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EXHAUST GAS PURIFICATION DEVICE

Abstract

An exhaust gas purification device includes a catalyst converter purifying exhaust gas from an exhaust manifold. The catalyst converter includes a metal porous body through which exhaust gas from the exhaust manifold passes, and an exhaust gas purification catalyst purifying exhaust gas passing through the porous body. The exhaust gas purification catalyst is electrically heated, with a pair of electrodes attached to a catalyst main body. Through-holes are formed in the porous body along the exhaust gas from upstream to downstream. Metal material is exposed on a surface of the porous body. Under a temperature environment of 25° C., a ratio of a heat capacity of the porous body to that of the catalyst main body is 8% or greater and 23% or smaller.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from Japanese patent application JP 2024-018634 filed on Feb. 9, 2024, the entire content of which is hereby incorporated by reference into this application.

BACKGROUND

Technical Field

[0002] The present disclosure relates to an exhaust gas purification device.

Background Art

[0003] For purification of an exhaust gas discharged from an engine, an exhaust gas purification device is connected to an exhaust manifold. The exhaust gas purification device includes an exhaust gas purification catalyst for purifying the exhaust gas from the exhaust manifold. The exhaust gas purification catalyst includes a metal catalyst that purifies the exhaust gas and a carrier (catalyst carrier) that carries the metal catalyst.

[0004] For example, as such an exhaust gas purification device, JP 2019-019817 A proposes a device including a catalyst converter. The catalyst converter includes a first catalyst that purifies the exhaust gas from the exhaust manifold, and a second catalyst that purifies the exhaust gas that has passed through the first catalyst. Here, the heat capacity of the first catalyst is smaller than that of the second catalyst. According to this catalyst converter, it is possible to raise the temperature of the first catalyst at an early stage and improve the exhaust performance at the time of starting engine.

SUMMARY

[0005] However, when a vehicle is rapidly accelerated, for example, the flow rate of the exhaust gas increases, and the exhaust gas passing through the first catalyst is rapidly heated by activation of the catalyst. As a result, when the exhaust gas with the temperature rapidly increased reaches the second catalyst, the exhaust gas purification catalyst as the second catalyst may be rapidly heated in some cases. It is assumed that as a result of the above, a thermal shock acts on the exhaust gas purification catalyst and thus generates cracks in the exhaust gas purification catalyst.

[0006] The present disclosure has been made in view of the above problem, and provides a catalyst purification device capable of suppressing generation of cracks in the exhaust gas purification catalyst by reducing the thermal shock acting on the exhaust gas purification catalyst.

[0007] In view of the above problem, an exhaust gas purification device according to the present disclosure includes: a catalyst converter that purifies an exhaust gas from an exhaust manifold. The catalyst converter includes a porous body made of a metal material through which the exhaust gas from the exhaust manifold passes, and an exhaust gas purification catalyst that purifies the exhaust gas that passes through the porous body. The exhaust gas purification catalyst is an electrically heated catalyst, with a pair of electrodes attached to a catalyst main body. A plurality of through-holes is formed in the porous body along the exhaust gas from upstream to downstream. The metal material is exposed on a surface of the porous body. Under a temperature environment of 25° C., a ratio of a heat capacity of the porous body to the heat capacity of the catalyst main body is equal to or greater than 8% and equal to or smaller than 23%.

[0008] According to the present disclosure, it is possible to suppress generation of cracks in the exhaust gas purification catalyst by reducing a thermal shock acting on the exhaust gas purification catalyst.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic conceptual view for explaining an exhaust gas purification device according to the present embodiment;

[0010] FIG. **2** is a schematic perspective view of a first catalyst converter of the exhaust gas purification device shown in FIG. **1**;

[0011] FIG. **3**A is a schematic plan view of a porous body shown in FIG. **2**;

[0012] FIG. **3**B is a modification of the porous body shown in FIG. **3**A;

[0013] FIG. **4** is a graph showing a relationship among a bed temperature, a temperature of an exhaust gas passing through the first catalyst converter, and a crack generated in the exhaust gas purification catalyst when the first catalyst converter according to Examples 1 and 2 and Comparative Examples 1 and 2 is used;

[0014] FIG. **5**A is a graph showing a relationship between a ratio of the heat capacity and an amount of reduction in speed of temperature increase of the first catalyst converter according to Examples 1 and 2 and Comparative Examples 1 and 2; and

[0015] FIG. **5**B is a graph showing a relationship between the ratio of the heat capacity and a rate of increase in pressure loss of the first catalyst converter according to Examples 1 and 2 and Comparative Examples 1 and 2.

