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

(11) EP 3 795 817 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.03.2021 Bulletin 2021/12

(21) Application number: **20196189.3**

(22) Date of filing: **15.09.2020**

(51) Int Cl.:
F02M 35/02 *(2006.01)* ***F02M 35/16*** *(2006.01)*
F02M 35/08 *(2006.01)* ***F02M 35/10*** *(2006.01)*
F02M 35/14 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **17.09.2019 JP 2019168682**

(71) Applicant: **YAMAHA HATSUDOKI KABUSHIKI KAISHA**
Iwata-shi Shizuoka 438-8501 (JP)

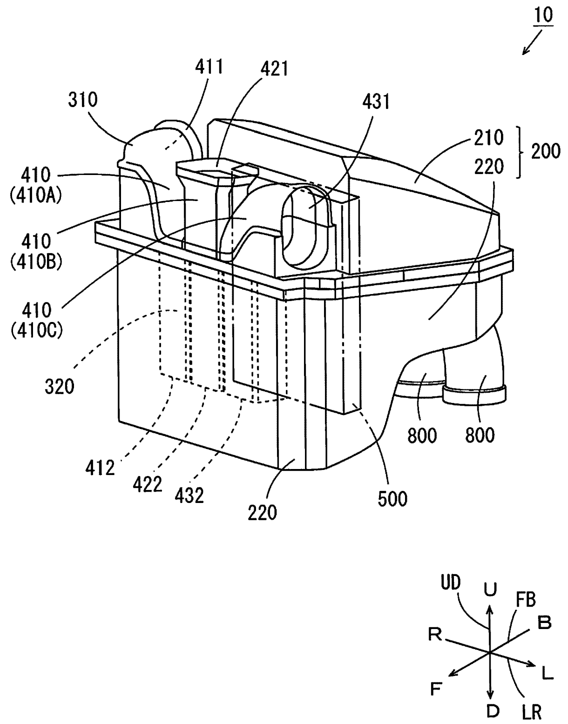
(72) Inventors:
- **TERASHIMA, Yoshiki**
  Iwata-shi, Shizuoka 438-8501 (JP)
- **HAMADA, Daisuke**
  Iwata-shi, Shizuoka 438-8501 (JP)
- **KANZAKI, Yuya**
  Iwata-shi, Shizuoka 438-8501 (JP)
- **SAITO, Hisanori**
  Iwata-shi, Shizuoka 438-8501 (JP)

(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

(54) **STRADDLED VEHICLE**

(57) An air cleaner 10 includes an air cleaner case 200 having an inner space, a filter element 500 that is stored in the air cleaner case 200 to section the inner space into an upstream space and a downstream space, and a plurality of three or more air intake ducts 410. Each air intake duct 410 has an upstream opening that opens to the outside of the air cleaner case 200 from an air intake passage formed inside of the air intake duct 410. Further, each air intake duct 410 has a downstream opening that opens to the outside of the air cleaner case 200 from an air intake passage formed inside of the air intake duct 410. The air that has passed through the plurality of air intake ducts 410, the upstream space, the filter element 500 and the downstream space is supplied to the engine.

FIG. 2



EP 3 795 817 A1

Description

[0001] The present invention relates to a straddled vehicle including an engine and an air cleaner.

[0002] Various air cleaners for reducing noise generated from a straddled vehicle during traveling of the vehicle have been suggested. For example, with the air cleaner structure described in JP 2011-57131 A, the length of an air intake passage that connects a main container of an air cleaner case to an engine is formed to be large, whereby the volume of intake noise is reduced while the output of a torque at medium and low speeds is ensured.

[0003] In a straddled vehicle, an air cleaner is generally provided at a position relatively close to the head of a rider with the rider riding the straddled vehicle. Therefore, the rider easily hears the intake noise generated from the air cleanerduring traveling of the vehicle. As such, the rider might recognize an operating state of the engine by hearing the intake noise generated from the air cleaner and adjust an operation amount of an accelerator grip during traveling of the vehicle. However, it is difficult to say that the relationship between an intake noise and an operating state of the engine is easy for the rider to recognize. It is difficult for a rider who is not skilled in driving a saddled vehicle to recognize the operating state of an engine even when hearing an intake noise.

