(19) DANMARK

(10) DK/EP 2801437 T3

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

(51) Int.Cl.: *B 23 P 15/02 (2006.01)* *F 01 D 5/14 (2006.01)* *F 04 D 29/02 (2006.01)* *F 04 D 29/32 (2006.01)* *F 04 D 29/38 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2019-08-19**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-06-26**

(86) Europæisk ansøgning nr.: **14167531.4**

(86) Europæisk indleveringsdag: **2014-05-08**

(87) Den europæiske ansøgnings publiceringsdag: **2014-11-12**

(30) Prioritet: **2013-05-08 SE 1300323**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **AB Akron-Maskiner, 531 94 Järpås, Sverige**

(72) Opfinder: **Hellsvik, Erik, Brinkagatan 3, 532 32 Skara, Sverige**
Svensson, Richard, Ekevägen 7, 531 57 LIDKÖPING, Sverige

(74) Fuldmægtig i Danmark: **RWS Group, Europa House, Chiltern Park, Chiltern Hill, Chalfont St Peter, Bucks SL9 9FG, Storbritannien**

(54) Benævnelse: **Fremgangsmåde til fremstilling af vinger til aksialstrømningsmaskiner**

(56) Fremdragne publikationer:
FR-A- 1 144 946
GB-A- 713 690
GB-A- 1 089 247
GB-A- 2 062 120
US-A- 2 514 525
US-A- 3 052 961

DESCRIPTION

Field of the invention

[0001] The present invention relates to a method for manufacturing blades for axial flow machines such as axial fans, axial compressors and axial turbines.

Background of the invention

[0002] The purpose of the flow machine is to create or use pressure differences appearing as the fluid flows through the machine.

[0003] A core component of an axial flow machine is the rotor. Commonly, the rotor consists of a hub and blades attached to the hub.

[0004] The blade of the axial flow machine has a profile, which means the shape of the cross-section of the blade at a right angle to the radial axis. The part of the blade profile which divides the oncoming flow is the leading edge, and the opposite part where the flow leaves the blade is the trailing edge. One side of the profile, from the leading edge to the trailing edge, is the pressure side and the opposite side of the profile, also from the leading to the trailing edge, is the suction side. An imaginary straight line from the leading to the trailing edge is the chord. The fluid flows relative to the blade from the leading to the trailing edge along the pressure and suction sides. The actual blade profiled is designed specifically for the application in order to provide a desired performance.

[0005] The blade speed relative to the fluid changes along the radial axis as the rotor spins. The part of the blade close to the hub has a low velocity compared to the part of the blade near the rotor periphery. To make most use of this velocity variation, the angle between the chord and the profile direction of motion, which can be defined as an angle of attack, is made to vary with the radial position of the blade. Using this definition, the angle of attack is large at the hub where the blade velocity is low and small near the periphery, where the blade velocity is high. The variation in the angle of attack is achieved by twisting the blade. A blade without twist cannot achieve the same high performance as a blade with twist.

[0006] The performance of a rotor, i.e., the ability to create or use a desired pressure difference, depends on the shape of the blade profile as well as the twist of the blade. High performance is achieved using complex blade shapes.

[0007] Complex blade shapes are achievable by e.g., metal casting which is the dominant manufacturing method. In order to keep a low manufacturing cost, simple tools are most often used. This prevents blades having cavities, which in turn leads to industrial fan blades usually

being solid which requires a lot of material. As a consequence the blades are heavy.

[0008] Blades having cavities or are hollow requires less material by comparison and are also lighter. Less material gives a lower material cost and a reduction in weight leads to less strain on load carrying parts, e.g., the rotor hub. It is therefore desirable to be able to create hollow blades with a desired outer shape without an expensive method of manufacturing. One way to manufacture a long hollow blade with a desired profile is by extrusion. Extrusion and other shaping methods cannot however include the possibility to have a twisted blade. An extruded blade without turning will then have a limited performance unless it is twisted to the desired turning after manufacturing. The process of twisting hollow thin-walled profiles is however associated with a risk of buckling. If a thin-walled metal tube with a closed cross-sectional profile is subjected to a turning moment, this turning moment will cause tension in the material in undesired directions. If the level of tension exceeds the yield strength, the tube will collapse before the desired turning angle along the tube length axis is achieved.

