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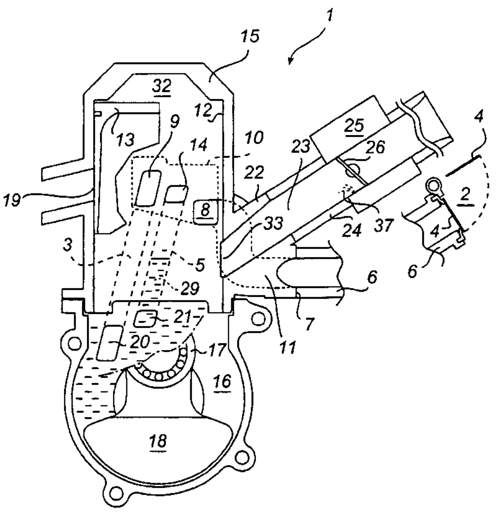
(54) Title: TWO-STROKE INTERNAL COMBUSTION ENGINE




**(57) Abstract:** A crankcase scavenged internal combustion engine of two-stroke type (1) having at least one cylinder (15) and at least one air passage arranged between an air inlet (2) and the upper part of a number of scavenging ducts (3, 3') with exhaust orientated scavenging ports (9, 9') located close to the exhaust port (19) of the cylinder. At least one intake orientated scavenging port (14, 14') is located close to the inlet port (33) of the cylinder and is fed by at least one scavenging duct (5, 5'), and the air passage and the scavenging ducts are so arranged that the scavenging ducts (3, 3') can be supplied with and hold so much air that they during the following scavenging process will scavenge essentially nothing but air. The air passage is arranged from an air inlet (2) provided with a restriction valve (4) controlled by at least one engine parameter, e.g. the carburettor throttle control, and the intake orientated scavenging port/s (14, 14') is/are so arranged that it/they begin/s to scavenge the air/fuel-mixture (2) later than the scavenging ports (9, 9') begin to scavenge air.

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# TWO-STROKE INTERNAL COMBUSTION ENGINE

## Technical field

The subject invention refers to a crankcase scavenged internal combustion engine of two-stroke type having at least one cylinder and one air passage arranged between an air inlet and the upper part of at least two scavenging ducts with scavenging ports located close to the exhaust port of the cylinder, and at least one intake orientated scavenging port is located close to the inlet port of the cylinder and is fed by at least one scavenging duct or similar, and the air passage and the scavenging ducts are so arranged that the scavenging ducts can be supplied with and hold so much air that they during the following scavenging process will scavenge essentially nothing but air. Fresh air is thus added into the scavenging ducts located most close to the exhaust gas port and is intended to serve as a buffer against the exhaust gas port for the air/fuel-mixture supplied more close to the inlet port. The fuel consumption and the exhaust gas emissions are thereby reduced. The engine is foremost intended for a handheld working tool.

## Background of the invention

Internal combustion engines provided with additional air to the scavenging ducts are known. They reduce the fuel consumption and exhaust emissions, but it is difficult to control the air/fuel ratio in such an engine. Further it can be difficult to reduce the exhaust emissions substantially.

In a recently published SAE-report with reference No. 2000-01-9000 is described an engine with a design as described initially. By way of check-valves, so called Reed-valves, the two scavenging ducts located closest to the exhaust port are fed with so much air that it is sufficient for the whole scavenging process. One or several more scavenging ducts with ports located close to the inlet side will instead scavenge air/fuel-mixture at the same time as the other ports will scavenge air. It is pointed out that this scavenging takes place in parallel, i.e. begins at the same time, and continues during the whole scavenging process. The principle is described as a stratified scavenging in the space. Compared to a conventional two-stroke engine the fuel consumption and exhaust emissions will be reduced substantially. However, at the same time it is noted that air/fuel-mixture will get lost through the exhaust gas port at the end of the scavenging process during the last 40-50 crank angle degrees before the exhaust gas port has been closed. Obviously this loss is unwanted. Furthermore, check valves are used for feeding the scavenging ducts located close to the exhaust gas port in a known way. The flow restriction in the check valves will complicate the filling of air. This type of check valves, usually called Reed-valves, have however a number of other disadvantages. They often have a tendency to come into resonant oscillations, and can have difficulties to cope with the high rotational speeds that many two-stroke engines can reach. Besides, it results in added cost and an increased number of engine components.

International patent application WO98/57053 shows a few different embodiments of an engine where air is supplied to the scavenging ducts via L-shaped or T-shaped recesses in the piston. Check valves are thus missing. Air is supplied to all the scavenging ducts and serves as a buffer against the subjacent air/fuel-mixture. The scavenging is thus stratified in time and not in space in contrast to the engine mentioned above. In all embodiments the piston recess has, where it meets the respective scavenging duct, a very limited height, which is essentially equal to the height of the actual scavenging duct. A consequence of this embodiment is that the passage for air delivery through the piston to the scavenging port is opened considerably later than the passage for air/fuel-mixture to the crankcase is opened by the piston. The period for the air supply is thus significantly shorter than the period for the supply of air/fuel-mixture, where the period can be counted as crank angle or time. This could complicate the control of the total air/fuel ratio of the engine. This also means that the amount of air that can be added to each scavenging duct is significantly reduced, since the underpressure driving this addition of air has decreased considerably, because the inlet port has already been open during a certain period of time when the air supply is opened. This implies that the period and the driving force for the air supply are both small. Furthermore, the flow resistance in the L-shaped and T-shaped ducts as shown is relatively high, partly because the cross-section of the duct is small close to the scavenging port and partly because of the sharp bend created by the L-shape or T-shape. When the air has just passed into the scavenging port it is forced to change direction abruptly away from the lateral direction of the cylinder to instead follow the scavenging duct outwards and then downwards, i.e. two curves of 90° in rapid succession. This is due to the fact that the scavenging ducts of the engine are running in a radial direction to the cylinder. All this contributes to increase the flow resistance and to reduce the amount of air that can be added to the scavenging ducts, which decreases the possibilities to reduce fuel consumption and exhaust emissions by means of this arrangement.

