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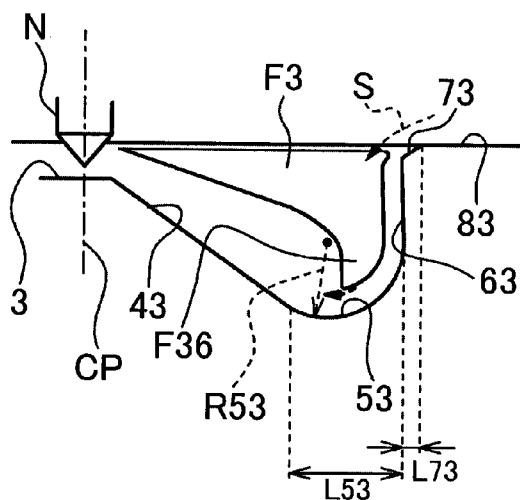
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- (54) Title: COMPRESSION IGNITION INTERNAL COMBUSTION ENGINE

FIG. 4A



- (57) Abstract: A compression ignition internal combustion engine includes a nozzle that is provided in a cylinder head and that injects fuel directly into a combustion chamber, and a piston in which a cavity is provided in a top surface thereof. The cavity includes a conical bottom surface, a curved surface that continues from the bottom surface toward a radial outside and curves toward the cylinder head side, and an inside surface that extends from the curved surface toward the cylinder head side. The inside surface includes a first inside surface, and a second inside surface that is separated from the first inside surface in a circumferential direction, and is closer to the nozzle than the first inside surface is. The nozzle injects a fuel spray toward each of the first and second inside surfaces. The curved surface includes first and second curved surfaces that are continuous with the first and second inside surfaces, respectively. A curvature radius of the first curved surface is smaller than a curvature radius of the second curved surface.

COMPRESSION IGNITION INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to a compression ignition internal combustion engine.

2. Description of Related Art

10 [0002] Japanese Patent Application Publication No. 2011-185242 (JP 2011-185242 A) describes technology in which a concave portion and a convex portion are formed lined up alternately in a circumferential direction in a cavity of a piston. Also, a fuel spray is injected from a nozzle toward each of the concave and convex portions.

15 SUMMARY OF THE INVENTION

[0003] Depending on the shape of the concave portion, a portion of fuel spray after striking the concave portion may flow toward the inside in the radial direction. This portion of fuel spray that flows toward the radial inside may interfere with the fuel spray that has struck the convex portion. If the two fuel sprays interfere with each other, the
20 fuel concentration may become locally large at that portion, for example, which may make smoke worse or the like, for example.

[0004] The invention provides a compression ignition internal combustion engine that inhibits interference between fuel sprays.

[0005] A first aspect of the invention relates to a compression ignition internal
25 combustion engine that includes a nozzle that is provided in a cylinder head and that injects fuel directly into a combustion chamber, and a piston in which a cavity is provided in a top surface of the piston. The cavity includes a conical bottom surface, a curved surface that continues from the bottom surface toward a radial outside and curves toward the cylinder head side, and an inside surface that extends from the curved surface toward
30 the cylinder head side. The inside surface includes a first inside surface, and a second inside surface that is separated from the first inside surface in a circumferential direction, and is closer to the nozzle than the first inside surface is. The nozzle injects a fuel spray toward each of the first inside surface and the second inside surface. The curved surface includes a first curved surface that is continuous with the first inside surface, and a second
35 curved surface that is continuous with the second inside surface. A curvature radius of

the first curved surface is smaller than a curvature radius of the second curved surface.

[0006] A second aspect of the invention relates to a compression ignition internal combustion engine that includes a nozzle that is provided in a cylinder head and that injects fuel directly into a combustion chamber, and a piston in which a cavity is provided in a top surface of the piston. The cavity includes a conical bottom surface, a curved surface that continues from the bottom surface toward a radial outside and curves toward the cylinder head side, and an inside surface that extends from the curved surface toward the cylinder head side. The inside surface includes a first inside surface, and a second inside surface that is separated from the first inside surface in a circumferential direction, and is closer to the nozzle than the first inside surface is. The nozzle injects a fuel spray toward each of the first inside surface and the second inside surface. The curved surface includes a first curved surface that is continuous with the first inside surface, and a second curved surface that is continuous with the second inside surface. A length in a radial direction of the first curved surface is shorter than a length in a radial direction of the second curved surface.

[0007] A third aspect of the invention relates to a compression ignition internal combustion engine that includes a nozzle that is provided in a cylinder head and that injects fuel directly into a combustion chamber, and a piston in which a cavity is provided in a top surface of the piston. The cavity includes a conical bottom surface, a flat surface that continues from the bottom surface toward a radial outside, and an inside surface that extends from the flat surface toward the cylinder head side. The inside surface includes a first inside surface, and a second inside surface that is separated from the first inside surface in a circumferential direction, and is closer to the nozzle than the first inside surface is. The nozzle injects a fuel spray toward each of the first inside surface and the second inside surface. The flat surface includes a first flat surface that is continuous with the first inside surface, and a second flat surface that is continuous with the second inside surface. A length in a radial direction of the first flat surface is shorter than a length in a radial direction of the second flat surface.

[0008] In the aspects described above, the cavity may include a first inclined surface that is positioned farther toward the radial outside than the first inside surface and is continuous with the top surface, and a second inclined surface that is positioned farther toward the radial outside than the second inside surface and is continuous with the top surface. Also, a length in a radial direction of the first inclined surface may be longer than a length in a radial direction of the second inclined surface.

[0009] In the aspects described above, the cavity may include a first inclined

surface that is positioned farther toward the radial outside than the first inside surface and is continuous with the top surface, and a second inclined surface that is positioned farther toward the radial outside than the second inside surface and is continuous with the top surface. Also, a length in a radial direction of the first inclined surface may be shorter than a length in a radial direction of the second inclined surface.

[0010] The above aspects of the invention are able to provide a compression ignition internal combustion engine that inhibits interference between fuel sprays.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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 an explanatory view of a compression ignition internal combustion engine;

FIG. 2A is a plan view of a piston, FIG. 2B is a sectional view taken along line A – A in FIG. 2A, and FIG. 2C is a sectional view taken along line B – B in FIG. 2A;

FIGS. 3A to 3C are explanatory views illustrating the flow of fuel sprays;

FIGS. 4A and 4B are explanatory views illustrating the flow of fuel spray injected toward an inside surface;

FIGS. 5A, 5B, and 5C are explanatory views of a piston according to a first modified example;

FIGS. 6A and 6B are explanatory views of a modified example of an inclined surface;

FIG. 7 is an explanatory view of a piston according to a second modified example;

FIG. 8 is another explanatory view of the piston according to the second modified example; and

FIG. 9 is yet another explanatory view of the piston according to the second modified example.

DETAILED DESCRIPTION OF EMBODIMENTS

[0012] Example embodiments of the invention will now be described with reference to the accompanying drawings.

