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# (54) Title: A TURBOMACHINE ASSEMBLY

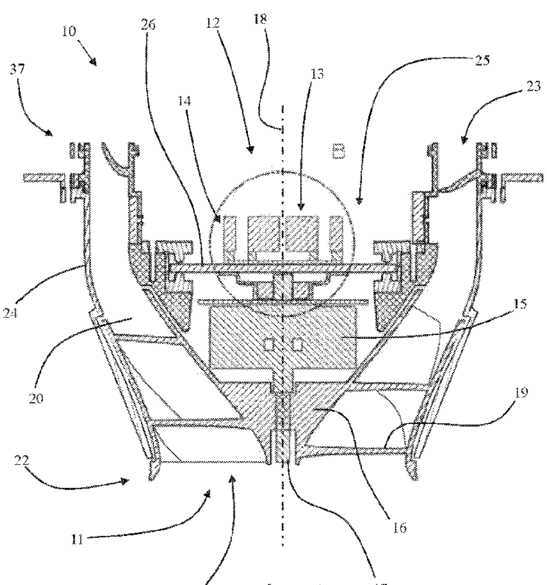


Fig. 1

**(57) Abstract:** A turbomachine assembly 10 comprising a turbomachine 11 comprising a motor 15, an impeller 16 driven by the motor 15 to rotate about a rotational axis 18, and a turbomachine housing 24 that houses the motor 15 and the impeller 16. The turbomachine assembly 10 also includes a tuned mass damper 13, 14 comprising an elastic member 27, 31 mounting a mass 28, 32 to the turbomachine housing 24, a centre of mass of the tuned mass damper 13, 14 being substantially aligned with the rotational axis 18 of the impeller 16. Also disclosed is a device including the turbomachine assembly and a method of forming the compressor assembly.

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# A TURBOMACHINE ASSEMBLY

## BACKGROUND

Many devices use turbomachines, such as fans, blowers or compressors, to transfer energy to a fluid (e.g. air). For example, such turbomachines may be present in consumer devices such as fans, heaters, humidifiers, and air purifiers. Typically, such turbomachines include a turbomachine housing that houses a motor that rotates an impeller to drive fluid along a fluid flow path (e.g. along a passage defined within the housing).

## SUMMARY

In a first aspect there is disclosed a turbomachine assembly comprising:

> a turbomachine comprising a motor, an impeller driven by the motor to rotate about a rotational axis, and a turbomachine housing that houses the motor and the impeller; and
>
> a tuned mass damper comprising an elastic member mounting a mass to the turbomachine housing, a centre of mass of the tuned mass damper being substantially aligned with the rotational axis of the impeller.

One consequence of the rotation of the components of a turbomachine (and their interaction with a fluid) is the generation of vibrations, which can manifest as noise. One source of such noise is structure-borne noise. This originates from rotation of the motor and/or impeller at particular rotational speeds, which excite structural resonances (modes) in the turbomachine so as to cause significant vibration of the turbomachine. These vibrations radiate into the air surrounding the turbomachine (or a device in which the turbomachine is mounted) and are perceived as noise by a user. Such noise can be particularly undesirable when the turbomachine is mounted within a consumer product (i.e. where such noise can be particularly detrimental to the experience of a user using the product).

It has been found that mounting a tuned mass damper to the housing of the turbomachine can reduce the noise (e.g., measured as average sound pressure level (SPL)) generated by the turbomachine at a given rotational speed (or at given rotational speeds) of the turbomachine. This reduces the noise generated by a device (in operation) in which the turbomachine is provided, to improve the experience of a user using the device.

Aligning the tuned mass damper on the rotational axis of the impeller can help to avoid the tuned mass damper introducing an imbalance to the turbomachine (which could be detrimental to noise reduction and, in some cases, performance of the turbomachine).

The tuned mass damper may be configured to reduce the amplitude of vibration of the turbomachine, in use, at a frequency that corresponds to a resonant frequency of the turbomachine. The resonant frequency may be a frequency that is excited by rotation of the motor (i.e., at a rotational speed that occurs in normal operation of the motor). In this way, the tuned mass damper may reduce the structure-borne noise generated when the turbomachine is operated at one or more rotational speeds that excite resonances of the turbomachine. Where the turbomachine assembly is mounted within a device, a secondary effect of suppressing structure-borne noise may be that transmission of the vibrations to the device can be reduced.

The cross-sectional shape of the mass, taken perpendicular to the rotational axis of the impeller, may be circular or annular (or any other suitable shape). This may avoid or reduce (in-use) imbalance of the turbomachine which could be introduced by a non-circular or non-annular cross-sectional shape.

A cross-sectional shape of the elastic member, taken perpendicular to rotational axis of the impeller, may be annular. Again, this may avoid or reduce (in-use) imbalance of the turbomachine which could be introduced by a non-circular or non-annular cross-sectional shape.

The mass may be of greater mass than the elastic member. The elastic member may have greater elasticity than the mass. The mass may be formed of steel. The elastic member may be formed of polyurethane.

The elastic member may space the mass from the turbomachine housing. That is, the mounting of the tuned mass damper may be such that the mass is spaced from (and may thus not contact) the turbomachine housing.

The tuned mass damper may be mounted to an external surface of the turbomachine housing. The tuned mass damper may be mounted to the turbomachine so as to be externally accessible.

