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(54) Benævnelse: **ENTALPIVEKSLERELEMENT OG FREMGANGSMÅDE TIL FREMSTILLING HERAF**

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WO-A1-2013/091099
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DESCRIPTION

[0001] The present invention refers to enthalpy exchanger elements. Furthermore, the invention discloses a method for the production of enthalpy exchanger elements. Finally, the invention refers to an enthalpy exchanger including inventive enthalpy exchanger elements.

[0002] CA 2 798 892 concerns heat exchanger elements which for enthalpy exchangers with plate elements with defined outer dimensions and corrugations in an area within a border, whereby the plates are in predefined areas and in predefined dimensions perforated and the perforations are filled with a polymer with latent energy recovery capability.

[0003] It is state of the art to use different kinds of heat exchangers for different purposes. Usually, heat exchangers are used to recover heat energy from one fluid or medium into another one. This kind of heat energy is called sensible energy. The heat energy or sensible energy of one fluid, normally air, is recovered into another one which is running adjacent, e.g. parallel, counter or cross flow, to the first where the fluid is at lower temperature. By inversing fluid flows, the exchange between the two will generate a cooler fluid. Heat exchangers used for sensible energy recovery are usually made of metal or plastic plates. There are different types as there can be cross flow, parallel flow or counter flow configurations. The plates are defining flow channels between themselves so that the fluids can flow between the plates. Such devices are e.g. used in residential and commercial ventilation (HRV).

[0004] Another type of energy exchangers refers to the so called latent energy which is the moisture. To exchange the latent energy it is known to use desiccant coated metal or plastic substrates or membranes made from desiccant impregnated cellulose or polymer. Between plates made from cellulose or polymer, air passages are defined or created to allow the fluids to pass along the surface of the plates, thereby transferring moisture from one fluid to the other one. As the membranes usually have no structural strength, it is known to combine the membranes with frames or grids which thereby define spacings between the membranes.

[0005] In case of a combination of the above, the energy exchangers are called enthalpy exchangers. Those enthalpy exchangers allow for the exchange of sensible and latent energy, resulting in total energy recovery.

[0006] Membrane materials as currently available are delivered by the roll. The membrane material is the most critical part of an enthalpy exchanger. The membrane must be fixed and sealed to a kind of grid or frame and arranged in a way to allow for a fluid to flow between each membrane layer. So, it is obvious that enthalpy exchangers of the known art are a compromise. They will usually lose in sensible energy exchange to gain in latent energy exchange as a result of the selective scope and characteristics of currently used membranes.

[0007] Such an enthalpy exchanger built from respective elements is e.g. WO 02/072242 A1. On grids respective membranes made of fibers are positioned. The grids are stapled or

stacked thereby altering the direction of the plates in order to create different air flow directions.

[0008] In view of the mentioned state of the art it is an **object** of the invention to provide enthalpy exchanger elements and enthalpy exchangers as well as a method for the production of enthalpy exchanger elements which allow for the creation of Enthalpy exchangers whereby the efficiency of sensible energy exchange and latent energy exchange can be varied and controlled and especially improved.

[0009] With the invention, the **solution** of the above mentioned object is presented by the teaching of the method according to claim 1 which comprises the step of applying to at least one side of the plate element a polymer film with water vapor permeation characteristics (water vapor transfer ratio, WVTR).

[0010] Preferably, metal foil, more preferably aluminum foil, is used for the plate.

[0011] The plate may be perforated using at least one of pins, die and punch, laser, or the like.

[0012] Preferably, the border areas of the plate element are not perforated.

[0013] Preferably, the forming and a cutting to shape in step b) is performed by embossing using progressive stamping techniques on a metal stamping press with dies and tools, which are rather standard forming processes.

[0014] The polymer film may be made of a sulfonated copolymer, preferably a block copolymer.

[0015] The polymer film may be bonded, preferably heat bonded and/or glued, to the formed plate element.