[0004] An object of the present invention is to provide a straddled vehicle that facilitates recognition of an operation state of an engine by a rider when the rider hears an intake noise.

[0005] An air cleaner includes an air cleaner case, a filter element, an air intake duct and an air supply duct, for example. The air cleaner case has an inner space. The filter element sections the inner space of the air cleaner case into an upstream space and a downstream space. The air intake duct is provided to guide air from the outside of the air cleaner case to the upstream space. The air that is guided to the upstream space is guided to the downstream space while being cleaned through the filter element. The air supply duct is provided so as to further guide the air in the downstream space of the air cleaner case to the engine.

[0006] The inventors of the present invention conducted an experiment in regard to the relationship between the rotation speed of the engine and the level (volume) of an intake noise heard by the rider by using an air cleaner including only one air intake duct. As a result, it was found that the level of intake noise increases at a substantially constant change rate as the rotation speed of the engine increases in the air cleaner including only one air intake duct.

[0007] With this relationship, it is considered that the rider can recognize a current rotation speed (operating state) of the engine according to the level of intake noise. However, it is actually difficult for the rider to accurately distinguish the level of intake noise that changes linearly during traveling of the vehicle.

[0008] In the following description, the change rate of the level of intake noise obtained when the rotation speed of the engine changes is referred to as an intake noise change rate.

[0009] The inventors of the present invention considered to make the intake noise change rate obtained when the rotation speed of the engine was in a specific rotation speed range be different from the intake noise change rate obtained when the rotation speed of the engine was in another rotation speed range. In this case, in a case where the rotation speed of the engine increases from being in the other rotation speed range to being in the specific rotation speed range, the level of intake noise increases abruptly, for example. With such a change in level of intake noise, the rider can relatively easily recognize whether the rotation speed of the engine is in the specific rotation speed range or the other rotation speed range.

[0010] Here, the air intake duct has a natural frequency, and an air column in the air intake duct resonates when an intake noise having a specific wavelength is generated. The inventors of the present invention paid attention to this mechanism, and fabricated a prototype and conducted an experiment in regard to the configuration of the air cleaner in which the intake noise change rate was made to be different depending on the rotation speed of the engine.

[0011] Specifically, the inventors of the present invention fabricated an air cleaner including three air intake ducts, and measured the level of an intake noise generated from the air cleaner when the rotation speed of an engine was increased. With this experiment, a measurement result in which the intake noise change rate in the specific rotation speed range was larger than the intake noise change rate in the other rotation speed range was obtained. This is because the resonance sounds generated from the three air intake ducts overlap with one another in the specific rotation speed range of the engine.

[0012] With the above-mentioned result of experiment, the inventors of the present invention have discovered that provision of three or more air intake ducts in an air cleaner caused the intake sound change rate to change to the rate at which the rider can identify the rotation speed of the engine based on an air intake noise.

[0013] The inventors of the present invention have hit upon the below-mentioned present invention from the results of the series of above-mentioned examination and experiments.

[0014] Above object is achieved by a straddled vehicle according to claim 1. Preferred embodiments are laid down in the dependent claims.

(1) A straddled vehicle according to one aspect disclosed herein includes an engine, and an air cleaner that cleans air supplied to the engine, the air cleaner including an air cleaner case having an inner space, a filter element that is stored in the air cleaner case to section the inner space into an upstream space

and a downstream space, and a plurality of three or more air intake ducts respectively forming a plurality of three or more air intake passages, wherein the plurality of air intake ducts are provided in the air cleaner case to respectively have a plurality of upstream openings that open to outside of the air cleaner case from the plurality of air intake passages, respectively have a plurality of downstream openings that open to the upstream space from the plurality of air intake passages and guide air outside of the air cleaner case to the upstream space through the plurality of air intake passages, and air that has passed through the plurality of air intake ducts, the upstream space, the filter element and the downstream space is supplied to the engine.