[0009] GB 713 690 A concerns a process for twisting turbo-machine blades fashioned from sheet metal. In the process according to this document a section of the profile of the blade, consisting of one or more parts of sheet metal, is distorted according to the required twist whilst an edge of the profile is still open, and is held in the twisted condition while that edge which is still open is closed to form a completely closed hollow element.

[0010] Another process for twisting a hollow blade for an axial flow turbo-machine is known from FR 1 144 946 A.

[0011] US 2 514 525 A relates i.e. to a method of producing a metal blade construction which is interiorly reinforced with a rib arrangement and which has its external surfaces disposed substantially symmetrically with respect to a plane extending longitudinally thereof.

Summary of the invention

[0012] The invention describes a method to produce blades for axial flow comprising the features of claim 1. Preferred embodiments of the method are presented in the dependent claims.

[0013] The construction part here denoted as blade refers to corresponding detail regardless of if it is called blade, shovel, wing, or something else. In the same manner, the denotation rotor also refers to an impeller, fan wheel or something else. The blades are described below without any description of the assembled rotor or the assembled flow machine.

[0014] One object of the invention is to produce light weight blades using less material than conventionally for axial flow machines, while the blade profile and blade turning still can be achieved to ensure desired performance. This and other objects are met by manufacturing the blades in units. The units consist of main parts which by their designs allow reshaping of the

unit to the desired turning without deforming the profile. Unwanted deformation can be avoided by letting the parts have openings along the longitudinal axis which allows different parts of the blade to move relatively to each other when turning the blade. By doing so, tensions larger than the yield strength are avoided. If one then fixes the different units to each other by e.g., welding or gluing, the blade shape including turning will persist after the turning moment has been removed.

[0015] The procedure can be summarized in short by the following steps (A-E):

1. A. Shaping of the main part to desired profile and length.
2. B. When applicable, joining more than one main part to a blade.
3. C. Turning of the blade and at the same time relative displacement of opposite surfaces in the parts.
4. D. Fixing the displaced surfaces in their new positions.
5. E. Mounting of additional parts when applicable.

[0016] A blade consists thereby of one or more longitudinal main parts that extends in the radial direction from the rotor hub to the periphery. The main parts can have a cross-section (perpendicular to the radial axis) profile that in form and shape is mainly fixed so that the parts can be manufactured by e.g., extrusion.

[0017] The blade is constructed using two or more main parts that together form a unit with a cross section comprising the entire blade profile or a part of the blade profile. If such main parts are shaped according to the invention, such a unit can also be twisted to a desired twist angle without deformation of the blade profile. The main part in this embodiment is equipped with attachment details extending along the blade length axis so that the blade cross section is kept while the main parts are allowed to move relative to each other along the blade length axis when twisting the blade to its desired shape. When the blade has been turned to the desired twist angle, this can be made permanent by fixing the main parts to each other in their new relative positions.

[0018] In an embodiment where more than one longitudinal main part is included in the unit, two or more of the main parts can have identical cross-sectional shapes so that only one type of main part is required to provide material to e.g., both the main part containing the pressure side and the part containing the suction side.

[0019] In addition to the main part, the blade contains one or more additional parts that together with the main parts compose the blade, profile and also act as protective parts over the fixing points where the profile parts are joined. These parts can also seal the ends of the blade in order to prevent undesired interior flow.

[0020] It should be mentioned that there are additional ways to provide the possibility to twist a hollow profile to a desired twist angle by allowing relative displacement of the ingoing parts

along the length axis and thereafter make the twist permanent by fixing the displaced surfaces to each other.

Short description of figures

[0021]

Fig. 1 shows a unit consisting of one single main part having cavities and openings.

Fig. 2 shows, in perspective, the unit according to Fig. 1.

Fig. 3 shows the unit according to Fig. 1 with the twisting made permanent by welding together of the openings of the main part.

Fig. 4 shows a main part used in the method according to one embodiment of the present invention in which the profile consists of more than one main part.

Fig. 5 shows, in cross section, two main parts according to Fig. 4, brought together to a unit.

Fig. 6 shows, in perspective, two main parts according to Fig. 4, brought together to a unit.

Fig. 7 shows two main parts according to Fig. 4 brought together with the twisting made permanent by riveting together the main parts to each other.

Fig. 8 shows an additional part for the side portions of the unit.

Fig. 9 shows an additional part for the ends of the unit.

