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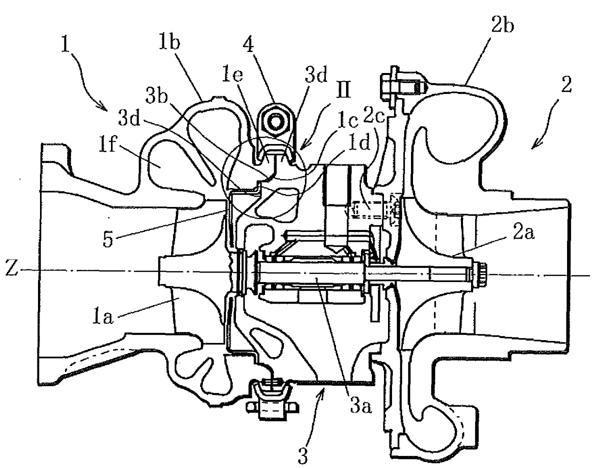
# (54) HOUSING FASTENING METHOD

(57) An object of the present invention is to provide, by contriving a housing structure, a housing fastening method and turbocharger capable of keeping down a reduction in fastening force applied by a G-coupling even when housings are exposed to high temperature.

The present invention provides a turbocharger comprising a turbine 1 including a bladed rotor 1a rotated by a fluid supplied thereto, a compressor 2 including anO impeller 2a for drawing in air, connected with the bladed rotor 1a by a rotating shaft 3a, a turbine housing 1b constituting an outer shape of the turbine 1, and a bearing housing 3 rotatably supporting the rotating shaft 3a, a projecting portion 3b of the bearing housing 3 being inserted in a recessed portion 1c of the turbine housing 1b such that an end face 3c of the projecting portion 3b butts against a step portion 1d of the recessed portion 1c serving as a stopper face, a flange portion 1e around the recessed portion 1c and a flange portion 3d around the projecting portion 3b being fastened together by an annular fastener positioned outside, wherein the shapes of the recessed portion 1c and the projecting portion 3b are determined by regulating the axial position of the stopper face of the step portion 1d.

FIG. 1A

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## Description

### Technical Field

**[0001]** This invention relates to a housing fastening method for fastening housings together by a fastener such as a G-coupling and a turbocharger having housings fastened together by a fastener such as a G-coupling, and particularly a housing fastening method and turbocharger capable of keeping down a reduction in fastening force applied by a fastener.

### Background Art

**[0002]** A rotary machine which obtains power by converting kinetic energy of a fluid supplied to its bladed rotor to rotation of the bladed rotor is generally called a turbine. A type in which a fluid is supplied to the bladed rotor radially and discharged axially is called a radial turbine, in particular. An automotive turbocharger is a device using such radial turbine. The automotive turbocharger comprises a gas turbine including a bladed turbine rotor rotated by exhaust gas supplied thereto and a compressor including an impeller for drawing in air, connected with the bladed turbine rotor coaxially. The air drawn in and compressed by the compressor is delivered to an engine, where it is mixed with fuel and burnt. Exhaust gas produced from combustion is sent to the gas turbine to do work, and finally emitted into the atmosphere. The passage through which the exhaust gas is supplied to the bladed turbine rotor includes a scroll portion extending spirally around the axis of rotation of the bladed turbine rotor so that the exhaust gas is accelerated and supplied to the bladed turbine rotor radially.

**[0003]** The automotive turbocharger as described above has a rotating shaft which connects the bladed turbine rotor of the gas turbine and the impeller of the compressor. The rotating shaft is supported by a bearing housing, rotatably. In some cases, a turbine housing and the bearing housing are connected together by fastening a fastener such as a G-coupling to flange portions of the turbine housing and bearing housing (see Patent Document 1, FIG. 12, for example).

Patent Document 1: Japanese Patent Application KOKAI Publication 2006-258108, FIG. 12

**[0004]** When the turbine housing and the bearing housing are fastened together by a fastener such as a G-coupling as in Patent Document 1, however, thermal expansion of the flange portions and fastener during use of the turbocharger sometimes produces a gap between the flange portions and the fastener due to difference in linear coefficient of expansion between the respective flange portions and the fastener, which results in a reduction in fastening force applied by the fastener. Further, exposure of the turbine housing inside to high-temperature exhaust gas causes thermal expansion of its flange portion, which in turn causes deformation of the fastener. This sometimes results in a reduction in fastening force applied by the fastener when the exhaust gas temperature drops.

### Disclosure of the Invention

**[0005]** The present invention has been made to solve the problems as mentioned above. An object of the present invention is to provide, by contriving a housing structure, a housing fastening method and turbocharger capable of keeping down the reduction in fastening force applied by a fastener such as a G-coupling even when housings are exposed to high temperature.

**[0006]** In order to achieve the above object, the present invention provides a housing fastening method comprising the steps of inserting a projecting portion of a housing in a recessed portion of another housing so that an end face of the projecting portion butts against a step portion of the recessed portion serving as a stopper face and that a flange portion around the recessed portion and a flange portion around the projecting portion face each other, and thereafter, fastening the housings together by an annular fastener with a grooved portion on its inside adapted to receive the flange portions facing each other, wherein the axial position of the stopper face of the step portion and the shapes of the recessed portion and the projecting portion are determined to ensure that a gap produced between the grooved portion of the fastener and the flange portions does not exceed a specified size even when the housings and the fastener experience thermal expansion during use.

