

DESCRIPTION

TITLE

ADSORPTION HEAT EXCHANGER

5

TECHNICAL FIELD

[0001]

The present disclosure relates to an adsorption heat exchanger.

10 BACKGROUND ART

[0002]

An adsorption heat exchanger having a surface on which an adsorption layer has been formed is known. For example, as described in Patent Document 1, the adsorption heat exchanger is provided for a humidity control apparatus configured to control the humidity of
15 air. Specifically, in this type of humidity control apparatus, the adsorption heat exchanger is provided for a refrigerant circuit for performing a refrigeration cycle. In an adsorption heat exchanger serving as an evaporator, moisture contained in air passing through the adsorption heat exchanger is adsorbed in the adsorption layer. In an adsorption heat exchanger serving as a condenser, the moisture desorbed from the adsorption layer is added to the air passing
20 through the adsorption heat exchanger.

[0003]

The adsorption heat exchanger includes a base sheet and an adsorbent supported on the base sheet by using a binder. The binder used can be, for example, an urethane resin.

25 CITATION LIST

PATENT DOCUMENT

[0004]

Patent Document 1: Japanese Unexamined Patent Publication No. 2009-019863

5 SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0005]

In the adsorption heat exchanger, adsorption performance may deteriorate, especially when the adsorption layer deteriorates in a short period of time.

10 [0006]

It is an object of the present disclosure to substantially prevent deterioration of the adsorption layer in the adsorption heat exchanger.

SOLUTION TO THE PROBLEM

15 [0007]

A first aspect of the present disclosure is directed to an adsorption heat exchanger (20) including: a base sheet (26); and an adsorbent (41) supported on the base sheet (26) by using a binder (42). The adsorption heat exchanger (20) satisfies at least one of a first condition in which amounts of the binder (42) and the adsorbent (41) supported after
20 immersing the base sheet (26) with the adsorbent (41) in 10% aqueous nitric acid solution for 40 hours at an environment temperature of 70°C are 32% to 100% of amounts of the binder (42) and the adsorbent (41) supported before the immersion, or a second condition in which amounts of the binder (42) and the adsorbent (41) supported after alternately exposing to a dry state at an environment temperature of 70°C and a humidity of 20% and a wet state with
25 water spraying over the adsorption heat exchanger (20), a total of 5000 times are 90% to

100% of amounts of the binder (42) and the adsorbent (41) supported before the exposure.

[0008]

In the first aspect, the adsorption heat exchanger (20) is configured to satisfy at least one of the first condition or the second condition. Thus, aging deterioration can be kept within
5 a desirable range when the adsorption heat exchanger (20) is practically used.

[0009]

A second aspect of the present disclosure is an embodiment of the first aspect. In the second aspect, the adsorption heat exchanger satisfies the first condition.

[0010]

10 In the second aspect, the adsorption heat exchanger (20) satisfies the first condition. Thus, aging deterioration can be kept within a desirable range when the adsorption heat exchanger (20) is practically used.

[0011]

15 A third aspect of the present disclosure is an embodiment of the first aspect. In the third aspect, the adsorption heat exchanger satisfies the second condition.

[0012]

In the second aspect, the adsorption heat exchanger (20) satisfies the second condition. Thus, aging deterioration can be kept within a desirable range when the adsorption heat exchanger (20) is practically used.

20 [0013]

In the fourth aspect of the present disclosure, the adsorption heat exchanger satisfies both the first and second conditions.

[0014]

25 In the fourth aspect, the adsorption heat exchanger (20) satisfies both the first and second conditions. Thus, aging deterioration can be kept within a desirable range more

reliably when the adsorption heat exchanger (20) is practically used.

[0015]

A fifth aspect of the present disclosure is an embodiment of any one of the first to fourth aspects. In the fifth aspect, an overall thickness of the binder (42) and the adsorbent (41) is in a range from 20 μm to 100 μm .

[0016]

A sixth aspect of the present disclosure is an embodiment of any one of the first to fifth aspects. In the sixth aspect, the binder includes at least one of a fluorine resin, an acrylic resin, an epoxy resin, or an urethane resin, and the crosslinking agent is a hydrocarbon having at least one of a carbodiimide group, an isocyanate group, or an ester group.

[0017]

In the sixth aspect, the adsorption heat exchanger can be realized by using specific materials described above as the respective components.

15 BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

FIG. 1 is a piping system diagram illustrating a configuration of a refrigerant circuit in a humidity control apparatus. In FIG. 1, an illustration (A) illustrates an operation during a first operation, and an illustration (B) illustrates an operation during a second operation.

20 FIG. 2 is a schematic perspective view of an adsorption heat exchanger.

FIG. 3 is a side view of a heat exchanger unit constituting the adsorption heat exchanger.

FIG. 4 is a sectional view taken along line A-A in FIG. 3.

FIG. 5 schematically illustrates a binder and an adsorbent provided on a base sheet.

25 FIG. 6 illustrates an example where a coating layer is provided on the base sheet in

FIG. 5.

FIG. 7 illustrates a test method of moisture permeability of the binder.

FIG. 8 illustrates moisture permeability of each type of binder and capacity of the adsorption heat exchanger.

5 FIG. 9 illustrates a test piece for testing tensile strength and the like of the binder.

FIG. 10 illustrates a relationship between elongation and tensile force applied for resins used in the binder.

DESCRIPTION OF EMBODIMENTS

10 [0019]

Embodiments of the present invention will be described in detail with reference to the drawings.