## Purpose of the invention

The purpose of the subject invention is to substantially reduce the above outlined problems and to achieve advantages in many respects.

## Summary of the invention

The above-mentioned purpose is achieved in a two-stroke internal combustion engine in accordance with the invention having the characteristics appearing from the appended claims.

The internal combustion engine according to the invention is thus essentially characterized in that the air passage is arranged from an air inlet provided with a restriction valve controlled by at least one engine parameter, e.g. the carburettor throttle control, and the intake orientated scavenging port/s is/are so arranged that it/they begin to scavenge air/fuel-mixture later than the exhaust orientated scavenging ports begin to scavenge air.

As the intake oriented scavenging ports begin to scavenge air/fuel-mixture later than the exhaust orientated scavenging ports begin to scavenge air, the air/fuel-mixture will have shorter time to reach the exhaust port. Thereby the losses of the air/fuel-mixture through the exhaust port can be reduced. This can be effected in that the scavenging ducts having intake orientated scavenging ports are partly filled with air or exhaust gases before the scavenging process begins. Thereby this gas will be scavenged first, which will delay the scavenging of the air/fuel-mixture. Furthermore, the intake orientated scavenging ports can also be arranged so that their respective upper edge will be located lower axially than the corresponding edge of the other scavenging ports.

Because at least one connecting port in the engine's cylinder wall is arranged so that it in connection with piston positions at the top dead center is connected with flow paths arranged in the piston, the supply of fresh air to the upper part of the scavenging ducts can be arranged entirely without check valves. This can be arranged because at positions at or near the top dead center there is an underpressure in the scavenging duct in relation to the ambient air. Consequently, hereby a piston ported air passage without any check valves can be arranged, which is a big advantage. Since the air supply has a very long period of time a substantial amount of air can be added, so that a very satisfactory exhaust emission reduction rate can be achieved. Control is applied by means of a restriction valve in the air inlet, controlled by at least one engine parameter. Such a control design is a considerably less complicated design than a variable inlet. The air inlet has preferably two connecting ports, which in one embodiment are so located that the piston is covering them at its bottom dead center. The restriction valve can preferably be controlled by the engine's throttling or rotational speed, alone or in combination with another engine parameter. These and other characteristic features and advantages will become more apparent from the following detailed description of various embodiments, supported by the enclosed drawing figures.

## Brief description of the drawings

The invention will be described in closer detail in the following by way of various embodiments thereof with reference to the accompanying drawing figures. For parts that are symmetrically located on the engine, the part on the one side has been given a numeric designation while the part on the opposite side has been given the same designation but with a '-symbol. In the drawings the parts with a '-symbol are located above the plane of the paper and are therefore not visible.

Figure 1 shows a side view of an engine according to the invention. The cylinder is shown in a cross-section, as well as parts of the piston, which is shown at the top dead center. The scavenging ducts are completely or partly filled by air.

Figure 2 shows a second embodiment of the invention having open scavenging ducts. The figures 2-5 are detailed enlargements compared to figure 1.

Figure 3 shows a third embodiment of the invention having intake orientated scavenging ducts designed as recesses in the cylinder wall cooperating with recesses in the piston. The scavenging ducts are filled with air.

Figure 4 shows the same type of scavenging duct as in figure 3, but in this case it is not fed with air.

Figure 5 shows such a kind of scavenging duct used alone and thus located straight above the engine's inlet port.

**Description of embodiments**

In figure 1 numeral reference 1 designates an internal combustion engine according to the invention. It is of two-stroke type and has scavenging ducts 3, 3'. The latter is not visible since it is located above the plane of the paper. The engine has a cylinder 15 and a crankcase 16, a piston 13 with a connecting rod 17 and a crank mechanism 18. Furthermore, the engine has an inlet duct 22 with an inlet port 33 and an intermediate section 24 connected to the inlet duct, which section in its turn connects to a carburettor 25 with a throttle valve 26. Fuel 37 is supplied by way of the carburettor. Usually the carburettor connects to an inlet muffler with a filter. These are not shown for the sake of clarity. The same applies for the exhaust port and the muffler of the engine. These are totally conventional. The transfer ducts 3, 3' have exhaust orientated ports 9, 9' in the cylinder wall 12 of the engine close to the exhaust port 19 of the cylinder. The engine has a combustion chamber 32 with a spark plug, which is not shown. All of this is conventional and will therefore not be described in closer detail.

What is special is that an air inlet 2 provided with a restriction valve 4 is arranged so that fresh air can be supplied to the cylinder. The air inlet 2 has a connecting duct 6 leading to the cylinder, which is provided with an outer connecting port 7. By connecting port is from now on meant the port of the connection on the inside of the cylinder, while its port on the outside of the cylinder is called the outer connecting port. The air inlet 2 suitably connects to an inlet muffler with a filter, so that cleaned fresh air is taken in. If the requirements are lower, this is of course not necessary. The inlet muffler is not shown for the sake of clarity.

The connecting duct 6 is thus connected to the outer connecting port 7. This is an advantage. At or after this port the duct divides into two branches 11, 11', which lead to a connecting port 8, 8' each. These are located symmetrically and the parts with a '-symbol are as mentioned lying above the plane of the paper. The outer connecting port 7 is thus located below the inlet duct 22, which brings a number of advantages such as lower air temperature and a better utilizing of space for a handheld working tool.

However, the outer connecting port 7 could also be located above the inlet duct 22, which then is directed more horizontally. Wherever they are located two outer connecting ports 7, 7' could be used. They could then also be located on each side of the inlet duct 22. The air inlet thus leads via at least one connecting port 6, 6' up to at least one connecting port 8, 8'.

