

SPECIFICATION

Inlet air flow passage arrangement in diesel engines

5 The invention relates to diesel engines, and more particularly to the introduction of air into the cylinder bores through a plurality of inlet air passages formed in the cylinder head or
10 heads thereof.

It is known to use a plurality of air inlet valves with corresponding air inlet ports communicating with the inlet air passages for each cylinder bore of diesel engines. In the
15 past, such air inlet passages have been helically configured to produce a swirling flow path of air into the cylinder bores. Swirling flow paths are shown in U.S. Patents 3,898,966, and 3,884,209. It has been
20 found, however, that excessive swirl in such air flow path is detrimental during start up and cold idle because it prolongs the time of "white smoke" operation of the engine and thus prolongs the period of objectionable hydrocarbon emissions. Further, it has been
25 found that excessive amounts of swirl inevitably are produced at the expense of volumetric efficiency of the engine.

Throttled inlet air passages are known to be
30 used for stratified charge versions of some engines such as the rotary piston engines, as shown in U.S. Patents 3,905,337 and 3,901,198. At low engine speeds or low loads the air enters through a restricted tangential passage located in the cylinder housing. This gives high entry velocity and makes stratified charge operation possible. At high engine speeds unrestricted passages in the end housing are opened in order to get the
40 needed volumetric efficiency. Such operation would, however, be detrimental in a direct injection diesel engine since it is advantageous at low speeds and light loads to operate with a minimum of turbulence in the air being
45 directed into the cylinder bores.

According to the present invention a diesel engine has a cylinder bore, a cylinder head, and an inlet air flow passage arrangement comprising a first air flow directing passage
50 for introducing air past a first valve to the cylinder bore along a first flow path substantially tangential to the bore and causing swirling of the air within the bore, a second air flow directing passage for introducing air past
55 a second valve to the bore along a second flow path having a component parallel to the axis of the bore and lying substantially in a plane parallel to the axis of the bore thereby causing minimal swirling of the air within the
60 bore, and control means for selectively utilizing the first and second flow paths either individually or in combination during various phases of engine operation, including means for closing the first passage during engine
65 start up and cold idle and means for closing

the second passage at intermediate engine speeds.

The invention includes a method of controlling inlet air flow to the cylinder bore of a
70 diesel engine to minimize undesirable emission on start up and cold idle operation while retaining high volumetric engine efficiency throughout the full range of engine speeds, the method comprising introducing air into
75 the cylinder bore through a non-swirling path during start up and cold idle engine operation and introducing air through a second path substantially tangential to the cylinder bore to cause swirling of the air within the cylinder
80 bore only when the engine is operating at other than start up and cold idle.

Examples of engines according to the invention will now be described with reference to the accompanying drawings in which:-

85 *Figure 1* is a partial perspective view of a direct injection diesel engine with inlet air passages;

Figure 2 is a partially sectioned plan view of an air flow entry arrangement with a control
90 and sensors shown schematically;

Figure 3 is a sectional view taken along line III-III of Fig. 2;

Figure 4 is a sectional view taken along line IV-IV of Fig. 2;

95 *Figure 5* is a sectional view illustrating an alternative embodiment of the structure shown in Fig. 4; and,

Figure 6 is a fragmentary view illustrating an alternative embodiment for the entry passage shown in Fig. 2.

100 Figs. 1 and 2 illustrate a diesel engine 10 which has one or more cylinder bores 12. An improved air flow entry arrangement 14, best seen in Fig. 2, includes a swirl type entry
105 passage 16 for introducing air flow to a first generally circular valve 18. The first valve 18 opens from a head 20 to the cylinder bore 12 and has its periphery 22 substantially tangential to the cylinder bore 12, and its axis 24
110 substantially parallel to an axis 26 of the cylinder bore 12. The air flow is introduced from the first valve 18 into the cylinder bore 12 substantially tangential to the outer wall thereof.

115 A non-swirl type entry passage 28 introduces air flow to a second generally circular valve 30 which opens to the head 20 of the cylinder bore 12. The air flow from the second valve 30 is introduced to the cylinder
120 bore 12 with substantially only axial and possibly radial velocity components, i.e., substantially parallel to or aimed at the axis 26. Thus, the air flow from the second valve 30 has primarily an axial as opposed to a tangential flow vector.
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First throttle valve means, including a first butterfly valve 32 is provided for controlling the amount of air flow through the swirl type entry passage 16. Further, means are provided for closing the first butterfly valve 32
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during start up and cold idle of the engine 10. In the embodiment illustrated in Figs. 1 and 2 the first throttle valve closing means comprises a control 34 which senses engine temperature via a temperature sensor 36 and motivates the movement of a lever 38 which opens or closes the butterfly valve 32. The swirl type entry passage 16 does not provide air flow to the cylinder bore 12 on start up or during cold idle operation under the direction of the control 34. The control 34 can also sense engine speed as via an engine speed sensor 40 for a purpose which will later be apparent.