[0013] FIG. 1 is an explanatory view of a compression ignition internal combustion engine. A diesel engine is one example of a compression ignition internal combustion engine. A combustion chamber E creates a swirl flow. A cylinder 101 is formed in a cylinder block 100. A piston 1 is housed in this cylinder 101. A cylinder head 110 is fixed to an upper portion of the cylinder block 100. The cylinder head 110,

the cylinder block 100, and the piston 1 together form the combustion chamber E. A portion 111 of a bottom wall portion of the cylinder head 110 that forms the combustion chamber E has a pent roof shape, but it is not limited to this. Two intake ports and two exhaust ports, not shown, are provided in the cylinder head 110. The intake ports and the exhaust ports open and close by intake valves and exhaust valves, respectively.

[0014] A nozzle N that injects fuel is provided in the cylinder head 110. The nozzle N injects fuel directly into the combustion chamber E. The nozzle N is provided on a central axis CP of the cylinder block 100. The nozzle N is connected to a common rail R via a conduit. Fuel that has been pressurized by a high-pressure pump P is supplied to the common rail R, where it is stored at a high pressure. Fuel is injected from a nozzle hole formed in a tip end portion of the nozzle N, in response to the nozzle hole being opened by a valve body.

[0015] An ECU 20 performs overall control of the engine. The ECU 20 is a computer formed by ROM (Read Only Memory), RAM (Random Access Memory), and a CPU (Central Processing Unit) and the like, not shown. The ECU 20 controls the pressure of the fuel in the common rail R by controlling the high-pressure pump P.

[0016] FIG. 2A is a plan view of the piston 1. FIG. 2B is a sectional view taken along line A – A in FIG. 2A. FIG. 2C is a sectional view taken along line B – B in FIG. 2A. A cavity C into which the fuel is injected is formed in an upper portion of the piston 1. The swirl flow flows in a clockwise direction SW.

[0017] The cavity C is formed in a concave shape in a top surface 8 of the piston 1, and has a generally elliptical shape when viewed from above. The cavity C includes a raised surface 3, a bottom surface 4 formed around the raised surface 3, a curved surface 5 that curves upward from the bottom surface 4, an inside surface 6 that extends upward from the curved surface 5, and an inclined surface 7 that is continuous with the inside surface 6. The raised surface 3 is positioned in substantially the center portion of the cavity C and rises upward, and is horizontal perpendicular to the reciprocating direction of the piston 1. The bottom surface 4 extends at an angle downward from the raised surface 3 toward the radial outside, and extends in a linear shape in a sectional view. The curved surface 5 curves from the bottom surface 4 toward the inside of the cavity C, and is formed around the bottom surface 4. The inside surface 6 is formed around the curved surface 5. The distance from the nozzle N to the inside surface 6 differs in the circumferential direction.

[0018] The inclined surface 7 that extends at an upward angle toward the radial outside is formed around the radial outside of the inside surface 6. The horizontal top

surface 8 is formed around the radial outside of the inclined surface 7. In FIG. 2A, the boundary between the bottom surface 4 and the curved surface 5 is indicated by a broken line. When the piston 1 is positioned at top-dead-center (TDC), the tip end portion of the nozzle N opposes the raised surface 3, as shown in FIGS. 2B and 2C.

5 [0019] As shown in FIG. 2A, the cavity C has a generally elliptical shape when viewed from above. The bottom surface 4 includes regions 41, 43, 45, and 47 that are separated by equiangular intervals in the circumferential direction around the central axis CP. The bottom surface 4 has a symmetrical shape that is symmetrical about the central axis CP. The regions 41 and 45 have gentle inclination angles, while the regions 43 and 10 47 have sharp inclination angles. The inclination angle of the bottom surface 4 changes gradually in the circumferential direction.

 [0020] The inside surface 6 includes regions 61, 63, 65, and 67 that are separated by equiangular intervals in the circumferential direction. The inside surface 6 also has a symmetrical shape that is symmetrical about the central axis CP. The distance between 15 the regions 61 and 65 in the horizontal direction perpendicular to the central axis CP is longer than the distance between the regions 63 and 67. The distance between the regions 61 and 65 corresponds to a long diameter of an ellipse, and the distance between the regions 63 and 67 corresponds to a short diameter of an ellipse. Therefore, the regions 61 and 65 of the inside surface 6 are the farthest from the nozzle N, and the regions 63 and 67 20 are the closest to the nozzle N.

 [0021] The curved surface 5 includes regions 51, 53, 55, and 57 that are separated by equiangular intervals in the circumferential direction, and these are connected to the regions 61, 63, 65, and 67 of the inside surface 6, respectively. As shown in FIG. 2A, regarding the lengths in the radial direction of the curved surface 5 viewed from the central 25 axis CP direction, the regions 51 and 55 are the shortest and the regions 53 and 57 are the longest. That is, the length in the radial direction of the regions 51 and 55 that are connected to the regions 61 and 65 that are the farthest of all of the regions of the inside surface 6 from the nozzle N is short. The length in the radial direction of regions 53 and 57 that are connected to the regions 63 and 67 that are the closest all of the regions of the 30 inside surface 6 to the nozzle N is long. Therefore, the regions 41 and 45 of the bottom surface 4 that are to the radial inside of the regions 51 and 55 are formed long and are gently inclined. The regions 43 and 47 of the bottom surface 4 that are to the radial inside of the regions 53 and 57 are short and are sharply inclined. This will be described in detail later.

35 [0022] The inclined surface 7 includes regions 71, 73, 75, and 77 that are

separated by equiangular intervals in the circumferential direction. These regions are to the radial outside of the regions 61, 63, 65, and 67 of the inside surface 6, respectively. Regarding the length in the radial direction of the inclined surface 7, the regions 71 and 75 are the longest, and the regions 73 and 77 are the shortest. That is, the length in the radial direction of the inclined surface 7 also differs in the circumferential direction.

[0023] The top surface 8 includes regions 81, 83, 85, and 87 that are separated by equiangular intervals in the circumferential direction. These regions are to the radial outside of the regions 71, 73, 75, and 77 of the inclined surface 7, respectively. The regions 81 and 85 have the smallest areas, and the regions 83 and 87 have the largest areas.

[0024] FIGS. 3A to 3C are explanatory views illustrating the flow of fuel sprays. In FIGS. 3A to 3C, some of the reference characters are omitted. As shown in FIG. 3A, a swirl flow is generated in a clockwise direction inside the combustion chamber E. With the reciprocating movement of the piston 1, a strong squish flow and a reverse squish flow are generated near the regions 83 and 87 that have large areas, and a weak squish flow and a reverse squish flow are generated near the regions 81 and 85 that have small areas. Therefore, the flow of air is large near the regions 63 and 67, and the flow of air is small near the regions 61 and 65.

