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(54) Title: A DEFLECTING MODULE FOR AN ANTI-SAND BARRIER, A BARRIER THUS OBTAINED AND A PROTECTION METHOD FROM WINDBLOWN SAND

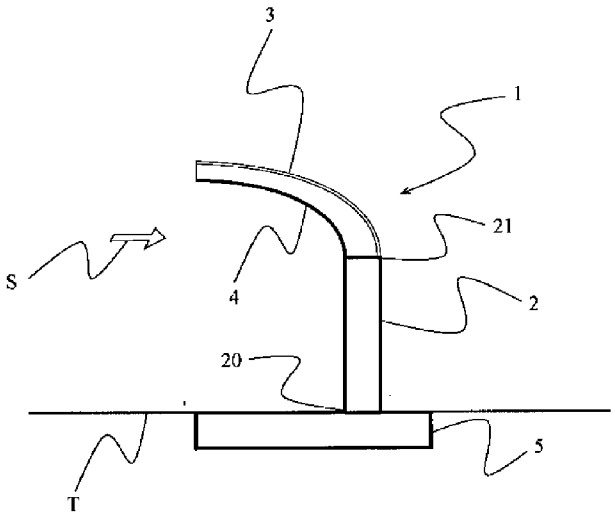


Fig. 2

(57) Abstract: The invention relates to a deflecting module (1) suitable for creating barriers against an incoming multiphase flow, specifically windblown sand (S), comprising a first support portion (2) with inclination ranging between 70° and 110° relative to the ground (T) and able to be fixedly connected to a corresponding foundation (5), a second support portion (3) and a deflecting panel (4) supported by the second support portion (3), wherein the deflecting panel (4) and the second support portion (3) have a concave profile relative to the direction of the incoming flow; the invention also relates to a barrier (B) obtained by combining a plurality of deflecting modules (1) for protecting a man-made work (M) by trapping the windblown sand (S); the invention also relates to a protection method of a man-made work (M) from windblown sand using at least one barrier (B). The preferred and advantageous application of the deflecting module, the barrier and the method according to the present invention resides in protecting transport and industrial line-like infrastructures, civil and industrial settlements, farms and cultivated areas, archaeological sites and the like and, more precisely, the deflecting module, the barrier and the method according to the present invention are preferably used to shelter communication lines and/ or buildings by separating them from the surrounding environment; the present invention is particularly suitable for use in desert and semi-desert regions, especially in very windy areas and also with multidirectional sand-laden winds.

"A deflecting module for an anti-sand barrier, a barrier thus obtained and a protection method from windblown sand"

DESCRIPTION

TECHNICAL FIELD

The present invention relates to the civil/environmental field and, specifically, to systems and methods for trapping windblown sand in order to protect areas of interest and/or man-made works, in particular avoiding the deposit of sand thereon.

More precisely, the present invention relates to a deflecting module suitable for creating barriers against windblown sand, a barrier obtained by combining to each other a plurality of deflecting modules and a method for protecting, by separating them from the surrounding environment, man-made works such as, for example, transport line-like infrastructures (railways, highways, roads, airport runways, etc.), industrial line-like infrastructures (pipelines, telecommunication lines, etc.), civil settlements (cities, villages, rural buildings, etc.), industrial settlements (sites, factories, plants, etc.), farms and cultivated areas, archaeological sites and the like.

The present invention is particularly suitable for use in desert and semi-desert regions, especially in very windy areas.

PRIOR ART

Systems intended to protect man-made works from sand or snow transported by the wind, which are both cases of multiphase flows resulting from the suspension of a solid particulate (snow or sand) in a fluid (wind) are known; such systems, commonly referred to as "mitigation measures", act as barriers to stop sand or snow so that they do not reach an area to be protected, where a man-made work of interest is possibly present.

Among the mitigation measures developed so far there exist the so-called "porous barriers", namely barriers whose surface is not continuous but has through holes that, though reducing the speed of the wind and facilitating the deposit of sand or snow, allow the passage of both there through; examples of such porous barriers are represented both in patent documents (CN201305845U relevant to meshes;

CN202706008U and CN201817781U relevant to holed panes; US4339114 relevant to staves; US3473786 and CN102505643 relevant to arrays of deflectors; CN200996134U relevant to suspended elements with different shapes) and in scientific publications (see citations [1] to [5]).

It is clear that the drawback of this type of barriers resides in that the deposit of sand or snow occurs on both faces of the barrier, upwind and downwind (i.e., also in the area to be protected), therefore a dune of sand or snow progressively grows around the porous barrier and, finally, covers it; furthermore, the maintenance of this type of barriers, that is the periodic removal of the accumulated sand or snow, is difficult because of the inherent weakness of the barrier and, above all, because the material deposited between the barrier and man-made work to be protected has to be brought outside the barrier, by passing over it or through openings provided therein.

Among the mitigation measures developed so far there also exist the so-called "solid barriers", namely barriers allowing the passage of both wind and sand or snow only over their upper ends; examples of such solid barriers, which may be orthogonal to the ground or either inclined or curved with respect thereto, are described both in patent documents (CN200996130) and in scientific publications (see citation [6], where the solid barrier is used as reference in the assessment of porous barriers, which are considered to be more performing).

Though facilitating the upwind deposit of sand or snow and, therefore, reducing the technical problems and the economic costs related to maintenance, the main disadvantage of this type of barriers consists in a lower efficiency with respect to the porous barrier (see, in particular, citations [5] and [6]), efficiency that, moreover, rapidly decreases with the growth of the profile of the accumulated material.

In order to improve the performance of solid barriers, they can be equipped with deflectors aiming at locally directing the multiphase flow (wind with sand or snow) towards a set direction relative to the barrier; more precisely, the deflectors may have a "downwind nose" configuration, i.e. with the upper free end oriented in the downwind direction towards the area and/or the man-made works to be protected, and an "upwind nose" configuration, i.e. with the upper free end oriented in the

upwind direction towards the incoming flow.

Examples of "downwind nose" solid barriers are described in JP2007120091, JP2001288715, CN102002916 and US4958806, in which the flow is guided to get over the man-made works, that is to ensure that the solid particles, upwards directed and accelerated, pass over such man-made works and deposit downwind them, in order to protect the man-made works from the flow direct impact and to exert a cleaning action, i.e. removing any particles deposited on the man-made works by wind; in particular, the above mentioned document JP2001288715 reports some experiments carried out in a wind tunnel showing the performance of "downwind nose" barriers noticeably better than that of an "upwind nose" barrier having the end inclined by 60° to the horizontal.

However, the above "downwind nose" solutions are not able to increase the wind speed so to allow the sand or snow to pass over the whole area to be protected, including the man-made work of interest, due to the granules sedimentation caused by gravity and to the extension of the area itself.

Examples of "upwind nose" solid barriers are described in the patents GB124377 and IT1224625.

The patent GB124377, filed in 1918, intends to solve the problem of stopping the sand transported by the wind by diverting it in pre-set areas and, to this purpose, it describes a module composed of a wooden support and two metallic thin plates nailed together, the first plate of which is named "hood" and has a section of an arc of circumference of about 230° and the second plate of which is named extension curve and has an "S" section; the two thin plates form a mixed geometry assembly, alternating concave and convex parts, with curvatures of opposite sign and inflection points.

The solution described in the British patent, which is very complex, has the disadvantages that it allows the sand to massively deposit on the joint portion of the two plates, thus inducing high loads on the bearing structure, and that it is practically impossible to be industrially produced and to be laid in work on great lengths.

The patent IT1224625, filed in 1988, intends to solve the problem of opposing sand-laden winds causing desertification and, to this purpose, it describes a module formed by a band-shaped element made of reinforced concrete developing towards the wind mainly at the ground attachment and, specifically, providing a parabolic junction at the module base in order to accompany the wind from the bottom upwards, thus creating a vertical flow ascending along the upwind face of the module and inducing a local flow.

The solution described in the Italian patent has the disadvantages that it allows the wind, and especially the sand transported by it, to pass over the barrier, consequently not achieving an effective protection, and that it make it difficult to remove the sand deposited at the base of the barrier due the geometric conformation of the latter.

As it can be seen from what above described, in addition to the fact that the most recent technical solutions deem it preferable to implement a "downwind nose" configuration to solve the problem of protecting from sand- or snow-laden winds areas and man-made works built therein, the "upwind nose" configurations according to the above discussed British and Italian patents do not meet the requirement of locally deflecting the wind flow at the upper free end of the module, creating a flow descending along the upwind face of the barrier and inducing a vortex, which occupies the whole volume underlying the module and which allows sand to deposit upwind; furthermore, the above patents do not meet additional requirements such as that to realize a simple and cheap modular structure and that to allow the proper means to operate by traveling parallel to the barrier and close to the vertical part of the upwind surface, so as to effectively remove the deposited sand.

Finally, in the scientific literature of the field, as far as known to the Inventors, there are no studies dedicated to assess the effectiveness of solid barriers, neither in the "downwind nose" case nor in the "upwind nose" case, solutions that in any case, as mentioned earlier, are considered to be less efficient than the porous barriers.

As mentioned, the need to protect an area and the man-made works built therein, by

modifying the wind flow to trap the sand transported by it and to direct it towards a pre-set position of accumulation at ground, precisely upwind, thus preventing the sand from getting over the barrier, is unsatisfied so far.

Furthermore, the need to achieve a high trapping efficiency of the windblown sand, even if sand already accumulated upwind at the base of the barrier is present, is unsatisfied too.

