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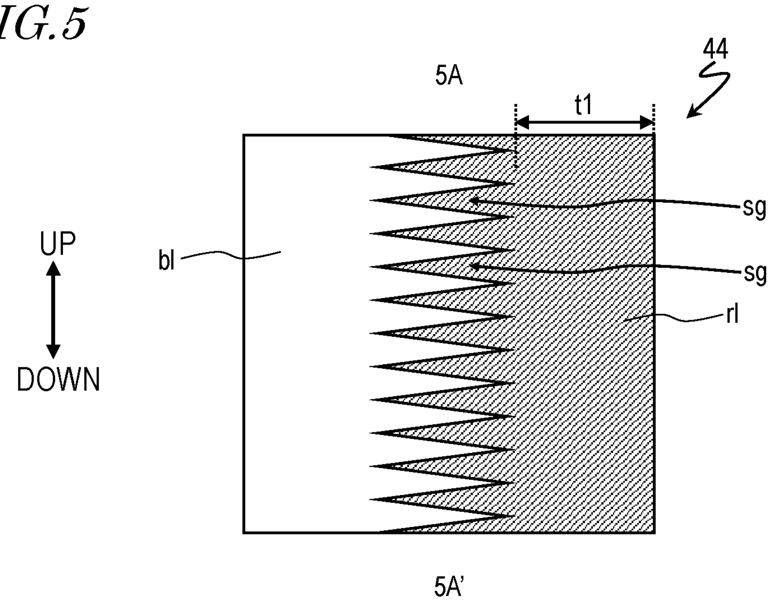
(54) **INTERNAL COMBUSTION ENGINE AND TRANSPORTATION DEVICE**

(57) An internal combustion engine **(100)** includes a piston **(40)** formed of an aluminum alloy, the piston including a piston head **(43)** and a piston skirt **(44)** extending from an outer circumferential portion of the piston head; and a cylinder block **(10)** formed of an aluminum alloy, the cylinder block including a cylinder wall **(12)** including a sliding surface **(12a),** along which the piston is slidable. The aluminum alloy is exposed to the sliding surface of the cylinder wall. The piston skirt includes a skirt substrate **(b1)** formed of an aluminum alloy, the skirt substrate including a plurality of streak grooves **(sg)** formed in an outer circumferential surface thereof, the piston skirt further including a resin layer **(rl)** formed on at least a part of the outer circumferential surface of the skirt substrate. The outer circumferential surface of the skirt substrate has a ten-point average surface roughness Rz_{JIS} of 20 μm or larger.

FIG.5



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an internal combustion engine, and specifically to an internal combustion engine including a piston formed of an aluminum alloy and a cylinder block formed of an aluminum alloy, and also relates to a transportation vehicle including such an internal combustion engine.

BACKGROUND ART

[0002] Recently, an aluminum alloy has been in a wide use as a material of a piston and a cylinder block for an internal combustion engine. In the case where a piston formed of an aluminum alloy and a cylinder block formed of an aluminum alloy are used in combination, a sleeve (liner) formed of cast iron is located in a cylinder bore or a surface of a cylinder wall is plated in order to guarantee a certain level of wear resistance.

[0003] Apart from the above, a technology of forming streak grooves in a surface of a skirt portion of a piston and forming a resin layer thereon is known (e.g., Patent Document No. 1). The formation of the streak grooves increases the adhesiveness between a substrate of the skirt portion and the resin layer. A sliding motion of the piston shaves the resin layer to decrease the surface roughness thereof. As a result, a sliding loss is decreased and the initial conformability is improved.

[0004] When the internal combustion engine is operated for a certain period time, the resin layer of the skirt portion is worn away. In the case where a sleeve formed of cast iron is located in the cylinder bore, or in the case where the surface of the cylinder wall is plated, the aluminum alloy forming the piston and the aluminum alloy forming the cylinder block do not contact each other even if the resin layer is worn away. Therefore, a problem of seizure or the like is not caused easily.

CITATION LIST

PATENT LITERATURE

[0005] Patent Document No. 1: Japanese Patent No. 6485952

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] It has been proposed to use a high-silicon aluminum alloy containing a high content of silicon (having a hyper eutectic composition) as a material of the cylinder block. Formation of a cylinder block of a high-silicon aluminum alloy makes it unnecessary to use a cast iron sleeve or to perform plating, and therefore, may reduce the weight of the internal combustion engine and simplify the production process thereof. It should be noted that, however, in the case where a cast iron sleeve is not used or plating is omitted, when the resin layer of the skirt portion of the piston is worn away, the aluminum alloy forming the piston and the aluminum alloy forming the cylinder block contact each other. This causes a risk of seizure.

[0007] An embodiment of the present invention made in light of the above-described problem has an object of, for an internal combustion engine including a cylinder block formed of an aluminum alloy and a piston formed of an aluminum alloy, realizing a structure that may suppress seizure after a resin layer is worn away even if a cast iron sleeve is not used or plating is omitted.

SOLUTION TO PROBLEM

[0008] This specification discloses the internal combustion engine and the transportation vehicle described in the following items.

[Item 1]

[0009] An internal combustion engine, including:

a piston formed of an aluminum alloy, the piston including a piston head and a piston skirt extending from an outer circumferential portion of the piston head; and a cylinder block formed of an aluminum alloy, the cylinder block including a cylinder wall including a sliding surface, along which the piston is slidable;

wherein the aluminum alloy is exposed to the sliding surface of the cylinder wall,

wherein the piston skirt includes a skirt substrate formed of an aluminum alloy, the skirt substrate including a plurality of streak grooves formed in an outer circumferential surface thereof, the piston skirt further including a resin layer formed on at least a part of the outer circumferential surface of the skirt substrate, and

wherein the outer circumferential surface of the skirt substrate has a ten-point average surface roughness Rz_{JIS} of 20 μm or larger.

[0010] In the internal combustion engine according to an embodiment of the present invention, the piston skirt includes the skirt substrate formed of an aluminum alloy and including the plurality of streak grooves formed in the outer circumferential surface thereof, and the resin layer formed on at least a part of the outer circumferential surface of the skirt substrate. The resin layer formed on the outer circumferential surface of the skirt substrate decreases the sliding loss and improves the initial conformability of the piston to the cylinder block. In the internal combustion engine according to the present invention, the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate is 20 μm or larger. This indicates that the streak grooves formed in the outer circumferential surface of the skirt substrate are relatively deep. During the formation of the resin layer on the outer circumferential surface of the skirt substrate, the resin material necessarily goes into the streak grooves. Thus, in the case where the steak grooves are deep, after the resin layer is worn away, a state where a portion of the surface of the piston skirt where the aluminum alloy is exposed and a portion of the surface of the piston skirt where the resin material remains are mixed may be kept for a long period of time. Therefore, even after the resin layer is worn away, the seizure of the piston formed of an aluminum alloy and the cylinder block formed of an aluminum alloy may be suppressed.

[Item 2]

[0011] The internal combustion engine of item 1,
wherein the plurality of streak grooves extend in a circumferential direction of the piston.

[0012] The streak grooves may be formed by, for example, a turning process performed by use of a cutting tool (blade). In this case, the streak grooves extend in the circumferential direction of the piston.

[Item 3]

[0013] The internal combustion engine of item 1 or 2, wherein the outer circumferential surface of the skirt substrate has an average peak-trough interval Sm of 100 μm or longer and 500 μm or shorter.

[0014] The average peak-trough interval Sm (corresponding to the pitch of the streak grooves) of the outer circumferential surface of the skirt substrate is preferably 100 μm or longer and 500 μm or shorter. In the case where the average peak-trough interval Sm is shorter than 100 μm, there is a risk that the productivity is decreased, or that the production of the blade is made difficult. In the case where the average peak-trough interval Sm is longer than 500 μm, there is a risk that the processing precision of the piston is decreased. In addition, the width of the portion where the aluminum alloy is exposed after the resin layer is worn away is increased, which causes a risk that the seizure resistance is decreased by a certain degree.

[Item 4]

[0015] The internal combustion engine of any one of items 1 through 3, wherein the resin layer has a thickness of 10 μm or greater and 50 μm or less.

[0016] From the point of view of keeping the resin layer for a long period of time, the thickness of the resin layer is preferably 10 μm or greater. From the point of view of ease of production, the thickness of the resin layer is preferably 50 μm or less.

[Item 5]

[0017] The internal combustion engine of any one of items 1 through 4, wherein the resin layer includes a solid lubricant agent and hard particles.

[0018] In the case where the resin layer includes hard particles, the occurrence of the state where the resin layer is worn away may be delayed.

[Item 6]

[0019] The internal combustion engine of any one of items 1 through 5, wherein the skirt substrate includes, at the outer circumferential surface thereof, an anodic oxide film formed by alumite treatment with a phosphoric acid.
[0020] In the case where the skirt substrate includes, at the outer circumferential surface thereof, the anodic oxide film formed by alumite treatment with a phosphoric acid, the adhesiveness of the resin layer to the skirt substrate may be improved.

[Item 7]

[0021] The internal combustion engine of any one of items 1 through 6, wherein the cylinder block is formed of an aluminum alloy containing silicon.
[0022] In the case where an aluminum alloy containing silicon is used as a material of the cylinder block, deposited silicon crystal grains are exposed to the sliding surface. As a result, the seizure resistance and the wear resistance may be improved.

[Item 8]

[0023] A transportation vehicle, including the internal combustion engine having any of the above-described structures.
[0024] The internal combustion engine according to an embodiment of the present invention is preferably usable in any of various types of transportation vehicles.