Flow paths 10, 10' are arranged in the piston so that they, in connection with piston positions at the top dead center, connect the respective connecting port 8, 8' to the upper part of the transfer ducts 3, 3' having exhaust orientated scavenging ports 9, 9'. The flow paths 10, 10' are formed by local recesses in the piston. The piston is simply manufactured, usually cast, with these local recesses.

The flow paths also connect scavenging ducts 5, 5' with intake orientated scavenging ports 14, 14' to each connecting port 8, 8' respectively. In the figure is illustrated schematically how the different scavenging ducts have been filled before the scavenging process is to begin. Air/fuel-mixture present in the crankcase is designated by numeral reference 29. It should be observed that the air/fuel-mixture 29 reaches up to approximately half of the scavenging duct 5. Above it there is air that has been fed from the air inlet 2. On the other hand the whole scavenging duct 3 is filled with air. The purpose of this is that from the exhaust orientated scavenging port 9 and its correspondence 9' shall during the scavenging process be fed nothing but air, which serves as a buffer against the exhaust port 19. On the other hand, from the intake orientated scavenging ports 14, 14' shall first be fed air and then air/fuel-mixture 29. Hereby the introduction of air/fuel-mixture will be delayed, which reduces the scavenging losses. As becomes apparent from the figure the upper edge of the intake orientated scavenging port 14, 14' is also located lower axially, i.e. more close to the crankcase than the corresponding upper edge of the other scavenging ports 9, 9' is. This could contribute to delaying the scavenging process in the intake orientated scavenging port. If so, also the scavenging of air will be delayed, which in turn delays the scavenging of the air/fuel-mixture 29. The determining factor for this to occur is how high up the upper edge of the intake orientated scavenging port is located in relation to, on the one hand the exhaust orientated scavenging ports and on the other hand to the exhaust port. When the piston in its descending motion begins to open the exhaust port the pressure in the combustion chamber above the piston will fall rapidly at the same time as the pressure in the crankcase 16 below the piston will increase slowly. When the piston begins to open the exhaust orientated scavenging ports 9, 9', there is a flow through each port in order to reduce the pressure difference between the combustion chamber and the crankcase. Since the piston is moving rapidly downwards there will often normally first be a small inflow of exhaust gases into the port then followed by an outflow of exhaust gases and air through the port. By locating the upper edge of the intake orientated scavenging port considerably lower than the upper edge of the exhaust orientated scavenging port, the scavenging through this port has already started before the intake orientated scavenging port begins to be opened by the piston. It is important that each scavenging port 5, 5' with intake orientated scavenging port 14, 14' respectively is fed with an amount of air that during the following scavenging process will end before the amount of air in the exhaust orientated scavenging ducts 9, 9' will end. Thereby each scavenging duct 5, 5' with intake orientated scavenging port 14, 14' begins to scavenge air/fuel-mixture during the scavenging process, which is necessary to make the fuel reach the combustion chamber. The determining factors for how much air/fuel-mixture that will have time to reach the combustion chamber are, on the one hand when the scavenging begins, which has been discussed above, and on the other hand how much air that was fed on top of each intake orientated scavenging duct 5, 5'. The latter is determined by the flow conditions from the inlet 2 and in through the exhaust orientated scavenging ports 9, 9' and in through the intake orientated scavenging ports 14, 14'. Since a much greater amount of air shall be supplied to the exhaust orientated scavenging ports 9, 9' this air inflow is given priority. This takes place partly due to that each intake orientated scavenging port will be connected later to the air inlet 2 at the piston's movement towards its top dead center. This is achieved since when the piston is located at its top dead center the axial distance between the upper edge of the flow path 10, 10', or the recess 10, 10' in the piston, and the lower edge of each intake orientated scavenging port 14, 14', is less than the corresponding distance for each exhaust orientated scavenging port 9, 9'. A priority of the air inflow to each exhaust orientated scavenging port 9, 9' is also given in that these ports are given a larger area than the intake orientated scavenging ports 14, 14'. This is mainly achieved because the upper edge is located much higher up. But also the lower edge is located lower. Obviously the exhaust orientated scavenging ports can also be made wider than the intake orientated ports. However, also the flow resistance in each scavenging duct has a great importance. It is therefore preferable to give precedence to a low flow resistance in the exhaust orientated scavenging ducts 3, 3' Preferably the exhaust orientated scavenging ducts 3, 3' run away from the respective scavenging port 9, 9' essentially in the lateral direction of the cylinder, i.e. essentially tangentially in relation to the circumference of the cylinder wall 12. The flow thus takes thus place in the lateral direction of the cylinder from the connecting ports 8, 8' and over to the exhaust orientated scavenging ports 9, 9' and further on in the same lateral basic direction, at the beginning of each scavenging duct 3, 3'. These ducts run in a lateral direction towards the exhaust side of the cylinder in order to turn off there in a soft turn down towards the crankcase and connect to it in a crankcase port 20. Such an arrangement of each scavenging duct 3, 3' is evident from PCT/SE00/00058 filed 14-01-2000. Obviously also the respective intake orientated scavenging duct can be given this run. However, since it preferably shall have a greater flow resistance and does not at all have to hold so much air, it could instead be preferable to run the intake orientated scavenging ducts 5, 5' down to the crankcase in the simplest way. Figure 1 shows such a simple run of a closed scavenging duct 5, 5' with crankcase port 21, 21'. However, this duct could be made even simpler by being open towards the cylinder in its entire length. It is then preferably formed as an axial groove in the cylinder wall, which can be formed directly at the die-casting process of the cylinder. When the piston is located at its top dead center, as shown in figure 1, it will close this groove to approximately a third of its length. Thereby air can only be filled up to haughtily this third. Haughtily considering the air that flows in after the top dead center when the piston is moving downwards and covers a greater part of the groove. Compared to a closed intake orientated scavenging duct this is a limitation, which however also means an advantage. For, at certain engine running conditions air can leak out from the bottom side of the piston so that a less varying amount of air is achieved at various engine running conditions.