[0016] With the invention, the **solution** of the above mentioned object is presented by an enthalpy exchanger element, produced using the method as defined in the previous paragraphs, including a plate element with a shape exhibiting a predetermined perforation pattern, wherein the plate element is formed into a desired embossing pattern and geometrical shape and at least one side of the plate element is covered by a thin polymer film with water vapor transmission characteristics (water vapor transfer ratio, WVTR).

[0017] Preferably, the plate element is made of metal foil, more preferably aluminum foil.

[0018] Preferably, the border areas of the plate element are not perforated, preferably in a range of 5 to 20 mm, more preferably in a range of 10 to 20 mm, from the outer dimensions of the plate element.

[0019] The shape of the plate element exhibits an embossing pattern. More preferably, the

perforated area of the plate element includes corrugated or embossed surface areas.

[0020] The polymer film may be made of a sulfonated copolymer, preferably a block copolymer.

[0021] The thin polymer film may be bonded, preferably heat bonded, to the plate element.

[0022] Preferably, the plate element has a border non-perforated area which allows gastight connection to another similar plate element.

[0023] Preferably, the perforations are openings of diverse shapes and with a surface area equivalent to hole diameters ranging from 50 µm to 5.0 mm. A total open area of no less than 50% of the available plate exchange surface is provided.

[0024] With the invention, the **solution** of the above mentioned object is presented by an enthalpy exchanger with at least three plates as enthalpy exchanger elements fixed to each other as a stack to form two fluid paths allowing fluids to flow there through, wherein the plates as enthalpy exchanger elements are elements as defined in the previous paragraphs.

[0025] Preferably, the enthalpy exchanger elements are fixed to each other by means of welding such as laser welding or ultrasonic welding, or by means of gluing.

[0026] According to the invention, a new hybrid exchanger element is provided which on one hand has enough structural strength and density to create air flow channels for any type of cross flow and/or counter flow energy exchanger, thereby allowing for the use of a structurally strong material which is good for sensible energy exchange, on the other hand by size and number of perforations or openings or holes it is possible to define an area which is covered by a thin polymer film with latent energy exchange characteristics. It will be appreciated by a person skilled in the art that the efficiency of sensible energy exchange on one hand and latent energy exchange on the other hand can be defined, controlled and adapted to the respective needs of the environment (dry air, humidity, outside temperature and the like).

[0027] According to the invention, the plate element can be made of a metal, preferably aluminum. The element can be provided with corrugations. Corrugations can be designed to optimize the efficiency to pressure drop ratio. The corrugations can be chosen to allow for creating flow channels between similar plates when those are stacked together. By the definition of the corrugation, one advantage will be the enhancement of the surface which is available for energy transfer. This can be built up as large as possible and can even reach an increase of 100% and more. Furthermore, the corrugations can be designed in a way to allow for the easy arrangement of counter flow or cross flow configurations, e.g. by choosing oriented corrugations and alternating the position of the plate.

[0028] The border of the plate defines an area where similar plates can be fixed together in an appropriate way. This can be welding and/or folding, hot crimping and the like. This stabilizes

the rigidity of the package as well as allows to build up the desired flow channels. The border area can be flattened, tongue/groove system, profiled or rimmed to allow for a tight sealable connection between plates.

[0029] The perforations can advantageously be performed prior to the plate forming step, which allows for a fast and convenient perforation step. That way plates can be perforated more easily and furthermore perforated in any desired area.

[0030] The polymer film can be made of a polymer according to the state of the art, e.g. like the product "Aquivion", a trademark of Solvay or "Nexar", a trademark of Kraton.

[0031] The material can be e.g. a ionomer in form of a copolymer produced from tetrafluoroethylene, C_2F_4, and Ethanesulfonyl fluoride, 1,1,2,2-tetrafluoro-2-[(trifluoroethenyl)-oxy], C_2F_3-O-$(CF_2)_2$-SO_2F, sulfonated block copolymer.

