TOP PLATE STRUCTURE FOR AIR CONDITIONER INSTALLED AT HIGH PLACE

An air conditioner has a body casing for receiving a fan and a fan motor, heat exchanger, drain pump, switch box, etc. and has a top plate placed at a top surface of the body casing and hanging the fan and fan motor, heat exchanger, drain pump, switch box, etc. The top plate is thinned to a thickness not more than a predetermined value. Reinforcement ribs are formed to radially extend from the central portion of the top plate, which supports the fan and motor, to an outer peripheral portion, which supports the heat exchanger. A section between each reinforcement rib is formed flat. The number, cross-sectional shape (shape of drawing), depth, width, etc. of the reinforcement ribs are optimally adjusted. As a result, the construction eliminates the need of forming a large number of auxiliary reinforcement ribs etc. conventionally used. In addition, the rigidity, strength, deflection characteristics, vibration characteristics, etc. of the top plate can be improved to a required level.
The distance between the main reinforcement ribs 32a increases at the peripheral side of the top plate 32. This levels by the main reinforcement ribs 32a. Hollowing depth, are formed in a heat exchanger support located at the outer side of the main reinforcement ribs 32a. From the top plate 32 with a width and depth set to predetermined values. A plurality of steps 32b, with a small downward extend from the central portion 33 to the peripheral portion 35. The main reinforcement rib 32a is hollowed downward portion 35 for supporting the generally annular heat exchanger 4. A plurality of main reinforcement ribs 32a radially the main body casing 3, is formed on the periphery of the top plate 32.

A rim 32c, which has a hooked cross-sectional for fitting into the periphery of the upper end of the main body casing 3, is formed on the periphery of the heat exchanger 4. The cassette type main body casing 3 is, for example, generally hexagonal and includes a side wall 31 made of a heat insulating material and a top plate 32 covering the upper part of the side wall 31.

A tube plate 11 is arranged on the two open ends of the heat exchanger 4, and the tube plates 11 are connected by a predetermined partition plate 12. The top plate 32 of the main body housing 3, the tube plate 11, the partition plate 12, and a switch box 13 attached to the lower surface of the bell-mouth 6 are all made of steel plate products. For example, the top plate 32 and the switch box 13 are respectively fixed to the upper end and the lower end of the partition plate 12 by screws, as shown in Fig. 14.

A cavity 14 for accommodating the switch box 13 is formed in the bell-mouth 6. A switch box connection portion 15 is formed at the lower end of the partition plate 12. An opening 16 facing the switch box connection portion 15 of the partition plate 12 is formed at the top surface 14a of the cavity 14. A pair of spaced upper attachment tabs 17 serving as a coupling portion for the top plate 32 are integrally formed at the upper end of the partition plate 12. The upper attachment tabs 17 are attached to the top plate 32 from underneath by a screw 18.

A pair of spaced attachment tabs 19 serving as a coupling part for the lower end of each tube plate 11 are integrally formed at the lower end of the partition plate 12. A middle attachment tab 15 serving as a coupling portion for the switch box 13 is welded and fixed to the lower end of the partition plate 12 at the middle part of the lower attachment tabs 19. The lower attachment tabs 19 are fixed to the tube plate 11 from underneath by a screw 20. The middle attachment tab 15 includes an L-shaped basal portion 15a serving as a coupling portion for the partition plate 12. An attachment tab 15b extending downward is integrally formed with the distal end of the basal portion 15a. The middle attachment tab 15 is fixed to the top surface 13a of the switch box 13 from underneath by a screw 21 with the attachment tab 15b facing into the cavity 14 from the opening 16.

A drain pump 22 and a float switch 23 are arranged in a drain pump accommodation portion 24. The drain pump accommodation portion 24 is partitioned by a partition plate 25. The switch box 13 is covered by a lid cover 26.

The basic rigidity, strength, deflection, and vibration characteristics of the top plate 32 are set at the desired levels by the main reinforcement ribs 32a. The distance between the main reinforcement ribs 32a increases at the peripheral side of the top plate 32. This results in insufficient rigidity, strength, etc. of the top plate 32.
A plurality of sub-reinforcement ribs 34 are thus formed between and adjacent to the plurality of main reinforcement ribs 32a, as shown in Fig. 15. The sub-reinforcement ribs 34 are formed to have the desired shape and size in correspondence with the magnitude and the like of the assumed load.

The static deflection of the top plate 32 is set to be lower than or equal to a constant value by the main reinforcement rib 32a, the step 32b, and the sub-reinforcement rib 34 when designing the air conditioner. Further, a primary characteristics frequency of the top plate 32 is maintained to be greater than or equal to a constant value to avoid resonance produced by the rotation of the fan motor 9.

A reinforcement rib 33a is also formed at the inner side of the support for the fan 5 and the fan motor 9 located at the central portion 33 of the top plate 32. The reinforcement rib 33a is formed to have a generally triangular shape when viewed from above. The reinforcement rib 33a improves the rigidity, strength, deflection, and the vibration characteristics of the support for the fan 5 and the fan motor 9.