The supply of air to the scavenging ducts could also be arranged by way of at least one duct, provided with a check valve and arranged from the air inlet 2 to the upper part of the scavenging ducts 3, 3'; 5, 5'. By providing the check valve belonging to the scavenging duct with the intake orientated scavenging port 14 another character than the check valve belonging to the scavenging duct close to the exhaust port 19 of the cylinder, a smaller amount of air can be supplied to the scavenging ducts with intake orientated scavenging ports. This means that also in this way the result described above can be achieved. Preferably the check valve belonging to the scavenging duct 5 is made harder than the check valve belonging to the scavenging duct 3. Thereby it will open later and close earlier, so that the airflow will be restricted.

In the embodiment according to figure 2 the scavenging duct 28 has been located to the side of the actual piston recess 10. The duct is arranged as an open scavenging duct, i.e. as an axial groove in the cylinder surface 12. At the bottom dead center the piston's upper side is located approximately in level with the upper edge of connecting port 8, 8'. The part of the open scavenging duct 28 that is located above this level is then to be considered as a scavenging port 27. In this case two symmetrically located scavenging ducts 28, 28' are used. Please observe that the scavenging duct 5 with port 14 in figure 1 has a more favorable location in relation to the exhaust port 19. It is namely directed more away from the exhaust port than the scavenging port 27 in figure 2 is. Even though the scavenging duct 28 is located to the side of the actual piston recess 10, it can still be fed with air from it at piston positions close to the top dead center. Two alternative air supply systems are shown in the figure, which also illustrates a possibility to feed exhaust gases down into the scavenging duct 28 when the piston is moving down towards its bottom dead center. The three shown solutions can be utilized either on their own or in combination of two or three.

At its top the scavenging port 27 is provided with a protruding part 35 that corresponds to the recess 10 in the piston when it is located close to its top dead center. Thereby air can flow from connecting port 8 via the recess 10 and the protruding part 35 to the upper part of scavenging duct 28. Using a suitable dimensioning of the width of the protruding part 35 an adapted amount of air will flow to the duct 28 so that it will be filled approximately down to the bottom side of the piston 13. The protruding part 34 of the recess 10 illustrates an alternative way to supply air into the scavenging duct 28. In the shown position at the top dead center and just before and after this, no air is supplied through the protruding part 34. Obviously this could be located lower down, but for the sake of clarity it is shown entirely above the scavenging port 27. However, when the upper edge of the recess 10 comes into contact with the bottom side of connecting port 8 the protruding part 34 begins to supply air to the scavenging duct 28 and continues to do so until it runs above the duct. It will thus supply air to the upper part of the duct 28 in a similar way that the protruding part 35 does. In figure 2 the upper edge of the scavenging port 27 has been extended higher up than the upper edge of the exhaust orientated scavenging duct 9. This means that the piston will open the scavenging duct 28 before it opens the scavenging duct 3. Thereby the scavenging duct 28 will sense a higher pressure and a greater downflow of exhaust gases than the scavenging duct 3 will sense. The upper edge of the scavenging duct 28 is preferably located so high axially that a desirable amount of exhaust gases will flow down into the scavenging duct 28. The adaptation can be such that this amount of exhaust gases alone ensures the desirable delay of the scavenging of the air/fuel-mixture through the scavenging duct 28. But it can also be such that the amount of exhaust gases completes an earlier supplied amount of air via the protruding part 35 and/or 34. Because exhaust gases are supplied when the piston is located essentially lower than at its top dead center, the open scavenging duct can be filled further down by means of exhaust gases than it could have been by means of only air, since the bottom side of the piston is located lower down when the exhaust gases are supplied.

Figure 3 shows an embodiment where scavenging port 27 has been given an advantageous position close to the scavenging port 9, in similarity with figure 1. However, this is achieved in a completely different way. At least one intake orientated scavenging port 27, 27' with scavenging duct 28, 28' is arranged in the form of a depression 27, 28: 27', 28' in the cylinder wall. In the scavenging process this depression will cooperate with an aperture 30, 30' in the piston, so that the scavenging gases pass the piston through the aperture and the depression. When the piston is located at its top dead center it will cover the whole depression except for a possible downwards protruding part 36. By this part an adapted smaller amount of air/fuel-mixture and air can be drained when the piston is approaching its top dead center. In case this down protruding part 36 is not used this mixture will instead be left, or be carried away by the passing airflow down into the exhaust orientated scavenging duct 3. This means that at piston positions close to the top dead center the depression will probably be filled with air, so much it can take. This is however a very small amount of air. The main part of all air will instead fill up the scavenging ducts 3, 3' close to the exhaust port. In the scavenging process the piston will be located so that its upper edge is approximately in level with the upper edge of the connecting port 8. The aperture 30 will thereby be connected to the scavenging duct part 28 of the depression, while the upper side of the depression will serve as scavenging port 27. Do observe that the upper edge of the scavenging port 27 is located considerably lower than the upper edge of scavenging port 9. This means that the scavenging process will be delayed and then begin with a small amount of air to be followed by the air/fuel-mixture.

Figure 4 shows an embodiment where the depression 27, 28 is not fed with air from the connecting port 8. Therefore it starts to scavenge air/fuel-mixture directly when the piston begins to open the scavenging port 27. By locating the upper edge of the depression 27, 28 especially low down a very short and late scavenging can be achieved. Possibly the upper edge of the piston can be chamfered locally in order to contribute to this. However, observe that this is later than the piston begins to open the scavenging port 9. The depression 27, 28; 27', 28' could be fed with air by the protruding parts 34, 35, 36, as shown in figure 2 and 3. Its upper edge could also be adapted for filling of the depression with exhaust gases as shown in figure 2.

