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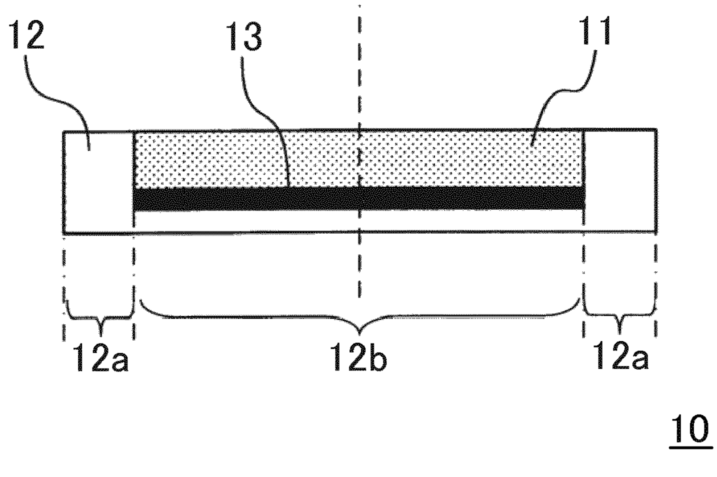
(54) STRUCTURAL BODY INSIDE OF WHICH THERMAL INSULATING SECTION IS PROVIDED, PISTON OF INTERNAL COMBUSTION ENGINE, AND INTERNAL COMBUSTION ENGINE

(57) In a structural body inside of which a thermal insulating section is provided, the coefficient of thermal expansion of a member constituting a first portion of the structural body is lower than the coefficient of thermal expansion of a member constituting a second portion of the structural body. The first portion is a portion interposed between a surface that undergoes a significant temperature change during the use of the structural body, and the thermal insulating section. The second portion is the other portion of the structural body than the first portion.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a structural body inside of which a thermal insulating section is provided, a piston of an internal combustion engine, and an internal combustion engine.

2. Description of Related Art

[0002] In some conventional internal combustion engines, a structural body inside of which thermal insulating sections, such as voids, are provided is disposed in a prescribed region on the top surface of a piston, with which the fuel injected through a fuel injection valve collides in a cylinder, to enhance the thermal insulating properties of the prescribed region (refer to, for example, Japanese Patent Application Publication No. 2005-076471 (JP 2005-076471) and Japanese Patent Application Publication No. 2000-297695 (JP 2000-297695)). Such a structural body hinders thermal conduction from the top surface to the body of the piston, thereby inhibiting a decrease in temperature of the top surface of the piston. This facilitates the evaporation of the fuel from the top surface of the piston, thereby facilitating the formation of an appropriate combustible air-fuel mixture, for example, even immediately after the start-up of the internal combustion engine. This leads to reduction in harmful emissions, such as reduction in unburnt fuel contained in the exhaust gas.

[0003] As described above, in an internal combustion engine in which a structural body inside of which a thermal insulating section is provided is disposed on the top surface of a piston, a decrease in temperature of the top surface of the piston is inhibited and thus a cooling loss is reduced. This facilitates the formation of an appropriate combustible air-fuel mixture, which leads to advantageous effects, such as reduction in harmful emissions.

[0004] However, when such an internal combustion engine is operated and thus the structural body undergoes a significant temperature change due to the combustion of fuel, the structural body may deform to cause cracking at the joint between the structural body and the body of the piston that supports the structural body. Cracking may occur also at the interface between a portion of the structural body, which is interposed between the contact surface of the structural body in contact with a heat source and the thermal insulating section (hereinafter, referred also to as "immediately upper portion disposed immediately above the thermal insulating section" or simply as "immediately upper portion") and a peripheral portion around the immediately upper portion (hereinafter, referred also to as "peripheral portion").

SUMMARY OF THE INVENTION

[0005] The invention is made in order to address the above-described problem. The invention provides a structural body inside of which a thermal insulating section is provided, the structural body being less likely to be deformed and/or cracked even when the structural body undergoes a significant temperature change.

[0006] With reference to FIG. 5A and FIG. 5B, description will be provided on a mechanism by which the structural body is deformed and/or cracked when the structural body undergoes a significant temperature change as described above. FIG. 5A and FIG. 5B schematically illustrate how a conventional structural body 50 inside of which a thermal insulating section 53 (void) is provided is deformed when the structural body 50 is exposed to high temperature. All the portions of the structural body 50 except the thermal insulating section 53 (void) are made of the same material and have the same coefficient of thermal expansion. The structural body 50 is disposed on the top surface of a piston 60 of an internal combustion engine.

[0007] Due to the contact with the fuel gas in a cylinder of the internal combustion engine, the structural body 50 is supplied with heat. The heat is then transferred from the contact surface (upper main surface in FIG. 5) of the structural body 50 in contact with a heat source (fuel gas), to the piston 60 that supports the structural body 50. However, due to low thermal conductivity of the thermal insulating section 53 provided inside the structural body 50, the heat is not readily transferred (dissipated) toward the piston 60 through a portion interposed between the contact surface of the structural body 50 in contact with the heat source and the thermal insulating section 53 (i.e., an immediately upper portion 51 disposed immediately above the thermal insulating section 53). As a result, the temperature of the immediately upper portion 51 increases.

[0008] In the structural body 50, no thermal insulating section is formed inside (in a lower portion of) a peripheral portion around the immediately upper portion 51. Thus, the heat is relatively readily transferred through the peripheral portion to the piston 60. As a result, the temperature of the peripheral portion becomes lower than that of the immediately upper portion 51. Because the thermal insulating section 53 hinders thermal transfer from the immediately upper portion 51, the temperature of a portion (hereinafter, referred also to as "immediately lower portion") located on the opposite side of the thermal insulating section 53 from the immediately upper portion 51 is less likely to increase. In addition, the immediately lower portion is in direct contact with the piston 60, and thus the immediately lower portion readily transfers the heat from the peripheral portion to the piston 60.