ADVANTAGEOUS EFFECTS OF INVENTION

[0025] According to an embodiment of the present invention, a structure, for an internal combustion engine including a cylinder block formed of an aluminum alloy and a piston formed of an aluminum alloy, may be realized that may suppress seizure after a resin layer is worn away even if a cast iron sleeve is not used or plating is omitted may be realized.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

FIG. 1 is a cross-sectional view schematically showing an engine (internal combustion engine) **100** according to an embodiment of the present invention.
FIG. **2** is a perspective view schematically showing a cylinder block **10** included in the engine **100.**
FIG. **3** is an enlarged plan view of a sliding surface **12a** of a cylinder wall **12.**
FIG. **4A** is a side view schematically showing a piston **40** included in the engine **100.**
FIG. **4B** is a side view schematically showing the piston **40.**
FIG. **5** is a cross-sectional view schematically showing a piston skirt **44** of the piston **40.**
FIG. **6** shows how wearing proceeds in a piston skirt **44'** in a comparative example.
FIG. **7** shows how wearing proceeds in the piston skirt **44.**
FIG. **8** is a graph showing, regarding examples 1, 2 and 3 and comparative examples 1 and 2, the relationship between the remaining ratio of a resin layer **rl** represented by the vertical axis and the test time period from the start represented by the horizontal axis.
FIG. **9** shows binarized photographs of an outer circumferential surface of the piston skirt **44** in each of comparative example 1 and example 3 at the elapse of specific test time periods from the start.
FIG. **10** is a cross-sectional view showing another example of structure of the piston skirt **44.**
FIG. **11** is a cross-sectional view schematically showing piston rings **42** of the piston **40.**
FIG. **12** is a side view schematically showing an automatic two-wheeled vehicle **300** including the engine **100.**

DESCRIPTION OF EMBODIMENTS

[0027] Hereinafter, an embodiment of the present invention will be described with reference to the drawings. While a water-cooled engine will be described as an example below, the engine according to an embodiment of the present invention is not limited to being of a water-cooled type and may be of an air-cooled type. While a single-cylinder engine will be described as an example below, there is no specific limitation on the number of the cylinders in the engine.

[Structure of the engine]

[0028] FIG. **1** shows an engine (internal combustion engine) **100** according to an embodiment of the present invention. FIG. **1** is a cross-sectional view schematically showing the engine **100.**

[0029] As shown in FIG. **1,** the engine **100** includes a cylinder block **10,** a cylinder head **20,** and a crankcase **30.** The engine **100** further includes a piston **40,** a crankshaft **50,** and a con rod (connecting rod) **60.** The following description will be made with settings that a direction from the cylinder block **10** toward the cylinder head **20** is an "upward direction" and a direction from the cylinder block **10** toward the crankcase **30** is a "downward direction".

[0030] The cylinder block (may also be referred to as a "cylinder body") **10** includes a cylinder wall **12** and an outer wall **13.** The cylinder wall **12** is formed to define a cylinder bore **11.** The outer wall **13** surrounds the cylinder wall **12** and forms an outer enclosure of the cylinder block **10.** A water jacket **14** holding cooling water is provided between the cylinder wall **12** and the outer wall **13.**

[0031] The cylinder head **20** is provided above the cylinder block **10.** The cylinder head **20** defines a combustion chamber **70** together with the cylinder wall **12** and the piston **40.** The cylinder head **20** includes an intake port **21,** through which fuel is to be introduced into the combustion chamber **70,** and an exhaust port **22,** through which exhaust gas is to be discharged from the combustion chamber **70.** An intake valve **23** is provided in the intake port **21,** and an exhaust valve **24** is provided in the exhaust port **22.**

[0032] The crankcase **30** is provided below the cylinder block **10.** Namely, the crankcase **30** is located so as to be on the side opposite to the cylinder head **20** with the cylinder block **10** being located therebetween. The crank case **30** may be separate from, or may be integrally formed with, the cylinder block **10.**

[0033] The piston **40** is accommodated in the cylinder bore **11.** In this embodiment, no cylinder sleeve is fit into the cylinder bore **11.** Therefore, the piston **40** moves up and down in a reciprocating manner in the cylinder bore **11** while being in contact with an inner circumferential surface (cylinder bore **11**-side surface) **12a** of the cylinder wall **12.** Namely, the inner circumferential surface **12a** of the cylinder wall **12** is a sliding surface along which the piston **40** is slidable.

[0034] The crankshaft **50** is accommodated in the crankcase **30.** The crankshaft **50** includes a crankpin **51** and a crank arm **52.**

[0035] The con rod **60** includes a rod main body **61** having a rod-like shape, a small end portion **62** provided at one end of the rod main body **61,** and a large end portion **63** provided at the other end of the rod main body **61.** The con rod **60** connects the piston **40** and the crankshaft **50** to each other. Specifically, a piston pin **48** of the piston **40** is inserted into a through-hole (piston pin hole) of the small end portion **62,** and the crankpin **51** of the crankshaft **50** is inserted into a through-hole (crankpin hole) of the large end portion **63.** This structure connects the piston **40** and the crankshaft **50** to each other. A bearing **66** is provided between an inner circumferential surface of the large end portion **63** and the crankpin **51.**

[0036] FIG. **2** is a perspective view schematically showing the cylinder block **10** of the engine **100.** As described above, the cylinder block **10** includes the cylinder wall **12** including the sliding surface **12a,** and the outer wall **13.** The water jacket **14** is provided between the cylinder wall **12** and the outer wall **13.** In this embodiment, the cylinder block **10** is formed of an aluminum alloy containing silicon. More specifically, the cylinder block **10** is formed of an aluminum-silicon-based alloy having a hyper eutectic composition. In this embodiment, the inner circumferential surface **12a** of the cylinder wall **12** is not plated. Therefore, the aluminum alloy is exposed to the inner circumferential surface (sliding surface) **12a** of the cylinder wall **12.**

[0037] FIG. **3** is an enlarged plan view of the sliding surface **12a** of the cylinder wall **12.** The cylinder wall **12** of the cylinder block **10** includes an aluminum-containing solid-solution matrix (alloy substrate) **1** and a plurality of primary-crystal silicon grains **2** dispersed in the matrix **1.** Some of the primary-crystal silicon grains **2** are exposed to the sliding surface **12a.** Namely, the cylinder block **10** includes the primary-crystal silicon grains **2** at the sliding surface **12a.**

[0038] Although not shown, the cylinder wall **12** further includes a plurality of eutectic silicon grains dispersed in the matrix **1.** Therefore, the cylinder block **10** may further include the eutectic silicon grains at the sliding surface **12a.** When a molten aluminum-silicon-based alloy having a hyper eutectic composition is cooled, relatively large silicon crystal grains are deposited first and then relatively small silicon crystal grains are deposited. The relatively large silicon crystal grains are the "primary-crystal silicon grains", and the relatively small silicon crystal grains are the "eutectic silicon grains".

[0039] FIG. **4A** and FIG. **4B** are side views schematically showing the piston **40** of the engine **100.** FIG. **4A** is a view of the piston **40** as seen in an axial direction of the piston pin **48** (see FIG. **1**) (hereinafter, will be referred to as a "piston pin axial direction"), whereas FIG. **4B** is a view of the piston **40** as seen in a direction perpendicular to the piston pin axial direction.

[0040] In this embodiment, the piston **40** (more specifically, a piston main body **41** described below) is formed of an aluminum alloy. The piston **40** may be formed by forging or casting.

[0041] As shown in FIG. **4A** and FIG. **4B,** the piston **40** includes the piston main body **41** and a plurality of piston rings **42.** The piston main body **41** includes a piston head **43** and a piston skirt **44.**

[0042] The piston head **43** is located at a top end of the piston **40.** Ring grooves holding the piston rings **42** are formed in an outer circumferential portion of the piston head **43.**

[0043] The piston skirt **44** extends downward from the outer circumferential portion of the piston head **43.** The piston skirt **44** includes two portions **44a** and **44b** (referred to as a "first skirt portion" and a "second skirt portion") located so as to sandwich, in a radial direction, a central axis (cylinder axis line) of the cylinder bore **11.**

[0044] The piston main body **41** includes a pair of piston pin bosses **45** having a piston pin hole **45a** into which the piston pin **48** (see FIG. **1**) is insertable, and ribs **46** connecting the piston pin bosses **45** and the piston skirt **44** to each other.

[0045] The piston rings **42** are attached to an outer circumferential portion of the piston main body **41,** more specifically, to the outer circumferential portion of the piston head **43.** In this embodiment, the piston **40** includes three piston rings **42.** The number of the piston rings **42** is not limited to three. Among the three piston rings **42,** the piston rings at a top position and at a central position (a top ring and a second ring) **42a** and **42b,** for example, are compression rings that keep the combustion chamber **70** in an airtight state. The piston ring at a bottom position (third ring) **42c** is an oil ring that scrapes off extra oil attached to the cylinder wall **12.** The piston rings **42** are formed of a metal material (e.g., steel).

[0046] The piston skirt **44** includes a resin layer **rl** formed on at least a part of an outer circumferential surface thereof. In the example shown in FIG. **4A** and FIG. **4B,** the resin layer **rl** is formed on generally the entirety of the outer circumferential surface thereof.

[0047] FIG. **5** shows an example of cross-sectional structure of the piston skirt **44.** As shown in FIG. **5,** the piston skirt **44** includes a skirt substrate **b1** formed of an aluminum alloy and the resin layer **rl** formed on at least a part of an outer circumferential surface of the skirt substrate **b1.**

[0048] A plurality of streak grooves **sg** are formed in the outer circumferential surface of the skirt substrate **b1.** The streak grooves **sg** are striped grooves. The streak grooves **sg** may be formed by, for example, a turning process performed by use of a cutting tool (blade). In this case, the streak grooves **sg** extend in a circumferential direction of the piston **40.** In the example shown in FIG. **5,** each of the streak grooves **sg** has a generally triangular cross-section in a direction perpendicular to the circumferential direction. The cross-section of the streak groove **sg** is not limited to having such a shape, and may be, for example, generally bow-shaped. In the example shown in FIG. **5,** the plurality of streak grooves **sg** are aligned with almost no gap. Alternatively, a flat portion may be present between adjacent streak grooves **sg.**

[0049] The resin layer **rl** includes, for example, a polymer matrix and solid lubricant particles (solid lubricant agent) dispersed in the polymer matrix. As a material of the polymer matrix, thermosetting polyamideimide, for example, is preferably usable. Needless to say, the material of the polymer matrix is not limited to this. As the solid lubricant particles, any of various known types of solid lubricant particles may be used. For example, graphite particles and molybdenum disulfide particles are preferably usable. The resin layer **rl** may be formed by, for example, applying a liquid resin material to the substrate **b1** by a spray method or any of various printing methods (a screen printing method, a pad printing method or the like).

