(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 108 706 B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: 24.08.88

(51) Int. Cl.⁴: **F 02 F 1/22**, F 02 B 25/02

(21) Application number: 83730100.1

(22) Date of filing: 21.10.83

(54) **Cylinder liner for a uniflow type two cycle internal combustion engine.**

(30) Priority: 04.11.82 JP 192509/82
10.11.82 JP 195967/82

(43) Date of publication of application:
16.05.84 Bulletin 84/20

(45) Publication of the grant of the patent:
24.08.88 Bulletin 88/34

(84) Designated Contracting States:
CH DE FR GB LI NL SE

(56) References cited:
CH-A- 200 570
DE-C- 736 326
DE-C- 754 166
GB-A- 851 353
US-A-1 732 856
US-A-2 720 195

The file contains technical information submitted after the application was filed and not included in this specification

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EP 0 108 706 B1

Courier Press, Leamington Spa, England.

Description

The present invention relates to a cylinder liner for an uniflow type two cycle internal combustion engine and more particularly to improvement of or relating to a cylinder liner of the type including a number of scavenging holes formed thereon in an equally spaced relation in the peripheral direction so as to assure improved scavenging efficiency.

DE—C—736 326 describes a cylinder liner for an uniflow type two-cycle internal combustion engine comprising a number of scavenging holes having different swirl angles at the upper and lower hole part.

US—A—27 20 195 indicates that scavenging can be improved not only by drilling the different portions at different angles but also by disposing the overlapping portions of the part obliquely to the cylinder axis.

To facilitate understanding of the present invention it will be helpful that a conventional cylinder liner for an uniflow type two cycle internal combustion engine will be described with reference to Figures 1 to 4.

Figure 1 schematically illustrates a part of an uniflow type two cycle internal combustion engine, wherein reference numeral 1 designates a cylinder liner, reference numeral 2 does a number of scavenging holes, reference 3 does a cylinder, reference numeral 6 does a piston, reference numeral 7 does a cylinder jacket, reference numeral 8 does a cylinder cover and reference numeral 9 does an exhaust valve.

As illustrated in Figures 2 to 4, the conventional uniflow type two cycle internal combustion engine usually has a number of scavenging holes 2 arranged in an equally spaced relation along the cylindrical wall of the cylinder liner 1 at its lower part by way of which fresh air is caused to flow into the interior of the cylinder 3 thereby to expell combustion gas upwardly in the axial direction. Thus, combustion gas is replaced with fresh air required for next combustion. Specifically, each of the scavenging holes 2 is formed in such a manner that the center line 5 extending on the lower edge surface 2_a is directed toward the center 4 of the cylinder and the upper edge surface 2_b is offset from the lower edge surface 2_a as illustrated in Figure 3 while the direction of extension of both the upper and lower edge surfaces 2_a and 2_b is maintained unchanged. As a result the whole air passage extending through the wall of the cylinder liner 1 is inclined in the same direction as that of swirl flow S. Accordingly, the upper edge surface 2_b of the scavenging hole extends inwardly in the radial direction with a certain offset from the center 4 of the cylinder equal to a radius R as illustrated in Figure 4. Due to the arrangement of the scavenging holes made in that way fresh air flows into the interior of the cylinder 3 toward the center 4 thereof at the lower part of the scavenging holes 2 but it flows thereinto at the upper part of the latter while it swirls in the horizontal direction.

Since the conventional cylinder liner has the scavenging holes 2 formed in the above-described manner, it has been found that scavenging flow in the cylinder 3 is achieved as illustrated in Figure 5(a) and thereby the exhaust stroke is completed with a part of combustion gas staying in A, B, C and D sections in the drawing. As is apparent from the drawing, the section A occupies the largest space in the cylinder and acts as a significant factor of adversely affecting scavenging efficiency. Further, the A section is an area where comparatively stable gas flow is achieved and the higher pressure difference between both the inside and outside of the cylinder 3 is, the bigger the space occupied by the section A becomes. As far as an internal combustion engine employing high scavenging pressure is concerned, it is an essential requirement that this section is reduced or minimized.

To obviate the foregoing problem of expelling residual exhaust gas staying in the section A there was proposed a method of extending the upper edge surface 2_b of the scavenging holes inwardly in the radial direction with substantially increased offset from the center of the cylinder 3. However, when the proposed method is employed in accordance with the conventional arrangement of the scavenging holes 2, it results that ribs 2_c between the adjacent scavenging holes 2 are caused to incline at an increased inclination angle which leads to reduction of their mechanical strength. On the other hand, when the ribs 2_c has a wide width to compensate for reduction of mechanical strength, there is no fear of causing a problem relative to mechanical strength, but another problem is that there occurs shortage in total area of the scavenging holes 2.

Thus, the present invention has been made with the above-mentioned background in mind and its object resides in providing an improved cylinder linear for an uniflow type two cycle internal combustion engine which assures that improved scavenging efficiency is achieved while ribs between adjacent scavenging holes are configured properly.

Other object of the present invention is to provide an improved cylinder liner for an uniflow type two cycle internal combustion engine which assures that ribs have a sufficiently high mechanical strength and scavenging holes have sufficient area in total while the configuration of the ribs on the inner wall of the cylinder is designed so that good lubrication is achieved when a piston passes by the scavenging holes.

Another object of the present invention is to provide an improved cylinder liner for an uniflow type two cycle internal combustion engine which can be manufactured with reduced working hours.

To accomplish the above objects there is proposed in accordance with the present invention a cylinder liner for an uniflow type two cycle internal combustion engine with the features described in claim 1 or claim 6.

The accompanying drawings will be briefly described below.

Figure 1 is a vertical sectional view of a part of an uniflow type two cycle internal combustion engine, schematically illustrating how a cylinder liner is fitted into a cylinder head.

Figure 2 is a fragmental vertical sectional view of the cylinder liner with a scavenging hole formed thereon, shown in an enlarged scale.

Figure 3 is a front view of the cylinder liner as seen in the direction as identified with reference numeral III in Figure 2.

Figure 4 is a cross-sectional view of the cylinder liner taken in line IV—IV in Figure 3.

Figure 5(a) schematically illustrates how scavenging is effected with the conventional cylinder liner while a part of exhaust gas resides in several sections in the latter after completion of exhaust stroke.

Figure 5(b) schematically illustrates how scavenging is effected with the cylinder liner of the invention while very few exhaust gas resides in several sections in the cylinder liner after completion of exhaust stroke.

Figures 6(a) to (c) schematically illustrate a cylinder liner in accordance with the first embodiment of the invention, wherein Figure 6(a) is a front view of the cylinder liner illustrating both the outer and inner openings of a scavenging hole formed on the cylinder liner, the outer opening being shown in real lines and the inner opening being shown in dotted lines, Figure 6(b) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 6(a), and Figure 6(c) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 6(a).

Figures 7(a) to (c) schematically illustrate a cylinder liner in accordance with the second embodiment of the invention, wherein Figure 7(a) is a front view of the cylinder liner similar to Figure 6(a), Figure 7(b) is a fragmental cross-sectional view of the cylinder liner taken in line A′—A′ in Figure 7(a), and Figure 7(c) is a fragmental cross-sectional view of the cylinder liner take in line B′—B′ in Figure 7(a).

Figures 8(a) to (c) schematically illustrate a cylinder liner in accordance with the third embodiment of the invention, wherein Figure 8(a) is a front view of the cylinder liner similar to Figure 6(a), Figure 8(b) is a fragmental cross-sectional view of the cylinder liner taken in line A″—A″ in Figure 8(a), and Figure 8(c) is a fragmental cross-sectional view of the cylinder liner taken in line B″—B″ in Figure 8(a).

Figures 9(a) to (c) illustrate results of experiments which were carried out under such a working condition that the lower swirl angle θ_1 is fixedly determined to 5 degrees and the upper swirl angle θ_2 varies in the range of 10 to 40 degrees, wherein Figure 9(a) is a fragmental cross-sectional view of a cylinder liner schematically illustrating how the swirl angles θ_1 and θ_2 are determined, Figure 9(b) illustrates by way of diagrams a relation between air intake ratio ρ and scavenging efficiency η_s, wherein the angles θ_1 and θ_2 serve as a parameter, and Figure 9(c) does a relation between swirl angle θ_2 and scavenging efficiency η_s, wherein swirl angle θ_1 is fixedly determined to 5 degrees and air intake ratio ρ is fixedly determined to 1.1.

Figures 10(a) to (d) schematically illustrate a cylinder liner in accordance with the fourth embodiment of the invention, wherein Figure 10(a) schematically illustrates an inner opening of a scavenging hole comprising three circular holes arranged in an end-to-end relation, shown by dotted lines, Figure 10(b) does an outer opening of the same, shown by real lines, Figure 10(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 10(a) and Figure 10(d) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 10(a).

Figures 11(a) to (d) schematically illustrate a cylinder liner in accordance with the fifth embodiment of the invention, wherein Figure 11(a) schematically illustrates an inner opening of a scavenging hole comprising three circular holes arranged in an end-to-end relation, shown by dotted lines, Figure 11(b) does an outer opening of the same, shown by real lines, Figure 11(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 10(a) and Figure 10(d) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 11(a).

Figures 12(a) to (d) schematically illustrate a cylinder liner in accordance with the sixth embodiment of the invention, wherein Figure 12(a) schematically illustrates an inner opening of a scavenging hole comprising three circular holes arranged in an end-to-end relation, shown by dotted lines, Figure 12(b) does an outer opening of the same, shown by real lines, Figure 12(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 12(a) and Figure 12(d) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 12(a).

Figures 13(a) to (d) schematically illustrate a cylinder liner in accordance with the seventh embodiment of the invention, wherein Figure 13(a) schematically illustrates an inner opening of a scavenging hole comprising three circular holes arranged in an end-to-end relation, shown by dotted lines, Figure 13(b) does an outer opening of the same, shown by real lines, Figure 13(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 13(a) and Figure 13(d) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 13(a).

Figures 14(a) to (d) schematically illustrate a cylinder liner in accordance with the eighth embodiment of the invention, wherein Figure 14(a) schematically illustrates an inner opening of a scavenging hole comprising three circular holes arranged in an end-to-end relation, shown by dotted lines, Figure 14(b) does an outer opening of the same, shown by real lines, Figure 14(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 14(a) and Figure 14(d) is a fragmental cross-sectional view of the cylinder liner taken in line B—B in Figure 14(a), and

Figures 15(a) to (c) illustrate results of experiments which were carried out under such a working condition that the lower swirl angle θ_1 is fixedly determined to 5 degrees, the central swirl angle θ_2 is fixedly determined to 10 degrees and the upper swirl angle θ_3 varies as a parameter in the range of 20 to 40 degrees, wherein Figure 15(a) is a fragmental cross-sectional view of a cylinder liner schematically illustrating how swirl angles θ_1, θ_2 and θ_3 are determined, Figure 15(b) illustrates by way of diagrams a relation between air intake ratio ρ and scavenging efficiency η_s, wherein the upper swirl angle θ_3 varies in three steps of 20, 30 and 40 degrees, and Figure 15(c) does a relation between swirl angle θ_3 and scavenging efficiency η_s, wherein swirl angle θ_1 is fixedly determined to 5 degrees, swirl angle θ_2 is fixedly determined to 10 degrees and air intake ratio ρ is fixedly determined to 1.1.