Furthermore, the need to have a module suitable for creating an anti-sand barrier simple and cheap to be designed, industrialized and implemented on a large scale basis is unsatisfied too.

Furthermore, the need to facilitate the passage of means used to remove sand deposited on the ground is unsatisfied too.

In summary, up to the present time, to the Inventors' knowledge, solutions enabling to effectively accumulate sand upwind, prevent an anti-sand barrier to be passed over and oppose sand deposition on line-like infrastructures and buildings are not known; therefore, the deflecting module for an anti-sand barrier, the barrier thus obtained and the method to protect an man-made work from windblown sand according to the present invention intend to remedy such lack.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the drawbacks of the known prior art related to the protection of areas and man-made works of interest from multiphase flows and, more precisely, from sand-laden winds.

It is a specific object of the present invention to overcome the drawbacks of the known prior art related to the protection of areas and man-made works of interest from sand-laden winds, avoiding that such sand-laden winds pass over the barriers provided for the purpose.

The present invention intends to solve the problem of trapping the windblown sand, by modifying the sand-laden wind flow to direct it towards a pre-set position of accumulation at ground, and precisely to facilitate the deposit upwind of the sand transported by it.

In particular, the present invention intends to provide a deflecting module, a barrier

obtained by combining a plurality of such deflecting modules and a protection method that uses such a barrier able to solve the problems mentioned above and to achieve the purposes stated above.

More precisely, the present invention intends to provide a deflecting module, a barrier obtained by combining a plurality of such deflecting modules and a protection method that uses such a barrier that, thanks to the provision of a concave profile, relative to the direction of the incoming windblown sand flow, of the deflecting part of the module, allow to locally deflect the wind flow at the upper free end of the module, to create a flow descending along the upwind face of the deflecting module and to induce a vortex that occupies the whole volume underlying the deflecting module and that makes the sand to deposit below and upwind the deflecting module itself, in a pre-set position at its base.

The aforesaid and other objects and advantages of the invention, as will appear from the following description, are achieved with a deflecting module like the one according to claim I.

Moreover, the aforesaid and other objects and advantages of the invention are achieved with an anti-sand barrier according to claim 9.

Moreover, the aforesaid and other objects and advantages of the invention are achieved with a protection method as the one according to claim 14.

Preferred embodiments and variants of the deflecting module, of the anti-sand barrier and of the protection method of the present invention are the subject-matter of the dependent claims.

Particularly, alternative embodiments provide different configurations of the deflecting module and, more particularly, different combinations of different support structures and different deflecting parts; more precisely, the present invention provides that the support structure of the module can be separated from the corresponding foundation or integral with it, and that it can be orthogonal to the direction of incoming flow or inclined at an acute or obtuse angle with respect to such a direction, and that the deflecting part having a concave profile can be curvilinear or polygonal.

Alternative embodiments are also provided for the barrier comprising a plurality of deflecting modules and, specifically, there are provided an arrangement of the barrier only on one side of the area and/or of the man-made works to be protected and an arrangement of the barrier on two opposite sides of the area and/or of the man-made works to be protected; furthermore, it can also be provided that the barrier is placed against the area and/or the man-made works be protected, or that the barrier is positioned at a predetermined distance from the area and/or from the man-made works to be protected so as to form one or more corridors.

It is understood that all the annexed claims form an integral part of the present description and that each of the technical features therein claimed is possibly independent and autonomously usable with respect to the other aspects of the invention.

It will be immediately evident that several modifications (for example relevant to shape, sizes, arrangements and parts with equivalent functionality) could be brought to what described without departing from the scope of the invention as claimed in the appended claims.

Advantageously, the technical solution according to the present invention that realizes the mitigation of a multiphase flow, precisely of a sand-laden wind, allows:

- to prevent sand from advancing over the anti-sand barrier;
- to facilitate the sand sedimentation upwind and in a pre-set position at the base of the barrier;
- to protect, both line-like and point, areas and man-made works;
- to achieve a high performance efficiency, even in presence of sand already accumulated upwind at the base of the barrier;
- to design, industrialize and implement on a large scale basis in a simple and cheap way; and
- to make maintenance easier.

Further advantageous features will appear more evident from the following description of preferred but not exclusive embodiments, merely given by way of explanatory and not limiting example.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described hereinbelow by means of some preferred embodiments, given by way of explanatory and not limiting example, with reference to the accompanying drawings. These drawings illustrate different aspects and examples of the present invention and, where appropriate, similar structures, components, materials and/or elements in different figures are denoted by similar reference numbers.

FIG. 1 is a cross-sectional view of a solid barrier according to the prior art;

FIG. 2 is a cross-sectional view of a first embodiment of the deflecting module according to the present invention;

FIG. 3 is a cross-sectional view of a second embodiment of the deflecting module according to the present invention;

FIG. 4 is a cross-sectional view of a third embodiment of the deflecting module according to the present invention;

FIG. 5 is a cross-sectional view of a fourth embodiment of the deflecting module according to the present invention;

FIG. 6 is a cross-sectional view of a fifth embodiment of the deflecting module according to the present invention;

FIG. 7 is a cross-sectional view of a sixth embodiment of the deflecting module according to the present invention;

FIG. 8 is a cross-sectional view of a seventh embodiment of the deflecting module according to the present invention;

FIG. 9 is a graphical representation of the performance of the solid barrier according to the prior art of Fig. 1 compared with the performances of the deflecting modules according to the invention of Fig. 2 and Fig. 3;

FIG. 10A shows the computational simulation of an incoming multiphase flow, or sand-laden wind, on the solid barrier according to the prior art of Fig. 1;

FIG. 10B shows the computational simulation of an incoming multiphase flow, or sand-laden wind, on the deflecting module according to the invention of Fig. 2;

FIG. 10C shows the computational simulation of an incoming multiphase flow, or

sand-laden wind, on the deflecting module according to the invention of Fig. 3;

FIG. 11 is a cross-sectional schematic representation of a first embodiment of anti-sand barrier according to the present invention;

FIG. 12 is a plan schematic representation of the barrier according to the invention of Fig. 11;

FIG. 13 is a cross-sectional schematic representation of a second embodiment of anti-sand barrier according to the present invention;

FIG. 14 is a plan schematic representation of the barrier according to the invention of Fig. 13; and

FIG. 15 is a flow chart showing the steps of the protection method according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

While the invention is susceptible of various modifications and alternative constructions, some preferred embodiments are shown in the drawings and will be described in detail hereinbelow.

It should be understood, however, that there is no intention to limit the invention to the specific illustrated embodiments but, on the contrary, the invention intends to cover all the modifications, alternative constructions and equivalents that fall within the scope of the invention as defined in the claims.

In the following description, therefore, the use of "for example", "etc." and "or" denotes non-exclusive alternatives without limitation, unless otherwise indicated; the use of "also" means "among, but not limited to", unless otherwise indicated; the use of "includes / comprises" means "includes / comprises, but not limited to", unless otherwise indicated.

The deflecting module, the anti-sand barrier and the protection method of the present invention are based on the innovative concept of providing a concave profile - with respect to the direction of an incoming multiphase flow, specifically sand-laden wind - of the deflecting part of the module in combination with an appropriate inclination of the supporting structure of the module itself, so as to modify such a flow, and precisely so as to locally deflect the flow at the upper free end of the

deflecting part of the module, creating a flow descending along the upwind face of the module itself and inducing a vortex of pseudo-trapezoidal shape that occupies the whole volume underlying the deflecting part of the module, so that on the one hand sand is prevented from passing over the anti-sand barrier and deposits on the man-made works that are beyond it and on the other hand the sand sedimentation under and upwind the barrier is caused.

An important feature of said deflecting module, anti-sand barrier and protection method resides in that they guarantee a controlled and excellent aerodynamic performance and, therefore, they are particularly suitable for - although certainly not limited to - applications for buildings and infrastructures, both point and line-like, in very windy desert and semi-desert regions and even with multidirectional winds.

To show the performance effectiveness of the technical solution according to the present invention, a known mitigation measure is used as basis for comparison, and precisely a solid barrier as previously described and illustrated in Fig. 1.

Referring to Fig. 1, a wall 2 joined to a corresponding foundation 5 are shown, in which the wall 2 rises above the ground T and is orthogonal thereto while the foundation 5 is placed below the ground level T; as it can be noted, the wall 2 does not have any deflecting part thereon and, therefore, it represents the most general form of solid barrier suitable for stopping, or at least for reducing, an incoming multiphase flow, specifically sand-laden wind S.

It is worthy here to point out that, for the purpose of performance comparison, the above-ground size of the solid barrier of Fig. 1, i.e. the height of the wall 2, will be equal to the overall height of the deflecting module according to the present invention.

Referring to Fig. 2, a first embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 comprises a first support portion 2, a second support portion 3 and a deflecting panel 4.

The first support portion 2 rises above-ground, i.e. above the level of ground T, and comprises, in turn, a base 20 and a head 21.

The first support portion 2 has an inclination ranging between 70° and 110° with respect to the ground T upwind; in the first embodiment shown in Fig. 2, the first support portion 2 has an angle equal to 90°, i.e. it is orthogonal, with respect to the ground T upwind.

The first support portion 2 can have a rectilinear or broken axis; in the first embodiment shown in Fig. 2, the first support portion 2 has a rectilinear axis, and precisely a rectilinear axis orthogonal to the ground T.