In use, the impeller may be configured to move air from an upstream end of the turbomachine to a downstream end of the turbomachine. The turbomachine may comprise an inlet at or towards the upstream end and may comprise an outlet at or towards the downstream end. The tuned mass damper may be mounted at the downstream end of the turbomachine (e.g., in proximity to the outlet).

The turbomachine may comprise an airflow passage extending from the inlet to the outlet. The turbomachine housing may define the airflow passage. Air may be driven along the passage by rotation of the impeller. The passage may be defined by the turbomachine housing. The passage may be annular. The passage may reduce in cross-sectional area in a direction from the inlet to the outlet (i.e., may have a smaller cross-sectional area at the outlet than the inlet). When annular, the passage may diverge from the inlet to the outlet (i.e., a radius of the annulus of the passage being greater at the outlet than the inlet).

The passage (when annular) may circumferentially surround the tuned mass damper. For example, the tuned mass damper may be disposed in a cavity defined within the annulus of the annular passage.

The motor may be disposed between the tuned mass damper and the impeller. In other words, the tuned mass damper may be on an opposite side of the motor to the impeller. The tuned mass damper may be positioned adjacent to the motor.

The tuned mass damper may be a first tuned mass damper. The elastic member may be a first elastic member and the mass may be a first mass. The turbomachine assembly may further comprise a second tuned mass damper. The second tuned mass damper may comprise a second elastic member mounting a second mass to the turbomachine housing. Providing a second tuned mass damper may provide a further reduction in the noise generated by the turbomachine in use. For example, the first tuned mass damper may be tuned to reduce the amplitude of vibration of the turbomachine in use at first frequency and the second tuned mass damper may be tuned to reduce the amplitude of vibration of the turbomachine in use at a second frequency that is different to the first frequency.

The first frequency may, for example, correspond to a resonant frequency of the turbomachine, excited at a first rotational speed of the motor. The second frequency may, for example, correspond to a resonant frequency of the turbomachine, excited at a second rotational speed (different to the first rotational speed). Thus, vibration amplitudes may be reduced at two frequencies, or at two different frequency ranges (which correspond to two different rotational speeds of the motor). The first and second frequencies may be resonant frequencies of the turbomachine. Each of the first and second tuned mass damper may have a cross-sectional shape that has axial symmetry about the rotational axis of the impeller. Each of the first and second tuned mass dampers may have an annular cross-sectional shape (although in other embodiments the first and second tuned mass dampers may take other suitable shapes).

The first and second tuned mass dampers may be arranged concentrically with respect to one another. In this way, both the first and second tuned mass dampers may be arranged such that their centres of mass are aligned with the rotational axis of the impeller. This may ensure that neither tuned mass damper creates an imbalance during operation of the turbomachine.

The turbomachine assembly may comprise a rigid mounting element mounting the first and second tuned mass dampers to the turbomachine housing. In this way, the first and second tuned mass dampers may be provided as a package (i.e., when mounted to the rigid mounting element) that can be affixed to the turbomachine. This may allow more convenient and accurate mounting of the first and second tuned mass dampers with respect to one another. Likewise, it allows the package to be provided as a modular component that can be added (e.g., retrofitted) to a turbomachine as necessary.

As may be appreciated, more than two (e.g., three, four, five, etc.) mass tuned mass dampers may be provided in the same manner as described above.

The turbomachine may be a compressor. Alternatively, the turbomachine may be a blower or a fan.

In a second aspect there is disclosed a device comprising an external device housing that houses a turbomachine assembly according to the first aspect, the turbomachine housing of the turbomachine assembly rigidly mounted to the device housing.

When there is a rigid mounting between the turbomachine assembly and the device housing, vibration of the turbomachine is transmitted via that rigid mounting to the external device housing, which subsequently results in noise. As has already been mentioned, the turbomachine assembly (due to the inclusion of the tuned mass damper) operated at reduced noise levels (and, indeed, in some cases with reduced tactile vibration). Thus, incorporating the turbomachine assembly into a device provides a device with reduced noise emissions and that may be more comfortable for a user to use.

The device may be a consumer device or appliance, such as, for example, a fan (e.g., a tower fan), a heater, an air purifier or a humidifier.

In a third aspect, there is disclosed a method of forming a turbomachine assembly, the method comprising:

providing a turbomachine that comprises a motor, an impeller driven by the motor to rotate about a rotational axis, and a turbomachine housing that houses the motor and the impeller;

identifying a resonant frequency of the turbomachine;

providing a tuned mass damper comprising a mass and an elastic member, the tuned mass damper configured to reduce the amplitude of vibration of the turbomachine, in use, at a frequency that corresponds to the identified resonant frequency; and

mounting the tuned mass damper to the turbomachine housing to form a turbomachine assembly, the mounting performed such that a centre of mass of the tuned mass damper is substantially aligned with rotational axis of the impeller.

As has already been discussed above, such a turbomachine assembly can provide an assembly that emits less noise.

The turbomachine assembly may be as according to any one of the preceding claims.

The step of identifying a resonant frequency may comprise identifying a resonant frequency that is excited by rotation of the motor and/or the impeller in normal operation of the turbomachine. This may be performed, for example, by way of structural simulations or vibroacoustic modal analysis. For example, a Campbell diagram for vibration or SPL measurements of the turbomachine can be used to identify significant tones which are not related to the blade pass frequency harmonics, and to identify at which rotational speeds of the turbomachine they pass through possible structural modes/resonances. These tones are likely to represent structure-borne noise. Experimental modal analysis techniques can be used to corroborate that these tones are exciting structural modes of the turbomachine.