In the straddled vehicle, the air outside of the air cleaner case is guided to the upstream space of the air cleaner case through the plurality of air intake passages of the plurality of air intake ducts during an operation of the engine. The air that has been guided to the upstream space is supplied to the engine through the downstream space of the air cleaner case while being cleaned by the filter element. The amount of air supplied from the air cleaner to the engine changes according to the rotation speed of the engine. Thus, the level (volume) of the intake noise generated in each air intake duct changes as the rotation speed of the engine changes.

Each of the plurality of air intake ducts has a natural frequency, and resonance occurs in a case where the rotation speed of the engine is in a specific rotation speed range. Therefore, in a case where the rotation speed of the engine changes from being in another rotation speed range to being in the specific rotation speed range, the resonance sounds generated from the three or more air intake ducts overlap with one another, and the level of intake noise increases abruptly. Therefore, the rider can easily identify a change in level of the intake noise generated from the air cleaner.

As a result, the rider can easily recognize an operating state of the engine based on the abrupt change in level of intake noise by hearing the intake noise.

(2) A length of one air intake passage out of the plurality of air intake passages may be different from a length of another air intake passage out of the plurality of air intake passages.

The natural frequency of each of the plurality of air intake passages is determined depending on the length of the air intake passage. Therefore, in a case where the length of one air intake passage is different from the length of another air intake passage, the resonance frequency of the intake noise generated by resonance in the one air intake passage is different from the resonance frequency of the intake noise generated by resonance in the other air intake passage.

Thus, the pitch of the intake noise generated from the one air intake passage is different from the pitch of the intake noise generated from the other air intake passage. Therefore, the intake noises that have different pitches and are generated from the plurality of air intake passages are simultaneously generated, whereby a chord including intake noises having two or more pitches is generated. Thus, the rider can have an improved driving feeling by hearing the chord including the intake sounds.

(3) Lengths of the plurality of air intake passages may be different from one another.

In this case, the pitches of the plurality of intake noises respectively generated from the plurality of air intake passages are different from one another. Therefore, the intake noises that have different pitches and are generated from the plurality of air intake passages are simultaneously generated, so that a chord including the intake noises having three or more pitches is generated. Thus, the rider can have an improved driving feeling by hearing the chord including the intake sounds.

(4) An aperture area of one upstream opening out of the plurality of upstream openings may be different from an aperture area of another upstream opening. The level of the intake noise generated in each of the plurality of air intake passages is determined depending on the rotation speed of the engine and the aperture area of the upstream opening of the air intake passage. Therefore, with the above-mentioned configuration, the level of an intake noise that has one frequency and is generated from one air intake duct can be set different from the level of an intake noise that has another frequency and is generated from another intake duct.

(5) A direction in which one upstream opening out of the plurality of upstream openings is directed may be different from a direction in which another upstream opening is directed.

Thus, a direction in which the intake noise generated from the one air intake duct is output is different from a direction in which the intake noise generated from the other air intake duct is output. This prevents the intake noise generated from the air cleaner from being concentrated in one direction to be output.

(6) Each air intake duct may be formed of a rigid material.

Thus, attenuation of the intake noise is suppressed. Therefore, the rider can accurately hear the intake noise to be output from the air cleaner based on the design of each air intake duct.

(7) The plurality of downstream openings may be directed in a common direction.

Thus, a flow of air generated in the upstream space is stabilized. Thus, an occurrence of turbulence in the upstream space is suppressed as compared to the case where the plurality of downstream openings are directed in different directions. Therefore, a reduction in output of the engine caused by an occurrence of turbulence in an air intake system is suppressed.

(8) The plurality of downstream openings may be located at a position farther downward than a filter of the filter element in the inner space, and a liquid drain may be formed in a portion located at a position farther downward than the plurality of air intake ducts in the air cleaner case.

In this case, even in a case where droplets of rainwater or the like enter the plurality of air intake passages, the droplets are guided to a position farther downward than the filter of the filter element in the inner space of the air cleaner case and drained from the liquid drain. This prevents adherence of droplets to the filter, so that the supply of droplets to the engine and a reduction in air intake efficiency due to the filter being wet are suppressed.