DETAILED DESCRIPTION

First Embodiment

[0016] Hereinafter, an exhaust gas purification device according to an embodiment of the present disclosure will be described with reference to FIGS. **1** to **5**. FIG. **1** is a schematic conceptual view for explaining an exhaust gas purification device **3** according to the embodiment of the present disclosure, and FIG. **2** is a schematic perspective view of a first catalyst converter **30** of the exhaust gas purification device **3** shown in FIG. **1**. In FIG. **2**, in order to show the inside of the first catalyst converter **30**, a housing **33** is shown in half.

[0017] As shown in FIG. **1**, the exhaust gas purification device **3** according to the present embodiment is a device that is attached downstream of an engine **2** and that purifies an exhaust gas after combustion in the engine **2**. The engine **2** may be either a gasoline engine or a diesel engine, and in the present embodiment, a gasoline direct injection engine is illustrated as an example in FIG. **1**.

[0018] In the engine **2**, air sucked via an intake valve **25** flows into a combustion chamber formed of a cylinder block **21** and a piston **22**, and is mixed with fuel (gasoline) injected by a fuel injection valve **28**. The mixed air-fuel mixture is ignited by a spark plug **27** and combusted in the combustion chamber, and the exhaust gas after combustion is discharged from an exhaust manifold **29** via an exhaust valve **26**.

[0019] The exhaust gas exhausted in the exhaust manifold **29** is purified in the exhaust gas purification device **3**. Specifically, the exhaust gas purification device **3** includes the first catalyst converter **30** connected to the exhaust manifold **29** and a second catalyst converter **37** downstream of and connected to the first catalyst converter **30** via an exhaust pipe **36**. The first catalyst converter **30** is arranged, for example, in an engine room (not shown) of a vehicle, and the second catalyst converter **37** is arranged, for example, under a floor (not shown) of a vehicle.

[0020] The first catalyst converter **30** includes a porous body **34** made of a metal material through which the exhaust gas from the exhaust manifold **29** passes, an exhaust gas purification catalyst **32** that purifies the exhaust gas from the exhaust manifold **29**, and the housing **33** that houses the exhaust gas purification catalyst **32**. Likewise, the second catalyst converter **37** includes an exhaust gas purification catalyst **38** that further purifies the exhaust gas that cannot be completely purified by the first catalyst converter **30** and a housing **39** that houses the exhaust gas purification catalyst

38. The porous body **34** and the housings **33**, **39** are made of a metal material, such as, stainless steel, carbon steel, or aluminum.

[0021] As shown in FIG. **2**, the exhaust gas purification catalyst **32** is an electrically heated catalyst with a pair of electrodes **35**, **35** attached to a catalyst main body **31**. The catalyst main body **31** has a cylindrical shape in a honeycomb structure. Each electrode **35** is in a comb shape and has a plurality of wiring portions **35***a* extending circumferentially around the catalyst main body **31**. The plurality of wiring portions **35***a* is fixed by means of fixing portions **35***c* so as to be spaced apart from each other in the axial direction of the catalyst main body **31**. The plurality of wiring portions **35***a* of each electrode **35** is coupled together by means of a coupling portion **35***b*. By supplying the pair of electrodes **35** with current, the catalyst main body **31** can be resistively heated so that the metal catalyst of the exhaust gas purification catalyst **32** can be activated.