A circular hollowed groove is formed at each corner of the base and vertex of the support for the fan 5 and the fan motor 9 reinforced by the reinforcement rib 33a. Attachment portions a, b, and c of the fan motor 9 are formed in the center of each hollowed groove. The fan motor 9 is suspended from the attachment portions a, b, and c of the fan motor 9 by a mount member 9m, which has a vibration absorbing characteristics, and an attachment bracket 9b. The fan 5 is also rotatably supported relative to the attachments a, b, and c of the fan motor 9 described above by a motor shaft 9a.

DISCLOSURE OF THE INVENTION

Cost reduction of the air conditioner described above has become necessary in view of various aspects, and the top plate 32 is no exception.

As a method for reducing cost, the present plate thickness (e.g., 0.8 mm) of the top plate 32 may be decreased (e.g., about 0.7 to 0.6 mm) to reduce the material cost and improve the processing characteristics for forming ribs.

However, in such a case, the rigidity and the strength of the top plate 32 decreases, and a vibration measure becomes necessary when driving the fan 5.

The material cost is reduced by decreasing the plate thickness of the top plate 32 from the present plate thickness. Further, processing characteristics may be improved since the pressure applied during press formation may be small. This improves processing characteristics.

However, when the thickness of the top plate 32 is decreased in the prior art structure, the amount of static deflection increases and the primary characteristics frequency decreases during rotation of the fan motor 9 in the conventional structure. Thus, design requirements cannot be satisfied at the same level as in the prior art structure.

Moreover, since the prior art top plate 32 includes many reinforcement ribs having complicated shapes, the cost of a die used to press the top plate 32 increases. Additionally, creases, cracks, warp, etc. tend to easily form when pressing the top plate 32.

Accordingly, it is an object of the present invention to provide a top plate structure for an air conditioner installed at high locations that may be made thinner, regardless of behavior of the top plate when the fan is driven, and has the desired rigidity, strength, and vibration characteristics.

To achieve the above object, one aspect of the present invention is a high location installation type air conditioner including a main body casing for accommodating a fan, a fan motor, a heat exchanger, a drain pump, and a switch box and a top plate arranged on a top surface of the main body casing for suspending the fan, fan motor, heat exchanger, drain pump, and switch box. The top plate structure of the high location installation type air conditioner is characterized by a central portion for supporting the fan motor and a peripheral portion for supporting the heat exchanger, a plurality of reinforcement ribs formed to extend radially from the central portion to the peripheral portion, and a flat surface extending between the reinforcement ribs.

In such top plate structure for a high location installation type air conditioner, many sub-reinforcement ribs having a complicated shape do not need to be formed like in the prior art by optimally adjusting the number and cross-sectional shape (drawing shape), depth, width, and the like of the plurality of reinforcement ribs even if the top plate is thinner than in the prior art. Further, the rigidity, strength, deflection, vibration characteristics, and the like of the top plate are improved to the desired level.

Accordingly, in comparison to when using many sub-reinforcement ribs, processing characteristics are satisfactory and the structure for the pressing die is simplified. Thus, unnecessary deformation, cracking, warping, and the like subsequent to processing do not occur.

Further, the manufacturing cost can be reduced since the thickness of the top plate is reduced and the processing characteristics is improved.

In the above structure, it is desirable that a step be formed in a support for the heat exchanger located at the periphery of the reinforcement ribs. In this case, the top plate is positioned at an optimal location for supporting the heat exchanger. This ensures that the heat exchanger is supported at the positioned location. Thus, the support state is further
stabilized. As a result; the vibration characteristics of the top plate is improved. Further, the step improves the strength of the reinforcement rib in the lateral direction. This further improves the deflection characteristics of the top plate.

[0032] In the above air conditioner, it is desirable that the reinforcement ribs be arranged on a support for the fan motor located at the central portion of the top plate. This improves the rigidity, strength, and vibration characteristics of the fan motor support located at the central portion of the top plate.

[0033] In the above air conditioner, it is preferred that the plate thickness of the plate be greater than or equal to 0.6 mm and less than 0.8 mm. In this case, the material cost is decreases as the top plate becomes thinner, and pressing is facilitated.

[0034] However, the strength and the rigidity of the top plate decreases, and the deflection and vibration characteristics are adversely affected. To compensate for this, the reinforcement ribs of the above structure are effective. However, there are limits when using only the reinforcement ribs, and the plate thickness must be greater than a predetermined thickness.

[0035] In view of the relationship between the plate thickness of the prior art product and the effect of the reinforcement ribs described above, the appropriate plate thickness of the top plate that reduces the material cost, improves the processing characteristics, and ensures the desired quality performance is preferably greater than or equal to 0.6 mm and less than 0.8 mm.