Second throttle valve means including a second butterfly valve 42 is provided in the non-swirl type entry passage 28 for controlling the amount of air flow therethrough. Further, means are generally provided for closing the second butterfly valve 42 at intermediate speeds of the engine 10. In the embodiment illustrated, the control 34 also includes means for closing the second butterfly valve 42. Said means can include a lever 44 motivated by the control 34. Movement of the lever 44 is controlled by the control 34 responsive to engine speed as sensed by the engine speed sensor 40 whereby the second butterfly valve 42 is closed at intermediate speeds of the engine 10. Thus, the non-swirl type entry passage 28 is generally open at start up and cold idle operation and at high engine speed operation, while being closed at intermediate engine speeds.

In Figs. 2 and 3, there is illustrated one preferred configuration of the swirl type entry passage 16. In this configuration a straight duct 46 has a generally circular or oval cross-section, and is angularly oriented relative to the first valve 18 so that a center line 48 of said duct 46 forms an angle A, in the range of about 30° to 50° with said valve axis 24. An inner wall 50 comprises that portion of the duct 46 nearest to the cylinder bore 12 and forms an angle, B, of at least about 40° with said valve axis 24. An outer wall 52 comprises that portion of said duct 46 farthest from the cylinder bore 12 and forms an angle, C, in the range of about 30° to 50° with said valve axis 24. The outer wall 52, if extended in the direction of air flow, clears a seat 54 of said first valve 18. Preferably, the clearance of the valve seat 54 is related to the diameter, D, of the cylinder bore 12 whereby said clearance falls within a range from about $0.005D$ to about $0.015D$. Preferably, the tube 46 has a length, L, from its intersection 56 with a plane defined by said valve seat 54 to an air entry end 58 thereof which falls within a range from about 0.5 to about 2.5 times a mean diameter, d, of said duct 46.

In the embodiment illustrated in Fig. 6 the swirl type entry passage 16' has a first portion 60 extending away from the first valve

18' generally parallel to the valve axis 24' and a second portion 62 generally perpendicular to the first portion 60 and extending away from the cylinder bore 12'. The passage

16' has an outer generally linearly extending wall 64 generally tangential to the cylinder bore 12' adjacent the first valve 18' and an inner wall 66 opposite the outer wall 64. A section 68 of the inner wall 66 adjacent the first valve 18' has a concave surface 70 which faces the outer wall 64. In the embodiment illustrated, the concave surface 70 is formed by a vane 72 in a recess 74 in the section 68 of the inner wall 66. The vane 72 extends from a first end 76 adjacent the first valve 18' to a second end 78 spaced from the first valve 18'. A pin 80 pivotally mounts the second end 78 of the vane 72 in the recess 74. Preferably, the concave surface 70 corresponds to a surface of a cylinder which has an axis parallel to the axis of the cylinder bore 12' and has a radius of curvature which falls within a range from about 65% to about 35% of the radius of curvature of the cylinder bore 12'. A chord 82 drawn across the concave surface 70 aims substantially at the axis 24' of the first valve 18' so that a distance from said axis 24' to a nearest extension of the chord 82 is preferably no more than about 10% of the length of the diameter, D, of the cylinder bore 12'.

Fig. 4 shows one embodiment of the non-swirl type entry passage 28. This passage has a curved tube 84 which bends the air path entering via the second valve 30 so that this air path enters generally directly axially of the cylinder bore 12.

Fig. 5 illustrates an alternate embodiment of the non-swirl type entry passage. In this embodiment, the non-swirl type entry passage 28' is similar to the structure illustrated in Fig. 3 and as has been discussed above for the swirl type entry passage 16. To remain non-swirl, the entry duct 28' introduces the air through the straight duct 46' in a nontangential direction relative to the cylinder bore 12' and more particularly generally axially and somewhat radially into the cylinder bore 12', e.g., in the position shown in Fig. 5.