Fig. 10 shows a into desired twisting fixed unit having two main parts according to Fig. 4 and two additional parts according to Fig. 8 and one additional part according to Fig. 9 mounted thereon.

Fig. 11 shows how different pieces, at the end of a unit, move relative to each other and form a step.

Detailed description of embodiments of the invention

[0022] One, according to the invention, early step is to provide a unit 8 having two or more, along a longitudinal axis A-A, extended main part(s) 1. Different examples of said unit 8 are shown in Fig. 1 and Fig. 5, respectively. Different examples of said main part 1 are shown in Fig. 1 and Fig. 4, respectively. Said unit 8 has at least one longitudinal side portion 10 which extends between opposite ends of the unit 8. In the side portions 10 there is a first longitudinal surface 13a which faces an opposite second longitudinal surface 13b. Said main parts 1 can

be manufactured so that they, along its extension or their extensions, either has regarding shape and size fixed or regarding shape and/or size variable cross section profile.

[0023] In an example the unit 8 is formed of one single main part 1 having at least one longitudinal side portion 10. Such a side portion 10 shows a longitudinal slot or opening 3 lying between said first longitudinal surface 13a and said second longitudinal surface 13b. The blades illustrated in Figs. 1, 2, 3, and 11 are made according to this example.

[0024] According to the invention the unit 8, with said first longitudinal surface 13a facing said second longitudinal surface 13b, is formed of two or more main parts 1 which are brought together. Two or more of the main parts 1 may in this embodiment either be given mutually identical or mutually different cross section profiles. In the case two or more main parts 1 are given mutually identical cross section profiles the invention gives the advantage that the manufacturing costs can be reduced since a less number of tools for the shaping process will then be necessary. Said two or more main parts 1 are according to the invention provided with attachment details 9 which lock together the main parts 1 without at the same time eliminate the possibility of the main parts to move relative to each other in the direction of the longitudinal axis A-A. Even such attachment details 9 can reduce the manufacturing costs since these form one, in the unit built in and for the following steps of the method, facilitating fixture. The blade illustrated in Figs. 4, 5 6, and 7, which comprises a unit 8 composed of two main parts 1 with attachment details 9 and side portions 10, is made according to this embodiment.

[0025] The blade according Figs. 1, 2, and 3 has an asymmetrical cross section profile with a thicker, in the figures left part, which forms the leading edge 5a of the blade profile and a thinner, in the figures right part, which forms the trailing edge 5b of the blade profile, which, for blades which are not intended to be reversed with maintained performance, is advantageous from an aerodynamic perspective. The blades illustrated in Figs. 4, 5, 6, 7, and 11 have symmetric cross section profile which, for blades which are intended to be reversed with maintained performance, is advantageous from an aerodynamic perspective.

[0026] In a particularly preferred embodiment of the invention the unit 8 is shaped so that said first and second longitudinal surfaces 13a-b extend up to one or several cavities 2 formed within in the blade. Such cavities 2 are advantageous since they on one hand reduce the weight of the blade, which reduces the demand regarding structural strength of weight carrying parts, and on the other hand gives lower consumption of material, which in its turn gives lower manufacturing costs. In Figs. 1 and 5 two material and weight saving cavities 2 extend within the unit 8. The cavities 2, which extend in major parts of the left respective right half of the blade, are connected with the area outside the unit 8 by openings 3 situated between said first and said second longitudinal surfaces 13a-b.

[0027] The openings 3 run along the whole extension of the unit 8 in the direction of the longitudinal axis A-A and can be shaped so that said first and said second longitudinal surfaces 13a-b are not in contact with each other or so that they are in contact with each other, but yet

have the possibility to slide against each other in the direction of the longitudinal axis A-A. The first and second longitudinal surfaces 13a-b may have the same shape, so that they on an extended surface fit against each other, if they are in contact with each other, or different shape, so that they only will come into contact with each other along a line in the direction of the longitudinal axis A-A.

[0028] In further particularly preferred embodiments of the invention the main parts 1 are manufacture so that they, along their extension, are straight without twisting and/or have regarding the form and size fix cross section profile, so that a cross section through a main part 1 through a plan perpendicular to the longitudinal axis will look the same independently where along the longitudinal axis A-A the section is taken. The main part 1, according to such embodiments, may be produced in a particularly simple way through extrusion. The invention even allows that the main parts 1 are manufactured with an initial twisting along its extension for example with the purpose that the following rotation should be able to be limited to become an adjustment of said initial twisting. Furthermore, the invention allows that the main parts 1 have regarding the shape and/or size varying cross section profile, a suitable shaping method for the main parts can then be casting.

