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Inventor(s)	NAKAWATASE; Akira et al.

BLOW-BY GAS PROCESSING APPARATUS, INTERNAL COMBUSTION ENGINE, AND SUPERCHARGER

Abstract

A blow-by gas processing apparatus includes an intake passage, a blow-by gas passage, and a storage chamber that stores emulsion contained in blow-by gas. The blow-by gas passage includes a separation chamber, an upstream passage through which the blow-by gas passes, and a downstream passage that connects the separation chamber to the intake passage. A facing wall of the separation chamber faces an upstream opening to which the upstream passage is connected. The storage chamber is located downward of the facing wall in a vertical direction. The facing wall is continuous with a defining wall that is a wall for defining the storage chamber.

Inventors: **NAKAWATASE; Akira (Toyota-shi, JP), TAKAHASHI; Masashige (Tokyo, JP)**

Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA** (Toyota-shi, JP); **IHI Corporation** (Tokyo, JP)

Family ID: **1000008374580**

Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA (Toyota-shi, JP); IHI Corporation (Tokyo, JP)**

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-023662 filed on Feb. 20, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a blow-by gas processing apparatus, an internal combustion engine, and a supercharger.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2021-008859 discloses a blow-by gas processing apparatus for an internal combustion engine. The blow-by gas processing apparatus mixes blow-by gas in a crankcase with intake air and then combusts the mixture in a combustion chamber of the internal combustion engine.

SUMMARY

[0004] In an internal combustion engine equipped with a supercharger, intake air containing blow-by gas is compressed by a compressor wheel of the supercharger and then supplied to a combustion chamber. The blow-by gas contains oil and water produced by the combustion of fuel. When these oil and water are mixed together, emulsion is generated. The emulsion has a higher density than the blow-by gas that does not contain emulsion. Therefore, there is a risk that the compressor wheel may be damaged when the emulsion collides with the compressor wheel.

[0005] A blow-by gas processing apparatus for an internal combustion engine for solving the above problem, includes an intake passage in which a compressor wheel of a supercharger is disposed, a blow-by gas passage, and a storage chamber for storing emulsion contained in blow-by gas, wherein the blow-by gas passage includes a separation chamber for separating the emulsion from the blow-by gas, an upstream passage that connects an interior of a crankcase of the internal combustion engine with the separation chamber, and a downstream passage that connects the separation chamber with the intake passage, the separation chamber includes an upstream opening to which the upstream passage is connected, and a facing wall facing the upstream opening, the storage chamber is located downward of the facing wall in a vertical direction, and the facing wall is continuous with a defining wall that defines the storage chamber.

[0006] A supercharger for an internal combustion engine for solving the above problem, includes an intake passage, a blow-by gas passage including a separation chamber configured to separate emulsion from blow-by gas, an upstream passage, and a downstream passage, a compressor wheel arranged in the intake passage, and a storage chamber for storing emulsion contained in the blow-by gas, wherein the separation chamber is connected with an interior of a crankcase of the internal combustion engine via the upstream passage and connected with the intake passage via the downstream passage, and includes an upstream opening to which the upstream passage is connected, and a facing wall facing the upstream opening, the storage chamber is located downward of the facing wall in a vertical direction, and the facing wall is continuous with a defining wall that defines the storage chamber.

[0007] In the blow-by gas processing apparatus, the internal combustion engine, and the supercharger disclosed in the present disclosure, the compressor wheel is unlikely to be damaged due to impingement of emulsion.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0009] FIG. **1** is a schematic diagram of an internal combustion engine equipped with a blow-by gas processing apparatus;

[0010] FIG. **2** is a sectional view showing a compressor housing of the internal combustion engine;

[0011] FIG. **3** is a sectional view of the compressor housing taken along line **3-3** in FIG. **2**; and

[0012] FIG. **4** is a sectional view showing a modification example of the blow-by gas processing apparatus.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] An embodiment of a blow-by gas processing apparatus **1** will be described below with reference to FIG. **1** to FIG. **3**. Note that the drawings may show components that are illustrated as being enlarged to facilitate understanding. The dimensional ratios of the components may differ from the actual ones or from those in other drawings. Furthermore, in the following description, upward and downward in a vertical direction may be simply referred to as up and down, respectively. When the relative positions of components in the up-down direction in the vertical direction are described, upper and lower parts of the components may be referred to.