[0025] As shown in FIG. 3B, the nozzle N injects eight fuel sprays at equiangular intervals (45 degree intervals). Fuel sprays F1, F3, F5, and F7 are injected toward the regions 61, 63, 65, and 67 of the inside surface 6, respectively. Fuel spray F2 is injected between fuel sprays F1 and F3, fuel spray F4 is injected between fuel sprays F3 and F5, fuel spray F6 is injected between fuel sprays F5 and F7, and fuel spray F8 is injected between fuel sprays F7 and F1.

[0026] These fuel sprays are injected simultaneously. Therefore, first, the fuel sprays F3 and F7 strike the regions 63 and 67 of the inside surface 6, respectively. Next, the fuel spray F2 strikes the region between the regions 61 and 63, the fuel spray F4 strikes the region between the regions 63 and 65, the fuel spray F6 strikes the region between the regions 65 and 67, and the fuel spray F8 strikes the region between the regions 67 and 61. Lastly, the fuel sprays F1 and F5 strike the regions 61 and 65, respectively. In this way, the fuel sprays strike the cavity of the piston 1, the fuel and air mix, and the fuel ignites.

[0027] Therefore, the fuel sprays F3 and F7 that ignite first correspond to a pilot injection. The fuel sprays F2, F4, F6, and F8 that ignite next correspond to a main ignition. The fuel sprays F1 and F5 that ignite last correspond to an after ignition.

[0028] Because the flow of air is large near the regions 63 and 67 as described above, the fuel sprays F3 and F7 ignite early and burn fast due to the strong flow of air in

the regions 63 and 67, respectively. In contrast, the flow of air is small near the regions 61 and 65, so the fuel sprays F1 and F5 ignite late and burn slowly due to the weak flow of air near the regions 61 and 65. The flow of air near is moderate in the regions between the regions 61 and 63, between the regions 63 and 65, between the regions 65 and 67, and between the regions 67 and 61. Therefore, the fuel sprays F2, F4, F6, and F8 ignite and burn at a moderate pace due to the moderate flow of air, after the fuel sprays F3 and F7 ignite and before the fuel sprays F1 and F5 ignite.

[0029] As a result, a difference in the rate of combustion among the fuel sprays is able to be ensured. Therefore, the peak value of the heat quantity is able to be suppressed, so the combustion temperature is able to be suppressed, compared to when a plurality of fuel sprays ignite simultaneously and the difference in the rate of combustion is small. Thus, NO_x can be reduced, and combustion noise can also be suppressed.

[0030] Also, depending on the shape of the cavity C of the piston 1, fuel sprays corresponding to the pilot injection, the main injection, and the after injection may be formed with a single fuel injection. For example, when achieving these injections in one combustion stroke, a nozzle that is extremely responsive to injection switching is required. Also, because there is a limit to injection switching responsiveness, the time interval of these injections is unable to be shorted beyond a predetermined amount. In this example embodiment, a desired combustion state is able to be ensured without such nozzle limitations.

[0031] As shown in FIG. 3C, when the fuel spray F3 strikes the region 63 and a spray f3 is formed, the spray f3 broadly diffuses in the circumferential and radial directions due to the swirl flow and the strong squish flow. When the fuel spray F2 strikes the region between the regions 61 and 63 and a spray f2 is formed, the spray f2 receives a weaker squish flow than the squish flow received by the spray f3. This is also the same when the fuel spray F8 strikes the region between the regions 61 and 67 and a spray f8 is formed. When the fuel spray F1 strikes the region 61 and a spray f1 is formed, the spray f1 flows in the circumferential direction from the region 81 to the region 83 due to the swirl flow. The other sprays and the like are not shown in FIG. 3C.

[0032] These sprays f1 to f3 diffuse at different positions in the radial direction downstream of the swirl flow, so interference among fuel sprays after they strike the cavity C is inhibited. As a result, the fuel and air mix evenly inside the combustion chamber E. Thus, the fuel concentration is inhibited from becoming locally high and smoke is inhibited from becoming worse.

[0033] FIG. 4A is an explanatory view illustrating the flow of the fuel spray F3

injected into the region 63 of the inside surface 6. FIG. 4B is an explanatory view illustrating the flow of the fuel spray F1 injected into the region 61 of the inside surface 6. FIGS. 4A and 4B correspond to FIGS. 2B and 2C, respectively. In the description below, the region 61 of the inside surface 6 will be given as an example of a first inside surface, and the region 63 will be given as an example of a second inside surface that is separated from the first inside surface in the circumferential direction, and closer to the nozzle N than the first inside surface. Also, the regions 51 and 53 of the curved surface 5 will be given as examples of first and second curved surfaces that are connected to the first and second inside surfaces, respectively.

[0034] As shown in FIGS. 4A and 4B, a length L51 in the radial direction of the region 51 of the curved surface 5 is shorter than a length L53 in the radial direction of the region 53. A curvature radius R51 of the region 51 is smaller than a curvature radius R53 of the region 53. The region 55 has the same shape as the region 51, and the region 57 has the same shape as the region 53. Each of the regions of the curved surface is a portion that is curved at a predetermined curvature.

[0035] Also, a length L71 in the radial direction of the region 71 of the inclined surface 7 is longer than a length L73 of the region 73. The region 75 has the same shape as the region 71, and the region 77 has the same shape as the region 73.

[0036] As shown in FIG. 4A, when the fuel spray F3 strikes the region 63 of the inside surface 6, the majority of the fuel spray F3 receives the strong squish flow from the region 83 and consequently flows downward along the region 63. The length L73 in the radial direction of the region 73 of the inclined surface 7 is relatively short, and the length in the radial direction of the region 83 of the top surface 8 is long so the squish area is large. Therefore, a strong squish flow S is generated near these regions.

[0037] Some of the fuel spray F3 that has flowed downward along the region 63 reverses direction due to the region 53 of the curved surface 5, and flows radially inward. The length L53 in the radial direction of the region 53 is long and the curvature radius R53 is also large, so flow resistance to the spray that flows along the region 53 is suppressed. The regions 57, 67, and 77 also have the same shapes as the regions 53, 63, and 73, respectively. As a result, some of the spray of the fuel sprays F3 and F7 are able to be guided radially inward.

[0038] Meanwhile, as shown in FIG. 4B, when the fuel spray F1 strikes the region 61 of the inside surface 6, an upper portion F17 of the fuel spray F1 flows radially outward along the region 71 of the inclined surface 7. The length L71 in the radial direction of the region 71 of the inclined surface 7 is longer than the length L73 of the region 73, and the

length in the radial direction of the region 81 of the top surface 8 is shorter than the region 83, so the squish area is small near the regions 71 and 81. Therefore, a strong squish flow is not generated near the region 71, so the upper portion F17 of the fuel spray F1 flows radially outward along the region 71. As a result, the fuel spray F1 is able to be guided
5 radially outward.

[0039] A lower portion F15 of the fuel spray F1 flows downward along the region 61, but is inhibited from flowing toward the center side of the cavity C. The length L51 in the radial direction of the region 51 of the curved surface 5 is shorter than the length L53, and the curvature radius R51 is also smaller than the curvature radius R53. Therefore, the
10 region 51 is curved at a steep angle. Thus, the flow resistance in the flow of fuel spray along the region 51 of the curved surface 5 is large. As a result, a lower portion F15 of the fuel spray F1 along the region 51 is inhibited from flowing radially inward. The regions 55, 65, and 75 also have the same shapes as the regions 51, 61, and 71, respectively.