[0022] In the housing **33** of the first catalyst converter **30**, an inlet side cone portion **33***a*, a body portion **33***b*, and an outlet side cone portion **33***c* are formed. The inlet side cone portion **33***a* is in a cone shape where the exhaust gas from the exhaust manifold **29** flows in and where a cross-section of a flow path of the exhaust gas enlarges from upstream toward downstream of the exhaust gas. The body portion **33***b* is formed so as to be continuous with the inlet side cone portion **33** on the upstream side of the exhaust gas flow and has a cylindrical shape in which the cross-section of the flow path of the exhaust gas is constant. The outlet side cone portion **33***c* is formed so as to be continuous with the body portion **33***b* on the upstream side of the exhaust gas flow and is in a cone shape where the cross-section of the flow path of the exhaust gas reduces from upstream toward downstream of the exhaust gas. In the present embodiment, the porous body **34** is disposed inside the inlet side cone portion **33***a* and the exhaust gas purification catalyst **32** is disposed inside the body portion **33***b*. This allows an axial center of the porous body **34** in a disk shape to align with an axial center of the exhaust gas purification catalyst **32**. As a result, the exhaust gas that has passed through the porous body **34** and the heat of which has been absorbed can be made to uniformly flow into the exhaust gas purification catalyst **32**.

[0023] In the present embodiment, since the engine **2** is a gasoline engine, the exhaust gas purification catalyst **32** is a three-way catalyst for purifying hydrocarbon (HC), carbon monoxide (CO), and nitride oxide (NOx) of the exhaust gas from the gasoline engine. Meanwhile, when the internal combustion engine is a diesel engine, the exhaust gas purification catalyst **32** is an oxidation catalyst that removes carbon monoxide (CO), hydrocarbon (HC), and the like. Note that the exhaust gas purification catalyst **38** housed in the second catalyst converter **37** is also provided with the same catalyst as that of the exhaust gas purification catalyst **32** in accordance with the type of the internal combustion engine.

[0024] In the catalyst main body **31** of the exhaust gas purification catalyst **32**, a metal catalyst that purifies the exhaust gas is carried on a carrier (catalyst carrier). A carrier **31***a* is in a honeycomb shape. A plurality of through-holes extending along an axial center of the carrier **31***a* is formed. The carrier **31***a* is made of a ceramic material, the examples of which may include a porous ceramic material containing any one type of alumina, zirconia, cordierite, titania, silicon carbide, and silicon nitride as a main component. The same holds true for the carrier of the exhaust gas purification catalyst **38**.

[0025] In the present embodiment, the carrier **31***a* is made of a SiC-based ceramic material. The SiC-based ceramic material is a material having SiC as a main material. Other ceramic materials may be further contained as long as the conductivity of the carrier **31***a* can be secured. In the present embodiment, since the carrier **31***a* is made of the SiC-based ceramic material, the catalyst main body **31** can be supplied with current through the electrode **35**. A metal catalyst containing at least one type of platinum, rhodium, and palladium is carried on a wall surface forming the honeycomb structure of the carrier **31***a*. When the carrier carries the metal catalyst, such a carrier can be obtained by coating a carrier with slurry containing the aforementioned ceramic material and metal catalyst and firing the coated carrier.