[0029] One, according to the invention, following step is to turn the unit around the longitudinal axis A-A so that one end of the unit 8 is turned relative to the other end of the unit 8, and that the first longitudinal surface 13a of said side portion or side portions 10 at the same time move relative to the opposite second longitudinal surface 13b in the direction of said longitudinal axis A-A. This step may be performed so that the twisting is either distributed evenly or unevenly along the extension of the unit 8. A bridge 7 extends along the longitudinal axis A-A in Fig. 1, which bridge connects the material at the pressure side 4b of the profile with the material of the suction side 4a of the profile, and in this way a unit 8 is formed with two cavities 2 separated from each other. Also in Fig. 5 a unit 8 is formed with two cavities 2 separated from each other when the main parts 1 are attached by the attachment details 9. When a moment is applied along the longitudinal axis A-A of the unit 8, according to any of the Figs. 1 or 5, the first longitudinal surface 13a will move relative to the second longitudinal surface 13b in the direction of the longitudinal axis A-A at both side portions 10 of the profile.

[0030] One according to the invention late step is to fixate said opposite first and second longitudinal surfaces 13a-b into each other in their, as a consequence of said turning relative to each other, new positions obtained and hereby make permanent the achieved twisting. In Figs. 1 and 4, respectively, the first and second longitudinal surfaces 13-b are not attached and the unit 8 would therefore spontaneously turn back to the straight shapes illustrated in Figs. 2 and 6, respectively, if such a twisting moment is removed. The fixation can be made in different ways, for instance by cwelding, riveting, upsetting, gluing or screwing. In Fig. 3 the desired twisting is shown made permanent by welding 6 together and in Fig. 7 by riveting 11 together of the first and second longitudinal surfaces 13-b of the unit to each other.

[0031] According to the invention the unit 8 is supplemented with one or several additional parts 12 which are arranged towards the main part 1 of the unit 8. Such supplementary

additional parts 12 may extend in the direction of the longitudinal axis A-A and be arranged against the side portions 10 of the main parts 1, for instance with the purpose of forming a portion of the exterior shape of the blade and/or to protect any part of the side portions 10 against exposure. Alternatively, supplementary additional parts 12 can be arranged towards the ends of the main parts 1 and then work as finishing parts. Such finishing parts can for instance form sealings, which on one hand protect inner cavities 2 of the unit 8 against exposure of impurities and on the other hand eliminate undesired flows of fluid within the unit 8. Said additional parts 12 may be manufacture so that they, along their extension, either have to form and shape fix or to form and/or size variable cross section profile. In the case they have fix cross section profile extrusion is an advantageous method of shaping. In the case the unit 8 is supplemented with more than one additional part 12 two or more of the additional parts 12 may in certain cases be given a mutual identical cross section profile and then obtain the advantage that the manufacturing costs can be reduced since less tools for the manufacturing method will be necessary. In view of the design of the main part 1 and of the additional part 12 and in view of the design of methods for turning and mounting on, the additional part 12 may be mounted on the unit 8 at the moment which is best suited; before, during or after turning of the unit 8. In the case the mounting of possible additional parts 12 is made before the turning of the unit 8, the attachment of the additional unit 8 can be performed simultaneously as the first and the second longitudinal surfaces 13a-b of the unit are fixated to each other in their relative to each other new positions.

[0032] The additional part 12 illustrated in Fig. 8 has a cross section which to its shape fits against, and may be pushed on to the side portions 10 of the main parts illustrated in Fig. 5 and may in this way on one hand form a portion of the external shape of the blade and on the other hand protect the joint 11 against exposing.

[0033] The additional part 12 according to Fig. 9 has a shape where the circumference corresponds to the external shape of the profile of the blade, and may, when it is mounted to the end of the blade, function as a sealing and then on one hand protect the inner cavities 2 of the unit 8 against exposing towards impurities and on the other hand eliminate unwanted flows of fluid within the unit 8. It should be mentioned that the invention is not limited to the forms of the additional part 12 as illustrated and combinations of the main part 1 and the additional part 12 as illustrated.