Now, the present invention will be described in a greater detail hereunder with reference to Figures 6 to 15 which illustrate several preferred embodiments of the invention. In this connection it should be noted that the same or similar parts and components illustrated throughout the drawings as those in the conventional cylinder liner illustrated in Figures 1 to 4 are identified with the same reference numerals.

First, Figures 6(a) to (c) schematically illustrate the construction of a cylinder liner in accordance with the first embodiment of the invention. As is apparent from the drawings, the center line Y_1—Y_1 extending across the outer opening 2_d of the scavenging hole on the outer peripheral surface of the cylinder liner is inclined at an angle of α_1 relative to the axis line Z—Z of the same. The direction of inclination of the angle α_1 is oriented opposite to that of the swirl flow S. On the other hand, the center line Y_2—Y_2 extending across the inner opening 2_e of the scavenging hole on the inner peripheral surface of the cylinder liner is inclined at an angle of α_2 relative to the axis line Z—Z of the same, wherein said inclination angle α_2 is determined less than that of the conventional cylinder liner, as is readily seen from Figure 6(a). It results that the center line Y_1—Y_1 on the outer opening formed on the outer peripheral surface of the cylinder liner is inclined at angle of $\alpha_1+\alpha_2(>0)$ relative to the other center line Y_2—Y_2 on the inner opening formed on the inner peripheral surface of the same.

Incidentally, Figure 6(b) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 6(a), whereas Figure 6(c) is a fragmental cross-sectional view similar to Figure 6(b) taken in line B—B in Figure 6(a). As is apparent from the drawings, the swirl angle θ_2 at the upper edge surface of the scavenging hole is designed substantially larger than the swirl angle θ_1 at the lower edge surface 2_a of the same and the swirl angle θ'_2 at the central part of the scavenging hole is designed appreciably larger than the swirl angle θ_1 at the lower edge surface 2_a of the cylinder liner. Thus, the following inequality will be established.

$$\theta_2>\theta'_2>\theta_1$$

Thus, the scavenging hole extends through the cylinder liner while it is increasingly twisted away from the vertical plane in the above-described manner.

Next, operation of the cylinder liner as constructed in accordance with the first embodiment of the invention will be described below.

At the beginning time when the scavenging holes are opened as the piston is displaced downwardly during its downward stroke scavenging air is caused to flow through the upper part of each of the scavenging holes. Since the scavenging hole extends at a large swirl angle θ_2 across the aforesaid upper part thereof, intensive swirling flow is produced whereby residual exhaust gas in the A section as illustrated in Figure 5(b) is blown away. As the piston is displaced downward further, the swirl angle θ_2 is gradually reduced. When the upper surface of the piston becomes flush with the lower edge surface 2_a of the scavenging hole, it assumes the minimum swirling angle θ_1 and thereby the swirling flow S is weakened with scavenging effected toward the center of the cylinder. As a result residual exhaust gas staying at the central part of the cylinder is scavenged. Thus, remarkably improved scavenging is assured for residual exhaust gas in the interior of the cylinder, as schematically illustrated in Figure 5(b). Further, since each of the scavenging hole ribs 2_c has a reduced inclination angle α_2 on the inner surface of the cylinder liner, it is assured that excellent lubrication is achieved when piston rings pass by the scavenging holes 2.

Next, Figures 7(a) to (c) schematically illustrate the construction of a cylinder liner in accordance with the second embodiment of the invention. In practice, this embodiment corresponds to the case where the inclination angle α_2 in the first embodiment as illustrated in Figure 6 liner becomes zero and therefore the center line Y_1—Y_1 extending across the outer opening of the scavenging hole 2 on the outer peripheral surface of the cylinder liner is inclined at an angle of $\alpha_1-\alpha_2(>0)$ relative to the center line Y_2—Y_2 extending across the inner opening on the inner peripheral surface of the same. As is apparent from Figure 7(a), the center line Y_2—Y_2 is superimposed on the axis line Z—Z of the cylinder.

Next, Figures 8(a) to (c) schematically illustrate the construction of a cylinder liner in accordance with the third embodiment of the invention. In this embodiment the center line Y_2—Y_2 extending across the inner opening of the scavenging hole 2 on the inner peripheral surface of the cylinder liner is inclined at an angle α_2 relative to the center axis Z—Z of the cylinder in the same direction as the center line Y_1—Y_1 extending across the outer opening on the outer peripheral surface of the same, the latter being inclined at an angle α_1 relative to the center axis Z—Z of the cylinder. In this case the center line Y_1—Y_1 is inclined at an angle of $\alpha_1-\alpha_2(>0)$ relative to the center line Y_2—Y_2 but the cylinder liner in accordance with this embodiment functions in the substantially same manner as in the first embodiment.

As described above, the cylinder liner in accordance with any one of the first to third embodiments is constructed in such a manner that the center line Y_1—Y_1 extending across the outer opening of the scavenging hole is inclined in the opposite direction to that of the swirl S.

Figures 9(a) to (c) illustrates improvement in scavenging efficiency which can be achieved by the construction of the scavenging holes on the cylinder liner in accordance with the first to third embodiments of the invention. Figures 9(b) and (c) show results of experiments which were conducted under the operating conditions where swirl angle θ_1 at the lower edge surface of the scavenging hole is fixedly determined to 5 degrees and swirl angle θ_2 on the upper edge surface of the same varies in the range of 10 to 40 degrees, as illustrated in Figure 9(a). Specifically, Figure 9(b) illustrates by way of diagrams a relation between air intake ratio ρ and scavenging efficiency η_s, wherein the angles θ_1 and θ_2 serve as a parameter, and Figure 9(c) does a relation between swirl angle θ_2 and scavenging efficiency η_s, wherein swirl angle θ_1 is fixedly determined to 5 degrees and air intake ratio ρ is fixedly determined to 1.1.

As is apparent from Figure 9(c) where air intake ratio ρ is determined to 1.1 and swirl angle θ_1 is determined to 5 degrees, scavenging efficiency tends to increase when swirl angle θ_2 at the upper part of the scavenging hole is determined to 10 degrees or more or less and it reaches the highest level when swirl angle θ_2 is determined to 30 degrees or more or less. In this case of experiments inclination angles α_1 and α_2 of openings of a scavenging hole on the cylinder line are determined as a function relative to height of scavenging hole, number of scavenging holes and swirl angle θ'_2.

As is readily understood from the above description, a cylinder liner for an uniflow type two cycle inner combustion engine in accordance with the first to third embodiments of the invention is constructed such that the center line Y_1—Y_1 extending across the outer opening of each of the scavenging holes on the outer peripheral surface of the cylinder liner is inclined in the opposite direction to that of the swirl flow S and the upper swirl angle θ_2 is determined larger than the lower swirl angle θ'_2 so that air passage extending through the scavenging holes is twisted away from the vertical plane. Thus, it is assured that scavenging efficiency is substantially improved while the configuration of ribs between a series of scavenging holes is determined properly.

Next, Figures 10(a) to (d) schematically illustrate a cylinder liner in accordance with the fourth embodiment of the invention, wherein Figures 10(a) and (b) are a fragmental view of a scavenging hole as seen from the position located outwardly of the peripheral surface of the cylinder liner. As is apparent from the drawings, the axis line Y_1—Y_1 extending across the outer opening 2_f of the scavenging hole on the outer peripheral surface of the cylinder liner (linear line extending through both the center O_1 of the lower hole and the center O_3 of the upper hole) is inclined at an angle of α_1 relative to the axis line Z—Z of the cylinder. It should be noted that the axis line Y_1—Y_1 is inclined in the opposite direction to that of the swirl S as illustrated in Figures 10(c) and (d). Further, the axis line Y_2—Y_2 extending across the inner opening 2_e of the scavenging hole on the inner peripheral surface of the cylinder liner is superimposed on the axis line Z—Z of the cylinder as is apparent from Figure 10(a). Accordingly, the axis line Y_1—Y_1 extending across the outer opening on the outer peripheral surface of the cylinder liner is inclined at an angle of α_1 relative to the axis line Y_2—Y_2 extending across the inner opening on the inner peripheral surface of the same.

Incidentally, Figure 10(c) is a fragmental cross-sectional view of the cylinder liner taken in line A—A in Figure 10(a) and Figure 10(d) is a fragmental cross-sectional view of the same taken in line B—B in Figure 10(a). As illustrated in Figures 10(c) and (d), the swirl angle θ_3 at the upper hole part of the scavenging hole is determined substantially larger than the swirl angle θ_1 at the lower hole part of the same. Further, as illustrated in Figure 10(c), the swirl angle θ_2 of the central part of the scavenging hole is determined appreciably larger than the swirl angle θ_1 of the lower part of the same. Accordingly, the following inequality will be established

$$\theta_3>\theta_2>\theta_1$$

Thus, the scavenging hole extends through the cylinder liner while it is increasingly twisted away from the vertical plane in the above-described manner.

As is apparent from Figures 10(c) and (d), the centers (O_1, O'_1), (O_2, O'_2) and (O_3, O'_3) of both the outer and inner openings of the scavenging hole are located on a plane extending at a right angle relative to the axis line Z—Z of the cylinder respectively.

It should be noted that as is apparent from Figures 10(c) and (d), the inner opening on the inner peripheral surface of the cylinder liner at each of the upper, central and lower parts of the scavenging hole has the same width B as measured in the peripheral direction.

Next, Figures 11(a) to (d) schematically illustrate a cylinder liner in accordance with the fifth embodiment of the invention. In this embodiment the center O_2 of the central part of the scavenging hole is located in alignment with the axis line Y_1—Y_1 which extends through both the center O_1 of the lower part and the center O_3 of the upper part as is the case with the fourth embodiment illustrated in Figure 10(b).

Next, Figures 12(a) to (d) schematically illustrate a cylinder liner in accordance with the sixth embodiment of the invention. This embodiment is substantially same to the foregoing ones as illustrated in Figures 10 and 11 with exception that each of hole parts constituting the scavenging hole has the same inner diameter. Assuming that each of the hole parts on the inner peripheral surface of the cylinder liner has the same width as measured in the peripheral direction as in case of the foregoing embodiments illustrated in Figures 10 and 11, it results that the inner diameter of each of the hole parts is caused to decrease as each of the swirl angles θ_1, θ_2 and θ_3 increases. On the other hand, when each of the hole parts has the same inner diameter as in case of the sixth embodiment as illustrated in Figure 12, the rib between the adjacent scavenging holes has a width which varies in dependence on the position on the latter. Therefore, in view of the above-described embodiments an intermediate case may be proposed where the width of the rib between the adjacent scavenging holes varies appreciably in dependence on the position on the latter and moreover the inner diameter of each of the hole parts varies appreciably in dependence on the position on the scavenging hole.

Next, Figures 13(a) to (d) schematically illustrate a cylinder liner in accordance with the seventh embodiment of the invention. In this embodiment the cylinder liner is constructed in the different manner from the fourth embodiment as illustrated in Figure 10 such that the axis line Y_2—Y_2 extending across the inner opening 2_e on the inner peripheral surface of the cylinder liner is inclined at an angle α_2 relative to the axis line Z—Z of the cylinder in the leftward direction while the axis line Y_1—Y_1 extending across the outer opening 2_f on the outer peripheral surface of the cylinder liner is inclined at an angle α_1 relative to the axis line Z—Z of the cylinder in the righthand direction as seen in the drawing. Accordingly, the axis line Y_1—Y_1 on the outer opening of the scavenging hole is inclined by an angle $\alpha_1+\alpha_2(>0)$ relative to the axis line Y_2—Y_2 on the inner opening of the same.