[0020]

<Configuration of Humidity Control Apparatus>

15 First, a humidity control apparatus provided with the adsorption heat exchanger (20) of the present embodiment will be described. The humidity control apparatus is configured to be capable of performing a dehumidifying operation in which dehumidified air is supplied into a room, and a humidifying operation in which humidified air is supplied into a room.

[0021]

20 As illustrated in FIG. 1, the humidity control apparatus includes a refrigerant circuit (10). The refrigerant circuit (10) is a closed circuit provided with a first adsorption member (11), a second adsorption member (12), a compressor (13), a four-way switching valve (14), and an electric expansion valve (15), and is filled with a refrigerant. The refrigerant fills and circulates in the refrigerant circuit (10) to perform a vapor compression refrigeration cycle.

25 The first adsorption member (11) and the second adsorption member (12) are both configured

as the adsorption heat exchanger (20) according to the present invention. Details of the adsorption heat exchanger (20) will be described later.

[0022]

In the refrigerant circuit (10), the compressor (13) has a discharge side connected to a first port of the four-way switching valve (14), and a suction side connected to a second port of the four-way switching valve (14). One end of the first adsorption member (11) is connected to a third port of the four-way switching valve (14). The other end of the first adsorption member (11) is connected to one end of the second adsorption member (12) via the electric expansion valve (15). The other end of the second adsorption member (12) is connected to a fourth port of the four-way switching valve (14).

[0023]

The four-way switching valve (14) is switchable between a first state (the state shown in the illustration (A) of FIG. 1) and a second state (the state shown in the illustration (B) of FIG. 1). In the first state, the first port and the third port communicate with each other, and the second port and the fourth port communicate with each other. In the second state, the first port and the fourth port communicate with each other, and the second port and the third port communicate with each other.

[0024]

<Configuration of Adsorption Heat Exchanger>

As mentioned above, the first adsorption member (11) and the second adsorption member (12) are each configured as the adsorption heat exchanger (20). The adsorption heat exchanger (20) will be described below with reference to FIGS. 2, 3, and 4.

[0025]

The adsorption heat exchanger (20) includes two subunits (21, 22) (see FIG. 2). The subunits (21, 22) each include a heat exchanger body (25), which is a so-called cross-fin-type

fin-and-tube heat exchanger, and an adsorption layer (30) formed to cover the surface of the heat exchanger body (25) (see FIG. 4). In the adsorption heat exchanger (20), two subunits (21, 22) are arranged to overlap each other, and a subunit located upstream of an air flow passing through the adsorption heat exchanger (20) is a first subunit (21), and a subunit located downstream of the air flow is a second subunit (22).

[0026]

The heat exchanger body (25) includes a circular heat transfer tube (27), which is a heat transfer tube member, and a plurality of fins (26). Each of the fins (26) is, for example, a rectangular plate-shaped member made of aluminum. The fins (26) stand to face each other, and are arranged in a row at regular intervals. The heat transfer tube (27) includes a straight tube (28) and a U-shaped tube (29) which are alternately formed into a meandering shape to the left and right. The heat transfer tube (27) is provided to penetrate the fins (26) in which the straight tube (28) is arranged. The straight tube (28) of the heat transfer tube (27) is joined to the fins (26), so that the outer peripheral surface of the straight tube (28) is in close contact with the fins (26).

[0027]

—Operation—

The humidity control apparatus allows the dehumidifying operation and the humidifying operation. The humidity control apparatus alternately repeats the first operation and the second operation at a predetermined time interval (e.g., at an interval of 3 minutes) during both the dehumidifying operation and the humidifying operation.

[0028]

The humidity control apparatus takes outdoor air (OA) as first air and indoor air (RA) as second air thereinto during the dehumidifying operation. The humidity control apparatus takes indoor air (RA) as first air and outdoor air (OA) as second air thereinto during

the humidifying operation.

[0029]

«First Operation»

First, the first operation will be described. During the first operation, the second air is
5 fed to the first adsorption member (11), and the first air is fed to the second adsorption
member (12). During the first operation, the four-way switching valve (14) is set to the first
state in the refrigerant circuit (10). Upon operation of the compressor (13), the refrigerant
circulates in the refrigerant circuit (10) to perform a refrigeration cycle. In this cycle, in the
refrigerant circuit (10), the first adsorption member (11) serves as a condenser, and the second
10 adsorption member (12) serves as an evaporator.

[0030]

Specifically, the refrigerant discharged from the compressor (13) dissipates heat and
condenses in the first adsorption member (11). The refrigerant that has condensed in the first
adsorption member (11) is decompressed while passing through the electric expansion valve
15 (15), and then adsorbs heat and evaporates in the second adsorption member (12). The
refrigerant that has evaporated in the second adsorption member (12) is sucked into the
compressor (13) and compressed, and is again discharged from the compressor (13).

[0031]

In the first adsorption member (11) configured as the adsorption heat exchanger (20),
20 the adsorption layer (30) on the surfaces of the fins (26) is heated by the refrigerant in the heat
transfer tube (27) and then desorbs moisture, and water vapor discharged from the adsorption
layer (30) is added to the second air. In the second adsorption member (12) configured as the
adsorption heat exchanger (20), the adsorption layer (30) on the surfaces of the fins (26)
absorbs moisture from the first air, and the refrigerant in the heat transfer tube (27) absorbs
25 heat generated at this time.

[0032]

Then, if the dehumidifying operation is in progress, the first air dehumidified in the second adsorption member (12) is supplied into the room, and water vapor discharged from the first adsorption member (11) is exhausted out of the room together with the second air. If the humidifying operation is in progress, the second air humidified in the first adsorption member (11) is supplied into the room, and the first air from which water vapor has been removed in the second adsorption member (12) is exhausted out of the room.