[0009] As described above, the temperature of the immediately upper portion 51 becomes higher than the temperature of the other portion 52 (including the peripheral portion and the immediately lower portion) in the structural body 50. Thus, the degree of expansion (in the direction indicated by the solid double-headed arrow) of the immediately upper portion 51 due to an increase in temperature is greater than that of the other portion 52, although the immediately upper portion 51 and the other portion 52 are made of the same material and have the same coefficient of thermal expansion. However, the expansion of the immediately upper portion 51 is hindered or restricted by the other portion 52 (the peripheral portion). As a result, high stress (indicated by the hollow arrows) is applied to the interface between the immediately upper portion 51 and the other portion 52.

[0010] When the stress is greater than the proof stress of the structural body 50, the structural body 50 may be deformed or cracking may occur at the interface between the immediately upper portion 51 and the other portion 52 (the peripheral portion). Such a deformation of the structural body 50 may cause "separation", that is, detachment of the structural body 50 from the piston 60 at a joint J (indicated by the thick line) between the structural body 50 and the piston 60.

[0011] With a decrease in temperature of the structural body 50, the portions of the structural body 50, which have expanded as described above, contract. Further, a decrease in temperature of the immediately upper portion 51 during contract is greater than that of the other portion 52. Thus, the degree of contraction of the immediately upper portion 51 due to the decrease in temperature is greater than that of the other portion 52. If the deformation of the structural body 50 due to the above described stress is only revisable deformation (elastic deformation), a decrease in temperature of the structural body 50 would allow the structural body 50 to recover its original shape observed before the increase in temperature. However, if the deformation of the structural body 50 contains irreversible deformation (plastic deformation), a decrease in temperature of the structural body 50 does not allow the structural body 50 to recover its original dimensions or shape observed before the increase in temperature, and residual strain remains.

[0012] By the above-described mechanism, a structural body inside of which a thermal insulating section is provided may be deformed and/or cracked when the structural body undergoes a significant temperature change.

[0013] After a diligent research, the inventor of the invention has found that a structural body inside of which a thermal insulating section is provided is less likely to be deformed and/or cracked when the correlation between the coefficient of thermal expansion of a portion interposed between the surface exposed to high temperature and the thermal insulating section and the coefficient of thermal expansion of the other portion of the structural body satisfies a prescribed condition.

[0014] More specifically, in a structural body inside of which a thermal insulating section is provided, the coefficient of thermal expansion of a portion interposed between the surface that undergoes a significant temperature change during the use of the structural body and the thermal insulating section is set lower than the coefficient of thermal expansion of the other portion of the structural body. The inventor of the invention has found that setting the coefficients of thermal expansion as described above makes it possible to reduce the occurrence of deformation and/or cracking of the structural body when the structural body undergoes a significant temperature change.

[0015] A first aspect of the invention relates to a structural body inside of which a thermal insulating section is provided. The structural body includes a first portion and a second portion. The first portion defines a part of a first outer surface of the structural body. The first outer surface is a surface that undergoes the greatest temperature change during the use of the structural body among outer surfaces of the structural body. The first portion is at least a part of a portion of the structural body, the portion being interposed between the first outer surface and the thermal insulating section. The first portion is constituted by a first member. The second portion defines the other part of the first outer surface than the part defined by the first portion. The second portion is constituted by a second member. The first member has a coefficient of thermal expansion that is lower than a coefficient of thermal expansion of the second member.

[0016] In the structural body according to the above aspect as well as in the conventional structural body described above, thermal conduction through the thermal insulating section is hindered, and when the first outer surface is exposed to high temperature, the temperature of the portion interposed between the first outer surface and the thermal insulating section becomes higher than that of the other portion. However, in the structural body according to the above aspect, the first portion (at least a part of the portion interposed between the first outer surface and the thermal insulating section) has a coefficient of thermal expansion that is lower than the coefficient of thermal expansion of the second portion (the other portion of the structural body than the first portion), as described above. That is, the coefficient of thermal expansion of the first member is lower than the coefficient of thermal expansion of the second member.

[0017] Therefore, even when the temperature of the portion interposed between the first outer surface and the thermal insulating section becomes higher than the temperature of the other portion in the structural body, the stress that is applied to the interface between the first portion and the second portion is reduced. The stress is applied to the interface because the degree of expansion of the first portion is greater than that of the second portion. As a result, the occurrence of deformation and/or cracking when the structural body undergoes a significant temperature change is reduced, despite the presence of the thermal insulating section provided inside the structural body.

[0018] In the above aspect, the thermal insulating section may be a void defined inside the structural body, the void being defined by the first portion and the second portion. With this thermal insulation section, thermal conduction through the thermal insulating section is effectively hindered by the void. Thus, it is not necessary to provide a special member and/or a special structure.

[0019] In the above aspect, the first member and the second member may be sintered materials. When the first member and the second member are sintered materials, it is possible to easily allow the structural body to have the above-described coefficients of thermal expansion and characteristics (for example, mechanical strength, density, thermal resistance, and dimensional stability) required for the use of the structural body.

[0020] In the above aspect, the first member and the second member may be sintered materials containing iron. Using the sintered materials containing iron as the first and second members is advantageous particularly when the structural body is used in, for example, a piston of an internal combustion engine.

[0021] Even in the case where the coefficient of thermal expansion of the first member is lower than that of the second member, when the difference between the coefficient of thermal expansion of the first member and that of the second member is excessively small, it may be difficult to sufficiently obtain the effect of reducing the occurrence of deformation and/or cracking of the structural body when the structural body undergoes a significant temperature change. In the above aspect, the coefficient of thermal expansion of the first member may be equal to or lower than 90% of the coefficient of thermal expansion of the second member. This makes it possible to more reliably obtain the effect of reducing the occurrence of deformation and/or cracking of the structural body when the structural body undergoes a significant temperature change.

[0022] On the other hand, when the coefficient of thermal expansion of the first member is excessively smaller than that of the second member (i.e., when the difference between the coefficient of thermal expansion of the first member and that of the second member is excessively large), the degree of expansion of the first member may be excessively smaller than the degree of expansion of the second member when the structural body is exposed to high temperature. As a result, cracking may occur at the interface between the first member and the second member, depending on the difference in coefficient of thermal expansion. In view of this, in the above aspect, the coefficient of thermal expansion of the first member may be equal to or higher than 40% of the coefficient of thermal expansion of the second member. This makes it possible to more reliably reduce the occurrence of cracking at the interface between the first member and the second member when the structural body undergoes a significant temperature change.