Finally, Figures 14(a) to (d) schematically illustrate a cylinder liner in accordance with the eighth embodiment of the invention. In this embodiment the axis line Y_2—Y_2 extending across the inner opening 2_e on the inner peripheral surface of the cylinder liner is inclined at an angle of α_2 relative to the axis line Z—Z of the cylinder in the rightward direction and the axis line Y_1—Y_1 extending across the outer opening 2_f on the outer peripheral surface of the same is inclined at an angle of α_1 relative to the axis line Z—Z of the cylinder in the rightward direction as seen in the drawing, that is, in the same direction as that of the axis line Y_2—Y_2. In this case the axis line Y_1—Y_1 is inclined at an angle $\alpha_1-\alpha_2(>0)$ relative to the axis line Y_2—Y_2.

As is readily understood from the above description, the cylinder liner in accordance with any one of the fourth to eighth embodiments is constructed such that the axis line Y_1—Y_1 extending across the outer opening of the scavenging hole is inclined in the opposite direction to that of the swirl flow S as in case of the first to third embodiments.

Next, operation of the cylinder liner as constructed in accordance with each of the fourth to eighth embodiments of the invention will be described below.

At the beginning time when the scavenging holes are opened as the piston is displaced downwardly during its downward stroke scavenging air is caused to flow through the upper part of each of the scavenging holes. Since the upper part of the scavenging hole extends through the wall of the cylinder liner at a large swirl angle θ_3, intensive swirling flow S is produced whereby residual exhaust gas staying in the A section as illustrated in Figure 5(b) is blown away.

When the piston is displaced downward further until all the scavenging holes are completely opened, swirl angle is reduced to an angle of θ_1 whereby scavenging air is caused to flow toward the center of the cylinder, resulting in residual exhaust gas in the central part of the cylinder being scavenged completely.

On the other hand, with respect to ribs between the adjacent scavenging holes the cylinder liner in accordance with the fifth embodiment as illustrated in Figure 11 has no inclination relative to the axis line Z—Z of the cylinder and the cylinder liner in accordance with the fourth and sixth embodiments as illustrated in Figures 10 and 12 has a certain inclination less than that of the ribs on the conventional cylinder liner. Owing to the arrangement made in that way it is assured that excellent lubrication is achieved when piston rings pass by the scavenging holes.

Figures 15(a) to (c) illustrates improvement in scavenging efficiency which can be achieved by the construction of the scavenging holes on the cylinder liner in accordance with the fourth to eighth embodiments of the invention, wherein Figure 15(a) is a fragmental cross-sectional view of the cylinder liner particularly illustrating how swirl angles θ_1, θ_2 and θ_3 are determined and Figures 15 (b) and (c) show results of experiments which were conducted under the operating conditions where swirl angle θ_1 at the lower hole part is fixedly determined to 5 degrees, swirl angle θ_2 at the central hole part is fixedly determined to 10 degrees and swirl angle θ_3 at the upper hole part varies at three stages of 20, 30 and 40 degrees. Specifically, Figure 15(b) illustrates by way of diagrams a relation between air intake ratio ρ and scavenging efficiency η_s with swirl angle θ_3 fixedly determined as a parameter and Figure 15(c) does a relation between swirl angle θ_3 and scavenging efficiency η_s when swirl angle θ_1 is fixedly determined to 5 degrees, swirl angle θ_2 is fixedly determined to 10 degrees and air intake ratio ρ is fixedly determined to 1.1. As is apparent from Figure 15(c), scavenging efficiency η_s increases as swirl angle θ_3 increases in the range of 20 to 30 degrees and it reaches the highest level when swirl angle θ_3 is determined to 30 degrees or more or less.

Inclination angles α_1 and α_2 of the scavenging holes are determined as function relative to height of scavenging holes, number of the latter and swirl angles. Since each of the scavenging holes on the cylinder liner in accordance with the fourth to eighth embodiments of the invention is constructed by a combination of plural circular holes, it is assured that it has a large swirl angle θ_3 at its upper hole part and a small swirl angle θ_1 at its lower hole part while each of the ribs between the adjacent scavenging holes has a proper configuration with working hours required for forming them being reduced to the minimum, resulting in improved scavenging efficiency guaranteed.

As described above, a cylinder liner for an uniflow type two cycle internal combustion engine in accordance with the fourth to eighth embodiments is constructed so that each of scavenging holes comprises a combination of plural circular holes which are arranged in an end-to-end relation in the substantially axial direction of the cylinder liner in such a manner that the axis line Y_1—Y_1 extending through the center of the lowermost hole part and the center of the uppermost hole part on the outer opening of the scavenging hole on the outer peripheral surface of the cylinder liner is inclined in the opposite direction to that of the scavenging swirl flow S, wherein the upper swirl angle θ_3 is determined larger than the lower swirl angle θ_1 so that the center line extending through the center of each of the hole parts constituting the scavenging hole is twisted away from the vertical plane. Owing to the arrangement made in that way it is assured that each of the scavenging holes is formed with the minimized working hours required while ribs between the adjacent scavenging holes have proper configuration and sufficiently high strength and moreover remarkably improved scavenging efficiency is achieved with excellent lubricating function being maintained when the piston passes by the scavenging holes.

Claims

1. A cylinder liner (1) for an uniflow type two cycle internal combustion engine of the type including a number of scavenging holes (2) formed in an equally spaced relation in the peripheral direction, characterized in that the center lines (Y_1—Y_1) extending across the outer openings (2d) of the scavenging holes (2) in the direction of the cylinder head on the outer peripheral surface of the cylinder liner are inclined with respect to the cylinder axis in the opposite direction to that of the scavenging swirl flow S and the swirl angle (θ_2) at the upper edge surface (2b) of each scavenging hole is determined larger than the swirl angle (θ'_2) at the lower edge surface (2a) of the same scavenging hole so that the air passages extending through each of the scavenging holes is twisted such that a swirl angle thereof is gradually increasing from the lower portion to the upper portion of the scavenging hole along the direction Z—Z parallel to the axial direction of the cylinder liner.

2. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 1, characterized in that each of the scavenging holes (2) has a substantially rectangular cross-sectional configuration.

3. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 2, characterized in that the center line (Y_2—Y_2) extending across the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner is inclined in the same direction as that of the scavenging swirl flow S relative to the axis line (Z—Z) of the cylinder.

4. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 2, characterized in that the center line (Y_2—Y_2) extending across the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner extends in parallel to the axis line (Z—Z) of the cylinder.

5. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 2, characterized in that the center line (Y_2—Y_2) extending across the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner is inclined in the opposite direction to that of the scavenging swirl flow S relative to the axis line (Z—Z) of the cylinder and its inclination angle α_2 is determined smaller than an inclination angle α_1 of the center line (Y_1—Y_1) extending across the outer opening of the scavenging holes on the outer peripheral surface of the cylinder liner.

6. A cylinder line (1) for an uniflow type two cycle internal combustion engine of the type including a number of scavenging holes (2) formed in an equally spaced relation in the peripheral direction, characterized in that each of the scavenging holes (2) comprises a combination of plural circular holes arranged in an end-to-end relation in the substantially axial direction of the cylinder and the linear line (Y_1—Y_1) extending through the center (O_1) of such lowermost hole part and the center (O_3) of such uppermost hole part on the outer opening (2f) of the scavenging holes on the outer peripheral surface of the cylinder liner in the direction of the cylinder head is inclined with respect to the cylinder axis in the opposite direction to that of the scavenging swirl flow S, and the swirl angle (θ_3) defined by the uppermost circular hole is larger than the swirl angle (θ_1) defined by the lowermost circular hole so that an air passage extending through each of the scavenging holes is twisted such that a swirl angle thereof is gradually increasing from the lower portion to the upper portion of the scavenging hole along the direction Z—Z parallel to the axial direction of the cylinder liner.

7. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 6, characterized in that the linear line (Y_2—Y_2) extending through the center (O_1') of the lowermost hole part and the center (O_3') of the uppermost hole part on the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner extends in parallel to the axis line (Z—Z) of the cylinder.

8. A cylinder liner for an uniflow type two cycle

internal combustion engine as defined in claim 6, characterized in that the linear line (Y_2—Y_2) extending through the center (O_1') of the lowermost hole part and the center (O_3') of the uppermost hole part on the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner is inclined in the same direction as that of the scavenging swirl flow S relative to the axis line (Z—Z) of the cylinder.

9. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 6, characterized in that the linear line (Y_2—Y_2) extending through the center (O_1') of the lowermost hole part and the center (O_3') of the uppermost hole part on the inner opening (2e) of the scavenging holes on the inner peripheral surface of the cylinder liner is inclined in the opposite direction to that of the scavenging swirl flow.

10. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 6, characterized in that the inner opening of each of the scavenging holes on the inner peripheral surface of the cylinder liner has the same width as measured in the peripheral direction.

11. A cylinder liner for an uniflow type two cycle internal combustion engine as defined in claim 6, characterized in that each of the scavenging holes has the same inner diameter.

Patentansprüche

1. Zylinderbüche einer Zweitaktbrennkraftmaschine vom Gleichstromtyp mit einer Anzahl von Spüllöcher (2), die in Umfangsrichtung in gleichmäßigem Abstand zueinander ausgebildet sind, dadurch gekennzeichnet, daß die Mittellinien (Y_1—Y_1), die sich über die äußeren Öffnungen (2d) der Spüllöcher (2) in Richtung des Zylinderkopfes auf der äußeren Umfangsfläche der Zylinderbüchse erstrecken, gegenüber der Zylinderachse in entgegengesetzter Richtung zu der der Spülwirbelströmung S geneigt sind, wobei der Wirbelwinkel (θ_2) an der oberen Kantenfläche (2b) jedes Spülloches größer als der Wirbelwinkel (θ_2) an der unteren Kantenfläche (2a) desselben Spülloches bestimmt wird, so daß der durch jedes der Spüllöcher verlaufende Luftkanal derart verwunden ist, daß deren Wirbelwinkel vom unteren Abschnitt zum oberen Abschnitt des Spülloches längs der Richtung Z—Z parallel zur Achsenrichtung der Zylinderbüchse nach und nach zunimmt.

2. Zylinderbüchse nach Anspruch 1, dadurch gekennzeichnet, daß jedes Spülloch (2) eine allgemein rechteckige Querschnittsform besitzt.

3. Zylinderbüchse nach Anspruch 2, dadurch gekennzeichnet, daß die Mittellinie (Y_2—Y_2). die sich über die Innenöffnung (2e) der Spüllöcher auf der Innenumfangsfläche der Zylinderbüchse erstreckt, in derselben Richtung geneigt ist wie die der Spülwirbelströmung S gegenüber der Achsenlinie (Z—Z) der Büchse.

4. Zylinderbüchse nach Anspruch 2, dadurch gekennzeichnet, daß die Mittellinie (Y_2—Y_2), die sich über die Innenöffnung (2e) der Spüllöcher auf der Innenumfangsfläche der Zylinderbüchse erstreckt, parallel zur Achsenlinie (Z—Z) des Zylinders verläuft.