[0033]

〈Second Operation〉

Next, the second operation will be described below. During the second operation, the first air is fed to the first adsorption member (11), and the second air is fed to the second adsorption member (12). During the second operation, the four-way switching valve (14) is set to the second state in the refrigerant circuit (10). Upon operation of the compressor (13), the refrigerant circulates in the refrigerant circuit (10) to perform a refrigeration cycle. In this cycle, in the refrigerant circuit (10), the second adsorption member (12) serves as a condenser, and the first adsorption member (11) serves as an evaporator.

[0034]

Specifically, the refrigerant discharged from the compressor (13) dissipates heat and condenses in the second adsorption member (12). The refrigerant condensed in the second adsorption member (12) is decompressed while passing through the electric expansion valve (15), and then absorbs heat and evaporates in the first adsorption member (11). The refrigerant evaporated in the first adsorption member (11) is sucked into the compressor (13) and compressed, and is again discharged from the compressor (13).

[0035]

In the second adsorption member (12) configured as the adsorption heat exchanger

(20), the adsorption layer (30) on the surfaces of the fins (26) is heated by the refrigerant in the heat transfer tube (27) and then desorbs moisture, and water vapor discharged from the adsorption layer (30) is added to the second air. In the first adsorption member (11) configured as the adsorption heat exchanger (20), the adsorption layer (30) on the surfaces of the fins (26) absorbs moisture from the first air, and the refrigerant in the heat transfer tube (27) absorbs heat generated at this time.

[0036]

Then, if the dehumidifying operation is in progress, the first air which has been dehumidified in the first adsorption member (11) is supplied into the room, and water vapor which has been discharged from the second adsorption member (12) is exhausted out of the room together with the second air. If the humidifying operation is in progress, the second air which has been humidified in the second adsorption member (12) is supplied into the room, and the first air from which water vapor has been removed in the first adsorption member (11) is exhausted out of the room.

[0037]

<Adsorption Layer>

As illustrated in FIG. 4, the adsorption layer (30) is formed to cover both side surfaces of the fins (26). The adsorption layer (30) has a thickness of, for example, about 0.25 mm. The adsorption layer (30) is formed not only on the surfaces of the fins (26), but also on the surface of a portion (such as the U-shaped tube (29)) of the heat transfer tube (27) which is not covered with the fins (26). The thickness of the adsorption layer (30) formed on the portion other than the fins (26) may differ from the thickness of the adsorption layer (30) on the surfaces of the fins (26).

[0038]

The adsorption layer (30) contains an adsorbent made of an organic polymer material

having hygroscopic properties. In the adsorbent, a plurality of polymer main chains each having a hydrophilic polar group (hydrophilic group) in a molecule are crosslinked with each other, thereby forming a three-dimensional structure of the crosslinked polymer main chains. As the adsorbent, silica or a metal organic framework (MOF) may also be used.

5 [0039]

FIG. 5 is an enlarged schematic sectional view of the fin (26) and the adsorption layer (30) on the surface of the fin (26). Each fin (26) is formed using a base sheet made of aluminum, for example. The adsorption layer (30) contains an adsorbent (41) and a binder (42) for supporting the adsorbent (41). As illustrated in FIG. 6, the fin (26) may be formed
10 using a base sheet including a resin coating layer (43). The resin used in the coating layer (43) can be, for example, an epoxy resin. An overall thickness of the binder (42) and the adsorbent (41) is in a range from 20 μm to 120 μm .

[0040]

The adsorption layer (30) may deteriorate with the use of the adsorption heat
15 exchanger (20), and as a result, the adsorbent (41) may be detached from the fins (26). If the adsorbent (41) is detached, the performance of the adsorption heat exchanger (20) decreases. The present inventors have confirmed that a cause of the deterioration of the adsorption layer (30) is NO_x (nitrogen oxide) and SO_x (sulfur oxide) in the atmosphere. Based on the finding, it is effective to use a binder (42) that is resistant to nitric acid and sulfuric acid, especially
20 nitric acid, in order to substantially prevent deterioration of the adsorption layer (30).

[0041]

Specifically, in the adsorption heat exchanger (20) including a base sheet (fins (26)) and an adsorbent (41) supported by a binder (42) on the base sheet, the binder (42) preferably is resistant to nitric acid.

25 [0042]

As a more specific evaluation method, the binder (42) has a mass loss of preferably 35% or less, more preferably 20% or less, yet more preferably 10% or less when immersed in 10% nitric acid at 70°C for 40 hours. When such a binder is used, the adsorbent (41) detached with the use of the adsorption heat exchanger (20) can be reduced effectively.

5 [0043]

In addition, the binder (42) preferably has a constant moisture permeability in order for the adsorption heat exchanger (20) to exhibit its performance. Specifically, when a film having a thickness of 100 μm is formed of the binder (42) as a material, the moisture permeation amount of the film per day is preferably 85 g/m^2 or more, more preferably 120

10 g/m^2 or more.

[0044]

If the adsorbent (41) absorbs moisture and expands (the volume of the adsorbent (41) increases), the binder (42) having a high elongation percentage is used to address the expansion, thereby reducing the adsorbent (41) detached.