The base 20 is suitable to be fixedly connected to a corresponding foundation 5, which is placed below the level of ground T; the fixed connection may be realized through any means known in the reference technical field and suitable for the purpose.

In a particular embodiment, shown in Fig. 8 and which will be illustrated in detail hereinbelow, the first support portion 2 and the foundation 5 are designed and realized in a single, monolithic, element.

The foundation 5 is preferably a shallow foundation, as visible in Figures 2 to 8, but it can also be an deep foundation, for example a micropile foundation (not shown), or another type known in the reference technical field, due to the variability of the geotechnical characteristics of the specific installation site.

The extrados of the foundation 5 may be at the level of ground T, as visible in Figures 2 to 6 and in Fig. 8, or at a lower level than the level of ground T (not shown) and then covered with a layer of backfill that restores the level of ground T, due to the variability of the geotechnical characteristics of the specific installation site.

The first support portion 2 is preferably prefabricated and made of reinforced concrete; however, it is possible to make it with a concrete cast in work or to employ any other material suitable for the purpose and, in particular, having appropriate mechanical properties.

The first support portion 2 is preferably band-shaped, i.e. it is continuous in the longitudinal direction of the module; the first support portion 2 can have a constant cross section in the longitudinal direction, or it can be realized with ribs on the downwind face, regularly spaced between them, preferably spaced apart by a pitch

ranging between 0.5 m and 6 m.

The second support portion 3 has one end suitable to be fixedly connected to the head 21 of the first support portion 2 while the other end is free.

The second support portion 3 is preferably point-shaped, i.e. it is discontinuous in the longitudinal direction of the module and it consists of a plurality of mutually and regularly spaced pillars, preferably spaced apart by a pitch ranging between 1 m and 6 m, anyhow preferably a submultiple of the longitudinal dimension of the module.

The second support portion 3 is preferably made of metallic material, for example stainless steel, or of reinforced concrete; however, it is possible to employ any other material suitable for the purpose and, in particular, having appropriate mechanical properties.

The deflecting panel 4 has one end, namely the lower end relative to the ground T, suitable to be put in contact with the head 21 of the first support portion 2 while the other end, namely the upper end relative to the ground, is free.

The deflecting panel 4 is supported by the second support portion 3 and, precisely, it is removably connected to the second support portion 3, according to connection systems known in the reference technical field.

The deflecting panel 4 is solid, continuous and preferably made of metallic material, for example stainless steel or Corten steel, or of plastic material, for example polymethylmethacrylate; however, it is possible to employ any other material suitable for the purpose giving the same properties.

The deflecting panel 4 is preferably a thin plate of homogeneous material having thickness ranging between 1 mm and 100 mm; however, it is possible to use multilayer box-type panels having thickness ranging between 50 mm and 200 mm.

If the deflecting panel 4 is a thin plate and if the pitch of the second support portion 3 is so long as to request it, it is possible to shape the upper free end of the deflecting panel 4 so as to increase the stiffness thereof without modifying the aerodynamic performance, for example by making a bending at the extrados.

Where appropriate, the deflecting panel 4 can be coated with materials or protective treatments, according to known techniques in the reference field.

The deflecting panel 4 and the second support portion 3 have a concave profile with respect to an incoming multiphase flow S; preferably the incoming multiphase flow S is sand-laden wind.

Preferably, the concave profile of the deflecting panel 4 and of the second support portion 3 is curvilinear or polygonal; in the first embodiment shown in Fig. 2, the concave profile is curvilinear.

The free end of the deflecting panel 4 and of the second support portion 3 ranges between -20° and +20° relative to the direction of the incoming multiphase flow S; in the first embodiment shown in Fig. 2, the free end of the deflecting panel 4 and of the second support portion 3 forms an angle equal to 0° with respect to the direction of the incoming multiphase flow S.

Thanks to the provision of the concave profile with respect to the direction of the incoming flow of sand-laden wind S, the deflecting panel 4 allows to locally deflect, at its free end, such a flow, to create a flow descending along the upwind face of the deflecting module 1 and to induce a vortex that occupies the whole volume underlying the deflecting module 1 and that makes the sand to deposit under and upwind the deflecting module itself, in a pre-set position at its base; this phenomenon will be explained in more detail hereinbelow with reference to Figures 9, 10A, 10B and 10C.

The deflecting panel 4 and the second support portion 3 are connected to the head 21 of the first support portion 2, thus realizing the deflecting module 1 according to the present invention.

The deflecting panel 4, and the relevant second support portion 3, can however also be connected to pre-existing structures, for example to solid barriers of the type shown in Fig. 1, thus representing a "retrofitting" measure.

The deflecting module 1 has an overall height ranging between 2 m and 10 m, depending on the incoming sand flow and/or on the requirements of maintainability and protection required for the man-made work, the height of the first support portion 2 ranging between 0.5 m and 7 m.

The deflecting module 1 has an overall size in the direction of the incoming wind

ranging between 1 m and 7 m, depending on the overall height of the deflecting module 1.

It is evident that all the above mentioned sizes both of the deflecting module 1 as a whole and of each single component thereof, can vary and be optimized depending on the specific local conditions, for example depending on the wind speed, the aerodynamic roughness of the ground surface, the incoming sand flow, the requirements of maintainability and protection required for the man-made work and also depending on the geometry of the module itself (height, inclination of its side surfaces, etc.); more generally, it is deemed useful to point out that the preferable size of the deflecting module 1 as a whole and of each single component thereof and of the corresponding foundation always all depend on the geotechnical characteristics of the installation site, in particular on the incoming sand flow, as well as on the requirements of maintainability and protection required for each single application.

It is similarly evident that the above mentioned materials for realizing both the deflecting module 1 as a whole and each single component thereof, can be selected among others more economic or more in accordance with the local weather conditions and, in any case, always the material resulting the most fitted for the specific application.

The first embodiment of the present invention, described hereinabove with reference to Fig. 2, offers the advantages that it can be realized in a simple and cheap way and that it achieves a good aerodynamic performance.

Referring to Fig. 3, a second embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the second embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 3 have in common most of the features that, for brevity, will not be repeated while the peculiar features of the sole second embodiment will be described.

According to the second embodiment of deflecting module according to the present

invention, the first support portion 2 has a broken axis; the axis of the first support portion 2 is broken at a distance ranging between 0.5 m and 6 m from the ground T, depending on the overall height, and the angle relative to the ground T upwind at the axis broken line ranges between 70° and 110°.

It should be noted that the axis of the first support portion 2 is broken at a distance from the ground T such as to be perfectly compatible with the gauge of a conventional cleaning machine that, therefore, can get close to the upwind wall of the first support portion 2 so as to achieve a complete removal of the deposited sand.

The second embodiment of the present invention, described hereinabove with reference to Fig. 3, offers the advantages that it achieves the best aerodynamic performance and that it allows rapid and optimum cleaning operations.

Referring to Fig. 4, a third embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the third embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 4 have in common most of the features that, for sake of brevity, will not be repeated while the peculiar features of the sole third embodiment will be described.

According to the third embodiment of the deflecting module according to the present invention, the first support portion 2 has an inclination ranging between 70° and 89° relative to the ground T upwind, thus forming an acute angle with respect to the ground T upwind.

Furthermore, in this third embodiment, the first support portion 2 has a rectilinear axis.

The third embodiment of the present invention, described hereinabove with reference to Fig. 4, offers the advantage of a good compromise between the aerodynamic performance and simplicity / cheapness of construction.

Referring to Fig. 5, a fourth embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the fourth embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 5 have in common most of the features that, for brevity, will not be repeated while the peculiar features of the sole fourth embodiment will be described.

According to the fourth embodiment of deflecting module according to the present invention, the first support portion 2 has an inclination ranging between 91° and 120° relative to the ground T upwind, thus forming an obtuse angle relative to the ground T upwind.

Furthermore, in this fourth embodiment, the first support portion 2 has a rectilinear axis.

The fourth embodiment of the present invention, described hereinabove with reference to Fig. 5, offers the advantage of further increasing the accumulation volume underlying the deflecting panel 4.

Referring to Fig. 6, a fifth embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the fifth embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 6 have in common most of the features that, for sake of brevity, will not be repeated while the peculiar features of the sole fifth embodiment will be described.

The deflecting panel 4 and the second support portion 3 have a concave profile relative to the incoming multiphase flow, said concave profile being either curvilinear or polygonal; in the fifth embodiment shown in Fig. 6, the concave profile is polygonal.

In this fifth embodiment, the internal angle of the oblique portions of the deflecting panel 4 and of the second support portion 3 having a polygonal concave profile ranges between 10° and 70° with respect to the incoming multiphase flow S.

Moreover, in this fifth embodiment, the first support portion 2, which can have an inclination ranging between 70° and 110° relative to the ground T, has an inclination equal to 90°, i.e. it is orthogonal, relative to the ground T.

Moreover, in this fifth embodiment, the first support portion 2 has a rectilinear axis, and precisely a rectilinear axis orthogonal to the ground T.

The fifth embodiment of the present invention, described hereinabove with reference to Fig. 6, offers the advantage of a more simple and economical construction of the deflecting portion (deflecting panel 4 and second support portion 3) of the deflecting module 1 since, instead of performing a curvature, a bending of the material is carried out.

Referring to Fig. 7, a sixth embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the sixth embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 7 have in common most of the features that, for sake of brevity, will not be repeated while the peculiar features of the sole sixth embodiment will be described.