**[0007]** The above-described housing fastening method according to the present invention was contrived through the inventor's keen research on reduction in fastening force applied by a fastener such as a G-coupling for fastening housings together, due to thermal expansion, which research led to the finding that there exists a connection between the axial position of the stopper face of the step portion and the fastening force applied by the fastener. This means that by regulating the axial position of the stopper face of the step portion, reduction in fastening force applied by the fastener can be kept down, without requiring full discovery of thermal expansion of the flange portions and fastener. Consequently, even under thermal expansion, the gap produced between the fastener and the flange portions can be easily controlled by appropriately determining the axial position of the stopper face of the step portion and the shapes of the recessed portion and the projecting portion. For example, by setting the axial position of the stopper face of the step portion nearer to the end (reducing the depth of the recessed portion) compared with the prior art, reduction in fastening force applied by the fastener due to thermal expansion can be kept down even when the inside of the housing is exposed to high temperature (ca 1000°C, for example).

**[0008]** In a preferred aspect of this housing fastening method, the axial position of the stopper face of the step portion is set within the axial projected width of the fastener.

**[0009]** This leads to a reduced axial distance between a contact position on the housing having the recessed portion against the fastener and the stopper face of the step portion. Consequently, the reduction in fastening force applied by the fastener due to thermal expansion can be kept down, even when the housing having the recessed portion is exposed to higher temperature compared with the housing having the projecting portion and the fastener, in particular.

**[0010]** Specifically, the axial distance between the contact positions on the respective flange portions against the fastener is equal to the axial distance between the stopper face and the contact position on the flange portion of the housing having the recessed portion against the fastener subtracted from the axial distance between the stopper face and the contact position on the flange portion of the housing having the projecting portion against the fastener. Theoretically, as long as the housings and the fastener experience uniform thermal expansion, there occurs no reduction in fastening force applied by the fastener. If, however, the housing having the recessed portion experiences a greater degree of thermal expansion compared with the housing having the projecting portion, the axial distance between the contact positions on the respective flange portions against the fastener relatively reduces, so that a gap is produced between the housings and the fastener.

**[0011]** In the preferred aspect, however, since the axial distance between the contact position on the flange portion of the housing having the recessed portion against the fastener and the stopper face of the step portion is small, the increase in the axial distance between the contact position and the stopper face due to thermal expansion of the housing having the recessed portion is very small. Consequently, even when the housing having the recessed portion is exposed to higher temperature compared with the housing having the projecting portion and the fastener, increase in size of the gap between the housings and the fastener due to thermal expansion can be kept down, so that reduction in fastening force applied by the fastener can be kept down.

**[0012]** In another aspect of the housing fastening method according to the present invention, the shape of the projecting portion is determined taking account of the thickness of a thin sheet held between the stopper face of the step portion and the end face of the projecting portion.

**[0013]** In this aspect, when a thin sheet, such as a spacer or a heat shield plate, is provided between the stopper face of the step portion of one of the adjoining housings and the end face of the projecting portion of the other housing, thermal expansion of this thin sheet is also taken into consideration, so that the reduction in fastening force applied by the fastener due to thermal expansion can be more effectively kept down.

**[0014]** In another aspect of the housing fastening method according to the present invention, the flange portion of the housing which is likely to experience a smaller degree of thermal expansion is formed to be greater in outside diameter than the flange portion of the housing which is likely to experience a greater degree of thermal expansion.

**[0015]** This aspect enables the edges of both flange portions to take approximately the same radial position at high temperature, although the housings fastened together experience different degrees of thermal expansion, thereby greatly reducing a force tending to tilt the fastener.

**[0016]** In a specific aspect, the axial distance Az from the contact position at which the fastener contacts the flange portion around the recessed portion to the stopper face of the step portion and the axial distance Bz from the contact position at which the fastener contacts the flange portion around the projecting portion to the end face of the projecting portion are determined to meet the condition $0 \leq Cg\text{-}C \leq$ allowable limit k, where C is an axial distance between the contact positions on the flange portions defined by an expression $C = t+Bz-Az$, on the basis of said axial distances Az and Bz, and Cg is an axial distance between the contact positions on the fastener. Here, the allowable limit k may be set on the basis of the allowable size for a gap produced between the fastener and the contact position on the flange portion at a specified temperature. Specifically, it is desirable to set the allowable limit k to meet the condition $0 \leq k < 0.0388/\cos(\theta/2)$, where θ is an angle of divergence of a pair of support portions of the fastener.

**[0017]** In this specific aspect, determining the axial distance Az in the recessed portion and the axial distance Bz in the projecting portion to meet the above-mentioned condition leads to limiting the size of the gap produced between the fastener and the flange portion at high temperature within a desired range. Consequently, reduction in fastening force applied by the fastener can be kept down.

**[0018]** The present invention also provides a turbocharger comprising a turbine including a bladed rotor rotated by a fluid supplied thereto, a compressor including an impeller for drawing in air, connected with the bladed rotor by a rotating shaft, a turbine housing constituting an outer shape of the turbine, and a bearing housing rotatably supporting the rotating shaft, a projecting portion of the bearing housing being inserted in a recessed portion of the turbine housing such that an end face of the projecting portion butts against a step portion of the recessed portion serving as a stopper face and that a flange portion around the recessed portion and a flange portion around the projecting portion face each other, the flange portions being fastened together by an annular fastener with a grooved portion on its inside adapted to receive the flange portions facing each other, wherein the bearing housing and the turbine housing are fastened together by the fastener according to any of the above aspects of the housing fastening method.

**[0019]** The turbocharger having a configuration described above can keep down the reduction in fastening force applied by the fastener due to thermal expansion.