15 [0045]

The ratio of the volume of the adsorbent (41) when expanded (in the state where the adsorbent (41) absorbs moisture to the maximum extent) to the volume of the adsorbent (41) when dried is defined as an expansion rate and is expressed by %. The ratio of the length of a strip-like sample of the binder (42) at the time when the sample is broken by pulling both

20 sides thereof to the initial length of the strip-like sample is defined as an elongation percentage of the binder (42), and is expressed by %. At this time, the elongation percentage of the binder (42) is preferably equal to or greater than the cubic root of $(X/100)*100$ (%). The binder (42) having such an elongation percentage is desirable because the binder (42) is unlikely to be broken even when the adsorbent (41) expands.

25 [0046]

The binder (42) has a tensile strength of preferably 12 N/mm^2 or less, more preferably 8 N/mm^2 or less, yet more preferably 6 N/mm^2 or less. Such a binder (42) can be easily elongated in response to the expansion of the adsorbent (41), thereby reducing the adsorbent (41) detached.

5 [0047]

The adsorption heat exchanger (20) including a base sheet (fins (26)) and an adsorbent (41) supported on the base sheet by using a binder (42) preferably satisfies a first condition in which amounts of the binder (42) and the adsorbent (41) supported after immersing the base sheet (26) with the adsorbent (41) in 10% aqueous nitric acid solution for
10 40 hours at an environment temperature of 70°C are 32% to 100% of those before the immersion.

[0048]

When the adsorption layer (30) (the adsorbent (41) and the binder (42)) is detached from the fins (26), the performance of the adsorption heat exchanger (20) may decrease.
15 However, when the amount of the adsorption layer (30) supported after the detachment is sufficient, a desirable performance is maintained. Specifically, even if the adsorption layer (30) is detached due to the immersion in nitric acid, desirable performance of the adsorption heat exchanger (20) is maintained when the amount of the adsorption layer (30) supported after the immersion is 50% to 100% of the amount supported before the immersion. The
20 amount of the adsorption layer (30) supported is expressed by mass. In other words, the mass of the adsorption layer (30) supported can be determined from the mass of the heat exchanger body (25) and the mass of the adsorption heat exchanger (20) before and after the immersion in nitric acid.

[0049]

25 The deterioration of the adsorption layer (30) may occur also with the repeated use of

the adsorption heat exchanger (20). The adsorption heat exchanger including a base sheet and an adsorbent supported on the base sheet by using a binder preferably satisfies a second condition in which amounts of the binder and the adsorbent supported after alternately exposing to a dry state at an environment temperature of 70°C and a humidity of 20% and a wet state with water spraying over the adsorption heat exchanger (20), a total of 5000 times are 90% to 100% of those before the exposure.

[0050]

The adsorption heat exchange more preferably satisfies both the first and second conditions.

10 [0051]

In the adsorption heat exchanger (20) including a base sheet (fins (26)) and an adsorbent (41) supported by a binder (42) on the base sheet, the adsorbent (41) may be supported using the binder (42) and a crosslinking agent. The crosslinking agent used in addition to the binder (42) allows the adsorbent (41) detached to be reduced.

15 [0052]

The base sheet (fins (26)) may be made of aluminum, for example. The base sheet may or may not be made of aluminum having a surface which has been coated with resin such as an epoxy resin. The adsorbent (41) may contain at least one of sodium polyacrylate, silica, or a metal organic framework (MOF), and preferably contains sodium polyacrylate. The binder (42) may contain at least one of a fluorine resin, an acrylic resin, an epoxy resin, or an urethane resin, and may preferably contain an acrylic resin. The crosslinking agent may be a hydrocarbon having at least one of a carbodiimide group, an isocyanate group, or an ester group, and is more preferably a hydrocarbon having a carboxyl group. These components may be mixtures of them.

25 [0053]

The binder (42) is used in an amount of preferably 16 parts by mass or more to 70 parts by mass, and the crosslinking agent is used in an amount of preferably 20 parts by mass or more to 50 parts by mass or less, with respect to 100 parts by mass of the adsorbent (41).

[0054]

5 The binder (42) is used in an amount of more preferably 20 parts by mass or more, yet more preferably 23 parts by mass or more, and more preferably 50 parts by mass or less, yet more preferably 30 parts by mass or less, with respect to 100 parts by mass of the adsorbent (41).

[0055]

10 The crosslinking agent is used in an amount preferably corresponding to the amount of the binder (42) used and the acid value or hydroxyl value of the binder (42). Specifically, the crosslinking agent has a relative acid value or a relative hydroxyl value to be described later of preferably 20% or more to 50% or less.

[0056]

15 First, the acid value (AV) is defined as the amount of potassium hydroxide in milligrams required to neutralize 1 g of resin. The hydroxyl value (OHV) is defined as the amount of potassium hydroxide in milligrams corresponding to the hydroxyl value per 1 g of the sample. The molecular weight of the entire crosslinking agent molecule per 1 mol of reactive group (-NCN-) of the crosslinking agent is the NCN equivalent, and the amount of
20 the reactive group (NCO) moiety of the crosslinking agent per 1 g of the crosslinking agent in milligrams is the effective NCO wt%. The formula weight of potassium hydroxide is 56.1 g/mol, and the formula weight of NCO is 42 g/mol.

[0057]

 In the COOH crosslinking, the required amount of the crosslinking agent is
25 determined by the following equation:

Required Amount of Crosslinking Agent = Relative Acid Value x (Amount of Binder x AV/56.1) x NCN Equivalent/1000 mol

In the OH crosslinking, the required amount of the crosslinking agent is determined by the following equation:

5 Required Amount of Crosslinking Agent = Relative Hydroxyl Value x (Amount of Binder x OHV/56.1) x 42/(NCO%/100)/1000 mol.