This sixth embodiment is different from the others since the first support portion 2 does not rise above-ground, i.e. above the level of ground T, but it is lowered relative to the level of ground T of a depth ranging between 0.2 m and 2 m from the surface of the ground T; furthermore, the pit obtained from the lowering relative to the level of the ground T has a width ranging between 1 m and 6 m, depending on the overall height of the module deflecting 1 considered from the level of the ground T; furthermore, the invitation angle to the pit ranges between 20° and 90°, preferably is equal to 30°.

Moreover, in this sixth embodiment, the first support portion 2, which can have an inclination ranging between 70° and 110° relative to the ground T upwind, has an inclination equal to 90°, i.e. it is orthogonal, relative to the ground T upwind.

Moreover, in this sixth embodiment, the first support portion 2 has a rectilinear axis,

and precisely a rectilinear axis orthogonal to the ground T.

The sixth embodiment of the present invention, described hereinabove with reference to Fig. 7, offers the advantages of improving the formation of the vortex, of collecting a larger accumulation volume of deposited sand and of facilitating the cleaning operations.

Referring to Fig. 8, a seventh embodiment of deflecting module according to the present invention is therein illustrated.

The deflecting module 1 according to the seventh embodiment comprises a first support portion 2, a second support portion 3 and a deflecting panel 4 similarly to the first embodiment of Fig. 2.

The two embodiments of Fig. 2 and Fig. 8 have in common most of the features that, for brevity, will not be repeated while the peculiar features of the sole seventh embodiment will be described.

This seventh embodiment is different from the others since the first support portion 2 does not comprise the base 20 and the first support portion 2 itself and the foundation 5 are formed in a single, monolithic, element.

It is to be noticed that, although the embodiment of the deflecting module 1 shown in Fig. 8 corresponds to that of the deflecting module 1 shown in Fig. 1, the type of the first support portion 2 and of the foundation 5 formed in a single piece can obviously be applied to any embodiment of the deflecting module 1 as shown in Fig. 2 to Fig. 7.

Furthermore, in this seventh embodiment, the first support portion 2, which can have an inclination ranging between 70° and 110° relative to the ground T upwind, has inclination equal to 90°, i.e. it is orthogonal, relative to the ground T.

Furthermore, in this seventh embodiment, the first support portion 2 has a rectilinear axis, and precisely a rectilinear axis orthogonal to ground T.

The seventh embodiment of the present invention, described hereinabove with reference to Fig. 8, offers the advantages of avoiding the use of means for making the first support portion 2 integral with the foundation 5 and, consequently, it gives a greater stability to the deflecting module 1.

It is evident that, according to the specific needs, any combination of configurations

of the first support portion 2 and of the deflecting panel 4 (and corresponding second support portion 3) as described above can be used, as well as any further combination with or without pit and with monolithic structure of the assembly first support portion 2 / foundation 5.

Reference is now made to Figures 9, 10A, 10B and 10C to illustrate the performance effectiveness of the deflecting module 1 according to the present invention, and precisely according to the first embodiment shown in Fig. 2 and to the second embodiment shown in Fig. 3, compared with the solid barrier according to the prior art shown in Fig. 1.

As already mentioned, for the purpose of the performance comparison, the above-ground size of the solid barrier of Fig. 1, i.e. the height of the wall 2, is equal to the overall height of the deflecting module 1 according to the two chosen embodiments of the present invention, this overall height resulting from the height of the first support portion 2 and of the panel 4 supported by the second support portion 3 .

Fig. 9, which shows a graphical representation of the performance of the solid barrier according to the prior art of Fig. 1 compared with the performances of the deflecting modules according to the invention of Fig. 2 and Fig. 3, shows the maximum accumulation capacity, expressed as a percentage, of each considered configuration.

The accumulation capacity is the maximum volume of sand that can be deposited upwind the barrier before that this latter is completely ineffective and it is evaluated as the volume of air in which the shear stress in the fluid is lower than the threshold value of sand erosion by the wind.

Each value of the accumulation capacity is scaled with respect to the accumulation capacity of the vertical solid barrier without deflector of Fig. 1, which is considered to be the term of comparison.

From this viewpoint, as it can be noticed, being the accumulation capacity of the known solution of Fig. 1 equal to 100%, the accumulation capacity of the embodiments of Fig. 2 and Fig. 3 are equal, respectively, to 155% and 160%.

Figures 10A, 10B and 10C show the computational simulations of an incoming multiphase flow, i.e. sand-laden wind, on the solid barrier according to the prior art

of Fig. 1, on the deflecting module according to the invention of Fig. 2 and on the deflecting module according to the invention of Fig. 3, respectively.

It is again worthy to specify that, for the purpose of the performance comparison, all the three barriers have the same height, in the particular case 4 meters, and they are subjected to the same incoming wind flow that, in the figures, comes from the left.

In the figures the current lines are represented, i.e. the trajectories of the particles of air or sand.

It can be noted that, in the case of the base barrier (Fig. 10A), the vortex is extremely small both longitudinally and vertically, while many current lines are deflected upward and then over the top of the barrier downwind; the sand transported along the current lines deflected upwards passes over the barrier and is deposited on the area and/or on the man-made works to be protected.

On the contrary, in Figures 10B and 10C the formation of an extended clockwise vortex under the deflecting module is observed; this vortex induces a reversed flow near the ground away upwind the free end of the deflecting panel, and the reduction of the wind speed far from the barrier, which causes the sedimentation of the transported sand.

As it can be seen in Fig. 10C, the configuration having the first support portion with a broken axis (Fig. 3) is particularly efficient because it induces a further extension upwind of the vortex.

The results of the computational simulations discussed above prove that, thanks to the provision of the concave profile with respect to the direction of the incoming flow of sand-laden wind S, the deflecting panel 4 of the deflecting module 1 according to the present invention allows to locally deflect this flow at the free end of the panel itself, to create a flow descending along the upwind face of the deflecting module 1 and to induce a vortex that occupies the whole volume underlying the deflecting module 1 and that makes the sand to deposit under and upwind the deflecting module itself, in a pre-set position at its base.

More precisely, the deflecting panel 4 of the module 1 acts as an aerodynamic appendix modifying the flow of the sand-laden wind along all the upwind face of the

module 1.

Still more precisely, the deflecting panel 4 induces a stable and coherent recirculation bubble on the upwind face of the module 1; this bubble is able to separate the windblown sand incoming on said upwind face of the module 1, to promote its sedimentation on the same face and to prevent the sand from passing over the module 1.

It is important to observe that the recirculation bubble is formed and maintained even while the level of accumulated sand gradually grows and, therefore, the trapping and sedimentation efficiency of the sand by the deflecting module 1 of the invention remains high even in presence of accumulated sand upwind at the base of the module itself.

The deflecting module 1 as above described, that is in accordance with the multiplicity of embodiments illustrated with reference to Figures 2 to 8 as well as in accordance with any further configuration achievable by suitably combining each single component of the deflecting module 1 itself, may be longitudinally joined in a fixed way to at least another deflecting module 1, so as to form an anti-sand barrier B suitable to protect a man-made work M from windblown sand S.

According to one aspect of the invention and referring to Figures 11 and 12, a plurality of deflecting modules 1 according to the invention are joined together to form a unilateral barrier B, that is a barrier B arranged on a single side of a man-made work M to be protected, for example a point building such as a civil or industrial settlement, a farm or a cultivated area, an archaeological site and the like.

This type of barrier is particularly suitable in all those cases in which, in addition, the sand-laden wind flow S is unidirectional.

Preferably the anti-sand barrier B is positioned at a predetermined distance from the man-made work M so as to form a corridor C; this distance ranges between 1 m and 100 m.

According to another aspect of the invention and referring to Figures 13 and 14, a plurality of deflecting modules 1 according to the invention are joined together to form a bilateral system of barriers B, that is a pair of barriers B arranged on two

opposite sides of an man-made work M to be protected, for example, a longitudinal construction such as a transport or industrial line-like infrastructures and the like.

This type of barrier is particularly appropriate also in all those cases in which the sand-laden wind flow S is multidirectional.

Preferably the pair of anti-sand barriers B is positioned at a predetermined distance on the two opposite sides of the man-made work M so as to form two corridors C; this distance ranges between 1 m and 100 m.

According to a further aspect of the invention and referring to Fig. 15, a plurality of deflecting modules 1 according to the invention, joined together to form an anti-sand barrier B, can be used in a protection method from windblown sand S.

The protection method of a man-made work M from windblown sand S according to the present invention comprises the following steps:

a. providing at least two deflecting modules 1 as previously described in detail (step 100);

b. where appropriate, fixedly connecting each deflecting module 1 to a corresponding foundation 5 (step 101);

c. longitudinally joining in a fixed way at least two deflecting modules 1, thus forming an anti-sand barrier B (step 102);

d. positioning the anti-sand barrier B on at least one side of the man-made work M to be protected, at a predetermined distance from the man-made work M so as to form at least one corridor C (step 103); and

e. thanks to the concave profile of the deflecting panel 4 and of the second support portion 3 of said at least two deflecting modules 1, modifying the incoming flow of windblown sand S inducing a coherent and stable recirculation bubble on the upwind side of the anti-sand barrier B , this bubble being able to separate the windblown sand S on the upwind side of the anti-sand barrier B, to promote its sedimentation on the same upwind side of the anti-sand barrier B and to prevent the windblown sand S from passing over the anti-sand barrier B (step 104).