**Brief Description of the Drawings**

**[0020]**

FIG. 1A is a longitudinal cross-sectional view of a turbocharger according to the present invention.
FIG. 1B is a front view of a G-coupling 4 shown in FIG. 1A.
FIG. 2A is a diagram showing portion II of FIG. 1A on an enlarged scale.
FIG. 2B is a diagram showing a portion corresponding to the portion shown in FIG. 2A in prior art, on an enlarged scale.
FIG. 3 is an explanatory diagram indicating sizes referred to in describing a housing fastening method according to an embodiment of the present invention.
FIG. 4A is a diagram showing a relation between a G-coupling 4 and flange portions 1e and 3d at normal temperature.
FIG. 4B is a diagram showing a relation between the G-coupling 4 and the flange portions 1e and 3d at high temperature.
FIG. 4C is a diagram showing a relation between gaps $\Delta g$ and $\Delta c$ shown in FIG. 4B.
FIG. 5A is a longitudinal cross-sectional view showing a fastening structure made by a housing fastening method according to another embodiment of the present invention.
FIG. 5B is a longitudinal cross-sectional view showing a fastening structure made by a housing fastening method according to another embodiment of the present invention.

**Best Mode of Carrying out the Invention**

**[0021]** Referring to FIGS. 1A to 5B, embodiments of the present invention will be described below. FIG. 1A is a longitudinal cross-sectional view of a turbocharger according to the present invention, and FIG. 1B a front view of a G-coupling shown in FIG. 1A. FIG. 2A shows portion II of FIG. 1A on an enlarged scale, and FIG. 2B shows a portion corresponding to the portion shown in FIG. 2A in prior art.

**[0022]** The turbocharger according to the present invention shown in FIG. 1A comprises a turbine 1 including a bladed rotor 1a rotated by a fluid supplied thereto, a compressor 2 including an impeller 2a for drawing in air, connected with the bladed rotor 1a by a rotating shaft 3a, a turbine housing 1b constituting an outer shape of the turbine 1, and a bearing housing 3 rotatably supporting the rotating shaft 3a. The turbine housing 1a and the bearing housing 3 and the bearing housing 3 [sic] are assembled as follows: A projecting portion 3b of the bearing housing 3 is inserted in a recessed portion 1c of the turbine housing 1a so that an end face 3c of the projecting portion 3b butts against a step portion 1d of the recessed portion 1c serving as a stopper face and that a flange portion 1e around the recessed portion 1c and a flange portion 3d around the projecting portion 3b face each other. Then, the flange portions 1e and 3e are fastened together by an annular G-coupling 4 with a grooved portion on its inside adapted to receive the flange portions 1e and 3d facing each other, where the axial position of the stopper face of the step portion 1d and the shapes of the recessed portion 1c and the projecting portion 3b are determined as described later. Incidentally, although the turbine 1 of the turbocharger shown in FIG. 1A has a multiple-chamber scroll portion 1f, the present invention is not limited to this configuration. The turbocharger may have a single-chamber scroll portion, and may include a variable nozzle for regulating flow rate, between the scroll portion 1f and the bladed rotor 1a. Further, although in the drawing, a compressor housing 2b and the bearing housing 3 are fastened together by bolts 2c distributed circumferentially, they may be fastened together in another manner.

**[0023]** In the turbocharger shown in FIG. 1A, the axial position of the stopper face of the step portion 1d is set, for example within the axial projected width Zg of the G-coupling 4, as indicated in FIG. 2A. Here, if the flange portions 1e and 3d are approximately equal in axial width, there exists a relationship $Za \leq 0.5Zg$, where Za is the axial distance between the end face of the flange portion 1e and the stopper face of the step portion 1d of the turbine housing 1b. In the prior art shown in FIG. 2B, on the other hand, the axial position of the stopper face of the step portion 1d is set outside the axial projected width Zg of the G-coupling 4, so that there exists a relationship $Za > 0.5Zg$. In the structure shown in FIG. 28, when the inside of the turbine housing 1b is exposed to high temperature (ca 1000°C, for example), thermal expansion of the respective members may produce a gap between the G-coupling 4 and the flange portion 3d, thereby causing a reduction in fastening force, or the flange portions 1e, 3d may stretch and deform the G-coupling 4. Through keen research, the inventor has discovered that there is a connection between the axial position of the stopper face of the step portion 1d and the fastening force applied by the G-coupling 4. Thus, in the present invention, the axial position of the stopper face of the step portion 1d is set nearer to the end face of the flange portion 1e compared with the prior art so as to solve the above-mentioned problems. In other words, in the turbocharger according to the present invention, the recessed portion 1c has a reduced depth (=Za) compared with the prior art.

**[0024]** In this configuration, the axial distance from the contact position on the flange portion 1e of the turbine housing 1b against the G-coupling 4 to the stopper face of the step portion 1d is reduced. Thus, even when the turbine housing 1b is exposed to higher temperature compared with the bearing housing 3 and the G-coupling 4, reduction in fastening force applied by the G-coupling 4 due to thermal expansion can be kept down.

**[0025]** Specifically, since the axial distance between the contact position on the flange portion 1e of the turbine housing 1b against the G-coupling 4 and the stopper face of the step portion 1d is small, increase in the axial distance between the contact position and the stopper face due to thermal expansion of the turbine housing 1b is very small. Thus, even when the turbine housing 1b is exposed to higher temperature compared with the bearing housing 3 and the G-coupling 4, increase in size of the gap produced between the housings and the fastener due to thermal expansion can be kept to a minimum, so that reduction in fastening force applied by the G-coupling 4 can be kept down.