5. Zylinderbüchse nach Anspruch 2, dadurch gekennzeichnet, daß die Mittellinie (Y_2—Y_2), die sich über die Innenöffnung (2e) der Spüllöcher auf der Innenumfangsfläche der Zylinderbüchse erstreckt, in entgegengesetzter Richtung zu der der Spülwirbelströmung S gegenüber der Achsenlinie (Z—Z) des Zylinders geneigt ist und deren Neigungswinkel α_2 kleiner als der Neigungswinkel α der über die Aussenöffnung der Spüllöcher auf der Aussenumfangsfläche der Zylinderbüchse verlaufenden Mittellinie (Y_1—Y_1) bestimmt ist.

6. Zylinderbüchse nach Anspruch 1, dadurch gekennzeichnet, daß jedes Spülloch (2) eine Kombination mehrerer kreisförmiger Löcher aufweist, die endweise zueinander in allgemein der axialen Richtung des Zylinders angeordnet sind und die Linie (Y_1—Y_1), die durch die Mitte (O_1) eines derartigen untersten Lochabschnitt und die Mitte (O_3) eines derartigen obersten Lochabschnitts auf der Aussenöffnung (2f) der Spüllöcher auf der Aussenumfangsfläche der Zylinderbüchse in der Richtung des Zylinderkopfes verläuft, gegenüber der Zylinderachse in der entgegengesetzten Richtung zu der der Spülwirbelströmung S geneigt ist, wobei der vom obersten kreisförmigen Loch bestimmte Wirbelwinkel (θ_3) größer ist als der vom untersten kreisförmigen Loch bestimmte Wirbelwinkel (θ_1), so daß ein durch jedes der Spüllöcher verlaufender Luftkanal derart verdreht ist, daß deren Wirbelwinkel vom unteren Abschnitt zum oberen Abschnitt des Spüllochs längs der Richtung Z—Z parallel zur Axialrichtung der Zylinderbüchse nach und nach zunimmt.

7. Zylinderbüchse nach Anspruch 6, dadurch gekennzeichnet, daß die Linie (Y_2—Y_2), die sich durch die Mitte (O_1') des untersten Lochabschnitts und die Mitte (O_3') des obersten Lochabschnitts auf der Innenöffnung (2e) der Spüllöcher auf der inneren Umfangsfläche der Zylinderbüchse erstreckt, parallel zur Achsenlinie (Z—Z) des Zylinders verläuft.

8. Zylinderbüchse nach Anspruch 6, dadurch gekennzeichnet, daß die Linie (Y_2—Y_2), die sich durch die Mitte (O_1') des untersten Lochabschnitts und die Mitte (O_3') des obersten Lochabschnitts auf der Innenöffnung (2e) der Spüllöcher auf der inneren Umfangsfläche der Zylinderbüchse erstreckt, in dieselbe Richtung wie die der Spülwirbelströmung S gegenüber der Achsenlinie (Z—Z) des Zylinders geneigt ist.

9. Zylinderbuchse nach Anspruch 6, dadurch gekennzeichnet, daß die Linie (Y_2—Y_2), die sich durch die Mitte (O_1') des untersten Lochabschnitts und die Mitte (O_3') des obersten Lochabschnitts auf der Innenöffnung (2e) der Spüllöcher auf der inneren Umfangsfläche der Zylinderbüchse erstreckt, in entgegengesetzter Richtung zu der der Spülwirbelströmung geneigt ist.

10. Zylinderbüchse nach Anspruch 6, dadurch gekennzeichnet, daß die Innenöffnung jedes Spülloches auf der inneren Umfangsfläche der

Zylinderbüchse dieselbe Breite wie die in der Umfangsrichtung gemessene besitzt.

11. Zylinderbüchse nach Anspruch 6, dadurch gekennzeichnet, daß jedes der Spüllöcher denselben Innendurchmesser hat.

Revendications

1. Chemise de cylindre (1) pour un moteur à combustion interne à deux temps du type équicourant, comprenant un certain nombre de lumières de balayage (2) formées dans des positions uniformément espacées dans la direction périphérique, caractérisée en ce que l'axe (Y_1—Y_1) allant d'un bord à l'autre des orifices extérieurs (2*d*) des lumières de balayage (2) dans la direction de la tête de cylindre au niveau de la surface périphérique extérieure de la chemise de cylindre est incliné par rapport à l'axe du cylindre, en sens inverse du sens de l'écoulement tourbillonnaire de balayage (S) et l'angle de déflexion tourbillonnaire (θ_2) de la surface du bord supérieur (2*b*) de chaque lumière de balayage est choisi plus grand que l'angle de déflexion tourbillonnaire (θ'_2) au niveau de la surface de bord inférieur (2*a*) de la même lumière de balayage, de sorte que les passages d'air qui s'étendent à travers chacune des lumières de balayage sont vrillés, de façon telle que l'angle de déflexion tourbillonnaire de ces passages d'accroît progressivement de la portion inférieure à la portion supérieure de la lumière de balayage, selon la direction (Z—Z) parallèle à la direction axiale de la chemise du cylindre.

2. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 1, caractérisée en ce que chacune des lumières de balayage (2) présente une configuration de section sensiblement rectangulaire.

3. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 2, caractérisée en ce que l'axe (Y_2—Y_2) allant d'un bord à l'autre de l'orifice intérieur (2*e*) des lumières de balayage au niveau de la surface périphérique intérieure de la chemise de cylindre, est incliné dans le même sens que le courant tourbillonnaire de balayage (S) par rapport à l'axe (Z—Z) du cylindre.

4. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 2, caractérisée en ce que l'axe (Y_2—Y_2) allant d'un bord à l'autre de l'orifice intérieur (2*e*) des lumières de balayage, au niveau de la surface périphérique intérieure de la chemise du cylindre s'étend parallèlement à l'axe (Z—Z) du cylindre.

5. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 2, caractérisée en ce que l'axe (Y_2—Y_2) allant d'un bord à l'autre de l'orifice intérieur (2*e*) des lumières de balayage au niveau de la surface périphérique intérieure de la chemise de cylindre est incliné en sens inverse de l'axe du courant tourbillonnaire de balayage (S) par rapport à l'axe (Z—Z) du cylindre et son angle d'inclinaison (α_2) est choisi plus petit que l'angle d'inclinaison (α) de l'axe (Y_1—Y_1) allant d'un bord à l'autre de l'orifice extérieur des lumières de balayage au niveau de la surface périphérique extérieure de la chemise de cylindre.

6. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant, comprenant un certain nombre de lumières de balayage (2) formées à espacement régulier dans la direction périphérique, caractérisée en ce que chacune des lumières de balayage (2) comprend une combinaison de trous circulaires multiples disposés bout à bout dans une direction sensiblement axiale du cylindre et l'axe (Y_1—Y_1) passant par le centre (O_1) du trou partiel inférieur et par le centre (O_3) du trou partiel extrême supérieur au niveau de l'orifice extérieur (2*f*) des lumières de balayage, au niveau de la surface périphérique extérieure de la chemise de cylindre dans la direction de la tête de cylindre est incliné par rapport à l'axe du cylindre en sens inverse de l'axe du courant tourbillonnaire de balayage (S), et l'angle de déflexion tourbillonnaire (θ_3) défini par le trou circulaire extrême supérieur est plus grand que l'angle de déflexion tourbillonnaire (θ_1) défini par le trou circulaire extrême inférieur, de sorte que le passage d'air qui s'étend à travers chacune des lumières de balayage est vrillé de telle manière que son angle de déflexion tourbillonnaire croisse progressivement de la partie inférieure à la partie supérieure de la lumière de balayage, le long de la direction (Z—Z) parallèle à la direction axiale de la chemise du cylindre.

7. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 6, caractérisée en ce que l'axe (Y_2—Y_2) qui passe par le centre (O'_1) du trou partiel extrême inférieur et par le contre (O'_3) du trou partiel extrême supérieur, au niveau de l'orifice intérieur (2*e*) des lumières de balayage, sur la surface périphérique intérieure de la chemise, s'étend parallèlement à l'axe (Z—Z) du cylindre.

8. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équicourant selon la revendication 6, caractérisée en ce que l'axe linéaire (Y_2—Y_2) qui passe par le centre (O'_1) ou trou partiel extrême inférieur et par le centre (O'_3) du trou partiel extrême supérieur au droit de l'orifice intérieur (2*e*) des lumières de balayage, au niveau de la surface périphérique intérieure de la chemise du cylindre est incliné dans le même sens que l'axe du courant tourbillonnaire de balayage (S) par rapport à l'axe géométrique (Z—Z) du cylindre.

9. Chemise de cylindre que un moteur à combustion interne à deux temps du type équicourant selon la revendication 6, caractérisée en ce que l'axe (Y_2—Y_2) qui passe par le centre (O'_1) du trou partiel extrême inférieur et par le centre (O'_3) du trou extrême supérieur au niveau de l'orifice intérieur (2*e*) des lumières de balayage, au niveau de la surface périphérique intérieure de la che-

mise du cylindre, est incliné en sens inverse de l'axe du courant tourbillonnaire de balayage.

10. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équi-courant selon la revendication 6, caractérisée en ce que l'orifice intérieur de chacun des lumières de balayage, au niveau de la surface périphérique intérieure de la chemise, possède la même largeur que celle mesurée dans la direction périphérique.

11. Chemise de cylindre pour un moteur à combustion interne à deux temps du type équi-courant selon la revendication 6, caractérisée en ce que toutes les lumières de balayage ont le même diamètre intérieur.