(9) The plurality of air intake ducts may include a first passage forming member that is constituted by a single member and forms one portion of the plurality of air intake ducts, and a second passage forming member that forms another portion of the plurality of air intake ducts, the air cleaner case and the second passage forming member may be constituted by an integrally formed single member, and the first passage forming member may be attached to the second passage forming member such that the plurality of air intake passages are formed.

Thus, facilitation of assembly of the air cleaner is realized while an increase in number of components is suppressed.

(10) The second passage forming member may be formed such that the another portion of the plurality of air intake ducts extends downwardly in the inner space.

Thus, even in a case where droplets of rainwater or the like enter the plurality of air intake passages, the droplets flow downwardly in the inner space of the air cleaner. This prevents the droplets from adhering to the filter, so that a reduction in air intake efficiency due to the filter being wet is suppressed. Further, the droplets that have entered the air cleaner is prevented from being supplied to the engine. Further, a high flow regulating effect can be obtained in the inner space of the air cleaner.

(11) A portion of the second passage forming member that is located in the inner space of the air cleaner case may have a plurality of tubular portions that are formed to respectively correspond to the plurality of air intake passages.

[0015] Thus, a high flow regulating effect can be obtained in the inner space of the air cleaner case. Further, with this configuration, the lengths of the plurality of tubular portions are set individually, so that a degree of freedom in selecting the frequency of the intake noise generated from the air cleaner is improved.

[0016] Other features, elements, characteristics, and advantages of the present invention will become more apparent from the following description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0017]

Fig. 1 is a side view of a motorcycle according to one embodiment of the present invention;
Fig. 2 is an external perspective view of an air cleaner of Fig. 1;
Fig. 3 is a front view of the air cleaner of Fig. 1;
Fig. 4 is a plan view of the air cleaner of Fig. 1;
Fig. 5 is a cross sectional view taken along the line A-A of Fig. 4;
Fig. 6 is an exploded perspective view of the air cleaner of Fig. 1;
Fig. 7 is a diagram for comparing the sizes of upstream openings of three air intake ducts;
Fig. 8 is a diagram showing a result of an intake noise change rate confirmation experiment; and
Fig. 9 is a diagram showing a result of a natural frequency experiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] A straddled vehicle according to one embodiment of the present invention will be described below with reference to the drawings. A motorcycle will be described as one example of the straddled vehicle.

[1] Schematic Configuration of Motorcycle

[0019] Fig. 1 is a side view of the motorcycle according to the one embodiment of the present invention. In Fig. 1, the motorcycle 100 standing up to be perpendicular to the road surface is shown. In each of Fig. 1 and subsequent given diagrams, a front-and-rear direction FB, a left-and-right direction LR and a top-and-bottom direction UD of the motorcycle 100 are suitably indicated by arrows. The direction in which the arrow is directed in the front-and-rear direction FB is referred to as forward, and its opposite direction is referred to as rearward. Further, the direction in which the arrow is directed in the left-and-right direction LR is referred to as leftward, and its opposite direction is referred to as rightward. Further, the direction in which the arrow is directed in the top-and-bottom direction UD is referred to as upward, and its opposite direction is referred to as downward. In part of Fig. 1 and subsequent given diagrams, forward, rearward, leftward, rightward, upward and downward are indicated by reference characters F, B, L, R, U and D, respectively.

[0020] The motorcycle 100 of Fig. 1 includes a metallic body frame 1. The body frame 1 includes a main frame 1M and a rear frame 1R. The front end of the main frame

1M constitutes a head pipe HP. The main frame 1M is formed to extend rearwardly and downwardly from the head pipe HP. The rear frame 1R is attached to the main frame 1M so as to extend rearwardly and slightly upwardly from the rear end and the vicinity of the rear end of the main frame 1M.

[0021] A front fork 2 is provided at the head pipe HP to be swingable in the left-and-right direction LR. A front wheel 3 is rotatably supported at the lower end of the front fork 2. A handle 4 is provided at the upper end of the front fork 2.