In figure 5 only one depression 27, 28 is used and located straight above the inlet port. If the piston is lowered to the described position at the bottom dead center it becomes evident how the flow can run through the aperture 30 and pass the piston through the depression 27, 28. An advantage of this embodiment is that only one depression is required, but a disadvantage is that this depression ends up opposite to the exhaust port 19, so that there is a risk that the scavenging gases will penetrate into the exhaust port earlier than in the other examples, especially those according to figure 1 and 3. The depression 27, 28 can be arranged in an insert piece, which from the outside is inserted into the cylinder, which thereby can be produced by die-casting, resulting in a cheaper cylinder. This is correspondingly valid for the examples according to figure 3 and 4.

Usually the connecting ports 8, 8' are so located in the axial direction of the cylinder that the piston covers them when it is located at its bottom dead center. Thereby exhaust gases cannot penetrate into the connecting port and further on through a possible air filter. But it is also possible that the connecting ports 8, 8' are located so high up that they to some extent are open when the piston is located at its bottom dead center. This is then adapted so that a desirable amount of exhaust gases will be supplied into the connecting duct 6. A highly located connecting port could also reduce the flow resistance of air at the changeover from connecting port to scavenging port 9.

The period of air supply from the connecting ports 8, 8' to the exhaust orientated scavenging port 9, 9' given priority is very important and is to a great extent determined by the flow paths in the piston, i.e. the recess 10, 10' in the piston.

Preferably the upper edge of the recess 10, 10' is located so high that it when the piston is moving upwards from the bottom dead center reaches up to the lower edge of the respective exhaust orientated scavenging port 9, 9' at the same time or earlier than the lower edge of the piston reaches up to the lower edge of the inlet port. Thereby the air connection between the connecting ports 8, 8' and the scavenging ports 9, 9' is opened at the same time or earlier as the inlet is opened. When the piston moves downwards again after being at the top dead center then the air connection will also be shut off at the same time or later than the inlet. Thereby the air supply has an essentially equally long or longer period than the inlet has, counted as crank angle or time. This will reduce its flow resistance. Often it is desirable that the inlet period and the air period are essentially equally long. Preferably the air period should be 90-110 % of the inlet period. Because both these periods are limited by the maximum period during which the pressure is low enough in the crankcase to enable a maximal inflow. Both periods are preferably maximized and equally long. The position of the upper edge of the recess 10, 10' will thus determine how early the recess will come into contact with each scavenging port 9, 9' respectively. Consequently, preferably the recess 10, 10' in the piston that meets each exhaust orientated scavenging port 9, 9' respectively locally at this port, has an axial height that is greater than 1,5 times the height of the respective scavenging port, but preferably greater than 2 times the height of the scavenging port. This provided that the port has a normal height so that the upper side of the piston, when located at its bottom dead center, is level with the underside of the scavenging port, or is protruding one or two millimeters.

The recess is preferably downwards shaped in such a way that the connection between the recess 10, 10' and the connecting port 8, 8' is maximized, since it reduces the flow resistance. This means that when the piston is located at its top dead center, the recess 10, 10' preferably reaches so far down that it does not cover the connecting port 8, 8' at all, as shown in figure 1. As a whole, this means that the recess 10, 10' in the piston that meets each connecting port 8, 8' respectively locally at this port, has an axial height that is greater than 1,5 times the height of the respective connecting port, but preferably greater than 2 times the height of the connecting port

The relative location axially of the connecting port 8, 8' and the exhaust gas orientated scavenging port 9, 9' can be varied considerably provided that the ports are shifted sideways, i.e. in the cylinder's tangential direction, as shown in figure 1. Figure

1 illustrates a case where the connecting port and the scavenging port 9, 9' have an axial overlap, i.e. that the upper edge of each connecting port respectively is located as high or higher in the cylinder's axial direction as the lower edge of each scavenging port respectively. One advantage is that the two ports are more aligned with each other in an arrangement of this kind, which reduces the flow resistance when air is being transported from the connecting port to the scavenging port. Consequently, more air can be transported, which can enhance the positive effects of this arrangement, i.e. reduced fuel consumption and exhaust emissions. For many two-stroke engines, the piston's upper side is level with the lower edge of the exhaust outlet and the lower edge of the scavenging port, when the piston is at its bottom dead center. However, it is also quite common for the piston to extend a millimeter or two above the scavenging port's lower edge. If the lower edge of the scavenging port is further lowered, an even greater axial overlap will be created between the connecting port and scavenging port. When air is supplied to the scavenging duct, the flow resistance is now reduced, both due to that the ports are more level with each other and also due to the greater surface area of the scavenging port.

Above is pointed out the importance of having a long period of air supply in order to achieve a low flow resistance at the changeover between cylinder and piston. Furthermore is pointed out the advantage that the connecting port is located as high or higher in the cylinder's axial direction as the lower edge of each scavenging port respectively. This provided that the connecting port/scavenging port are shifted sideways in relation to each other along the periphery of the cylinder wall. Hereby the transition from port 8 to port 9 via the piston can occur in a slightly upwards direction in relation to the cylinder's lateral direction. If the port 8 had instead been located right below port 9, then the transition had occurred in a straight upwards direction. The result had been that the flow would at first turn upwards and then after reaching the scavenging port turn into a horizontal direction, i.e. two sharp turns in succession. Owing to the fact that the ports are shifted sideways this enables a slightly upward flow with small turns. As mentioned it is a big advantage if the exhaust orientated scavenging ducts 3, 3' are arranged essentially in the cylinder's lateral direction. The result will be that the slightly upward flow from port 8 to port 9 will turn slightly and then continue in a straight lateral direction out into the transfer duct. Preferably the transfer duct runs in the cylinder's lateral direction until it is in height with the cylinder wall where a soft turn takes place, so that the transfer duct connects to the crankcase where it has its mouth 20. Preferably each branch 11, 11' leading to each connecting port 8, 8' respectively is arranged so that it is directed in the cylinder's lateral direction, or slightly upwards from this. Hereby the advantageous main flow direction, which is arranged through the cylinder and piston, is pointed out. In the shown embodiment each branch arrives obliquely from below from an outer connecting port 7, so that the branch first turns upwards after the outer connecting port and then continues upwards and turns into a lateral direction up to the connecting port 8, 8' in the cylinder wall 12. At the transition from cylinder to piston is therefore created a slightly upward direction of the flow, which then preferably turns slightly into a straight lateral flow direction in the transfer duct. Since the connecting port 8 must be located at a lower level than each scavenging port 9 respectively, this is a natural arrangement. But it is also possible to place one or two outer connecting ports above the inlet 22-25. If so, this is preferably angled more in the cylinder's lateral direction than in the shown case. In this case this could be arranged so that each branch 11, 11' is directed essentially in the cylinder's lateral direction up to each connecting port 8, 8' respectively.