Internal Combustion Engine

[0014] The internal combustion engine **2** equipped with this blow-by gas processing apparatus **1** is an internal combustion engine that burns hydrogen as fuel.

[0015] As shown in FIG. **1**, the internal combustion engine **2** includes a cylinder block **3**, a crankcase **8** attached to a lower part of the cylinder block **3**, and a cylinder head **9** attached to an upper part of the cylinder block **3**. The internal combustion engine **2** includes an oil pan **7** attached to a lower part of the crankcase **8**, and a head cover **12** attached to an upper part of the cylinder head **9**.

[0016] The cylinder block **3** has a cylinder **4**. The cylinder **4** houses a reciprocating piston **5**. The cylinder block **3** and the cylinder head **9** have a combustion chamber **6** in which hydrogen is burned. The combustion chamber **6** is located above a piston **5** in the cylinder **4**. Oil is stored in the oil pan **7**. The cylinder head **9** has an intake port **10** and an exhaust port **11**.

[0017] The internal combustion engine **2** includes an intake valve **14** that opens and closes the intake port **10**, an exhaust valve **15** that opens and closes the exhaust port **11**, a fuel injection valve **16**, and an ignition device **17**.

[0018] The internal combustion engine **2** includes an intake passage **22** connected to the intake port **10**, and an exhaust passage **23** connected to the exhaust port **11**.

[0019] The internal combustion engine **2** includes a supercharger **13**. The supercharger **13** includes a compressor wheel **26**, and a compressor housing **27** that houses the compressor wheel **26**. The intake passage **22** includes a portion provided within the compressor housing **27** (hereinafter, may be referred to as an in-housing intake passage **22**A), a portion upstream of the in-housing intake passage **22**A, and a portion downstream of the in-housing intake passage **22**A. A throttle valve **29** is provided in a portion of the intake passage **22** downstream of the compressor housing **27**.

Blow-by Gas Processing Apparatus

[0020] As shown in FIG. **1**, the blow-by gas processing apparatus **1** includes a ventilation passage **32**, a blow-by gas passage **33**, and a PCV valve **36**. The ventilation passage **32** connects a downstream portion of the throttle valve **29** in the intake passage **22** with the interior of the crankcase **8**. The blow-by gas passage **33** connects the in-housing intake passage **22**A of the intake passage **22** with the interior of the crankcase **8**. The PCV valve **36** is provided in the ventilation

passage **32**. The PCV valve **36** opens during blow-by gas processing.
[0021] As shown in FIG. **1** to FIG. **3**, the blow-by gas processing apparatus **1** includes the intake passage **22** and a storage chamber **37** that stores emulsion **46** contained in the blow-by gas. The compressor wheel **26** of the supercharger **13** is disposed in a portion upstream of the throttle valve **29** in the intake passage **22**.