[0022] The main frame 1M supports an engine 5 at a position farther downward than the head pipe HP. An air cleaner 10 and a fuel tank 8 are provided so as to be located at a position farther upward than the engine 5 and farther rearward than the head pipe HP. A seat 9 is provided at a position farther rearward than the fuel tank 8. The air cleaner 10 and the fuel tank 8 are supported by the main frame 1M, located above the main frame 1M and arranged in this order in the rearward direction. The seat 9 is supported mainly by the rear frame 1R and located above the rear frame 1R.

[0023] A rear arm 6 is provided to extend rearwardly from a lower portion at the rear end of the main frame 1M. The rear arm 6 is supported by the main frame 1M via a pivot shaft. A rear wheel 7 is rotatably supported at the rear end of the rear arm 6. The rear wheel 7 is rotated as a drive wheel by the motive power generated from the engine 5.

[0024] As indicated by the thick-dotted arrow in Fig. 1, when the motorcycle 100 having the above-mentioned configuration is traveling, air outside of the motorcycle 100 is guided to the air cleaner 10, and supplied to the engine 5 while being cleaned. At this time, the level of sound pressure (volume) of an intake noise generated in the air cleaner 10 changes according to a rotation speed of the engine 5.

[0025] In the following description, the change rate of the level of intake noise obtained when the rotation speed of the engine 5 changes is referred to as an intake noise change rate. Further, the intake noise change rate obtained when the rotation speed of the engine 5 is in a predetermined specific rotation speed range (hereinafter referred to as a specific range) is referred to as a first intake noise change rate. Further, the intake noise change rate obtained when the rotation speed of the engine 5 is in a rotation speed range other than the specific range (hereinafter referred to as a non-specific range) is referred to as a second intake noise change rate.

[0026] The air cleaner 10 according to the present embodiment is configured such that the first intake noise change rate is larger than the second intake noise change rate. Details of the air cleaner 10 will be described below.

[2] Configuration of Air Cleaner 10 and Intake Noise

(a) Basic Configuration of Air Cleaner 10

[0027] Fig. 2 is an external perspective view of the air cleaner 10 of Fig. 1, and Fig. 3 is a front view of the air cleaner 10 of Fig. 1. Further, Fig. 4 is a plan view of the air cleaner 10 of Fig. 1, and Fig. 5 is a cross sectional view taken along the line A-A of Fig. 4.

[0028] As shown in Fig. 2, the air cleaner 10 has the configuration in which an air cleaner case 200 is provided with three air intake ducts 410 and three air supply ducts 800. In the following description, when being distinguished, the three air intake ducts 410 are respectively referred to as air intake ducts 410A, 410B, 410C.

[0029] The air intake ducts 410A, 410B, 410C are provided in the front half part of the air cleaner case 200 so as to be arranged in this order from the right to the left. The three air supply ducts 800 are provided in the rear half part of the air cleaner case 200 (the rear half part of a space forming member 220 described below) so as to be arranged in the left-and-right direction LR.

[0030] The air cleaner case 200 has an inner space. As indicated by the two-dots and dash lines in Figs. 2 to 4, a rectangular plate-shaped filter element 500 is stored in the inner space of the air cleaner case 200. As shown in Fig. 5, the filter element 500 is constituted by a filter 501 and a filter holder 502. The filter holder 502 holds the filter 501, and is fixed in the air cleaner case 200 such that the inner space of the air cleaner case 200 is sectioned into two spaces arranged in the front-and-rear direction FB with the filter 501 interposed therebetween.

[0031] In the following description, the one space located forwardly of the filter element 500 in the inner space of the air cleaner case 200 is referred to as an upstream space US. Further, the other space located rearwardly of the filter element 500 in the inner space of the air cleaner case 200 is referred to as a downstream space DS.