We imagine that we can see the preferred flow from above as from the outer connecting port 7 to the connecting port 8 and over to the scavenging port 9 and further on into the scavenging duct 3. Then it becomes apparent that the scavenging duct 3 up to the scavenging port 9 is running in an essentially tangential direction in relation to the cylinder and the same is to a great extent also valid for the first part of the branch 11 from the connecting port 8. Thereby the changes of direction will become small when the air passes from the branch 11 over to the piston recess 10 and into the scavenging duct 3.

CLAIMS

1. Crankcase scavenged two-stroke internal combustion engine (1) having at least one cylinder (15) and at least one air passage arranged between an air inlet (2) and the upper part of at least two scavenging ducts (3, 3') with exhaust orientated scavenging ports (9, 9') located close to the exhaust port (19) of the cylinder, and at least one intake orientated scavenging port (14, 14'; 27, 27') is located close to the inlet port (33) of the cylinder and is fed by at least one scavenging duct (5, 5'; 28, 28') or similar, and the air passage and the scavenging ducts are so designed that the scavenging ducts (3, 3') can be supplied with and hold so much air that they during the following scavenging process will scavenge essentially nothing but air, c h a r a c t e r i z e d in that the air passage is arranged from an air inlet (2) provided with a restriction valve (4) controlled by at least one engine parameter, e.g. the carburettor throttle control, and the intake orientated scavenging port/s (14, 14'; 27, 27') are so arranged that it/they begin/s to scavenge air/fuel-mixture (29) later than the exhaust orientated scavenging ports (9, 9') begin to scavenge air.

2. Crankcase scavenged internal combustion engine (1) according to claim 1, c h a r a c t e r i z e d in that each intake orientated scavenging port (14, 14'; 27, 27') has an upper edge that is located lower axially, i.e. more close to the crankcase than the corresponding upper edge of the other scavenging ports (9, 9').

3. Crankcase scavenged internal combustion engine (1) according to claim 1 or 2, c h a r a c t e r i z e d in that also the upper part of each scavenging duct (5, 5'; 28, 28') with intake orientated scavenging port (14, 14'; 27, 27') is connected with the air inlet (2), but having such an arrangement that it/they is/are fed with such an adapted amount of air that it during the following scavenging process will end before the amount of air in the exhaust orientated scavenging ports (9, 9') will end, so that the intake orientated scavenging port/s begin/s to scavenge the air/fuel-mixture during the scavenging process.

4. Crankcase scavenged internal combustion engine (1) according to claim 1 or 2, c h a r a c t e r i z e d in that the air inlet via at least one connecting duct (6, 6') leads up to at least one connecting port (8, 8') in the engine's cylinder wall (12), which

is so arranged that it in connection with piston positions at the top dead center is connected with flow paths (10, 10') arranged in the piston (13), which flow paths lead to a number of scavenging ducts (3, 3') via exhaust orientated scavenging ports (9, 9').

5. Crankcase scavenged internal combustion engine (1) according to claim 3 and 4, characterized in that the flow paths (10, 10') also lead to a number of scavenging ducts (5, 5': 28, 28') via intake orientated scavenging ports (14, 14'; 27, 27').

6. Crankcase scavenged internal combustion engine (1) according to claim 5, characterized in that, when the piston is located at its top dead center the axial distance between the upper edge of each flow path (10, 10'), or recess (10, 10') in the piston and the lower edge of each intake orientated scavenging port (14, 14'; 27, 27') is less than the corresponding distance for each exhaust orientated scavenging port (9, 9'), so that each intake orientated scavenging port will be connected later to the air inlet (2) when the piston is moving up towards its top dead center.

7. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that at least one intake orientated scavenging port (27, 27') with scavenging duct (28, 28') is arranged in the form of a depression (27, 28, 27', 28') in the cylinder's (15) wall, which depression during the scavenging process will cooperate with an aperture (30, 30') in the piston, so that the scavenging gases will pass the piston through the aperture and the depression.

8. Crankcase scavenged internal combustion engine (1) according to claim 7, characterized in that, when the piston is located at its top dead center it covers the entire depression (27, 28, 27', 28'), so that air cannot leak out from the depression.

9. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that the cylinder's connecting port (8, 8') and each exhaust orientated scavenging port (9, 9') are shifted sideways in relation to each other along the periphery of the cylinder wall (12), and the exhaust orientated scavenging ports (3, 3') are running essentially in the cylinder's lateral direction away from each scavenging port (9, 9').

10. Crankcase scavenged internal combustion engine (1) according to claim 9,

characterized in that each connecting branch (11, 11'), which leads to each connecting port (8, 8') respectively is directed in the cylinder's lateral direction, or slightly upwards from this.

11. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that the flow paths are so arranged that the recess (10, 10') in the piston that meets the respective exhaust orientated scavenging port (9, 9') is arranged so that the air supply is given an essentially equally long or longer period, counted as crank angle or time, in relation to the inlet.

12. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that the period of the air supply is greater than 90 % of the inlet period but smaller than 100 % of the inlet period.

13. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that the recess (10, 10') in the piston that meets the respective exhaust orientated scavenging port (9, 9') locally at this port has an axial height that is greater than 1,5 times the height of each scavenging port (9, 9'), preferably greater than 2 times the height of the scavenging port.

14. Crankcase scavenged internal combustion engine (1) according to any one of the preceding claims, characterized in that the upper edge of each connecting port (8, 8') is located as high as or higher in the cylinder's axial direction as the lower edge of each exhaust orientated scavenging port (9, 9').

15. Crankcase scavenged internal combustion engine (1) according to claim 1 or 2, characterized in that at least one duct, provided with a check valve, is arranged from the air inlet (2) to the upper part of a number of scavenging ducts (3, 3').

16. Crankcase scavenged internal combustion engine (1) according to claim 3 and 9, characterized in that at least one duct, provided with a check valve, is arranged from the air inlet (2) to the upper part of at least one scavenging duct (5, 5') with intake orientated scavenging port (14, 14'), and this check valve is adapted to supply a more restricted airflow than the check valves belonging to the scavenging ducts located close to the cylinder's exhaust port (19).

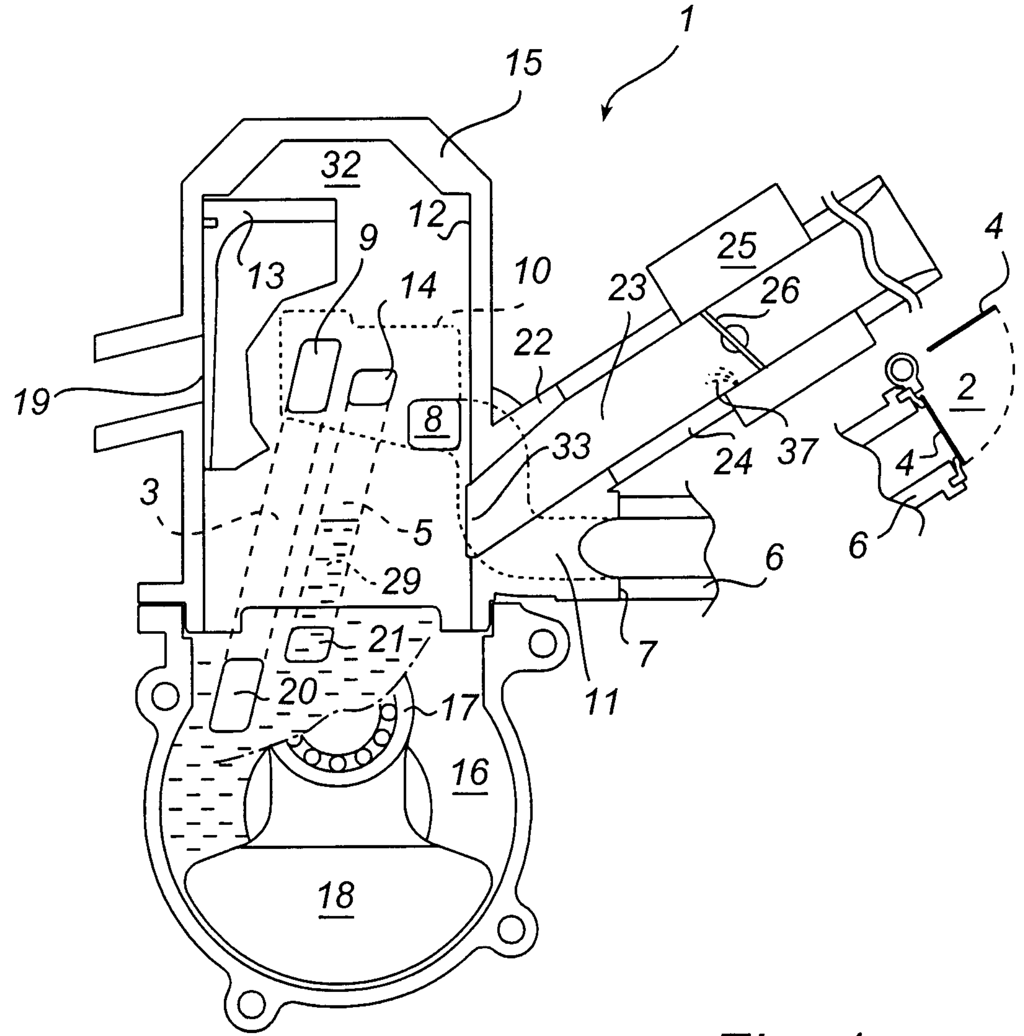
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Fig. 1

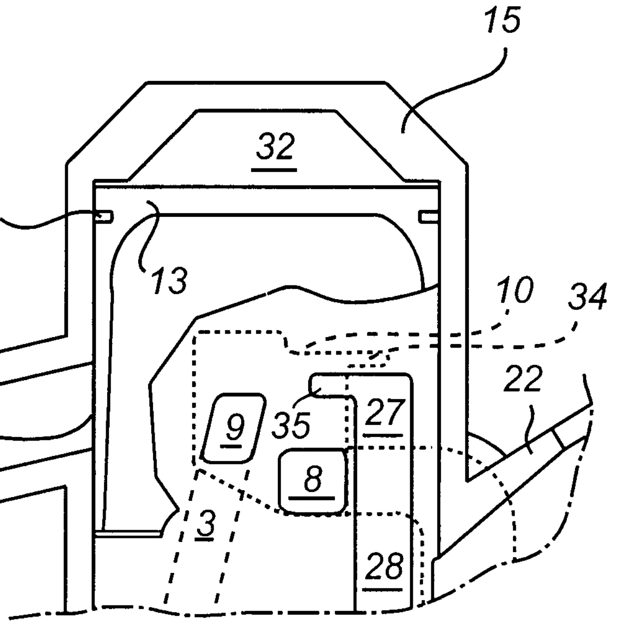
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Fig. 2