It is to be noticed that the operation for connecting the deflecting module 1 to the corresponding foundation 5 indicated in step 101 is not necessary when the first

support portion 2 and the foundation 5 are formed in a single, monolithic, element.

The method according to the present invention provides for the application to man-made works M to be protected such as transport or industrial line-like infrastructures, civil or industrial settlements, farms and cultivated areas, archaeological sites and the like.

As it is deducible from the above description, the innovative technical solution herein described has the following advantageous features:

- the separation and accumulation efficiency of sand is greater than that of the solutions of the known prior art;
- the separation and accumulation efficiency of sand remains very high even in the presence of already accumulated sand, while the separation and accumulation efficiency of sand of the prior art solutions rapidly decreases as the accumulation level increases;
- a high efficiency in preventing the incoming sand-laden wind flow from passing over the barrier is achieved;
- the accumulation of sand on areas and/or works to be protected, such as transport or industrial infrastructures, villages, cities, buildings, plants, farms and cultivated areas, archaeological sites, etc., is avoided;
- the maintenance operations of the aforesaid areas and/or works to be protected during their lifetime are reduced;
- the periodic maintenance is simple and cheap, because the accumulated sand lies only outside the protected area;
- the complete solution of security issues caused by the sand accumulation on the aforesaid areas and/or works to be protected, such as for example the derailment of trains in the railway sector, is achieved; and
- the mitigation of problems relevant to the full serviceability caused by the sand sedimentation on the aforesaid areas and/or works to be protected, such as for example the contamination of the ballast from sand in the railway sector.

From the above description it is clear, therefore, as the deflecting module, the barrier obtained by combining a plurality of such deflecting modules and the protection

method that uses such a barrier described hereinabove allow to reach the proposed objects.

It is similarly evident, to a person skilled in the art, that modifications and variants can be made to the solution described with reference to the attached figures, without departing from the teaching of the present invention and from the scope as defined in the appended claims.

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CLAIMS

1. A deflecting module (1) comprising:
   - a first support portion (2), in turn comprising a base (20) and a head (21), wherein said base (20) is suitable to be fixedly connected to a corresponding foundation (5);
   - a second support portion (3), one end of which is suitable to be fixedly connected to said head (21) and the other end is free; and
   - a deflecting panel (4), one end of which is suitable to be put in contact with said head (21) and the other end is free, supported by said second support portion (3),

   characterized in that said deflecting panel (4) and said second support portion (3) have a concave profile with respect to an incoming multiphase flow (S) and in that said first support portion (2) has inclination ranging between 70° and 110° with respect to the ground (T).
2. A deflecting module (1) according to claim 1, wherein said first support portion (2) and said foundation (5) are formed in a single, monolithic, element.
3. A deflecting module (1) according to claim 1 or 2, wherein the concave profile of said deflecting panel (4) and said second support portion (3) is curvilinear or polygonal.
4. A deflecting module (1) according to claim 3, wherein the free end of said deflecting panel (4) and said second support portion (3) ranges between -20° and +20° with respect to said incoming multiphase flow (S).
5. A deflecting module (1) according to any of the preceding claims, wherein the axis of said first support portion (2) is rectilinear or broken.
6. A deflecting module (1) according to any of the preceding claims, wherein the height of said first support portion (2) ranges between 1 m and 7 m, and wherein the overall height of said deflecting module (1) ranges between 2 m and 10 m, and wherein the overall width of said deflecting module (1) ranges between 1 m and 7 m.
7. A deflecting module (1) according to any of the preceding claims, wherein said

incoming multiphase flow (S) is sand-laden wind.

8. A deflecting module (1) according to any of the preceding claims, wherein said deflecting panel (4) is continuous and wherein said second support portion (3) consists of a plurality of mutually and regularly spaced pillars.

9. An anti-sand barrier (B) comprising at least two deflecting modules (1) according to any of the preceding claims, wherein said at least two deflecting modules (1) are longitudinally joined together in a fixed way to protect a man-made work (M) from windblown sand (S).

10. An anti-sand barrier (B) according to claim 9, wherein said deflecting modules (1) joined to each other are arranged on one side of said man-made work (M) to be protected.

11. An anti-sand barrier (B) according to claim 10, wherein said deflecting modules (1) are positioned at a pre-set distance from said man-made work (M) so as to form a corridor (C).

12. An anti-sand barrier (B) according to claim 9, wherein said deflecting modules (1) joined to each other are arranged on two opposite sides of said man-made work (M) to be protected.

13. An anti-sand barrier (B) according to claim 12, wherein said deflecting modules (1) are positioned at a predetermined distance on the two opposite sides of said man-made work (M) so as to form two corridors (C).

14. A protection method of a man-made work (M) from windblown sand (S) comprising the following steps:

a. providing at least two deflecting modules (1) according to any claim 1 to 10 (step 100);

b. where appropriate, fixedly connecting each deflecting module (1) to a corresponding foundation (5) (step 101);

c. longitudinally joining in a fixed way at least two deflecting modules (1), thus forming an anti-sand barrier (B) (step 102);

d. positioning said anti-sand barrier (B) at least on one side of said man-made work (M) to be protected, at a predetermined distance from said man-made

work (M) so as to form at least one corridor (C) (step 103); and

e. thanks to the concave profile of said deflecting panel (4) and said second support portion (3) of said at least two deflecting modules (1), modifying the incoming flow of windblown sand (S) by inducing a coherent and stable recirculation bubble around the upwind side of said anti-sand barrier (B), such bubble being able to segregate the windblown sand (S) on the upwind side of said anti-sand barrier (B), to promote its sedimentation on the same upwind side of said anti-sand barrier (B) and to prevent the windblown sand (S) from passing over said anti-sand barrier (B) (step 104).

15. A method according to claim 14, wherein said man-made work (M) to be protected is an transport or industrial line-like infrastructure, a civil or industrial settlement, an archaeological site and the like.