[0023] In the above aspect, the immediately upper portion need not be entirely constituted by the first member as the first portion, as long as at least a part of the immediately upper portion is constituted by the first member as the first portion. In the above aspect, an equivalent circle diameter of the first portion may be within a range from 50% to 110% of an equivalent circle diameter of the thermal insulating section, in projection view on a plane parallel to the first outer surface. This makes it possible to more reliably obtain the effect of reducing the occurrence of deformation and/or cracking of the structural body when the structural body undergoes a significant temperature change.

[0024] As described above, the degree (amount) by which the first portion projects into the peripheral portion is set based on the dimension of the thermal insulating section. In addition, the degree (amount) by which the first portion projects into the peripheral portion, with respect to the dimension of the peripheral portion, should be within a favorable range.

[0025] In the above aspect, a difference obtained by subtracting an equivalent circle diameter of the thermal insulating section from an equivalent circle diameter of the first portion may be equal to or lower than 55% of a difference obtained by subtracting the equivalent circle diameter of the thermal insulating section from an equivalent circle diameter of the structural body, in projection view on a plane parallel to the first outer surface. This makes it possible to more reliably obtain the effect of reducing the occurrence of deformation and/or cracking of the structural body when the structural body undergoes a significant temperature change.

[0026] The structural body according to the above aspect is particularly advantageous when being used in a piston of an internal combustion engine. Therefore, a second aspect of the invention relates to a piston of an internal combustion engine. The piston includes the structural body according to the first aspect, and the structural body is disposed in a recess provided on a top surface of the piston.

[0027] A third aspect of the invention relates to an internal combustion engine including the piston according to the second aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic sectional view illustrating the configuration of a structural body according to a first embodiment of the invention (first structural body);

FIG. 2 schematically illustrates a method of manufacturing the first structural body;

FIG. 3A and FIG. 3B illustrate the first structural body that is not deformed even when the first structural body is exposed to high temperature;

FIG. 4A schematically illustrates a second portion that enters an immediately upper portion in a structural body according to a second embodiment of the invention (second structural body);

FIG. 4B schematically illustrates a first portion that projects from an immediately upper portion in a structural body according to the second embodiment of the invention (second structural body); and

FIG. 5A and FIG. 5B illustrate how a conventional structural body inside of which a thermal insulating section is provided is deformed when the structural body is exposed to high temperature.

DETAILED DESCRIPTION OF EMBODIMENTS

First Embodiment

[0029] Hereinafter, a structural body according to a first embodiment of the invention (hereinafter, referred also to as "first structural body 10") will be described with reference to the attached drawings. The first structural body 10 is in the form of a disk having a thickness of 2.4 mm and a diameter of 30 mm.

Configuration of First Structural Body

[0030] FIG. 1 is a schematic sectional view of the first structural body 10 taken along a plane perpendicular to a first outer surface that undergoes the greatest temperature change during the use of the first structural body 10. The first outer surface is the top surface of the first structural body 10 in FIG. 1. The first structural body 10 includes a thermal insulating section 13 that is a void defined inside the first structural body 10. The thermal insulating section 13 has a thickness (i.e., a dimension in the direction of the normal to the first outer surface) of 0.2 mm and a diameter of 24 mm. The first structural body 10 includes a first portion 11 that is the entirety of a portion of the first structural body 10, which is interposed between the first outer surface and the thermal insulating section 13 (i.e., an immediately upper portion disposed immediately above the insulating section 13). The first portion 11 is constituted by a first member. The first portion 11 has a thickness of 1.2 mm.

[0031] The first structural body 10 also includes a second portion 12 that is the other portion of the first structural body 10 than the first portion 11. The second portion 12 is constituted by a second member. As described above, the first portion 11 occupies the entirety of the immediately upper portion in the first structural body 10. The second portion 12 therefore coincides with a portion composed of a peripheral portion 12a that is disposed around the thermal insulating section 13 in projection view on a plane parallel to the first outer surface of the first structural body 10 and an immediately lower portion 12b that is disposed on the opposite side of the thermal insulating section 13 from the immediately upper portion (i.e., that is disposed immediately below the thermal insulating section 13). The immediately lower portion 12b has a thickness of 1.0 mm, for example. The first member constituting the first portion 11 and the second member constituting the second portion 12 in the first structural body 10 are sintered materials containing iron (iron-based sintered materials). The compositions of the first member and the second member will be described later in detail.

Method of Manufacturing First Structural Body

[0032] The first structural body 10, which is made of iron-based sintered materials as described above, is manufactured through a method illustrated in FIG. 2, for example. First, in Step (1), base powder (powder B) for the second member that constitutes the second portion 12 is charged into a mold. The mold has a cylindrical molding space having an axis extending in the up-down direction in FIG. 2. In Step (2), a sheet for forming a void as a thermal insulating section 13 is placed on the powder B. The sheet is made of a material, such as resin, that can be burnt out in a sintering step performed later. The sheet has a shape and dimensions corresponding to the void having a shape and dimensions required to form the thermal insulating section 13. The sheet is in the form of a disk, and disposed concentrically with the first structural body 10 to be formed. Then, a cylinder is disposed on the sheet, so that the sheet is fixed by the cylinder.

[0033] In Step (3), powder B is further charged around the cylinder. The powder B charged into the mold in Step (1) and powder B charged into the mold in Step (3) form the second portion 12. In Step (4), powder A is charged into the cylinder. The powder A charged into the cylinder in Step (4) forms the first portion 11.

[0034] In Step (5), the cylinder is removed from the mold. In Step (6), the powder A, the powder B, and the sheet in the mold are compressed at a prescribed contact pressure (see the black-filled arrows) to be formed into a compact. The compact is then sintered in the sintering step (not illustrated). In the sintering step, the sheet is burnt out to form a void in the sintered compact. The void functions as the thermal insulating section 13. In this way, the first structural body 10 is manufactured.