Supercharger

[0022] The supercharger **13** functions as a part of the blow-by gas processing apparatus **1**. The blow-by gas passage **33** includes a separation chamber **39** configured to separate the emulsion **46** from the blow-by gas, an upstream passage **33**A, and a downstream passage **33**B. The upstream passage **33**A includes a portion extending from the crankcase **8** to the compressor housing **27**, and a portion provided in the compressor housing **27** (hereinafter, may be referred to as an in-housing gas passage **331**A). The in-housing gas passage **331**A is a passage defined by the inner wall of a portion inserted into a through-hole **20** in the PCV union **40**. The compressor housing **27** has the in-housing gas passage **331**A, the downstream passage **33**B, and the separation chamber **39**. The separation chamber **39** also includes an upstream opening **39**A to which the upstream passage **33**A is connected, a downstream opening **39**B to which the downstream passage **33**B is connected, and a facing wall **41** facing the upstream opening **39**A. The facing wall **41** is a part of the inner wall of the compressor housing **27**.
[0023] The compressor housing **27** has a through-hole **20** that connects the outside of the compressor housing **27** to the separation chamber **39**. The upstream opening **39**A is an opening of the through-hole **20** on the separation chamber **39** side. A PCV union **40** into which blow-by gas flows from the upstream passage **33**A flows is inserted into the through-hole **20**. The separation chamber **39** is caused to communicate with the interior of the crankcase **8** of the internal combustion engine **2** via the upstream passage **33**A, and communicates with the in-housing intake passage **22**A via the downstream passage **33**B.
[0024] The compressor housing **27** has the storage chamber **37**. The storage chamber **37** is located at a lower part of the compressor housing **27**. The storage chamber **37** is located downward of the facing wall **41**. Furthermore, the facing wall **41** is continuous with a defining wall **42** that defines the storage chamber **37**. The facing wall **41** and the defining wall **42** being continuous includes a case where the facing wall **41** and the defining wall **42** are directly connected to each other, as well as a case where the facing wall **41** and the defining wall **42** are connected to each other via another wall.
[0025] A case where two walls out of the facing wall **41**, the defining wall **42**, and one or more other walls connecting both the walls **41**, **42** are directly connected to each other includes a case where a ridge line or a valley line exists at the boundary portion between the two walls, and a case where a ridge line or a valley line does not exist. In the case where a ridge line or a valley line does not exist at the boundary portion between the two walls, the boundary portion between the two walls is formed by the same flat surface or the same curved surface.
[0026] When the facing wall **41** and the defining wall **42** are directly connected to each other, the emulsion **46** flows down along the facing wall **41** toward the defining wall **42**. When the facing wall **41** and the defining wall **42** are connected to each other via another wall, the emulsion **46** first flows down along the facing wall **41** toward the other wall, and then flows down along the other wall toward the defining wall **42**.
[0027] The compressor housing **27** has a communication hole **43** that connects the separation chamber **39** and the storage chamber **37** with each other. The communication hole **43** extends in an arc shape along the circumferential direction of the compressor wheel **26**. The storage chamber **37** has an opening **18** to which the communication hole **43** is connected.
[0028] In the present embodiment, the defining wall **42** is continuous with the facing wall **41** through the inner wall of the communication hole **43**. The inner wall of the communication hole **43** is an example of another wall that connects the facing wall **41** and the defining wall **42** to each

