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(71) Applicant: **TVS MOTOR COMPANY LIMITED**
[IN/IN]; TVS Motor Company Limited, Jayalakshmi Es-
tates, No.29 (old No.8) Haddows Road, Chennai 600 006
(IN).

(72) Inventors: **LOGANATHAN BALASUBRAMANIAN, Thiruvallur**; TVS Motor Company Limited, Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600 006 (IN). **IYENGAR LAKSHMINARASIMHAN, Varadha**; TVS Motor Company Limited, Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600 006 (IN).

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(54) Title: AN EXHAUST GAS RECIRCULATION SYSTEM

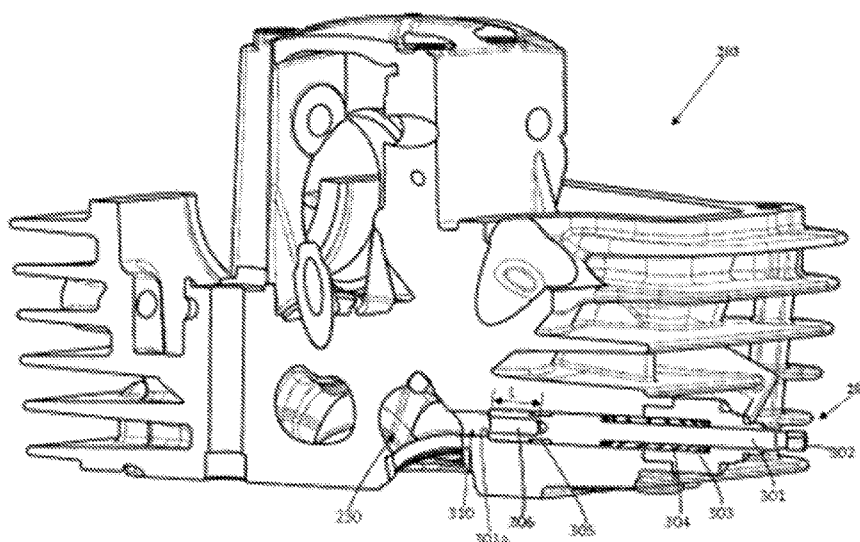


Fig. 3

(57) Abstract: An internal combustion (IC) engine (101) for a two wheeled vehicle comprises of a cylinder block (204) and a cylinder head (203). The cylinder head comprises of an EGR intake passage (310) extending from an intake port (230) and an EGR exhaust passage (320) extending from the exhaust port (240), the EGR exhaust passage (320) intersecting the EGR intake passage to permit the flow of exhaust gases from at least one of said exhaust port to at least one of said intake port through an EGR control mechanism (201). The EGR control mechanism is easy to implement in any two wheeled or three wheeled vehicles in spite of space and layout constraints. This mechanism also decreases the number of components and thereby is cost effective. Furthermore, effective control during various throttle positions can be achieved to significantly reduce NO_x at all stages of vehicle operation.



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AN EXHAUST GAS RECIRCULATION SYSTEM

Technical Field

[1] The present invention relates generally to an internal combustion engine of a two wheeled or three wheeled vehicles. More particularly, but not exclusively, to an exhaust gas recirculation system for use with an internal combustion engine, for purification of exhaust gas.

Background

[2] An internal combustion (IC) engine converts thermal energy obtained from burning of a fuel with air into mechanical energy, which can be employed to provide motive force for movement of an automobile. The main parts of the IC engine include a cylinder head, a reciprocating piston on a cylinder block and a connecting rod which connects the piston to the reciprocating crankshaft. During operation of the IC engine, the burning of fuel and air occurs in a combustion chamber interposed between the cylinder and cylinder block and transfers mechanical energy to the reciprocating piston. Upon combustion, the IC engine generates lot of exhaust gases which is directed to the outside environment. With continuous tightening in emission norms, controlling, cleaning and reducing harmful emissions in the IC engines has become an absolute necessity to meet the future legislative requirements. Control of the exhaust emissions vary based on target emissions such as carbon monoxide, hydrocarbons, various nitrogen oxides (NO_x) and particulate matter among others. Conventionally, the NO_x emissions controlled by retarding the engine ignition timing which lead to a drop in fuel economy. So special control techniques to reduce NO_x are devised. Exhaust gas

recirculation (EGR) is one such emission control technique mainly targeted to reduce NO_x emissions where a portion of exhaust gases from the IC engine is recirculated back to the intake system to reduce the combustion temperature. NO_x is primarily formed when a mixture of nitrogen and oxygen is subjected to high temperature, a lower combustion chamber temperature reduces the amount of NO_x generated during the combustion. In conventional EGR control mechanisms, the mechanism of control of the EGR control mechanism is usually operated with the aid of electric power and said mechanism is disposed outside the cylinder head occupying space. However, such EGR control mechanism with electrically operated control mechanism and disposed outside the cylinder head is easy to implement in larger capacity engines in bigger vehicles like cars. But in smaller IC engines or small vehicles such as any two & three wheeled vehicles including saddle type vehicles, it is difficult to implement because of space and layout constraints. The conventional setup also increases the number of components and thereby is not cost effective. Further, effective control during various throttle positions is required to fully realise NO_x reduction at all stages of operation.

Summary of the Invention

[3] The present invention has been devised in view of the above circumstances.

[4] Thus to address above discussed problems, the present subject matter in an embodiment proposes an internal combustion engine comprising of a cylinder head and a cylinder block for a two wheeled vehicle, wherein an EGR intake passage, an EGR exhaust passage and the EGR control mechanism disposed within the cylinder head.

[5] Accordingly, it is an object of the present invention to provide a simple, fully mechanical, low cost EGR control mechanism for a two wheeled vehicle which can be disposed & collocated within the IC engine cylinder head. It is another object of the present invention to reduce the temperature of exhaust gases before they enter the intake system without significantly altering the engine design and layout. It also another object to resolve above mentioned problems as well as significantly improve the aesthetics of the two wheeled vehicle by preventing exposure of the EGR control mechanism outside the IC engine. The EGR control mechanism uses a control shaft with an internal passage operated by a spring load.

10 The proposed mechanism can be disposed within the intake EGR passage and hence disposed entirely within the cylinder head. The mechanism is actuated by the throttle cable and hence offers a low cost alternative to other EGR control mechanisms.

[6] Summary provided above explains the basic features of the invention and does not limit the scope of the invention. The nature and further characteristic features of the present invention will be made clearer from the following descriptions made with reference to the accompanying drawings.

Brief Description of Drawings

[7] The detailed description is described with reference to the accompanying figures. The same numbers are used throughout the drawings to reference like features and components.

[8] Fig. 1. illustrates the side view of a two wheeled vehicle employing an embodiment of the present subject matter.