In accordance with the method of the present invention air flow is controlled to a cylinder bore 12 of a direct injection diesel type engine 10 to minimize undesirable emission on start up and cold idle while retaining high volumetric engine efficiency at all operating speeds. A non-swirl air flow is introduced substantially parallel to or coplanar with the axis 26 of the cylinder bore 12 during start up and cold idle operation via the second valve 30. A swirl air flow is introduced tangentially to the cylinder bore 12 via the first valve 18 only when the engine 10 operates at other than start up and cold idle. Introduction of the non-swirl air flow is stopped during intermediate speed operation of the engine 10

by controlled operation of the second butterfly valve 42. Introduction of the non-swirl air flow is restarted during high speed operation of the engine 10 so that air is permitted to flow through both passages to provide optimum volumetric efficiency. This can be controlled by a control 34 operating in response to engine speed as sensed by an engine speed sensor 40. Generally, the introducing, stopping and restarting of the non-swirl air flow comprises opening, closing and reopening of a non-swirl flow throttle valve, in the embodiment illustrated the second butterfly valve 42. The introducing of the swirl air flow generally comprises opening a swirl flow throttle valve, in the embodiment illustrated the first butterfly valve 32. The opening of the first butterfly valve 32 can be controlled, for example, through use of the control 34 operating responsive to a signal from the engine temperature sensor 36.

Through operating as just described above, engine efficiency is substantially improved and the previously mentioned problems of the prior art are substantially eliminated.

CLAIMS

1. A diesel engine having a cylinder bore; a head covering the bore; and an inlet air flow passage arrangement comprising a first air flow directing passage for introducing air past a first valve to the cylinder bore along a first flow path substantially tangential to the bore and causing swirling of the air within the bore, a second air flow directing passage for introducing air past a second valve to the bore along a second flow path having a component parallel to the axis of the bore and lying substantially in a plane parallel to the axis of the bore thereby causing minimal swirling of the air within the bore, and control means for selectively utilizing the first and second flow paths either individually or in combination during various phases of engine operation, including means for closing the first passage during engine start up and cold idle and means for closing the second passage at intermediate engine speeds.

2. An engine according to claim 1, wherein the first air flow directing passage comprises a straight duct angularly oriented relative to the first valve such that a centerline of the duct forms an angle, A, of about 30° to 50° with an axis of the first valve; an inner wall of the duct which comprises that portion of the duct nearest to the cylinder bore forms an angle, B, of at least about 40° with the valve axis; and an outer wall of the duct which comprises that portion of the duct farthest from the cylinder bore forms an angle, C, in the range of about 30° to 50° with the valve axis, the duct having a generally circular or oval cross-section, and the outer wall, is extended in the direction of air flow clearing a seat of the first valve.

3. An engine according to claim 1, wherein the first air flow directing passage comprises a first portion extending away from the first valve generally parallel to an axis thereof and a second portion generally perpendicular to the first portion and extending away from the cylinder bore, the first air flow directing passage having an outer generally linearly extending wall generally tangential to the cylinder bore adjacent the first valve and an inner wall opposite the outer wall, a concave surface forming a section of the inner wall, adjacent the first valve and facing towards the outer wall.

4. An engine according to any of claims 1 to 3, wherein the second air flow directing passage comprises a straight duct angled to the second valve at an angle, A, in the range of about 30° to 50° with an axis of said second valve, an inner wall of the duct which comprises that portion of the duct nearest to the cylinder bore forms an angle, B, of at least about 40° with the valve axis and an outer wall of the duct which comprises that portion of the duct farthest from the cylinder bore forms an angle, C, in the range of about 30° to 50° with the valve axis, the duct having a generally circular or oval cross-section, and the outer wall if extended in the direction of air flow clearing a seat of the valve.

5. An engine according to claim 1, wherein the first air flow directing passage comprises a first portion extending away from the first valve generally parallel to an axis thereof, a second portion generally perpendicular to the first portion and extending away from the cylinder bore, and having an outer generally linearly extending wall generally tangential to the cylinder bore adjacent the first valve and an inner wall opposite the outer wall, a concave surface forming a section of the inner wall adjacent the first valve and facing towards the outer wall.

6. An engine according to claim 1, substantially as described with reference to any of the examples shown in the accompanying drawings.

7. A method of controlling air flow to a cylinder bore of a direct injection diesel type engine to minimize undesirable emission on start up and cold idle while retaining high volumetric engine efficiency at all engine operating speeds, comprising introducing a non-swirl axial air flow to the cylinder bore during start up and cold idle engine operation; and introducing a swirling air flow substantially tangentially to the cylinder bore only when the engine is operating at other than start up and cold idle.

8. A method according to claim 7, including stopping introduction of the non-swirl air flow during intermediate speed engine operation.

