A separating device for fine particles which comprises a housing provided with an inlet port adapted to intake the engine exhaust gas and an outlet port through which a cleaned exhaust gas is discharged. Within the housing, a magnetic unit having a plurality of magnetic elements is arranged in parallel in the axial direction of the housing with a space from each other to form magnetic fields in each space. The magnetic unit is also spaced from the inner surface of the housing. The space between the magnetic elements forms a part of a gas passage connecting the inlet port to the outlet port of the housing. The fine particles coming to this space are forced away from the space due to the magnetic force therein and cleaned exhaust gas is discharged to the outside of the housing through its outlet port.

6 Claims, 5 Drawing Figures
SEPARATING DEVICE FOR FINE PARTICLES, SUCH AS CARBONS AND THE LIKE

This invention relates to separating devices for fine particles from engine exhaust gas and more particularly to separating devices for carbon, lead compounds, and fine heavy metal particles and other floating fine particles causing air pollution from engine exhaust gas.

It is known that carbon monoxide, hydrocarbon, and oxidized nitrogen in the exhaust gas are main substances causing air pollution. It is further known that photochemical reaction, which is generated when ultraviolet rays of sun act upon oxidized nitrogen and hydrocarbon, affects eyes and throat, and causes hypnosis and impediment of eyesight. The amount of carbon monoxide and hydrocarbon can be decreased by raising the combustion efficiency of an engine, while oxidized nitrogen increases as the maximum combustion temperature of the engine is raised. Thus, in a known cleaning device used to reduce oxidized nitrogen, a part of the exhaust gas discharged through an exhaust pipe of the engine is again returned to an intake passage of the engine in a convenient manner so as to reduce the amount of intake oxygen. Thus, lowering the maximum combustion temperature, the creation of nitrogen monoxide (NO) is prevented. In such a cleaning device, a control valve is provided at an inlet through which the exhaust gas is returned into the intake passage. The control valve opens to the exhaust gas when the larger amount of oxidized nitrogen is created under high speed operations of the engine and closes when the smaller amount of oxidized nitrogen is created at engine idling. The fine particles such as carbons entrained in the returned exhaust gas have a bad effect on the smooth movement of the control valve and pollute the inside of the engine to hasten wear and tear thereof. Accordingly, it is suggested to remove them from the exhaust gas to be returned.

On the other hand, Diesel engine car running in the city with black exhaust gas discharging from the exhaust pipes will not only diffuse the appearance of the city but also give uncomfortable feelings to anyone therein. Therefore, recently in many countries, the allowable degree of black of the exhaust gas has been prescribed. To reduce the degree of black, it is usual to separate and collect the soot on the way of exhaust line.

Many technical difficulties have been experienced to remove the carbon particles in the exhaust gas. Normally, the carbon particles comprises fine particles in the range of 0.02–0.04 μ and combined particles of these fine particles in the range of 1–30 μ, so that these carbon particles cannot be effectively removed from the exhaust gas by the conventional filter media. Furthermore, the filter media have to be heat-proof to resist the high temperature in the exhaust line. But, a filter media which will require a higher pressure to pass through is not acceptable.

An object of the present invention is to provide a cleaning device which will satisfy the above-mentioned requirements.

Another object of the present invention is to provide a separating device wherein fine particles such as carbons entrained in an exhaust gas and charged with electricity while they are travelling along a combustion system and an exhaust line are fed to a magnetic field and are removed therefrom to be separated from the exhaust gas discharged outside an exhaust pipe.

Another object is to provide a separating device wherein the exhaust gas entraining the fine particles charged with electricity is forced to uniformly pass through the magnetic field to reduce the pressure drop therethrough.

Another object is to provide a separating device wherein a magnetic separating unit is combined with a known centrifugal separating unit or a known filter media to provide a better separating efficiency.

Other objects of the present invention will become apparent in the course of the following specification.

This invention is based upon a known phenomenon that an electron (electric charge: e coulomb) moving vertically with respect to a magnetic field of a fixed valve H gau at a velocity of v (cm/sec) is given a force f (dyne) as follows:

\[ f = \frac{1}{10} Hev \]

This force acts vertically to the moving direction of the electron, so that, without changing the velocity (v), the electron goes away from the magnetic field along a circular path. As the value of the magnetic field gets higher, the electron will be thrown away from the magnetic field along the circular path.