- [9] Fig. 2. illustrates the isometric view of an internal combustion engine employing the embodiment of the present subject matter.
- [10] Fig. 3. illustrates a cut sectional view of a cylinder head showing an EGR control mechanism according to the embodiment of the present subject matter.
- 5 [11] Fig. 4. illustrates the exploded view of the EGR control mechanism assembled on the cylinder head according to the embodiment of the present subject matter.
- [12] Fig. 5. illustrates the top view of the cylinder head illustrating an intake EGR passage and an outlet EGR passage according to the embodiment of the
- 10 present subject matter.
- [13] Fig. 6a. illustrates the cut sectional view of the cylinder head and the EGR control mechanism in low throttle position according to the embodiment of the present subject matter.
- [14] Fig. 6b. illustrates the cut sectional view of the cylinder head and the
- 15 EGR control mechanism in normal throttle position according to the embodiment of the present subject matter.
- [15] Fig. 6c. illustrates the cut sectional view of the cylinder head and the EGR control mechanism in full throttle position according to the embodiment of the present subject matter.
- 20 [16] Fig. 7 illustrates a second embodiment of the present subject matter.

Detailed Description

[17] Thus to address above discussed problems, the present subject matter proposes a mechanically controlled EGR control mechanism for a two wheeled vehicle disposed within the cylinder head. Various other features and embodiments of the present invention here will be discernible from the following
5 further description thereof, set out hereunder. According to an embodiment, the internal combustion (IC) engine described here operates in four cycles and is implemented in a straddle type two wheeled vehicle. It is contemplated that the concepts of the present invention may be applied to other types of vehicles such as step-through scooter type two wheeled vehicles and other types of IC engine such
10 as a two cycle IC engine within the spirit and scope of this invention. The detailed explanation of the constitution of parts other than the present invention which constitutes an essential part has been omitted at suitable places.

[18] During combustion of air-fuel mixture in the combustion chamber, due to high heat and pressure, the nitrogen and oxygen in air-fuel mixture combine to
15 form oxides of nitrogen (hereafter referred to as NO_x). The presence of NO_x in IC engine exhaust gases is a cause of concern and emission norms are becoming stricter to regulate and reduce NO_x emissions from IC engine of vehicles. Exhaust gas recirculation (EGR) system is one such technique to control and regulate the NO_x emissions from the IC engine.

[19] The principle of the EGR control mechanism is that, a part of the exhaust
20 gases is taken from the previous combustion cycle and is recirculated back to the intake system usually due a pressure difference across the intake port and exhaust port. The presence of exhaust gases before the combustion of air-fuel mixture

provides inert atmosphere for the combustion to occur and dilutes the oxygen present in the combustion chamber. Additionally, the exhaust gases act as absorbents of heat produced during combustion to reduce temperatures inside. Since NO_x is primarily formed when a mixture of nitrogen and oxygen is subjected to high temperature, a lower combustion chamber temperature reduces the amount of NO_x generated during the combustion.

[20] Generally, EGR control mechanism comprises an intake EGR passage from the intake port of the cylinder head, an exhaust EGR passage from the exhaust port of the cylinder head, an EGR valve connecting the intake EGR passage and exhaust EGR passage, and an EGR control mechanism to control the EGR valve. The EGR control mechanism is required as it controls the amount and timing of exhaust gas recirculation such that the impact of EGR control mechanisms on engine performance is negligible. The EGR control mechanism can either be mechanically controlled or electronically controlled. Electronically controlled EGR control mechanism involves use of solenoid actuated EGR valves and electronic control unit to control the solenoid actuated EGR valve. Mechanically controlled EGR control mechanism either automatically or by driver actuation offers benefits compared to electronically controlled EGR valves, as they have lower cost, easy replacement of parts and easier to install and operate.

[21] The control of the recirculation of exhaust gas in the EGR control mechanism from the IC engine to the intake system is essential as it may lead to deteriorating performance at certain operating conditions of the IC engine. The

volume of recirculation of exhaust gas in the EGR control mechanisms based on the throttle position depends on various parameters specific to the IC engine design and intended reduction in NO_x, and hence needs to be controlled for optimum performance of the engine. At low throttle position ranges and during idling, the temperature inside the combustion chamber is below the operating temperature. Since one of the essential conditions in EGR control mechanism is to decrease the overall temperature, exhaust gas recirculation during low throttle position and idling further lowers the operating temperatures and this may affect the startability of the IC engine & give rough idling. Hence, until the engine reaches normal operating temperature the EGR valve is to be closed. Further, there is decreased NO_x production at low throttle or idling condition. Further, exhaust gas recirculation is not employed at full throttle position because it would reduce peak power output. At full throttle position, the intake charge density is reduced, hence presence of exhaust gases will decrease the presence of oxygen in the combustion chamber and hence ability of fuel combustion is reduced. For above reasons, the EGR valve is controlled to allow exhaust gases when required and close when conditions are not required.

[22] Despite the advantages offered with an EGR control mechanism, implementing an EGR control mechanism in a two wheeled vehicle operating on a single cylinder bore IC engine has drawbacks. The EGR valve, the EGR control mechanism and also the intake EGR passage and exhaust EGR passage are located outside the cylinder head. In two wheeled vehicles, the layout and space constraints make it very disadvantageous to accommodate the EGR control

mechanism outside the cylinder head. Further such EGR control mechanisms have negative impact on the overall aesthetics of the two wheeled vehicle and makes it aesthetically unpleasing. Also, the using mechanically controlled EGR control mechanism outside the cylinder head is mechanically complex and involves use of multiple parts. An external disposition of the EGR can have additional drawbacks in terms of response time, ducting losses as well as adverse thermal effects resulting in poor engine performance & poor control of emissions.

[23] Accordingly, it is an object of the present invention to provide a simple, fully mechanical, low cost EGR control mechanism for a two wheeled vehicle which can be disposed & collocated within the IC engine cylinder head. It is another object of the present invention to reduce the temperature of exhaust gases before they enter the intake system without significantly altering the engine design and layout. It also another object to resolve above mentioned problems as well as significantly improve the aesthetics of the two wheeled vehicle by preventing exposure of the EGR control mechanism outside the IC engine.

[24] With the above proposed invention, the EGR control mechanism uses a control shaft with an internal passage operated by a spring load. The proposed mechanism can be disposed within the intake EGR passage and hence disposed entirely within the cylinder head. The mechanism is actuated by the throttle cable and hence offers a low cost alternative to other EGR control mechanisms. The present EGR control mechanism reduces NOx emissions without affecting the engine's fuel economy and rated engine specifications and is capable of closing the EGR valve during low throttle, idling or full throttle conditions. The present

invention also provides a means for incorporating EGR control mechanisms without significantly impacting the aesthetic appearance of such two wheeled vehicles. Further, the emitted exhaust gases can be cooled before recirculating it back to the intake system if the exhaust EGR passage is located close to oil cooled
5 jackets within the cylinder head.

[25] The present invention along with all the accompanying embodiments and their other advantages would be described in greater detail in conjunction with the figures in the following paragraphs.

