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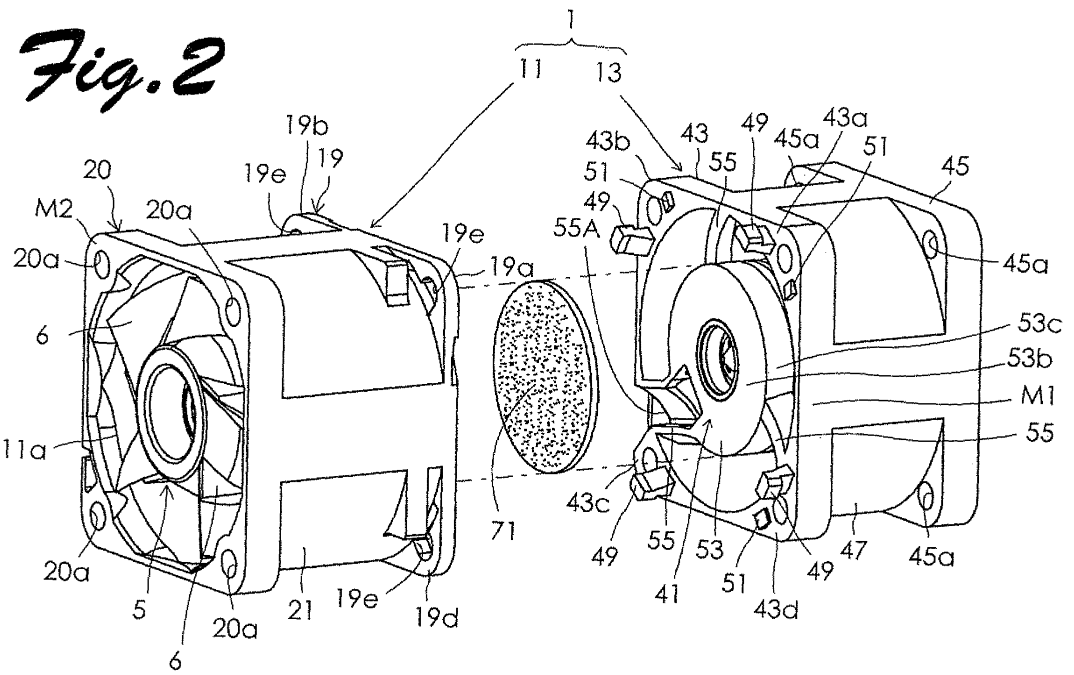
(54) DUAL REVERSAL-ROTATING TYPE AXIAL BLOWER

(57) A counter-rotating axial flow fan is provided, in which vibration generation may be reduced more than ever in a wide rotational speed range including a high speed range.

A disk-shaped cushioning member 71 is disposed between a circular plate portion 23b of a first support frame main body half portion 23 and a circular plate portion 53b of a second support frame main body half portion 53. The cushioning member 71 is disposed as it is compressed with hook portions 49 forming a plurality of engaging portions and hole portions 19e forming a plurality of engaged portions completely engaged with each other.

Fig.2



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Description

Technical Field

[0001] The present invention relates to a counter-rotating axial flow fan for use to cool the inside of an electric device and the like.

Background Art

[0002] Japanese Unexamined Patent Application Publication No. 2004-278370 (Patent Document 1) and US Patent No. 7,156,611 (Patent Document 2) each disclose a counter-rotating axial flow fan including a housing including a housing main body having defined therein an air channel having a suction port at one end in an axial direction and a discharge port at the other end in the axial direction, and a motor support frame disposed at a center portion of the air channel. In the counter-rotating axial flow fan, a first impeller rotated by a first motor is disposed in a first space in the housing between the motor support frame and the suction port. Also, a second impeller rotated by a second motor is disposed in a second space in the housing between the motor support frame and the discharge port. The first impeller rotates in the opposite direction to the second impeller. In the counter-rotating axial flow fan, the housing includes a first split housing unit and a second split housing unit coupled to each other by a coupling structure. The first split housing unit includes a first housing main body half portion including a first cylindrical air channel half portion having defined therein a main portion of the first space, and a first support frame half portion which is one of two pieces obtained by splitting the motor support frame along an imaginary reference split plane extending in a radial direction perpendicular to the axial direction. The second split housing unit includes a second housing main body half portion including a second cylindrical air channel half portion having defined therein a main portion of the second space, and a second support frame half portion which is the other of the two pieces obtained by splitting the motor support frame along the imaginary reference split plane.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2004-278370
[Patent Document 2] US Patent No. 7,156,611

Summary of Invention

Technical Problem

[0003] In the counter-rotating axial flow fan according to the related art, however, vibration increases in a plurality of rotational speed ranges (resonance ranges) as the rotational speeds of the first and second motors are increased. If the counter-rotating axial flow fan is used within any of such rotational speed ranges with increased vibration, the counter-rotating axial flow fan may produce significant vibration, which may result in significant noise.

[0004] An object of the present invention is to provide a counter-rotating axial flow fan in which vibration generation may be reduced more than ever in a wide rotational speed range.

Solution to Problem

[0005] The present invention provides a counter-rotating axial flow fan including a housing, a first impeller, a first motor, a second impeller, and a second motor. The housing includes a housing main body having defined therein an air channel having a suction port at one end in an axial direction and a discharge port at the other end in the axial direction, and a motor support frame disposed at a center portion of the air channel. The first impeller is disposed in a first space defined in the housing between the motor support frame and the suction port, and includes a plurality of blades. The first motor includes a first rotary shaft to which the first impeller is fixed to rotate the first impeller in a first rotational direction in the first space. The second impeller is disposed in a second space defined in the housing between the motor support frame and the discharge port, and includes a plurality of blades. The second motor includes a second rotary shaft to which the second impeller is fixed to rotate the second impeller in a second rotational direction opposite the first rotational direction in the second space.

[0006] The motor support frame includes a support frame main body located at the center portion of the air channel and a plurality of webs disposed between the support frame main body and the housing main body at predetermined intervals in a circumferential direction of the rotary shafts to couple the support frame main body and the housing main body.

[0007] The housing includes a first split housing unit and a second split housing unit coupled to each other by a mechanical coupling structure. The first split housing unit includes a first housing main body half portion including a first cylindrical air channel half portion having the suction port at one end and having defined therein a main portion of the first space, and a first support frame half portion which is one of two pieces obtained by splitting the motor support frame along a split plane extending in a radial direction perpendicular to the axial direction. The second split housing unit includes a second housing main body half portion including a second cylindrical air channel half portion having the discharge port at one end and having defined therein a main portion of the second space, and a second support frame half portion which is the other of the two pieces obtained by splitting the motor support frame along the split plane.

[0008] The coupling structure adopted in the present invention includes a plurality of engaging portions integrally formed with the first housing main body half portion and disposed at intervals in the circumferential direction, and a plurality of engaged portions integrally formed with the second housing main body half portion and disposed at intervals in the circumferential direction to be engaged with the plurality of engaging portions. The coupling structure and the first and second split housing units are configured such that an opposed surface of the first support frame half portion and an opposed surface of the second support frame half portion entirely contact each other when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other. The phrase "opposed surfaces entirely contact each other" as used herein means that opposed surfaces contact each other through a large number of point contacts as seen from a microscopic point of view.