[0032] The thin polymer film may be a multilayer film comprising a sequence of polymer layers of different polymer types. Preferably, the polymer type of each polymer layer is selected from the group consisting of polyether ester, polyether amide and polyether urethane. Preferably the total thickness of the thin polymer multilayer film is between 5 µm and 200 µm, more preferably between 10 µm and 150 µm. Preferably, the thickness of each individual polymer layer within the thin polymer multilayer film is between 2 µm and 20 µm, more preferably between 5 µm and 20 µm.

[0033] However, the polymers can be adapted to the desired characteristic and features.

[0034] It will be appreciated by a person skilled in the art that the amount or efficiency of latent energy recovery depends on the surface provided by the holes or perforations, their shapes and their locations. So it is possible to adapt the heat exchanger plates to the environmental and functional conditions.

[0035] By using the highly heat conductive materials as the structural elements for the Enthalpy membrane, high sensible efficiency is ensured. By defining the perforations and choosing the polymer for water vapor transfer, high latent recovery is ensured. According to the invention, a total "open area" for water vapor transfer of no less than 50% of the available plate exchange surface is provided.

[0036] The polymer can be combined with additives to manifold and magnify its attributes. It can be, for instance, efficiently anti-bacterial and can meet fire resistance requirements (UL). Its viscosity can be adjusted to achieve the optimal tunable exchange features of the plate allowing as high a moisture exchange as possible.

[0037] Before applying the polymer film to the plate element, the plate element is formed to exhibit the aforementioned features, e.g. corrugations, side walls, flat border areas and the like. The polymer film is then formed into the same shape as the plate element and can be

permanently bonded or glued to said plate element. The bonding or gluing may be performed with or without heating.

[0038] The polymer film may be applied to one side of the plate element after the forming step of said plate element, thereby completely covering the plate element as well as the holes or perforations. Therefore the perforations are not limited in size and can be chosen in any desired dimension.

[0039] It will be appreciated by a person skilled in the art that the sensible energy transfer and the latent energy transfer capabilities of the heat exchanger are tunable and adjustable. The plates are adaptable to environmental conditions by the variable mosaic geometry of the perforations. E.g. an exchanger can be designed to operate at a temperature under the freezing point (-10°C) without ice build-up only by choosing the right position of the perforations and polymeric treatment of the constitutive plates.

[0040] However, under harsh conditions, especially plate exchangers tend to build ice in the narrow border channels, thus decreasing the exchange efficiency of the plate exchanger. This is due to a reduced flow velocity of fluids in said border channels.

[0041] In order to overcome this issue, the width of corrugations in the border area of the plate element is larger compared to the width of the corrugations in the middle area of the plate element. Thus, the width of the resulting flow channels in the border area is increased and as a result the flow velocity of the fluid is increased, thus preventing or at least delaying ice from building up.

[0042] The rigidity of the structural elements could make the plate and thereby the polymer film capable of handling a pressure differential up to 1kPa within the exchanger. This advantage opens the door to larger exchanger constructions for commercial applications.

[0043] The invention provides a simple method for the production of total energy exchanger plates allowing sensible as well as latent energy exchange. The design and the adaptability of the plates allows for the construction and design of plate exchangers which are optimized with regard to the technical requirements and/or the environmental conditions.

[0044] Stamped, corrugated or embossed aluminum, stainless steel, resin based plates and/or vacuum formed plastic plates can be made using proven automation technologies including the assembly, e.g. by vacuum grip, and seal, e.g. by laser welding, ultra sound welding, folding, crimping, to obtain packages of superposed rigid plates. The plates are washable, fire retardant, antibacterial, sealed e.g. leakage proof. They have all valuable advantages that are necessary to create highly efficient total energy exchangers.

[0045] The plate perforation, too, can be performed by pre-programmed continuous laser processes, by mechanical systems like needle-roller and the like, or chemical etching processes.