[26] Fig. 1 illustrates the two wheeled vehicle in accordance with one
10 embodiment of the present invention. The IC engine (101) is installed in a straddle type motorcycle, and the present invention can be implemented in other two wheeled vehicles without deviating from the scope of the present subject matter. The two wheeled vehicle comprises, a front wheel (110), a rear wheel (103), a frame structure, a fuel tank (121) and seat (106). The frame structure includes a
15 head pipe (111), a main tube (not shown), a down tube (not shown), and seat rails (not shown). The head pipe (111) supports a steering shaft (not shown) and two telescopic front suspension(s) (114) (only one shown) is attached to the steering shaft through a lower bracket (107). The two telescopic front suspension(s) (114) supports the front wheel (110). The upper portion of the front wheel (110) is
20 covered by a front fender (115) mounted to the lower portion of the telescopic suspension (114) at the end of the steering shaft. A handlebar (108) is fixed to upper bracket (not shown) and can rotate to both sides. A head light (109), visor guard (125) and instrument cluster (not shown) is arranged on an upper portion of

the head pipe (111). The down tube is located in front of the IC engine (101) and stretches slanting downward from head pipe (111). Main tube is located above the IC engine (101) and stretches rearward from head pipe (111). The IC engine (101) is mounted at the front by the down tube and connects the rear of the IC engine (101) at the rear portion of the main tube. A fuel tank (121) is mounted on the horizontal portion of the main tube. Seat rails are joined to main tube and stretch rearward to support a seat (106). A rear swing arm (118) is connected to the frame structure to swing vertically, and a rear wheel (103) is connected to rear end of the rear swing arm (118). Generally, the rear swing arms (118) are supported by a mono suspension (117) (as illustrated in the present embodiment) or two suspensions on either side of the two wheeled vehicle. A tail light unit (104) is disposed at the end of the two-wheeled vehicle at the rear of the seat (106). A grab rail (105) is also provided on the rear of the seat rails. The rear wheel (103) arranged below seat (106) rotates by the driving force of the IC engine (101) transmitted through a chain drive (116) from the IC engine (101). A rear fender (127) is disposed above the rear wheel (103). There is front brake (119) and back brake (not shown) arranged on the front wheel (110) and back wheel (103) respectively.

[27] Fig. 2. illustrates a perspective view of the IC engine (101) employing the embodiment of the present subject matter. The IC engine (101) is made up of a cylinder head (203), cylinder block (204), a cylinder head cover (202) and crankcase (205). The crankcase (205) is made up of left-hand crankcase (205b) and right-hand crankcase (205a). A combustion chamber (not shown) is

interposed between the cylinder head (203) and cylinder block (204) wherein the combustion of air fuel mixture occurs. The IC engine (101) also has a sprocket (not shown) disposed outside (on the other side) of the LH crankcase (205b) and is linked to the rear wheel (103) with the chain drive (116). In the present
5 embodiment, the IC engine (101) is an oil cooled engine utilizing lubricating oil for cooling the combustion chamber. The oil is circulated around cooling jackets disposed around the combustion chamber and cylinder head (203) to extract heat and consequently cool the surroundings around the combustion chamber and cylinder block (204). As a consequence, the IC engine (101) comprises a heat
10 exchanger (240) which functions to cool the incoming hot oil. The heat exchanger (240) is exposed to the natural flow of atmospheric air which cools the oil before it circulates back into the IC engine (101) through an output channel. The cylinder head (203) comprises an EGR intake boss portion (203a) through which the intake passage (310) passes and provides access to the intake port (230). The intake
15 passage (310) accommodates the EGR control mechanism (201) through the intake boss portion (203a). The exhaust passage (320) extends from the exhaust port and connects the intake passage (310) and extends up to the cylinder head outer surface (see 203b). The EGR control mechanism (201) is operated by means of the throttle position. Since, the throttle position is controlled by a throttle cable
20 (not shown) operated by the rider of the two wheeled vehicle, during operation of the throttle cable, simultaneous actuation of the EGR control mechanism (201) takes place with the aid of an EGR cable (210). Hence, the EGR cable (210) operates in tandem with the throttle cable so that, the exhaust gas control can

occur based on the throttle position. In another embodiment, the EGR control may be controlled through an ECU receiving signal from a throttle system. In the present embodiment, the EGR control mechanism (201) is disposed facing the rightward direction of the IC engine (101), as viewed from the two wheeled

5 vehicle rear.

[28] Fig. 3. illustrates the cut sectional view of a cylinder head (203) showing an EGR control mechanism (201) according to the embodiment of the present subject matter. The EGR control mechanism (201) to control the exhaust gas recirculation based on the throttle position comprises a control shaft (301), said
10 control shaft (301) comprising an exhaust gas channel (306) coaxial to the control shaft (301), and extending from the inner end of the control shaft (301) up to an opening (305) disposed at a predetermined distance (L) from the inner end of the control shaft (301a), an elastic member (304) attached to the control shaft (301) exerting a positive bias force against the control shaft (301), and a plug (303) to
15 provide support to the control shaft (301) and permit attachment of the elastic member (304). The plug (303) also prevents the leakage of exhaust gases from the EGR intake passage. In the present embodiment the elastic member (304) is a helical spring. The predetermined length of the exhaust gas channel (306) is lesser than the distance between the closed end position of the control shaft (301) and
20 the zone of intersection (P). The opening (305) is designed to have conical cross-section to permit partial entry of air during the transition from part throttle to full throttle position.

[29] Fig. 4. illustrates the top view of the cylinder head (203) showing the intersection of the intake passage (310) and the exhaust passage (320). In the embodiment of the present subject matter, the IC engine uses four valves and hence the cylinder head (203) has a valve-train with 4 valves (2 intake valves and 2 exhaust valves). The intake passage (310) and the exhaust passage (320) extends from any one of the two intake/exhaust valves to intersect. The diameter of the intake passage (310) is made greater than the diameter of the exhaust passage (320) and extends till the outer surface of the cylinder head (203) to accommodate the EGR control mechanism (201) from outside. This arrangement also permits the access of EGR control mechanism (201) from outside to permit servicing, inspection and part replacement. The intake passage (310) is designed to be substantially parallel to the horizontal plane. The exhaust passage (320) also designed to be substantially parallel to the horizontal plane and may extend beyond the zone of intersection (P). This is mainly to permit ease of manufacturing while drilling the passage to access the exhaust port (240).

[30] In one embodiment Fig. 5, shows the control shaft (301) illustrated in the exploded view of the EGR control mechanism assembled on the cylinder head (203) according to the embodiment of the present subject matter. The EGR control valve (201) coaxially inserted into the EGR intake passage to be disposed within the cylinder head (203), and EGR control valve configured to control the flow of exhaust gases from the one or more exhaust port to the one or more intake port. The control of exhaust gas flow will be highlighted in the preceding paragraphs.