[0026] As shown in FIG. **3**A, a carrier of the porous body **34** is in a disk shape and is a structure in which a plurality of through-holes through which the exhaust gas passes is formed inside a metal frame body (outer peripheral portion) **34***a* in a ring shape. Specifically, a metal strip **34***b* bent in a wavy shape and a metal strip **34***c* in a plate shape are wound in a superimposed manner inside the metal frame body **34***a*. In this manner, a plurality of through-holes **34***h* is formed in the porous body **34** along the exhaust gas from upstream toward downstream.
[0027] In the present embodiment, the heat capacity of the porous body **34** is smaller than the heat capacity of the catalyst main body **31**. Specifically, under a temperature environment of 25° C., the ratio of the heat capacity of the porous body **34** to that of the catalyst main body **31** is equal to or greater than 8% and equal to or smaller than 23%. For example, the heat capacity of the catalyst main body **31** is in a range of 184 to 322 J/K under the temperature environment of 25° C. The heat capacity of the porous body 34 is in a range of 14.7 to 74.1 J/K under the temperature environment of 25° C. The heat capacities in these ranges are those of catalysts applied in accordance with the displacements of engines of typical vehicles on the market, and the heat capacities can be made to fit within the ranges by appropriately selecting the aforementioned materials and the like.
[0028] According to the present embodiment, the exhaust gas flowing into the first catalyst converter **30** from the exhaust manifold **29** passes through the porous body **34**, reaches the exhaust gas purification catalyst **32**, and is purified by the exhaust gas purification catalyst **32**. Since the exhaust gas purification catalyst **32** is an electrically heated catalyst, at the start of the engine **2**, current is supplied between the pair of electrodes **35** so that the exhaust gas purification catalyst **32** can be heated. This activates the heated exhaust gas purification catalyst **32** at an early stage, even if an exhaust gas with a relatively low-temperature reaches the exhaust gas purification catalyst **32** at the start of the engine **2**. As a result, the purification efficiency of the exhaust gas can be increased from the start of the engine **2**.
[0029] On the other hand, when a vehicle is rapidly accelerated or the like, the engine speed of the engine **2** increases, and the exhaust gas with a relatively high-temperature flows into the first catalyst converter **30** from the exhaust manifold **29**. Further, since the exhaust gas flowing into the exhaust manifold **29** increases, the activation of the exhaust gas purification catalyst **32** is also increased, thereby facilitating rapid increase in temperature.
[0030] In the present embodiment, even in such a state, since the metal material is exposed on the surface of the porous body **34**, the heat of the exhaust gas with a relatively high-temperature flowing into the first catalyst converter **30** can be absorbed by the porous body **34**. As a result, excessive activation of the exhaust gas purification catalyst **32** disposed downstream of the exhaust gas can be suppressed. Consequently, the thermal shock acting on the exhaust gas purification catalyst **32** is reduced so that generation of cracks in the exhaust gas purification catalyst **32** can be suppressed. For exhibiting such an advantageous effect, the ratio of the heat capacity of the porous body **34** to that of the catalyst main body **31** is equal to or greater than 8% under the temperature environment of 25° C. according to the later-described experiments or the like conducted by the inventors. Further, since the pressure loss of the exhaust gas passing through the porous body **34** increases as the ratio of the heat capacity increases, the ratio of the heat capacity of the porous body **34** to that of the catalyst main body **31** is equal to or smaller than 23%. The appropriate range of the ratio of the heat capacity is described in the following examples.
[0031] Further, as shown in FIG. **3**B, in a plan view of a porous body **34**A, the heat capacity per unit area in a circular center region **34***s* of the porous body **34**A is greater than the heat capacity per unit area in a doughnut-shaped surrounding region **34***t* that surrounds the center region **34***s*. The "heat capacity per unit area" is a value obtained by dividing the entire heat capacity of a region under the temperature environment of 25° C. by the area of the region in a plan view. The flow velocity of the exhaust gas flowing toward the center region **34***s* is higher and the flow rate of the exhaust gas is also higher as compared to the surrounding region **34***t*. Therefore, by increasing the heat capacity in the center region **34***s*, the heat of the exhaust gas passing through the center region

34*s* can be efficiently absorbed. Accordingly, the temperature increase at the center of the exhaust gas purification catalyst **32** in a plan view can be suppressed, thereby enabling the thermal shock on the catalyst main body **31** to be reduced.