Coefficient of Thermal Expansion

[0035] In the first structural body 10, the first member that constitutes the first portion 11 and that is made from the powder A, has a coefficient of thermal expansion lower than that of the second member that constitutes the second portion 12 and that is made from the powder B. More specifically, the coefficient of thermal expansion of the first member is within a range from 40% to 90% of the coefficient of thermal expansion of the second member.

[0036] Next, detailed description will be provided on the correlation between the ratio of the coefficient of thermal expansion of the first member constituting the first portion 11 to the coefficient of thermal expansion of the second member constituting the second portion 12, and the occurrence of deformation and/or cracking of the first structural body 10 when the first structural body 10 undergoes a significant temperature change. Table 1 illustrates the composition (weight %) of each of the base powders (powder A1 to powder A6 and powder B) used for manufacturing iron-based sintered materials for structural bodies 1a to If that were subjected to experiments regarding the correlation described above, the coefficient of thermal expansion (CTE) (10^{-6}/°C) of each of the sintered materials made from the base powders, and the ratio (%) of the coefficient of thermal expansion of the first member to the coefficient of thermal expansion of the second member. The coefficient of thermal expansion was calculated based on a dimensional change of each sintered material after an increase in temperature from a room temperature to 400°C.

Table 1

Base Powder	Composition (wt %)			CTE	CTE ratio
	Fe	SUS304L	W	(10^{-6}/°C)	(%)
B	0	100	0	18.2	100
A1	28	72	0	16.8	92
A2	35	65	0	16.3	90
A3	80	20	0	14.5	80
A4	70	0	30	11.0	60
A5	30	0	70	7.3	40
A6	27	0	73	6.9	38

[0037] The structural bodies 1a to If illustrated in Table 2 illustrated below were manufactured from base powders (powder A1 to powder A6 and powder B). As illustrated in Table 2, the ratio of the coefficient of thermal expansion of the first member to that of the second member (CTE ratio) is within a range from 40% to 90% in each of the structural bodies 1b to 1e. The structural bodies 1b to 1e are examples of the first structural body 10, and the structural bodies 1a, 1f are comparative examples. The configuration of the structural bodies 1a to If and the method of manufacturing the structural bodies 1a to If are as described above.

[0038] Each of the structural bodies 1a to If manufactured through the method described above was fixedly fitted in a recess formed on the top surface of a support 20 made of aluminum, which is a model of the top surface of a piston of an internal combustion engine. Each structural body supported by the support 20 was subjected to heat cycles under the condition similar to that in a combustion chamber of the internal combustion engine. Then, whether each structural body was deformed and whether cracking occurred at the interface between the first portion and the second portion in each structural body were visually checked.

[0039] More specifically, the immediately upper portion of each of the structural bodies 1a to If was heated with a high-frequency coil, while the peripheral portion thereof was cooled, causing a difference in temperature between the immediately upper portion and the other portion. The immediately upper portion was subjected to 500 heat cycles. In each heat cycle, the immediately upper portion was heated from 320°C to 450°C in 30 seconds, kept at 450°C for 40 seconds, and then cooled from 450°C to 320°C in 30 seconds. In each heat cycle, the temperature of the peripheral portion was changed within a range from 210°C to 240°C, in a manner similar to that in which the temperature of the immediately upper portion was changed. The results of the visual check are also illustrated in Table 2.

Table 2

Serial Number of Structural Body	First Member	Second Member	CTE Ratio (%)	Deformation of Structural Body	Cracking at Interface
1a	A1	B	92	Observed	Not Observed
1b	A2	B	90	Not Observed	Not Observed
1c	A3	B	80	Not Observed	Not Observed
1d	A4	B	60	Not Observed	Not Observed
1e	A5	B	40	Not Observed	Not Observed
1f	A6	B	38	Not Observed	Observed

[0040] As is clear from the results illustrated in Table 2, deformation of the structural body 1a, which is a comparative example, was observed after the thermal treatment described above. In addition, cracking was observed at the interface between the first portion and the second portion in the structural body If, which is another comparative example, after the thermal treatment. In contrast to this, in each of the structural bodies 1b to 1e, which are the examples of the first structural body 10, neither deformation of the structural body nor cracking at the interface between the first portion and the second portion was observed after the thermal treatment. Although not illustrated in Table 2, in a conventional structural body including a first portion and a second portion that are both manufactured from the powder B, deformation of the structural body was observed after the structural body was subjected to 10 heat cycles described above.

[0041] Next, description will be provided on the behavior of each of the structural bodies 1b to 1e, which are examples of the first structural body 10. FIG. 3A and FIG. 3B schematically illustrate the first structural body 10 that is not deformed even when the first structural body 10 is exposed to high temperature. As described above, in the first structural body 10, the first member constituting the first portion 11 has a prescribed coefficient of thermal expansion that is lower than the coefficient of thermal expansion of the second member constituting the second portion 12. As a result, as illustrated in FIG. 3A, the degree of thermal expansion of the first portion 11 (in the direction indicated by the solid double-headed arrow) does not become excessively greater than the degree of thermal expansion of the second portion 12, even when thermal conduction through the thermal insulating section 13 is hindered and thus the temperature of the immediately upper portion becomes higher than that of the other portion while the first outer surface of the first structural body 10 is exposed to high temperature. Thus, the stress (in the direction indicated by the hollow arrows) applied to the interface between the first portion 11 and the second portion 12 is reduced. As a result, as illustrated in FIG. 3B, the occurrence of deformation and/or cracking when the first structural body 10 undergoes a significant temperature change is reduced, despite the presence of the thermal insulating section 13 provided inside the first structural body 10.

Modified Examples of Thermal Insulating Section

[0042] As described above, the thermal insulating section 13 of the first structural body 10 is a void defined inside the first structural body 10. However, a thermal insulating section provided inside the structural body may have any configuration or may be made of any material, as long as thermal conduction through the thermal insulating section is hindered and no inconvenience is caused in the use of the structural body inside of which the thermal insulating section is provided. More specifically, the thermal insulating section may be made of a material that has a coefficient of thermal conductivity corresponding to the thermal insulating properties required for the use of the structural body. Examples of such a material include ceramics, such as alumina, zirconia, yttria, silicon carbide, silicone nitride, aluminum nitride, cordierite, mullite, and silica.