[0009] In the present invention, in particular, a soft cushioning member is disposed between the first support frame half portion and the second support frame half portion, the cushioning member being compressed when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other. A plurality of independent air bubbles are dispersed in the soft cushioning member adopted in the present invention. The independent air bubbles may include not only individual air bubbles but also large independent air bubbles formed by incorporating a plurality of air bubbles. When such a cushioning member is used, it is possible to generally suppress an increase in vibration over a wide rotational speed range from a low rotational speed range to a high rotational speed range. Specific preferred embodiments of the soft cushioning member with a plurality of independent air bubbles dispersed therein include an acrylic foam sheet. If an acrylic foam sheet is used as the soft cushioning member, the thickness of the acrylic foam sheet is preferably not less than 0.4 mm and not more than 0.8 mm. If the thickness of the acrylic foam sheet is less than 0.4 mm, the thickness of the cushioning member itself is too small to provide a sufficient vibration absorption effect. If the thickness of the acrylic foam sheet is more than 0.8 mm, it is necessary to separately provide a gap in which the acrylic foam sheet is to be disposed between the first support frame half portion and the second support frame half portion. However, providing such a gap is not preferred because it changes the resonance frequencies of vibration and thus complicates measures taken against the vibration.

[0010] The specific soft cushioning member used in the present invention also serves a function of reducing vibration produced between the first support frame half portion and the second support frame half portion. As a result, according to the present invention, it is possible to generally suppress an increase in vibration over a wide rotational speed range from a low rotational speed range to a high rotational speed range compared to the related art.

[0011] The soft cushioning member may be entirely disposed between the first support frame half portion and the second support frame half portion.

[0012] The first and second split housing units may be formed from a synthetic resin material, or may be formed from a metal material such as aluminum.

Brief Description of Drawings

[0013]

Fig. 1 is an exploded cross-sectional view of a half portion of a counter-rotating axial flow fan according to an embodiment of the present invention.

Fig. 2 is an exploded perspective view of the counter-rotating axial flow fan according to the embodiment of the present invention.

Figs. 3A and 3B are graphs showing the results of vibration measurements performed to verify the effect of the present invention.

Figs. 4A and 4B are graphs showing the results of vibration measurements performed to verify the effect of the present invention.

Fig. 5 is a graph showing the detailed results of vibration measurements performed to verify the effect of the present invention.

Description of Embodiments

[0014] An embodiment of the present invention will be described in detail below with reference to the drawings. Fig. 1 is an exploded cross-sectional view of a half portion of a counter-rotating axial flow fan according to an embodiment of the present invention. Fig. 2 is an exploded perspective view of the counter-rotating axial flow fan. As shown in the drawings, the counter-rotating axial flow fan according to the embodiment includes a housing 1, a first motor 3, a first impeller 5, a second motor 7, and a second impeller 9. The first impeller 5 is disposed in a first space S1 defined in the housing 1 between a motor support frame (23, 53) to be discussed later and a suction port 11a, and includes a plurality of blades 6. The first motor 3 includes a first rotary shaft 4 to which the first impeller 5 is fixed to rotate the first impeller 5 in a first rotational direction in the first space S 1. The second impeller 9 is disposed in a second space S2 defined in the housing 1 between the motor support frame (23, 53) and the discharge port 13b, and includes a plurality of blades 10. The second motor 7 includes a second rotary shaft 8 to which the second impeller 9 is fixed to rotate the second impeller 9 in a second rotational direction opposite the first rotational direction in the second space S2.

[0015] The housing 1 is configured by assembling a first split housing unit 11 and a second split housing unit 13 via a coupling structure. The first split housing unit 11 is formed from a synthetic resin material or a metal material such as aluminum. As shown in Fig. 1, the first split housing unit 11 includes a first housing main body half portion 15 and a first support frame half portion 17 integrally formed with each other. The first housing main body half portion 15 includes first and second flange portions 19 and 20 and a first cylindrical air channel half portion 21. The first flange portion 19 includes first to fourth corners 19a to 19d arranged in a circumferential direction of the rotary shaft 4 (hereinafter simply referred to as "circumferential direction") arranged on a common axis A of the first and second motors 3 and 7. The first flange portion 19 includes the suction port 11a at one end in the direction of the common axis A. Four hole portions 19e are respectively formed at the four corners of the first flange portion 19 (the first to fourth corners 19a to 19d) to serve as engaged portions for use in forming a coupling structure with the second split housing unit 13. The details of the shape of the hole portions 19e and the details of the engagement relationship between the hole portions 19e and the hook portions 49 forming engaging portions to be discussed later are the same as the relationship between hole portions and hook portions forming a coupling structure disclosed in Japanese Unexamined Patent Application Publication No. 2004-278370 (US Patent No. 7,156,611), and therefore are not described herein. The second flange portion 20 is formed with through holes 20a through which mounting members for mounting the counter-rotating axial flow fan to an electric device are to be inserted. The first and second flange portions 19 and 20 are integrally formed with both ends of the first cylindrical air channel half portion 21. The first cylindrical air channel half portion 21 extends in an axial direction of the rotary shafts 4 and 8 (hereinafter simply referred to as "axial direction") arranged on the common axis A.

[0016] The first support frame half portion 17 includes a first support frame main body half portion 23 to which the first motor 3 is fixed and three first web half portions 25. The first support frame main body half portion 23 includes a circular plate portion 23b having a cylindrical boss portion 23a at a center portion thereof, and a peripheral wall portion 23c extending in the axial direction from the outer peripheral portion of the circular plate portion 23b. A first metallic bearing holder 27 made of brass is fixedly fitted in the boss portion 23a. A base plate 29 of a stator of the first motor 3 is disposed to block a space surrounded by the circular plate portion 23b and the peripheral wall portion 23c. A stator core 33 including a plurality of winding portions 31 is fitted with the bearing holder 27.

[0017] The three first web half portions 25 are disposed between the peripheral wall portion 23c of the first support frame main body half portion 23 and an inner peripheral surface of the first housing main body half portion 15 at predetermined intervals in the circumferential direction to couple the first support frame main body half portion 23 and the first housing main body half portion 15.

[0018] A cup-shaped member 35 made of a magnetically permeable material is fixed to one end of the rotary shaft 4 to support the impeller 5 including the plurality of blades 6. A plurality of permanent magnets 37 are fixed to the inner peripheral portion of the cup-shaped member 35.

[0019] The second split housing unit 13 is also formed from a synthetic resin material or a metal material such as aluminum. As shown in Fig. 1, the second split housing unit 13 includes a second housing main body half portion 39 and a second support frame half portion 41 integrally formed with each other. The second housing main body half portion 39 includes first and second flange portions 43 and 45 and a second cylindrical air channel half portion 47. The first flange portion 43 includes four corners, namely first to fourth corners 43a to 43d, arranged in a circumferential direction of the rotary shaft 8 (hereinafter simply referred to as "circumferential direction") arranged on the common axis A of the first and second motors 3 and 7. Four hook portions 49 and four projections 51 are respectively integrally formed with the four corners of the first flange portion 43 (the first to fourth corners 43a to 43d) to serve as engaging portions for use in forming a coupling structure with the first split housing unit 11. The details of the engagement relationship of the hook portions 49 and the projections 51 with the hole portions 19e are the same as the relationship between hole portions and hook portions forming a coupling structure disclosed in Japanese Unexamined Patent Application Publication No. 2004-278370. As disclosed in Japanese Unexamined Patent Application Publication No. 2004-278370 (US Patent No. 7,156,611), the hook portions 49 are partly fitted in the hole portions 19e, and the second split housing unit 13 is rotated by a predetermined angle about the common axis A. Then, the projections 51 are fitted in fitting recesses (not shown) formed in an end surface of the first flange portion 19 of the first split housing unit 11. As a result, the second split housing unit 13 is prevented from rotating. Also, engagement between the hook portions 49 and edge portions around the hole portions 19e prevents the second split housing unit 13 from separating from the first split housing unit 11 in the axial direction. The second flange portion 45 is formed with through holes 45a through which mounting members for mounting the counter-rotating axial flow fan to an electric device are to be inserted. The first and second flange portions 43 and 45 are integrally formed with both ends of the second cylindrical air channel half portion 47. The second cylindrical air channel half portion 47 extends in the axial direction (the axial direction of the rotary shafts 4 and 8 arranged on the common axis A).