[0040] As shown in FIG. 2, the length in the radial direction of the inclined surface 7 changes gradually in the circumferential direction. Therefore, the length in the radial direction of the region between the regions 71 and 73 of the inclined surface 7 is shorter than the length L71 and longer than the length L73. The region between the regions 73 and 75, the region between the regions 75 and 77, and the region between the
20 regions 77 and 71 are also similar.

[0041] Also, the length in the radial direction of the region between the regions 51 and 53 of the curved surface 5 is longer than the length L51 and shorter than the length L53. The curvature radius of the region between the regions 51 and 53 of the curved surface 5 is larger than the curvature radius R51 and smaller than the curvature radius R53.
25 The region between the regions 53 and 55, the region between the regions 55 and 57, and the region between the regions 57 and 51 are also similar.

[0042] As described above, the fuel sprays F1 and F5 can be guided radially outward, and the fuel sprays F3 and F7 can be guided radially inward. Also, the fuel sprays F2, F4, F6, and F8 are formed so as to stay between the fuel sprays F1 and F5, and
30 the fuel sprays F3 and F7 in the radial direction. As a result, interference among fuel sprays after the fuel sprays have contacted the cavity C is inhibited, and a difference in the rate of combustion among the fuel sprays is able to be ensured. Consequently, smoke is inhibited from becoming worse.

[0043] An inner edge of the region 71 is positioned higher than an inner edge of
35 the region 73, but it is not limited to this. For example, even if the inner edge of the

region 71 and the inner edge of the region 83 are positioned at same height, the region 71 may be made longer than the region 73 by forming the inclination angle of the region 71 more gentle than the region 73.

[0044] Even if the curvature radii R51 and R53 are the same or if the curvature radius R51 is larger than the curvature radius R53, if the length L53 is longer than the length L51, fuel spray is able to be guided to the inside in the radial direction along the region 53.

[0045] FIGS. 5A, 5B, and 5C are explanatory views of a piston 1a according to a first modified example. Similar structures are denoted by like reference characters, so redundant descriptions will be omitted. FIG. 5B is a sectional view taken along line C – C in FIG. 5A, and FIG. 5C is a sectional view taken along line D – D in FIG. 5A. A flat surface 5a is horizontal and is not curved. The length in the radial direction of the flat surface 5a differs in the circumferential direction. A length L51a in the radial direction of a region 51a is shorter than a length L53a in the radial direction of a region 53a. Therefore, a portion of the fuel spray F1 that strikes a region 61a and flows downward is inhibited from flowing toward the inside because the length of the region 51a is short, while a portion of the fuel spray F3 that strikes a region 63a and flows downward will flow toward the radial inside because the length of the region 53a is long. Even with the piston 1a of such a modified example, each spray is able to be guided to the desired position, so interference among fuel sprays after the fuel sprays have contacted the cavity C is able to be inhibited.

[0046] FIGS. 6A and 6B are explanatory views of a modified example of the inclined surface. As shown in FIGS. 6A and 6B, a length L71' in the radial direction of a region 71' of the inclined surface may be shorter than a length L73' of a region 73'. For example, when the engine is large, a difference between a distance from the nozzle Z to the regions 61 and 65 of the inside surface 6, and a distance from the nozzle N to the regions 63 and 67 may be able to be sufficiently ensured. In this case, the squish flow generated on the side with the regions 63 and 67 may become too strong. In such a case, the squish flow generated on the side with the regions 63 and 67 is able to be inhibited from becoming excessively strong by making the length in the radial direction of the regions 73 and 77 longer than the length of the regions 71 and 75. Just as with the example embodiment described above, the length in the radial direction of the inclined surface preferably differs in the circumferential direction.

[0047] FIGS. 7 to 9 are explanatory views of a piston 1b according to a second modified example. FIG. 8 is a sectional view taken along line E – E in FIG. 7, and FIG. 9

is a sectional view taken along line F – F in FIG. 7. As shown in FIG. 7, a cavity Cb has a long hole shape when viewed from a direction of the central axis CP. Valve recess surfaces 91 to 94 that have recessed shapes with shallow bottoms are formed in the piston 1b. The valve recess surfaces 91 and 92 are provided in order to avoid contact with the two intake valves, and the valve recess surfaces 93 and 94 are provided in order to avoid contact with the two exhaust valves. Also, the cavity Cb includes a raised surface 3b, a bottom surface 4b, a curved surface 5b, an inside surface 6b, an inclined surface 7b, and a top surface 8b.

[0048] As shown in FIGS. 8 and 9, lengths L51b and L55b in the radial direction of regions 51b and 55b of the curved surface 5b are shorter than lengths L53b and L57b of regions 53b and 57b. Also, curvature radii R51b and R55b are smaller than curvature radii R53b and R57b. As a result, some of the fuel spray that strikes regions 61b and 65b of the inside surface 6b and flows downward is inhibited from flowing toward the radial inside, and some of the fuel spray that strikes the regions 63b and 67b and flows downward flows more easily toward the radial inside. As a result, interference among fuel sprays after the fuel sprays have contacted the cavity Cb is able to be inhibited.

[0049] Also, the valve recess surfaces 91 to 94 are formed overlapping with the top surface 8, and the lengths in the radial direction of regions 71b and 75b of the inclined surface 7b are longer than the lengths in the radial direction of regions 73b and 77b, respectively, as shown in FIG. 7. Therefore, fuel spray injected toward the regions 61b and 65b is guided toward the radial outside. A boundary between the region 53b and the region 63b is a portion where the curvature of the region 53b changes.

[0050] While example embodiments of the invention have been described in detail, the invention is not in any way limited to these specific example embodiments. Various modifications and variations are also possible within the scope of the invention described in the scope of the claims.

[0051] The number of nozzle holes in the nozzle is not limited to the number described in the example above. There only need to be at least two nozzle holes in the nozzle. Also, the shape of the cavity is not limited to an elliptical shape as described above. The shape of the cavity may alternatively be a generally round shape when viewed from above, and the position of the nozzle may be a position away from the central axis of the cavity. This is because even if the nozzle is arranged in a position away from the central axis of the cavity in this way, the distance from the nozzle to the inside surface of the cavity in the radial direction of the nozzle differs in the circumferential direction.