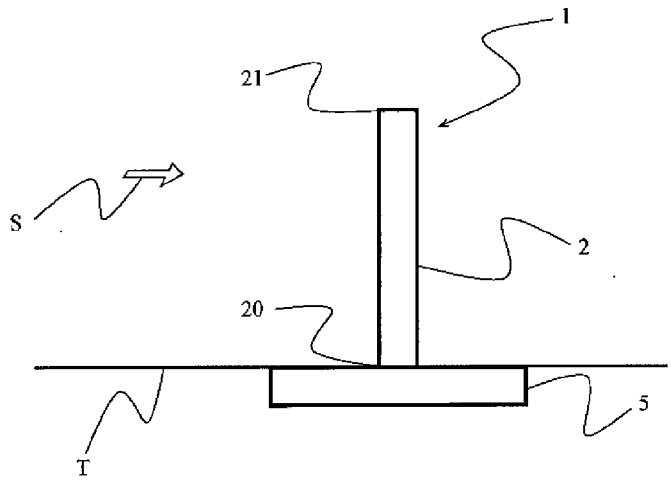


Fig. 1

PRIOR ART

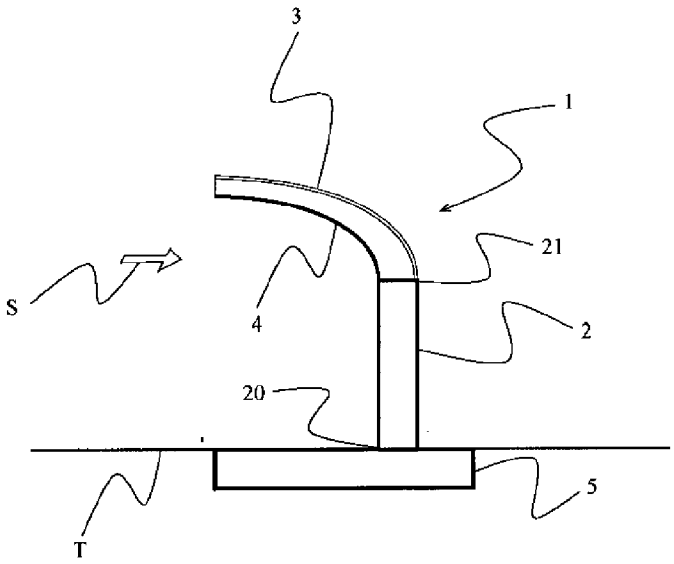


Fig. 2

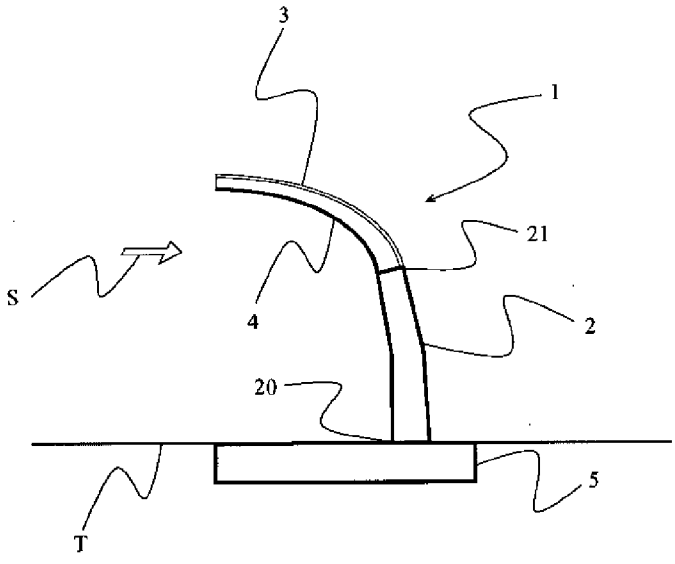


Fig. 3

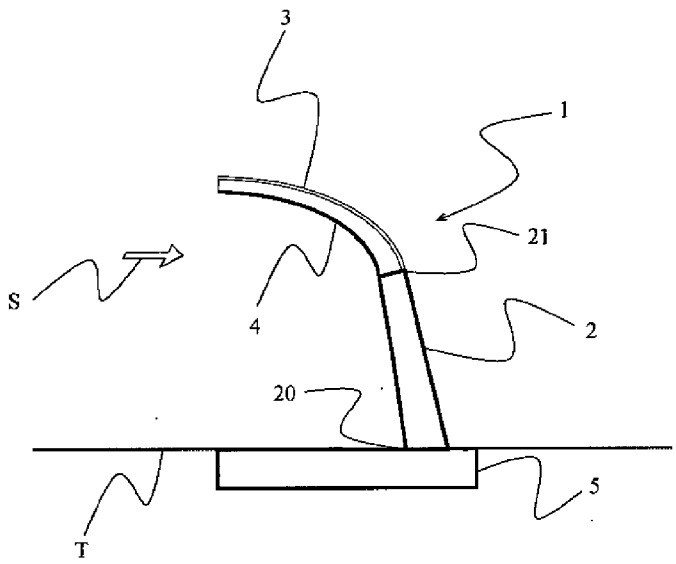


Fig. 4

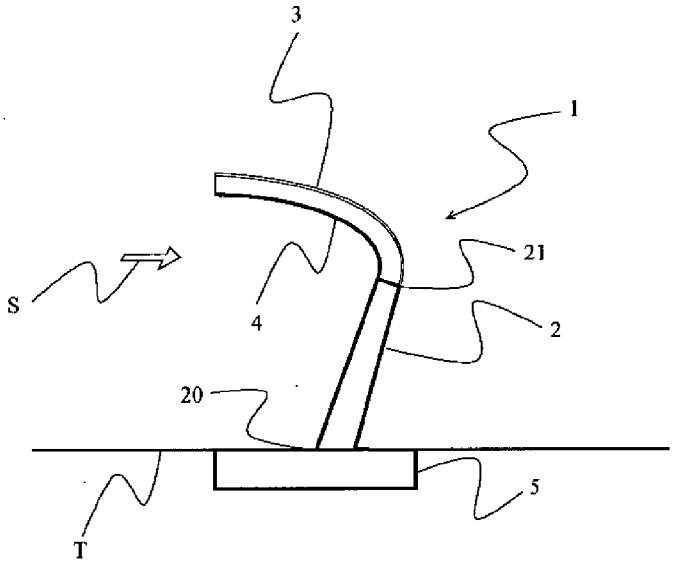


Fig. 5

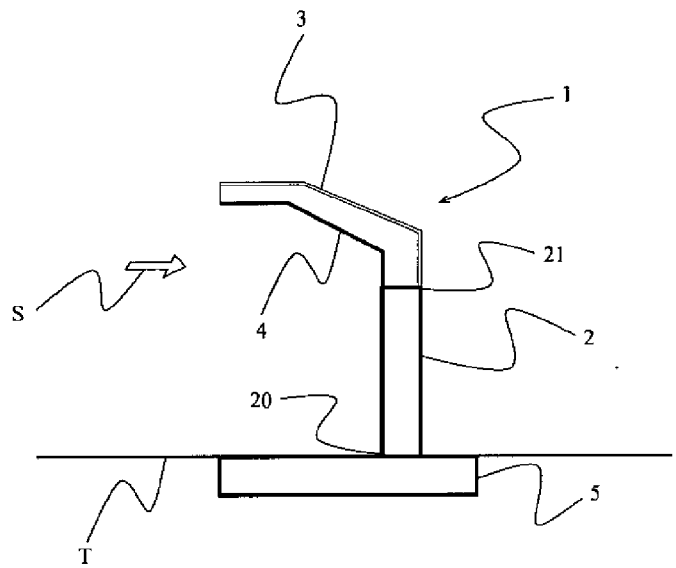


Fig. 6

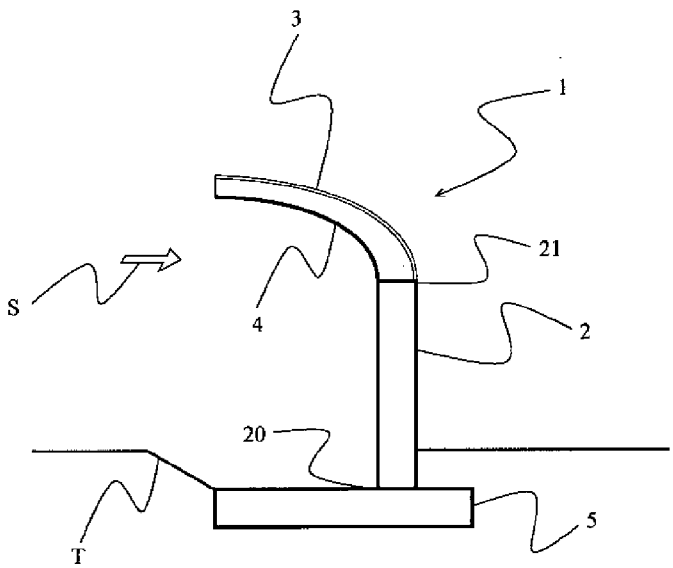


Fig. 7

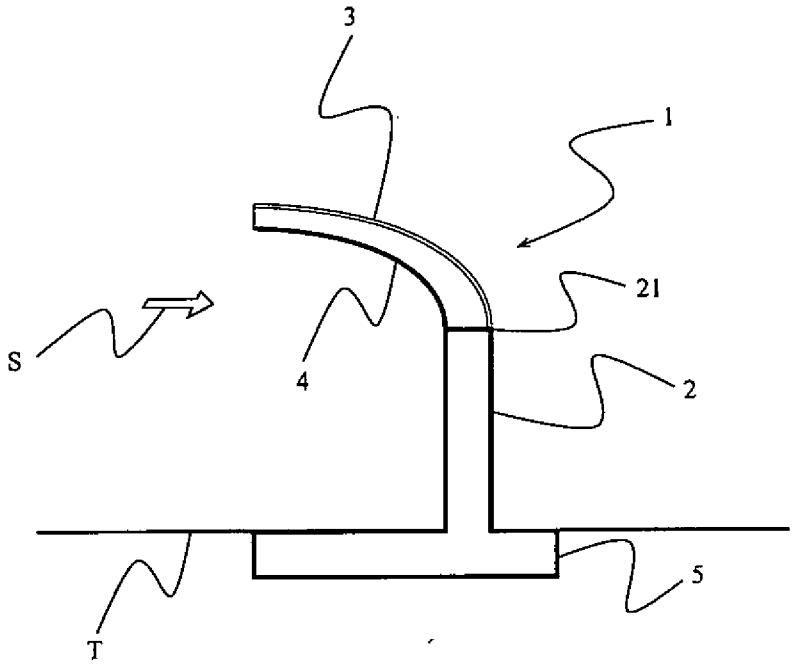

3
1
21
S
4
2
5
T

Fig. 8

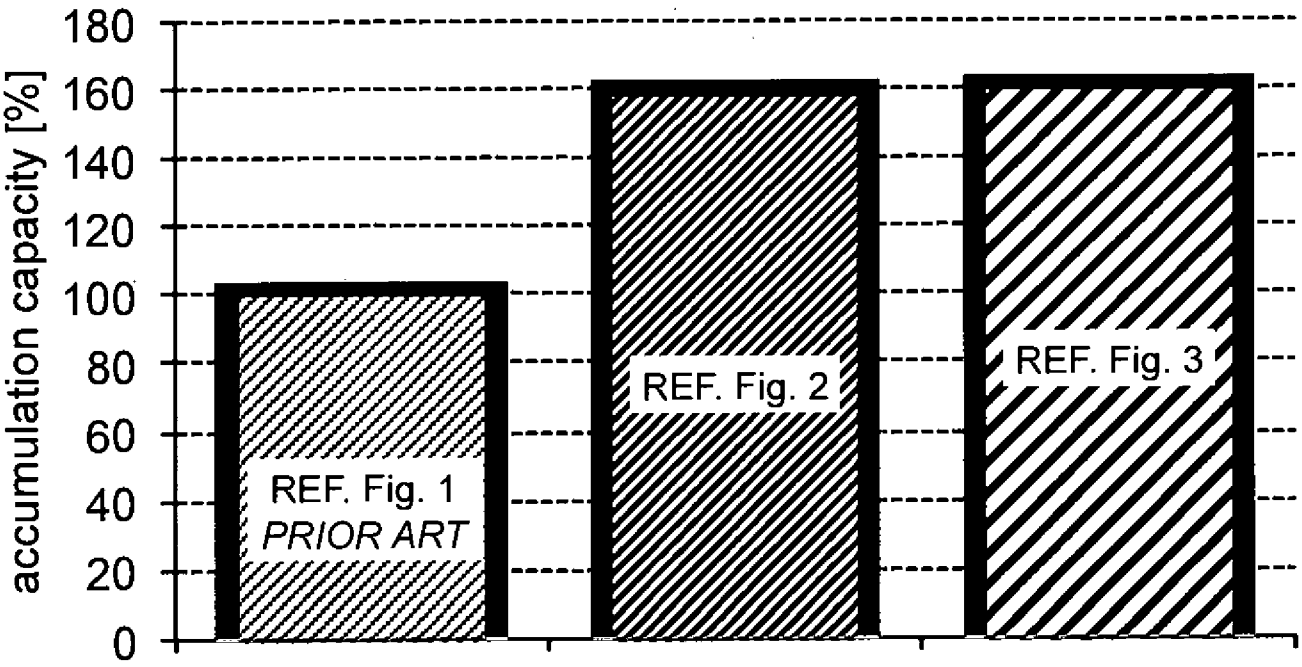

accumulation capacity [%]
180
160
140
120
100
80
60
40
20
0
REF. Fig. 1
PRIOR ART
REF. Fig. 2
REF. Fig. 3