[0034] The symmetrical unit 8 illustrated in Fig. 10 is made up of two portions which are identical and along its extension uniform main parts 1. At both side portions 10 of the unit 8 and at one end of the unit 8 additional parts 12 are arranged. The unit 8 is turned to the desired twisting. The parts 1 mounted together and turned according to the figure form a complete blade which is ready to be mounted on a hub to a reversible axial fan.

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- GB713690A **[0009]**
- FR1144946A **[0010]**
- US2514525A **[0011]**

Patentkrav

1. Fremgangsmåde til fremstilling af vinger til strømningsmaskiner af aksial type, hvilken fremgangsmåde omfatter de følgende trin:
at tilvejebringe en enhed (8) ved at samle to eller flere hoveddele (1), der strækker sig langs en længdeakse (A-A), hvilke samlede hoveddele (1) danner enheden (8) med to langsgående sidedele (10), som strækker sig mellem to modstående ender af enheden (8), idet hver sidedel (10) omfatter en første langsgående overflade (13a), der vender mod en modstående anden langsgående overflade (13b)
at forsyne hoveddelen (1) med fastgørelseselementer (9), hvor fastgørelseselementerne (9) låser hoveddelene (1) sammen uden samtidig at fjerne muligheden for, at hoveddelene (1) bevæger sig i forhold til hinanden i retning af længdeaksen (A-A)
snoning af enheden (8) omkring længdeaksen (A-A), således at de første langsgående overflader (13a) af sidedelene (10) bevæger sig i forhold til de modstående andre langsgående overflader (13b) i retning af længdeaksen (A-A)
efter snoning til ønsket vinkelforskel mellem begge ender af enheden (8), fastgørelse af de første langsgående overflader (13a) af sidedelene (10) i deres i forhold til de modstående andre langsgående overflader (13b) af sidedelene (10) nye position, hvorved den opnåede snoning gøres permanent, og
placering af mindst én supplerende tillægsdel (12) mod enheden (8), hvorved den supplerende tillægsdel (12) strækker sig i retning af længdeaksen (A-A) og er placeret mod enhedens (8) sidedele (10).

2. Fremgangsmåde ifølge krav 1, hvorved hoveddelene (1) er fremstillet langs deres forlængelser med faste tværsnitsprofiler, og hvorved hoveddelene (1) fremstilles ved ekstrudering.

3. Fremgangsmåde ifølge krav 1, hvorved to eller flere af hoveddelene (1) har indbyrdes identiske tværsnitsprofiler.

4. Fremgangsmåde ifølge krav 1, hvorved den mindst ene supplerende tillægsdel (12) er fremstillet langs sine forlængelser med faste tværsnitsprofiler, og hvorved den mindst ene supplerende tillægsdel (12) fremstilles ved ekstrudering.

5. Fremgangsmåde ifølge krav 1, hvorved to supplerende tillægsdele (12), der er placeret ved forskellige positioner i enheden (8), har indbyrdes identiske tværsnitsprofiler.

6. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvorved trinnet med tilvejebringelse af en enhed (8) omfatter, forud for snoning, tilvejebringelse af én helt lige eller flere helt lige hoveddel(e) (1) uden snoning.

7. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvorved trinnet med tilvejebringelse af en enhed (8) omfatter fremstilling af de første langsgående overflader (13a) og de andre langsgående overflader (13b), således at de strækker sig ind i mindst ét hulrum (2), der dannes i enheden (8).

8. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvorved trinnene til fastgørelse af den første og anden langsgående overflade (13a-b) mod hinanden omfatter, at overfladerne er svejset, nittet, opstukket, limet eller skruet sammen.