CLAIMS:

1. A compression ignition internal combustion engine comprising:

a nozzle provided in a cylinder head, the nozzle being configured to inject fuel
5 directly into a combustion chamber; and

a piston in which a cavity is provided in a top surface of the piston,

the cavity including a conical bottom surface, a curved surface that continues from
the bottom surface toward a radial outside and curves toward the cylinder head side, and an
inside surface that extends from the curved surface toward the cylinder head side,

10 the inside surface including a first inside surface, and a second inside surface that is
separated from the first inside surface in a circumferential direction, the second inside
surface being closer to the nozzle than the first inside surface,

the nozzle being configured to inject a fuel spray toward each of the first inside
surface and the second inside surface,

15 the curved surface including a first curved surface that is continuous with the first
inside surface, and a second curved surface that is continuous with the second inside
surface, and

a curvature radius of the first curved surface being smaller than a curvature radius of
the second curved surface.

2. A compression ignition internal combustion engine comprising:

a nozzle provided in a cylinder head, the nozzle being configured to inject fuel
directly into a combustion chamber; and

a piston in which a cavity is provided in a top surface of the piston,

25 the cavity including a conical bottom surface, a curved surface that continues from
the bottom surface toward a radial outside and curves toward the cylinder head side, and an
inside surface that extends from the curved surface toward the cylinder head side,

the inside surface including a first inside surface, and a second inside surface that is
separated from the first inside surface in a circumferential direction, the second inside
30 surface being closer to the nozzle than the first inside surface,

the nozzle being configured to inject a fuel spray toward each of the first inside
surface and the second inside surface,

the curved surface including a first curved surface that is continuous with the first
inside surface, and a second curved surface that is continuous with the second inside
35 surface, and

a length in a radial direction of the first curved surface being shorter than a length in a radial direction of the second curved surface.

3. A compression ignition internal combustion engine comprising:

5 a nozzle provided in a cylinder head, the nozzle being configured to inject fuel directly into a combustion chamber; and

a piston in which a cavity is provided in a top surface of the piston,

10 the cavity including a conical bottom surface, a flat surface that continues from the bottom surface toward a radial outside, and an inside surface that extends from the flat surface toward the cylinder head side,

the inside surface including a first inside surface, and a second inside surface that is separated from the first inside surface in a circumferential direction, the second inside surface being closer to the nozzle than the first inside surface,

15 the nozzle being configured to inject a fuel spray toward each of the first inside surface and the second inside surface,

the flat surface including a first flat surface that is continuous with the first inside surface, and a second flat surface that is continuous with the second inside surface, and

a length in a radial direction of the first flat surface being shorter than a length in a radial direction of the second flat surface.

20 4. The compression ignition internal combustion engine according to any one of claims 1 to 3, wherein

the cavity includes a first inclined surface that is positioned farther toward the radial outside than the first inside surface and is continuous with the top surface, and the cavity 25 includes a second inclined surface that is positioned farther toward the radial outside than the second inside surface and is continuous with the top surface; and

a length in a radial direction of the first inclined surface is longer than a length in a radial direction of the second inclined surface.

30 5. The compression ignition internal combustion engine according to any one of claims 1 to 3, wherein

the cavity includes a first inclined surface that is positioned farther toward the radial outside than the first inside surface and is continuous with the top surface, and the cavity includes a second inclined surface that is positioned farther toward the radial outside than 35 the second inside surface and is continuous with the top surface; and

a length in a radial direction of the first inclined surface is shorter than a length in a radial direction of the second inclined surface.