[0036] Therefore, with the top plate structure for a high location installation type air conditioner according to the present invention, stable support rigidity, support strength, and low noise capacity are achieved while decreasing the thickness of the top plate and reducing costs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Fig. 1 is a bottom view showing the structure of a top plate portion of an air conditioner (in a state in which a heat exchanger is attached) according to a preferred embodiment of the present invention;

Fig. 2 is a bottom view showing the structure of the top plate portion of the air conditioner (in a state in which the heat exchanger is not attached);

Fig. 3 is a front view showing the top plate portion;

Fig. 4 is an enlarged cross-sectional view taken along line 4-4 of Fig. 2;

Fig. 5 is an enlarged cross-sectional view taken along line 5-5 of Fig. 2 and showing the structure of a reinforcement rib, which is an essential part of the top plate portion;

Fig. 6 is a bottom view showing the structure of a conventional model manufactured under a specification structure similar to the top plate portion of Fig. 1;

Fig. 7 is a graph showing the relationship between the plate thickness and the attachment method of the heat exchanger that affects maximum deflection of the top plate;

Fig. 8 is a graph showing the relationship between the plate thickness and the attachment method of the heat exchanger that affects the resonance rotation speed of the top plate;

Fig. 9 is a graph showing the relationship between the maximum deflection amount of the top plate and the depth of the sub-reinforcement rib;

Fig. 10 is a graph showing the relationship between the resonance rotation speed of the top plate and the depth of the sub-reinforcement rib;

Fig. 11 is a graph showing the relationship between the maximum deflection amount of the top plate and the depth of the main reinforcement rib;

Fig. 12 is a graph showing the relationship between the resonance rotation speed of the top plate and the depth of the main reinforcement rib;

Fig. 13 is a central cross-sectional view showing the entire structure of an air conditioner in the prior art, the cross-section of the top plate portion corresponding to a cross-section taken along line 13-13 in Fig. 15;

Fig. 14 is a bottom view taken from the lower side of the air conditioner of Fig. 13 in a state in which a cosmetic panel and a main body casing are removed; and

Fig. 15 is an exploded perspective view showing the attachment relationship of the top plate, a bell-mouth, and a switch box of the air conditioner of Fig. 13.

BEST MODE FOR CARRYING OUT THE INVENTION

[0038] Figs. 1 to 5 show a top plate structure for a high location installation type air conditioner according to a preferred embodiment of the present invention.

[0039] A top plate 32 of the present embodiment is applied to the main body casing 3 (see Fig. 3) of a ceiling embedment
The top plate 32 has a plate thickness $D_4$ of about 0.7 mm, which is thinner than the prior art 0.8 mm, and the top plate 32 is shaped to be generally hexagonal shape in correspondence with the shape of the cassette type main body casing 3 of the air conditioner, as shown in Figs. 1 and 2. A rim 32c, which has a hook-shaped cross-section for fitting into the periphery of the upper end of the main body casing 3, is formed around the periphery of the top plate 32.

The top plate 32 includes a central portion 33, which supports the fan 5 and the fan motor 9 shown in Figs. 13 to 15, and a peripheral portion 35, which supports a generally annular heat exchanger 4. A plurality of reinforcement ribs 32a extend radially from the central portion 33 to the peripheral portion 35. As shown in Figs. 4 and 5, each reinforcement rib 32a is formed by downwardly hollowing of the top plate 32 and has a reversed trapezoidal cross-section. Each reinforcement rib 32a has a bottom surface with a width of $W_1$, an upper end with a width set of $W_2$, a depth of $D_2$, and a peripheral portion 35, which supports a generally annular heat exchanger 4. The downward hollowing depth $D_3$ for each step 32b is set to be smaller than $D_2$ by a predetermined dimension.

A reinforcement rib 33a having a depth of $D_1$ is also formed at the support for the fan 5 and the fan motor 9 at the central portion 33 of the top plate 32 ($D_1=D_2$). In other words, the depth $D_1$ of the reinforcement rib 33a formed at the support is equal to the depth $D_2$ of the reinforcement ribs 32a. The reinforcement rib 33a extends between five fan motors supports a to e enabling three point and four point support and are in contact with the inner sides of the supports a to e of the fan motor 9 (see Figs. 1 and 2).

The reinforcement rib 33a effectively improves the rigidity, strength, deflection, and vibration characteristics of the supports of the fan 5 and the fan motor 9.

Furthermore, heavy objects such as the heat exchanger 4, the fan 5, the fan motor 9, a drain pump 22, a switch box 13, and the like are attached to the top plate 32 of the present embodiment, as shown in Fig. 1, in the same manner as in the prior art.

As described above, in the present embodiment, a plurality of the reinforcement ribs 32a radially extend from the central portion 33 of the top plate 32 at where the fan 5 and the fan motor 9 are supported to the peripheral portion 35 of the top plate 32 at where the heat exchanger 4 is supported. Further, the surface between the reinforcement ribs 32a is flat.