DRAWINGS

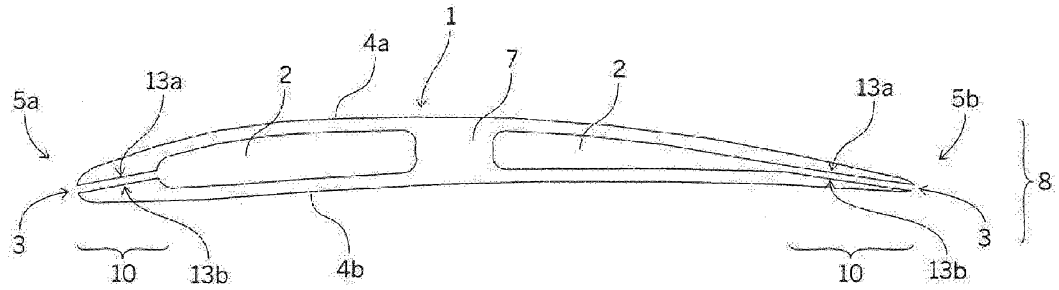

Fig. 1

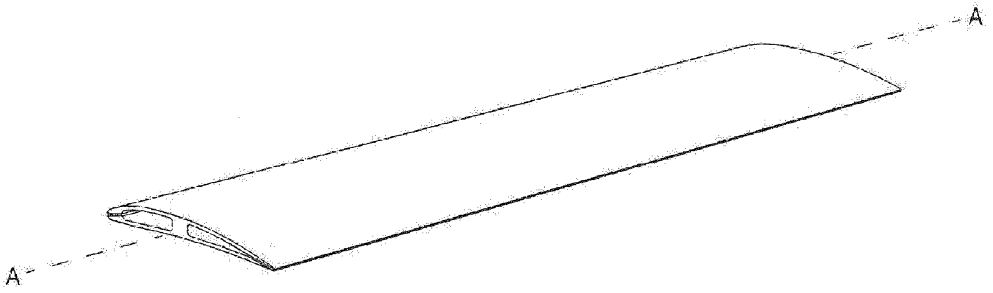

Fig. 2

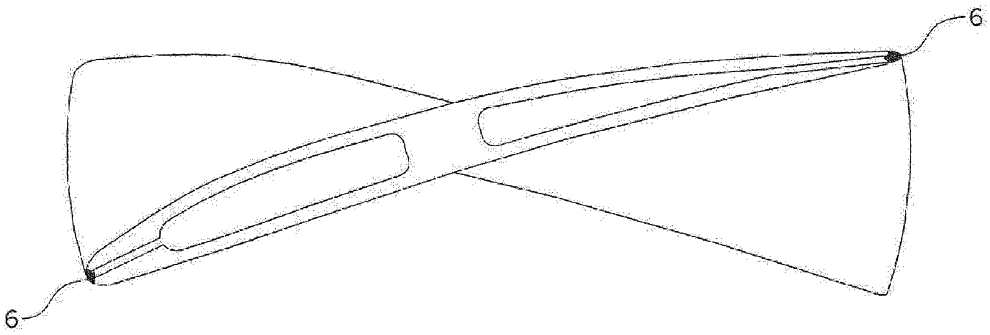

Fig. 3

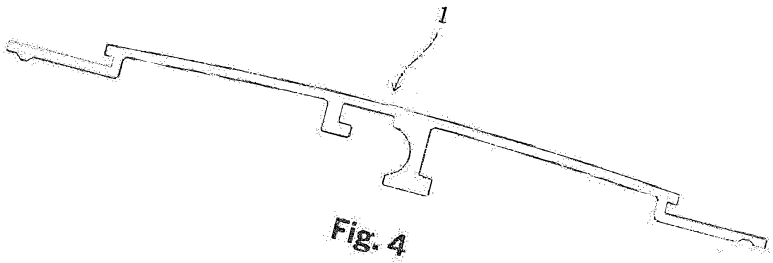

Fig. 4

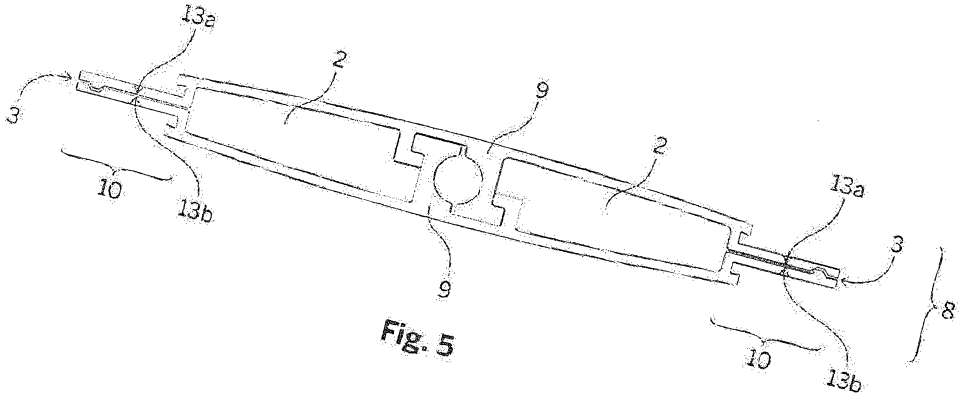

Fig. 5