[0032] More specifically, in the carrier of the porous body **34**A, a metal strip **34***bt* (**34***bs*) bent in a wavy shape and a metal strip **34***ct* (**34***cs*) in a plate shape are wound in a superimposed manner inside the metal frame body **34***a* in a circular ring shape. The wave-pitch of the metal strip **34***bs* in the center region **34***s* is greater than that of the metal strip **34***bt* in the surrounding region **34***t*. Thus, in a plan view of the porous body **34**, an opening area of a through-hole **34***hs* formed in the center region **34***s* is smaller than an opening area of a through-hole **34***ht* formed in the surrounding region **34***t*. Further, the number of the through-holes **34***hs* per unit area in the center region **34***s* is larger than the number of the through-holes **34***ht* per unit area in the surrounding region **34***t*. In this manner, in addition to the aforementioned advantageous effects, the opening area of the through-hole **34***hs* in the center region **34***s* is reduced and the number of the through-holes **34***hs* is correspondingly increased so that the pressure loss of the exhaust gas can be reduced while securing the heat capacity in the center region **34***s*.

EXAMPLES

[0033] Examples of the present disclosure will be described below.

Example 1

[0034] As shown below, the first catalyst converter **30** shown in FIG. **2** was prepared. As the porous body **34**, a porous body in a disk shape made of stainless steel having a diameter of 70 mm and a length of 10 mm was prepared. The thickness of the metal frame body **34***a* in a ring shape was 1.0 mm. The thickness of the metal strip **34***b* in a wavy shape and the metal strip **34***c* in a plate shape was 30 um. The number of cells (the number of through-holes) per square inch of the porous body **34** was 600. The mass of the porous body **34** was 41.0 g. The heat capacity of the porous body **34** was 18.9 K/J under a temperature environment of 25° C. Next, as a metal catalyst, slurry of ceria-zirconia containing a predetermined percentage of rhodium particles was coated on a SiC substrate (carrier), dried, and then calcined. The mass of the catalyst main body **31** obtained as such was 244 g. The heat capacity of the catalyst main body **31** was 174 K/J under the temperature environment of 25° C. The ratio of the heat capacity of the porous body **34** to that of the catalyst main body **31** was 11% under the temperature environment of 25° C.

Example 2

[0035] The first catalyst converter **30** was prepared in the same manner as in Example 1. The difference from Example 1 is that the length of the porous body **34** was set to be 15 mm. The mass of the porous body **34** was 62.0 g. The heat capacity of the porous body **34** was 28.6 K/J under the temperature environment of 25° C.

Comparative Example 1

[0036] The first catalyst converter was prepared in the same manner as in Example 1. The difference from Example 1 is that the porous body **34** was not provided.

Comparative Example 2

[0037] The first catalyst converter was prepared in the same manner as in Example 1. The difference from Example 1 is that the length of the porous body **34** was set to be 5 mm. The mass of the porous body **34** was 21.0 g. The heat capacity of the porous body **34** was 9.7 K/J under the temperature environment of 25° C.

Evaluation Test

[0038] The first catalyst converter of each of Examples 1 and 2 and Comparative Examples 1 and 2 was connected to an exhaust pipe having a bypass path from an engine having a displacement of 2.5 L. Then, a test under a condition of rapid acceleration of 500 cycles was conducted, by setting, as one cycle, a process of changing the engine speed from 1000 rpm to 3000 rpm. At this time, whether cracks have been generated in the catalyst main body was checked. In addition, the bed temperature of the catalyst main body and change in temperature (the maximum speed of