The present invention has incorporated this phenomenon in a separating device for carbon or other fine particles charged with electricity in an exhaust gas. Accordingly, the conventional disadvantages experienced with the use of the filter media have been eliminated by the present invention.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawing showing by way of example only, preferred embodiments of the inventive idea.

In the drawing:

FIG. 1 is a cross-sectional view showing a separating device according to the present invention;

FIG. 2 is a plane view showing a supporter for a magnetic element;

FIG. 3 is a cross-sectional view showing main portions of a separating device according to a second embodiment of the present invention, in which magnetic elements becoming larger in their diameters as they go to an outlet port of the device are arranged in parallel;

FIG. 4 is a cross-sectional view showing main portions of a separating device according to a third embodiment of the present invention, in which baffle plates are provided in the device; and

FIG. 5 is a cross-sectional view showing a separating device according to a fourth embodiment of the present invention.

Referring now to a separating device according to a first embodiment of the present invention shown in FIG. 1, a cylindrical body 1 is provided with an inlet conduit 10 and an outlet conduit 18 for engine exhaust gas. The inlet conduit 10 passes through the center portion of a front closure plate 11 and is fixed thereto to allow the engine exhaust gas to enter into the cylindrical body 1. The closure plate 11 is connected to a cylindrical member 16 by bolts 13 passing through a flange 15 at an open end of the cylindrical member 16 and cramped to nuts 14 at the front circumferential surface.
of the closure plate 11 with a gasket 12 interposed between the plate 11 and the flange 15. The flange 15 is welded to the cylindrical member or may be integral therewith.

Within the cylindrical body 1 a magnetic unit 50 is disposed along the axial direction thereof with a predetermined annular space from the inner surface of the cylindrical member 16. The magnetic unit 50 is held in its position by a rear retainer cup 40 and a front retainer cup 30, both being loosely and removable engaged at their circumferential edges with the inner surface of the cylindrical member 16. The rear retainer cup 40 seats at its outer circumferential edge portions against an annular gasket 19 which is placed on the inner circumferential portions of the rear retainer cup 17. The rear closure plate 17 has the outlet conduit 18 provided through a central opening thereof.

The front retainer cup 30 receives an end of a compressed spring 20 the other end of which seats upon the rear surface of the front closure plate 11, so that the front retainer cap 30 slideable along the inner surface of the cylindrical member biases the magnetic unit 50 toward the rear retainer cup 40. The front retainer cup 30 is provided at its circumferential portion with a plurality of openings 31 through which gas can pass. The rear end of the magnetic unit 50 is received by the rear retainer cup 40 with an annular gasket 44 interposed therebetween.

The magnetic unit comprises, in the embodiments shown in the drawings, six flat cylindrical magnetic elements 51, five supporters 52 interposed between each two magnetic members 51 to support them in parallel with a predetermined space, a cap shaped metal member 53, a bolt 54 passing through the all magnetic elements and supporters, and a nut 56 threaded to the bolt 54 with a washer 55 interposed between it and the cap shaped metal member 53. The foremost magnetic element 51 has a relatively small central bore 57 so that the bolt 54 passing therethrough may be seated at its head portion to the front surface thereof. The other magnetic elements have a relative large bore 58, which forms an annular space about the bolt to permit the exhaust gas to pass therethrough.

Each supporter 52 for magnetic element 51 has a small central hole 59 through which the bolt 54 passes, a circumferential flange 60 forwardly folded to snugly receive the outer cylindrical surface of the magnetic element 51, and three rearwardly folded legs 61 of circular sections the diameters of which are larger than the larger bore 58 of the magnetic element 51 to enable the legs 61 to rest upon the front surface of the adjacent magnetic element and to define a predetermined space between the two adjacent magnetic elements 51.

The cap-shaped metal member 53 at the rear end of the magnetic unit 50 has a relatively small hole 62 through which the bolt 54 passes. The cap-shaped member 53 also has a plurality of openings formed through its cylindrical wall 63 the diameters of which are substantially the same as those of the legs 61 of the supporters 52.

In assembly of the magnetic unit 50, magnetic elements 51 are so arranged that the magnetic pole S in one magnetic element may face the magnetic pole N in the adjacent magnetic element with the space determined by the length of the legs 61 of the supporter. Thus, magnetic fields are formed in every space between the magnetic elements. The magnetic element 51 may be a permanent magnet or an electrical magnet, not shown, in which a cylindrical iron member is wound by a conductive wire to apply electric current.