[0050] In this embodiment, the piston **40** is formed such that the outer circumferential surface of the skirt substrate **b1** has a ten-point average surface roughness Rz_{JIS} in a predetermined range. Specifically, the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** is 20 μm or larger in generally the entirety of the outer circumferential surface.

[0051] As represented by the following expression, the ten-point average surface roughness Rz_{JIS} is of a certain reference length of a profile curve, and is a difference between an average value of elevations of the highest peaks through the fifth highest peaks R1, R3, R5, R7 and R9, and an average value of elevations of the lowest trough through the fifth lowest trough R2, R4, R6, R8 and R10. The ten-point average surface roughness Rz_{JIS} may be measured by use of a surface roughness meter (e.g., Surfcom 1400D produced by Tokyo Seimitsu Co., Ltd.).

[Expression 1]

$$Rz_{JIS} = \{(R1+R3+R5+R7+R9) - (R2+R4+R6+R8+R10)\}/5$$

[0052] As described above, in the engine **100** in this embodiment, the piston skirt **44** includes the skirt substrate **b1** formed of an aluminum alloy and including the plurality of streak grooves **sg** formed in the outer circumferential surface thereof, and the resin layer **rl** formed on at least a part of the outer circumferential surface of the skirt substrate **b1.** The resin layer **rl** formed on the outer circumferential surface of the skirt substrate **b1** decreases the sliding loss and improves the initial conformability of the piston **40** to the cylinder block **10.**

[0053] In the engine **100** in this embodiment, the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** is 20 μm or larger. This indicates that the streak grooves **sg** formed in the outer circumferential surface of the skirt substrate **b1** are relatively deep. During the formation of the resin layer **rl** on the outer circumferential surface of the skirt substrate **b1,** the resin material necessarily goes into the streak grooves **sg.** Thus, in the case where the steak grooves **sg** are deep, after the resin layer **rl** is worn away, a state where a portion of the surface of the piston skirt **44** where the aluminum alloy is exposed and a portion of the surface of the piston skirt **44** where the resin material remains are mixed may be kept for a long period of time. Therefore, even after the resin layer **rl** is worn away, seizure of the piston **40** formed of an aluminum alloy and the cylinder block **10** formed of an aluminum alloy may be suppressed. The ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** may be adjusted by, for example, changing the cutting tool to be used to apply a turning process to the skirt substrate **b1.**

[0054] Now, reasons why the seizure may be suppressed will be described with reference to FIG. **6** and FIG. **7.**

[0055] FIG. **6** and FIG. **7** show how the wearing proceeds in a piston skirt **44'** in a comparative example having relatively shallow streak grooves **sg** (having a ten-point average surface roughness Rz_{JIS} of an outer circumferential surface of, for example, about 1.6 to about 3.2 μm) and in the piston skirt **44** in this embodiment. FIG. **6** and FIG. **7** each show an initial state, a state where the resin layer **rl** is worn away (i.e., a state where the skirt substrate **b1** starts to be exposed), and a state where the wearing further proceeds thereafter.

[0056] As can be seen from FIG. **6,** in the piston skirt **44'** in the comparative example, when the wearing proceeds after the resin layer **rl** is worn away, the ratio of the aluminum alloy exposed to the outer circumferential surface is rapidly increased. Therefore, the seizure occurs quickly.

[0057] By contrast, in the piston skirt **44** in this embodiment, as can be seen from FIG. **7,** even when the wearing proceeds after the resin layer **rl** is worn away, the ratio of the aluminum alloy exposed to the outer circumferential surface is increased merely slowly. Therefore, occurrence of the seizure may be delayed.

[0058] Samples of the piston **40,** the outer circumferential surface of the skirt substrate **b1** of which had a ten-point average surface roughness Rz_{JIS} of 20 μm or larger, were produced (examples 1, 2 and 3), and the effect of suppressing (delaying) the occurrence of the seizure was investigated by a sliding test. The results will be described below. For the investigation, pistons in examples 1, 2 and 3 were compared against pistons in comparative examples 1 and 2. The ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** was 24.8 μm, 66.7 μm and 67.8 μm in examples 1, 2 and 3 respectively, and was 1.9 μm and 11.6 μm in comparative examples 1 and 2 respectively. The resin layer **rl** had a thickness of 3 to 5 μm in examples 1, 2 and 3 and comparative examples 1 and 2 (as described below, the thickness of the resin layer **rl** may be 10 μm or greater, but in this test, the thickness of the resin layer **rl** was set to of a relatively small value in order to shorten the test time).

[0059] FIG. **8** and FIG. **9** show the results of the sliding test. The sliding test was performed under the conditions that the load was 980 N, the rotation rate was 600 rpm, and the temperature was 140°C. FIG. **8** is a graph showing, regarding examples 1, 2 and 3 and comparative example 1 and 2, the relationship between the remaining ratio of the resin layer **rl** (the ratio occupied by the area size of the remaining resin layer **rl** with respect to the area size of a region of the outer circumferential surface of the piston skirt **44** where the resin layer **rl** was formed) represented by the vertical axis, and the test time period from the start represented by the horizontal axis. FIG. **9** shows, in a top part, binarized photographs of the outer circumferential surface of the piston skirt **44'** in comparative example 1 at the elapse of specific test time periods from the start. FIG. **9** shows, in a bottom part, such binarized photographs of the piston skirt **44** in example 3. In each of the photographs shown in FIG. **9,** black portions are portions where the aluminum alloy of the skirt substrate **b1** is exposed, and gray portions are portions where the resin layer **rl** remains. Each of the photographs in FIG. **9** is accompanied by the remaining ratio of the resin layer **rl.**

[0060] As shown in FIG. **8,** in comparative examples **1** and 2, the remaining ratio of the resin layer **rl** was rapidly decreased as the test time period from the start was extended. In comparative examples 1 and 2, the seizure occurred at the elapse of the test time periods from the start of 3060 seconds and 3600 seconds, respectively. By contrast, in examples 1, 2 and 3, the remaining ratio of the resin layer **rl** was decreased slowly as the test time period from the start was extended. The seizure did not occur even when the test time period from the start exceeded 7000 seconds.

[0061] It is also seen from a comparison between the top part and the bottom part of FIG. **9** that in example 3, the remaining ratio of the resin layer **rl** is decreased more slowly than in comparative example 1 and that a state where the seizure does not occur (state where a relatively large amount of the resin layer **rl** remains) may be kept for a long period of time in example 3.

[0062] From the above-described results of the investigation, it is confirmed that the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** of 20 μm or larger may suppress the seizure of the piston **40** formed of an aluminum alloy and the cylinder block **10** formed of an aluminum alloy for a long period of time.

[0063] There is no specific limitation on the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1.** In the case where the ten-point average surface roughness Rz_{JIS} is too large, an adverse effect may be exerted on the processing precision of the piston. Therefore, from the point of view of the processing precision of the piston, the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** is preferably 50 μm or smaller.

[0064] The outer circumferential surface of the skirt substrate **b1** preferably has an average peak-trough interval Sm (corresponding to the pitch of the streak grooves **sg**) of 100 μm or longer and 500 μm or shorter. In the case where the average peak-trough interval Sm is shorter than 100 μm, there is a risk that the productivity is decreased, or that the production of the blade used to turn the skirt substrate **b1** is made difficult. In the case where the average peak-trough interval Sm is longer than 500 μm, there is a risk that the processing precision of the piston is decreased. In addition, the width of the portion where the aluminum alloy is exposed after the resin layer **rl** is worn away is increased, which causes a risk that the seizure resistance is decreased by a certain degree. The average peak-trough interval Sm may be measured by a surface roughness meter like the ten-point average surface roughness Rz_{JIS}.

[0065] FIG. **4A** and FIG. **4B** each show an example in which the resin layer **rl** is formed on generally the entirety of the outer circumferential surface of the piston skirt **44.** The resin layer **rl** may be formed only on a part of the outer circumferential surface. It should be noted that, however, from the point of view of enhancing the effects of, for example, decreasing the sliding loss and improving the initial conformability, it is preferred that the resin layer **rl** is formed on a maximum possible area of the outer circumferential surface of the piston skirt **44.** For example, with respect to the outer circumferential surface of the piston skirt **44,** the resin layer **rl** has an area size occupying a ratio of preferably 500 or higher, more preferably 70% or higher, and still more preferably 90% or higher (namely, the resin layer **rl** is formed on generally the entirety of the outer circumferential surface of the piston skirt **44**).

[0066] In the structure described above, the resin layer **rl** includes solid lubricant particles. The resin layer **rl** may include hard particles in addition to the solid lubricant agent. In the case where the resin layer **rl** includes hard particles, the occurrence of the state where the resin layer **rl** is worn away may be delayed. As the hard particles, for example, metal oxide particles may be used. The amount, the particle diameter and the like of the hard particles are appropriately adjusted in accordance with the type of the hard particles used.