FIG. 1

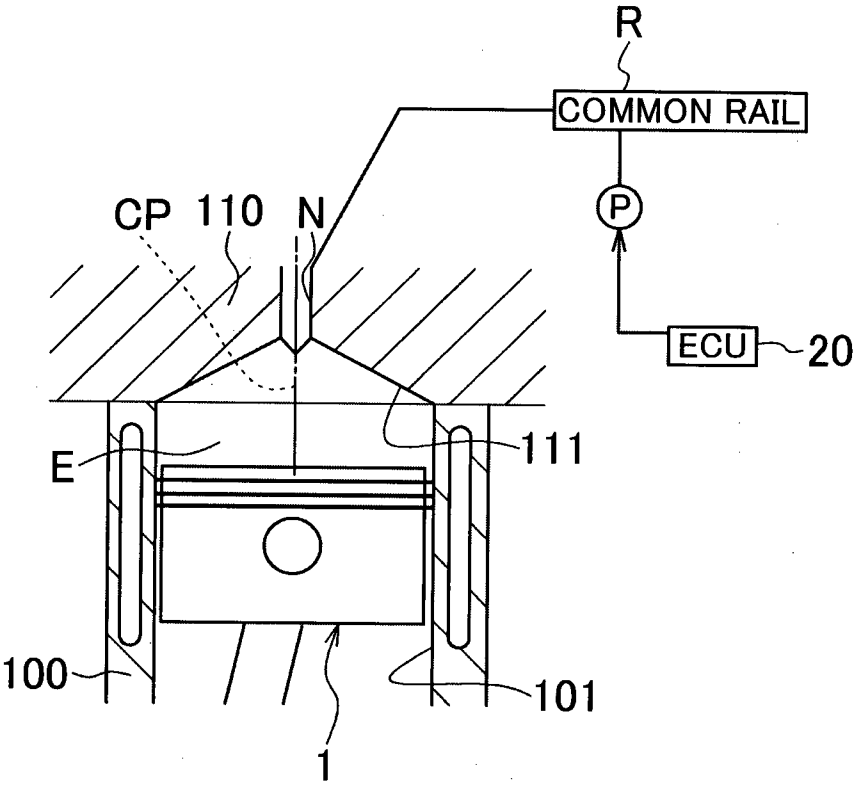


FIG. 2A

FIG. 2C

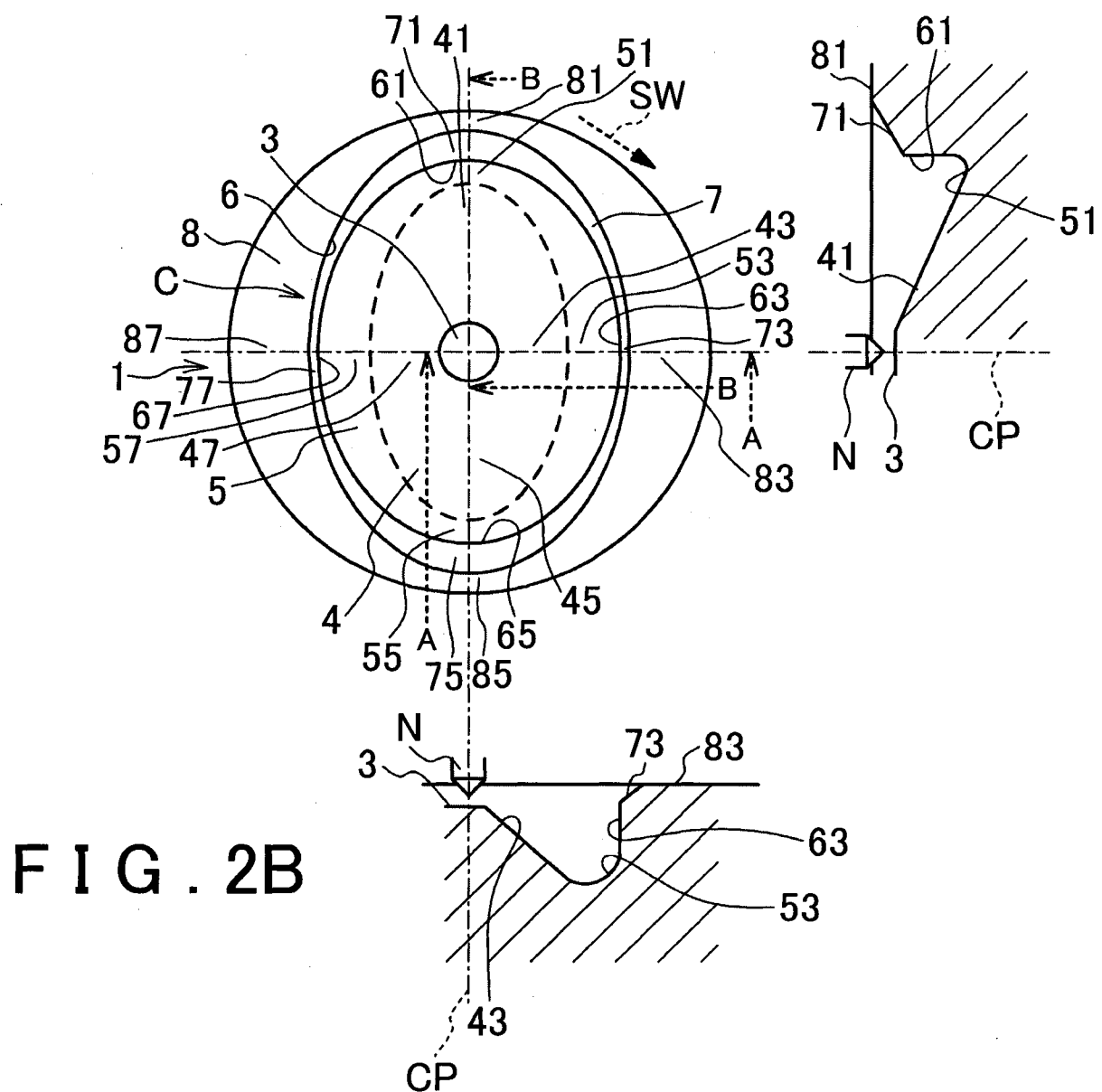


FIG. 3A

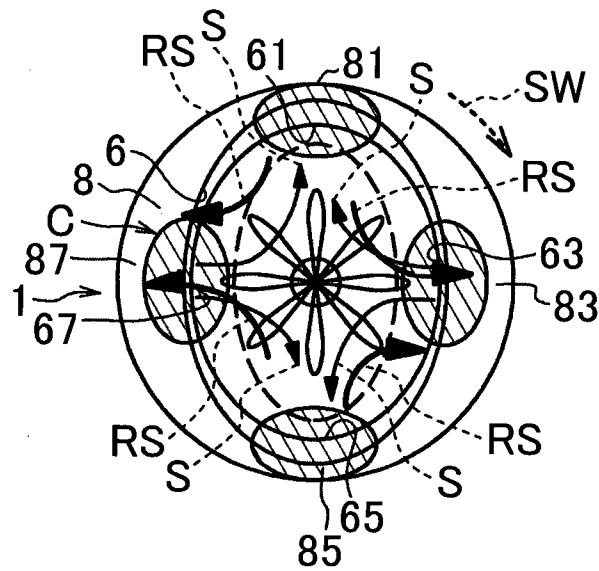


FIG. 3B

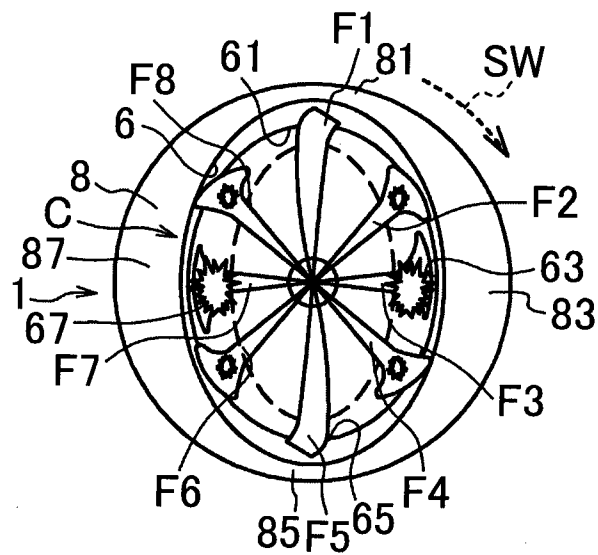