[0020] The second support frame half portion 41 includes a second support frame main body half portion 53 to which the second motor 7 is fixed and three second web half portions 55. The second support frame main body half portion 53 includes a circular plate portion 53b having a cylindrical boss portion 53a at a center portion thereof, and a peripheral wall portion 53c extending in the axial direction from the outer peripheral portion of the circular plate portion 53b. A second metallic bearing holder 57 made of brass is fixedly fitted in the boss portion 53a. A base plate 59 of a stator of the second motor 7 is disposed to block a space surrounded by the circular plate portion 53b and the peripheral wall portion 53c. A stator core 63 including a plurality of winding portions 61 is fitted with the bearing holder 57.

[0021] The three second web half portions 55 are disposed between the peripheral wall portion 53c of the second support frame main body half portion 53 and an inner peripheral surface of the second housing main body half portion 39 at predetermined intervals in the circumferential direction to couple the second support frame main body half portion 53 and the second housing main body half portion 39. Of the three web half portions 55, one web half portion has a groove 55A formed for receiving lead wires.

[0022] A cup-shaped member 65 made of a magnetically permeable material is fixed to one end of the rotary shaft 8 to support the impeller 9 including the plurality of blades 10. A plurality of permanent magnets 67 are fixed to the inner peripheral portion of the cup-shaped member 65.

[0023] In the embodiment, the first and second support frame half portions 17 and 41 are assembled to form the motor support frame (23, 53). In other words, the first and second support frame half portions 17 and 41 are formed by splitting the motor support frame (23, 53) into two pieces along a split plane extending in a radial direction perpendicular to the axial direction in which the common axis A extends. With this configuration of the embodiment, the coupling structure and the first and second split housing units 11 and 13 are configured such that an opposed surface of the first support frame half portion 17 and an opposed surface of the second support frame half portion 41 entirely contact each other when the four engaging portions (the four hook portions 49) and the four engaged portions (the four hole portions 19e) are completely engaged with each other.

[0024] In the embodiment, a soft disk-like cushioning member 71 with a plurality of independent air bubbles dispersed therein is disposed between the first support frame half portion 17 and the second support frame half portion 41, specifically between the circular plate portion 23b of the first support frame main body half portion 23 and the circular plate portion 53b of the second support frame main body half portion 53. As the soft cushioning member 71, preferably, an acrylic foam sheet may be used. The cushioning member 71 is disposed as it is compressed with the four hook portions 49 forming the plurality of engaging portions and the four hole portions 19e forming the plurality of engaged portions completely engaged with each other. When the cushioning member 71 with a plurality of independent air bubbles dispersed therein is compressed, the cushioning member 71 produces a restoring force substantially evenly from its entirety to return from a compressed state to an original state. The restoring force acts in a direction to release the engagement between the plurality of engaging portions (the four hook portions 49) and the plurality of engaged portions. As a result, the coupling force between the plurality of engaging portions (the four hook portions 49) and the plurality of engaged portions (the edge portions around the four hole portions 19e) is strengthened, which prevents generation of a large gap between the first and second split housing units 11 and 13 which will cause vibration therebetween, and to reduce vibration that is actually produced. The cushioning member 71 also serves a function of absorbing vibration produced between the first support frame half portion 17 and the second support frame half portion 41 to reduce such vibration. As a result, according to the present invention, it is possible to generally suppress an increase in vibration within a wide rotational speed range compared to the related art.

[0025] In the above embodiment, the soft cushioning member 71 is disposed only between the circular plate portion 23b of the first support frame main body half portion 23 and the circular plate portion 53b of the second support frame main body half portion 53 to obtain favorable results. However, an enhanced vibration suppression effect is obtained by disposing a soft cushioning member also between the first web half portions 25 and the second web half portions 55.

[0026] Vibration measurement tests were performed as described below to verify the effect of the present invention. Figs. 3 to 5 are each a graph showing the results of vibration measurement tests. In the vibration measurement tests, the vibration acceleration (m/s^2) at a measurement location M1 (a portion of the first flange portion 43 of the second split housing unit 13) in the circumferential direction and the vibration acceleration (m/s^2) at a measurement location M2 (near a through hole 20a of the second flange portion 20 of the first split housing unit 11) at the discharge port in the axial direction were measured, and the obtained vibration accelerations (m/s^2) were synthesized and plotted on a graph. Fig. 3A is a graph showing the results of measuring the relationship between the rotational speed (the rotational speed of the second motor rotating at high speeds) and the vibration acceleration of vibration produced when the present invention is applied to a counter-rotating axial flow fan available from the applicant (Sanyo Denki Co., Ltd.) under the product number 9CRA0412P5J03, and when the present invention is not applied thereto. In Fig. 3A, X indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a soft cushioning member 71 (Embodiment 1), and Y indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with no cushioning member 71 (Comparative Example 1). As the soft cushioning member, a cushioning member commercially available from Sumitomo 3M Limited under the product name Y-4615 was used. From the measurement results, it is found that generation of vibration was suppressed in a wide rotational speed range from a low rotational speed range to a high rotational speed range by using the cushioning member.

[0027] Fig. 3B is a graph showing the results of measuring the relationship between the rotational speed (the rotational speed of the second motor rotating at high speeds) and the vibration acceleration of vibration produced when the present invention is applied to another type of counter-rotating axial flow fan also available from the applicant (Sanyo Denki Co., Ltd.) but under a different product number 9CRA0412P4J03 and of different dimensions from the counter-rotating axial flow fan used in Fig. 3A, and when the present invention is not applied thereto. In Fig. 3B, X indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a cushioning member 71 (Embodiment 2), and Y indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with no cushioning member 71 (Comparative Example 2). The soft cushioning member used was the same as that used in Fig. 3A. Also from the measurement results of these embodiments, it is found that generation of large vibration was significantly suppressed in a wide rotational speed range from a low rotational speed range to a high rotational speed range by using the cushioning member.

[0028] Fig. 4A is a graph showing the results of measuring the relationship between the rotational speed (the rotational speed of the second motor rotating at high speeds) and the vibration acceleration of vibration produced when the present invention is applied to a counter-rotating axial flow fan produced by and available from a manufacturer other than the applicant, and when the present invention is not applied thereto. In Fig. 4A, X indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a cushioning member 71 (Embodiment 3), and Y indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with no cushioning member 71 (Comparative Example 3). The cushioning member used was the same as that used in Fig. 3A. From the measurement results, it is found that generation of vibration was generally suppressed through the entire rotational speed range by using the cushioning member.