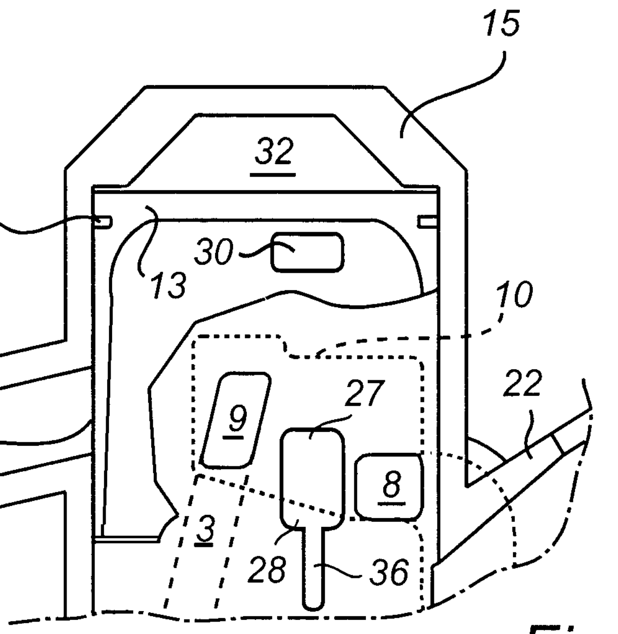
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Fig. 3

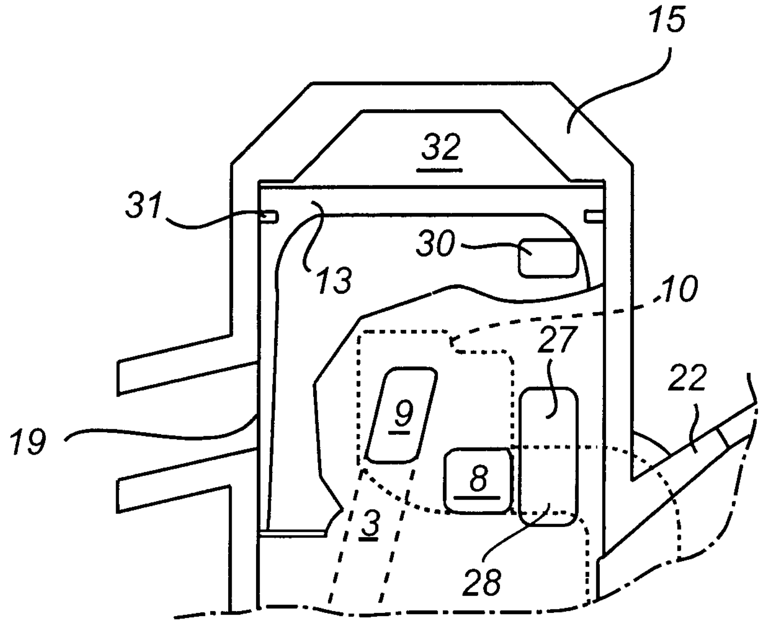


Fig. 4

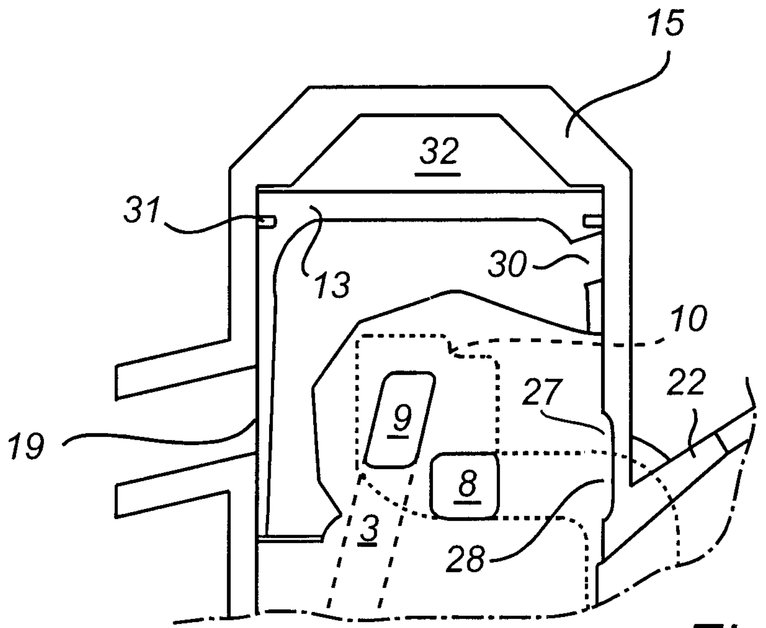


Fig. 5

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00789

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02B 25/14, F02B 33/04, F02F 1/22
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F02B, F02F

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

SE,DK,FI,NO classes as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| A | EP 0992660 A1 (KOMATSU ZENOAH CO.), 12 April 2000 (12.04.00)<br>-- | 1-16 |
| A | EP 0337768 A2 (TAIT, ROBERT, JOHN), 18 October 1989 (18.10.89)<br>-- | 1-16 |
| A | US 4075985 A (TOMI IWAI), 28 February 1978 (28.02.78)<br>--<br>-------- | 1-16 |

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

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"A" document defining the general state of the art which is not considered to be of particular relevance

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 December 2000 | 19 -12- 2000 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br>Per-Olof Warnbo/mj<br>Telephone No. +46 8 782 25 00 |

# INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE 00/00789

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| | | | | JP | 55029435 | A | 01/03/80 |
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