[0043] In addition, the thermal insulating section may be constituted by any member configured to achieve a coefficient of thermal conductivity corresponding to the thermal insulating properties required for the use of the structural body. Examples of such a member include members with voids provided thereinside (for example, porous members).

Modified Examples of First Portion and Second Portion

[0044] As described above, the first member constituting the first portion 11 and the second member constituting the second portion 12 in the first structural body 10 are sintered materials containing iron. However, a first member and a second member may be made of any materials, as long as the coefficient of thermal expansion of the first member is lower than that of the second member and the first member and the second member have characteristics (for example, mechanical strength, density, thermal resistance, and dimensional stability) required for the use of the structural body.

Examples of such materials include iron-based sintered materials and nonferrous sintered materials. However, the first and second members may be made of materials other than sintered materials.

Modified Examples of Coefficients of Thermal Expansion of First Member and Second Member

[0045] As described above, in the first structural body 10, the coefficient of thermal expansion of the first member constituting the first portion 11 is within a range from 40% to 90% of the coefficient of thermal expansion of the second member constituting the second portion 12. However, as described above, the coefficient of thermal expansion of the first member may be any value that is lower than that of the second member as long as the difference between the coefficient of thermal expansion of the first member and that of the second member is neither excessively small nor excessively large. The concrete ratio of the coefficient of thermal expansion of the first member to that of the second member may be set as appropriate depending on, for example, the detailed configuration of the structural body and the materials of the first member and the second member.

[0046] Thus, as long as the coefficient of thermal expansion of the first member is lower than that of the second member, even when the coefficient of thermal expansion of the first member is higher than 90% of that of the second member, the occurrence of the structural body when the structural body undergoes a significant temperature change is reduced. Even when the coefficient of thermal expansion of the first member is lower than 40% of that of the second member, the occurrence of cracking in the structural body when the structural body undergoes a significant temperature change can be reduced depending on the configuration of the structural body.

Second Embodiment

[0047] As in the first structural body 10 described above, typically, the entirety of the portion interposed between the first outer surface and the thermal insulating section is constituted by the first member, while the other portion is constituted by the second member. Among the outer surfaces of the first structural body 10, the first outer surface undergoes the greatest temperature change during the use of the structural body 10. In other words, typically, the entirety of the portion (immediately upper portion) interposed between the first outer surface and the thermal insulating section is the first portion, and the other portion (the peripheral portion and the immediately lower portion) is the second portion.

[0048] However, the immediately upper portion need not be entirely constituted by the first member as a first portion, and only a part of the immediately upper portion may be constituted by the first member as a first portion. In this case, a second portion enters the immediately upper portion, as indicated by the hollow arrow in FIG. 4A. Conversely, a first portion constituted by the first member may extend into the peripheral portion around the immediately upper portion. In this case, the first portion projects into the peripheral portion, as indicated by the black-filled arrow in FIG. 4B

[0049] For example, when the first member and the second member are iron-based sintered materials that are obtained by sintering iron-based powder as in the first structural body 10, the above-described configurations may be unintentionally generated in a process in which the base powder for the first member and the base powder for the second member are charged into a mold to form the first and second members.

[0050] A structural body according to a second embodiment of the invention (hereinafter, referred also to as "second structural body") includes a second portion that enters the immediately upper portion or a first portion that projects into the peripheral portion. More specifically, in the second structural body, the width (amount) by which the second portion enters the immediately upper portion in an in-plane direction parallel to the first outer surface is equal to or less than 25% of the dimension (length) of the thermal insulating section, or the width (amount) by which the first portion projects into the peripheral portion in an in-plane direction parallel to the first outer surface is equal to or less than 10% of the dimension (length) of the thermal insulating section. In other words, in the second structural body, the equivalent circle diameter of the first portion is within a range from 50% to 110% of the equivalent circle diameter of the thermal insulating section in projection view on a plane parallel to the first outer surface.

[0051] Next, detailed description will be provided on the correlation between the ratio of the equivalent circle diameter of the first portion to the equivalent circle diameter of the thermal insulating section (diameter ratio) in projection view on a plane parallel to the first outer surface, and the deformation of the second structural body that occurs when body undergoes a significant temperature change. Table 3 illustrates the diameter ratio in each of structural bodies (structural bodies 2a to 2k) that were subjected to experiments regarding the correlation described above, and the presence or absence of deformation of each of the structural bodies. Table 3 also illustrates the ratio of the width (amount) by which the second portion enters the immediately upper portion to the dimension (length) of the thermal insulating section (entrance ratio) in each of the structural bodies, and the ratio of the width (amount) by which the first portion projects into the peripheral portion to the dimension (length) of the thermal insulating section (projection ratio) in each of the structural bodies.

[0052] As illustrated in Table 3, the diameter ratio of each of the structural bodies 2c to 2i is within a range from 50% to 110%. That is, the structural bodies 2c to 2i are examples of the second structural body, and the structural bodies 2a, 2b, 2j, 2k are comparative examples. The structural bodies 2a to 2k each have the same configuration as that of the first structural body 10 except that the second portion enters the immediately upper portion or the first portion projects into the peripheral portion. The method of manufacturing each of the structural bodies 2a to 2k is the same as that of manufacturing the first structural body 10 described above. The structural bodies 2a to 2k each include a void that functions as a thermal insulating section and first and second portions that are the same as those of the structural body 1c, which is an example of the first structural body 10. The structural bodies 2a to 2k obtained in this way were subjected to the same thermal treatment as for the first structural body 10, and whether each structural body was deformed was visually checked. The results of the visual check are also illustrated in Table 3.