[31] Fig. 6a, Fig. 6b, and Fig 6c illustrates the operation of the EGR control mechanism (201) to control the flow of exhaust gases from the exhaust port (240) to the intake port (230) according to one embodiment of the present subject matter. Fig. 6a illustrates the position of the control shaft (301) during idling or part throttle condition. Since, the actuation of the EGR cable (210) is simultaneously actuated by the actuation of the throttle bar, during idling the positive bias force of the elastic member keeps the opening away from the zone of intersection (P) and hence no exhaust gas flow is observed. When the throttle position is altered, the EGR cable (210) moves pulling the control shaft (301) against the bias force of the spring. During this linear movement of the control shaft (301), the opening will meet the zone of intersection (P) and a pathway between the exhaust passage (320), the opening, the exhaust gas channel (306) and the intake passage (310) form a pathway. Due to pressure difference between the exhaust port (240) and intake port (230), the exhaust gases can flow from the exhaust port (240) back to intake port (230). Fig. 6b illustrates the position of the control shaft (301) in normal throttle condition illustrating the flow of exhaust gases. When the throttle further increased to full throttle position, the control shaft (301) engages in linear movement beyond the zone of intersection (P), this again closes the exhaust gas circuit and prevents exhaust gases from recirculating to the intake port. Fig. 6c illustrates the position of the control shaft (301) in full throttle condition. The mouth of the opening has a cross section being conical in shape. Hence, during simultaneous linear movement of the control shaft (301), the opening can be partly exposed to the exhaust passage (320) at the zone

of intersection (P). Also, the throttle positions at which the opening shall be exposed to the exhaust passage (320) at the zone of intersection (P) can be varied as per the requirement thereby providing the leverage to decide at which throttle position EGR shall be switched ON & OFF. Hence, simultaneously and continuous variation and control of exhaust gas flow at desired throttle positions can be achieved when the throttle position is varied. This operation is completely achieved through mechanical movement without the need of expensive solenoid operated EGR valves and control units. Further, the EGR control mechanism is enclosed & collocated completely within the cylinder head (203). Furthermore, the exhaust passage (320) can be drilled close to oil passages meant for cooling (see 350, Fig. 6a). This achieves additional functionality of cooling the exhaust gases before recirculation. EGR cooling cools the exhaust gases so that the exhaust gas has lower latent heat content. The cooled exhaust gas and air mixture lowers the combustion temperatures in the combustion chamber, which results in less NO_x produced from the engine.

[32] Fig. 7 illustrates another embodiment of the EGR system assembled in the cylinder head (203). Cam chain chamber (250) is disposed on opposite side of the EGR mechanism. In this embodiment, an exhaust control mechanism (201) comprises of a diaphragm valve (701) is used enclosed within the cylinder head (203). The diaphragm valve (701) controls a control shaft (705) which has an indentation (705a) on its surface & supported by plug (708). The indentation (705a) connects the intersection of the intake passage (702) and exhaust passage (703). A pressure control passage (704) is connected to one chamber of the

diaphragm valve, and the other chamber is connected to the intake passage (703).

While one end of the control shaft (705) is connected to a diaphragm material (706), the other end of the control shaft is subjected to bias force of a spring (707).

The EGR flow is determined by the control shaft (705) position. The linear
5 movement of the control shaft (705) is determined by vacuum force between the two chambers of the diaphragm valve (701). The advantage of this embodiment is that, it does not need any external control of the control shaft (705) to control the exhaust gas recirculation.

[33] Many modifications and variations of the present subject matter are
10 possible in the light of above disclosure. Therefore, within the scope of claims of the present subject matter, the present disclosure may be practiced other than as specifically described.

We claim:

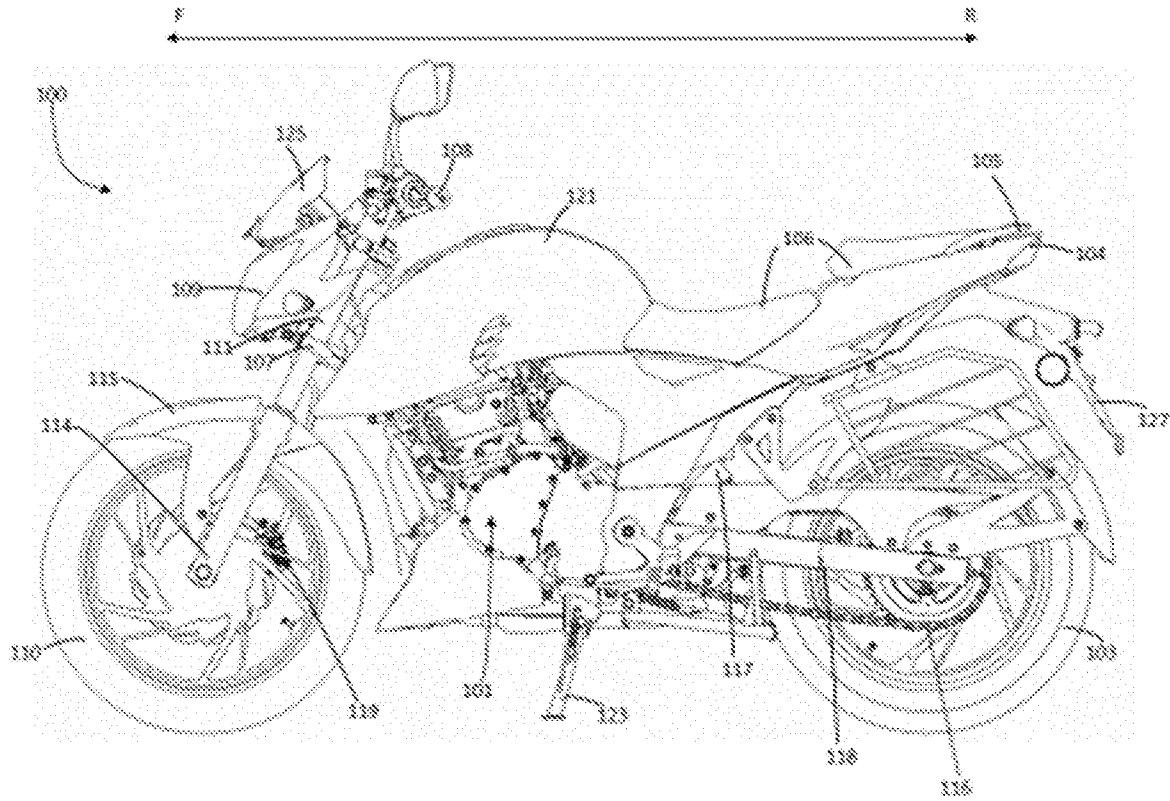
1. An internal combustion (IC) engine (101) for a two wheeled vehicle (100), said internal combustion (IC) engine (101) comprising:
a cylinder block (204), inside which the combustion of air-fuel mixture occurs and exhaust gases are generated as a result of the combustion;
a cylinder head (203) disposed above the cylinder block (204), said cylinder head (203) comprising:
at least one intake port (230) configured to allow entry of air-fuel mixture inside the cylinder block (204);
at least one exhaust port (240) configured to allow exit of exhaust gases out of the cylinder block (204);
characterized in that:
the cylinder head (203) comprises of an EGR intake passage (310) extending from the intake port (230);
an EGR exhaust passage (320) extending from the exhaust port (240), said EGR exhaust passage (320) intersecting the EGR intake passage (310) to permit the flow of exhaust gases from at least one of said exhaust port (240) to at least one of said intake port (230).
2. The internal combustion (IC) engine (101) for a two wheeled vehicle (100) as claimed in claim 1 wherein at least one of the EGR intake passage (310) coaxially accommodates at least one EGR control mechanism (201).
3. The internal combustion (IC) engine (101) for a two wheeled vehicle (100) as claimed in claim 1 or claim 2 wherein the EGR intake passage (310) and the EGR control mechanism (201) are disposed within the cylinder head (203), said EGR control mechanism (201) configured to control the flow of exhaust gases from the exhaust port (240) to the intake port (230).
4. The internal combustion (IC) engine (101) for a two wheeled vehicle (100) as claimed in claim 1 or claim 2 wherein the amount of EGR through the EGR intake

passage (310) is controlled by the actuation of the EGR control mechanism (201) on variation of the throttle position.