The tuned mass damper may be a first tuned mass damper. The mass maybe a first mass and the elastic member may be a first elastic member. The method may comprise providing a second tuned mass damper comprising a second mass and a second elastic member.

The method may comprise mounting the second tuned mass damper to the turbomachine housing to form a turbomachine assembly. The mounting of the second tuned mass damper may be performed such that a centre of mass of the second tuned mass damper is substantially aligned with the rotational axis of the impeller. In this way, each of the first and second tuned mass dampers may have its centre of mass aligned with the rotational axis. Likewise, the centre of mass of the combination of the first and second tuned mass dampers may be aligned with the rotational axis.

The method may comprise identifying a second resonant frequency of the turbomachine. The second tuned mass damper may be configured to reduce the amplitude of vibration of the turbomachine, in use, at a frequency that corresponds to the identified second resonant frequency.

The first and second tuned mass dampers may be as described with respect to the first aspect. Thus, for example, the first and second tuned mass dampers may be concentrically arranged with respect to one another (and each may e.g., have an annular cross-sectional shape).

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a section view of a turbomachine assembly;

Figure 2A is a perspective view of a tuned mass damper assembly forming part of the turbomachine assembly of Figure 1;

Figure 2B is a section view of the tuned mass damper of Figure 2A;

Figure 3 is a plot showing the effect of the tuned mass damper on the noise generated by the turbomachine in use; and

Figure 4 is a schematic view of a device including the turbomachine assembly of Figure 1.

## DETAILED DESCRIPTION

Aspects and embodiments will now be discussed with reference to the accompanying figures. Further aspects and embodiments will be apparent to those skilled in the art.

Figure 1 shows a turbomachine assembly 10 that includes a turbomachine 11 (in the form of a compressor) and a tuned mass damper assembly 12 formed of a first tuned mass damper 13 and a second tuned mass damper 14 (shown in more detail in Figures 2A and 2B).

The turbomachine 11 comprises a motor 15 (in this case, an electric motor) and an impeller 16 that is driven by the motor 15, via a drive shaft 17, so as to rotate about a rotational axis 18. The impeller 16 includes blades 19 which, when the impeller 16 is rotated, move air through an annular passage 20 of the turbomachine 11. In particular, air is moved by the blades 19 from an inlet 21 at an upstream end 22 of the turbomachine 11 to an outlet 23 at a downstream end 37 of the turbomachine 11.

As should be apparent from Figure 1, the annular passage 20 narrows in a direction from the upstream end 22 to the downstream end 37 (i.e., so as to have a smaller cross-sectional area at the outlet 23 than at the inlet 21). The passage 20 also diverges from the rotational axis 18 in the downstream direction (i.e., in a direction from the inlet 21 to the outlet 23) such that the annulus of the annular cross-section of the passage 20 has a greater diameter at the outlet 23 than at the inlet 21.

The annular passage 20 is defined by a turbomachine housing 24, which also houses the motor 15, the impeller 16 and the drive shaft 17 connecting the motor 15 to the impeller 16. The turbomachine housing 24 packages these components so that the turbomachine 11 can be installed into a device as a single package (rather than as individual components). As well as facilitating manufacture, this can improve replaceability and repair of the turbomachine 11 when installed in a device.

The diverging shape of the passage 20, as described above, means that at the downstream end 37 of the turbomachine 11, the housing 24 defines a generally cylindrical cavity 25 (i.e., recessed into the downstream end 37 of the housing 24). At the base of this cavity 25, the housing 24 includes an end wall 26 (adjacent to the motor 15) to which the tuned mass damper assembly 12 is mounted. In this way, the tuned mass damper assembly 12 is positioned adjacent to the motor 15, which is between the tuned mass damper assembly 12 and the impeller 16.

As should be apparent from Figure 1, each of the first tuned mass damper 13 and the second tuned mass damper 14 is aligned so that its respective centre of mass is aligned with the rotational axis 18 of the impeller 17. This reduces (or avoids) the possibility of the tuned mass dampers 13, 14 introducing an imbalance to the turbomachine assembly 10 in operation (which could be detrimental to operation of the turbomachine 11 and/or to the noise generated by the turbomachine assembly 10).

The tuned mass damper assembly 12 is shown in more detail in Figures 2A and 2B. As mentioned above, the tuned mass damper assembly 12 includes a first tuned mass damper 13 and a second tuned mass damper 14. These are arranged concentrically with the second tuned mass damper 14 extending circumferentially about (and radially spaced from) the first tuned mass damper 13. In this way, each of the first 13 and second 14 tuned mass dampers can be arranged such its centre of mass is aligned on the rotational axis 18 (shown in Figure 1) of the impeller 17.

The first tuned mass damper 13 includes a first elastic member 27 (formed of polyurethane rubber) mounting a first mass 28 (formed of steel) to the turbomachine housing 24. In particular, the first elastic member 27 is mounted to a lowermost surface of the first mass 28 such that when the tuned mass damper assembly 13 is mounted to the turbomachine housing 24, the first elastic member 27 is disposed between the first mass 28 and the turbomachine housing 24.