9. A method according to claim 8, including restarting introduction of the non-swirl air



by controlled operation of the second butterfly valve 42. Introduction of the non-swirl air flow is restarted during high speed operation of the engine 10 so that air is permitted to flow through both passages to provide optimum volumetric efficiency. This can be controlled by a control 34 operating in response to engine speed as sensed by an engine speed sensor 40. Generally, the introducing, stopping and restarting of the non-swirl air flow comprises opening, closing and reopening of a non-swirl flow throttle valve, in the embodiment illustrated the second butterfly valve 42. The introducing of the swirl air flow generally comprises opening a swirl flow throttle valve, in the embodiment illustrated the first butterfly valve 32. The opening of the first butterfly valve 32 can be controlled, for example, through use of the control 34 operating responsive to a signal from the engine temperature sensor 36.

Through operating as just described above, engine efficiency is substantially improved and the previously mentioned problems of the prior art are substantially eliminated.

CLAIMS

1. A diesel engine having a cylinder bore; a head covering the bore; and an inlet air flow passage arrangement comprising a first air flow directing passage for introducing air past a first valve to the cylinder bore along a first flow path substantially tangential to the bore and causing swirling of the air within the bore, a second air flow directing passage for introducing air past a second valve to the bore along a second flow path having a component parallel to the axis of the bore and lying substantially in a plane parallel to the axis of the bore thereby causing minimal swirling of the air within the bore, and control means for selectively utilizing the first and second flow paths either individually or in combination during various phases of engine operation, including means for closing the first passage during engine start up and cold idle and means for closing the second passage at intermediate engine speeds.

2. An engine according to claim 1, wherein the first air flow directing passage comprises a straight duct angularly oriented relative to the first valve such that a centerline of the duct forms an angle, A, of about 30° to 50° with an axis of the first valve; an inner wall of the duct which comprises that portion of the duct nearest to the cylinder bore forms an angle, B, of at least about 40° with the valve axis; and an outer wall of the duct which comprises that portion of the duct farthest from the cylinder bore forms an angle, C, in the range of about 30° to 50° with the valve axis, the duct having a generally circular or oval cross-section, and the outer wall, is extended in the direction of air flow clearing a seat of the first valve.

3. An engine according to claim 1, wherein the first air flow directing passage comprises a first portion extending away from the first valve generally parallel to an axis thereof and a second portion generally perpendicular to the first portion and extending away from the cylinder bore, the first air flow directing passage having an outer generally linearly extending wall generally tangential to the cylinder bore adjacent the first valve and an inner wall opposite the outer wall, a concave surface forming a section of the inner wall, adjacent the first valve and facing towards the outer wall.

4. An engine according to any of claims 1 to 3, wherein the second air flow directing passage comprises a straight duct angled to the second valve at an angle, A, in the range of about 30° to 50° with an axis of said second valve, an inner wall of the duct which comprises that portion of the duct nearest to the cylinder bore forms an angle, B, of at least about 40° with the valve axis and an outer wall of the duct which comprises that portion of the duct farthest from the cylinder bore forms an angle, C, in the range of about 30° to 50° with the valve axis, the duct having a generally circular or oval cross-section, and the outer wall if extended in the direction of air flow clearing a seat of the valve.

5. An engine according to claim 1, wherein the first air flow directing passage comprises a first portion extending away from the first valve generally parallel to an axis thereof, a second portion generally perpendicular to the first portion and extending away from the cylinder bore, and having an outer generally linearly extending wall generally tangential to the cylinder bore adjacent the first valve and an inner wall opposite the outer wall, a concave surface forming a section of the inner wall adjacent the first valve and facing towards the outer wall.

6. An engine according to claim 1, substantially as described with reference to any of the examples shown in the accompanying drawings.

7. A method of controlling air flow to a cylinder bore of a direct injection diesel type engine to minimize undesirable emission on start up and cold idle while retaining high volumetric engine efficiency at all engine operating speeds, comprising introducing a non-swirl axial air flow to the cylinder bore during start up and cold idle engine operation; and introducing a swirling air flow substantially tangentially to the cylinder bore only when the engine is operating at other than start up and cold idle.

8. A method according to claim 7, including stopping introduction of the non-swirl air flow during intermediate speed engine operation.

9. A method according to claim 8, including restarting introduction of the non-swirl air



flow during high speed engine operation.

10. A method according to claim 9, wherein the introducing, stopping and restarting of the non-swirl air flow comprises opening, closing and re-opening of a non-swirl flow throttle valve.
11. A method according to any of claims 7 to 10, wherein the introducing of the swirl air flow comprises opening a swirl flow throttle valve.
12. A method according to claim 7, substantially as described with reference to the accompanying drawings.

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