other.
[0029] The compressor housing **27** has a discharge hole **47** for discharging the emulsion **46** stored in the storage chamber **37** to the outside of the compressor housing **27**. The discharge hole **47** is preferably located at a lower part of the compressor housing **27**. The discharge hole **47** connects the storage chamber **37** and the outside of the compressor housing **27** with each other. The compressor housing **27** has a lid **48** that blocks the discharge hole **47**. The lid **48** is configured to be detachable from the discharge hole **47**. In the present embodiment, the discharge hole **47** extends downward from the storage chamber **37**. The lid **48** blocks the discharge hole **47** from the outside of the compressor housing **27**.
Separation of Blow-by Gas and Emulsion
[0030] The oil and water inside the crankcase **8** are mixed with each other inside the crankcase **8**. The mixed oil and water flow through the upstream passage **33**A together with the blow-by gas. When the oil and the water pass through the upstream passage **33**A, they are gradually reduced in temperature, and liquefied. As a result, emulsion **46** occurs in the upstream passage **33**A.
[0031] The blow-by gas that flows from the upstream opening **39**A into the separation chamber **39** impinges against the facing wall **41**. Since the emulsion **46** has a higher density than the blow-by gas, the emulsion **46** has a larger inertial force than the blow-by gas that does not contain the emulsion **46**. Therefore, when the blow-by gas impinges against the facing wall **41**, the emulsion **46** contained in the blow-by gas adheres to the facing wall **41**. As a result, the emulsion **46** is separated from the blow-by gas.
[0032] As shown in FIG. **2**, the emulsion **46** attached to the facing wall **41** gradually drops due to gravity acting on the emulsion **46** and flows into the communication hole **43**. The emulsion **46** that has flowed into the communication hole **43** flows down along the inner wall of the communication hole **43**, and then flows into the storage chamber **37** from the opening **18**.
[0033] On the other hand, as indicated by an imaginary line B in FIG. **2**, the blow-by gas from which the emulsion **46** has been separated flows from the downstream opening **39**B into the downstream passage **33**B, and merges with the intake air flowing through the in-housing intake passage **22**A.
[0034] The greater the difference between the flow direction of the blow-by gas from the upstream opening **39**A to the facing wall **41** and the flow direction of the blow-by gas when the blow-by gas impinges against the facing wall **41**, passes from the separation chamber **39** through the downstream opening **39**B and then flows into the downstream passage **33**B, the greater the amount of emulsion **46** that adheres to the facing wall **41**. On the other hand, when the difference in the flow direction of the blow-by gas described above becomes large, the pressure loss when the blow-by gas flows increases, so that the amount of blow-by gas flowing into the in-housing intake passage **22**A tends to decrease. For this reason, it is desirable to adopt the following configuration.
[0035] First, a portion connected to the upstream opening **39**A in the upstream passage **33**A is referred to as an upstream portion **44**, and a portion connected to the downstream opening **39**B in the downstream passage **33**B is referred to as a downstream portion **45**. An imaginary line extending in parallel to an extension direction of the upstream portion **44** is referred to as a first imaginary line **44**A. Furthermore, among imaginary lines extending in parallel to the extension direction of the downstream portion **45**, an imaginary line that intersects with the first imaginary line **44**A is referred to as a second imaginary line **45**A.
[0036] In this case, it is preferable that an intersection angle θ**1** which is the intersection angle between the first imaginary line **44**A and the second imaginary line **45**A shown in FIG. **2** is 70 degrees or more and 110 degrees or less. Furthermore, it is more preferable that the intersection angle θ**1** is 80 degrees or more and 100 degrees or less. In the present embodiment, the intersection angle θ**1** is 90 degrees.
[0037] In the present embodiment, the facing wall **41** is a flat surface. As the blow-by gas impinges against the facing wall **41** more perpendicularly, the amount of the emulsion **46** adhering to the

facing wall **41** is more likely to be large. Therefore, it is preferable that an impingement angle θ**2** which is the intersection angle between the first imaginary line **44**A shown in FIG. **2** and the facing wall **41** is 70 degrees or more and 110 degrees or less. Furthermore, it is more preferable that the impingement angle θ**2** is 80 degrees or more and 100 degrees or less. In the present embodiment, the impingement angle θ**2** is 90 degrees.

Actions and Effect of Present Embodiment

[0038] (1) The blow-by gas that flows into the separation chamber **39** impinges against the facing wall **41**. At this time, the emulsion **46** contained in the blow-by gas adheres to the facing wall **41**, so that the amount of emulsion **46** that flows from the separation chamber **39** through the downstream passage **33**B into the in-housing intake passage **22**A is reduced. As a result, damage of the compressor wheel **26** which is caused by the impingement of the emulsion **46** against the compressor wheel **26** is less likely to occur.

[0039] (2) The emulsion **46** adhering to the facing wall **41** flows down along the facing wall **41** toward the defining wall **42**. The emulsion **46** that has flown down is stored in the storage chamber **37**. Since the storage chamber **37** is located downward of the facing wall **41** and the communication hole **43**, the emulsion **46** is stored at the lower part of the storage chamber **37**. Therefore, the emulsion **46** is unlikely to return to blow-by gas again.

[0040] (3) Since the impingement angle θ**2** is 90 degrees, that is, the blow-by gas impinges perpendicularly against the facing wall **41**, the emulsion **46** is likely to adhere to the facing wall **41**. Therefore, the amount of the emulsion **46** separated from the blow-by gas is likely to increase.