**[0026]** The G-coupling 4 is a type of fastener, and as shown in FIG. 1B, includes a pair of semicircular arc portions 4a, 4a, flange portions 4b, 4b at an end of the respective semicircular arc portions 4a, turned-back portions 4c, 4c at the opposite end of the respective semicircular arc portions 4a, a fastener 4d such as a bolt and nut for fastening the flange portions 4b together, and a ring 4e for binding the turned-back portions 4c, 4c. As seen from the cross-sectional view shown in FIG. 2A, each semicircular arc portion 4a has the grooved portion adapted to receive the flange portion 1e of the turbine housing 1b and the flange portion 3d of the bearing housing 3, inside. The grooved portion has sloping sides gradually diverging from each other from the bottom to the top of the grooved portion. The flange portion 1a of the turbine housing 1b and the flange portion 3d of the bearing housing 3 each taper such that the flange portion can contact the corresponding sloping surface of the G-coupling 4. In the cross-sectional view shown in FIG. 2A, the tapering surfaces of the flange portions 1e, 3d each contact the corresponding sloping surface of the G-coupling 4 at one point. Actually, each tapering surface and the corresponding sloping surface make a line contact along the length of each semicircular arc portion 4a shown in FIG. 1B. By fastening the fastener 4d with the flange portion 1e of the turbine housing 1b and the flange portion 3d of the bearing housing 3 held between the inner sloping surfaces of the G-coupling 4, the turbine housing 1b and the bearing housing 3 are fastened together. Incidentally, the G-coupling 4 is sometimes called a V-band coupling.

**[0027]** As shown in FIGS. 1A and 2A, a heat shield plate 5, which is a thin sheet formed into a tubular shape, is arranged with its edge portion held between the stopper face of the step portion 1d of the turbine housing 1b and the end face 3c of the projecting portion 3b of the bearing housing 3. The heat shield plate 5 is a member for protecting the bearing housing 3 from high-temperature exhaust gas flowing backward from the turbine housing 1b. Although this structure itself does not differ from that in the prior art as shown in FIG. 2B, the heat shield plate 5 in the present invention has a greater axial length compared with the prior art, which results from setting the axial position of the stopper face of the step potion 1d nearer to the end face of the flange portion 1e. When the heat shield plate 5 is to be held between the stopper face of the step portion 1d of the turbine housing 1b and the end face 3c of the projecting portion 3b of the bearing housing 3 as in the illustrated example, the shape of the projecting portion 3b needs to be designed, taking account of the sheet thickness thereof. It is to be noted that the heat shield plate 5 is not an indispensable element. In place of the heat shield plate 5, a spacer in the form of a thin annular sheet serving as a sealing member may be held between the stopper face and the end face, or the stopper face of the step portion 1d of the turbine housing 1b may be in direct contact with the end face 3c of the projecting portion 3b of the bearing housing 3.

**[0028]** Next, a housing fastening method according to an embodiment of the present invention will be described in detail. FIG. 3 is an explanatory diagram indicating sizes referred to in describing a housing fastening method according to an embodiment of the present invention. FIG. 4A shows a relation between the G-coupling 4 and the flange portions 1e and 3d at normal temperature, while FIG. 4B shows a relation between the G-coupling 4 and the flange portions 1e and 3d at high temperature. FIG. 4C shows a relation between gaps $\Delta g$ and $\Delta c$ shown in FIG. 4B.

**[0029]** Explanation of symbols relating to sizes in components indicated in FIG. 3 is given below:

Pa: Contact position on the turbine housing 1b against the G-coupling 4
Az: Axial distance from the stopper face of the step portion 1d of the turbine housing 1b to the contact position Pa
Ar: Radial distance to the contact position Pa on the turbine housing 1b (from the axis Z)
Pb: Contact position on the bearing housing 3 against the G-coupling 4
Bz: Axial distance from the end face 3c of the projecting portion 3b of the bearing housing 3 to the contact position Pb
Br: Radial distance to the contact position Pb on the bearing housing 3 (from the axis Z)
$\theta$: Angle of divergence of the G-coupling 4
t: Sheet thickness of the heat shield plate 5
C: Axial distance between the contact positions Pa and Pb

**[0030]** Explanation of symbols relating to linear coefficients of expansion for components at high temperature and difference in temperature of components compared with when exposed to normal temperature is given below:

$\alpha$: Linear coefficient of expansion for the turbine housing 1b at high temperature
$\beta$: Linear coefficient of expansion for the bearing housing 3 at high temperature
$\gamma$: Linear coefficient of expansion for the G-coupling 4 at high temperature
$\varepsilon$: Linear coefficient of expansion for the heat shield plate 5 at high temperature
$\Delta Ta$: Difference in temperature of the turbine housing 1b when exposed to high temperature, compared with when exposed to normal temperature
$\Delta Tb$: Difference in temperature of the bearing housing 3 when exposed to high temperature, compared with when exposed to normal temperature
$\Delta Tg$: Difference in temperature of the G-coupling 4 when exposed to high temperature, compared with when exposed to normal temperature
$\Delta Ts$: Difference in temperature of the heat shield plate 5 when exposed to high temperature, compared with when exposed to normal temperature

**[0031]** As shown in FIG. 4A, at normal temperature, the flange portion 1e of the turbine housing 1b and the flange portion 3d of the bearing housing 3 contact the G-coupling 4 at contact positions Pa, Pb, respectively. Generally, between the flange portions 1e and 3d, there exists a slight gap $\Delta p$, which is exaggerated in the drawings. The inventor's research has confirmed that, as shown in FIG. 4B, when the inside of the turbine housing 1b is exposed to high temperature (ca 1000°C, for example), the existence of this gap $\Delta p$ leads to formation of a gap $\Delta g$ between the flange portion 3d of the bearing housing 3 and the G-coupling 4 due to thermal expansion of the respective components. For example, in the prior art shown in FIG. 2B, when exhaust gas supplied to the turbine 1 is at 1050°C, a gap $\Delta g$ of 0.0388mm is formed. Even the gap of such a small size leads to a reduction in fastening force applied by the G-coupling 4. Thus, the present invention needs to reduce the gap $\Delta g$ formed when the exhaust gas supplied to the turbine 1 is at 1050°C, at least below the size (=0.0388mm) in the prior art.