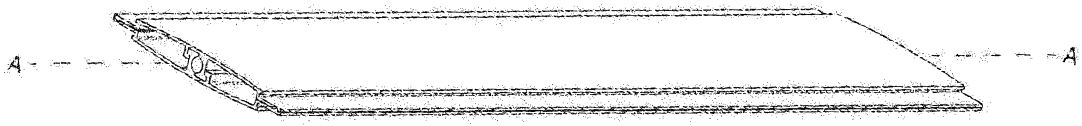

Fig. 6

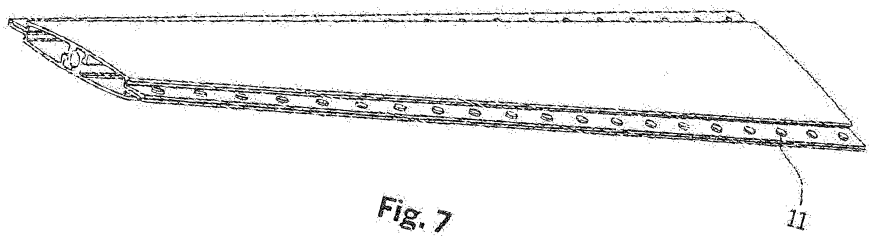

Fig. 7

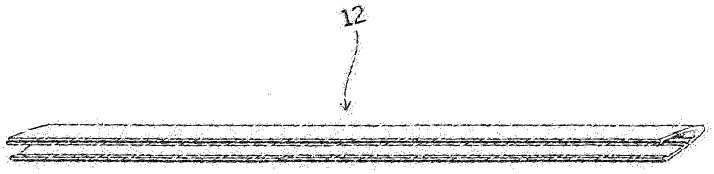

Fig. 8

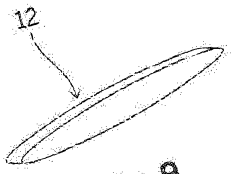

Fig. 9

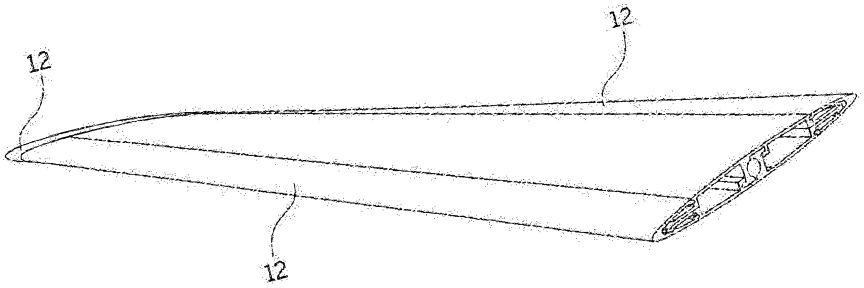

Fig. 10

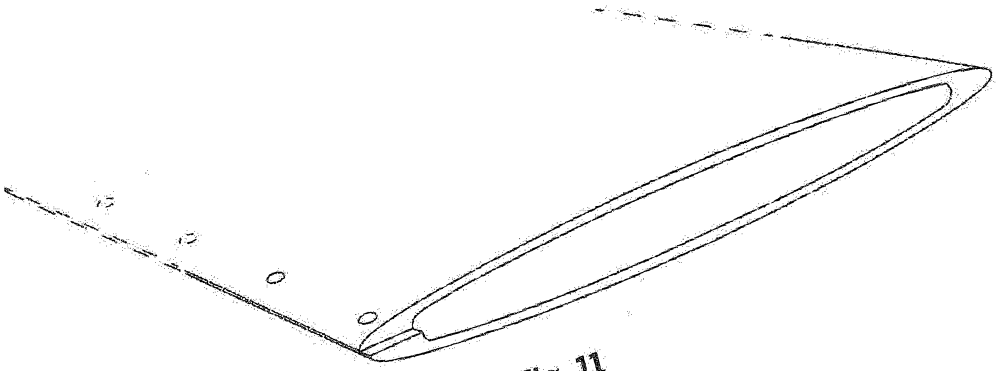

Fig. 11