As a result, even if the top plate 32 has a decreased plate thickness compared with the prior art, many sub-reinforcement ribs 34 or the like do not need to be formed by optimally adjusting the quantity, cross-sectional shape (drawing shape), depth, width, and the like of the reinforcement ribs 32a. Further, the rigidity, strength, deflection, vibration characteristics, and the like of the top plate 32 may also be improved to the desired level.

Therefore, distortion, unnecessary deformation, crack, warp, or the like after processing are not produced since processing characteristics are satisfactory and the structure of the pressing mode is simplified compared to when combining many sub-reinforcement ribs 34 or the like.

The manufacturing cost can be reduced as the plate thickness of the top plate 32 is decreased and processing characteristics are improved.

In such a structure, the steps 32b are formed at the support of the heat exchanger 4 at the outer side of the reinforcement ribs 32a.

Therefore, when supporting the heat exchanger 4 with the top plate 32, appropriate positioning is performed to support the heat exchanger 4 with the top plate 32. Furthermore, the heat exchanger 4 is supported in a state in which it is engaged with the steps 32b. This further stabilizes the support state.

As a result, vibration characteristics of the top plate 32 is further improved.

The steps 32b enhance the strength of the reinforcement rib 32a in the widthwise direction. Thus, deflection characteristics of the top plate 32 are also further improved.

Moreover, in the above structure, the reinforcement ribs 32a are also formed at the periphery of the supports a to e for the fan 5 and the fan motor 9 located at the central portion 33 of the top plate 32. Thus, the rigidity, strength, and vibration characteristics of the support for the fan 5 and the fan motor 9 are also improved at the central portion 33 of the top plate 32.

In the present embodiment, the plate thickness of the top plate 32 is preferably greater than or equal to 0.6 mm and less than 0.8 mm.

As the plate thickness of the top plate 32 decreases, the material cost is reduced, and the pressing is facilitated.

However, the strength and the rigidity of the top plate 32 decreases, and deflection and vibration characteristics are adversely affected. Although the reinforcement ribs 32a of the above structure are effective in compensating for this, there are limits with only the reinforcement ribs 32a. Thus, the plate thickness of the top plate 32 must be greater than a predetermined thickness.

In view of the relationship between the plate thickness (0.8 mm) of the conventional product and the effect of the reinforcement rib 32a described above, the appropriate plate thickness of the top plate 32 that decreases the material
cost, improves processing characteristics, and ensures the desired quality performance is preferably greater than or equal to 0.6 mm and less than 0.8 mm.

Therefore, according to the top plate structure of the high location installation type air conditioner of the present embodiment, stable supporting rigidity, supporting strength, and lower noise performance are achieved while reducing the thickness of the top plate 32 and cost as much as possible.

(Experimental Example)

In order to actually check the above effect, that is, the influence of the arrangement, depth, length etc. of the reinforcement rib 32a on the behavior of the top plate 32, for example, as shown in Fig. 6, the top plate 32 having the same structure (including main reinforcement ribs 32a and sub-reinforcement rib 34) as the prior art example shown in Figs. 13 to 15 was manufactured with the same specification (plate thickness, shape, support of fan 5 and fan motor 9) as the top plate 32 of the present embodiment shown in Fig. 2. The strength and vibration for each plate were analyzed. The finite element method analysis (FEM analysis), which is one approximation analysis method for analyzing deformation and stress of a structural object, was used in this analysis. In this analysis, finite element analysis software (I-DEAS MS9m2 Model Solution manufactured by EDF Co.) was used.

(1) Analysis Model

In both the air conditioner of the embodiment shown in Fig. 2 and that of the prior art example (present) shown in Fig. 6, the top plate 32 was modeled by shell elements of four nodes using heavy objects, such as the heat exchanger 4, the fan 5, the fan motor 9, the drain pump 22, and the switch box 13 that are attached to the top plate 32, as concentrated mass elements, and the connection of the top plate 32 and the heavy objects was modeled as a rigid body element.

Points A to E in Figs. 2 and 6 indicate the attachment positions of the heat exchanger 4, and supports a to e indicate the attachment positions of the fan 5 and the fan motor 9.

The drain pump 22 was fixed to the heat exchanger 4 to act as a load on the top plate 32 through points A to E, which are the attachment positions for the heat exchanger 4.

The switch box 13 is also fixed to the bell-mouth 6. Thus, the load acting on the top plate 32 through the attachment position thereof was unknown.

The following two methods are methods for attaching the heat exchanger 4 and the fan motor 9 to the top plate 32. Each method for the heat exchanger 4 and the fan motor 9 has been analyzed.

<In the Case of Heat Exchanger 4>

(First Method)

Attachment at three points A, B, and C in Figs. 2 and 6.

(Second Method)

Attachment at four points A, B, D and E in Figs. 2 and 6.

<In the Case of Fan Motor 9>

(First Method)

Attachment at three points a, b, and c in Figs. 2 and 6.