In this equation, the relative acid value or the relative hydroxyl value is set to 20% to 50%, thereby determining the desired amount of the crosslinking agent.

[0058]

10 In other words, the crosslinking agent used preferably has an acid group or a hydroxyl group in an amount corresponding to 20% to 50% of an acid group or a hydroxyl group of the binder (42).

[0059]

15 The adsorbent (41) is supported preferably by using an additive in addition to the binder (42) and the crosslinking agent. As the additive, a hydrocarbon having a carboxyl group, a hydroxyl group having a hydroxyl group, or the like can be used, and a mixture thereof may also be used. In particular, the additive used is preferably a hydrocarbon having a carboxyl group.

[0060]

20 The additive is used in an amount of preferably 1 parts by mass or more to 5 parts by mass or less with respect to 100 parts by mass of the adsorbent (41). Further, the additive is used in an amount of more preferably 2 parts by mass or more, and more preferably 3 parts by mass or less, with respect to 100 parts by mass of the adsorbent (41).

[0061]

25 (Examples)

--Evaluation of Binder--

Table 1 shows evaluation results of chemical resistance of the binder. The binder used was, an acrylic resin, a fluorine resin, and an urethane resin. The crosslinking agent was used in an amount to have 25% (relative acid value) to the acid value of the binder. The crosslinking agent used was a crosslinking agent having a carbodiimide group.

[0062]

A test piece was prepared by causing sodium polyacrylate as an adsorbent to be supported, by using the binder and the crosslinking agent, on a base sheet made of aluminum. The test piece was immersed in 10% aqueous nitric acid solution and sulfuric acid in an environment of 70°C for 40 hours, and then, the state of the supporting was checked.

[0063]

As shown in Table 1, deterioration (detachment of the adsorbent) did not occur when the acrylic resin and the fluorine resin were used. In contrast, deterioration due to nitric acid occurred when the urethane resin was used.

[0064]

The fluorine resin is preferably a tetrafluoroethylene-based resin, and may be a copolymer. The fluorine resin is a copolymer of tetrafluoroethylene and a hydrocarbon monomer.

[0065]

Table 1 also shows changes in the amount supported in the case of the immersion in nitric acid.

[0066]

When the urethane resin was used, the amount supported before the immersion in nitric acid was 0.7103 g, which was reduced to 0.0104 g after the immersion (under the conditions described above), and only 1.46% remained.

[0067]

In contrast, when the acrylic resin was used, the amount supported was reduced from 0.7069 g to 0.23046 g, and 32.59% remained after the test. When the fluorine resin was used, the amount supported was reduced from 0.77779 g to 0.7393 g, and 95.04% remained after the test.

[0068]

As can be seen from the above, in the case where the fluorine resin is used, the reduction in the amount supported, due to nitric acid is small, and the degree of deterioration is small when fluorine resin is used in the adsorption heat exchanger. When the acrylic resin is used, the reduction in the amount supported, due to nitric acid is smaller than that when the fluorine resin is used, but is greatly superior compared to that when the urethane resin is used, and the degree of deterioration is small when the acrylic resin is practically used in the adsorption heat exchanger.

[0069]

It is desirable that the binder is resistant to both nitric acid and sulfuric acid. Many resins which are resistant to nitric acid have resistance to sulfuric acid. Therefore, to reduce cost, time, etc., only the resistance to nitric acid may be tested.

[0070]

[Table 1]

Binder	Acrylic Resin		Fluorine Resin		Urethane Resin	
Solution	Sulfuric Acid	Nitric Acid	Sulfuric Acid	Nitric Acid	Sulfuric Acid	Nitric Acid
Evaluation (Deterioration)	None	None	None	None	None	Present
Amount Supported before Immersion	—	0.7069	—	0.7779	—	0.7103
Amount Supported after Immersion	—	0.2304	—	0.7393	—	0.0104
Amount (%) Supported after Test	—	32.59	—	95.04	—	1.46

[0071]

The evaluation of the state of the adsorbent supported on the base sheet by using the binder has been described above. In addition to this, resin itself of the binder was also
5 evaluated.

[0072]

Specifically, samples of the acrylic resin, fluorine resin, and urethane resin were weighed, and then immersed in 10% aqueous nitric acid solution in an environment of 70°C. The samples were thereafter taken out, washed with water, dried for 1 hour at 100°C, and then
10 weighed.

[0073]

Table 2 shows the results. The reduction in weight due to the immersion in nitric acid was 16% for acrylic resin and 5% for fluorine resin. In these cases, the deterioration of the performance of the adsorption heat exchanger (20) with time is reduced to an allowable range.
15 In contrast, the reduction in weight due to the immersion in nitric acid was 38% for urethane resin. In this case, the deterioration of the performance of the adsorption heat exchanger (20) with time progresses beyond the allowable range.

[0074]

Chemical-induced changes in the samples were also checked by Fourier-transform
20 infrared spectroscopy (FT-IR) and thermo-gravimetric analysis (TG). The changes due to the acrylic resin and the fluorine resin before and after a chemical resistance test, checked by the FT-IR and TG were little or not shown. In contrast, the change due to urethane resin before and after the chemical resistance test was significant. In FT-IR, peak shift and peak increase, indicating the change in molecular structure, was found. Also in TG, an obvious change in
25 curve was found.

[0075]

For the above reason, the acrylic resin or the fluorine resin is desirable as a binder.