FIG. 3C

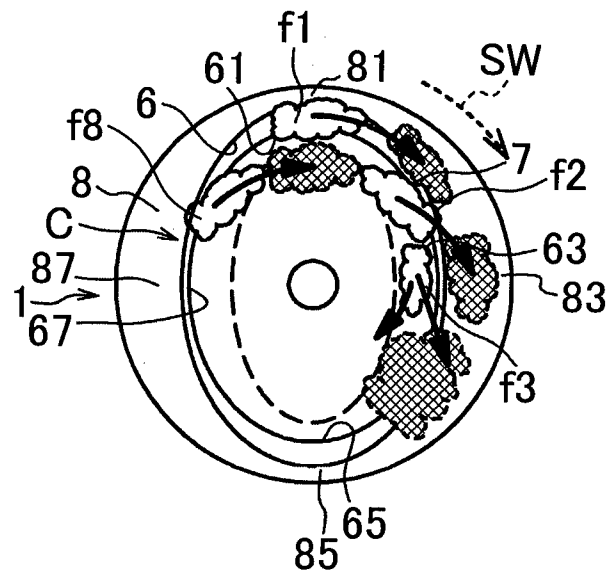


FIG. 4A

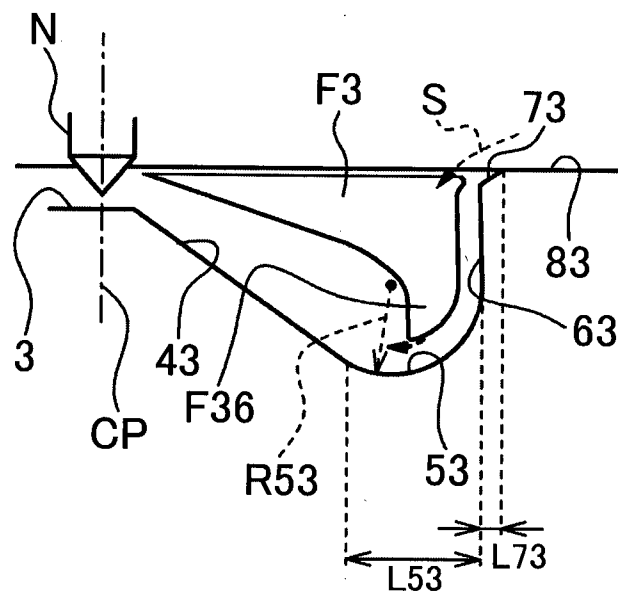


FIG. 4B

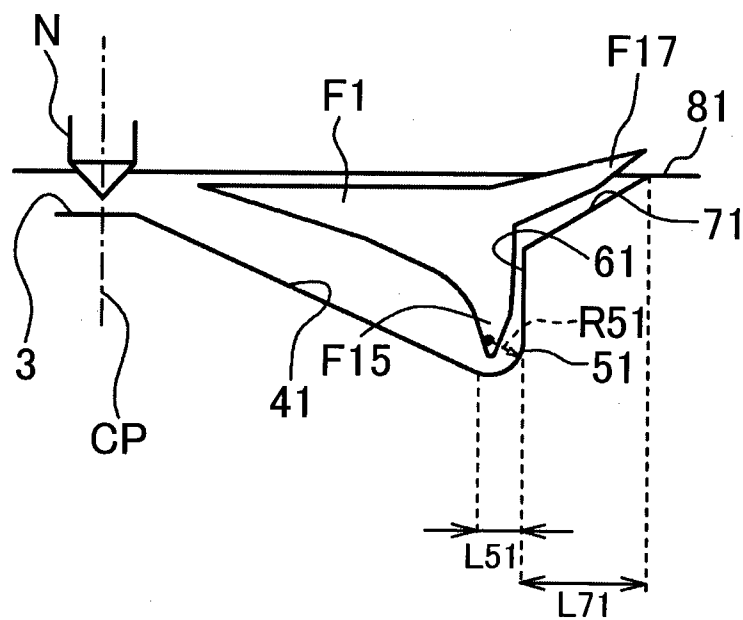
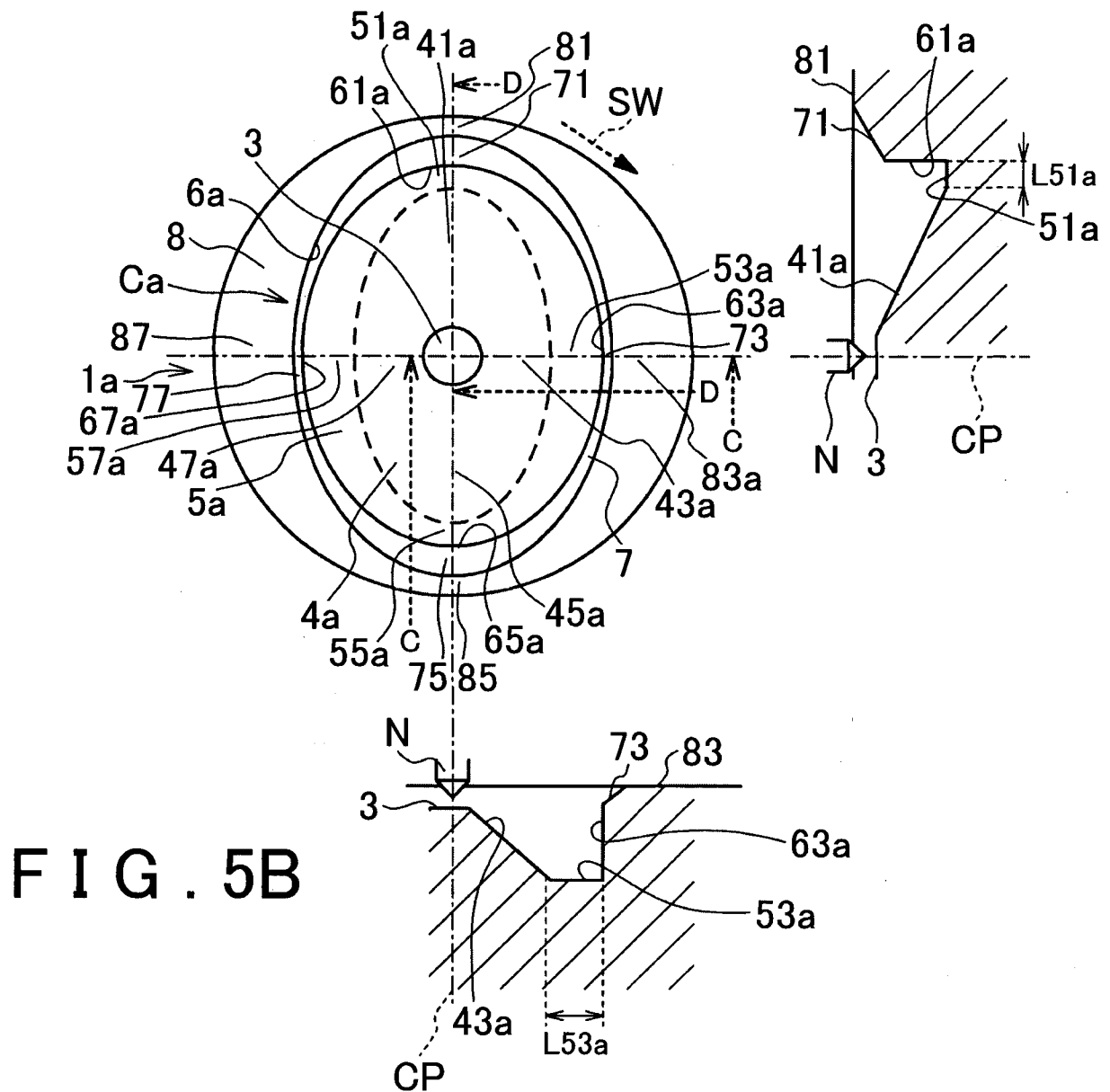