[0046] Further features, advantages and aspects of the invention become obvious from the following description of the drawings. The drawings show:

Fig. 1
: a flow chart illustrating a sequence of steps of the production method according to the invention; and

Fig. 2
: a sequence of states of the production of an enthalpy exchanger element in cross sectional view during the production method according to the invention.

[0047] In Fig. 1, a sequence of steps of the production method according to the invention are shown. Each step shown in Fig. 1 corresponds to a resulting state schematically shown in Fig. 2. It should be noted that the illustrated geometric parameters such a thicknesses, hole diameters, curvatures etc. in Fig. 2 are for exemplary purposes, only. Therefore, they do not necessarily represent the proper or preferred ratios of such parameters.

[0048] In providing step S1, a flat yet unformed metal plate element 1 with defined outer dimensions is provided. In perforating step S2, a portion of the flat metal plate element 1 is transferred to a perforation device (not shown) where the flat metal plate element 1 is perforated by a punching die (not shown) selected in accordance with the desired size of the holes. In the present case, the entire plate element 1 is perforated with a symmetric hole pattern, except for the border areas (not shown) to allow welding of the plate elements 1 in order to form the plate exchanger (not shown). The perforation pattern is made up of a plurality of holes 2 extending across the entire plate thickness from a first surface 1a to a second surface 1b of the plate element 1.

[0049] Subsequently to the perforating step, in plate forming step S3 (a first forming step), the now perforated flat plate element 1 is transferred to a first forming device (not shown), which is embodied by a metal stamping press with dies and tools or an embossing device, where the flat plate element 1 is formed into a desired shape. In this plate forming step S3, the border areas, fluid inlets and outlets and corrugations 4 are formed into the plate element 1. The corrugation pattern is made up of a plurality of corrugations 4 extending across the plate area.

[0050] Subsequently to the plate forming step S3, in plate contacting step S4, a thin polymer film 3 is moved next to one side, i.e. surface 1a, of the now perforated and formed plate element 1.

[0051] Subsequently to the plate contacting step S4, in polymer film forming step S5 (a second forming step), the now perforated, formed and polymer-film-contacted plate element 1 is then transferred to a second forming device (not shown), which is embodied by a thermoforming device, preferably a vacuum forming device, where said one side, i.e. surface 1a, of the now perforated, formed and polymer-film-contacted plate element 1 is completely covered by the

thin polymer film 3. The polymer film 3 is made of a proprietary sulfonated block copolymer or any type of such sulfonated block copolymers.

[0052] In the present embodiment of the invention, the border areas are being formed in non-perforated areas, while the corrugations are being formed in perforated areas of the plate element 1.

[0053] Thereby, during the plate forming step S3, which is a separate forming step of the flat plate element 1, and during the polymer film forming step S5, which is a separate forming step of the thin polymer film 3, the plate element 1 and the thin polymer film 3 are formed into the exact same shape and are permanently bonded to each other, due to the heat, which is applied by the vacuum forming device.

[0054] These first formed and then thin-polymer-film-covered plates 1 constitute the enthalpy exchanger plates according to the invention. They will be stacked to build an enthalpy exchanger (also referred to as a total energy exchanger) core e.g. for ventilation systems to exchange heat from outgoing to incoming air (or vice versa for free cooling in summer) as well as humidity from outgoing to incoming air in winter (or vice versa for moisture reduction in summer or all year round in hot and humid climatic zones).

[0055] The cross sectional shape of the corrugations 4 may be rectangular, square or triangular. It may also be trapezoidal such half hexagonal.

[0056] The drawing and the description do in no way restrict the invention and are meant for illustrating the invention by an example, only.