Each of the first elastic member 27 and first mass 28 have a tubular shape (i.e., so as to have an annular cross-sectional shape, taken perpendicular to the rotational axis 18) and are both aligned on the rotational axis 18 when mounted to the turbomachine housing 24. One benefit of the tubular shape of the first mass 28 is that its central hollow 29 (or bore) provides fluid communication between the central hollow 30 of the first elastic member 27 and the external environment. If on the other hand, air was trapped within the central hollow 30 of the elastic member, it could alter the response of the tuned mass damper to vibration of the turbomachine (and such response could change with temperature of the turbomachine). Likewise, the provision of the central hollow 30 may permit the release of gases that can sometimes be released when adhering the tuned mass damper 13.

As is apparent from Figure 2B, the central hollow 29 of the first elastic member 27 has a greater diameter than the central hollow 30 of the first mass 28. On the other hand, the outer diameters of the first elastic member 27 and the first mass 28 are the same such that their respective outer circumferential surfaces are coplanar.

The second tuned mass damper 14 includes a second elastic member 31 (formed of polyurethane rubber) mounting a second mass 32 (formed of steel) to the turbomachine housing 24. Each of the second elastic member 31 and second mass 32 have a tubular shape and are both aligned on the rotational axis 18 when mounted to the turbomachine housing 24. The second elastic member 31 circumferentially surrounds (and is radially spaced from) the first elastic member 27, and the second mass 32 circumferentially surrounds (and is radially spaced from) the first mass 28. As a result, the first tuned mass damper 13 is not in direct contact with the second tuned mass damper 14.

The first tuned mass damper 13 is, however, connected to the second tuned mass damper 14 by way of a mounting element 33 (in the form of a circular mounting plate). Both the first 27 and second 31 elastic members are mounted to an upper surface 34 of the mounting element 33 and, thus, are mounted to the turbomachine housing 24 by the mounting element 33. In this way, the first tuned mass damper 13, second tuned mass damper 14 and the mounting element 33 (defining the tuned damper assembly 12) can be formed as a package, which can then be mounted to the turbomachine housing 24.

The tuned mass damper assembly 12 is configured to reduce the noise generated by the turbomachine 11 in operation. This is best illustrated by Figure 3, which is a plot showing the effect of mounting the tuned mass damper assembly 12 to the turbomachine 11. In particular, the plot illustrates the average sound pressure level (dB) over a range of motor speeds (RPM) of the motor 15, both with and without the tuned mass damper assembly 12 mounted to the turbomachine 11.

For the purpose of generating this data, both the first 28 and second 32 masses had a mass of 77 g. The first tuned mass damper 13 had a static stiffness of 289,000 N/m and the second tuned mass damper 14 had a static stiffness of 436,000 N/m. Static stiffness was measured using compression testing along the axis of oscillation (i.e., parallel to the rotational axis when mounted).

Referring firstly to the data (illustrated using a broken line) in which the tuned mass damper assembly 12 is not mounted to the turbomachine 11, it apparent that there are two motor speed ranges (i.e., first 35 and second 36 critical motor speed ranges) that elicit a greater response in average sound pressure level (i.e., when compared to other measured motor speeds). The greater response in average sounds pressure level (which is perceived as a user as increased noise) is a result of the particular motor speeds exciting resonant frequencies of the turbomachine 11.

Turning now to the data (illustrated using a solid line) in which the tuned mass damper assembly 12 is mounted to the turbomachine 11, it is apparent that the average sound pressure level at each of the abovementioned first 35 and second 36 critical motor speed ranges is significantly reduced (thus reducing the noise experienced by a user). This is achieved by provision of the first 13 and second 14 tuned mass dampers, each of which is tuned (i.e., by selection of a particular mass and static stiffness) to reduce mechanical vibration of the turbomachine 11 at one of the first 35 and second 36 motor speed ranges.

In particular, the first tuned mass damper 13 (which has a lower static stiffness than the second tuned mass damper 14) is configured to reduce mechanical vibration of the turbomachine 11 associated with operation of the turbomachine 11 at the first critical motor speed range 35. Likewise, the second tuned mass damper 14 is configured to reduce mechanical vibration of the turbomachine 11 associated with operation of the turbomachine 11 at the second critical motor speed range 36. In this way, during operation of the turbomachine 11, when the motor 15 is operated within the critical speed ranges 35, 36 there is reduced noise.

As may be appreciated, the turbomachine assembly 10 may be suitable for use in a range of devices. One such example is shown in Figure 4, which schematically illustrates the turbomachine 11 installed within a device 37, which is in the form of a tower fan. The device 37 includes an inlet 40 into which air enters the device 47 and an outlet 41, from which air is discharged. The turbomachine assembly 10 is installed so as to be rigidly mounted to a housing 38 of the device 37 by way of a tubular rigid mounting portion 39. As may be appreciated, this rigid mounting ensures secure mounting of the turbomachine assembly 10 within the device 37, but also means that vibration of the turbomachine assembly 10 can be easily transmitted to the device housing 38 (which can result in noise during operation of the device 37). However, as has been described above, the provision of the tuned mass damper assembly 12 reduces this issue by minimising such vibration.