FIG. 5A

FIG. 5C



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FIG. 6A

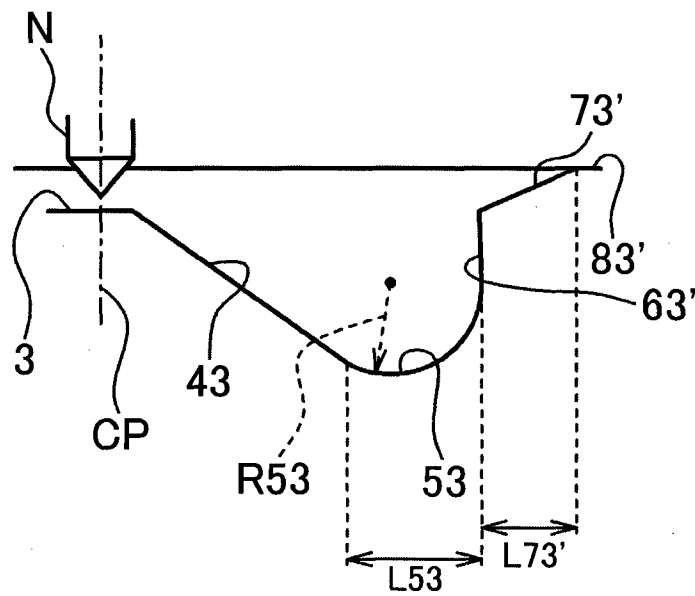


FIG. 6B

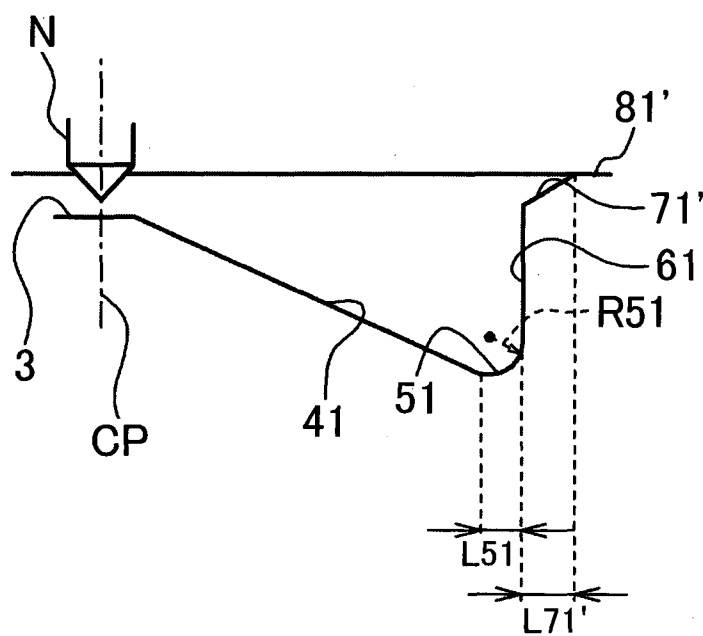


FIG. 7

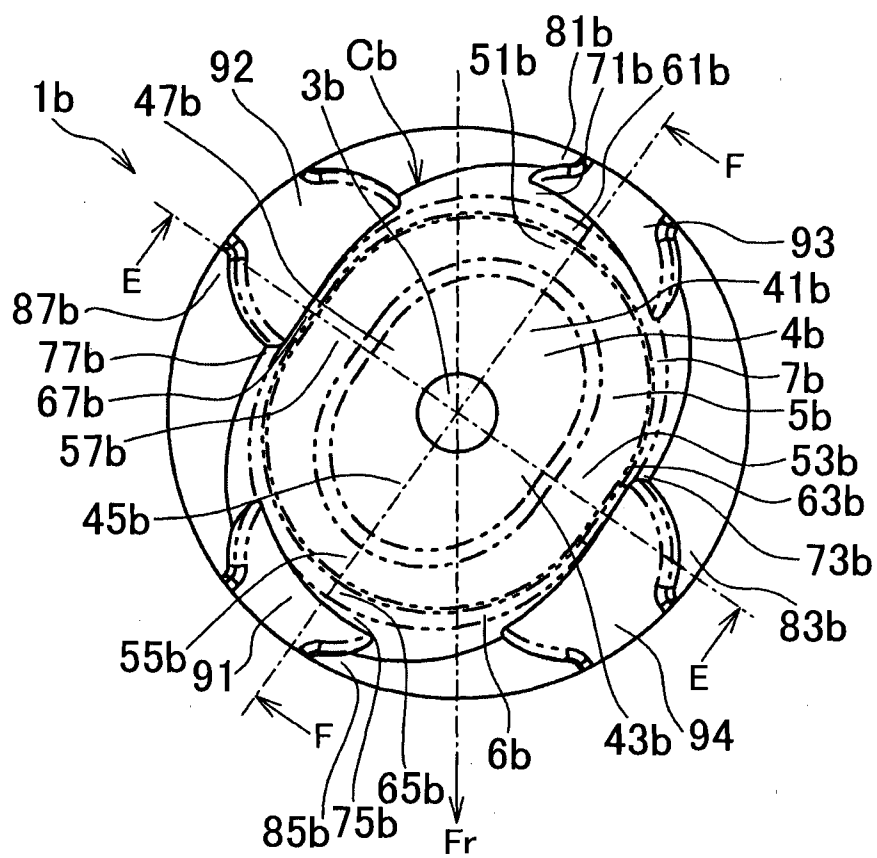


FIG. 8

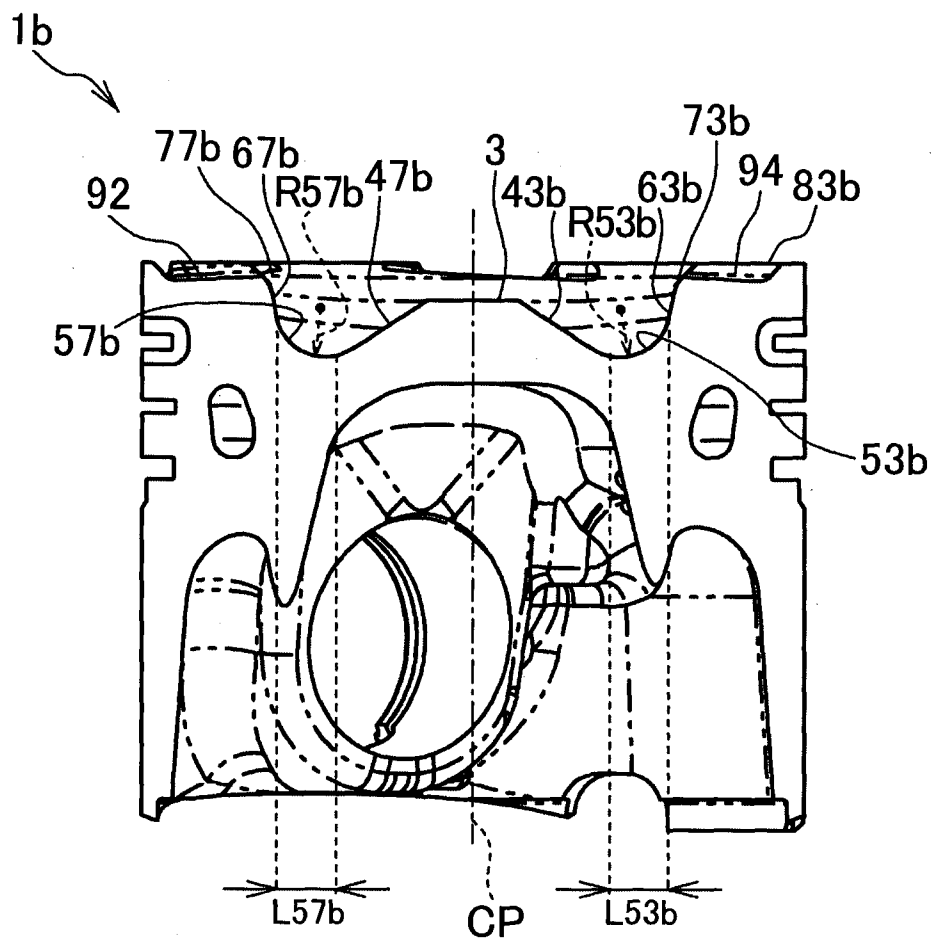


FIG. 9