[0029] Like Fig. 4A, Fig. 4B is a graph showing the results of measuring the relationship between the rotational speed (the rotational speed of the second motor rotating at high speeds) and the vibration acceleration of vibration produced when the present invention is applied to another type of counter-rotating axial flow fan produced by and available from a manufacturer other than the applicant, and when the present invention is not applied thereto. In Fig. 4B, X indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a cushioning member 71 (Embodiment 4), and Y indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with no cushioning member 71 (Comparative Example 4). The cushioning member used was the same as that used in Fig. 3A. From the measurement results, it is found that generation of vibration was generally suppressed through the entire rotational speed range by using the cushioning member.

[0030] As a result of the above vibration measurements (Figs. 3 and 4), it was found that favorable results were obtained by using an acrylic-foam cushioning member with independent air bubbles. Further, a preferable thickness range of the acrylic-foam cushioning member was confined and it was verified whether or not materials other than the acrylic foam were suitable for use as the cushioning member. Fig. 5 is a graph showing the results of measuring the relationship between the rotational speed (the rotational speed of the second motor rotating at high speeds) and the vibration acceleration of vibration produced by the same counter-rotating axial flow fan as in Fig. 3 under the same measurement conditions as in Fig. 3, where the thickness of the acrylic foam sheet was changed, a cushioning member made of a material other than the acrylic foam was used, no cushioning member was used, and a gap was positively provided in place of a cushioning member.

[0031] In Fig. 5, the "dotted line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with the soft cushioning member 71 formed by an acrylic foam sheet having a thickness of 0.4 mm (Embodiment 5). The "broken line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with the cushioning member 71 formed by an acrylic foam sheet having a thickness of 0.8 mm (Embodiment 6). The "thick solid line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with no cushioning member 71 (Comparative Example 5). The "thick broken line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a gap of 0.2 mm positively provided between the first support frame main body half portion 23 and the second support frame main body half portion 53 (Comparative Example 6). The normal "solid line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a cushioning member formed by an aluminum sheet having a thickness of 0.46 mm (Comparative Example 7). The "dash and dot line" indicates changes in vibration acceleration of a counter-rotating axial flow fan provided with a cushioning member formed by a plastic sheet having a thickness of 0.5 mm (Comparative Example 8).

[0032] The measurement results are described below. When no cushioning member was used (Comparative Example 5), a plurality of resonance points (peaks) appeared in the vibration acceleration. In particular, a very high peak was exhibited in the vibration acceleration in a high rotational speed range around 14000 [rpm]. When an aluminum sheet was used as the cushioning member (Comparative Example 7) and when a plastic sheet was used as the cushioning member (Comparative Example 8), the plurality of resonance points (peaks) in the vibration acceleration in a high rotational speed range were slightly decreased. However, the resonance point (peak) in the vibration acceleration around 14000 [rpm] remained relatively high, although it was not as high as when no cushioning member 71 was used (Comparative Example 5).

[0033] In contrast, when an acrylic foam sheet having a thickness of 0.4 mm was used as the cushioning member 71 (Embodiment 5), the plurality of peaks in the vibration acceleration in a high rotational speed range were decreased, and in addition, the peak in the vibration acceleration around 14000 [rpm] was reduced by 40% with respect to when no cushioning member 71 was used (Comparative Example 5), and reduced by 30% with respect to when an aluminum sheet and a plastic sheet were used as the cushioning member 71 (Comparative Examples 7 and 8). Also, when an acrylic foam sheet having a thickness of 0.8 mm was used as the cushioning member 71 (Embodiment 6), the plurality of peaks in the vibration acceleration in a high rotational speed range were decreased, and in addition, the peak in the vibration acceleration around 14000 [rpm] was reduced by 60% with respect to when no cushioning member 71 was used (Comparative Example 5), and reduced by 50% with respect to when an aluminum sheet and a plastic sheet were used as the cushioning member 71 (Comparative Examples 7 and 8). When an acrylic foam sheet having a thickness of 0.8 mm was used (Embodiment 6), the peak in the vibration acceleration around 14000 [rpm] was reduced by 30% with respect to when an acrylic foam sheet having a thickness of 0.4 mm was used (Embodiment 5).

[0034] When a gap of 0.2 mm was provided without using a cushioning member (Comparative Example 6), a peak higher than the highest peak that appeared when no cushioning member 71 was used (Comparative Example 5) was exhibited in the vibration acceleration around 12000 [rpm] although no high peak was exhibited in the vibration acceleration around 14000 [rpm]. Moreover, the number of peaks in the vibration acceleration that were relatively high was increased compared to when no cushioning member 71 was used (Comparative Example 5). Consequently, it is found that generation of vibration cannot be reduced in a wide rotational speed range from a low rotational speed range to a high rotational speed range by simply providing a gap with no cushioning member disposed therein, although vibration can be suppressed in a high rotational speed range by transferring high peaks in the vibration acceleration to a lower rotational speed range (by causing a shift phenomenon).

[0035] As can be seen from the above results, it is possible to not only suppress significant vibration that is produced in a high rotational speed range but also generally suppress an increase in vibration over a wide rotational speed range by setting the thickness of the acrylic foam sheet used as the cushioning member 71 in a range from 0.4 mm to 0.8 mm. If the thickness of the acrylic foam sheet is less than 0.4 mm, it is expected that the thickness of the cushioning member itself is too small to provide a necessary and sufficient vibration absorption effect. If the thickness of the acrylic foam sheet is more than 0.8 mm, it is necessary to separately provide a gap in which the thick acrylic foam sheet is to be disposed between the first support frame half portion and the second support frame half portion. It is not preferable to positively provide a gap because the effect of the shift phenomenon, as discussed earlier when a gap of 0.2 mm was provided, appears.

[0036] In the above embodiment, the cushioning member 71 is disposed only between the circular plate portion 23b of the first support frame main body half portion 23 and the circular plate portion 53b of the second support frame main body half portion 53. However, it is a matter of course that the cushioning member 71 may also be disposed between the first web half portions 25 and the second web half portions 55.

<u>Industrial Applicability</u>

[0037] According to the present invention, a soft cushioning member with a plurality of independent air bubbles dispersed therein is disposed between a first support frame half portion and a second support frame half portion, the cushioning member being compressed when a plurality of engaging portions and a plurality of engaged portions are completely engaged with each other. Therefore, it is possible to generally suppress an increase in vibration over a wide rotational speed range compared to the related art.