(Second Method)

Attachment at four points a, b, d and e in Figs. 2 and 6.

(2) Analysis Sample

2-1) Air conditioner of the present embodiment shown in Fig. 2

The plate thickness $D_4$ was 0.7 mm, and the depth $D_2$ of the reinforcement rib 32a was between 8.8 to 12.8 mm.
2-2) Air Conditioner of Prior Art Example shown in Fig. 6

<Sample 1>

[0070] The top plate 32 had a plate thickness $D_{4}$ of 0.8 mm, the depth $D_{2}$ of the reinforcement rib 32a was 8.8 mm, and the depth $D_{5}$ of the sub-reinforcement rib 34 was 8.8 mm.

<Sample 2>

[0071] The top plate 32 had a plate thickness $D_{4}$ of 0.7 mm, the depth $D_{2}$ of the reinforcement rib 32a was 8.8 mm, and the depth $D_{5}$ of the sub-reinforcement rib 34 was 8.8 mm.

<Sample 3>

[0072] The top plate 32 had a plate thickness $D_{4}$ of 0.6 mm, the depth $D_{2}$ of the reinforcement rib 32a was 8.8 mm, and the depth $D_{5}$ of the sub-reinforcement rib 34 was 8.8 mm.

(3) Analysis Method

[0073] Dynamic analysis and the static analysis were performed on each top plate 32 in a state in which the periphery of each top plate 32 was fixed, with the above heavy objects attached. Only the weight of the top plate 32 and each heavy object were taken into consideration in the static analysis, and the moment of inertia of each heavy object was not taken into consideration in the dynamic analysis. Since the ratio $W_{a}$ of the weight of the switch box 13 acting on the top plate 32 was unknown, the mass and the center of mass position of each heavy object (ratio of the weight of the switch box 13 acting on the top plate 32) $W_{a}$ were varied at 25.0% to 100.0%. The mass and the center of mass position of each heavy object are shown in table 1.

<Mass and Center of Mass Position of Each Heavy Object>

[0075]
<table>
<thead>
<tr>
<th>Heavy Object</th>
<th>Motor</th>
<th>Fan</th>
<th>Heat Exchanger</th>
<th>Drain Pump</th>
<th>Ratio $W_\alpha$ of Weight of Switch Box Acting on Top Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.396</td>
<td>2.417</td>
<td>7.373</td>
<td>0.8158</td>
<td>100.0%</td>
</tr>
<tr>
<td>Mass ($\times 10^{-4}$kgf$^2$/mm)</td>
<td>1.529</td>
<td>1.148</td>
<td>0.7645</td>
<td>0.3822</td>
<td>75.0%</td>
</tr>
<tr>
<td>Center of Mass(mm)</td>
<td>0.0,0.0,56.7</td>
<td>0.0,0.0,126.5</td>
<td>0.0,0.0,126.7</td>
<td>326.0,276.0,150.0</td>
<td>50.0%</td>
</tr>
<tr>
<td></td>
<td>150.0,-296.5,300.0</td>
<td></td>
<td></td>
<td></td>
<td>25.0%</td>
</tr>
</tbody>
</table>
Materials shown in table 2 were used as the material of each top plate 32.

<table>
<thead>
<tr>
<th>Item</th>
<th>Material</th>
<th>Young’s Modulus (kgf/mm²)</th>
<th>Poisson’s Ratio</th>
<th>Density (kgf²/mm⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>SECD-DKA</td>
<td>21078.7</td>
<td>0.29</td>
<td>7.97×10⁻¹⁰</td>
</tr>
</tbody>
</table>

(SECD-DKA : Galvanized Steel Plate in Compliance With JIS G 3313)

The overall evaluation was performed based on the result of the prior art top plate 32 (plate thickness D₁=0.8 mm) shown in Fig. 6 as the reference. Maximum deflection (mm) and resonance rotation speed (rpm) of the top plate 32 were used as evaluation items. Maximum Mises stress was not used as an evaluation item but will be described for reference. This is because the maximum Mises stress is produced at the attachment part (or the vicinity thereof), which is a singular point of stress. The Mises stress is a representative equivalent stress used in comparing the value at the triaxial stress field with a uniaxial stress value (e.g., data value obtained through material experiment).

(4) Analysis Result

The following analysis results were obtained from the above analysis.

The following result evaluation was performed based on the prior art example (present) of Fig. 6 shown in table 3.