Fig. 9

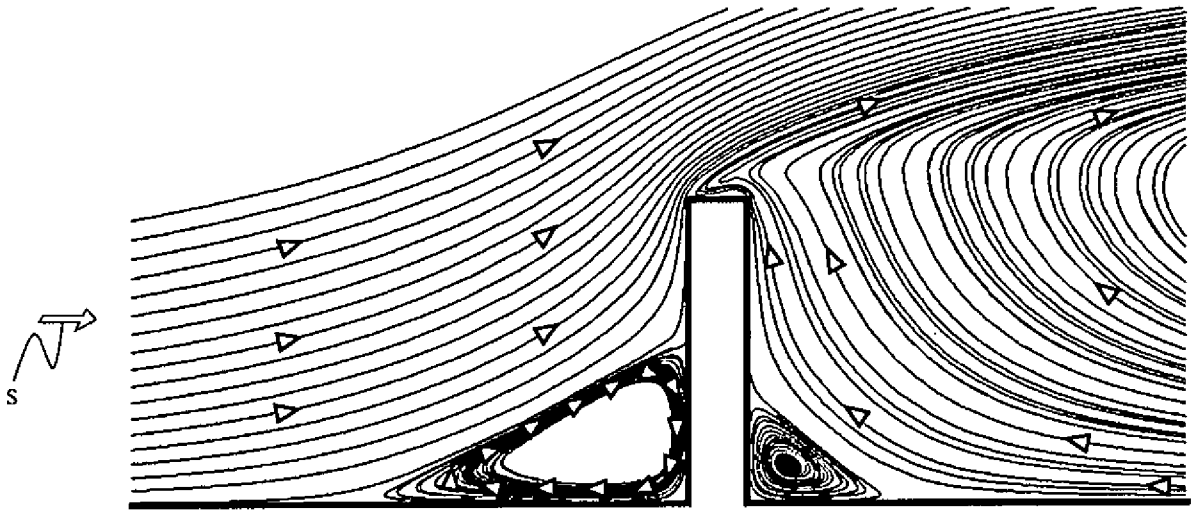


Fig. 10A

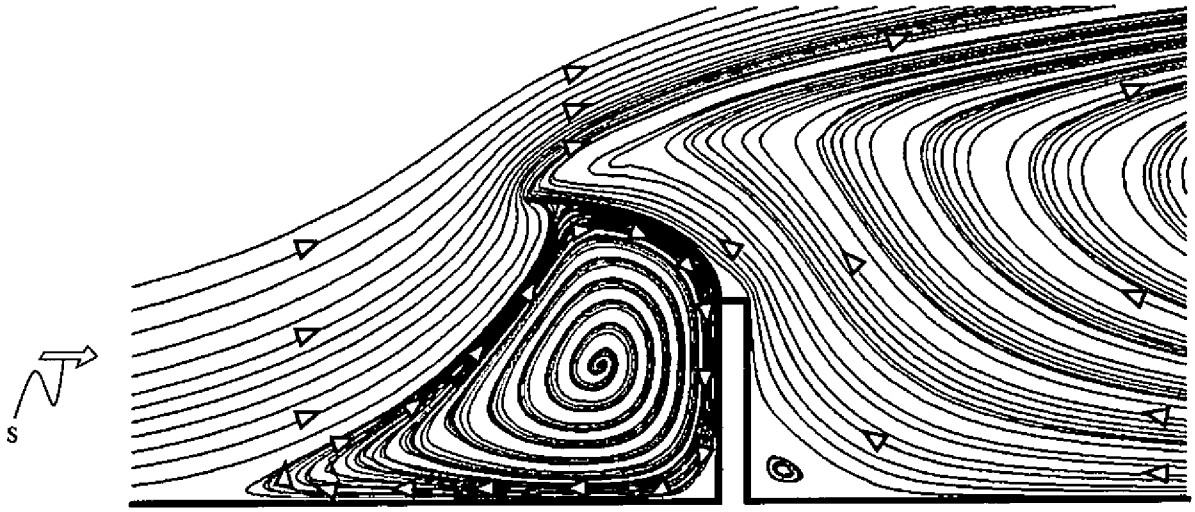


Fig. 10B

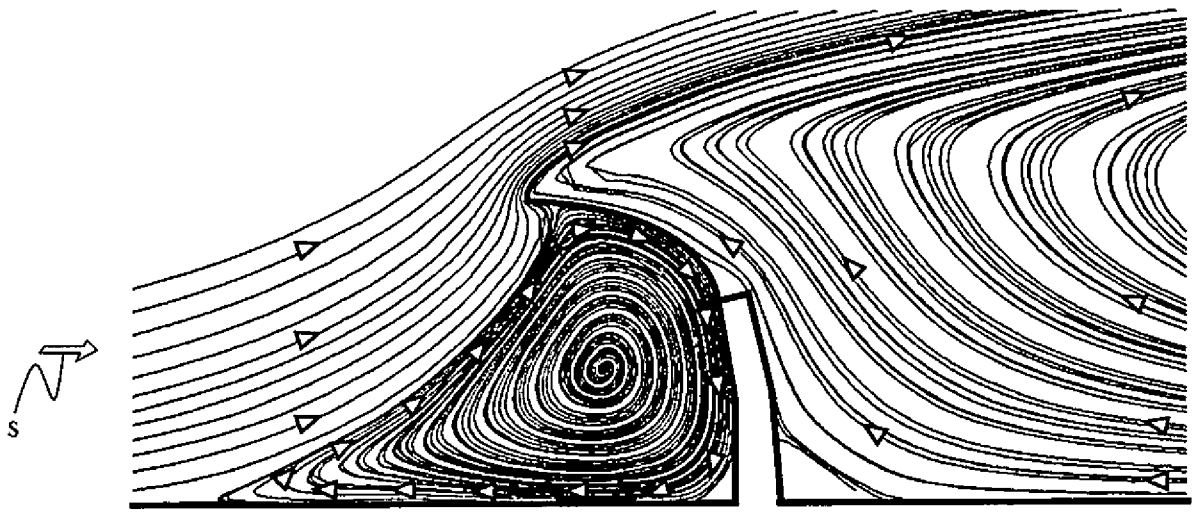


Fig. 10C

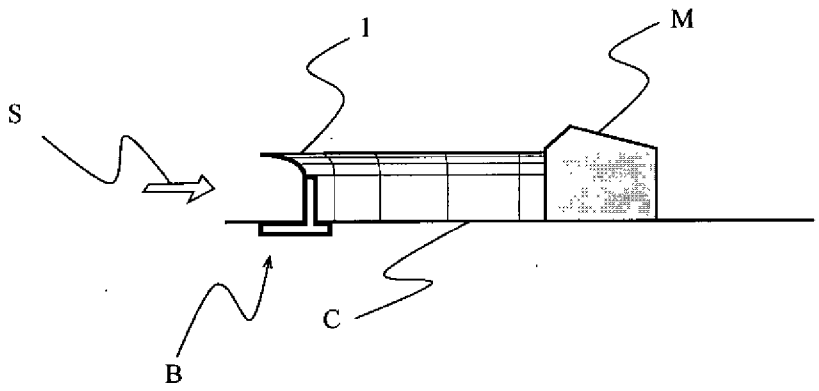


Fig. 11

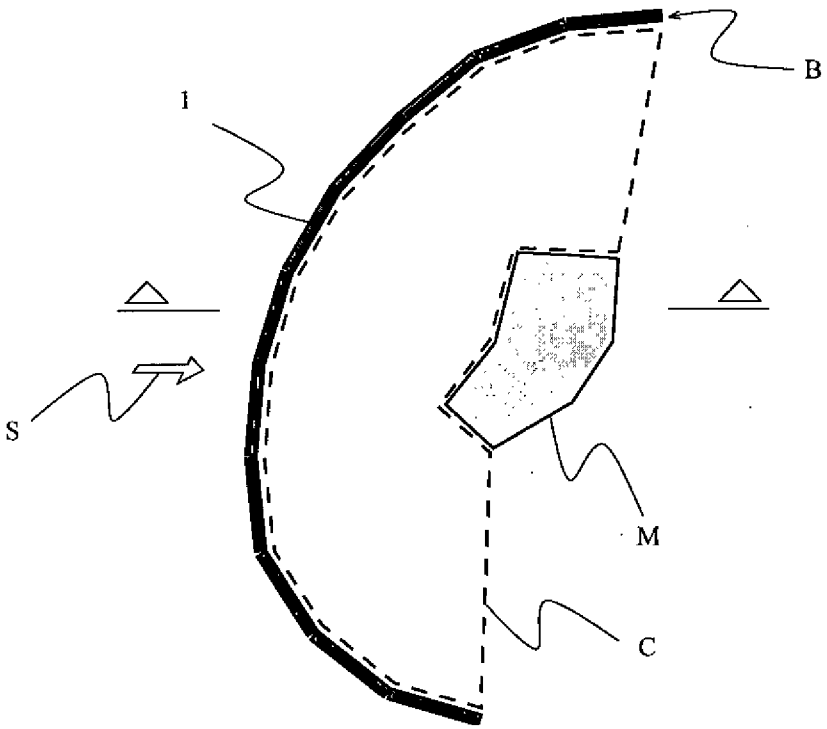


Fig. 12

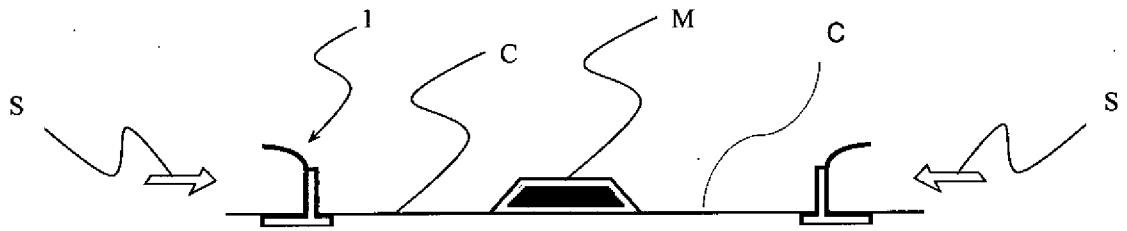


Fig. 13

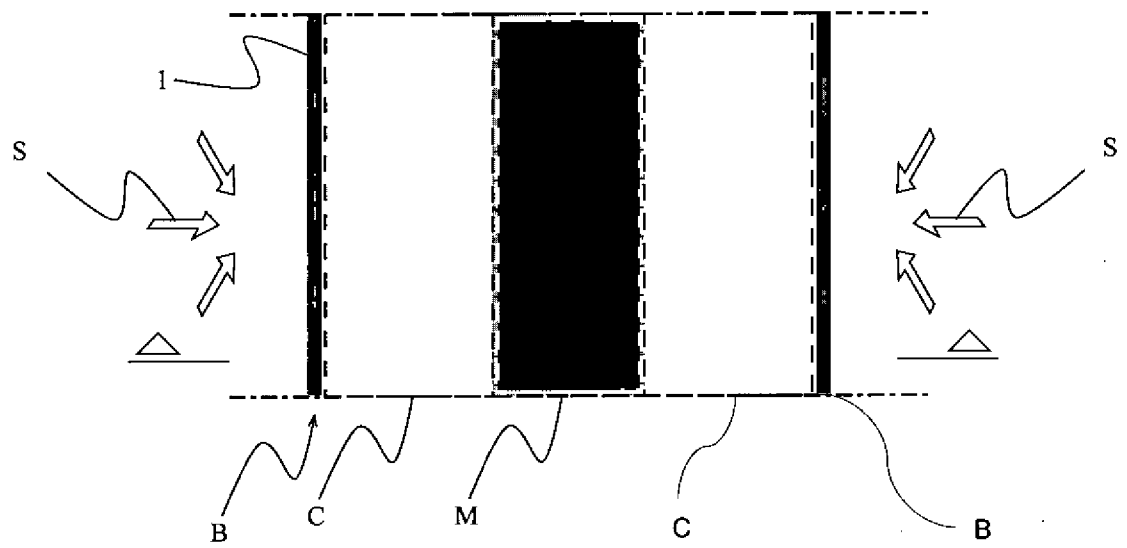


Fig. 14

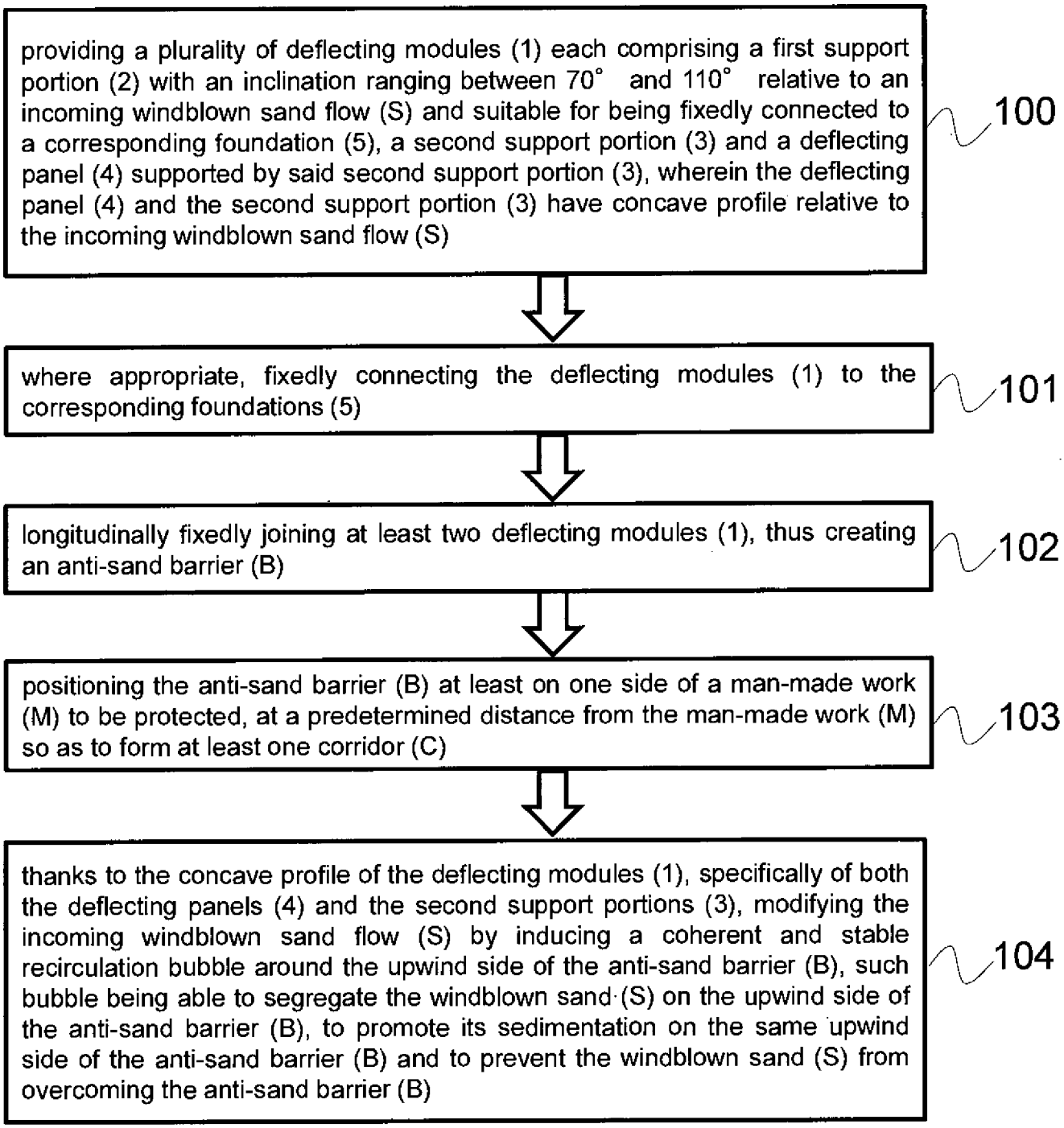

providing a plurality of deflecting modules (1) each comprising a first support portion (2) with an inclination ranging between 70° and 110° relative to an incoming windblown sand flow (S) and suitable for being fixedly connected to a corresponding foundation (5), a second support portion (3) and a deflecting panel (4) supported by said second support portion (3), wherein the deflecting panel (4) and the second support portion (3) have concave profile relative to the incoming windblown sand flow (S)
100
where appropriate, fixedly connecting the deflecting modules (1) to the corresponding foundations (5)
101
longitudinally fixedly joining at least two deflecting modules (1), thus creating an anti-sand barrier (B)
102
positioning the anti-sand barrier (B) at least on one side of a man-made work (M) to be protected, at a predetermined distance from the man-made work (M) so as to form at least one corridor (C)
103
thanks to the concave profile of the deflecting modules (1), specifically of both the deflecting panels (4) and the second support portions (3), modifying the incoming windblown sand flow (S) by inducing a coherent and stable recirculation bubble around the upwind side of the anti-sand barrier (B), such bubble being able to segregate the windblown sand (S) on the upwind side of the anti-sand barrier (B), to promote its sedimentation on the same upwind side of the anti-sand barrier (B) and to prevent the windblown sand (S) from overcoming the anti-sand barrier (B)
104

Fig. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2015/000129

A. CLASSIFICATION OF SUBJECT MATTER
INV. E01F7/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E01F E01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 731 320 A (NEWELL JOSEPH PETTUS [US]) 16 June 1903 (1903-06-16) the whole document	1-15
X	US 4 958 806 A (SATO AKIRA [JP] ET AL) 25 September 1990 (1990-09-25) cited in the application the whole document	1-6,9-13
A	JP S53 37443 Y2 (N N) 11 September 1978 (1978-09-11) the whole document	1,9,14
A	CN 203 320 430 U (XINJIANG TRAFFIC SCIENCE INST OF COMM) 4 December 2013 (2013-12-04) the whole document	1,9,14

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

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 February 2016	11/02/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Flores Hokkanen, P

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2015/000129

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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