Reference numerals:

[0057]

1
: flat plate element

1a
: first surface

1b
: second surface

2
: hole

3
: thin polymer film

4
: corrugation

S1

providing step

S2

perforating step

S3

plate forming step (first forming step)

S4

plate contacting step

S5

polymer film forming step (second forming step)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CA2798892 [0002]
- WO02072242A1 [0007]

ENTALPIVEKSLERELEMENT OG FREMGANGSMÅDE TIL FREMSTILLING HERAF

Patentkrav

1. Fremgangsmåde til fremstilling af entalpivekslerelementer, der omfatter følgende trin:
   a) perforering af et fladt pladeelement (1) ifølge et forudbestemt perforeringsmønster inden for pladens ydre dimensioner;
   b) formning af pladeelementet (1) til et ønsket prægningsmønster og en ønsket geometrisk form; kendetegnet ved:
   c) påføring af en polymerfilm (3) med vanddamppermeabilitetskarakteristika på mindst én side (1a) af pladeelementet (1), hvorved der tilvejebringes et fuldstændigt åbent område til vanddampoverførsel på ikke mindre end 50 % af den tilgængelige pladevekslingsoverflade.

2. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at der til pladeelementet (1) anvendes metalfolie, fortrinsvis aluminiumfolie.

3. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at pladeelementet (1) perforeres under anvendelse af mindst ét ud af stifter, matrice og stempel, laser.

4. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at formdannelsen i trin b) og en udskæring udføres i henhold til progressive stempelteknikker på en metalstempelpresse med matricer og værktøjer.

5. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at polymerfilmen (3) fremstilles af en blokcopolymer.

6. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at polymerfilmen (3) bindes, fortrinsvis varmebindes, til det formede pladeelement (1).

7. Entalpivekslerelement, som er fremstillet under anvendelse af fremgangsmåden som defineret i et hvilket som helst af kravene 1 til 6, og som indbefatter et pladeelement (1) med en form, der har et forudbestemt perforeringsmønster, hvor pladeelementet (1) formes til et ønsket prægningsmønster og en ønsket geometrisk form, hvor mindst én side (1a) af pladeelementet (1) er belagt med en tynd

polymerfilm (3) med vanddamppermeabilitetskarakteristika, hvorved der tilvejebringes et fuldstændigt åbent område til vanddampoverførsel på ikke mindre end 50 % af den tilgængelige pladevekslingsoverflade.

8. Entalpivekslerelement ifølge krav 7, kendetegnet ved, at pladeelementet (1) fremstilles af metalfolie, fortrinsvis aluminiumfolie.

9. Entalpivekslerelement ifølge krav 7 eller 8, kendetegnet ved, at pladeelementets (1) grænseområder ikke er perforerede.

10. Entalpivekslerelement ifølge et hvilket som helst af de foregående krav 7 til 9, kendetegnet ved, at pladeelementets (1) form har et prægningsmønster.

11. Entalpivekslerelement ifølge et hvilket som helst af de foregående krav 7 til 10, kendetegnet ved, at den tynde polymerfilm (3) bindes, fortrinsvis varmebindes og/eller limes, til pladeelementet (1).

12. Entalpivekslerelement ifølge et hvilket som helst af de foregående krav 7 til 11, kendetegnet ved, at pladeelementet (1) har et ikke-perforeret grænseområde, der muliggør gastæt forbindelse til et andet tilsvarende pladeelement.

13. Entalpiveksler med mindst tre plader, som entalpivekslerelementer, fastgjort til hinanden som en stabel med henblik på at danne to fluidbaner, der gør det muligt for fluider at strømme derigennem, kendetegnet ved, at de mindst tre plader er entalpivekslerelementer ifølge et hvilket som helst af kravene 7 til 12.

14. Entalpiveksler ifølge krav 13, kendetegnet ved, at entalpivekslerelementerne fastgøres til hinanden under anvendelse af mindst ét ud af crimpe-, svejse- og limeprocesser.