[0067] The resin layer **rl** has a thickness **t1** (see FIG. **5**) that is not specifically limited. From the point of view of keeping the resin layer **rl** for a long period of time, the thickness **t1** of the resin layer **rl** is preferably 10 μm or greater. From the point of view of ease of production, the thickness **t1** of the resin layer **rl** is preferably 50 μm or less. As can be seen from FIG. **5,** the thickness **t1** of the resin layer **rl** does not include a thickness of the portion of the resin material in the streak grooves **sg.** The expression "the resin layer **rl** is worn away" indicates that the resin material is made non-existent except for the resin material in the streak grooves **sg,** and does not indicate that the resin material in the streak grooves **sg** is also made non-existent.

[0068] FIG. **10** shows another example of structure of the piston skirt **44.** In the example shown in FIG. **10,** the skirt substrate **b1** includes, at the outer circumferential surface thereof, an anodic oxide film **b1a** formed by alumite treatment with a phosphoric acid (phosphoric acid-alumite film **b1a**). In the case where the skirt substrate **b1** includes the phosphoric acid-alumite film **b1a** at the outer circumferential surface thereof, the adhesiveness of the resin layer **rl** to the skirt substrate **b1** may be improved. The phosphoric acid-alumite film **b1a** has a thickness **t2** of, for example, 30 μm or greater and 200 μm or less.

[0069] FIG. **11** is a cross-sectional view showing an example of structure of the piston ring **42** of the piston **40.** In the example shown in FIG. **11,** a diamond-like carbon layer (hereinafter, referred to as a "DLC layer") **42D** is formed on an outer circumferential portion (outer circumferential surface) of the piston ring **42.** The outer circumferential portion of the piston ring **42** is a portion to be in contact with the cylinder wall **12.** The piston ring **42** does not need to include the DLC layer **42D.** However, the DLC layer **42D** formed on the outer circumferential surface of each of the piston rings **42** may prevent, with more certainty, the cylinder wall **12** from being scuffed by the piston rings **42.**

[0070] The DLC layer **42D** is preferably formed by a deposition method (e.g., a CVD method or a PVD method) . The DLC layer **42D** may have any composition or a thickness with no specific limitation. From the point of view of preventing the scuffing with more certainty, the thickness of the DLC layer **42D** is preferably 2 μm or greater. From the point of view of the adhesiveness, the thickness of the DLC layer **42D** is preferably 20 μm or less.

[0071] In the case where an aluminum alloy containing silicon as described in this embodiment as an example is used as a material of the cylinder block **10,** deposited silicon crystal grains (primary-crystal silicon grains **2**) may be exposed to the sliding surface **12a.** As a result, the seizure resistance and the wear resistance may be improved.

[0072] From the point of view of sufficiently improving the wear resistance and the strength of the cylinder block **10,** the aluminum alloy as the material of the cylinder block **10** preferably contains silicon at a content of 15% by mass or higher and 25% by mass or lower. In the case where the silicon content is 15% by mass or higher, a sufficiently large amount of the primary-crystal silicon grains **2** may be deposited, which may sufficiently improve the wear resistance of the cylinder block **10**. In the case where the silicon content is 25% by mass or lower, the strength of the cylinder block **10** may be kept sufficiently high. The aluminum alloy contains aluminum at a content of, for example, 73.4% by mass or higher and 79.6% by mass or lower. The aluminum alloy may contain copper. In this case, the aluminum alloy contains copper at a content of, for example, 2.0% by mass or higher and 5.0% by mass or lower.

[0073] The primary-crystal silicon grains **2** have an average grain diameter in the range of 8 μm or longer and 50 μm or shorter. In this case, the wear resistance of the cylinder block **10** may be further improved. In the case where the average grain diameter of the primary-crystal silicon grains **2** is longer than 50 μm, the number of the primary-crystal silicon grains **2** per unit area size of the sliding surface **12a** is small. Therefore, a large load is applied to each of the primary-crystal silicon grains **2** while the engine **100** is operated, and the primary-crystal silicon grains **2** may possibly be crushed. The crushed pieces of the primary-crystal silicon grains **2** act undesirably as polishing particles, which causes a risk that the sliding surface **12a** is significantly worn. In the case where the average grain diameter of the primary-crystal silicon grains **2** is shorter than 8 μm, merely a small part of the primary-crystal silicon grains **2** is embedded in the matrix **1**. Therefore, the primary-crystal silicon grains **2** easily fall while the engine **100** is operated. The primary-crystal silicon grains **2** that have fallen act undesirably as polishing particles, which causes a risk that the sliding surface **12a** is significantly worn.

[0074] By contrast, in the case where the average grain diameter of the primary-crystal silicon grains **2** is 8 μm or longer and 50 μm or shorter (more preferably 12 μm or longer and 50 μm or shorter), the primary-crystal silicon grains **2** are present in a sufficient number per unit area size of the sliding surface **12a.** Therefore, the load applied to each of the primary-crystal silicon grains **2** while the engine **100** is operated is relatively small, which suppresses the crushing of the primary-crystal silicon grains **2**. Since the part of the primary-crystal silicon grains **2** that is embedded in the matrix **1** is sufficiently large, the fall of the primary-crystal silicon grains **2** is suppressed. Therefore, the wear of the sliding surface **12a** by the primary-crystal silicon grains **2** that have fallen is suppressed.

[0075] The eutectic silicon grains have an average grain diameter shorter than that of the primary-crystal silicon grains **2**. The average grain diameter of the eutectic silicon grains is, for example, 7.5 μm or shorter.

[0076] The average grain diameters of the primary-crystal silicon grains **2** and the eutectic silicon grains may be measured as follows by image processing performed on an image of the sliding surface **12a**. First, a diameter (equivalent diameter) of each of the silicon crystal grains with an assumption that the silicon crystal grains are of a true circle is calculated based on an area size of each silicon crystal grain obtained by the image processing. As a result, the number (frequency) and the diameters of the silicon crystal grains are specified. Tiny crystal grains each having a diameter shorter than 1 μm are not counted as silicon crystal grains. Based on the calculated number (frequency) and the calculated diameters of the silicon crystal grains, a grain size distribution of the silicon crystal grains is obtained. The obtained grain size distribution (histogram) includes two peaks. The grain size distribution is divided into two regions with the threshold being a diameter of a portion forming a trough between the two peaks. The region corresponding to longer diameters is set as the grain size distribution of the primary-crystal silicon grains, and the region corresponding to shorter diameters is set as the grain size distribution of the eutectic silicon grains. Based on each of the grain size distributions, the average crystal diameter of the primary-crystal silicon grains and the average crystal diameter of the eutectic silicon grains may be calculated.

[Transportation vehicle]

[0077] The engine **100** according to an embodiment of the present invention is preferably usable for various types of transportation vehicles. FIG. **12** shows an example of automatic two-wheeled vehicle including the engine **100** according to an embodiment of the present invention.

[0078] In an automatic two-wheeled vehicle **300** shown in FIG. **12,** a head pipe **302** is provided at a front end of a main body frame **301.** A front fork **303** is attached to the head pipe **302** so as to be swingable in a left-right direction of the vehicle. A front wheel **304** is rotatably supported at a bottom end of the front fork **303.**

[0079] A seat rail **306** is attached so as to extend rearward from a top portion of a rear end of the main body frame **301.** A fuel tank **307** is provided on the main body frame **301,** and a main seat **308a** and a tandem seat **308b** are provided on the seat rail **306.**

[0080] A rear arm **309** extending rearward is attached to the rear end of the main body frame **301.** A rear wheel **310** is rotatably supported at a rear end of the rear arm **309.**

[0081] The engine **100** is held on a central portion of the main body frame **301.** A radiator **311** is provided to the front of the engine **100.** An exhaust pipe **312** is connected to an exhaust port of the engine **100,** and a muffler **313** is attached to a rear end of the exhaust pipe **312.**

[0082] A transmission **315** is coupled with the engine **100.** A drive sprocket **317** is attached to an output shaft **316** of the transmission **315.** The drive sprocket **317** is coupled with a rear wheel sprocket **319** of the rear wheel **310** via a chain **318.** The transmission **315** and the chain **318** act as a transmission mechanism that transmits power generated by the engine **100** to the driving wheel.

[0083] In this embodiment, the automatic two-wheeled vehicle is shown as an example of the transportation vehicle. The engine according to an embodiment of the present invention is not limited to being used for an automatic two-wheeled vehicle, and is also preferably usable for any other transportation vehicle such as an automatic four-wheeled vehicle, an automatic three-wheeled vehicle, a seacraft or the like.

[0084] As described above, the internal combustion engine **100** according to an embodiment of the present invention includes the piston **40** formed of an aluminum alloy, the piston **40** including the piston head **43** and the piston skirt **44** extending from the outer circumferential portion of the piston head **43;** and the cylinder block **10** formed of an aluminum alloy, the cylinder block **10** including the cylinder wall **12** including the sliding surface **12a,** along which the piston **40** is slidable. The aluminum alloy is exposed to the sliding surface **12a** of the cylinder wall **12.** The piston skirt **44** includes the skirt substrate **b1** formed of an aluminum alloy, the skirt substrate **b1** including the plurality of streak grooves **sg**

formed in the outer circumferential surface thereof, the piston skirt **44** further including the resin layer **rl** formed on at least a part of the outer circumferential surface of the skirt substrate **b1.** The outer circumferential surface of the skirt substrate **b1** has a ten-point average surface roughness Rz_{JIS} of 20 μm or larger.

