlæg, omfattende en form (11 - 14), der har en i tværsnit kavitetsformet fordybning (16 - 19), ind i hvilken materialet (7, 8) til et rotorbladsbælte (6) kan indlægges eller er indlagt, samt en fladeformet formafdækning (21), der tætner fordybningen (16 - 19), hvor fordybningen (16 - 19) har sidevægge (23), en af sidevæggene (23) begrænset åbning og en bundflade (22) mellem sidevæggene (23), kendetegnet ved, at en højde af sidevæggene (23) svarer til en højde af rotorbladsbæltets (6) sider, hvor der for i det mindste en rand af fordybningen (16 - 19) er omfattet i det mindste et aftageligt føringslegeme (24).

2. Anordning (1 - 4) ifølge krav 1, kendetegnet ved, at den fordybede bundflade (22) har en yderligere fordybet tilløbskanal (30), der især er afdækket med en for indløbsmateriale gennemtrængelig fladeformet kanalafdækning (31), hvor et udsugningsmiddel (32, 32'), især et udsugningsrør (32) eller en udsugningskanal (32'), er anbragt eller kan anbringes mellem materialet (7, 8) til rotorbladsbæltet (6) og formafdækningen (21).

3. Anordning (1 - 4) ifølge krav 2, kendetegnet ved, at tilløbskanalen (30) er anbragt i bundfladen (22) på den ene side af fordybningen (16 - 19), og udsugningsmidlet (32, 32') er anbragt eller kan anbringes på en i forhold til tilløbskanalen (30) i fordybningens (16 - 19) tværsnit diagonalt modstående side af fordybningen (16 - 19).

4. Anordning (1 - 4) ifølge krav 2 eller 3, kendetegnet ved, at der er omfattet en flydehjælp (34), der på den fladeformede kanalafdækning (31) i retning til den modstående sidevæg (23) er anbragt på fordybningens (16 - 19) bundflade (22), hvor der under og/eller over rotorbladsbæltets (6) materiale (7, 8) er anbragt eller kan anbringes yderligere materialelag, især afrivningsvæv, hulfolier (40) og/eller udsugningsfilt (42).

5. Anordning (1 - 4) ifølge et af kravene 1 til 4, kendetegnet ved, at der er omfattet en semipermeabel membran (33), der er anbragt under formafdækningen (21), hvor membranen (33) er tætnet mod formafdækningen (21), og membranen (33) og formafdækningen (21) mellem sig indeslutter udsugningsmidlet (32, 32').

6. Fremgangsmåde til fremstilling af et rotorbladsbælte (6) til et rotorblad til et vindenergianlæg, kendetegnet ved, at fibermateriale (7) og/eller fiberforstærket materiale til et rotorbladsbælte indlægges i en kavitetsformet fordybning (16 - 19) i en form (11 - 14) i en anordning (1 - 4) ifølge et af kravene 1 til 6, således at materialet (7, 8) med hensyn til sin højde slutter i niveau med fordybningens (16 - 19) sidevægge (23), fordybningen (16 - 19) med den fladeformede formafdækning (21) tætnes, materialet (7, 8) til rotorbladsbæltet (6) sammenføjes, og rotorbladsbæltet (6) derefter udtages af formen (11 - 14), hvor der først på rotorbladsbæltets forkant og/eller bagkant indsættes legemer af et kernemateriale (8), især af balsa eller skumstof, i fordybningen (16 - 19), mellem hvilke fibermaterialet (7) og/eller det fiberforstærkede materiale derefter indlægges.

7. Fremgangsmåde ifølge krav 6, kendetegnet ved, at fibermaterialet (7) og/eller det fiberforstærkede materiale omfatter tørre fiberduge, prepreg-fibermaterialer og/eller pultruderede stave af fiberforstærket materiale.

8. Fremgangsmåde ifølge krav 6 eller 7, kendetegnet ved, at sammenføjningen af fibermaterialet (7) eller det fiberforstærkede materiale i fordybningen (16 - 19) sker ved hjælp af harpiksinfusion, som flyder ind gennem en tilløbskanal (30) i fordybningens (16 - 19) bundflade (22), især på den ene side af bundfladen (22).

9. Fremgangsmåde ifølge et af kravene 6 til 8, kendetegnet ved, at materialelag, som efter en afformning af

rotorbladsbæltet (6) efter dets fremstilling bliver tilbage som ydre lag af rotorbladsbæltet (6), plant med sidevæggene (23) afslutningsvist lægges ind i fordybningen (16 - 19).