[0076]

[Table 2]

	Acrylic Resin	Fluorine Resin	Urethane Resin
Weight (g) before Immersion	0.114	0.146	0.121
Weight (g) after Immersion	0.095	0.138	0.075
Weight Loss Rate (%)	16	5	38
Determination	OK	OK	NG

5

[0077]

--Evaluation of Crosslinking Agent--

Table 3 shows evaluation results for the crosslinking agent. As a binder, a fluorine resin was used, and as a crosslinking agent, a crosslinking agent having an isocyanate group or a carbodiimide group was used. Table 3 also shows results of the case of using no crosslinking agent. The crosslinking agent was used in an amount to have 25% (relative acid value, relative hydroxyl value) of the acid value or the hydroxyl value of the binder.

10

[0078]

In the same manner as in the evaluation of the binder, an adsorbent was supported on a base sheet, which was then immersed in 10% nitric acid or 10% sulfuric acid in an environment of 70°C for 40 hours, and thereafter, the state of the supporting was checked.

15

[0079]

As can be seen from Table 3, deterioration occurred when no crosslinking agent was used. In contrast, no deterioration occurred when either crosslinking agent was used.

20

[0080]

[Table 3]

Crosslinking Agent	Isocyanate		Carbodiimide		None	
Solution	Sulfuric Acid	Nitric Acid	Sulfuric Acid	Nitric Acid	Sulfuric Acid	Nitric Acid
Evaluation (Deterioration)	None	None	None	None	Present	Present

[0081]

--Dry-Wet Cycle Test--

- 5 An adsorption heat exchanger (20) in which an adsorption layer (30) was supported on a heat exchanger body (25) by using a binder was repeatedly subjected to a test (dry-wet cycle test) of alternately exposing to the dry and wet states to evaluate detachment of the adsorbent.

[0082]

- 10 The dry state is specifically a state where the adsorption heat exchanger (20) is installed in a test chamber maintained at 70°C and a humidity of 20%, and air is ventilated at an average air velocity of 2.0 mm/sec. The wet state is a state where water is sprayed to cause the adsorption layer (30) to fully adsorb water. The dry-wet cycle test is repeatedly performed a total of 5000 times by alternately exposing to the dry state for 9 minutes and 55 seconds and
- 15 the wet state for 5 seconds.

[0083]

- More specifically, for example, a duct is installed in a thermostatic bath set at 70°C, a plurality of test samples (30 mm × 100 mm) of the heat exchanger are arranged at an inlet of the duct. The test samples are exposed to air at an average air velocity of 2.0 m/sec by
- 20 blowing air into the duct from an air blower. A water spray nozzle is installed opposite to the inlet of the duct to spray water on the test samples. For each spray (the wet state), approximately 400 ml of distilled water is used. The water spray is adjusted to ensure that 1/4 to 1/8 of the upwind side of each test sample is wet.

[0084]

Before the adsorption layer (30) is supported, the mass of the heat exchanger body (25) was measured, and the mass of the adsorption heat exchanger (20) before and after the dry-wet cycle test was measured to determine the changes in the amounts (masses) of the binder (42) and the adsorbent (41) supported before and after the test.

[0085]

When the amounts supported after the dry-wet cycle test is 90% to 100% of the amounts supported before the test, sufficient performance of the adsorption heat exchanger (20) is maintained at the time when the adsorption heat exchanger (20) is practically used.

10 [0086]

Table 4 shows results of the dry-wet cycle test of Examples 1 and 2 and Comparative Examples 1 and 2 to be described below.

[0087]

(Example 1)

15 As a binder, a 1 : 1 (mass ratio) mixture of a fluorine resin and an acrylic resin was used. As a crosslinking agent, a crosslinking agent having a carbodiimide group was used. The crosslinking agent was used in an amount to have 25.5% (relative acid value, relative hydroxyl value) of the acid value or the hydroxyl value of the binder. An adsorbent was supported on a base sheet made of aluminum by using the binder and the cross-linking agent.

20 Thus, a test sample of Example 1 was obtained.

[0088]

(Example 2)

As a binder, an acrylic resin was used. The type and amount of the crosslinking agent used are the same as those in Example 1. An adsorbent was supported on a base sheet made of

25 aluminum by using the binder and the cross-linking agent. Thus, a test sample of Example 2

was obtained.

[0089]

(Comparative Example 1)

As a binder, an urethane resin was used, and a crosslinking agent was not used. An
5 adsorbent was supported on a base sheet made of aluminum by using the binder. Thus, a test
sample of Comparative Example 1 was obtained.

[0090]

(Comparative Example 2)

As a binder, an acrylic resin was used, and a crosslinking agent was not used. An
10 adsorbent was supported on a base sheet made of aluminum by using the binder. Thus, a test
sample of Comparative Example 2 was obtained.

[0091]

Table 4 shows test results of the two examples and the two comparative examples. In
Comparative Examples 1 and 2, the adsorbent was not detached when the number of
15 repetitions was more than about 1000. However, in Comparative Example 1, the adsorbent
was detached when the number of repetitions exceeded 3000, and in Comparative Example 2,
the adsorbent was detached when the number of repetitions was 5000 or less.

[0092]

In contrast, in Example 1, the adsorbent was not detached even when the number of
20 repetitions exceeded 7000, and was finally detached when the number of repetitions exceeded
10000.

[0093]

In Example 2, the adsorbent was not detached even when the number of repetitions
was 8530.

25 [0094]

As can be seen from above, when the crosslinking agent is further used in addition to the acrylic resin or fluorine resin, the adsorbent is not detached even after a total of 5000 cycles of the dry-wet cycle test. With such a configuration, the degree of deterioration of the performance as the adsorption heat exchanger with time is within the allowable range.