[0085] In the internal combustion engine **100** according to an embodiment of the present invention, the piston skirt **44** includes the skirt substrate **b1** formed of an aluminum alloy and including the plurality of streak grooves **sg** formed in the outer circumferential surface thereof, and the resin layer **rl** formed on at least a part of the outer circumferential surface of the skirt substrate **b1.** The resin layer **rl** formed on the outer circumferential surface of the skirt substrate **b1** decreases the sliding loss and improves the initial conformability of the piston **40** to the cylinder block **10.** In the internal combustion engine **100** according to the present invention, the ten-point average surface roughness Rz_{JIS} of the outer circumferential surface of the skirt substrate **b1** is 20 μm or larger. This indicates that the streak grooves **sg** formed in the outer circumferential surface of the skirt substrate **b1** are relatively deep. During the formation of the resin layer **rl** on the outer circumferential surface of the skirt substrate **b1,** the resin material necessarily goes into the streak grooves **sg.** Thus, in the case where the steak grooves **sg** are deep, after the resin layer **rl** is worn away, a state where a portion of the surface of the piston skirt **44** where the aluminum alloy is exposed and a portion of the surface of the piston skirt **44** where the resin material remains are mixed may be kept for a long period of time. Therefore, even after the resin layer **rl** is worn away, the seizure of the piston **40** formed of an aluminum alloy and the cylinder block **10** formed of an aluminum alloy may be suppressed.

[0086] In an embodiment, the plurality of streak grooves **sg** extend in the circumferential direction of the piston **40.**

[0087] The streak grooves **sg** may be formed by, for example, a turning process performed by use of a cutting tool (blade). In this case, the streak grooves **sg** extend in the circumferential direction of the piston **40.**

[0088] In an embodiment, the outer circumferential surface of the skirt substrate **b1** has an average peak-trough interval Sm of 100 μm or longer and 500 μm or shorter.

[0089] The average peak-trough interval Sm (corresponding to the pitch of the streak grooves **sg)** of the outer circumferential surface of the skirt substrate **b1** is preferably 100 μm or longer and 500 μm or shorter. In the case where the average peak-trough interval Sm is shorter than 100 μm, there is a risk that the productivity is decreased, or that the production of the blade is made difficult. In the case where the average peak-trough interval Sm is longer than 500 μm, there is a risk that the processing precision of the piston is decreased. In addition, the width of the portion where the aluminum alloy is exposed after the resin layer **rl** is worn away is increased, which causes a risk that the seizure resistance is decreased by a certain degree.

[0090] In an embodiment, the resin layer **rl** has the thickness **t1** of 10 μm or greater and 50 μm or less.

[0091] From the point of view of keeping the resin layer **rl** for a long period of time, the thickness **t1** of the resin layer **rl** is preferably 10 μm or greater. From the point of view of ease of production, the thickness **t1** of the resin layer **rl** is preferably 50 μm or less.

[0092] In an embodiment, the resin layer **rl** includes a solid lubricant agent and hard particles.

[0093] In the case where the resin layer **rl** includes hard particles, the occurrence of the state where the resin layer **rl** is worn away may be delayed.

[0094] In an embodiment, the skirt substrate **b1** includes, at the outer circumferential surface thereof, the anodic oxide film **b1a** formed by alumite treatment with a phosphoric acid.

[0095] In the case where the skirt substrate **b1** includes, at the outer circumferential surface thereof, the anodic oxide film **b1a** formed by alumite treatment with a phosphoric acid, the adhesiveness of the resin layer **rl** to the skirt substrate **b1** may be improved.

[0096] In an embodiment, the cylinder block **10** is formed of an aluminum alloy containing silicon.

[0097] In the case where an aluminum alloy containing silicon is used as a material of the cylinder block **10,** deposited silicon crystal grains (primary-crystal silicon grains **2**) may be exposed to the sliding surface **12a.** As a result, the seizure resistance and the wear resistance may be improved.

[0098] A transportation vehicle according to an embodiment of the present invention includes the internal combustion engine **100** having any of the above-described structures.

[0099] The internal combustion engine **100** according to an embodiment of the present invention is preferably usable in any of various types of transportation vehicles.

INDUSTRIAL APPLICABILITY

[0100] According to an embodiment of the present invention, a structure, for an internal combustion engine including a cylinder block formed of an aluminum alloy and a piston formed of an aluminum alloy, may be realized that may suppress the seizure after a resin layer is worn away even if a cast iron sleeve is not used or plating is omitted. The internal combustion engine according to an embodiment of the present invention is preferably usable in any of various types of transportation vehicles including an automatic two-wheeled vehicle.

REFERENCE SIGNS LIST

[0101] **1:** matrix (alloy substrate); **2:** primary-crystal silicon grain; **10:** cylinder block; **11:** cylinder bore; **12:** cylinder wall; **12a:** sliding surface (inner circumferential surface of the cylinder wall); **13:** outer wall; **14:** water jacket; **20:** cylinder head; **21:** intake port; **22:** exhaust port; **23:** intake valve; **24:** exhaust valve; **30:** crankcase; **40:** piston; **41:** piston main body; **42:** piston ring; **42a:** top ring; **42b:** second ring; **42c:** third ring; **42D:** diamond-like carbon layer; **43:** piston head; **44:** piston skirt; **44a:** first skirt portion; **44b:** second skirt portion; **45:** piston pin boss; **45a:** piston pin hole; **46:** rib; **48:** piston pin; **50:** crankshaft; **51:** crankpin; **52:** crank arm; **60:** con rod; **61:** rod main body; **62:** small end portion; **63:** large end portion; **70:** combustion chamber; **100:** engine (internal combustion engine); **300:** automatic two-wheeled vehicle; **b1:** skirt substrate; **b1a:** anodic oxide film (phosphoric acid-alumite film); **rl:** resin layer; **sg:** streak groove

Claims

1. An internal combustion engine, comprising:

   a piston formed of an aluminum alloy, the piston including a piston head and a piston skirt extending from an outer circumferential portion of the piston head; and
   a cylinder block formed of an aluminum alloy, the cylinder block including a cylinder wall including a sliding surface, along which the piston is slidable;
   wherein the aluminum alloy is exposed to the sliding surface of the cylinder wall,
   wherein the piston skirt includes a skirt substrate formed of an aluminum alloy, the skirt substrate including a plurality of streak grooves formed in an outer circumferential surface thereof, the piston skirt further including a resin layer formed on at least a part of the outer circumferential surface of the skirt substrate, and
   wherein the outer circumferential surface of the skirt substrate has a ten-point average surface roughness Rz_{JIS} of 20 μm or larger.

2. The internal combustion engine of claim 1,
   wherein the plurality of streak grooves extend in a circumferential direction of the piston.

3. The internal combustion engine of claim 1 or 2, wherein the outer circumferential surface of the skirt substrate has an average peak-trough interval Sm of 100 μm or longer and 500 μm or shorter.

4. The internal combustion engine of any one of claims 1 through 3, wherein the resin layer has a thickness of 10 μm or greater and 50 μm or less.

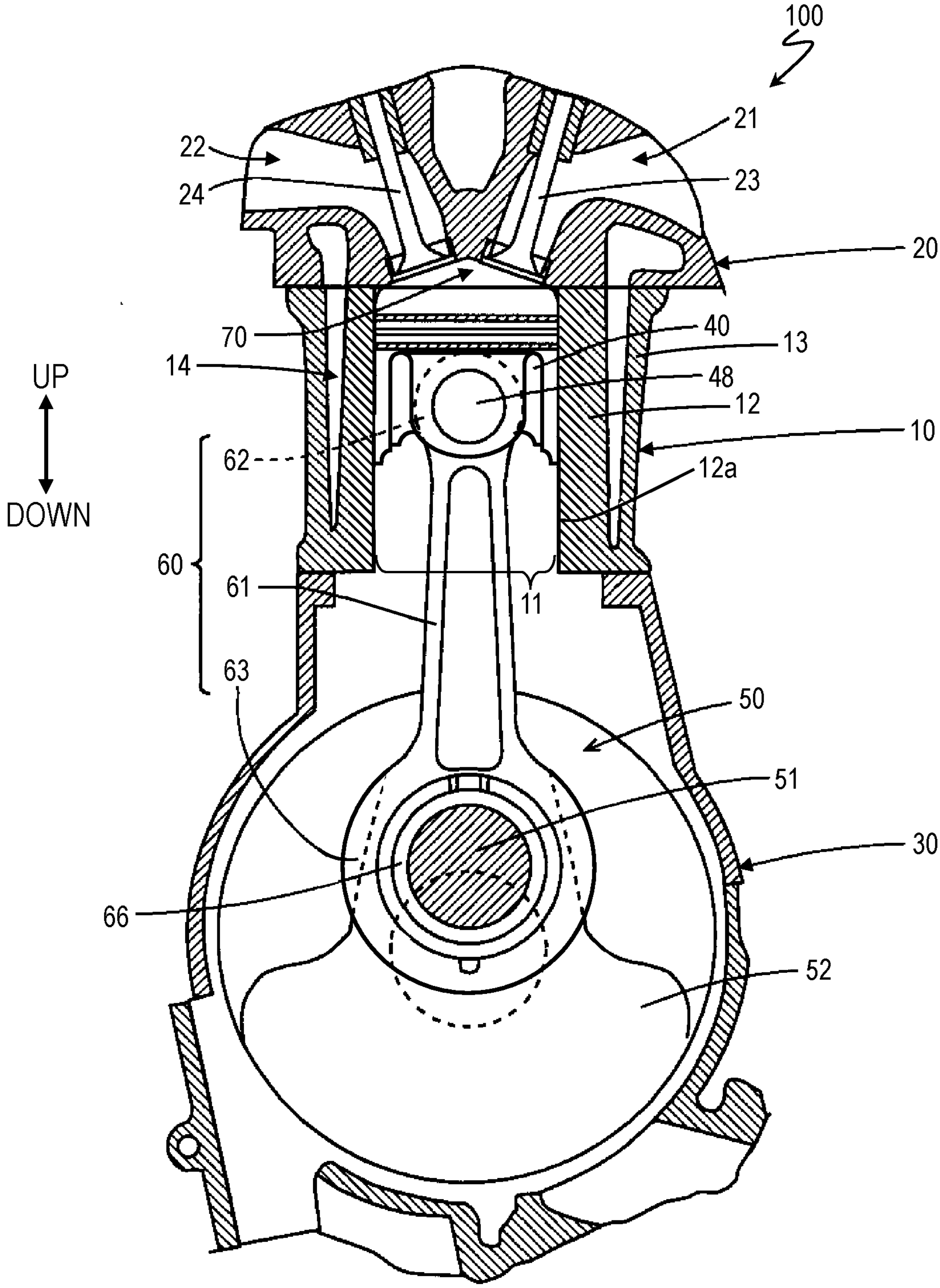
5. The internal combustion engine of any one of claims 1 through 4, wherein the resin layer includes a solid lubricant agent and hard particles.