5. The internal combustion (IC) engine (101) as claimed in claim 1 or claim 2 wherein, the EGR control mechanism (201) is controlled by an EGR cable (210) configured to be simultaneously actuated in response to the actuation of a throttle handle of the two wheeled vehicle (100).
6. The internal combustion (IC) engine (101) as claimed in claim 2 or 5 wherein, the EGR control mechanism (201) is disposed outside the cylinder head (203).
7. The internal combustion (IC) engine (101) as claimed in claim 2 or 5, wherein the EGR control mechanism (201) comprises:

the EGR exhaust passage (320) with an exhaust gas channel (306) coaxially accommodating a control shaft (301) from the inner end of the exhaust gas channel (306) up to an opening (305) disposed at a predetermined distance from the inner end of the control shaft (301).
8. The internal combustion (IC) engine (101) as claimed in claim 3 or 5 wherein the EGR exhaust passage (320) and the EGR intake passage (310) are disposed within the cylinder head (203) and the EGR control mechanism (201) is disposed outside the cylinder head (203).
9. The internal combustion (IC) engine (101) as claimed in claim 8 wherein the control shaft (301) is attached to an elastic member (304), said elastic member (304) exerting a positive bias force against the control shaft (301).
10. The internal combustion (IC) engine (101) as claimed in claim 8 wherein the control shaft (301, 705) is supported through a plug (303, 708) to permit retaining of the elastic member (304) on the control shaft (301).
11. The internal combustion (IC) engine (101) as claimed in claim 8 wherein the EGR control mechanism (201) is disposed outside the cylinder head (203) and the cylinder block (204).

12. The internal combustion (IC) engine (101) as claimed in claim 2 or claim 8 wherein the EGR control mechanism (201) comprises of a diaphragm valve (701)
13. The internal combustion (IC) engine (101) as claimed in claim 2 or 8 wherein the EGR control mechanism (201), EGR exhaust passage (320) and the EGR intake passage (310) are disposed within the cylinder block (204).
14. The internal combustion (IC) engine (101) as claimed in claim 2 or 8 wherein the EGR control mechanism (201), EGR exhaust passage (320) and the EGR intake passage (310) are disposed at a mating position of the cylinder head (203) and the cylinder block (204) and the disposition is partially in the cylinder head (203) and partially in the cylinder block (204).



201

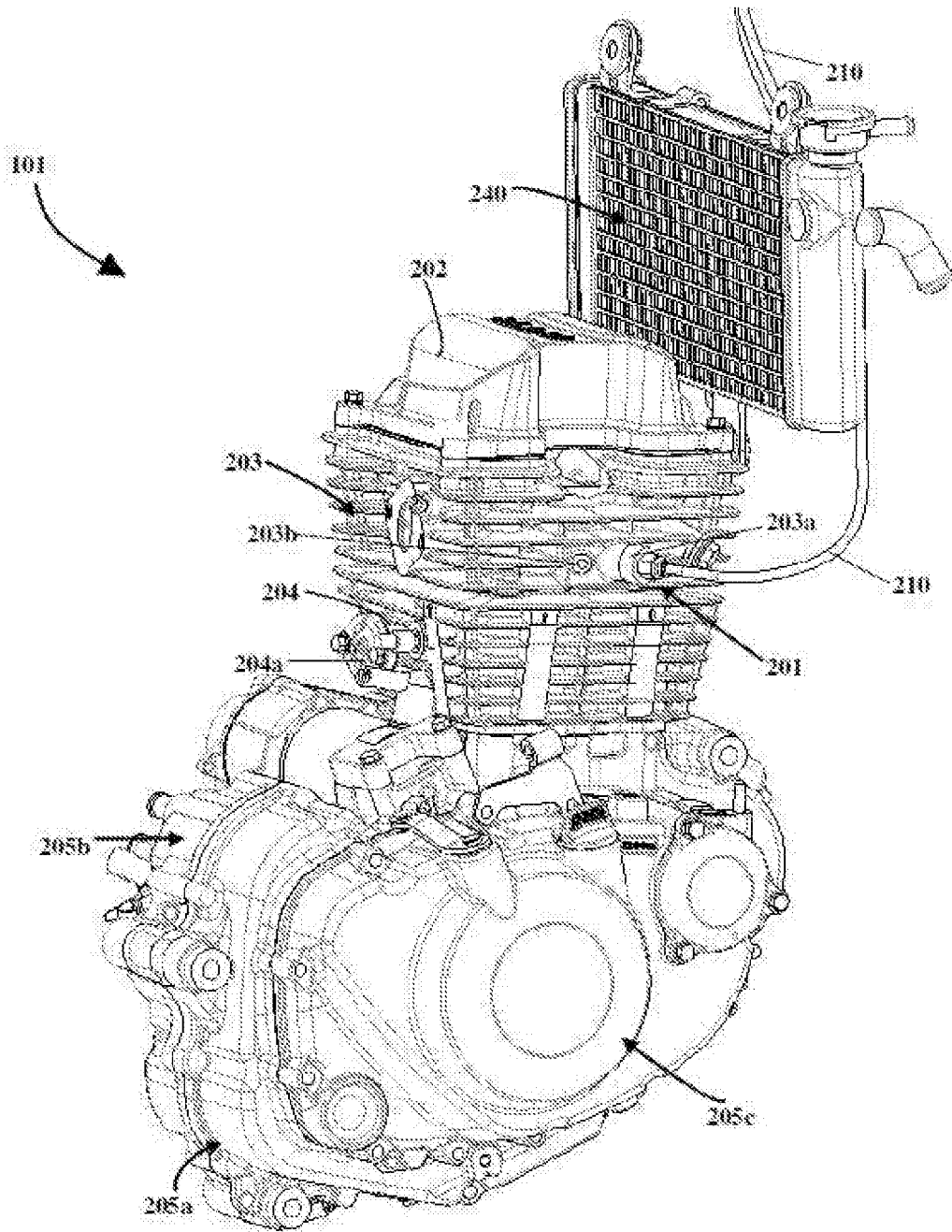


FIG. 2.