5 [0095]

[Table 4]

	Example 1	Example 2	Comparative Example 1	Comparative Example 2
Binder	Fluorine Resin+ Acrylic Resin	Acrylic Resin	Urethane Resin	Acrylic Resin
Crosslinking Agent	Used	Used	Disuse	Disuse
Number of Times repeated	7325	844	1015	1093
Loss	None	None	None	None
Number of Times repeated	10401	8530	3034	4793
Loss	Present	None	Present	Present

[0096]

10 Table 5 shows the amounts supported after the dry-wet cycle test in the case where the fluorine resin, acrylic resin, and urethane resin were each used as a binder. Each sample was prepared by causing an adsorbent to be supported on a base sheet made of aluminum by using each binder, and the amount supported at the time 5452 cycles of the dry-wet cycle test were ended is shown.

[0097]

15 As can be seen from Table 5, when the fluorine resin or the acrylic resin was used, the residual rate of the binder and the adsorbent was 100.00% after a total of 5452 cycles of the test, which indicated that the adsorbent was not detached. In contrast, when the urethane resin was used, the residual rate was 89.97% after a total of 5452 cycles of the test, which

indicated that 10% or more of the adsorbent was detached.

[0098]

As can be seen from above, the use of the fluorine resin or acrylic resin is desirable because the amounts of the binder and the adsorbent supported after the dry-wet cycle test (the number of repetitions: 5000) is kept at 90% or more of the amounts supported before the test, and the deterioration of the adsorption heat exchanger is substantially prevented.

[0099]

[Table 5]

	Acrylic Resin	Fluorine Resin	Urethane Resin
Residual Rate	100.00	100.00	89.97
Determination	OK	OK	NG

10 [0100]

--Evaluation of Moisture Permeability of Binder--

The type of the binder affects the performance of the adsorption heat exchanger.

Thus, resin used as a binder desirably realizes at least the performance which is similar to that of the known adsorption heat exchanger in addition to having excellent chemical resistance.

15 In this regard, the inventors have found that the moisture permeability of the binder correlates with the performance of the adsorption heat exchanger (20). Thus, the moisture permeability of each binder was evaluated.

[0101]

FIG. 7 illustrates a test method of moisture permeability of the binder. A binder resin film (54) is obtained by forming a resin used as a binder into a film with a thickness of 100 μm . An opening of a container (51) which does not permeate moisture is sealed with the binder resin film (54). A sufficient amount of desiccant (52) is placed in the container (51), and the humidity is set to 0%. The container (51) is placed in a thermostatic bath (51). The

thermostatic bath (51) is maintained at a temperature of 25°C and a humidity of 90%.

[0102]

In this way, moisture permeates from the thermostatic bath (51) (outside the container (51)) through the binder resin film (54) and moves into the container (51) (indicated by arrow (53)) because of the difference in humidity between the thermostatic bath (50) and the container (51) across the binder resin film (54). Thus, by measuring the change in mass of the container (51) (the mass of the container (51) including the binder resin film (54) and the desiccant (52)) with time, the amount of moisture that has permeated the binder resin film (54) can be measured.

10 [0103]

FIG. 8 shows the moisture permeability of four types of binder resin films (54) (film thickness: 100 μm) of an urethane resin, a fluorine resin, a 1 : 1 mixture of a fluorine resin and an acrylic resin, and an acrylic resin. The unit is $\text{g}/\text{m}^2\cdot\text{day}$, i.e., the moisture permeation amount (g) per day, of 1 m^2 of the film converted. The measurements were taken several times, and each result is represented by a black circle ($\bullet$), and an average value is represented by a hollow square ($\square$).

[0104]

FIG. 8 further shows the performance of the adsorption heat exchanger using each resin as a binder by a relative value to the performance of the adsorption heat exchanger using an urethane resin as a binder as 100%.

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[0105]

In the case where only the fluorine resin was used, the moisture permeability was 60.42 $\text{g}/\text{m}^2\cdot\text{day}$, and the performance of the adsorption heat exchanger was 84.8% relative to that using the urethane resin. In the case where a 1 : 1 mixture of the fluorine resin and the acrylic resin was used, and the case where only the acrylic resin was used, the moisture

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permeabilities were $86.52 \text{ g/m}^2\cdot\text{day}$ and $136.45 \text{ g/m}^2\cdot\text{day}$, and the performances of the adsorption heat exchangers were 89.7% and 90.2% relative to that using the urethane resin.

[0106]

The moisture permeability is preferably $85 \text{ g/m}^2\cdot\text{day}$ or more in order to substantially prevent the reduction in performance of the adsorption heat exchanger compared to that using the urethane resin. However, it is conceivable to use a fluorine resin in consideration of other factors.

[0107]

--Tensile Strength and Elongation Percentage of Binder--

Depending on the type, adsorbents expand (increase in volume) when they absorb moisture. For example, sodium polyacrylate expands by water absorption. At this time, if the binder can be elongated in response to the expansion of the adsorbent, deterioration such as detachment of the adsorbent due to breakage of the binder can be substantially prevented.

[0108]

Specifically, the ratio of the volume of the adsorbent (41) when expanded (in the state where the adsorbent (41) adsorbs moisture to the maximum extent) to the volume of the adsorbent (41) when dried is defined as an expansion rate and is expressed by %.(the expansion rate is 200% when the volume doubles in the expansion, and is 100% when there is no change in volume due to the expansion, and the like).