6. The internal combustion engine of any one of claims 1 through 5, wherein the skirt substrate includes, at the outer circumferential surface thereof, an anodic oxide film formed by alumite treatment with a phosphoric acid.

7. The internal combustion engine of any one of claims 1 through 6, wherein the cylinder block is formed of an aluminum alloy containing silicon.

8. A transportation vehicle, comprising the internal combustion engine of any one of claims 1 through 7.

FIG.1


100
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22
24
23
20
70
40
13
14
48
UP
12
DOWN
10
62
12a
60
61
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51
30
66
52

FIG.2

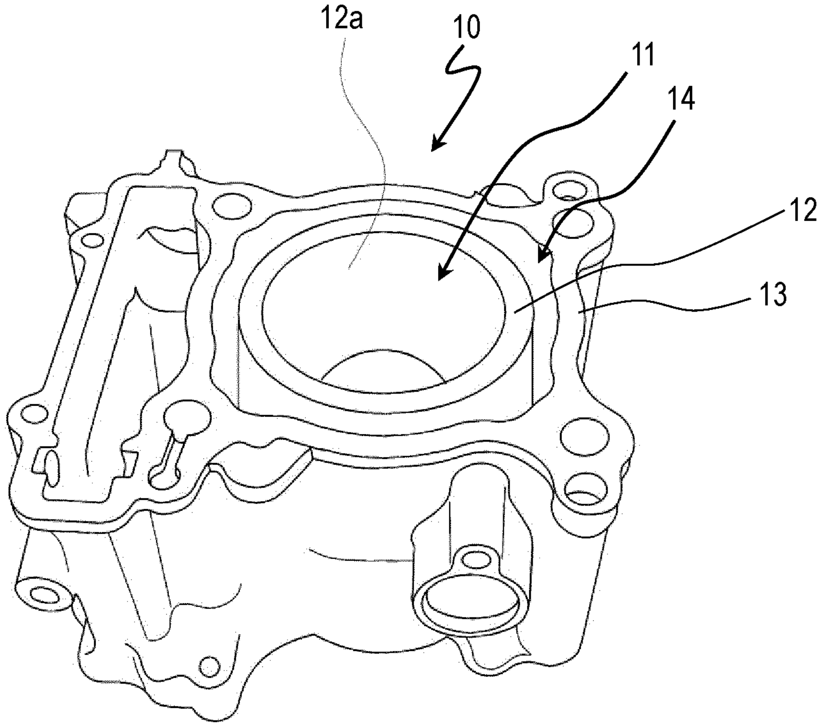


FIG.3