Table 3

Serial Number of Structural Body	Diameter Ratio (%)	Entrance Ratio (%)	Projection Ratio (%)	Deformation of Structural Body
2a	40	30	-	Observed
2b	48	26	-	Observed
2c	50	25	-	Not Observed
2d	60	20	-	Not Observed
2e	80	10	-	Not Observed
2f	100	0	0 (0)	Not Observed
2g	102	-	1 (11)	Not Observed
2h	106	-	3 (33)	Not Observed
2i	110	-	5 (55)	Not Observed
2j	112	-	6 (66)	Observed
2k	114	-	7 (77)	Observed

[0053] As is clear from the results illustrated in Table 3, deformation of each of the structural bodies 2a, 2b, 2j, 2k, which are the comparative examples, was observed after the thermal treatment described above. In contrast to this, in each of the structural bodies 2c to 2i which are the examples of the second structural body, deformation of the structural body was not observed after the thermal treatment. In other words, in the second structural body in which the equivalent circle diameter of the first portion is within a range from 50% to 110% of the equivalent circle diameter of the thermal insulating section in projection view on a plane parallel to the first outer surface, the occurrence of deformation of the structural body when the structural body undergoes a significant temperature change was reduced.

[0054] A mechanism of occurrence of the above-described phenomena will be considered as follows. As described above, the first portion of the structural body is constituted by the first member having a relatively small coefficient of thermal expansion, whereby the occurrence of deformation and/or crack in the structural body when the structural body undergoes a significant temperature change is reduced. Therefore, it is considered that, when the second portion largely enters the immediately upper portion and thus the ratio of the first portion to the immediately upper portion located immediately above the thermal insulating section is excessively low as in the structural bodies 2a, 2b, it is difficult to sufficiently obtain the effect of reducing the occurrence of deformation of the structural body when the structural body undergoes a significant temperature change.

[0055] Conversely, it is considered that, when the first portion largely projects into the peripheral portion and thus the ratio of the second portion to the peripheral portion is excessively low as in the structural bodies 2j, 2k, an excessively large difference is caused between the degree of expansion of the immediately upper portion side (first outer surface side) and the degree of expansion of the immediately lower portion side when the structural body undergoes a significant temperature change, and thus deformation of the structural body, such as warpage, occurs.

[0056] In the above description, the degree (amount) by which the first portion projects into the peripheral portion is set based on the dimension of the thermal insulating section. In addition, as described above, the degree (amount) by which the first portion projects into the peripheral portion, with respect to the dimension of the peripheral portion, should be within a favorable range. More specifically, the ratio (projection ratio with respect to the peripheral portion) of the difference (corresponding to the width (amount) by which the first portion projects into the peripheral portion) obtained by subtracting the equivalent circle diameter of the thermal insulating section from the equivalent circle diameter of the first portion to the difference (corresponding to the width of the peripheral portion) obtained by subtracting the equivalent circle diameter of the thermal insulating section from the equivalent circle diameter of the second structural body is equal to or less than 55%, in projection view on a plane parallel to the first outer surface of the second structural body. With this configuration, it is possible to more reliably obtain the effect of reducing the occurrence of deformation of the structural body when the structural body undergoes a significant temperature change. Note that each of the values inside the parentheses in the boxes indicating the projection ratio is the "protection ratio with respect to the peripheral portion" described above.

Third Embodiment

[0057] As described above, the structural body may be particularly preferably used in a piston of an internal combustion engine, for example. Therefore, a third embodiment of the invention relates to a piston of an internal combustion engine, in which any one of the structural bodies according to the above-described embodiments and modified examples is disposed in a recess formed in the top surface of the piston.

Fourth Embodiment

[0058] A fourth embodiment of the invention relates to an internal combustion engine including the piston according to the third embodiment of the invention.

Claims

1. A structural body inside of which a thermal insulating section (13) is provided, the structural body comprising:

a first portion (11) defining a part of a first outer surface of the structural body, the first outer surface being a surface that undergoes a greatest temperature change during use of the structural body among outer surfaces of the structural body, the first portion (11) being at least a part of a portion of the structural body, the portion being interposed between the first outer surface and the thermal insulating section (13), and the first portion (11) being constituted by a first member; and
a second portion (12) defining the other part of the first outer surface than the part defined by the first portion (11), the second portion (12) being constituted by a second member, wherein
the first member has a coefficient of thermal expansion that is lower than a coefficient of thermal expansion of the second member.

2. The structural body according to claim 1, wherein the thermal insulating section (13) is a void defined inside the structural body, the void being defined by the first portion (11) and the second portion (12).

3. The structural body according to claim 1 or 2, wherein the first member and the second member are sintered materials.

4. The structural body according to claim 3, wherein the first member and the second member are sintered materials containing iron.

5. The structural body according to any one of claims 1 to 4, wherein the coefficient of thermal expansion of the first member is equal to or lower than 90% of the coefficient of thermal expansion of the second member.

6. The structural body according to any one of claims 1 to 5, wherein the coefficient of thermal expansion of the first member is equal to or higher than 40% of the coefficient of thermal expansion of the second member.

7. The structural body according to any one of claims 1 to 6, wherein an equivalent circle diameter of the first portion (11) is within a range from 50% to 110% of an equivalent circle diameter of the thermal insulating section (13), in projection view on a plane parallel to the first outer surface.

8. The structural body according to any one of claims 1 to 7, wherein a difference obtained by subtracting an equivalent circle diameter of the thermal insulating section (13) from an equivalent circle diameter of the first portion (11) is equal to or lower than 55% of a difference obtained by subtracting the equivalent circle diameter of the thermal insulating section (13) from an equivalent circle diameter of the structural body, in projection view on a plane parallel to the first outer surface.

9. A piston of an internal combustion engine, the piston comprising the structural body according to any one of claims

1 to 8, the structural body being disposed in a recess provided on a top surface of the piston.