**[0032]** Here, symbol Pg denote a position on the G-coupling 4 which contacted the contact position Pb at normal temperature. At high temperature, the axial distance Cg between the contact positions Pa and Pg on the G-coupling 4 is longer than the axial distance C between the contact positions Pa and Pb on the flange portions 1e and 3d. $\Delta C$ denotes this difference (Cg-C). Regarding $\Delta C$ and $\Delta g$, a relationship $\Delta C = Ag/\cos(\theta/2)$ is obtained from FIG. 4C. As mentioned above, $\Delta g$ needs to meet at least the condition $\Delta g < 0.0388$mm. Consequently, $\Delta C$ needs to meet the condition $\Delta C < 0.0388/\cos(\theta/2)$. For this difference $\Delta C$, an allowable limit k is set. Specifically, in order to achieve at least a slight increase in fastening force applied by the G-coupling 4 compared with the prior art when the exhaust gas supplied to the turbine 1 is at 1050°C, the allowable limit k needs to be set within the range of $0 \leq k < 0.0388/\cos(\theta/2)$ (in mm). Further, in the present invention, in order to effectively keep down the reduction in fastening force applied by the G-coupling 4, the gap $\Delta g$ should desirably be around 0.002mm. In this case, the allowable limit k should be set within the range of $0 \leq k \leq 0.002/\cos(\theta/2)$ (in mm). When a standard G-coupling 4 is used, the range within which the allowable limit k should be set can be expressed by $0 \leq k \leq 0.0016$ (in mm).

**[0033]** Using the symbols defined above, the axial distance C between the contact positions Pa and Pb at high temperature can be expressed by

$$C = \{t(1+\varepsilon\Delta Ts)+Bz(1+\beta\Delta Tb)\}-Az(1+\alpha\Delta Ta)\ldots(1)$$

On the other hand, the axial distance Cg between the contact positions Pa and Pg at high temperature is expressed by

$$Cg = (t+Bz-Az)(1+\gamma\Delta Tg)-\{Ar(1+\alpha\Delta Ta) -(Ar+Br)(1+\gamma\Delta Tg)+Br(1+\beta\Delta Tb)\}\tan(\theta/2)\ \ldots(2)$$

Thus, once the allowable limit k is set, the axial distance Az from the stopper face of the step portion 1d of the turbine housing 1b to the contact position Pa and the axial distance Bz from the end face 3c of the projecting portion 3c of the bearing housing 3 to the contact position Pb can be determined to meet the relationship $0 \leq \Delta C \leq k$.... (3) In other words, in the present embodiment, by using the above expressions (1), (2) and (3), the values of the parameters (axial distance Bz, radial distance Br, angle of divergence $\theta$, etc.) relating to the shape of the projecting portion 3b can be determined taking account of the sheet thickness t (thickness of the thin sheet), and therefore the shape of the projecting portion

3b can be designed taking account of the sheet thickness t.

**[0034]** By determining the axial distance Az in the recessed portion and the axial distance Bz in the projecting portion according to the above-described housing fastening method, reduction in fastening force applied by the G-coupling 4 can be kept down, irrespective of the model or capacity of the turbocharger. This method is applicable to products other than turbochargers (waste gate valves, exhaust manifolds and mufflers, for example) having housings to be fastened by a G-coupling 4.

**[0035]** Next, referring to FIGS. 5A and 5B, housing fastening methods according to other embodiments of the present invention will be described. FIG. 5A is a longitudinal cross-sectional view showing a fastening structure made by a housing fastening method according to another embodiment of the present invention, and FIG. 5B is a longitudinal cross-sectional view showing a fastening structure according to a further embodiment. The components similar to those shown in FIG. 2A are assigned the same reference characters, and the explanation of such components is omitted to avoid repetition.

**[0036]** In the embodiment shown in FIG. 5A, the flange portion 3d of the bearing housing 3 is $\Delta h$ greater in outside diameter (radius) than the flange portion 1e of the turbine housing 1b. This is out of consideration for the fact that the turbine housing 1b is likely to experience a greater temperature rise and therefore a greater degree of thermal expansion than the bearing housing 3. In other words, considering that the difference in thermal expansion results in difference in radial displacement between contact positions Pa and Pb, the configuration is determined such that, at high temperature, the contact positions Pa and Pb are displaced onto a line approximately parallel to the axial direction. To this case, the above-mentioned expressions for calculating the axial distance C between contact positions Pa and Pb and the axial distance Cg between contact positions Pa and Pg can be applied without modification. It is to be noted, however, that even when the housing fastening method shown in FIG. 5A is not adopted, the axial distance C between contact positions Pa and Pb can be easily calculated taking account of an angle between a line connecting the contact positions Pa and Pb and the axial direction.

**[0037]** In the embodiment shown in FIG. 5B, the stopper face of the step portion 1d of the recessed portion 1c of the turbine housing 1b is in direct contact with the end face 3c of the projecting portion 3b of the bearing housing 3. In other words, this is the case not requiring a heat shield plate 5 as shown in FIG. 2A. This is presented considering the fact that some models of turbocharger do not require a heat shield plate 5. In this case, the axial distances C and Cg can be easily calculated only by eliminating the variables relating to the heat shield plate 5 ($t$, $\varepsilon$, $\Delta Ts$) from the above-mentioned expressions for calculating the axial distance C between contact positions Pa and Pb and the axial distance Cg between contact positions Pa and Pg, respectively. Further, in the case where a spacer or a sealing member is provided between the stopper face of the step portion 1d and the end face 3c of the projecting portion 3b in place of the heat shield plate 5, the axial distances C, Cg can be calculated by introducing the sheet thickness and liner coefficient of expansion for such member.

**[0038]** The present invention is not limited to the above-described embodiments. Needless to say, it allows a variety of modifications not departing from the spirit and scope of the present invention. For example, the present invention is applicable to fasteners other than the G-coupling.