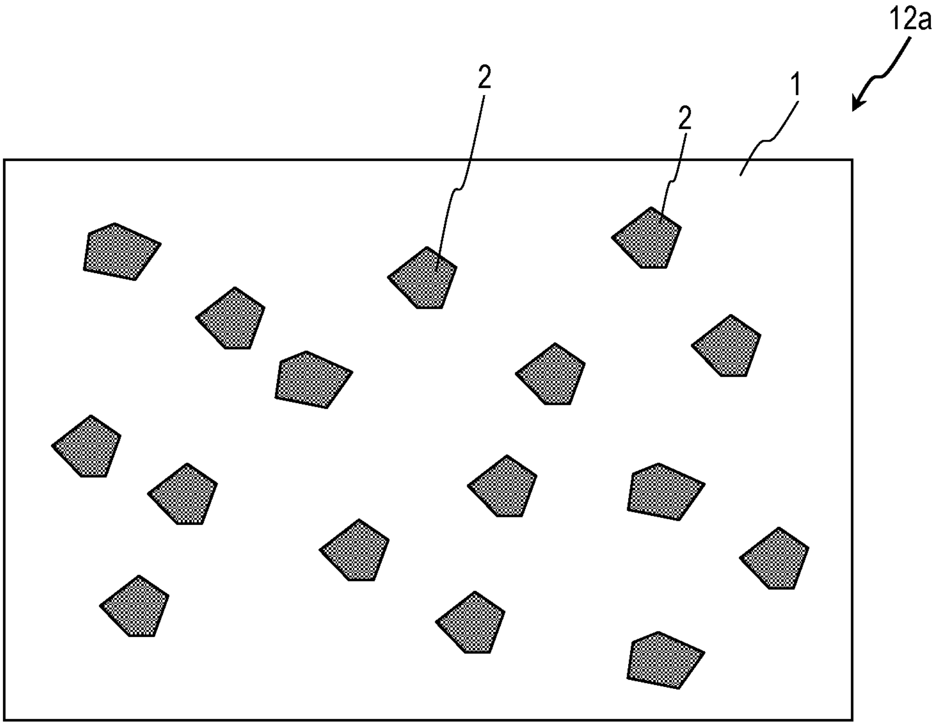


FIG.4A

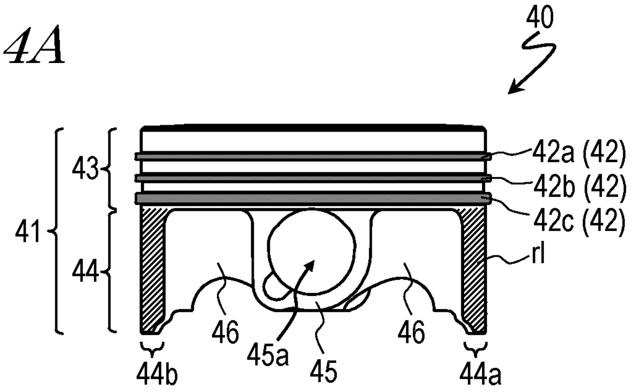


FIG.4B

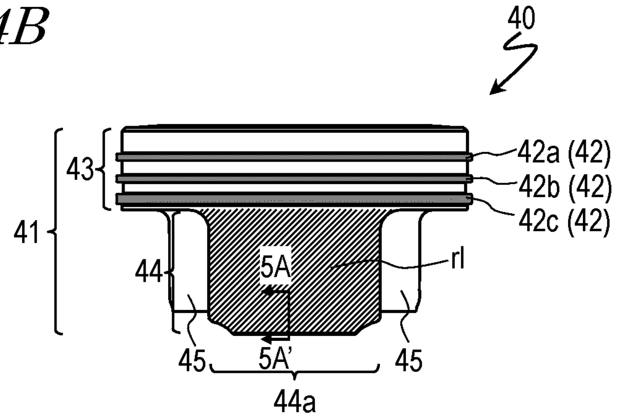


FIG.5

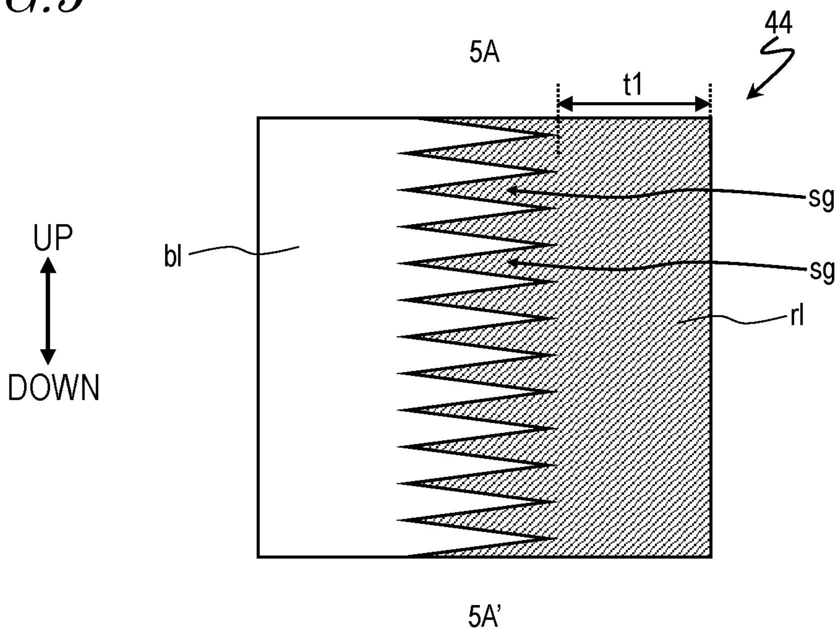


FIG.6

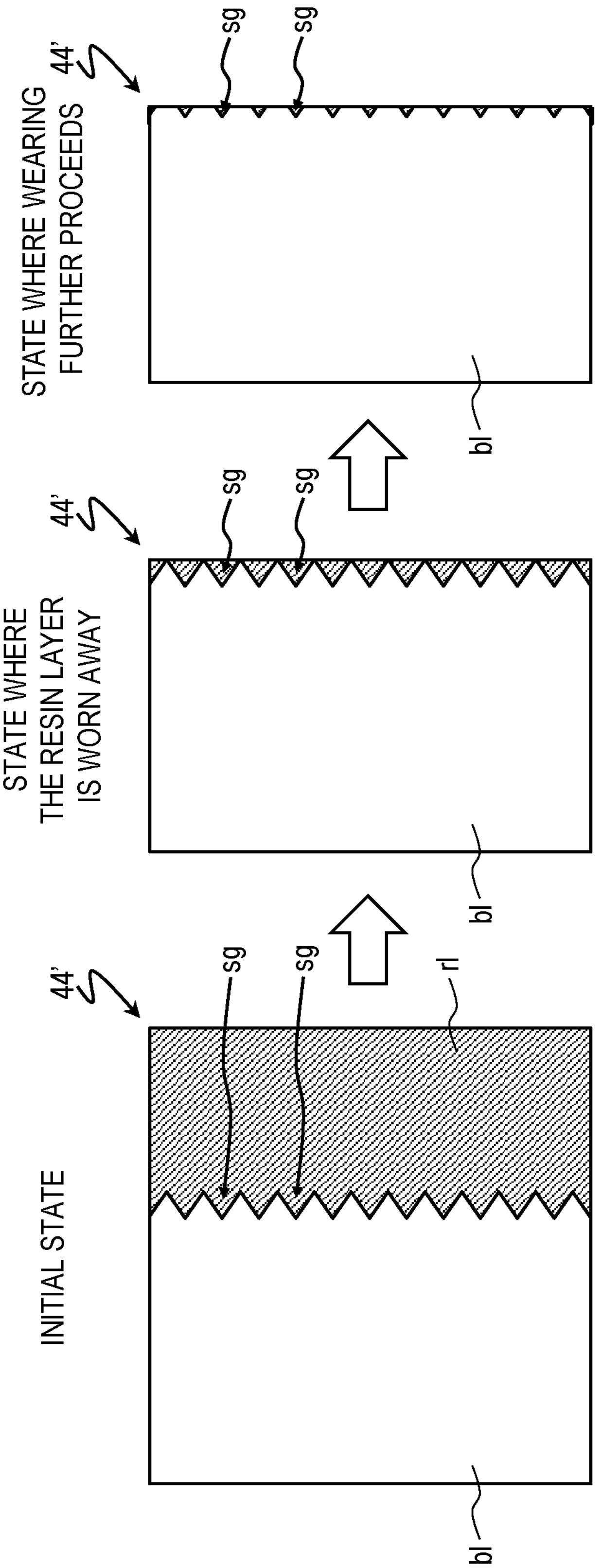

INITIAL STATE
STATE WHERE THE RESIN LAYER IS WORN AWAY
STATE WHERE WEARING FURTHER PROCEEDS
44'
sg
rl
bl

FIG.7

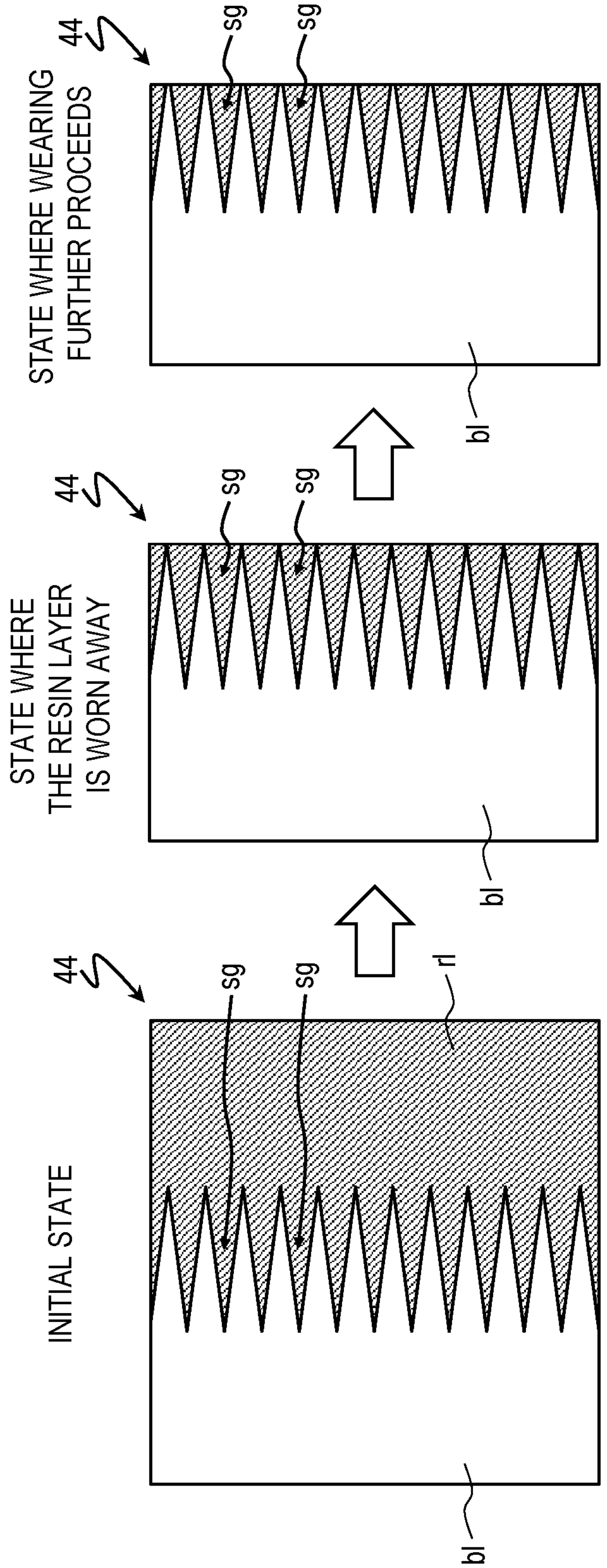
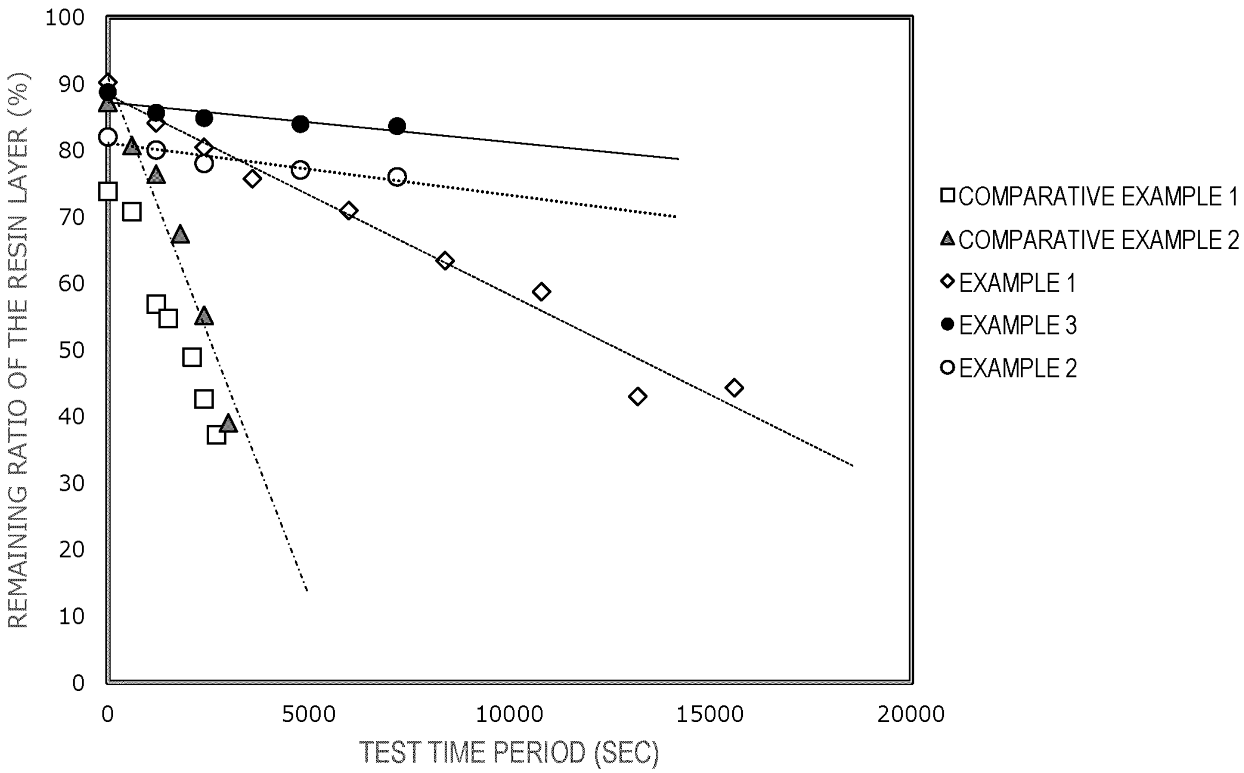

INITIAL STATE
STATE WHERE
THE RESIN LAYER
IS WORN AWAY
STATE WHERE WEARING
FURTHER PROCEEDS
44
sg
rl
bl

FIG.8



100
90
80
70
60
50
40
30
20
10
0
REMAINING RATIO OF THE RESIN LAYER (%)
0
5000
10000
15000
20000
TEST TIME PERIOD (SEC)
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
EXAMPLE 1
EXAMPLE 3
EXAMPLE 2