FIG.1

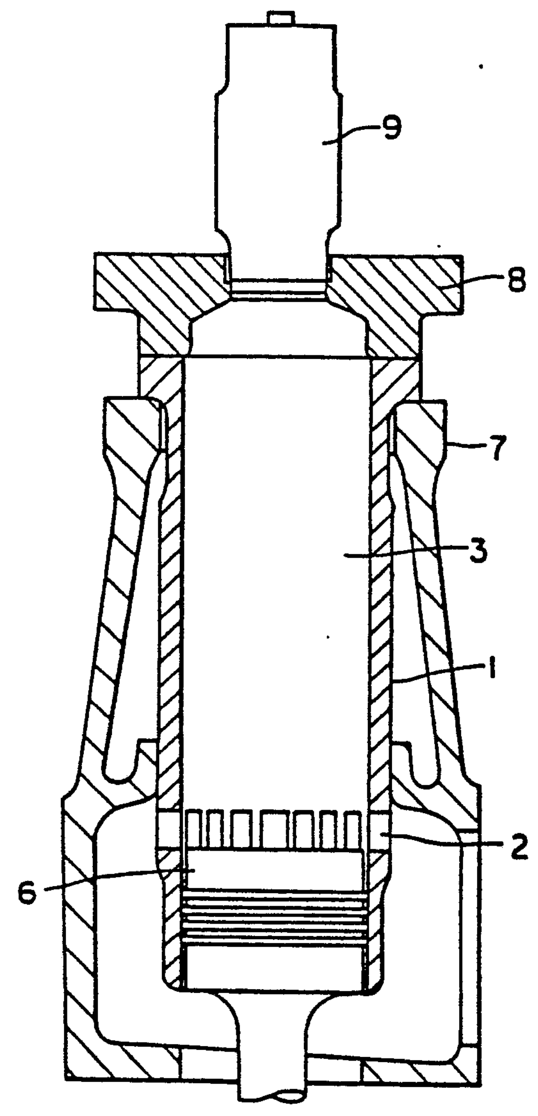


FIG.2

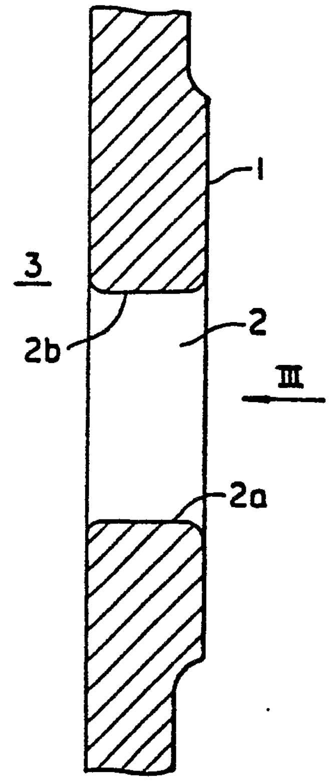


FIG.3

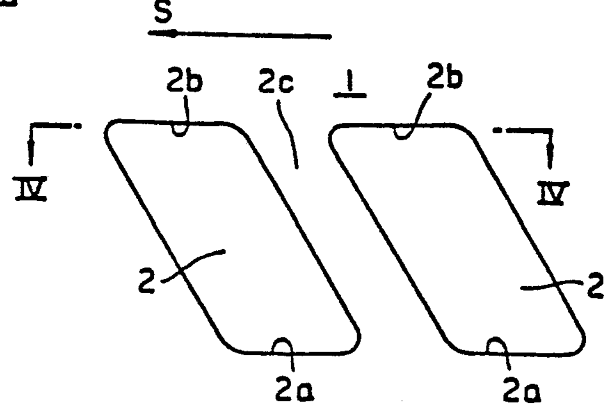


FIG.4

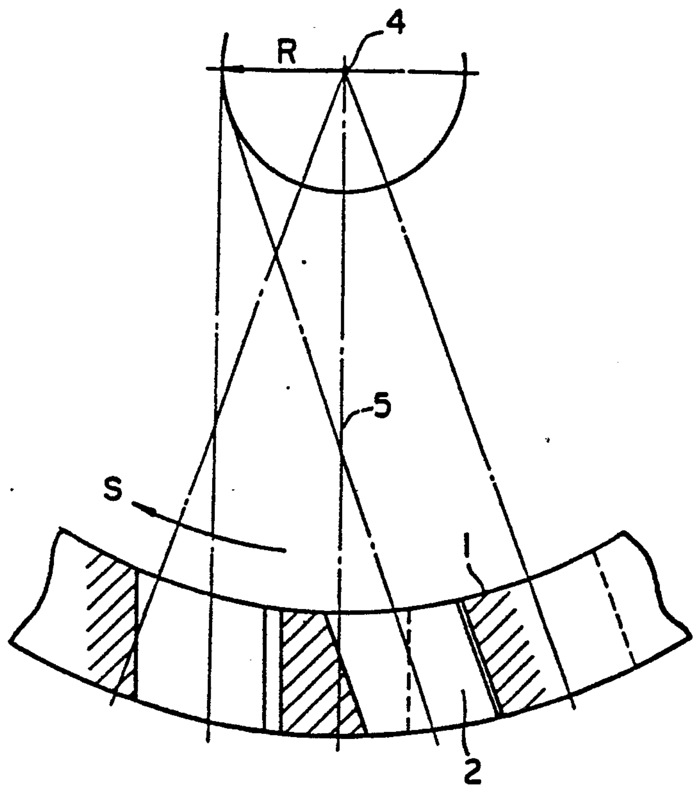


FIG.5

(a) (b)

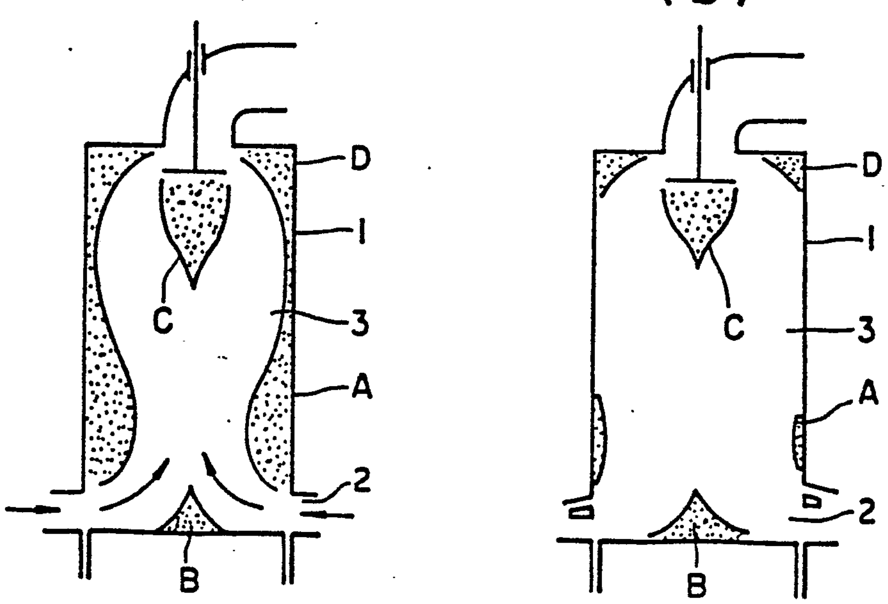


FIG. 6

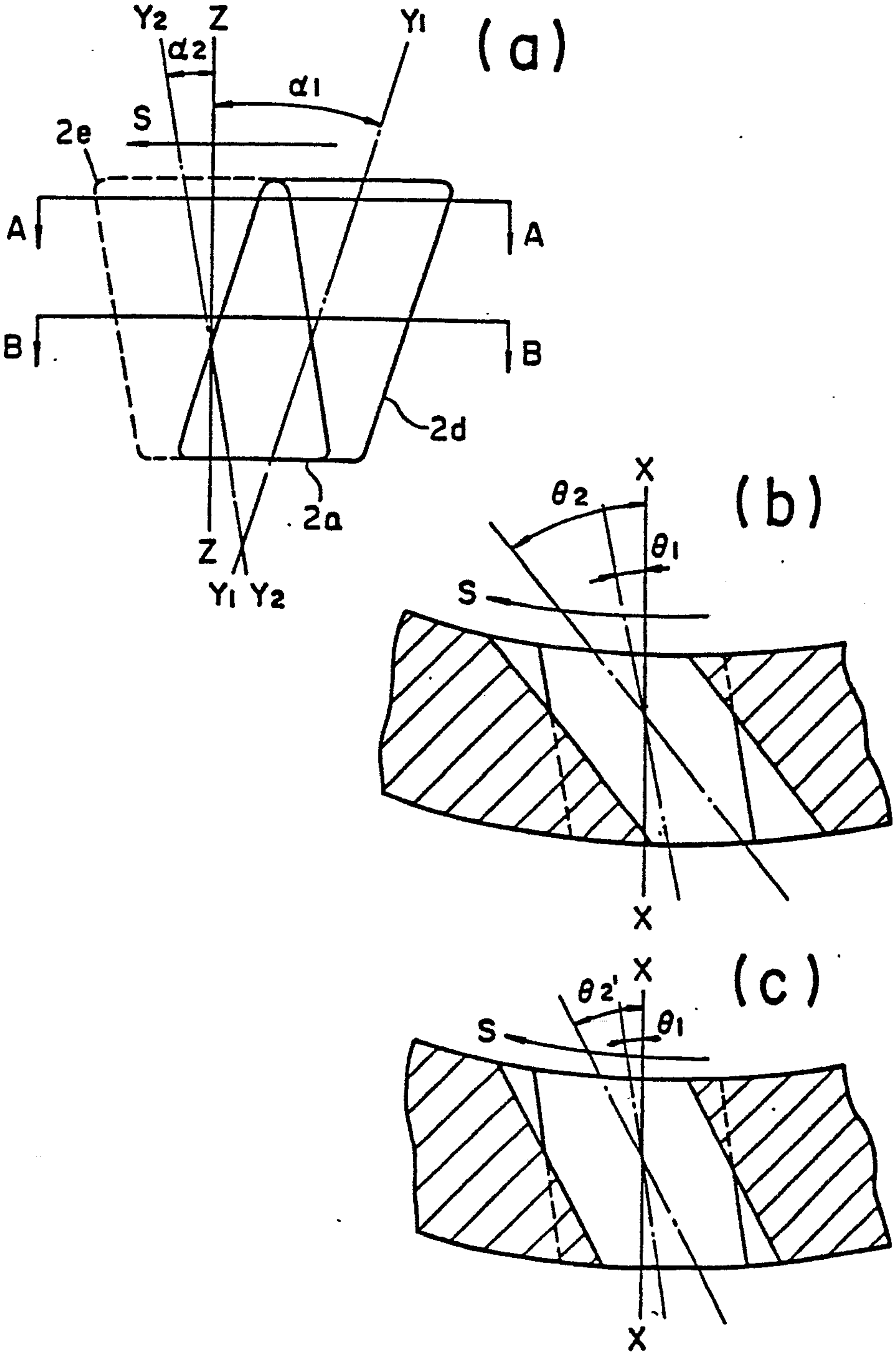
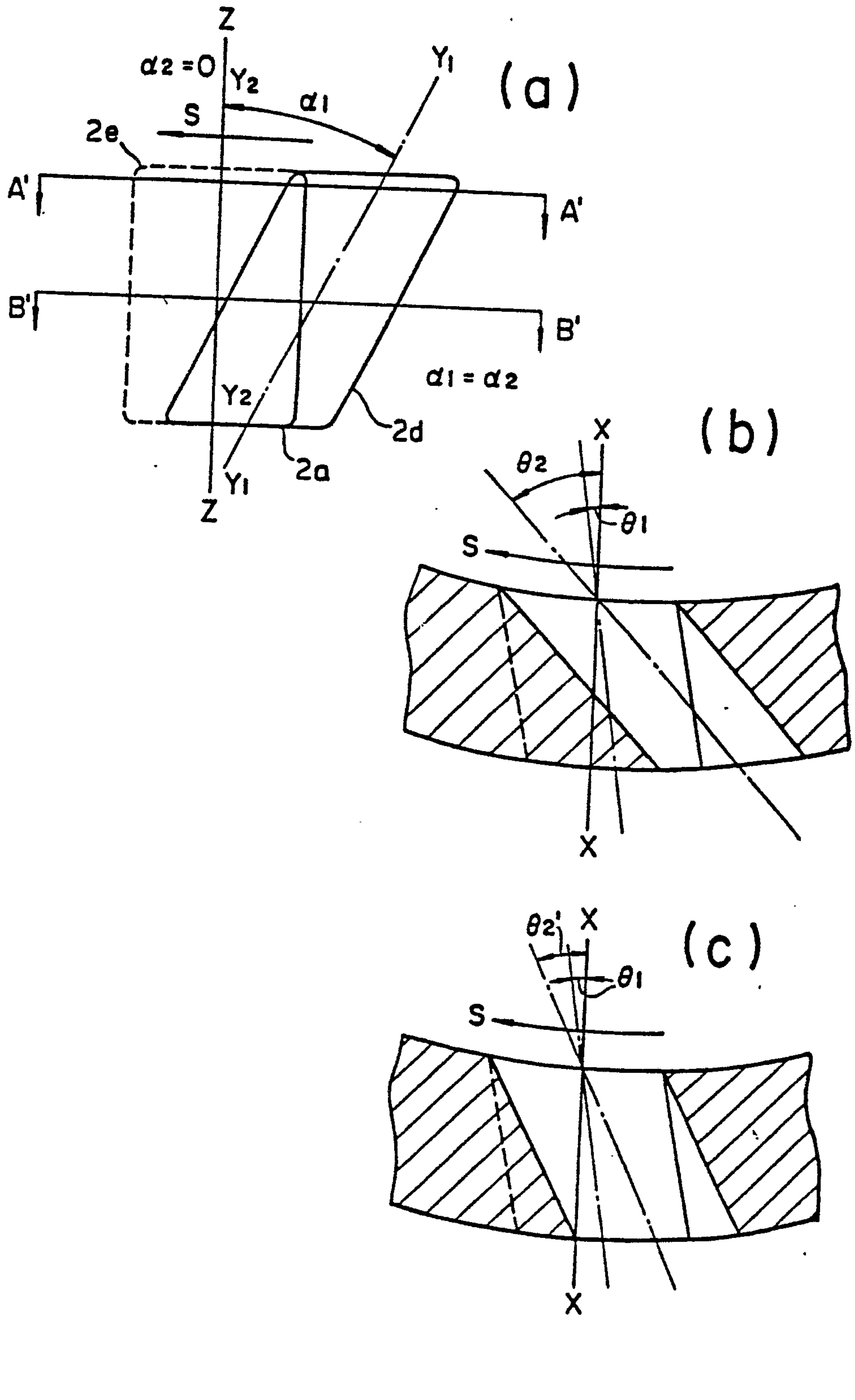
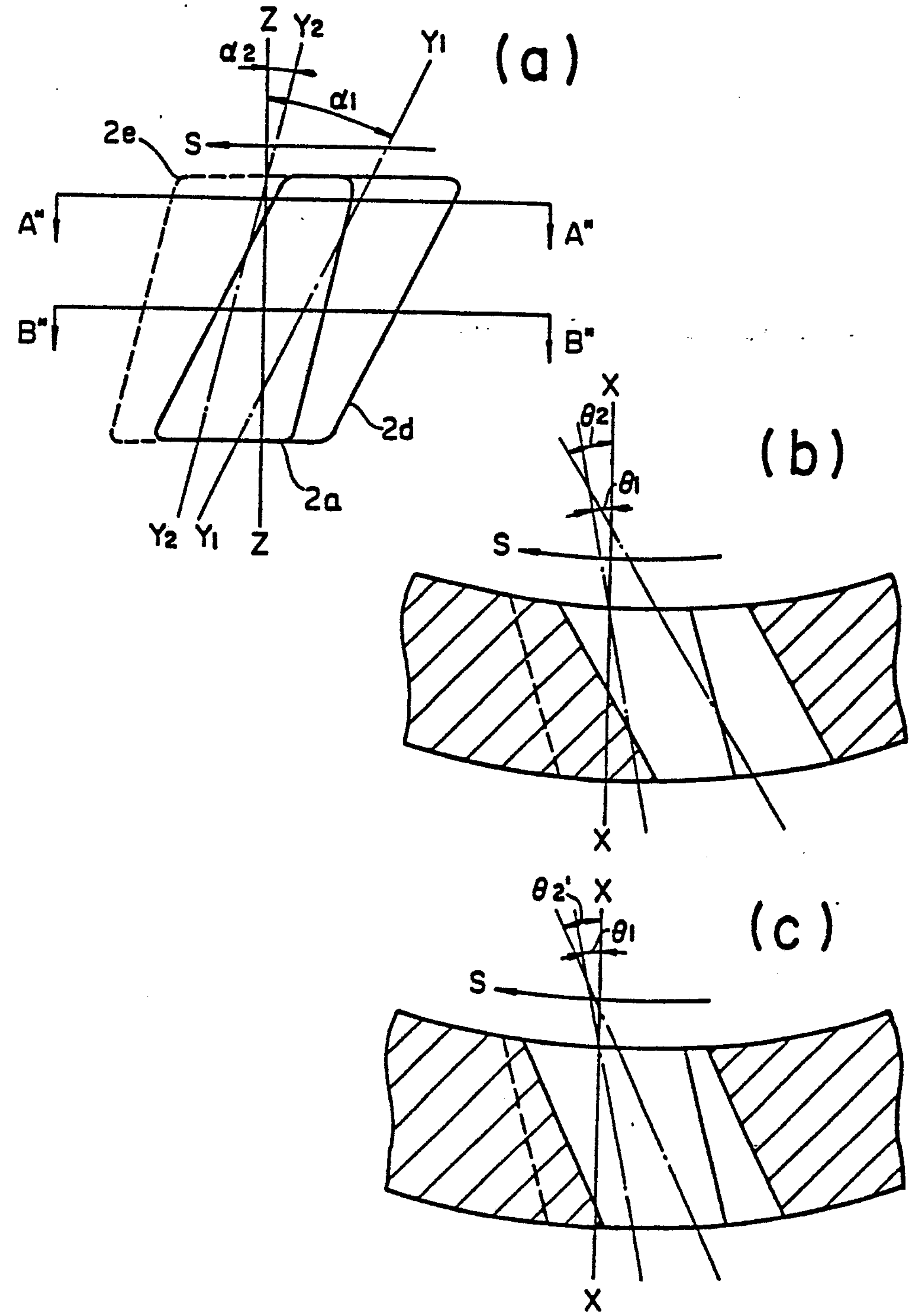