## Claims

1. A housing fastening method comprising steps of inserting a projecting portion of a housing in a recessed portion of another housing so that an end face of the projecting position butts against a step portion of the recessed portion serving as a stopper face and that a flange portion around the recessed portion and a flange portion around the projecting portion face each other, and thereafter, fastening the flange portions together by an annular fastener with a grooved portion on its inside adapted to receive the flange portions facing each other, wherein the axial position of the stopper face of the step portion and the shapes of the recessed portion and the projecting portion are determined to ensure that a gap produced between the grooved portion of the fastener and the flange portions does not exceed a specified size even when the housings and the fastener experience thermal expansion during use.

2. The housing fastening method according to claim 1, wherein the axial position of the stopper face of the step portion is set within the axial projected width of the fastener.

3. The housing fastening method according to claim 1, wherein the shape of the projecting portion is determined taking account of the thickness of a thin sheet held between the stopper face of the step portion and the end face of the projecting portion.

4. The housing fastening method according to claim 1, wherein when the housings are likely to experience different degrees of thermal expansion during use, the flange portion of the housing which is likely to experience a smaller

degree of thermal expansion is formed to be greater in outside diameter than the flange portion of the housing which is likely to experience a greater degree of thermal expansion.

**5.** The housing fastening method according to claim 1, wherein an axial distance Az from a contact position at which the fastener contacts the flange portion around the recessed portion to the stopper face of the step portion and an axial distance Bz from a contact position at which the fastener contacts the flange portion around the projecting portion to the end face of the projecting portion are determined to meet the condition $0 \leq Cg-C \leq$ allowable limit k, where C is an axial distance between the contact positions on the flange portions defined by an expression $C = t+Bz-Az$, on the basis of said axial distances Az and Bz, and Cg is an axial distance between the contact positions on the fastener.

**6.** The housing fastening method according to claim 5, wherein the allowable limit k is set on the basis of the allowable size for a gap produced between the fastener and the contact position on the flange portion at a specified temperature.

**7.** The housing fastening method according to claim 5, wherein the allowable limit k is set to meet the condition $0 \leq k < 0.0388/\cos(\theta/2)$, where 0 is an angle of divergence of a pair of support portions of the fastener.

**8.** A turbocharger comprising a turbine including a bladed rotor rotated by a fluid supplied thereto, a compressor including an impeller for drawing in air, connected with the bladed rotor by a rotating shaft, a turbine housing constituting an outer shape of the turbine, and a bearing housing rotatably supporting the rotating shaft, a projecting portion of the bearing housing being inserted in a recessed portion of the turbine housing such that an end face of the projecting position butts against a step portion of the recessed portion serving as a stopper face and that a flange portion around the recessed portion and a flange portion around the projecting portion face each other, the flange portions being fastened together by an annular fastener with a grooved portion on its inside adapted to receive the flange portions facing each other, wherein
the bearing housing and the turbine housing are fastened together by the fastener by employing the housing fastening method according to any of claims 1 to 7.