FIG.9

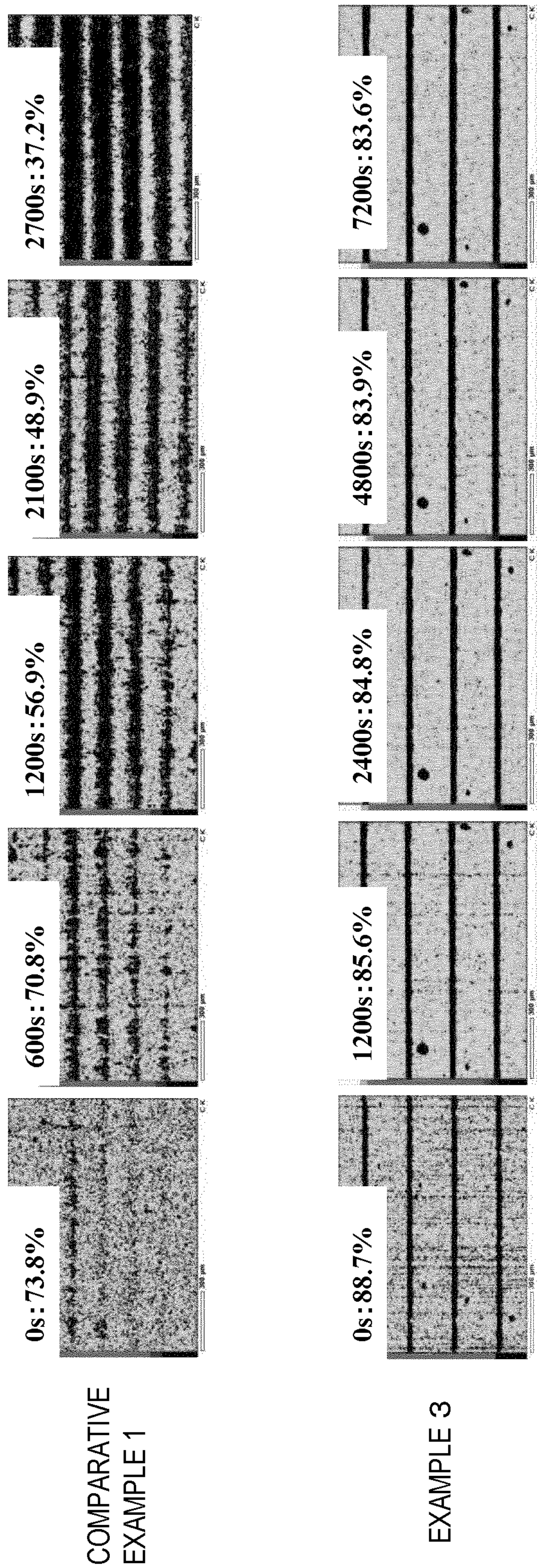

COMPARATIVE EXAMPLE 1
0s : 73.8%
600s : 70.8%
1200s : 56.9%
2100s : 48.9%
2700s : 37.2%
EXAMPLE 3
0s : 88.7%
1200s : 85.6%
2400s : 84.8%
4800s : 83.9%
7200s : 83.6%

FIG.10

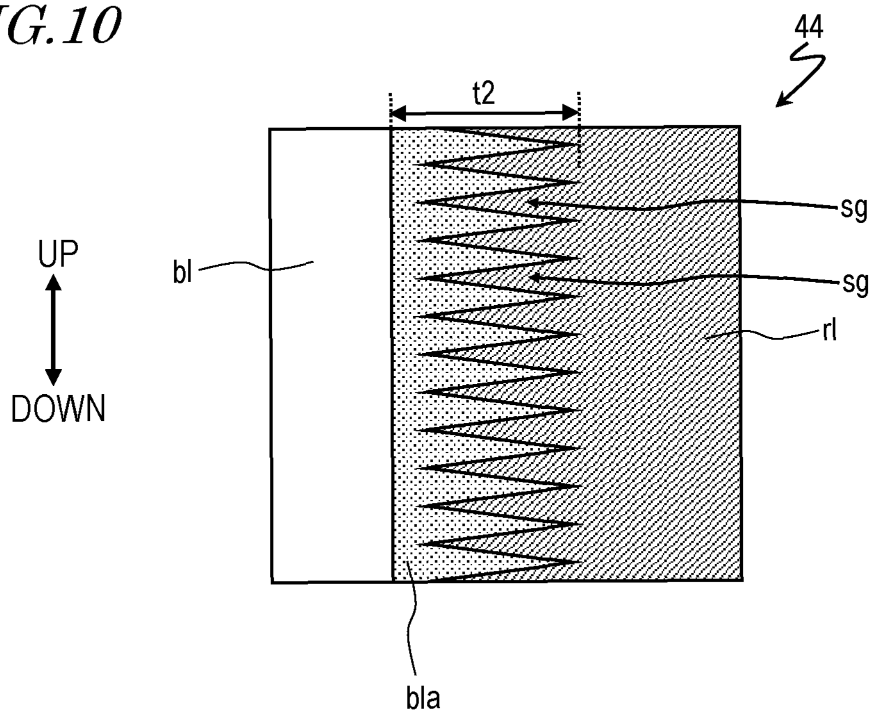


FIG.11

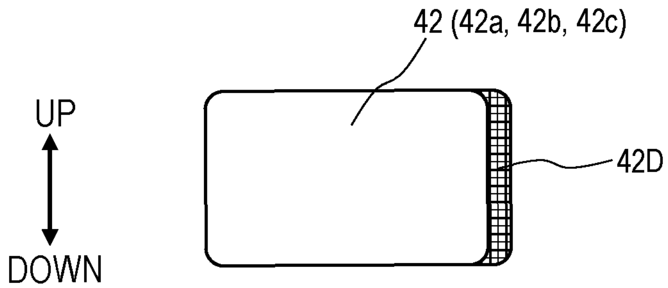
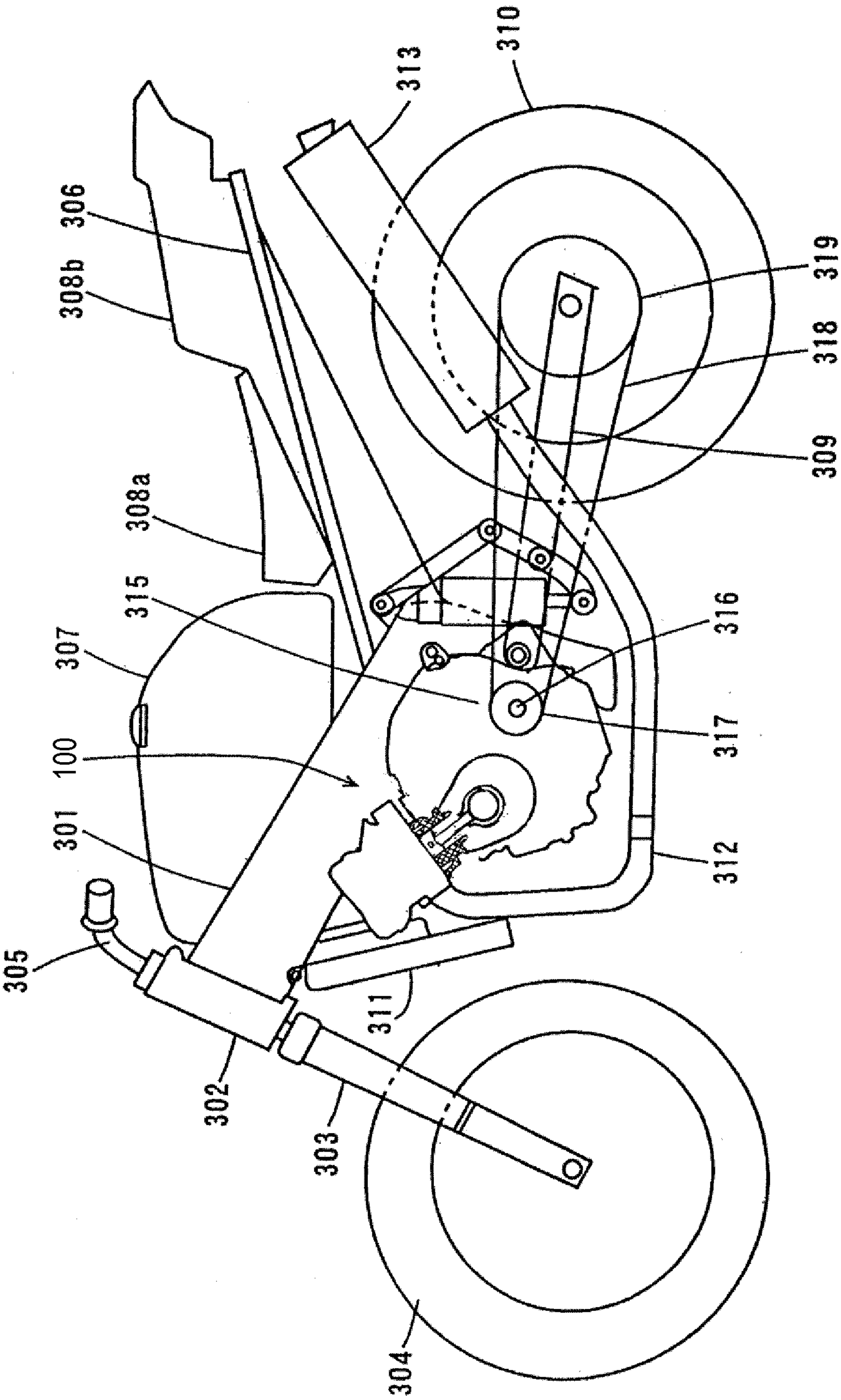


FIG.12


300
310
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319
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308a
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307
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301
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311
302
303
304

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/045975

A. CLASSIFICATION OF SUBJECT MATTER

F02F 1/00(2006.01)i
FI: F02F1/00 C

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02F1/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 1-253553 A (HONDA MOTOR CO LTD) 09 October 1989 (1989-10-09) p. 2, upper right column, lines 3-8, p. 3, upper left column, line 8 to p. 3, lower left column, line 3, p. 3, lower right column, line 16 to p. 4, upper left column, line 17, p. 4, upper right column, line 16 to p. 5, lower left column, line 11, fig. 3	1-8
Y	JP 7-97517 A (TOYOTA MOTOR CORP) 11 April 1995 (1995-04-11) paragraphs [0025]-[0042], fig. 2	1-8
Y	JP 2004-144014 A (NTN CORP) 20 May 2004 (2004-05-20) paragraph [0003]	1-8
Y	JP 59-108850 A (MAZDA MOTOR) 23 June 1984 (1984-06-23) claim 1	1-8

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2022	**01 February 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/045975

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 1-253553 A	09 October 1989	(Family: none)	
JP 7-97517 A	11 April 1995	US 5486299 A column 7, line 30 to column 11, line 28, fig. 2	
JP 2004-144014 A	20 May 2004	(Family: none)	
JP 59-108850 A	23 June 1984	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6485952 B **[0005]**