In arranging the magnetic elements 51 in a predetermined parallel spaced relation by the supporters, the bolt 54 is inserted through the aligned bores and holes of the magnetic elements 51 and the supporters 52, respectively, and is cramped at its rear end passing beyond the cap-shaped metal cap 53 by the nut 56.

Before assembling the magnetic unit 50 within the cylindrical body, the rear retainer cup provided with a central opening 42 is disposed within the cylindrical body 1 by interposing the gasket 19 between the circumferential edge portion 43 of the rear retainer cup 40 and the rear closure plate 17. Then, the cap-shaped metal member 53 of the magnetic unit 50 is inserted through the central opening 42 of the rear retainer cup 40 by interposing the gasket 44 between the rearmost magnet element 51 and rear retainer cup portion which is adjacent the central opening 42. The front retainer cup 30 permits the head of the bolt 54 to pass through a central hole 33 thereof. Thus, the magnetic unit 50 is prevented from lateral movement by the front and rear retainer cups 30 and 40. Then, the spring 20 is compressed between the front retainer cup 30 and the front closure plate 11, so that the front retainer cup 30 urges the magnetic unit 50 toward the rear retainer cup 40 to firmly set the magnetic unit in the cylindrical body under any vibratory conditions. The assembly is completed by cramping the flange 15 of the cylindrical member 16 to the circumferential portions of the front closure plate 11 by the bolts 13 and nuts 14.

When this separating device is associated with an exhaust line, the exhaust gas enters into the separating device through the inlet conduit 10. Then, passing through, in turn, the peripheral holes 31 of the front retainer cup 30, the annular space between the cylindrical member and the magnetic unit 50, the annular spaces between the magnetic elements 51 forming magnetic fields, a plurality of openings between the rearwardly folded legs 61 of the supporters 52, the large bores 58 of the magnetic elements 51, the holes 64 in the cylindrical wall 63 of the cap-shaped metal member 53, and the outlet conduit 18, the exhaust gas is discharged outside of the separating device.

Fine particles such as carbon particles entrained in the engine exhaust gas are charged with electricity while they travel through combustion system and discharge line, so that, when they enter into the annular spaces of each pair of adjacent magnetic elements having opposite magnetic poles at their opposing sides, they are effected by the magnetic field in the annular spaces and are forced away from the annular spaces. Thus, the outwardly forced particles are attracted to the inner surface of the cylindrical member 16 and cannot pass through the magnetic field. Only the exhaust gas free from such particles passes through the annular spaces between the magnetic elements 51 and is discharged through the outlet conduit by way of the succeeding passages in the cylindrical body. The exhaust gas coming to the outlet conduit may be again returned to the combustion system to reduce oxidized nitrogen and, especially, nitrogen monoxide or may be directly discharged into the atmosphere.

A test example of the separating device according to the present invention shall be described hereinafter:
Six permanent magnet bodies 51 each having a diameter of 60mm and a thickness of 10mm were spaced in parallel with each other at intervals of 3mm and disposed, as shown in FIG. 1, within the cylinder having an inner diameter of 70mm. The magnetic field in each annular space between the two adjacent magnetic bodies had the value of 1,500 gauss. This separating device was assembled to an exhaust line of 1,800cc gasoline engine which was operated with the use of gasoline not containing lead under the conditions of one-half load and 1,500r.p.m. The exhaust gas of 200 l/min, which amount corresponds to 10–20 percent by volume of the whole exhaust gas, was introduced into the separating device. After continuous operation of the engine for 100 hours, the fine particles of 1.62g were separated from all harmful fine particles of 1.96g in the exhaust gas and attached to the inner surface of the cylindrical member 16, from which the separated particles were removed. Furthermore, it has been noted that the pressure rise caused by the provision of this separating device was 6mm Hg, which amount is low enough to enable this device to be practically used.

In order to facilitate the electric charge of the fine particles such as carbon and, thereby, to separate them more effectively, preferably, an electrode member 65 is provided within the inlet conduit 10.

In the first embodiment disclosed above, all magnetic elements 51 have the same, so that the larger amount of exhaust gas entered into the cylindrical body 1 will pass through the annular spaces between the magnetic elements 51 at the side of the inlet conduit 10.

In a second embodiment of the separating device according to the present invention shown in FIG. 3, in order to uniformly flow the exhaust gas entered into the cylindrical body 1 through the conduit 10 to each annular space between the magnetic elements 51, the magnetic elements 51 increase in diameter as they extend from the inlet conduit side to the outlet conduit side.