FIG.7



F I G. 8



F I G . 9

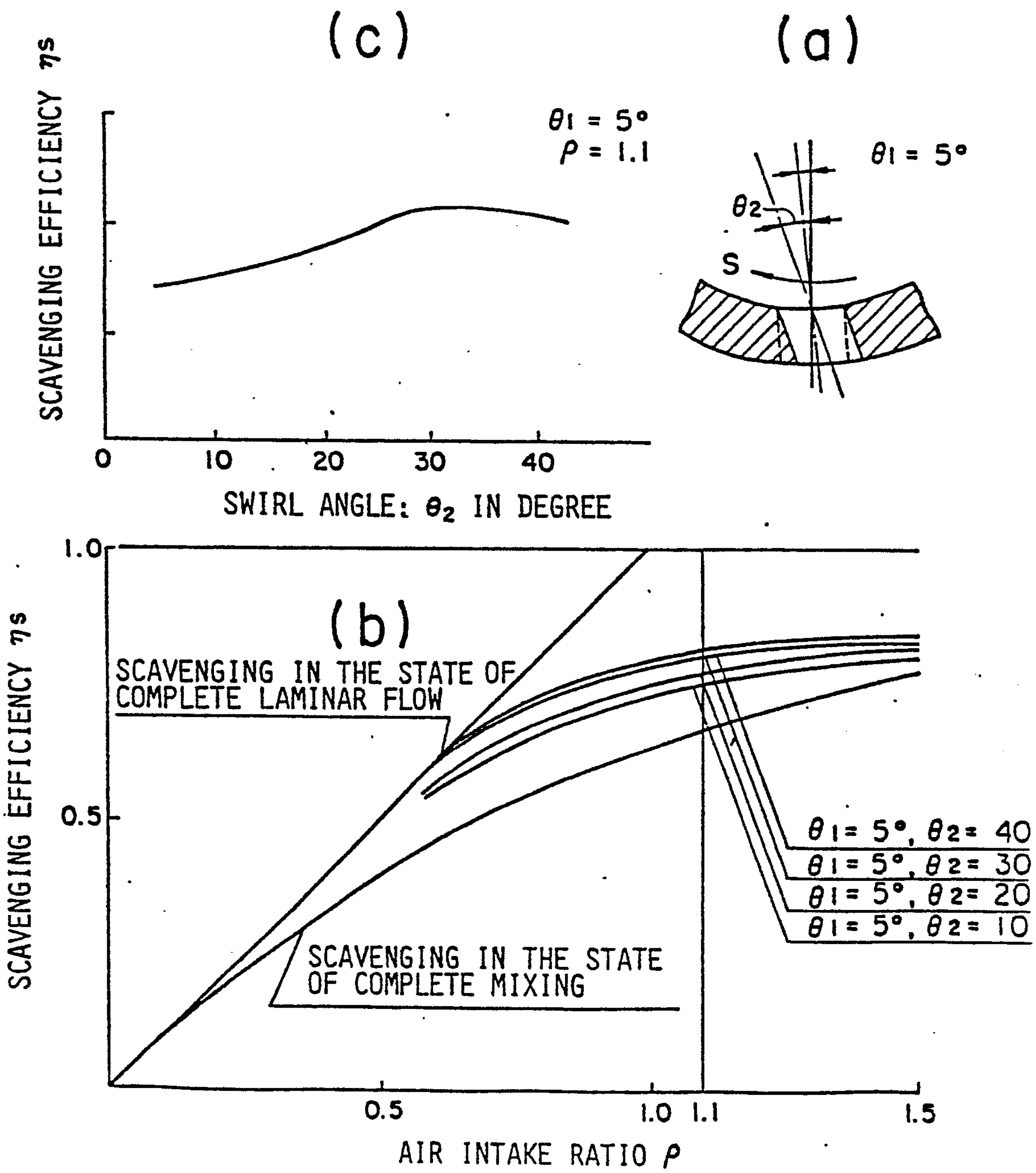
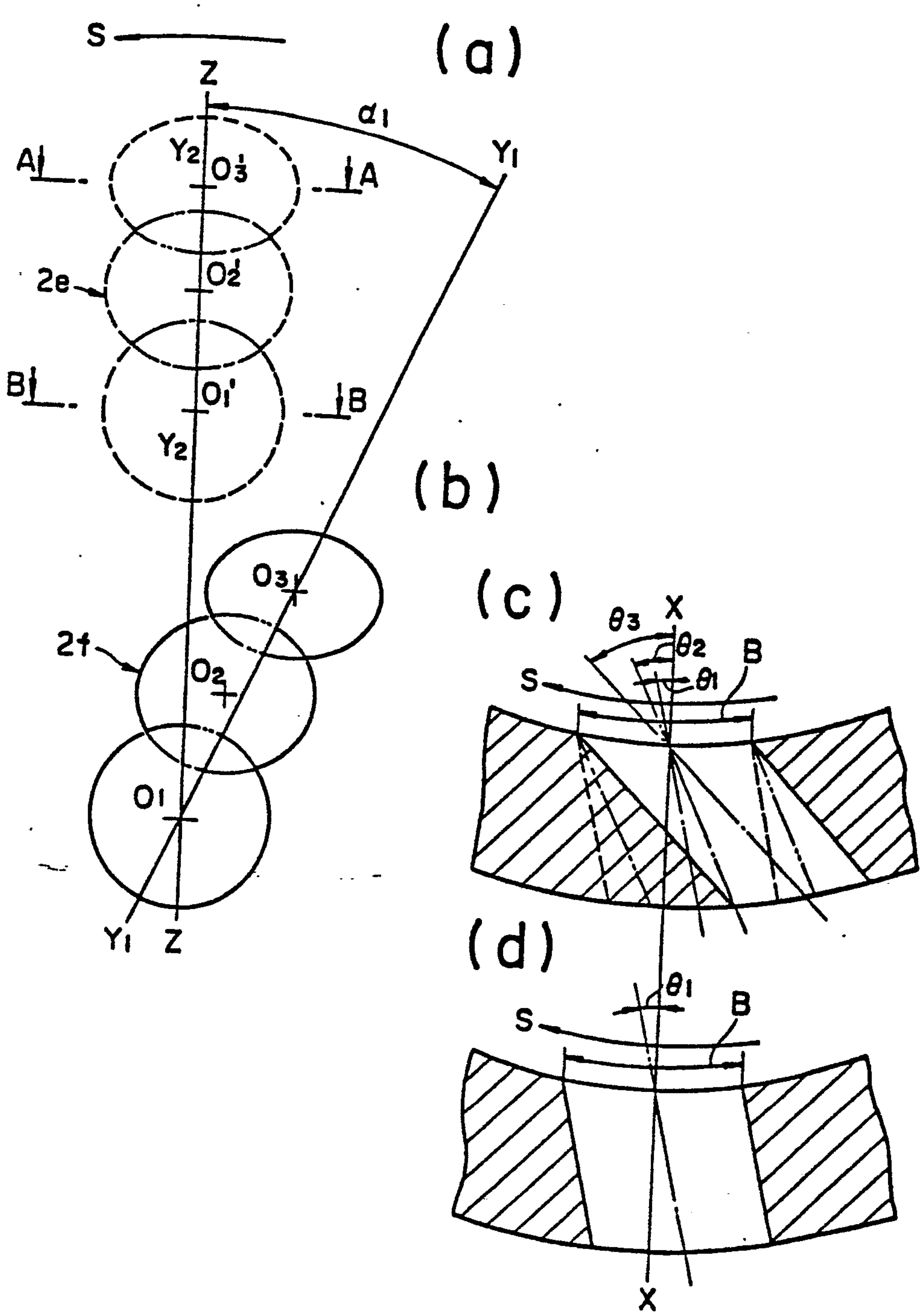
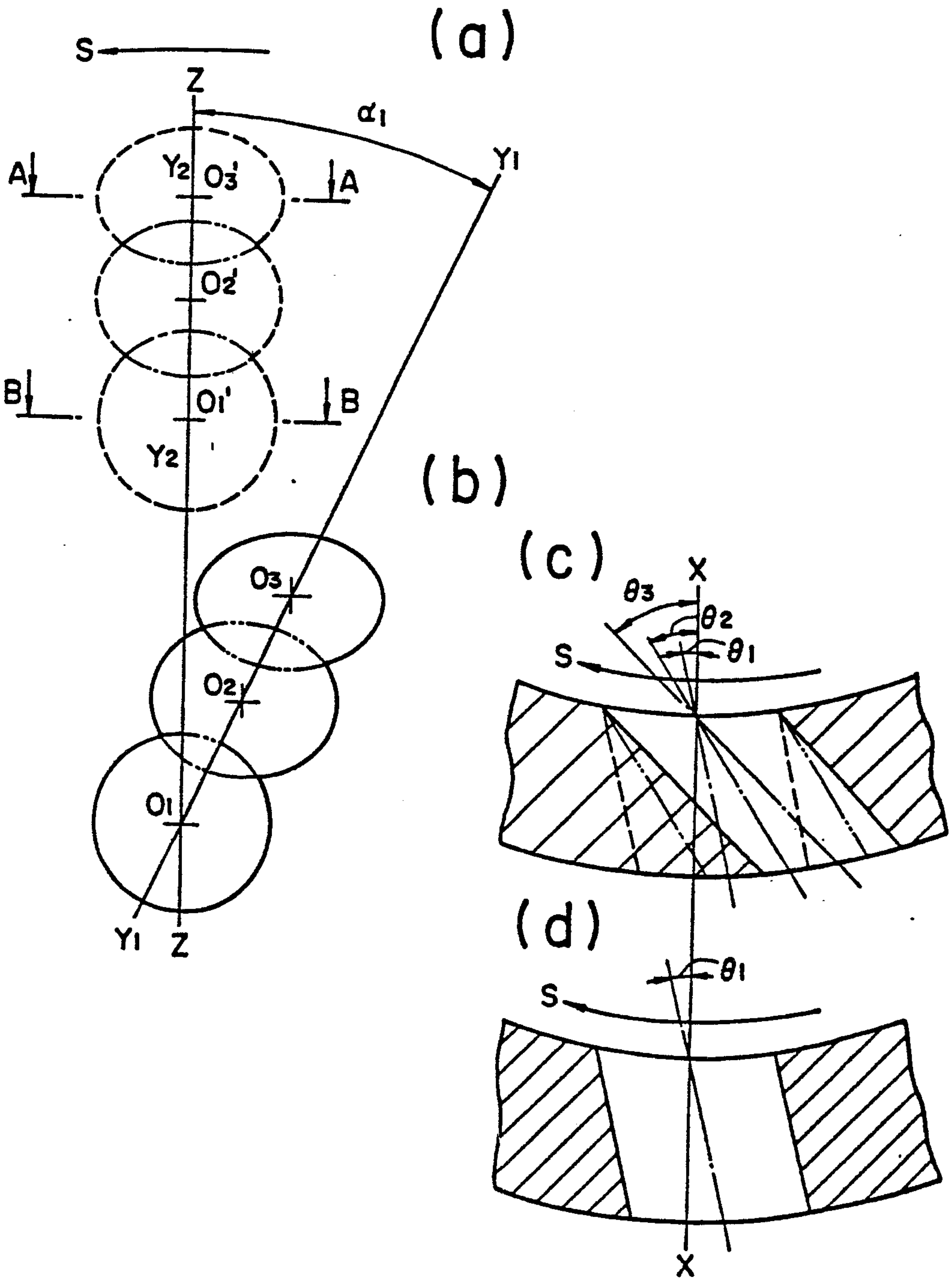