The features disclosed in the foregoing description, or in the following claims, or in the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for obtaining the disclosed results, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

For the avoidance of any doubt, any theoretical explanations provided herein are provided for the purposes of improving the understanding of a reader. The inventors do not wish to be bound by any of these theoretical explanations.

Any section headings used herein are for organizational purposes only and are not to be construed as limiting the subject matter described.
Throughout this specification, including the claims which follow, unless the context requires otherwise, the word “comprise” and “include”, and variations such as “comprises”, “comprising”, and “including” will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

It must be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by the use of the antecedent “about,” it will be understood that the particular value forms another embodiment. The term “about” in relation to a numerical value is optional and means for example +/- 10%.

CLAIMS

1. A turbomachine assembly comprising:

a turbomachine comprising a motor, an impeller driven by the motor to rotate about a rotational axis, and a turbomachine housing that houses the motor and the impeller; and

a tuned mass damper comprising an elastic member mounting a mass to the turbomachine housing, a centre of mass of the tuned mass damper being substantially aligned with the rotational axis of the impeller.

2. A turbomachine assembly according to claim 1 wherein the tuned mass damper is configured to reduce the amplitude of vibration of the turbomachine, in use, at a frequency that corresponds to a resonant frequency of the turbomachine.

3. A turbomachine assembly according to claim 1 or 2 wherein a cross-sectional shape of the mass, taken perpendicular to the rotational axis of the impeller, is circular or annular.

4. A turbomachine assembly according to any one of the preceding claims wherein a cross-sectional shape of the elastic member, taken perpendicular to rotational axis of the impeller, is annular.

5. A turbomachine assembly according to any one of the preceding claims wherein, in use, the impeller moves air from an upstream end of the turbomachine to a downstream end of the turbomachine, and wherein the tuned mass damper is mounted at the downstream end of the turbomachine.

6. A turbomachine assembly according to any one of the preceding claims wherein the motor is disposed between the tuned mass damper and the impeller.

7. A turbomachine assembly according to any one of the preceding claims wherein the tuned mass damper is a first tuned mass damper, and the turbomachine assembly further

comprises a second tuned mass damper comprising a second elastic member mounting a second mass to the turbomachine housing.

8. A turbomachine assembly according to claim 7 wherein the first and second tuned mass dampers are arranged concentrically with respect to one another.

9. A turbomachine assembly according to claim 7 or 8 wherein the first tuned mass damper is tuned to reduce the amplitude of vibration of the turbomachine in use at first frequency and the second tuned mass damper is tuned to reduce the amplitude of vibration of the turbomachine in use at a second frequency that is different to the first frequency.

10. A turbomachine assembly according to any one of claims 7 to 9 comprising a rigid mounting element mounting the first and second tuned mass dampers to the turbomachine housing.

11. A turbomachine assembly according to any one of the preceding claims wherein the turbomachine housing defines an airflow passage, and wherein rotation of the impeller moves air along the airflow passage.

12. A turbomachine assembly according to any one of the preceding claims wherein the turbomachine is a compressor.

13. A device comprising an external device housing that houses a turbomachine assembly according to any one of the preceding claims, the turbomachine housing of the turbomachine assembly rigidly mounted to the device housing.

14. A method of forming a turbomachine assembly, the method comprising:

providing a turbomachine that comprises a motor, an impeller driven by the motor to rotate about a rotational axis, and a turbomachine housing that houses the motor and the impeller;

identifying a resonant frequency of the turbomachine;

providing a tuned mass damper comprising a mass and an elastic member, the tuned mass damper configured to reduce the amplitude of vibration of the turbomachine, in use, at a frequency that corresponds to the identified resonant frequency; and

mounting the tuned mass damper to the turbomachine housing to form a turbomachine assembly, the mounting performed such that a centre of mass of the tuned mass damper is substantially aligned with rotational axis of the impeller.