In a third embodiment of the separating device according to the present invention shown in FIG. 4, instead of changing the diameters of the magnetic elements 51 as in the second embodiment, baffle plates 66 and 67 each having an opening larger than the diameters of the magnetic elements 51 are fixed to the inner surface of the cylindrical member 16. The baffle plate 66 at the side of the inlet conduit 10 has an opening larger than that of 67 at the side of the outlet conduit 18.

In a fourth embodiment of the separating device according to the present invention shown in FIG. 5, the separating device comprises, in addition to the first embodiment, deflecting blades 34 rearwardly adjacent to the peripheral holes 31 of the front retainer cup 30, a restricted hole 68 through a part of the cylindrical member 16, a cylindrical bulge member 69 encircling the cylindrical member 16 with an annular dust chamber 70 therebetween, which chamber communicates with the inside of the cylindrical member 16 through the opening 69, a sheet-type filter media 72 enclosing the magnetic elements 51, and a plurality of annular depth-type filter media 71 interposed between the magnetic elements 51. The sheet-type and depth-type filter media 72 and 71 are made of heat-proof substances such as glass wool or wire net.

The separating device according to the fourth embodiment is so constructed that the exhaust gas entering into the cylindrical body through the peripheral holes 31 of the front retainer cup 30 is forced to spiral flow by means of the deflecting blades 34. Accordingly, the heavier particles in the exhaust gas come close to the inner surface of the cylindrical member 16 by centrifugal force of the spiral flow and pass through the restricted hole 68 to be collected in the dust chamber 70. Only the remaining smaller particles which were not caught by the sheet-type filter media 72 can enter into the spaces between the magnetic elements 51, from where the smaller particles are separated by the effect of magnetic field and the depth-type filter media 71.

Many modifications and changes in the described embodiments may be made, for example, the sheet-type filter media and depth-type filter media in the fourth embodiment can be eliminated.

What is claimed is:

1. A separating device for fine particles charged with electricity, such as carbons and the like, from an engine exhaust gas, comprising a housing having an inlet port adapted to in-take said engine exhaust gas and an outlet port through which a cleaned exhaust gas is discharged, a magnetic unit having a plurality of magnetic elements arranged in parallel with a space in between, adjacent magnetic elements having opposite facing magnetic poles to form magnetic fields in said spaces, said space forming a part of the gas passage connecting said inlet port to said outlet port, and means mounting said magnetic unit within said housing with a space from the inner surface of said housing, said magnetic unit comprising a plurality of flat cylindrical magnetic elements, a plurality of supporters for said magnetic elements, each of said supporters having circumferentially spaced legs to define an annular space between adjacent magnetic elements, a cap shaped metal member having openings for cleaned exhaust gas and located at the outside of the rearmost magnetic element adjacent said outlet port of said housing, and means interconnecting said magnetic elements, said supporters and said metal member, whereby fine particles in said exhaust gas entering into said housing through said inlet port and coming into said spaces between said magnetic elements are forced away from said spaces due to the magnetic force therein, while cleaned exhaust gas is discharged to the outside of said housing through said outlet port thereof.

2. A separating device in accordance with claim 1, wherein said mounting means comprises a front retainer plate having a hole through which said exhaust gas entraining said fine particles is guided around said magnetic unit, said front retainer plate being slidable relatively to the inner surface of said housing, a spring pressing said plate to said magnetic unit, and a rear retainer plate slidable relating to the inner surface of said housing and pressed against the rear end of said housing by said magnetic unit.

3. A separating device in accordance with claim 2, further comprising deflecting blades located adjacent said hole of said front retainer plate for imparting spiral flow to the exhaust gas passing therethrough, and a dust chamber communicating with said hole of said front retainer plate through a hole in the wall of said housing.

4. A separating device in accordance with claim 1, wherein said magnetic elements have the same diameter.
3,762,135

ters and said separating device further comprises a plurality of baffle plates mounted on the inner surface of said housing and extending in the axial direction thereof with a space therebetween, one of said baffle plates at the side of said inlet port of said housing having an opening which is larger than that of another baffle plate at the side of said outlet port.

5. A separating device in accordance with claim 1, wherein said magnetic elements have larger diameters as they extend toward said outlet port.

6. A separating device as claimed in claim 1, wherein a plurality of filter medias made of glass wool are interposed between said magnetic elements.

* * * * *