Fig. 1

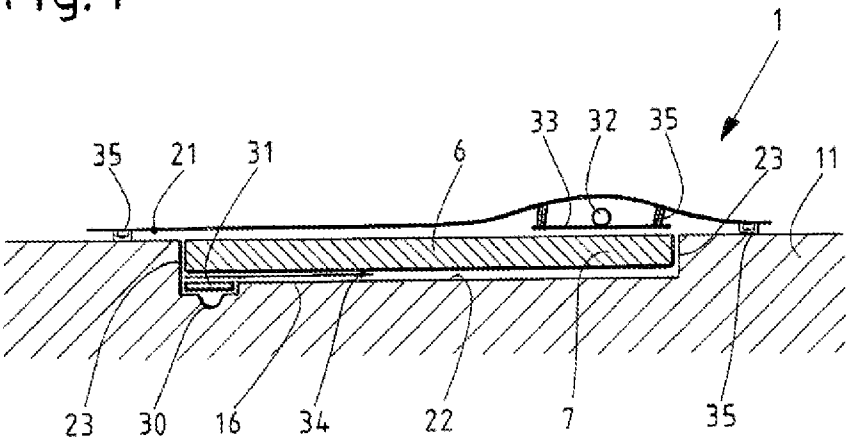

Fig. 2

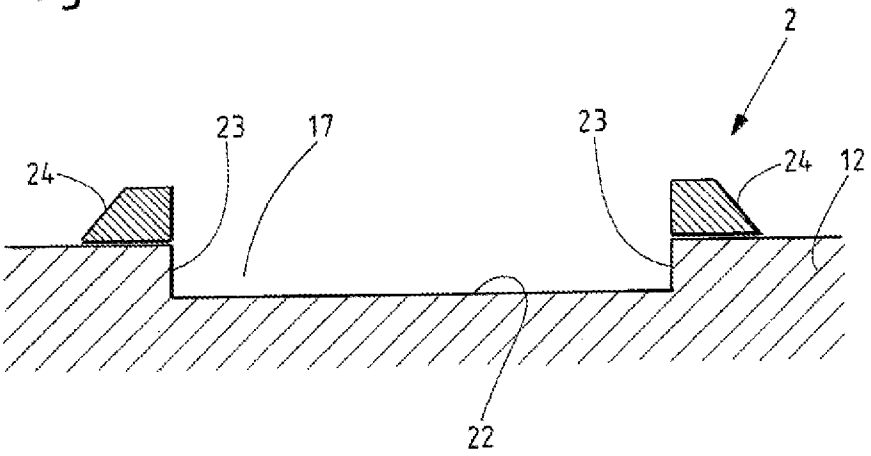

Fig. 3

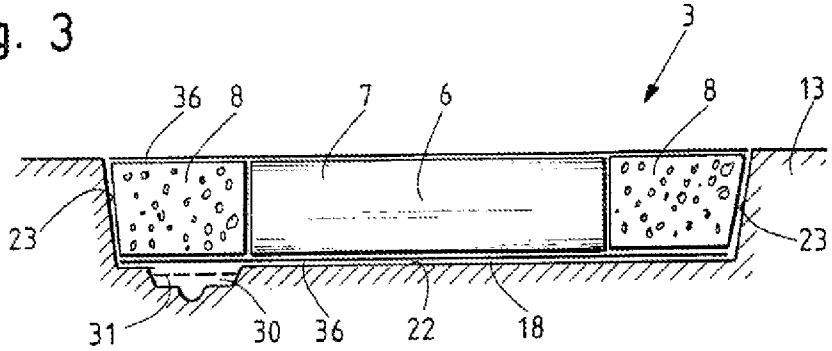

Fig. 4

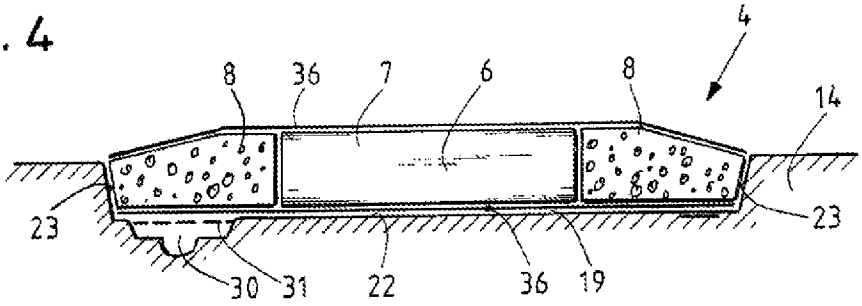

Fig. 5

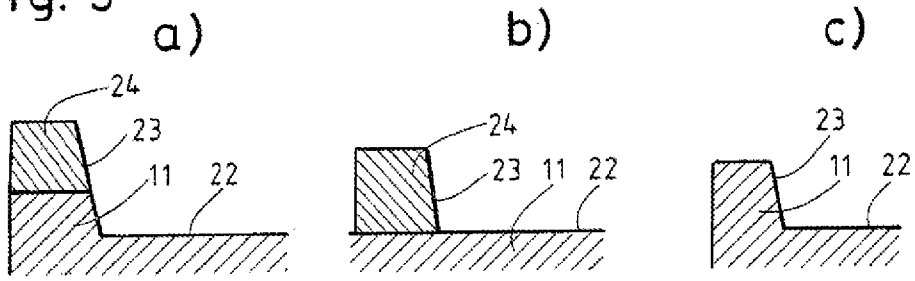

Fig. 6