<Analysis Result of Prior Art Example (Present Top Plate 32) of Fig. 6>
### Table 3

<table>
<thead>
<tr>
<th>Plate Thickness (mm)</th>
<th>Maximum Deflection (mm)</th>
<th>Maximum Mises Stress (kgf/mm²)</th>
<th>Resonance Rotation Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>1.30</td>
<td>8.70</td>
<td>742.0</td>
</tr>
</tbody>
</table>
The attachment method of the heat exchanger 4, plate thickness $D_4$, change in the maximum deflection, the maximum Mises stress and the resonance rotation speed of the top plate 32 resulting from differences in the ratio $W_\alpha$ of the weight of the switch box 13 acting on the top plate 32 are shown in tables 4 and 5. The order shown in table 5 indicates the order of characteristics frequency. The influence of the plate thickness $D_4$ and the ratio $W_\alpha$ of the weight of the switch box 13 on the maximum deflection and the resonance rotation speed are shown in Figs. 7 and 8. The following observations were obtained.

4-1) In the second method of the heat exchanger 4, the maximum deflection of the top plate 32 barely changed compared to the first method, whereas the resonance rotation speed was apparently higher than the first method. It can be apparent from this result that the second method is superior. Therefore, the second method was used in the following analysis.

4-2) When varying the ratio $W_\alpha$ of the weight of the switch box 13 between 25.0% and 100.0%, the maximum deflection of the top plate 32 increased by about 4.0% in the first method. As a result, the rigidity of the top plate 32 decreased. The resonance rotation speed decreased by about 14.0%. As a result, the behavior of the top plate 32 was improved. In the second method, the maximum deflection was increased by about 3.0%. This increasing width was smaller than the first method. Further, the resonance rotation speed decreased by about only 2.0%. In either case, the influence of $W_\alpha$ on the behavior of the top plate 32 was limited. Thus, $W_\alpha$ was 50.0% in the following analysis.

4-3) As a result, it is obvious that the maximum deflection of the top plate 32 is significantly increased and the resonance rotation speed is drastically decreased as the plate thickness $D_4$ decreases. It is assumed that the plate thickness $D_4$ of the top plate 32 must be greater than or equal to 0.8 mm in order to ensure the same behavior (see table 3) as the prior art top plate 32.

4-4) <Ratio $W_\alpha$ of the Weight of Switch box 13 Acting on Top Plate 32 and Change in Maximum Deflection and Maximum Mises Stress of Top Plate 32 Resulting from Difference in Plate Thickness $D_4$>
## Table 4

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>Heat Exchanger Attached (1st Method)</th>
<th>Heat Exchanger Attached (2nd Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Deflection (mm)</td>
<td>Maximum Mises Stress (kgf/mm²)</td>
</tr>
<tr>
<td></td>
<td>$W_{\alpha}$</td>
<td>$W_{\alpha}$</td>
</tr>
<tr>
<td>0.8%</td>
<td>1.23</td>
<td>1.21</td>
</tr>
<tr>
<td>50.0%</td>
<td>1.57</td>
<td>1.54</td>
</tr>
<tr>
<td>25.0%</td>
<td>2.09</td>
<td>2.05</td>
</tr>
</tbody>
</table>
[0087] <Ratio $W_{13}$ of Weight of Switch Box 13 Acting on Top Plate 32 and Change in Resonance Rotation Speed Resulting from Difference in Plate Thickness $D_4$>
## Table 5

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>Order</th>
<th>$W_{\alpha}$ (1st Method)</th>
<th>$W_{\alpha}$ (2nd Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>1</td>
<td>728.5</td>
<td>985.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>978.6</td>
<td>1173.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1181.4</td>
<td>1214.9</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1189.7</td>
<td>1755.4</td>
</tr>
<tr>
<td>0.7</td>
<td>1</td>
<td>622.3</td>
<td>870.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>860.4</td>
<td>1021.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1027.3</td>
<td>1052.9</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1030.1</td>
<td>1515.9</td>
</tr>
<tr>
<td>0.6</td>
<td>1</td>
<td>518.3</td>
<td>751.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>738.1</td>
<td>868.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>869.7</td>
<td>891.1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>873.6</td>
<td>1277.3</td>
</tr>
</tbody>
</table>
Influence of Weight of Fan 5 and Attachment Method of Fan Motor 9 (When Attachment Method of Heat Exchanger 4 is Second Method)

In the following analysis, the second method was employed as the attachment method for the heat exchanger 4, and the ratio $W_\alpha$ of the weight of the switch box 13 acting on the top plate 32 is assumed as being 50.0%.

The maximum deflection and the resonance rotation speed at the top plate 32 when reducing the weight of the fan 5 from 2.370 kgf to 1.960 kgf and when changing the attachment method of the fan motor 9 from the first method to the second method are shown in tables 6 and 7, respectively. The following observations were made.

5-1) When reducing the weight of the fan 5, the amount of maximum deflection of the top plate 32 decreased and the resonance rotation speed increased. Thus, it can be understood that the behavior of the top plate 32 was improved.