FIG. 1A

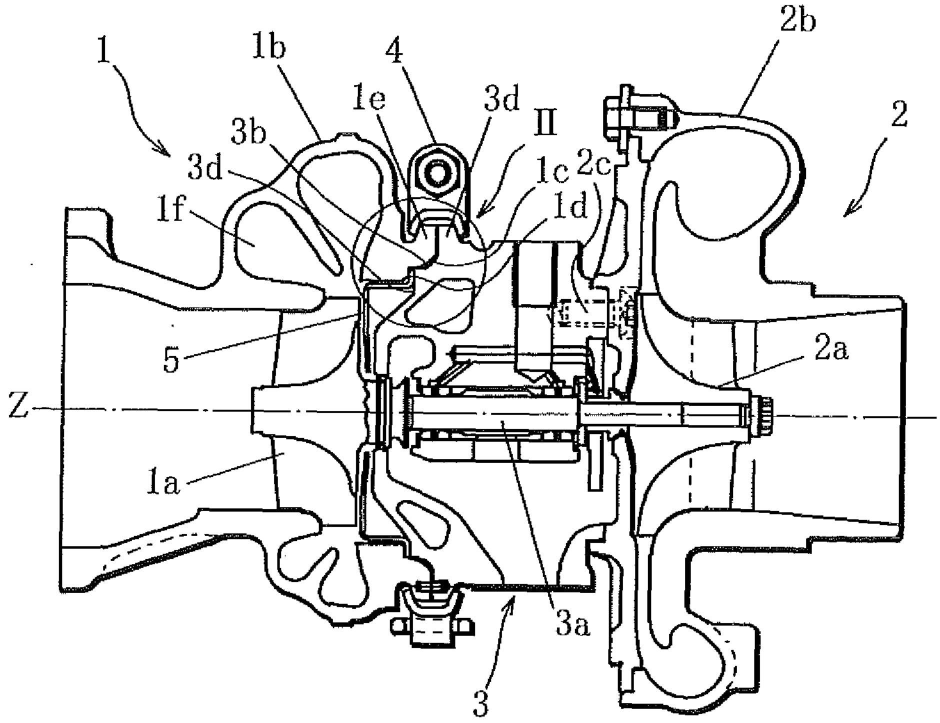

1
1b
4
1e
3d
II
2b
2
3b
3d
1c
2c
1f
1d
5
2a
Z
1a
3a
3

FIG. 1B

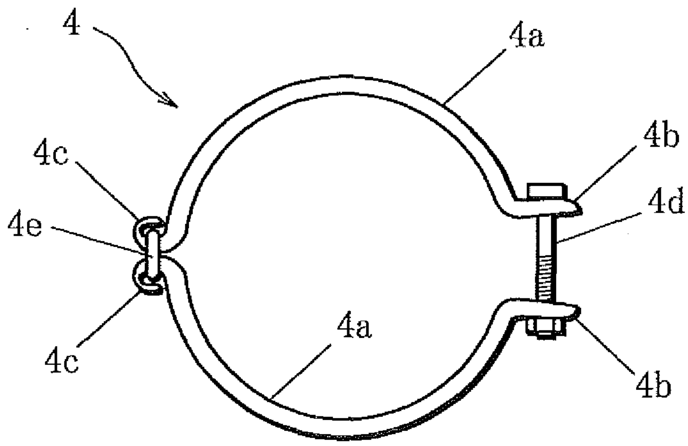

4
4a
4c
4b
4e
4d
4a
4c
4b

FIG. 2A

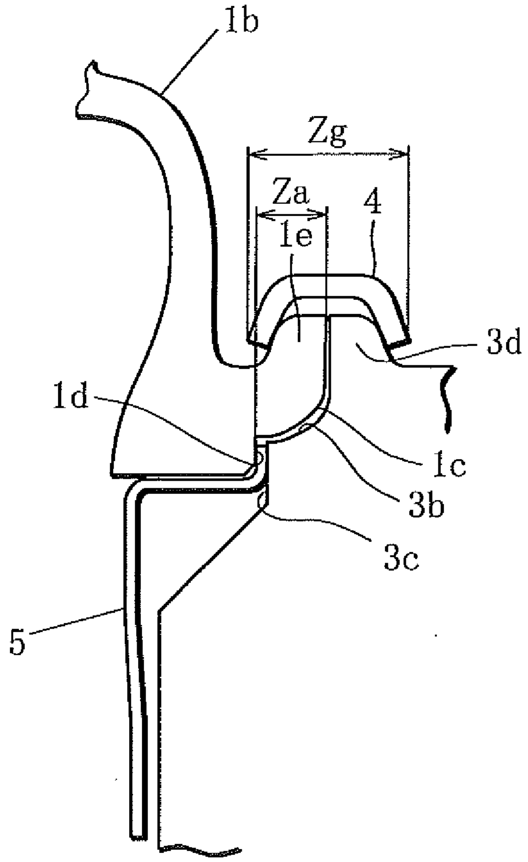


FIG. 2B

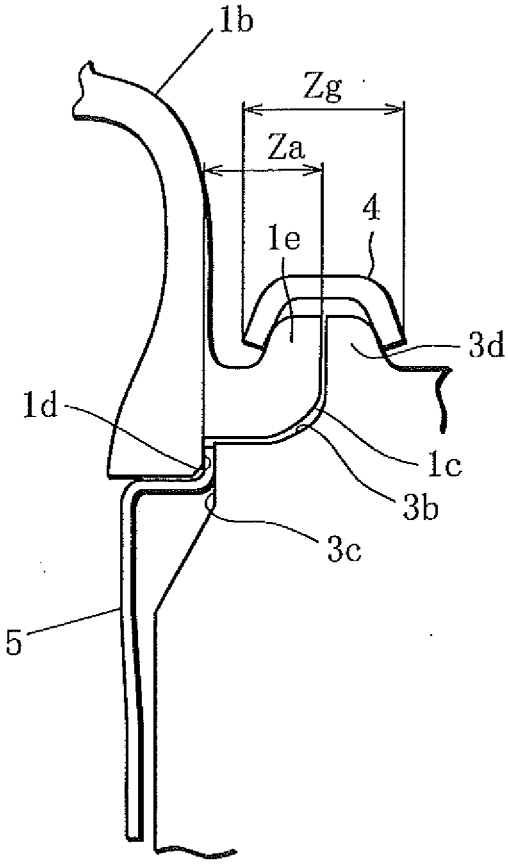


FIG. 3

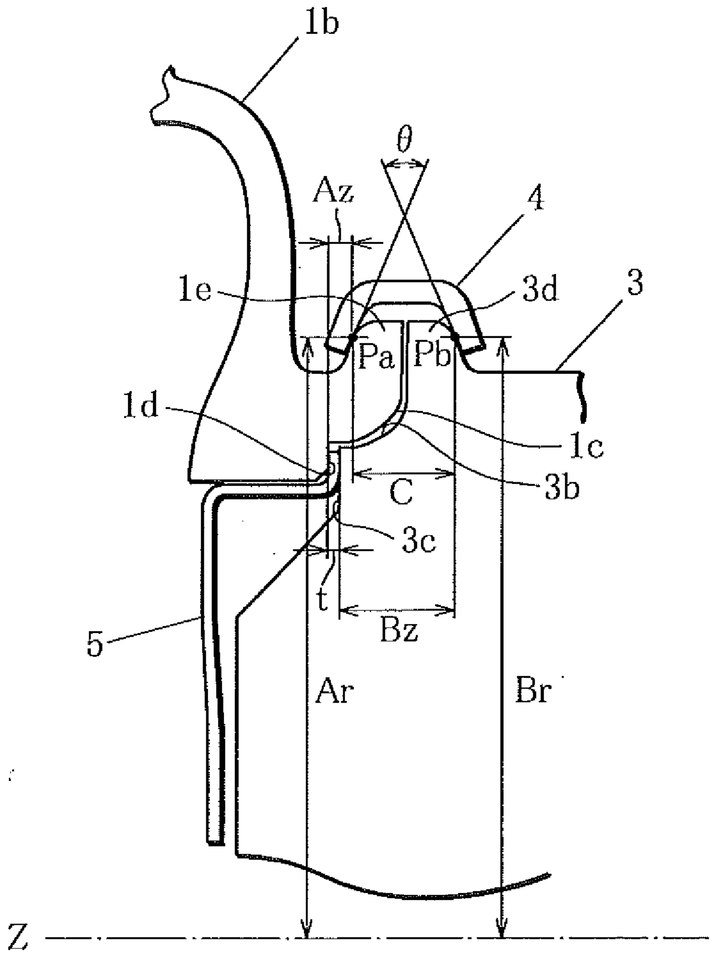


FIG. 4A

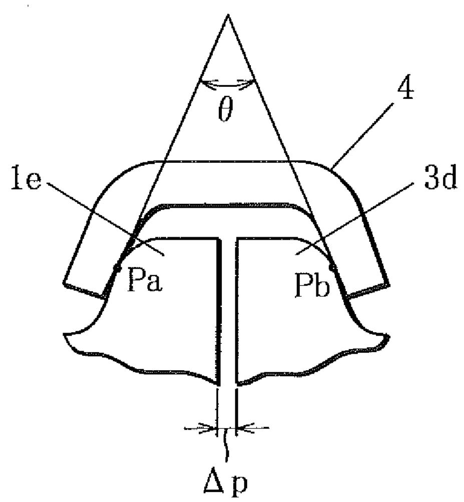



FIG. 4B

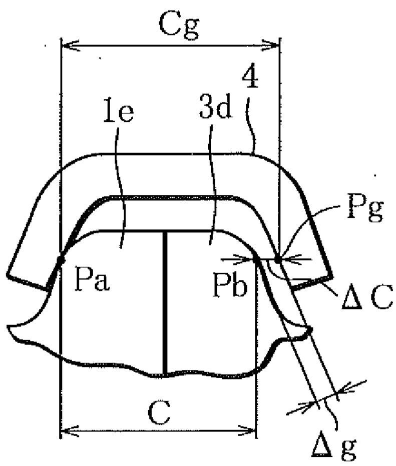



FIG. 4C

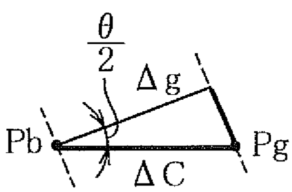


FIG. 5A

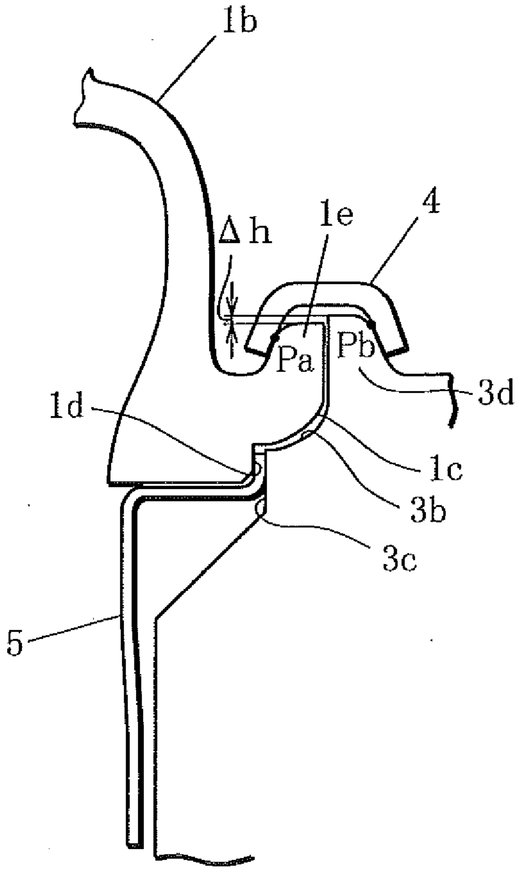
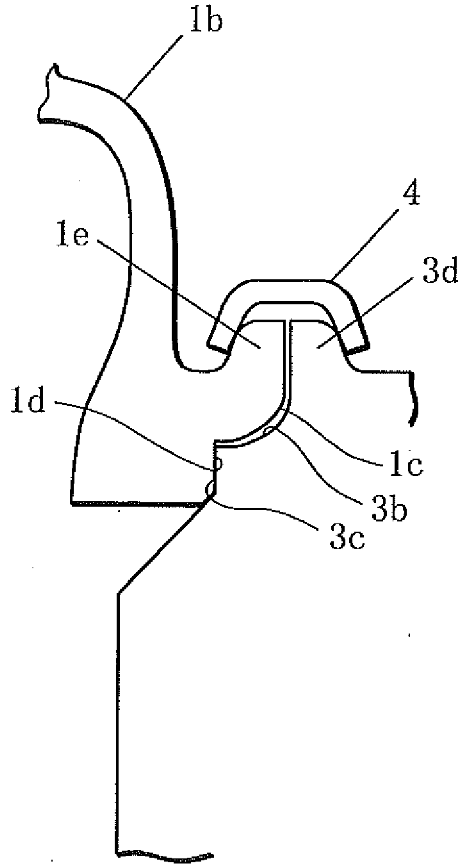


FIG. 5B



## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062942

A. CLASSIFICATION OF SUBJECT MATTER
*F02B39/00*(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)
F02B39/00

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 | 1996-2008 |
| 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. |
|---|---|---|
| X | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 156345/1987(Laid-open No. 061432/1989) (Toyota Motor Corp.), 19 April, 1989 (19.04.89), Fig. 1 (Family: none) | 1-8 |
| X | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 170171/1988(Laid-open No. 090301/1990) (Mitsubishi Heavy Industries, Ltd.), 18 July, 1990 (18.07.90), Fig. 1 (Family: none) | 1-8 |

☒ 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
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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 |
|---|---|
| 04 September, 2008 (04.09.08) | 16 September, 2008 (16.09.08) |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japanese Patent Office | |
| Facsimile No. | Telephone No. |

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2008/062942

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 03-292489 A (Nissan Motor Co., Ltd.), 24 December, 1991 (24.12.91), Full text; all drawings (Family: none) | |

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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