Claims

1. A counter-rotating axial flow fan comprising:

    a housing including a housing main body having defined therein an air channel having a suction port at one end in an axial direction and a discharge port at the other end in the axial direction, and a motor support frame disposed at a center portion of the air channel;
    a first impeller disposed in a first space defined in the housing between the motor support frame and the suction port and including a plurality of blades;
    a first motor including a first rotary shaft to which the first impeller is fixed to rotate the first impeller in a first rotational direction in the first space;
    a second impeller disposed in a second space defined in the housing between the motor support frame and the discharge port and including a plurality of blades; and
    a second motor including a second rotary shaft to which the second impeller is fixed to rotate the second impeller in a second rotational direction opposite the first rotational direction in the second space,
    the motor support frame including a support frame main body located at the center portion of the air channel and a plurality of webs disposed between the support frame main body and the housing main body at predetermined intervals in a circumferential direction of the rotary shafts to couple the support frame main body and the housing main body,
    the housing including a first split housing unit and a second split housing unit coupled to each

other by a mechanical coupling structure,
the first split housing unit including a first housing main body half portion including a first cylindrical air channel half portion having the suction port at one end and having defined therein a main portion of the first space, and a first support frame half portion which is one of two pieces obtained by splitting the motor support frame along a split plane extending in a radial direction perpendicular to the axial direction,
the second split housing unit including a second housing main body half portion including a second cylindrical air channel half portion having the discharge port at one end and having defined therein a main portion of the second space, and a second support frame half portion which is the other of the two pieces obtained by splitting the motor support frame along the split plane,
the coupling structure including a plurality of engaging portions integrally formed with the first housing main body half portion of the first split housing unit and disposed at intervals in the circumferential direction, and a plurality of engaged portions integrally formed with the second housing main body half portion of the second split housing unit and disposed at intervals in the circumferential direction to be engaged with the plurality of engaging portions,
the coupling structure and the first and second split housing units being configured such that an opposed surface of the first support frame half portion and an opposed surface of the second support frame half portion entirely contact each other when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other,
the first support frame half portion including a first support frame main body half portion to which the first motor is fixed and a plurality of first web half portions, and
the second support frame half portion including a second support frame main body half portion to which the second motor is fixed and a plurality of second web half portions,
wherein a soft cushioning member with a plurality of independent air bubbles dispersed therein is disposed between the first support frame main body half portion and the second support frame main body half portion, the cushioning member being compressed when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other.

2. A counter-rotating axial flow fan comprising:

a housing including a housing main body having defined therein an air channel having a suction port at one end in an axial direction and a discharge port at the other end in the axial direction, and a motor support frame disposed at a center portion of the air channel;
a first impeller disposed in a first space defined in the housing between the motor support frame and the suction port and including a plurality of blades;
a first motor including a first rotary shaft to which the first impeller is fixed to rotate the first impeller in a first rotational direction in the first space;
a second impeller disposed in a second space defined in the housing between the motor support frame and the discharge port and including a plurality of blades; and
a second motor including a second rotary shaft to which the second impeller is fixed to rotate the second impeller in a second rotational direction opposite the first rotational direction in the second space,
the motor support frame including a support frame main body located at the center portion of the air channel and a plurality of webs disposed between the support frame main body and the housing main body at predetermined intervals in a circumferential direction of the rotary shafts to couple the support frame main body and the housing main body,
the housing including a first split housing unit and a second split housing unit coupled to each other by a mechanical coupling structure,
the first split housing unit including a first housing main body half portion including a first cylindrical air channel half portion having the suction port at one end and having defined therein a main portion of the first space, and a first support frame half portion which is one of two pieces obtained by splitting the motor support frame along a split plane extending in a radial direction perpendicular to the axial direction,
the second split housing unit including a second housing main body half portion including a second cylindrical air channel half portion having the discharge port at one end and having defined therein a main portion of the second space, and a second support frame half portion which is the other of the two pieces obtained by splitting the motor support frame along the split plane,
the coupling structure including a plurality of engaging portions integrally formed with the first housing main body half portion of the first split housing unit and disposed at intervals in the circumferential direction, and a plurality of engaged portions integrally formed with the second housing main body half portion of the second split housing unit and disposed at intervals in the circumferential direction to be engaged with the plurality of engaging portions, and
the coupling structure and the first and second

split housing units being configured such that opposed surfaces of the first and second support frame half portions entirely contact each other when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other,
wherein a soft cushioning member with a plurality of independent air bubbles dispersed therein is disposed between the first support frame half portion and the second support frame half portion, the cushioning member being compressed when the plurality of engaging portions and the plurality of engaged portions are completely engaged with each other.

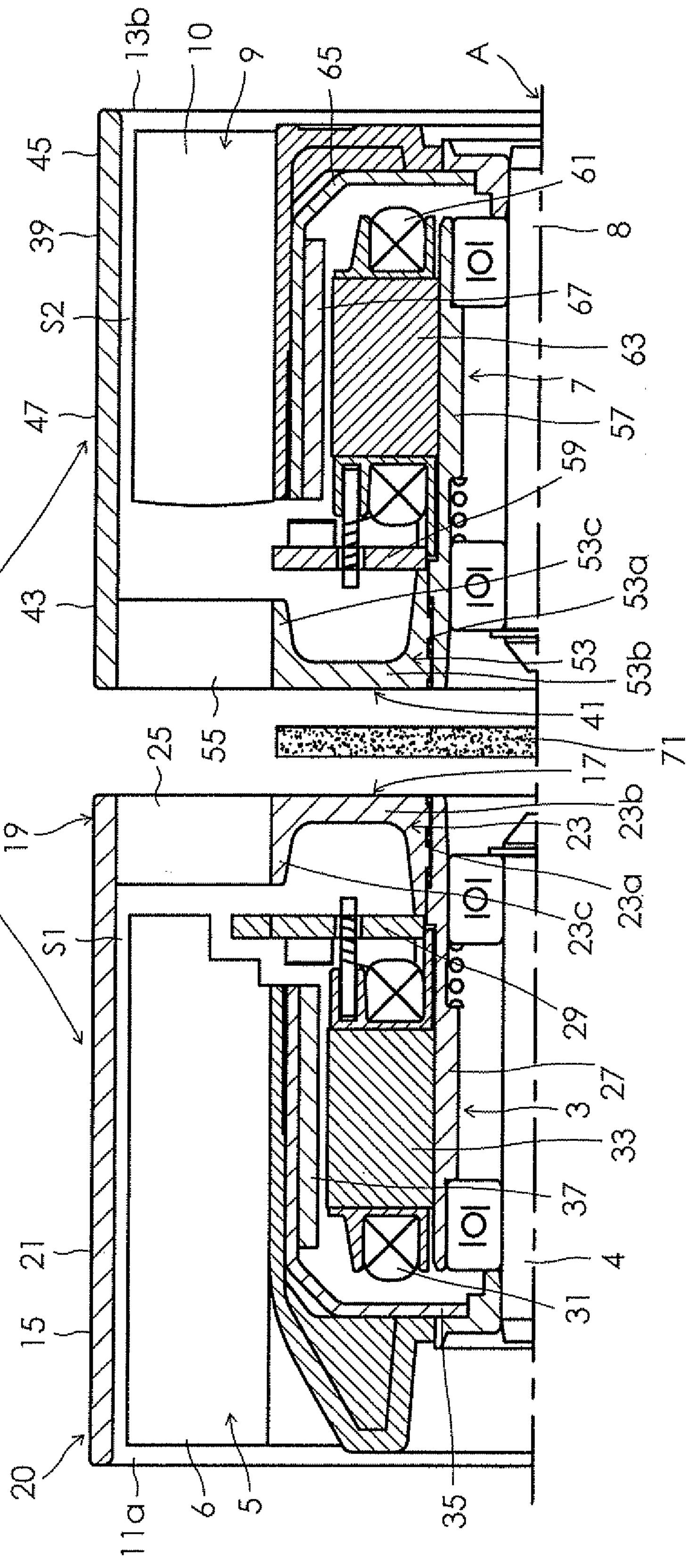
3. The counter-rotating axial flow fan according to claim 2, wherein
the first support frame half portion includes a first support frame main body half portion to which the first motor is fixed,
the second support frame half portion includes a second support frame main body half portion to which the second motor is fixed, and
the cushioning member is disposed between the first support frame main body half portion and the second support frame main body half portion.