[0041] (4) The temperature of the compressor housing **27** increases due to heat generated when the compressor wheel **26** compresses air. Therefore, the temperature of the facing wall **41** also increases. As a result, the viscosity of the emulsion **46** adhering to the facing wall **41** decreases. Therefore, the emulsion **46** tends to quickly flow down from the facing wall **41** into the storage chamber **37**.

[0042] (5) As the temperature of the compressor housing **27** increases, the temperature of the defining wall **42** of the storage chamber **37** also increases similarly to that of the facing wall **41**. This reduces the viscosity of the emulsion **46** to be stored in the storage chamber **37**. Accordingly, it is easier to discharge the emulsion **46** in the storage chamber **37** to the outside through the discharge hole **47**.

[0043] (6) The emulsion **46** stored in the storage chamber **37** is discharged to the outside through the discharge hole **47** by detaching the lid **48**. In particular, when the discharge hole **47** extends downward from the storage chamber **37**, the lid **48** blocks the discharge hole **47** from below in the vertical direction. Therefore, the emulsion **46** in the storage chamber **37** can be efficiently discharged to the outside by detaching the lid **48**.

[0044] (7) The emulsion **46** adhering to the facing wall **41** flows into the communication hole **43**. When the emulsion **46** flows down from the facing wall **41** toward the storage chamber **37**, the emulsion **46** is surrounded by the inner wall of the communication hole **43**, so that the emulsion is unlikely to scatter to the surroundings.

[0045] (8) In an internal combustion engine that burns hydrogen as fuel, the emulsion contained in the blow-by gas tends to increase, for example, as compared with an internal combustion engine that burns gasoline as fuel. This makes it easier for the compressor wheel to be damaged due to the impingement of the emulsion. Therefore, according to the present embodiment, an effect of restraining damage to the compressor wheel **26** is significant.

Modification

[0046] The above embodiment can be implemented by altering the configuration as follows. The above embodiment and the following modification can be implemented in combination with each other to the extent that they are not technically inconsistent. Note that the same components as those in the above embodiment are given the same reference signs and duplicative descriptions thereof are omitted.

[0047] In the modification shown in FIG. **4**, the compressor housing **27** is provided with one space **25** below a rotation axis **26**A of the compressor wheel **26** in the vertical direction. The rotation axis **26**A is an imaginary straight line that passes through the rotation center of the compressor wheel **26** and extends along the axis of the compressor wheel **26**.
[0048] The separation chamber **39** is located at an upper part of the space **25**. The storage chamber **37** is located at a lower part of the space **25**. The facing wall **41** is continuous with the defining wall **42**. In the present modification, the facing wall **41** is directly connected to the defining wall **42**.
[0049] The facing wall **41** is directly connected to the defining wall **42**. Therefore, the emulsion **46** is less likely to scatter to the surroundings when it flows down from the facing wall **41** into the storage chamber **37**.
[0050] Furthermore, since the storage chamber **37** is located downward of the rotation axis **26**A in the vertical direction, the emulsion **46** stored in the storage chamber **37** can be easily discharged quickly to the outside through the discharge hole **47**.
[0051] At least one of the separation chamber **39**, the storage chamber **37**, the upstream passage **33**A, the downstream passage **33**B, and the communication hole **43** may be provided in a portion other than the compressor housing **27** of the supercharger **13**, for example, in a turbine housing that accommodates a turbine wheel.
[0052] The separation chamber **39** and the storage chamber **37** may both be provided outside the compressor housing **27**. In the present modification, the storage chamber **37** is also located below the facing wall **41**. Furthermore, the facing wall **41** is continuous with the defining wall **42**.
[0053] Out of the separation chamber **39** and the storage chamber **37**, the storage chamber **37** may be disposed outside the compressor housing **27**. In the present modification example, the storage chamber **37** is located below the facing wall **41**. The storage chamber **37** is connected to the separation chamber **39** via an external pipe installed outside the compressor housing **27**. The external pipe is configured to cause the emulsion **46** separated in the separation chamber **39** to flow into the storage chamber **37**. The facing wall **41** is continuous with the defining wall **42** via the inner wall of the external pipe. The inner wall of the external pipe is an example of another wall for connecting the facing wall **41** and the defining wall **42**.
[0054] The facing wall **41** may have a curved surface. When the facing wall **41** has a curved surface, the impingement angle θ**2** described above is an intersection angle between the first imaginary line **44**A and a tangent to the curved surface at the intersection point between the first imaginary line **44**A and the facing wall **41**. When the facing wall **41** has a curved surface, in order to increase the amount of emulsion **46** adhering to the facing wall **41**, it is preferable that the curved surface has a shape that is recessed toward the opposite side to the upstream opening **39**A rather than a shape that bulges toward the upstream opening **39**A.
[0055] In the upstream passage **33**A, the upstream portion **44**, which is a connecting portion with the upstream opening **39**A, may be provided with a convex portion such as a partition plate or a protrusion in a state where it has an opening portion through which the blow-by gas flows. By providing the convex portion in the upstream portion **44**, a part of the blow-by gas flowing through the upstream passage **33**A impinges against the convex portion, so that a part of the emulsion **46** accumulates near the convex portion. This makes it possible to reduce the amount of emulsion **46** flowing into the separation chamber **39**, and makes it possible to miniaturize the storage chamber **37**.
[0056] In the above modification, it is desirable that the convex portion is provided at the lower part of the upstream portion **44** in the vertical direction. The lower part of the upstream portion **44** trends to pass a larger amount of emulsion **46** therethrough in the vertical direction than the upper part of the upstream portion **44**. Therefore, the amount of emulsion **46** to accumulate near the convex portion increases. As a result, the present modification can further contribute to the miniaturization of the storage chamber **37**.