(c)
(a)
SCAVENGING EFFICIENCY ηs
θ1 = 5°
ρ = 1.1
θ1 = 5°
θ2
S
0
10
20
30
40
SWIRL ANGLE: θ2 IN DEGREE
1.0
0.5
(b)
SCAVENGING IN THE STATE OF COMPLETE LAMINAR FLOW
SCAVENGING IN THE STATE OF COMPLETE MIXING
θ1 = 5°, θ2 = 40
θ1 = 5°, θ2 = 30
θ1 = 5°, θ2 = 20
θ1 = 5°, θ2 = 10
0.5
1.0
1.1
1.5
AIR INTAKE RATIO ρ

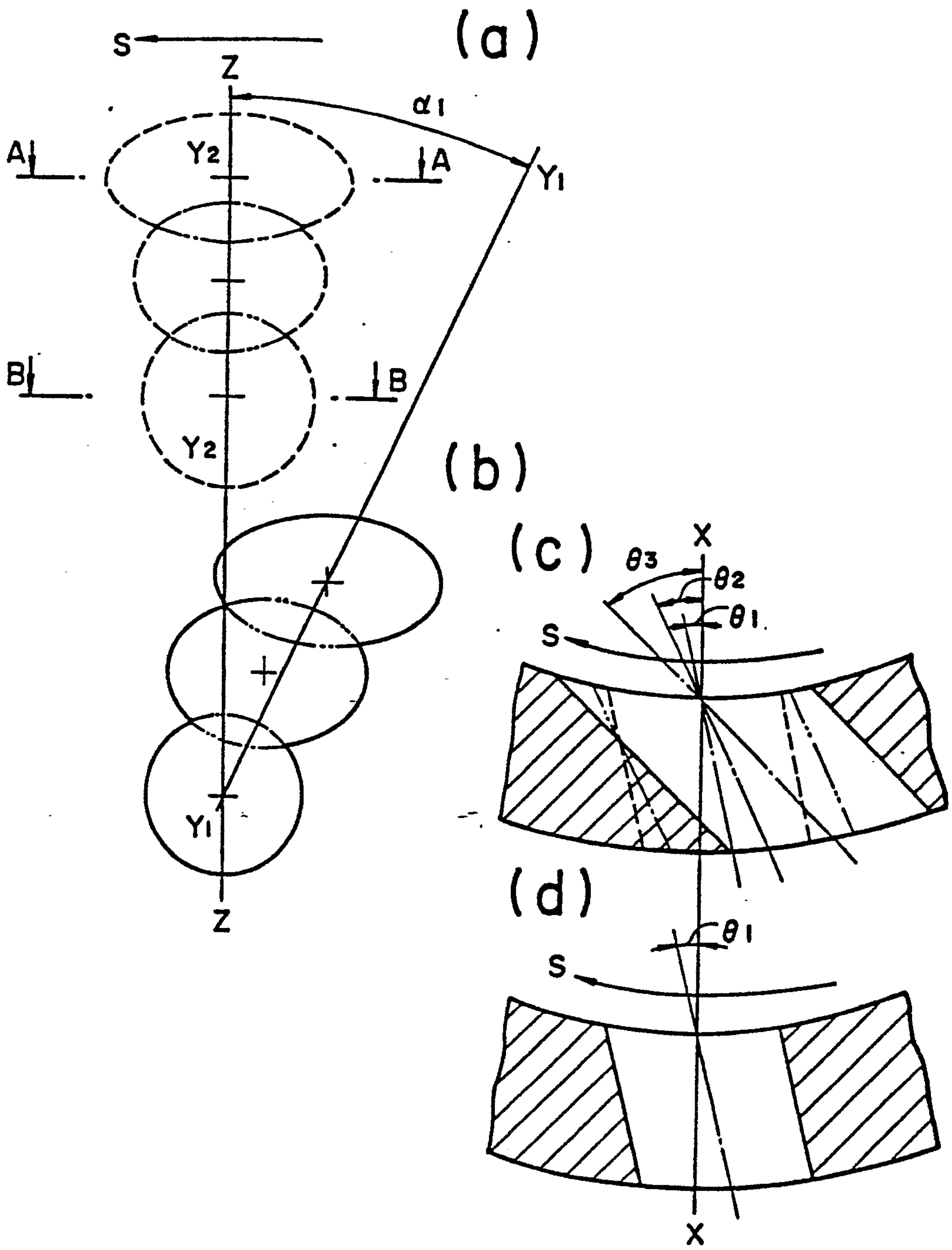
FIG.10


(a)
S
Z
α1
Y1
Y2
O3'
A
A
2e
O2'
B
O1'
B
Y2
(b)
O3
2f
O2
O1
Y1
Z
(c)
θ3
X
θ2
B
S
θ1
(d)
θ1
S
B
X