5-2) When employing the second method as the attachment method of the fan motor 9, the amount of maximum deflection of the top plate 32 decreased and the resonance rotation speed increased in comparison with the first method. Thus, it can be understood that the behavior of the top plate 32 was improved although its effect was limited.
<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>2.370kgf</th>
<th>1.960kgf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Deflection</td>
<td>Maximum Mises Stress</td>
</tr>
<tr>
<td>0.8</td>
<td>1.20</td>
<td>7.57</td>
</tr>
<tr>
<td>0.7</td>
<td>1.52</td>
<td>8.70</td>
</tr>
<tr>
<td>0.6</td>
<td>2.00</td>
<td>10.49</td>
</tr>
</tbody>
</table>
[0093] <Maximum Deflection Resulting from Difference in Attachment Location of Fan Motor 9 and Change in Maximum Mises Stress and Resonance Rotation Speed of Top Plate 32 (Attachment Method of Heat Exchanger 4 (Second Method): $W_\alpha=50.0\%$; Weight of Fan Motor 9 2.370 kgf>
<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>Motor Attachment (1st Method)</th>
<th>Motor Attachment (2nd Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Deflection</td>
<td>Maximum Mises Stress</td>
</tr>
<tr>
<td>0.8</td>
<td>1.20</td>
<td>7.57</td>
</tr>
<tr>
<td>0.7</td>
<td>1.52</td>
<td>8.70</td>
</tr>
<tr>
<td>0.6</td>
<td>2.00</td>
<td>10.49</td>
</tr>
</tbody>
</table>
5-3) The shape of the reinforcement ribs 32a arranged on the top plate 32 must be optimized so that the top plate 32 of which plate thickness $D_4$ has been reduced to 0.7 mm to maintain substantially the same behavior as the top plate 32 of the prior art (see table 6).

In this analysis, the radials rib shown in Fig. 6 are referred to as the main reinforcement ribs 32a, and the ribs located between the main reinforcement ribs 32a are referred to as the sub-reinforcement ribs 34. The influence of the ribs 32a and 34 on the behavior of the top plate 32 will now be discussed. This analysis was conducted under the following conditions.

The ratio $W_{\alpha}$ of the weight of the switch box 13 acting on the top plate 32 was 50.0% and the present weight of the fan 5 was 2.370 kgf.

The attachment method of the fan motor 9 was the first method, and the attachment method of the heat exchanger 4 was the second method.

The plate thickness $D_4$ was 0.7 mm.

The analysis result for when the depth of the sub-reinforcement ribs 34 was varied between 0.0 to 0.8 mm (present depth) while maintaining the depth of the main reinforcement ribs 32a at the present depth (8.8 mm) is shown in table 8 and Figs. 9 and 10.
### Table 8

<table>
<thead>
<tr>
<th>Depth of Sub-Reinforcement Ribs (mm)</th>
<th>0.0</th>
<th>0.8</th>
<th>1.6</th>
<th>2.8</th>
<th>3.8</th>
<th>4.8</th>
<th>5.8</th>
<th>6.8</th>
<th>7.8</th>
<th>8.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Deflection</td>
<td>1.38</td>
<td>1.43</td>
<td>1.46</td>
<td>1.49</td>
<td>1.52</td>
<td>1.54</td>
<td>1.55</td>
<td>1.55</td>
<td>1.54</td>
<td>1.52</td>
</tr>
<tr>
<td>Resonance Rotation Speed</td>
<td>902.0</td>
<td>893.0</td>
<td>892.0</td>
<td>887.0</td>
<td>882.0</td>
<td>878.0</td>
<td>877.0</td>
<td>878.0</td>
<td>882.0</td>
<td>887.0</td>
</tr>
</tbody>
</table>
The following observations were obtained.

1. It is apparent that the behavior (maximum deflection and resonance rotation speed) of the top plate 32 differs depending on the depth of the sub-reinforcement ribs 34. The behavior of the top plate 32 decreases as the depth increases when the depth of the sub-reinforcement rib 34 is in the range of 0.0 to 5.8 mm. However, the decrease in the behavior of the top plate 32 becomes small as the depth exceeds 5.8 mm. When the depth of the sub-reinforcement rib 34 is 0.0 mm, that is, when the sub-reinforcement rib 34 is omitted and the surface between the main reinforcement ribs 32a becomes flat, it can be understood that the maximum deflection of the top plate 32 becomes minimum, and the resonance rotation speed becomes maximum.

2. When the depth of the sub-reinforcement rib 34 is increased to become greater than the present depth of 8.8 mm, it is believed that the behavior of the top plate 32 was improved compared to when there were no sub-reinforcement ribs 34. However, deep sub-reinforcement ribs 34 are not desirable due to restrictions in the arrangement and metal plate processing of the heat exchanger 4. The top plate (plate thickness $D_4=0.7$ mm) 32 free of the sub-reinforcement rib 34 and exhibiting the most superior behavior within the range of 0.0 to 0.8 mm has substantially the same maximum deflection (1.30mm → 1.38 mm) and high resonance rotation speed (742.0rpm → 902.0rpm) compared to the current top plate ($D_4=0.8$ mm) shown in Fig. 6.