10. An internal combustion engine comprising the piston according to claim 9.

FIG. 1

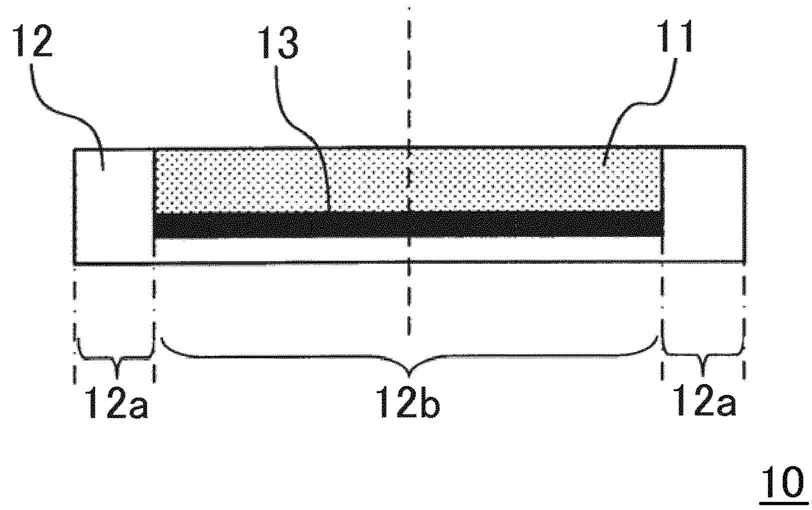
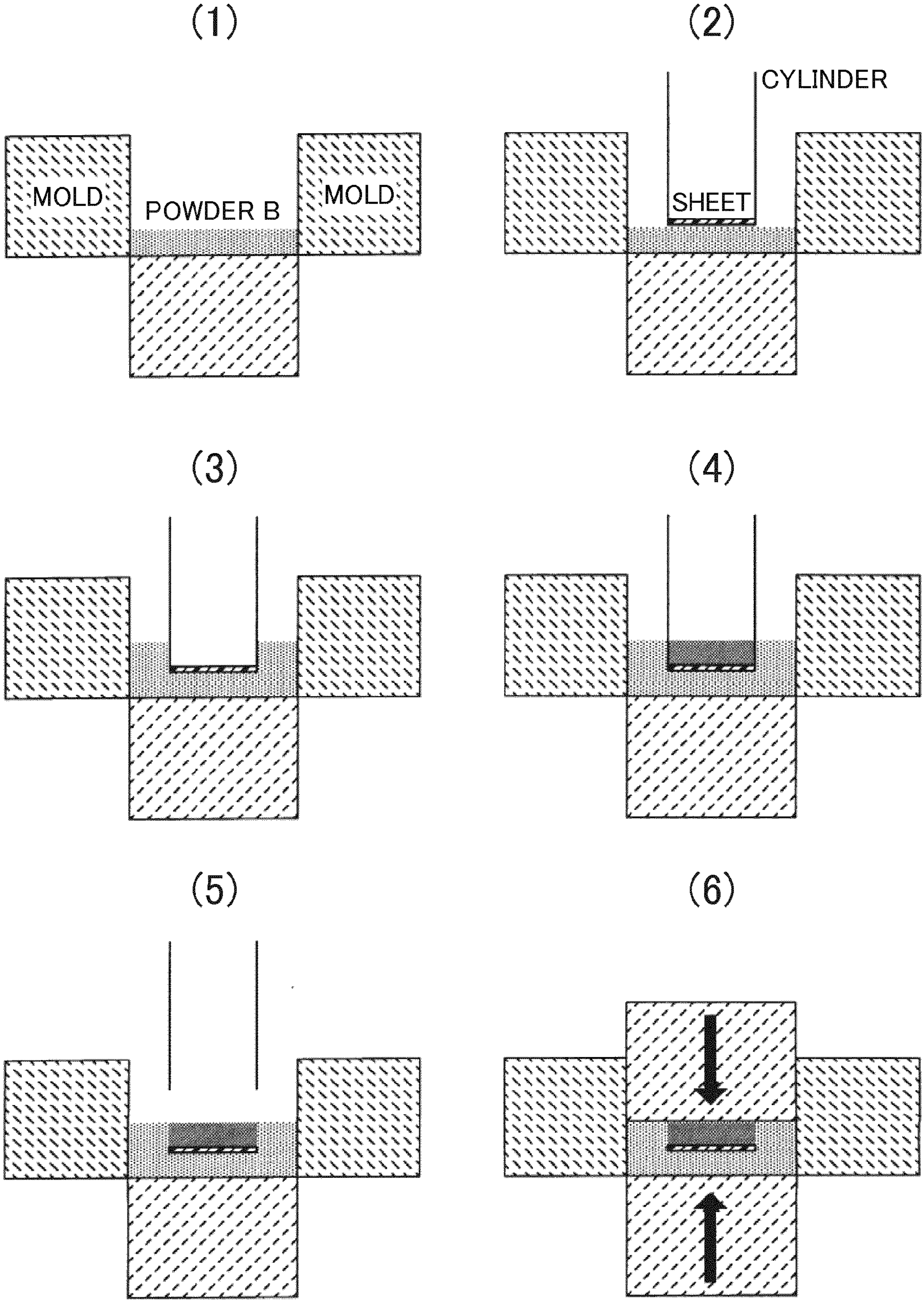
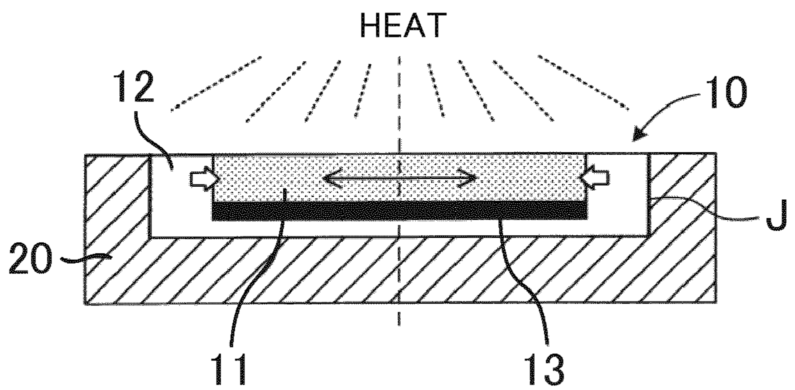