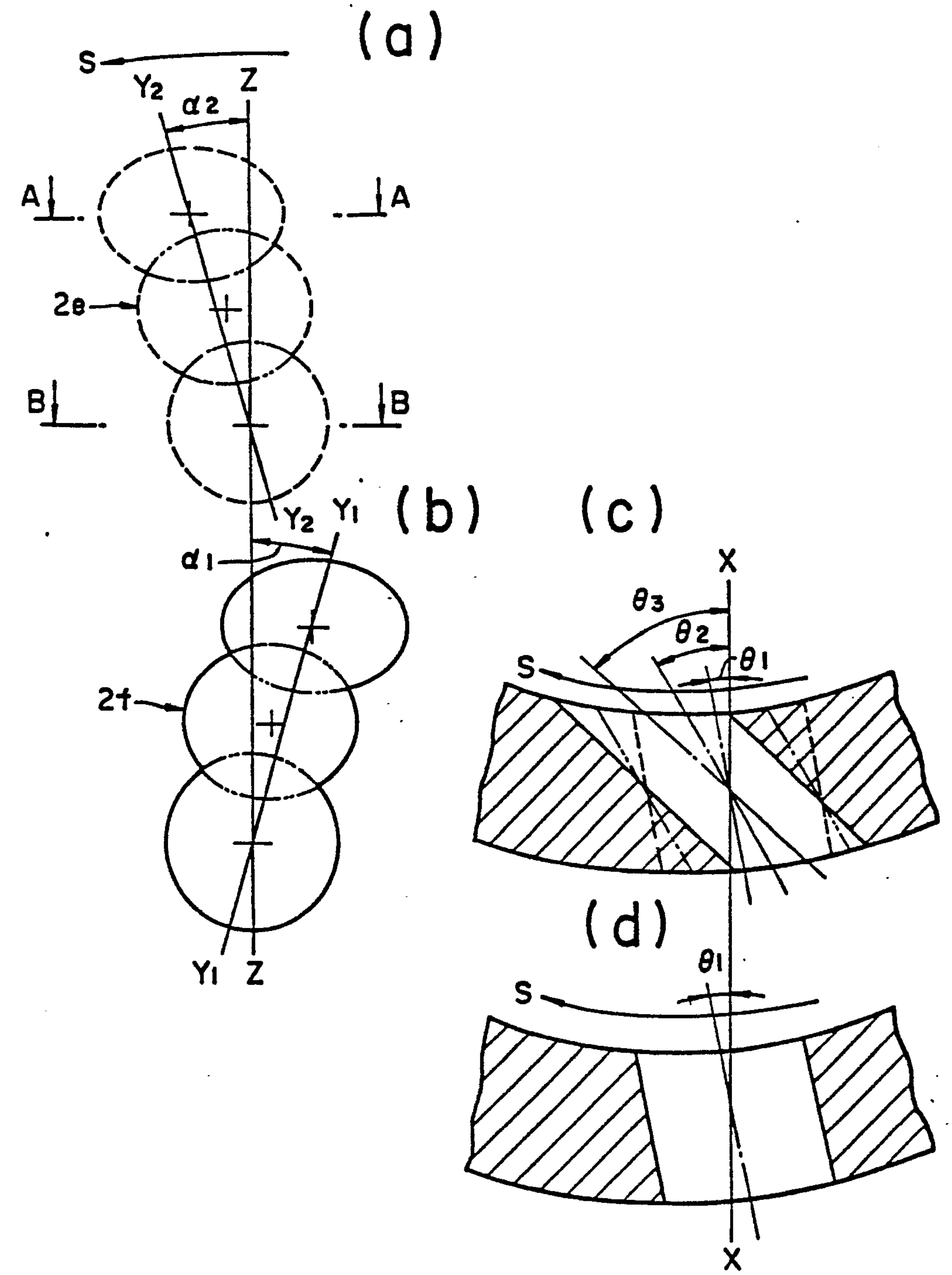
F I G. 11



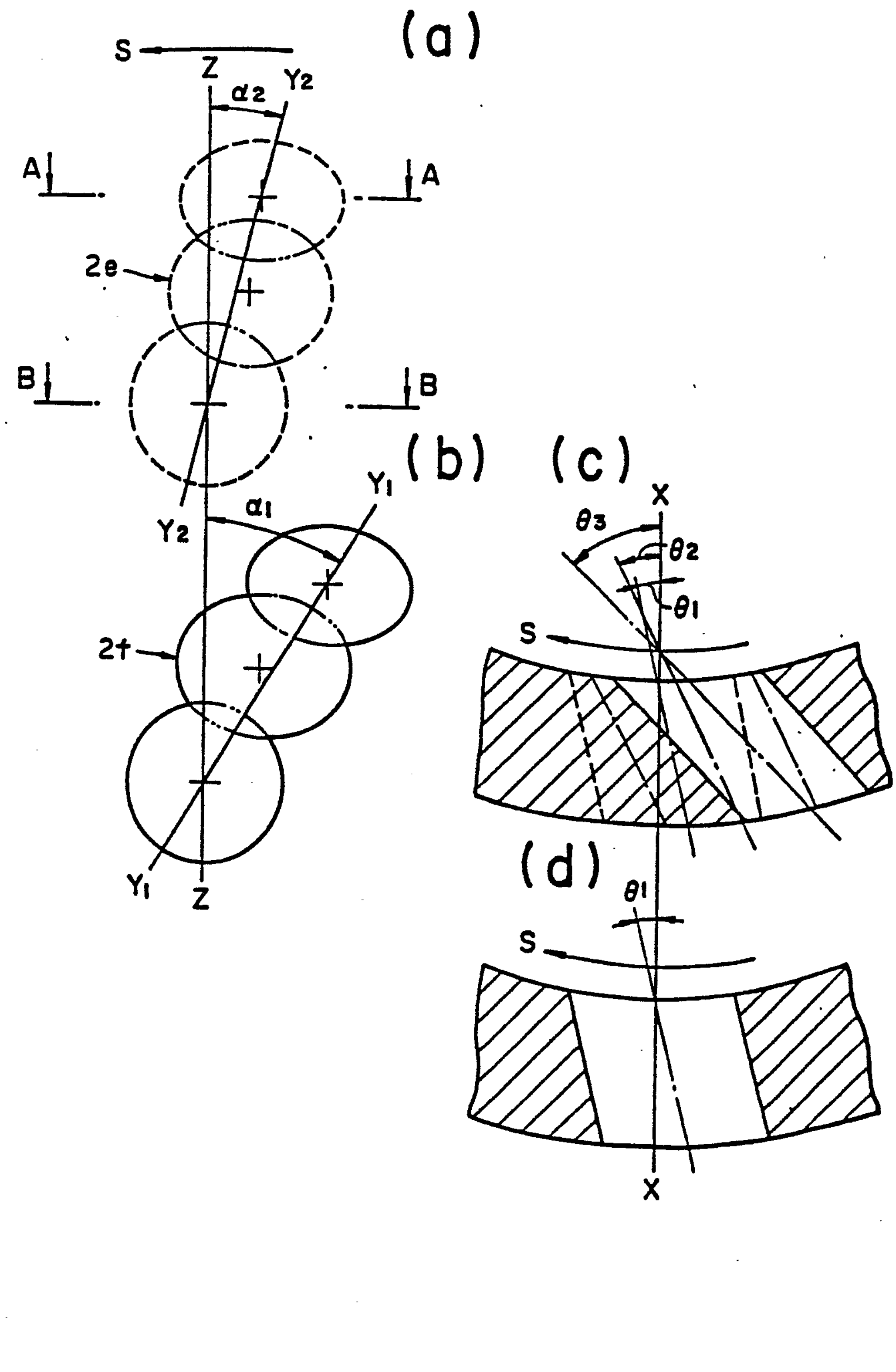
F I G. 12



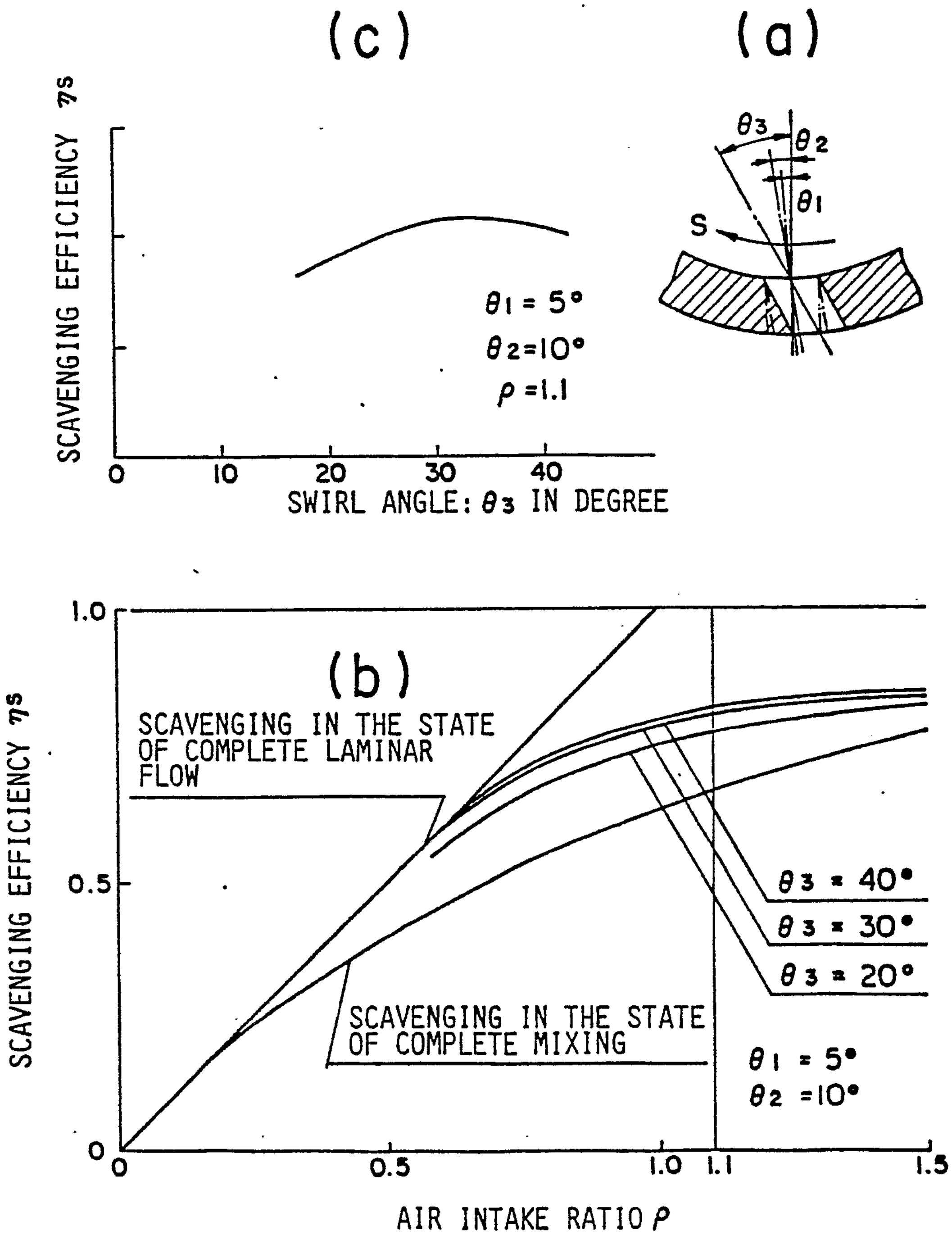
F I G. 13


(a)
S
Y_2
Z
α_2
A
A
2e
B
B
Y_2
Y_1
(b)
α_1
2f
Y_1
Z
(c)
X
θ_3
θ_2
θ_1
S
(d)
θ_1
S
X

F I G. 14



F I G.15


(c)
(a)
SCAVENGING EFFICIENCY ηs
θ1 = 5°
θ2=10°
ρ =1.1
0
10
20
30
40
SWIRL ANGLE: θ3 IN DEGREE
θ3
θ2
θ1
S
(b)
1.0
0.5
0
SCAVENGING IN THE STATE OF COMPLETE LAMINAR FLOW
SCAVENGING IN THE STATE OF COMPLETE MIXING
θ3 = 40°
θ3 = 30°
θ3 = 20°
θ1 = 5°
θ2 =10°
0.5
1.0
1.1
1.5
AIR INTAKE RATIO ρ