temperature increase) at a position downstream of the porous body by 5 mm were measured. The results are shown in FIG. **4** and Table 1. Next, the amount of reduction in speed of temperature increase of Examples 1 and 2 and Comparative Example 2 was measured on the basis of the maximum speed of temperature increase of Comparative Example 1. The results are shown in Table 1 below and FIG. **5**A. The rate of increase in pressure loss of Examples 1 and 2 and Comparative Example 2 was measured on the basis of the pressure loss of the exhaust gas of Comparative Example 1. The results are shown in Table 1 and FIG. **5**B below. Furthermore, as a reference example, the test under the condition of rapid acceleration of 500 cycles was conducted on the catalyst converter of Comparative Example 1, by setting, as one cycle, a process of changing the engine speed from 1000 rpm to 2900 rpm. The aforementioned results are shown in Table 1.
TABLE-US-00001 TABLE 1 Porous body Condition Maximum Ratio of of rapid speed of Pressure heat acceleration temperature loss Size (mm) capacity of 500 cycles increase ° C./s Crack increase Example 1 φ70 × L10 11% 1000 rpm 142(.box-tangle-solidup.8) None 9% .fwdarw.3000 rpm Example 2 φ70 × L15 16% 1000 rpm   135(.box-tangle-solidup.15) None 14%   .fwdarw.3000 rpm Comparative None 1000 rpm 150 Present None Example 1 .fwdarw.3000 rpm Reference None 1000 rpm 137 None None Example .fwdarw.2900 rpm Comparative φ70 × L5   6% 1000 rpm 146(.box-tangle-solidup.4) Present 6% Example 2 .fwdarw.3000 rpm
Results and Consideration
[0039] No crack was generated in the catalyst main body of Examples 1 and 2, while cracks were generated in the catalyst main body of Comparative Examples 1 and 2. As a reason for this, it is assumed that since under the condition of rapid acceleration, the heat of the exhaust gas was sufficiently absorbed by the porous body in Examples 1 and 2, no crack was generated in the catalyst main body of Examples 1 and 2. Further, it is assumed that when the engine speed was changed from 1000 rpm to 2900 rpm as in the reference example, the temperature of the exhaust gas was low and the flow rate of the exhaust gas was also low, and therefore, even with the use of the catalyst converter of Comparative Example 1, no crack was generated in the catalyst main body. Considering such points, for preventing generation of cracks in the catalyst main body, the ratio of the heat capacity of the porous body to that of the catalyst main body is equal to or greater than 8% as shown in FIG. **5**A, and more preferably, equal to or greater than 11%. Further, as shown in FIG. **5**B, considering the pressure loss of the porous body, the ratio of the heat capacity of the porous body to that of the catalyst main body is equal to or smaller than 23%, and more preferably equal to or smaller than 16%.

Claims

1. An exhaust gas purification device comprising a catalyst converter that purifies an exhaust gas from an exhaust manifold, wherein the catalyst converter includes a porous body made of a metal material through which the exhaust gas from the exhaust manifold passes, and an exhaust gas purification catalyst that purifies the exhaust gas that passes through the porous body, the exhaust gas purification catalyst is an electrically heated catalyst, with a pair of electrodes attached to a catalyst main body, a plurality of through-holes is formed in the porous body along the exhaust gas from upstream to downstream, and the metal material is exposed on a surface of the porous body, and under a temperature environment of 25° C., a ratio of a heat capacity of the porous body to the heat capacity of the catalyst main body is equal to or greater than 8% and equal to or smaller than 23%.
2. The exhaust gas purification device according to claim 1, wherein the catalyst converter comprises a housing made of metal that houses the porous body and the exhaust gas purification catalyst, in the housing, an inlet side cone portion where the exhaust gas from the exhaust manifold flows in and where a cross-section of a flow path of the exhaust gas enlarges from upstream toward downstream of the exhaust gas, a body portion that is continuous with the inlet side cone portion

and where the cross-section of the flow path of the exhaust gas is constant, and an outlet side cone portion that is continuous with the body portion and where the cross-section of the flow path of the exhaust gas reduces from upstream toward downstream of the exhaust gas are formed, the porous body is disposed inside the inlet side cone portion, and the exhaust gas purification catalyst is disposed inside the body portion.

3. The exhaust gas purification device according to claim 2, wherein the porous body is disk-shaped, and in a plan view of the porous body, a heat capacity per unit area in a center region of the porous body is greater than the heat capacity per unit area in a surrounding region that surrounds the center region.

4. The exhaust gas purification device according to claim 3, wherein in the plan view of the porous body, an opening area of each through-hole formed in the center region is smaller than the opening area of each through-hole formed in the surrounding region, and a number of the through-holes per unit area in the center region is greater than the number of the through-holes per unit area in the surrounding region.

5. The exhaust gas purification device according to claim 1, wherein the catalyst main body comprises a carrier in a honeycomb shape made of a SiC-based ceramic material.