[0109]

The ratio of the length L of a strip-like sample of the binder (42) when the sample is broken by pulling both sides thereof to the initial length L_0 of the strip-like sample is defined as an elongation percentage of the binder (42), and is expressed by %. That is, the elongation percentage is $(L/L_0)*100$ (%).

[0110]

If the elongation percentage of the binder is the cubic root of $X/100 \times 100$ (%) or more when the expansion rate of the adsorbent is represented by X (%), the binder is sufficiently elongated in response to the expansion of the adsorbent, and can avoid breakage.

[0111]

5 FIG. 9 shows the test method of the elongation percentage. A test piece (60) which is 1 cm in width, 7 cm in length, and 10 μm to 300 μm in film thickness was prepared by using resin used as a binder. Holding regions (61) of 1 cm at both ends of the test piece are held between chucks, and pulled toward both sides until the test piece (60) breaks. Since the initial distance between the chucks is equal to the length (5 cm) of the elongation region (62), the
10 elongation percentage can be obtained by measuring the distance between the chucks at the time of breakage.

[0112]

The elongation of dimensions is the cubic root of X when the expansion rate of the adsorbent is X . Thus, when the elongation percentage of the binder resin film (54) is equal to
15 or higher than the cubic root of X , breakage of the binder due to expansion of the adsorbent can be substantially prevented.

[0113]

The binder (42) has a tensile strength of preferably 12 N/mm^2 or less, more preferably 8 N/mm^2 or less, yet more preferably 6 N/mm^2 or less. Such a binder (42) can be
20 easily elongated in response to the expansion of the adsorbent (41), thereby reducing the adsorbent (41) detached.

[0114]

In this regard, FIG. 10 shows a relationship between the elongation ($L - L_0$) and an applied force (force per sectional area) for a urethane resin, a fluorine resin, and mixtures of a
25 fluorine resin and an acrylic resin. The mixtures include three kinds of mixtures of the

fluorine resin : the acrylic resin with a mixing ratio by mass of 3 : 7, 5 : 5, and 7 : 3. The applied force increases with the increase in the elongation, and the force drops to zero when the resin breaks.

[0115]

5 The elongation at breakage exceeds 50.0 mm, the length at the breakage exceeds 100.0 mm compared to the initial length of 50.0 mm. That is, the elongation percentage is 200% or more.

[0116]

 The expansion rate of the sodium polyacrylate is about 200%. Thus, when the
10 elongation percentage of the binder is about equal to or higher than the cubic root of $(200/100)*100$, i.e., about 126% or more, the breakage can be substantially prevented. Thus, all examples shown in FIG. 10 satisfy the condition.

[0117]

 When the adsorbent expands, it is desirable that the resin used as a binder is easily
15 elongated. In other words, it is preferable to use a binder that is elongated with a smaller force because the binder is easily elongated in response to the expansion of the adsorbent. Specifically, the tensile strength is desirably 12 N/mm^2 or less. The tensile strength is more preferably 8 N/mm^2 or less, yet more preferably 6 N/mm^2 or less.

[0118]

20 Therefore, from this viewpoint, it is preferable to use a mixture of a fluorine resin and an acrylic resin.

[0119]

 While the embodiments have been described above, it will be understood that various changes in form and details may be made without departing from the spirit and scope of the
25 claims. The embodiments and the variations thereof may be combined and replaced with each

other without deteriorating intended functions of the present disclosure.

INDUSTRIAL APPLICABILITY

[0120]

5 As can be seen from the foregoing description, the present disclosure is useful for an adsorption heat exchanger.

DESCRIPTION OF REFERENCE CHARACTERS

[0121]

- 10 20 Adsorption Heat Exchanger
- 25 Heat Exchanger Body
- 26 Fin (Base Sheet)
- 30 Adsorption Layer
- 41 Adsorbent
- 15 42 Binder
- 43 Coating Layer
- 50 Thermostatic Bath
- 51 Container
- 52 Desiccant
- 20 53 Arrow
- 54 Binder Resin Film
- 60 Test Piece
- 61 Holding Region
- 62 Elongation Region

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CLAIMS

1. An adsorption heat exchanger comprising:

a base sheet (26); and

5 an adsorbent (41) supported on the base sheet (26) by using a binder (42), wherein
the adsorption heat exchanger (20) satisfying at least one of a first condition in which
amounts of the binder (42) and the adsorbent (41) supported after immersing the base sheet
(26) with the adsorbent (41) in 10% aqueous nitric acid solution for 40 hours at an
environment temperature of 70°C are 32% to 100% of amounts of the binder (42) and the
10 adsorbent (41) supported before the immersion, or

a second condition in which amounts of the binder (42) and the adsorbent (41)
supported after alternately exposing to a dry state at an environment temperature of 70°C and
a humidity of 20% and a wet state with water spraying over the adsorption heat exchanger
(20), a total of 5000 times are 90% to 100% of amounts of the binder (42) and the adsorbent
15 (41) before the exposure.

2. The adsorption heat exchanger of claim 1,
satisfying the first condition.

20 3. The adsorption heat exchanger of claim 1,
satisfying the second condition.

4. The adsorption heat exchanger of claim 1,
satisfying both the first and second conditions.

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5. The adsorption heat exchanger of any one of claims 1 to 4, wherein
an overall thickness of the binder (42) and the adsorbent (41) is in a range from 20
μm to 100 μm.

5 6. The adsorption heat exchanger of any one of claims 1 to 5, wherein
the binder includes at least one of a fluorine resin, an acrylic resin, an epoxy resin, or
an urethane resin, and
the crosslinking agent is a hydrocarbon having at least one of a carbodiimide group,
an isocyanate group, or an ester group.

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