3. Accordingly, a top plate 32 free of the sub-reinforcement ribs 34 and having a flat surface between the main reinforcement ribs 32a not only exhibits superior behavior but also facilitates pressing, lowers costs due to material reduction, and improves product processing quality.

The analysis results of when the sub-reinforcement ribs 34 are omitted and the depth $D_2$ of the main reinforcement ribs 32a was varied are shown in table 9 and Figs. 11 and 12. The following observations were made.

1. As the main reinforcement rib 32a becomes deeper, the behavior of the top plate 32 was significantly improved. However, it is apparent that the rate of improvement gradually decreased.

2. It is apparent that the influence of the main reinforcement ribs 32a on the behavior of the top plate 32 was extremely large.

<Maximum Deflection of Top Plate 32 Resulting from Change in Depth of Main Reinforcement Rib 32a and Change in Maximum Mises Stress and Resonance Rotation Speed (Free of Sub-Reinforcement Ribs 34)>
<table>
<thead>
<tr>
<th>Depth of Main Reinforcement Ribs (mm)</th>
<th>8.8</th>
<th>9.0</th>
<th>9.2</th>
<th>9.4</th>
<th>9.6</th>
<th>9.8</th>
<th>10.0</th>
<th>10.4</th>
<th>10.8</th>
<th>11.2</th>
<th>11.6</th>
<th>12.0</th>
<th>12.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Deflection</td>
<td>1.38</td>
<td>1.36</td>
<td>1.33</td>
<td>1.30</td>
<td>1.28</td>
<td>1.26</td>
<td>1.24</td>
<td>1.20</td>
<td>1.17</td>
<td>1.14</td>
<td>1.11</td>
<td>1.09</td>
<td>1.06</td>
</tr>
<tr>
<td>Resonance Rotation Speed</td>
<td>902.0</td>
<td>909.0</td>
<td>916.0</td>
<td>922.0</td>
<td>927.0</td>
<td>933.0</td>
<td>938.0</td>
<td>947.6</td>
<td>956.0</td>
<td>964.0</td>
<td>971.0</td>
<td>978.0</td>
<td>984.0</td>
</tr>
</tbody>
</table>
Claims

1. A high location installation type air conditioner including a main body casing for accommodating a fan, a fan motor, a heat exchanger, a drain pump, and a switch box and a top plate arranged on a top surface of the main body casing for suspending the fan, fan motor, heat exchanger, drain pump, and switch box, the top plate structure of the high location installation type air conditioner being characterized by:
   a central portion for supporting the fan motor and a peripheral portion for supporting the heat exchanger;
   a plurality of reinforcement ribs formed to extend radially from the central portion to the peripheral portion; and
   a flat surface extending between the reinforcement ribs.

2. The top plate structure for the high location installation type air conditioner according to claim 1, being characterized by a step formed in a support for the heat exchanger located at the periphery of the reinforcement ribs.

3. The top plate structure for the high location installation type air conditioner according to claim 1 or 2, being characterized in that the reinforcement ribs are arranged on a support for the fan motor located at the central portion of the top plate.

4. The top plate structure for the high location installation type air conditioner according to any one of claims 1 to 3, being characterized in that the plate thickness of the top plate is greater than or equal to 0.6 mm and less than 0.8 mm.
Fig. 5
Fig. 6
Fig. 9

Maximum Deflection Amount (mm)

Influence of Sub-Reinforcement Ribs

Depth of Sub-Reinforcement Ribs (mm)
Fig. 10

Influence of Sub-Reinforcement Ribs

Resonance Rotation Speed (rpm)

Depth of Sub-Reinforcement Ribs (mm)
Fig. 11
Fig. 14
# INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/JP2005/010961

## A. CLASSIFICATION OF SUBJECT MATTER

**Int.Cl7** F24F1/00

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**Int.Cl7** F24F1/00

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

- **Jitsuyo Shinan Koho** 1922-1996
- **Jitsuyo Shinan Toroku Koho** 1996-2005
- **Kokai Jitsuyo Shinan Koho** 1971-2005
- **Toroku Jitsuyo Shinan Koho** 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
<tr>
<td><strong>Y</strong></td>
<td>JP 11-201496 A (Daikin Industries, Ltd.), 30 July, 1999 (30.07.99), Fig. 3 (Family: none)</td>
<td>1-4</td>
</tr>
<tr>
<td><strong>Y</strong></td>
<td>JP 2002-147789 A (Hitachi, Ltd.), 22 May, 2002 (22.05.02), Figs. 7, 9 (Family: none)</td>
<td>1-4</td>
</tr>
</tbody>
</table>

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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- **&** document member of the same patent family

Date of the actual completion of the international search: 25 August, 2005 (25.08.05)

Date of mailing of the international search report: 13 September, 2005 (13.09.05)

Name and mailing address of the ISA/Authorized officer

**Japanese Patent Office**

Facsimile No. Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)
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Patent documents cited in the description

• JP 11201496 A [0019]