4. The counter-rotating axial flow fan according to claim 1 or 2, wherein
the first and second split housing units are formed from a synthetic resin material.

5. The counter-rotating axial flow fan according to claim 1 or 2, wherein
the first and second split housing units are formed from aluminum.

6. The counter-rotating axial flow fan according to claim 1 or 2, wherein
the cushioning member is an acrylic foam sheet with a thickness of not less than 0.4 mm and not more than 0.8 mm.

Fig. 1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S2
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53b
13
41
55
71
1
25
17
11
23b
19
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23a
23c
S1
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27
3
33
37
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4
31
15
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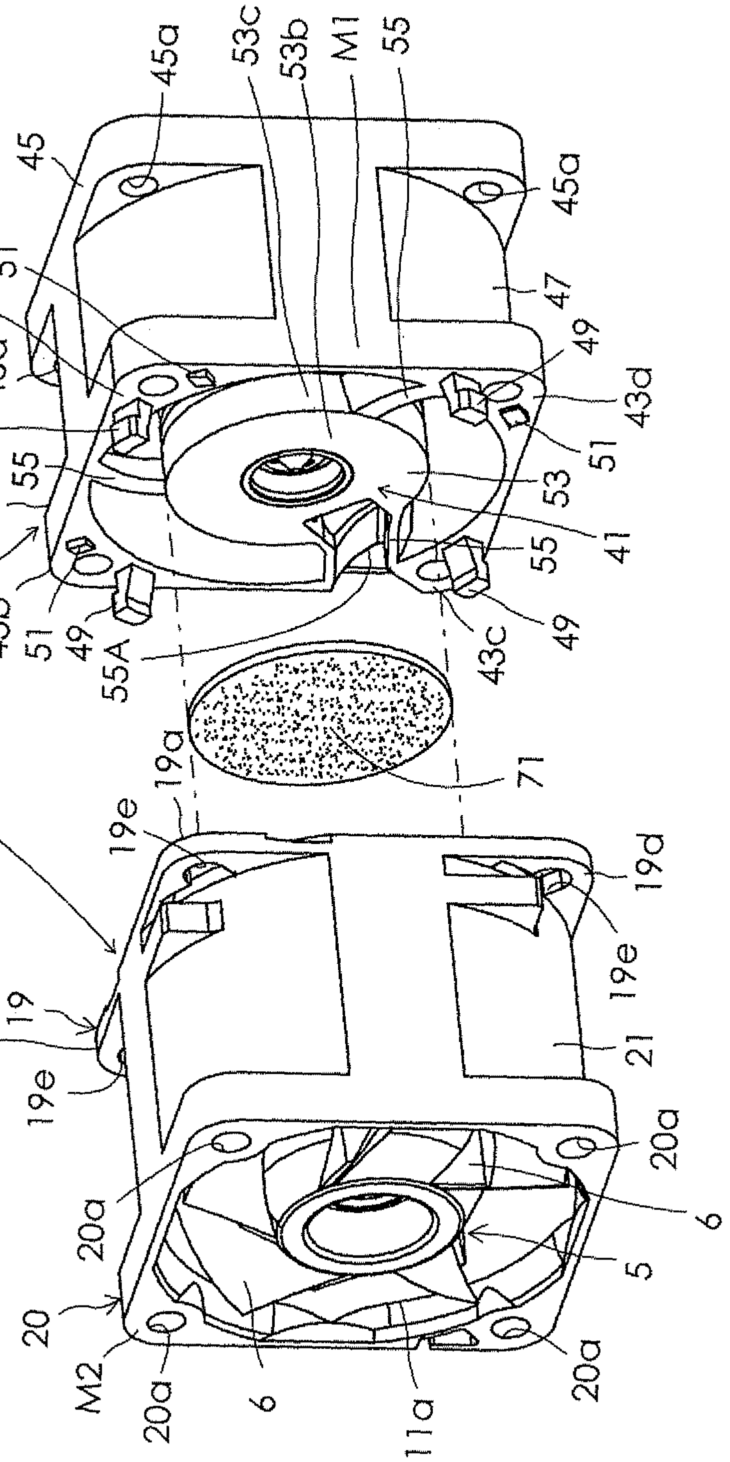
5
35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53b
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45a
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43d
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55
13
43b
51
49
55A
49
43c
1
11
71
19a
19e
19d
19e
19
19b
19e
21
20a
20a
6
5
20
M2
20a
6
11a
20a

Fig.2

Fig.3A

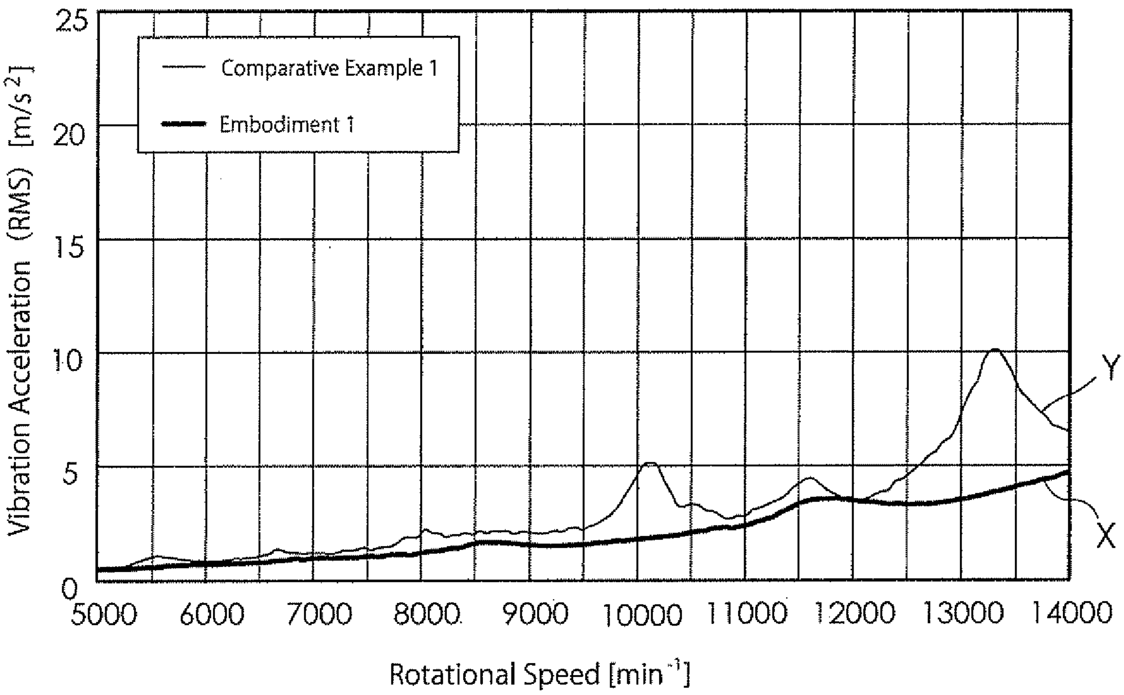
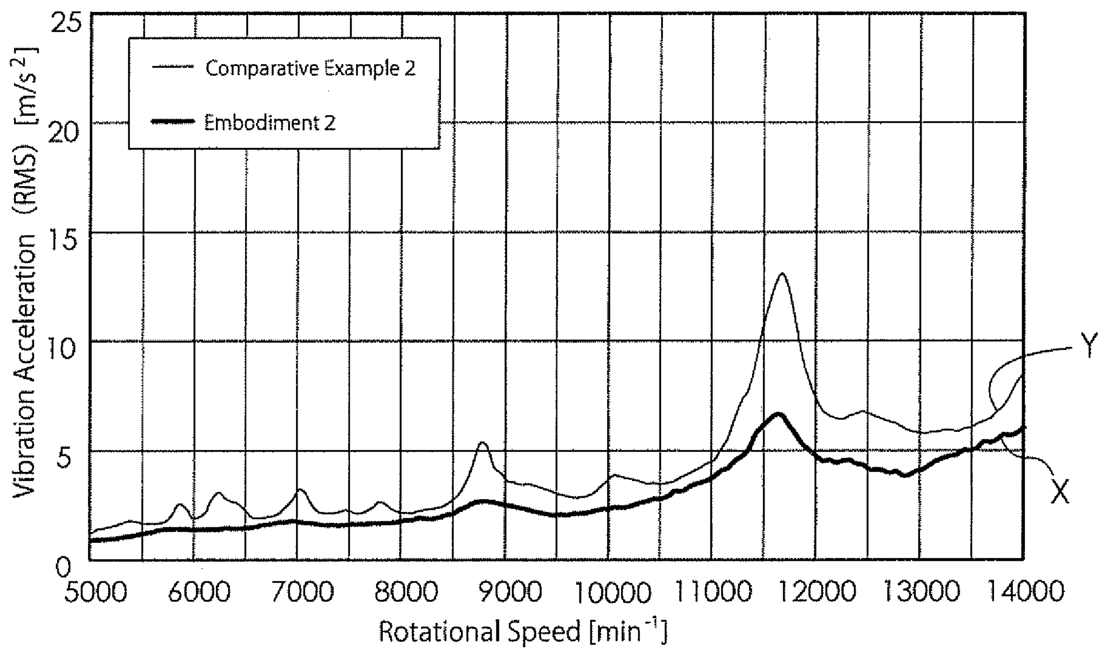