FIG. 2



F I G . 3A



F I G . 3B

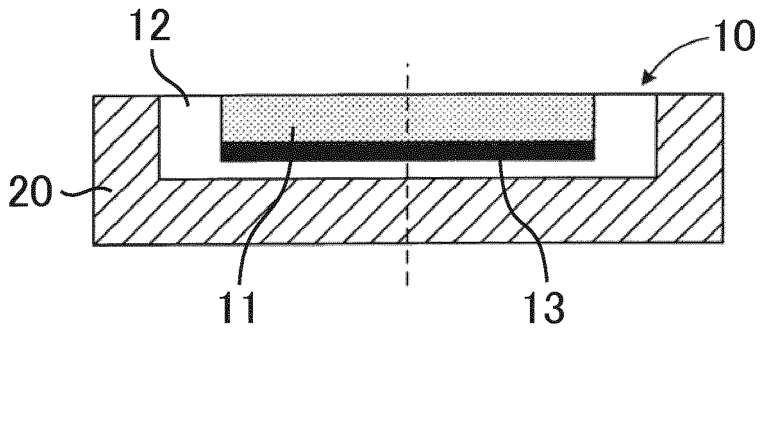


FIG. 4A

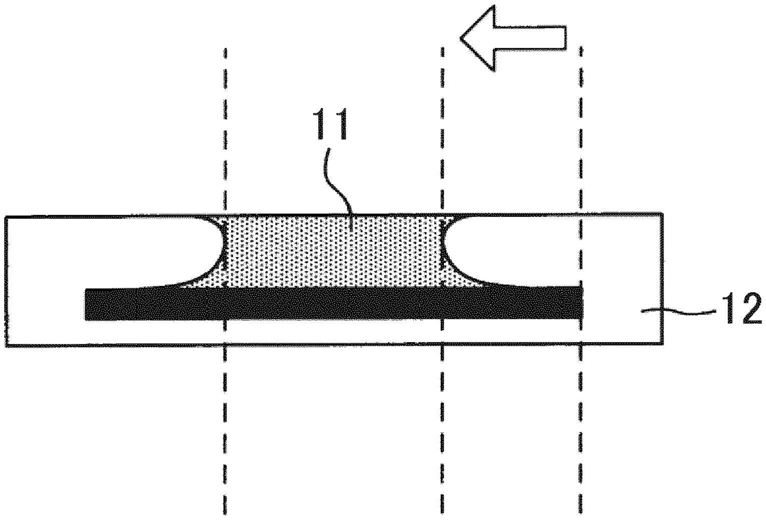


FIG. 4B

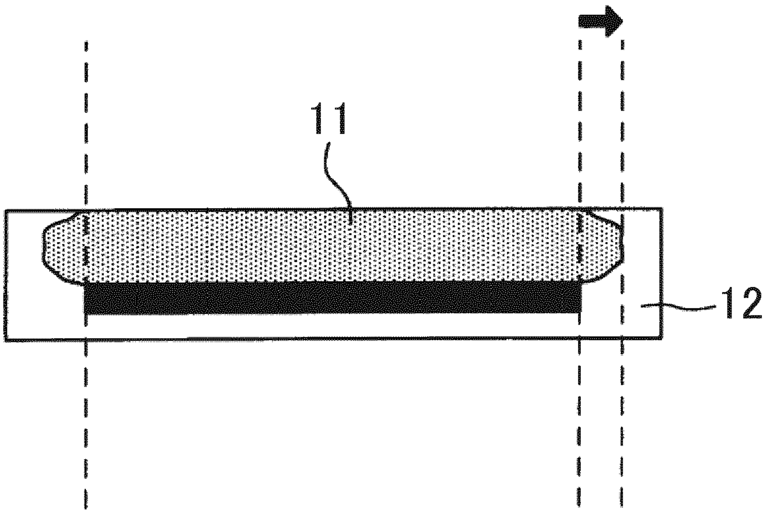


FIG. 5A

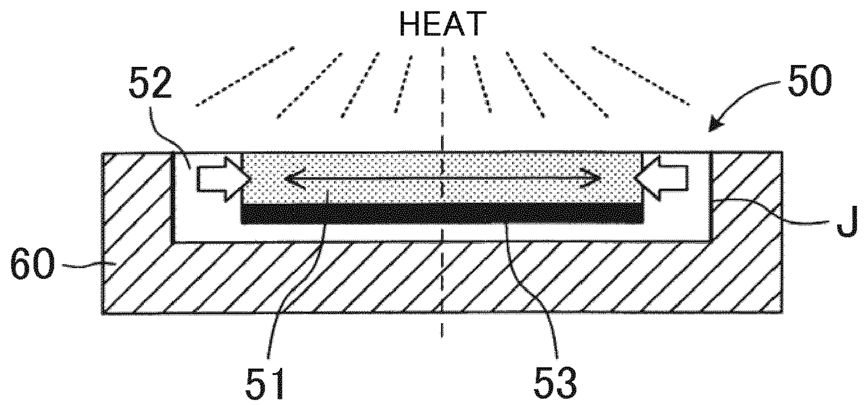
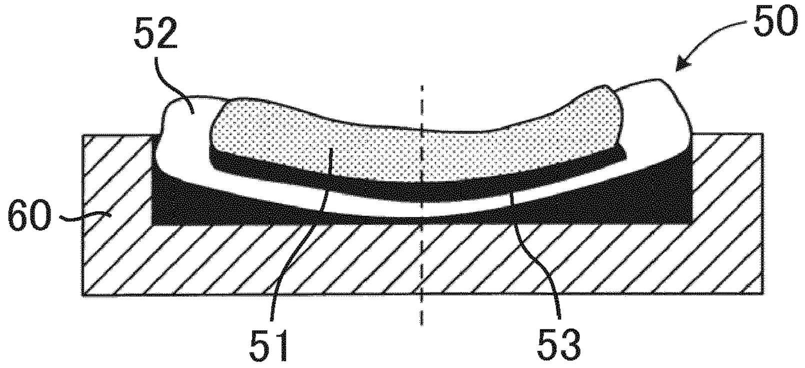


FIG. 5B



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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 0328

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	JP 2005 076471 A (TOYOTA MOTOR CORP) 24 March 2005 (2005-03-24) * paragraph [0035] * -----	1-10	INV. F02F3/04 F02F3/14 F02F3/28 ADD. F02B23/06
X	JP 59 130046 U (A) 31 August 1984 (1984-08-31) * figure 1 *	1-10	
X	& JP H05 10209 A (ISUZU MOTORS LTD) 19 January 1993 (1993-01-19) * paragraph [0032] * * paragraph [0006] * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

F02F
F02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	31 March 2016	Coniglio, Carlo

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31-03-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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JP 59130046 U	31-08-1984		

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