DRAWINGS

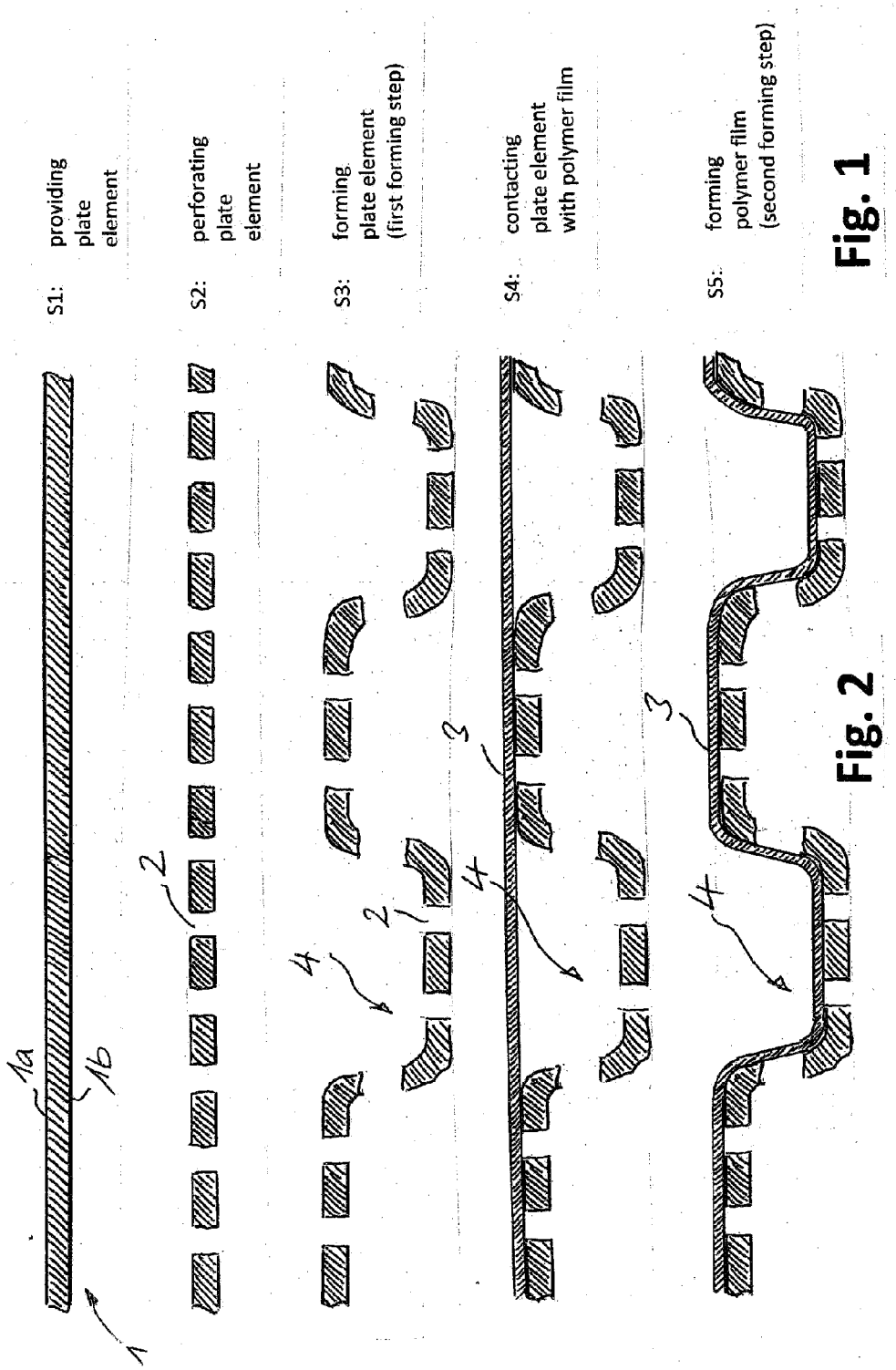

Fig. 1

Fig. 2