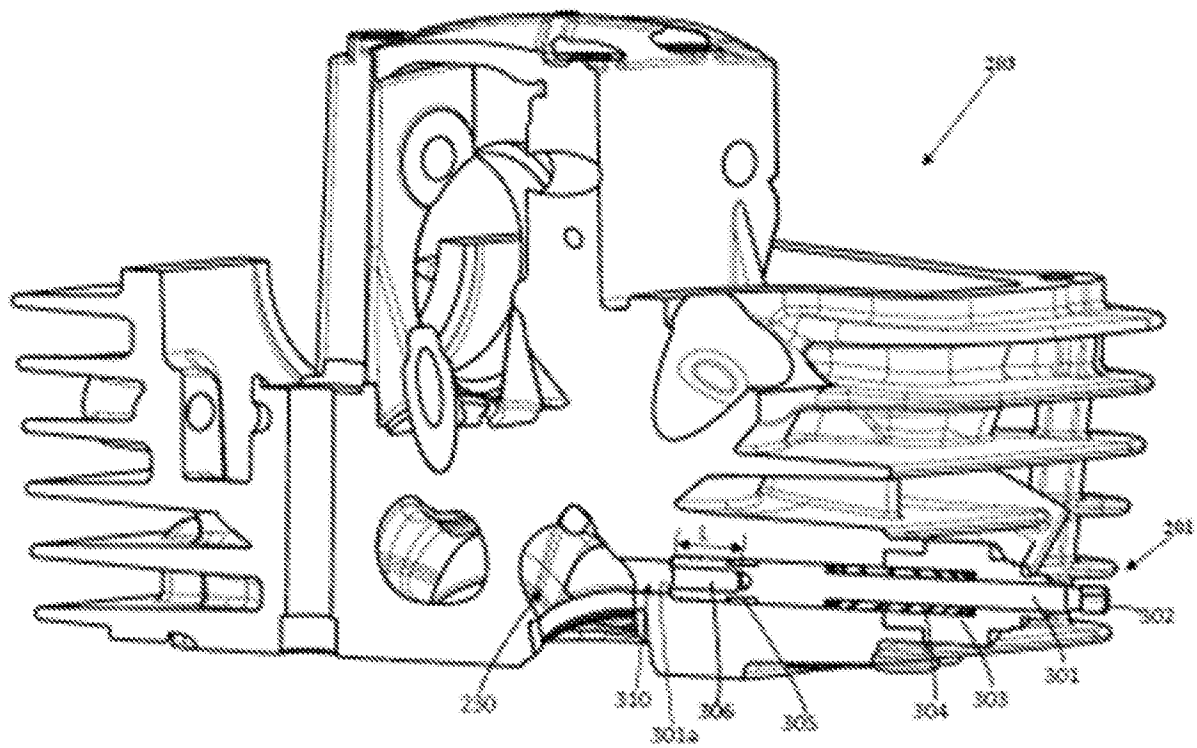


Fig. 3

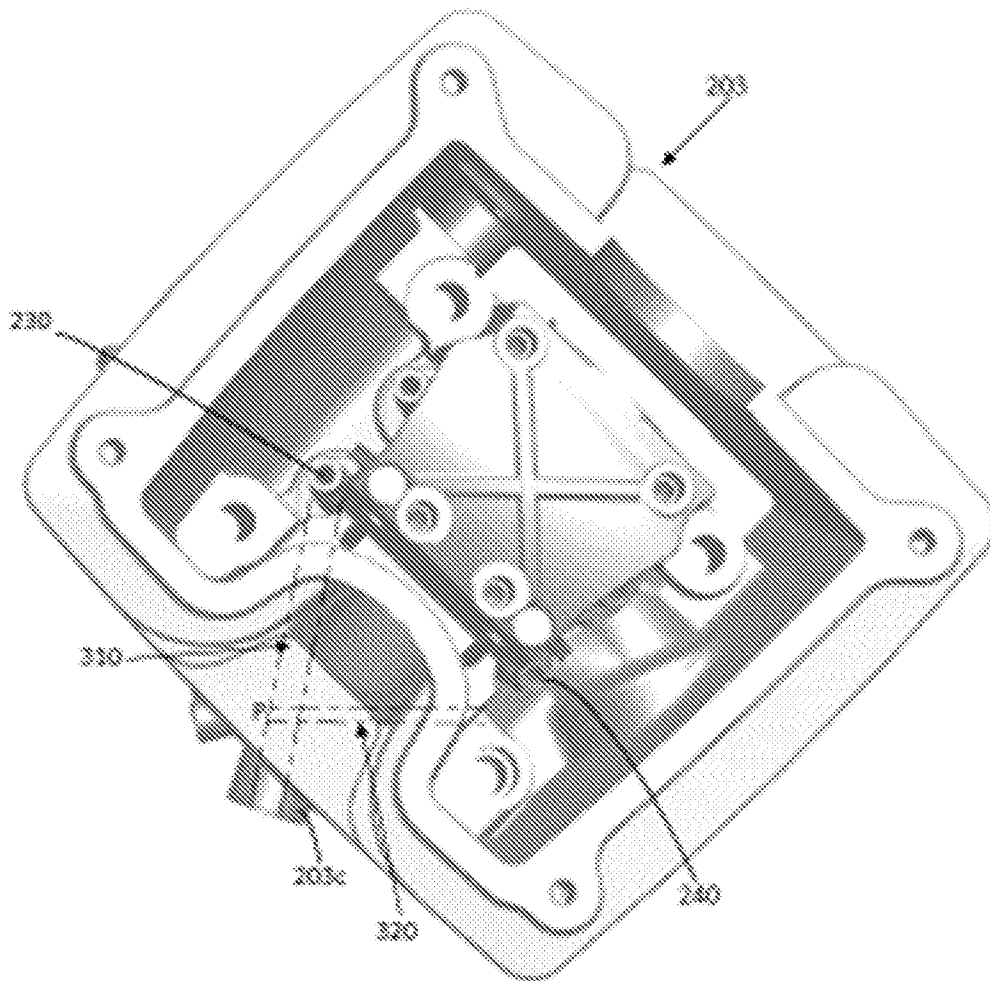


Fig. 4

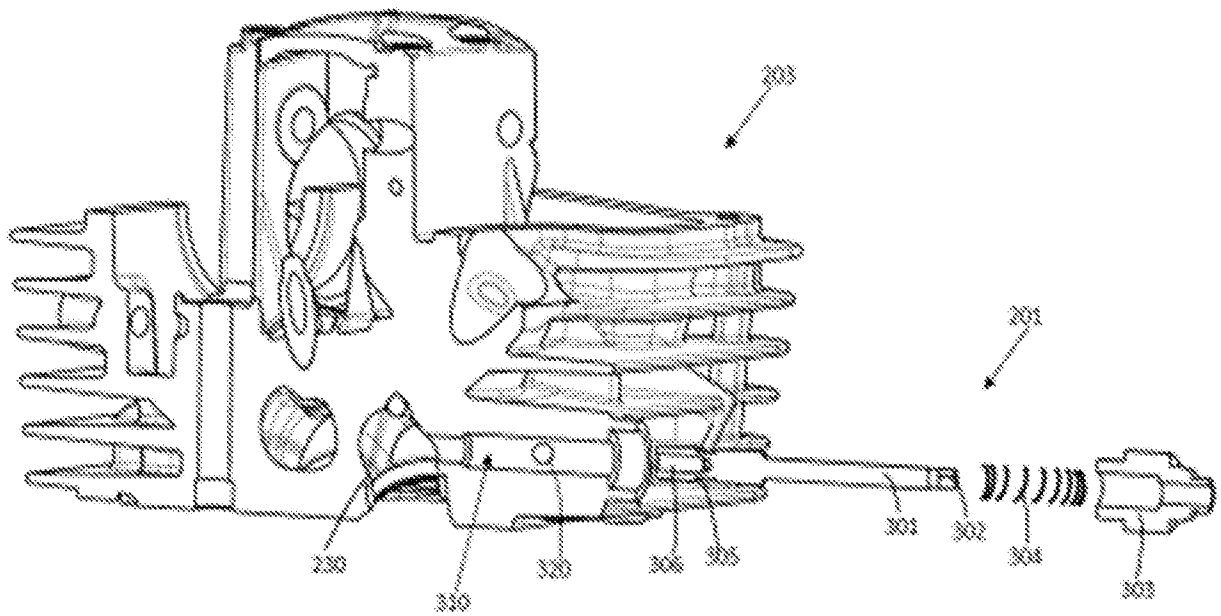


Fig. 5

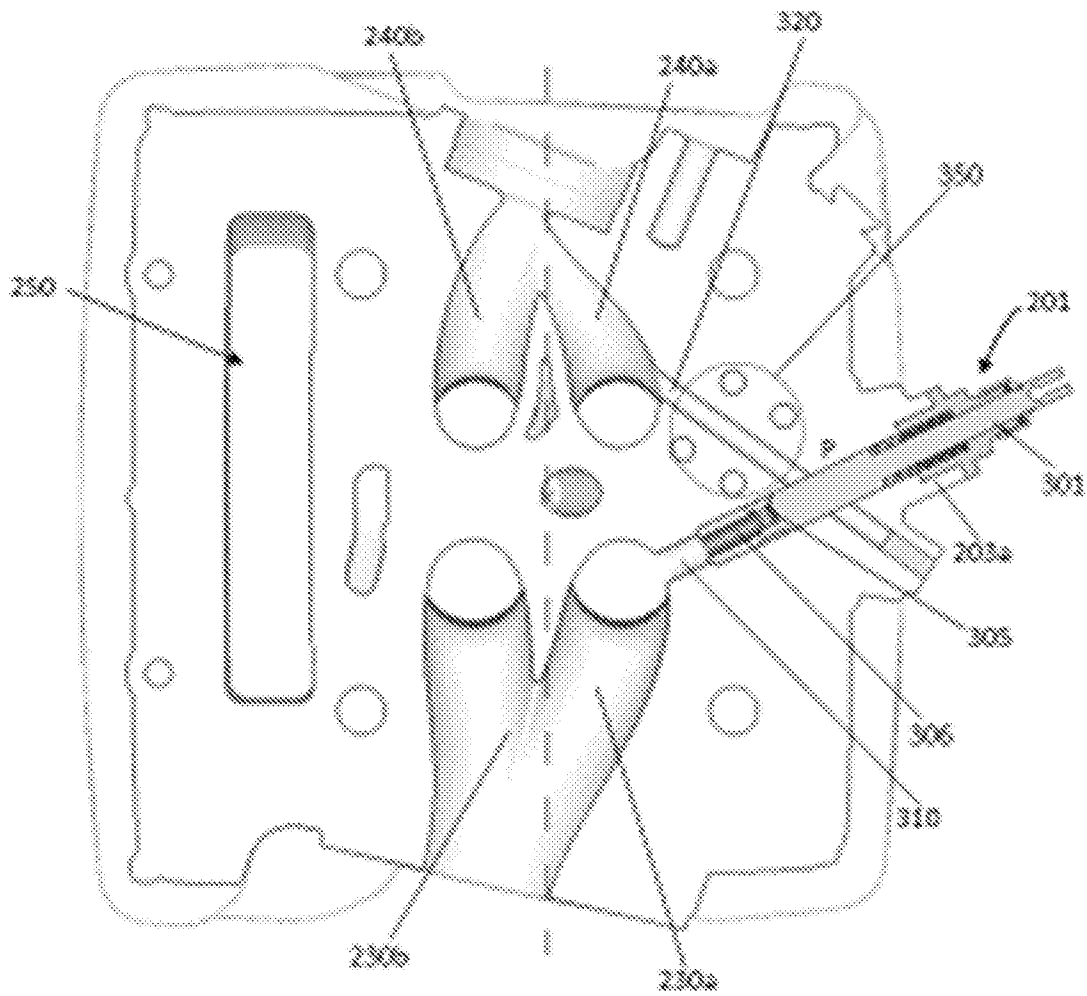


Fig. 6a

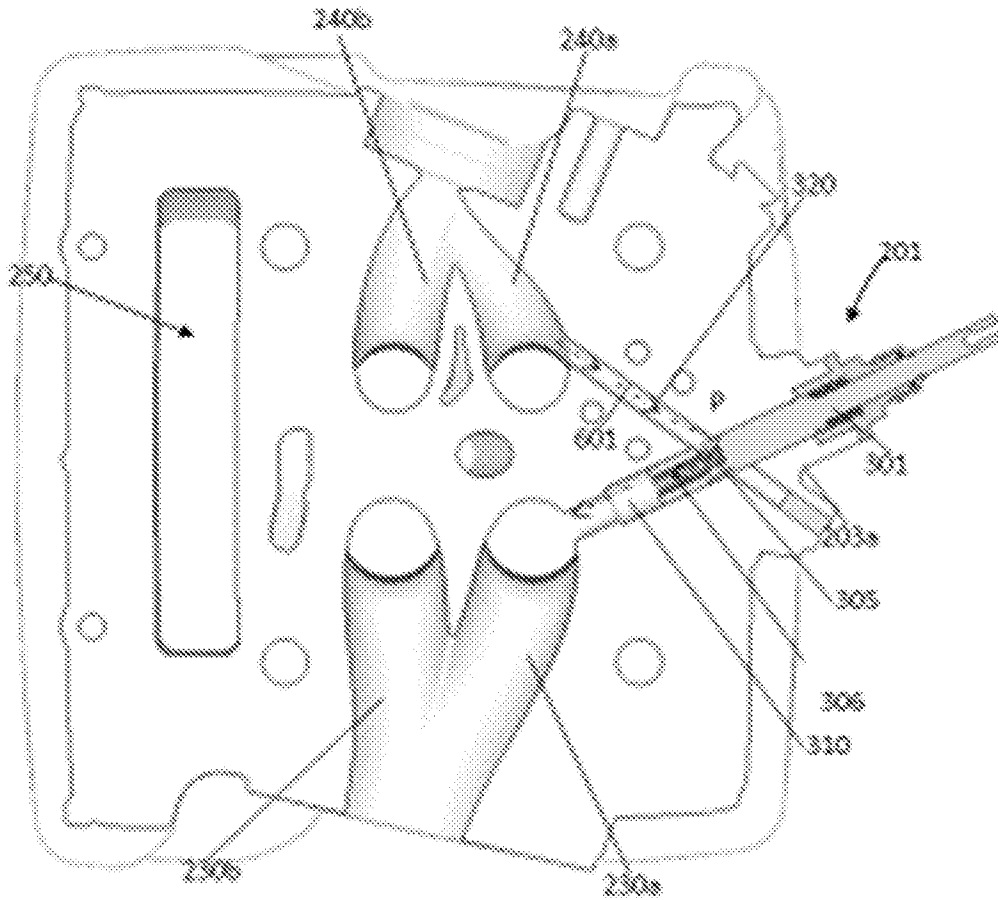


Fig. 6b

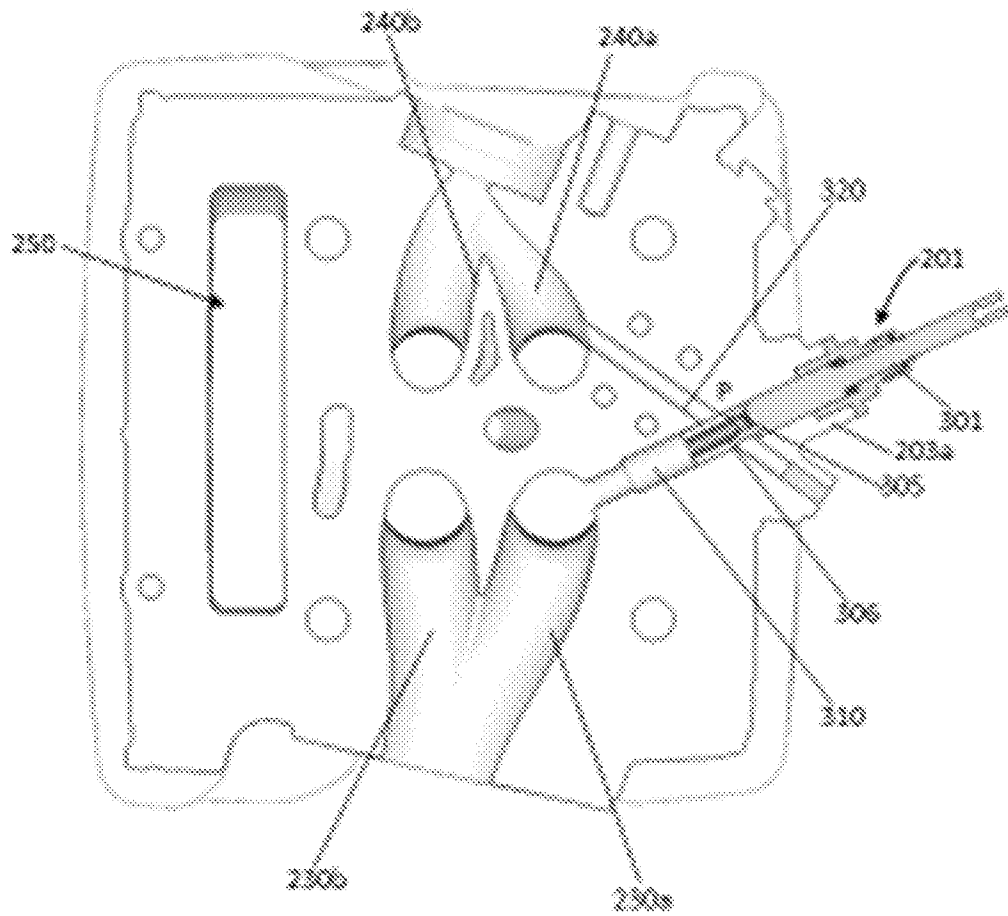


Fig. 6c

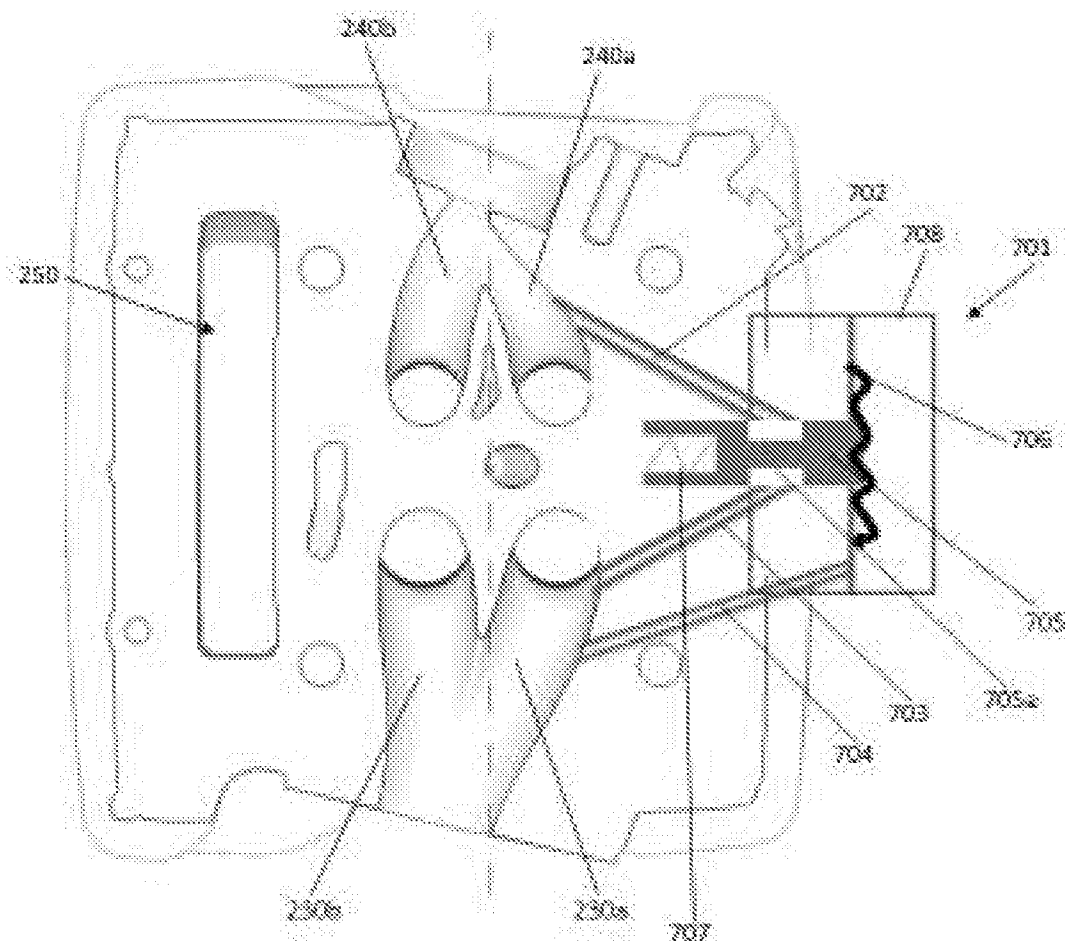


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2018/051401

A. CLASSIFICATION OF SUBJECT MATTER
F02M26/00 Version=2018.01

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)

F02M

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

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

TotalPatent One, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP2075450A1 (YAMAHA MOTOR CO LTD [JP]) 01 Jul 2009 (01-07-2009) Abstract; Paragraph [0007], [0051], [0061], [0063]; Figure 1, 2	1-4, 6
Y	EP2075450A1 (YAMAHA MOTOR CO LTD [JP]) 01 Jul 2009 (01-07-2009) Abstract; Paragraph [0007], [0051], [0061], [0063]; Figure 1, 2	5, 7-14
Y	CN101892926A (ZHEJIANG FAI ELECTRONICS CO LTD) 24 Nov 2010 (24-11-2010) Abstract; Paragraph [0019], [0020], [0034]; Figure-6	5, 7-14

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

27-06-2018

Date of mailing of the international search report

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Name and mailing address of the ISA/

Indian Patent Office
Plot No.32, Sector 14, Dwarka, New Delhi-110075
Facsimile No.

Authorized officer

Nathu Singh Shankla

Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2018/051401

Citation	Pub.Date	Family	Pub.Date
EP 2075450 A1	01-07-2009	JP 2009156146 A	16-07-2009