Comparative Example 1
Embodiment 1
Vibration Acceleration (RMS) [m/s²]
25
20
15
10
5
0
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Rotational Speed [min⁻¹]
Y
X

Fig.3B



Comparative Example 2
Embodiment 2
Vibration Acceleration (RMS) [m/s²]
Rotational Speed [min⁻¹]
0
5
10
15
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6000
7000
8000
9000
10000
11000
12000
13000
14000
Y
X

Fig.4A

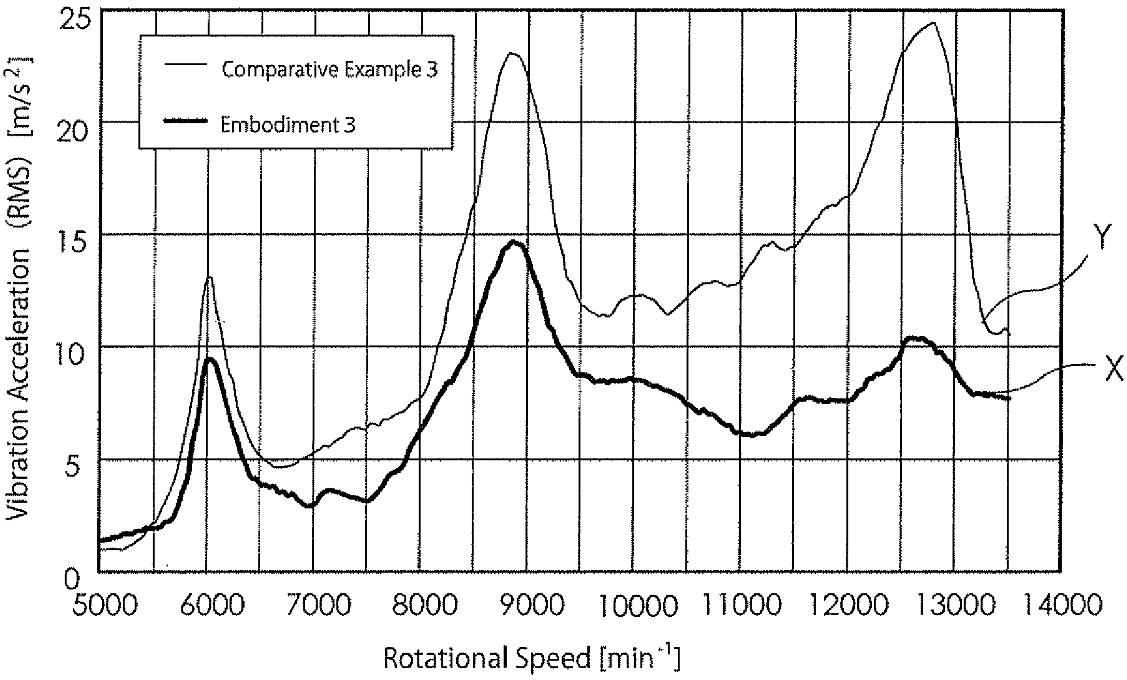
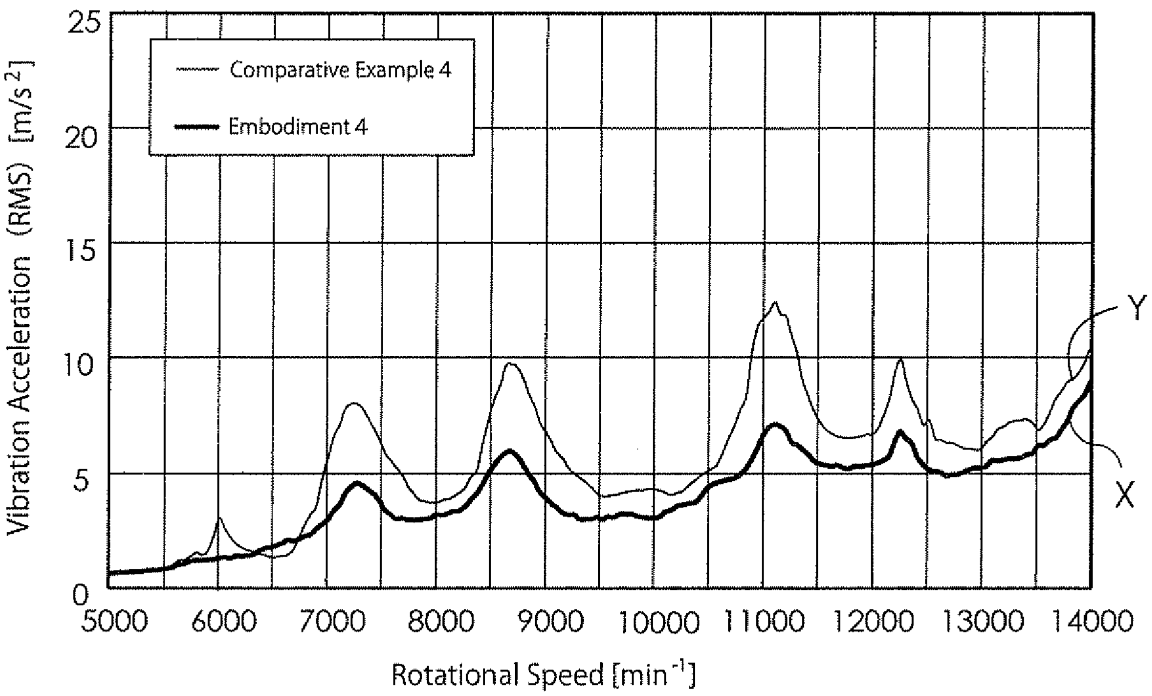