[0057] The internal combustion engine **2** may be an internal combustion engine that burns gasoline as fuel.

Claims

1. A blow-by gas processing apparatus for an internal combustion engine equipped with a supercharger, comprising: an intake passage in which a compressor wheel of the supercharger is disposed; a blow-by gas passage; and a storage chamber for storing emulsion contained in blow-by gas, wherein: the blow-by gas passage includes a separation chamber for separating the emulsion from the blow-by gas, an upstream passage that connects an interior of a crankcase of the internal combustion engine with the separation chamber, and a downstream passage that connects the separation chamber with the intake passage, the separation chamber includes an upstream opening to which the upstream passage is connected, and a facing wall facing the upstream opening, the storage chamber is located downward of the facing wall in a vertical direction, and the facing wall is continuous with a defining wall that defines the storage chamber.

2. The blow-by gas processing apparatus according to claim 1, wherein a compressor housing that houses the compressor wheel has the separation chamber and the storage chamber.

3. The blow-by gas processing apparatus according to claim 2, wherein the compressor housing has a communication hole that connects the separation chamber and the storage chamber with each other.

4. An internal combustion engine that burns hydrogen as fuel, comprising the blow-by gas processing apparatus according to claim 1.

5. A supercharger for an internal combustion engine, comprising: an intake passage; a blow-by gas passage including a separation chamber configured to separate emulsion from blow-by gas, an upstream passage, and a downstream passage; a compressor wheel arranged in the intake passage; and a storage chamber for storing emulsion contained in the blow-by gas, wherein: the separation chamber is connected with an interior of a crankcase of the internal combustion engine via the upstream passage, and connected with the intake passage via the downstream passage, and includes an upstream opening to which the upstream passage is connected, and a facing wall facing the upstream opening, the storage chamber is located downward of the facing wall in a vertical direction, and the facing wall is continuous with a defining wall that defines the storage chamber.

6. The supercharger according to claim 5, wherein: a compressor housing that houses the compressor wheel has a space located downward of a rotation axis of the compressor wheel in a vertical direction; the separation chamber is located at an upper part of the space; the storage chamber is located at a lower part of the space; and the facing wall is directly connected to the defining wall.