15. A method according to claim 14 wherein the turbomachine assembly is as according to any one of claims 1 to 12.

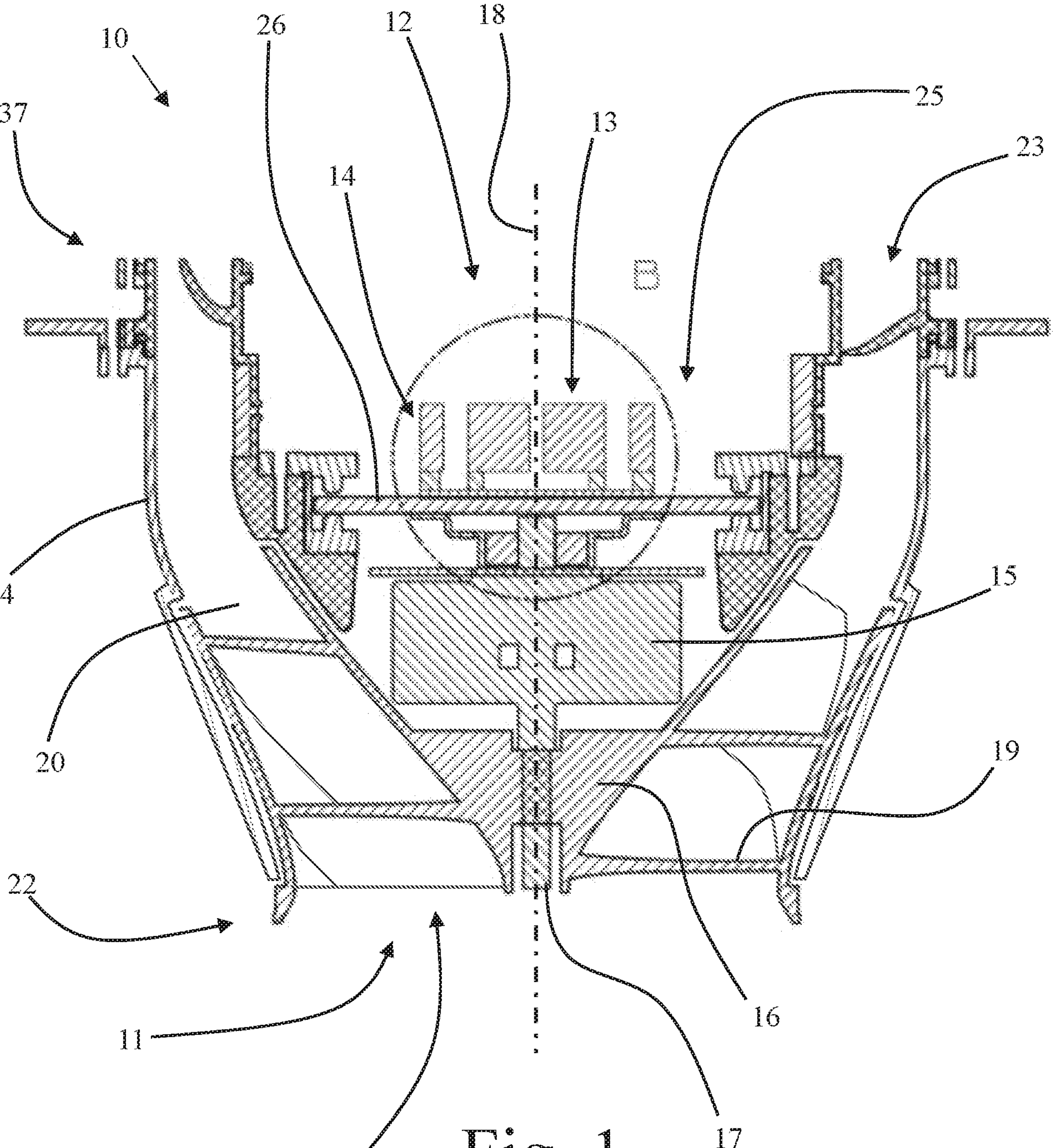


Fig. 1

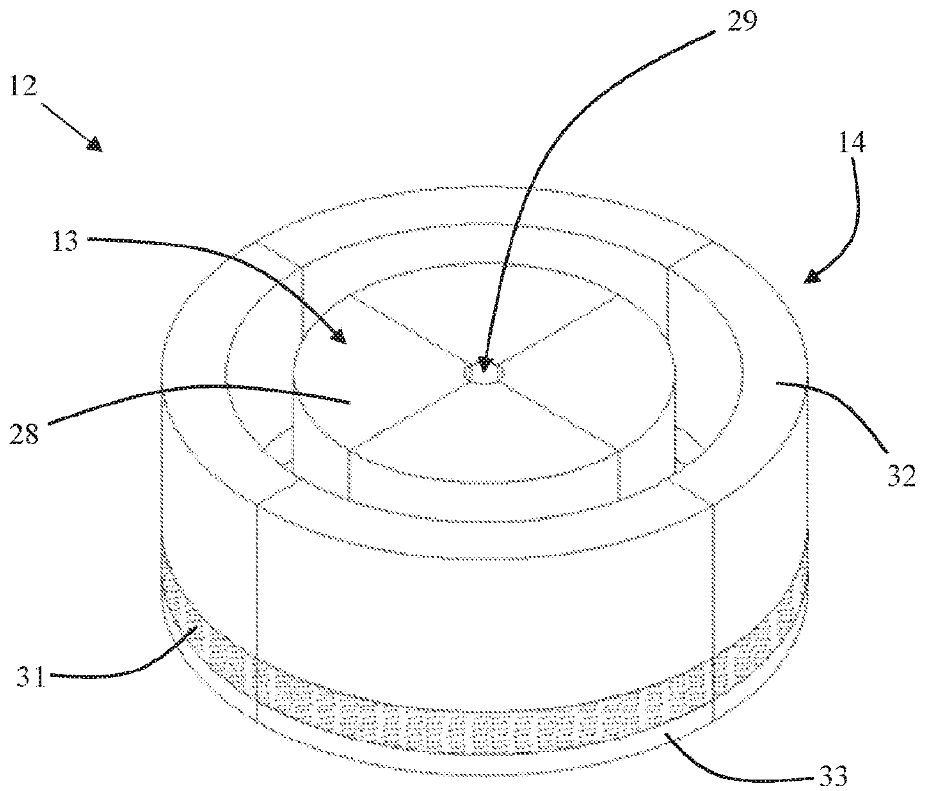


Fig. 2A

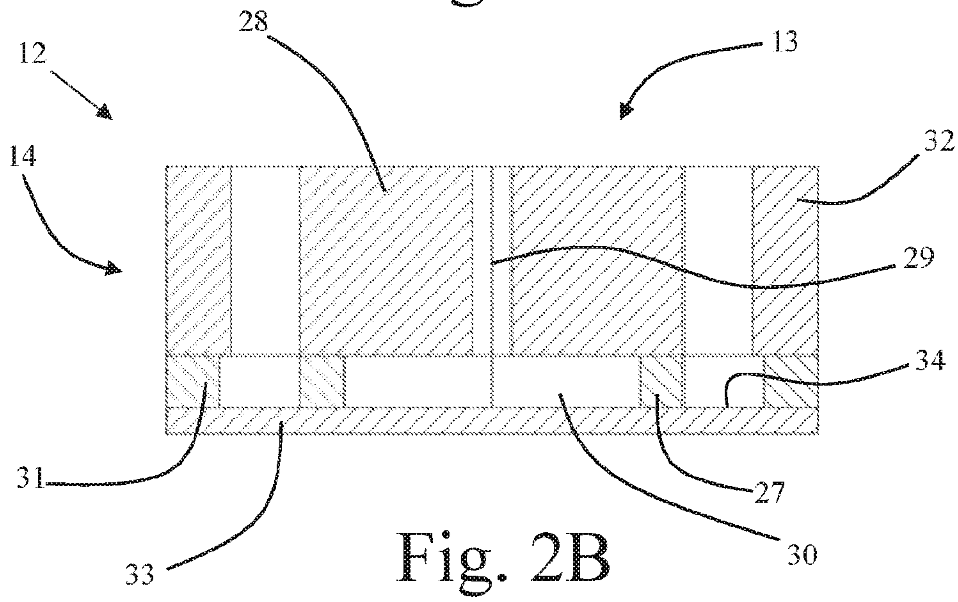


Fig. 2B

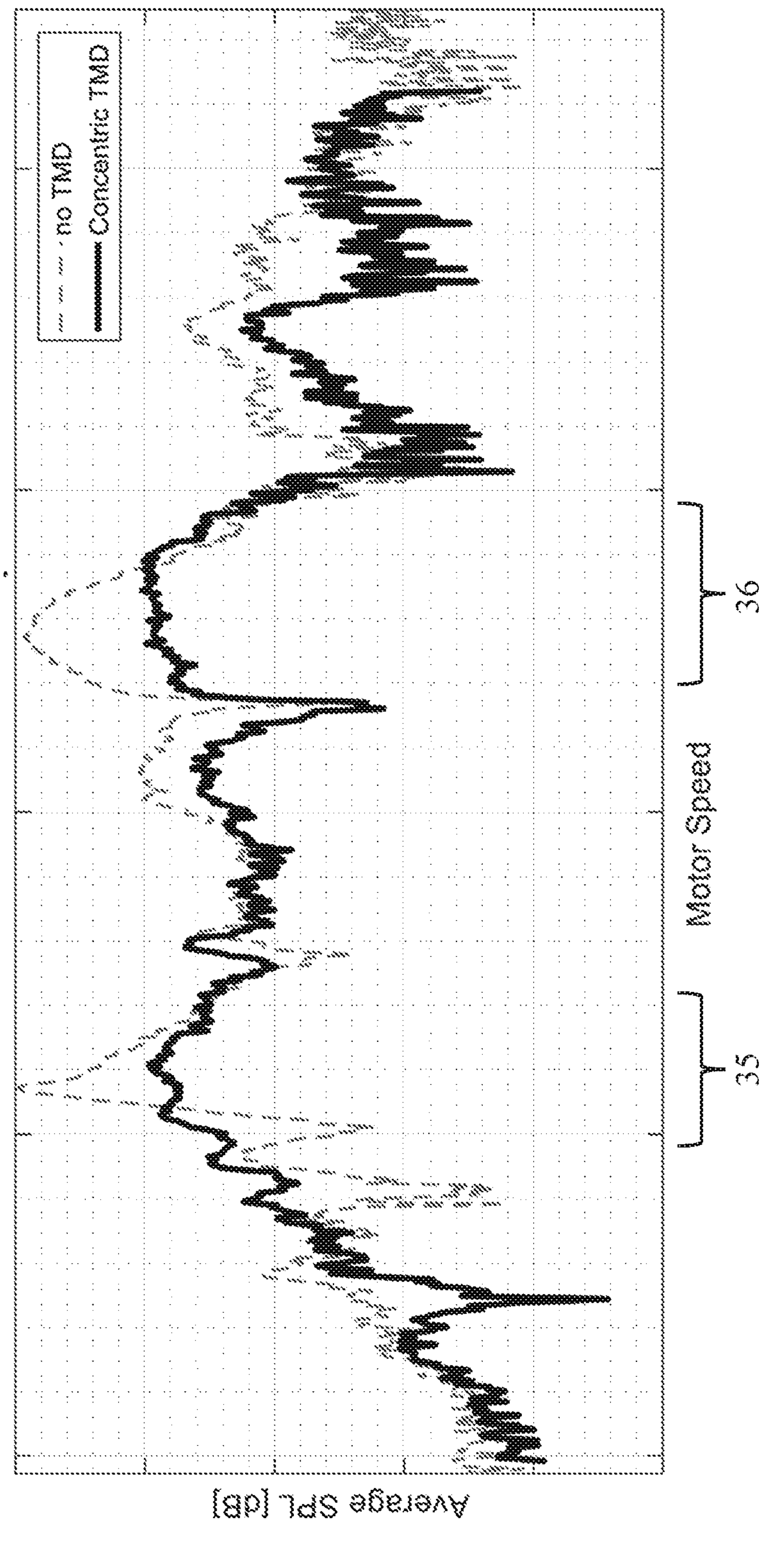


Fig. 3

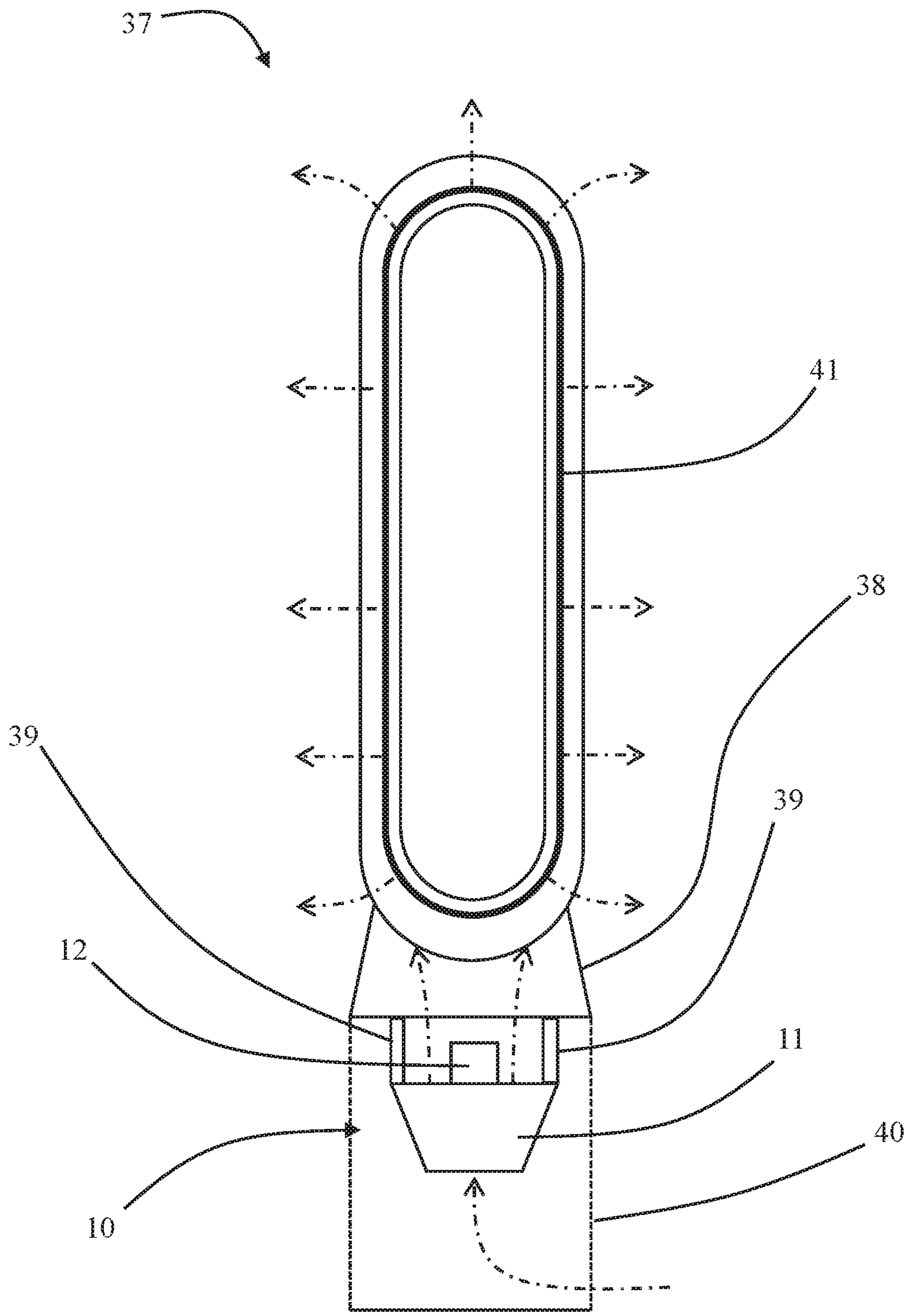


Fig. 4

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/052363

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. F04D17/10 F04D25/06 F04D29/42 F04D29/66 H02K5/24
ADD.

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)
F04D H02K

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

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

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 98/31939 A1 (FLAEKT OY [FI]; HULKKONEN RAULI TAPANI [FI] ET AL.) 23 July 1998 (1998-07-23) | 1-7,9-15 |
| A | page 2, line 19 - page 3, line 18 figures 1-6 ----- | 8 |
| X | US 2012/128484 A1 (HAMOCHI MITSURU [JP]) 24 May 2012 (2012-05-24) paragraph [0050] - paragraph [0065] figures 1-3 ----- | 1-4,11, 13-15 |
| A | CN 114 607 646 A (HAUPIFU FAN TECH SUZHOU LIMITED COMPANY) 10 June 2022 (2022-06-10) abstract figures 1-5 ----- | 1-15 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 May 2024 | 23/05/2024 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Lovergine, A |

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# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/IB2024/052363

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| WO 9831939 | A1 | 23-07-1998 | AU | 5665598 | A | 07-08-1998 |
| | | | EP | 0953116 | A1 | 03-11-1999 |
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| CN 114607646 | A | 10-06-2022 | NONE | | | |