25
20
15
10
5
0
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Vibration Acceleration (RMS) [m/s²]
Rotational Speed [min⁻¹]
Comparative Example 3
Embodiment 3
Y
X

Fig.4B


Comparative Example 4
Embodiment 4
Vibration Acceleration (RMS) [m/s²]
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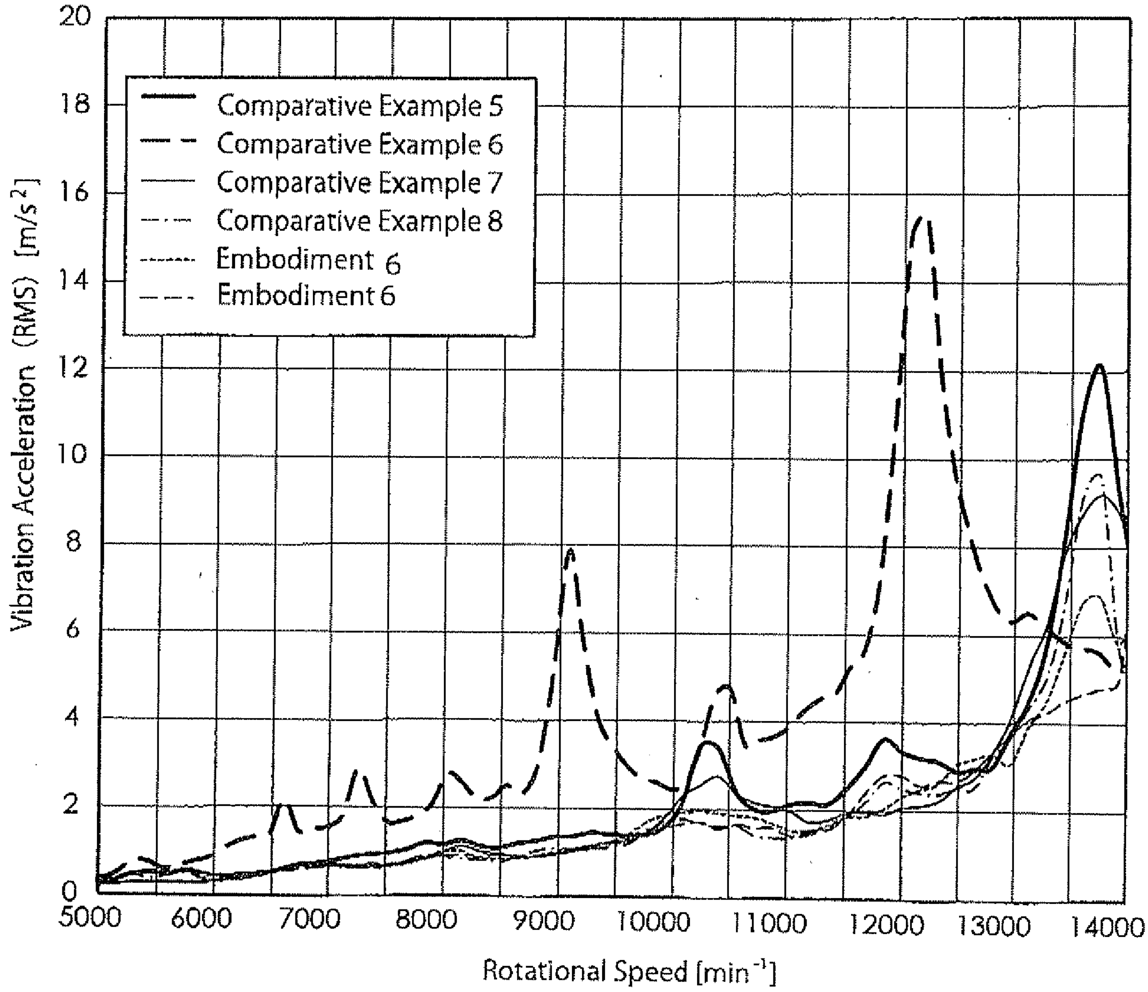
15
10
5
0
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Rotational Speed [min⁻¹]
Y
X

Fig. 5



20
18
16
14
12
10
8
6
4
2
0
Vibration Acceleration (RMS) [m/s²]
Comparative Example 5
Comparative Example 6
Comparative Example 7
Comparative Example 8
Embodiment 6
Embodiment 6
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Rotational Speed [min⁻¹]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062312

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/66(2006.01)i

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)
F04D29/66

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	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-278371 A (Sanyo Denki Co., Ltd.), 07 October, 2004 (07.10.04), Par. Nos. [0011] to [0026]; Figs. 1 to 3 & US 2005/0106026 A1 & EP 1653087 A1 & WO 2004/081387 A1	1-6
Y	JP 2007-46572 A (Toshiba Carrier Corp.), 22 February, 2007 (22.02.07), Par. Nos. [0012] to [0025]; Figs. 1 to 3 (Family: none)	1-6

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search
09 September, 2008 (09.09.08)

Date of mailing of the international search report
22 September, 2008 (22.09.08)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062312

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 23156/1992(Laid-open No. 75541/1993) (Tokico, Ltd.), 15 October, 1993 (15.10.93), Par. Nos. [0009] to [0012]; Figs. 1 to 8 (Family: none)	1-6
Y	JP 2006-30681 A (Fuji Electric Holdings Co., Ltd.), 02 February, 2006 (02.02.06), Par. Nos. [0021] to [0022] (Family: none)	1-6
Y	JP 7-305489 A (Kaneka Corp.), 21 November, 1995 (21.11.95), Par. No. [0022] (Family: none)	1-6
Y	JP 2003-11295 A (Fumiaki MAEJIMA), 15 January, 2003 (15.01.03), Par. No. [0003] (Family: none)	1-6
Y	JP 2006-250142 A (Samsung SDI Co., Ltd.), 21 September, 2006 (21.09.06), Par. Nos. [0068] to [0073]; Fig. 1 & US 2006/0210859 A1	1-6
Y	JP 2006-2762 A (NIDEC Corp.), 05 January, 2006 (05.01.06), Par. No. [0066] & US 2005/0260065 A1	4-5
A	WO 2005/113983 A1 (Delphi Technologies, Inc.), 01 December, 2005 (01.12.05), Par. No. [0017] & JP 2007-532085 A & US 2005/0254975 A1 & EP 1756424 A2	1-6
A	JP 2005-163554 A (KPS Industry Co., Ltd.), 23 June, 2005 (23.06.05), Par. No. [0038] (Family: none)	1-6
A	JP 2003-42099 A (Hitachi, Ltd.), 13 February, 2003 (13.02.03), Par. No. [0035] (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004278370 A **[0002] [0015] [0019]**
- US 7156611 B **[0002] [0015] [0019]**