[0032] Here, the air intake duct 410A has an air intake passage P1 (see the portion indicated by the thick one-dot and dash line in Fig. 3) formed therein and has an upstream opening 411 and a downstream opening 412. The upstream opening 411 opens the air intake passage P1 of the air intake duct 410A to the outside of the air cleaner case 200. On the other hand, the downstream opening 412 opens the air intake passage P1 of the air intake duct 410A to the upstream space US of the air cleaner case 200. The cross section that is perpendicular to the direction of the central axis of the air intake passage P1 extending from the upstream opening 411 to the downstream opening 412 is substantially constant.

[0033] Further, the air intake duct 410B has an air intake passage P2 (see the portion indicated by the thick one-dot and dash line in Fig. 3) formed therein and has an upstream opening 421 and a downstream opening 422. The upstream opening 421 opens the air intake passage P2 of the air intake duct 410B to the outside of the air cleaner case 200. On the other hand, the downstream opening 422 opens the air intake passage P2 of the air intake duct 410B to the upstream space US of the air cleaner case 200. The cross section that is perpendicular to the direction of the central axis of the air intake passage P2 extending from the upstream opening 421 to the downstream opening 422 is substantially constant.

[0034] Further, the air intake duct 410C has an air intake passage P3 (see the portion indicated by the thick one-dot and dash line in Fig. 3) formed therein, and has an upstream opening 431 and a downstream opening 432. The upstream opening 431 opens the air intake passage P3 of the air intake duct 410C to the outside of the air cleaner case 200. On the other hand, the downstream opening 432 opens the air intake passage P3 of the air intake duct 410C to the upstream space US of the air cleaner case 200. The cross section that is perpendicular to the direction of the central axis of the air intake passage P3 extending from the upstream opening 431 to the downstream opening 432 is substantially constant.

[0035] Each of the three air supply ducts 800 has an air supply passage formed therein. The downstream space DS of the air cleaner case 200 communicates with the outside of the air cleaner case 200 through the air supply passages of the three air supply ducts 800. The downstream ends of the air supply ducts 800 are connected to the engine 5 of Fig. 1 through a throttle body (not shown).

[0036] As indicated by the thick dotted arrows in Fig. 5, when the motorcycle 100 is traveling, the air outside the air cleaner case 200 passes through the three air intake ducts 410, the upstream space US, the filter element 500 and the downstream space DS. Thereafter, the air that has passed through the downstream space DS is supplied to the engine 5 of Fig. 1 through the three air supply ducts 800.

(b) Various Components Constituting Air Cleaner 10 and Its Assembly

[0037] Fig. 6 is an exploded perspective view of the air cleaner 10 of Fig. 1. As shown in Fig. 6, the air cleaner 10 is mainly constituted by the air cleaner case 200, a first passage forming member 310, the filter element 500 and the three air supply ducts 800. Further, the air cleaner case 200 includes a lid member 210 and a space forming member 220.

[0038] The space forming member 220 has a bottom portion 228 and a peripheral wall portion 229 that form an inner space, and an upper opening 221 that opens the inner space upwardly. The three air supply ducts 800 are attached to the rear end of the space forming member 220.

[0039] The lid member 210 is attached to the upper end of the space forming member 220 so as to close the upper opening 221 of the space forming member 220 with the filter element 500 arranged inside of the space forming member 220. Thus, the air cleaner case 200 including the lid member 210 and the space forming member 220 is completed. At this time, the filter element 500 is fixed in the air cleaner case 200, and the inner space of the air cleaner case 200 is sectioned into the upstream space US and the downstream space DS (see Fig. 5).

[0040] The lid member 210 is provided with a second passage forming member 320 corresponding to the first passage forming member 310. The lid member 210 and the second passage forming member 320 are constituted by an integrally formed single member.

[0041] The first passage forming member 310 is constituted by a single member, and forms one portion (an upper end portion of the three air intake ducts 410 in the present example) of the three air intake ducts 410 of Fig. 2. On the other hand, the second passage forming member 320 forms another portion (the portion other than the upper end portion of the three air intake ducts 410 in the present example) of the three air intake ducts 410 of Fig. 2. Thus, the first passage forming member 310 is attached to the upper end of the second passage forming member 320. Therefore, the three air intake ducts 410 of Fig. 2 are completed, and the air intake passages P1, P2, P3 (Fig. 3) are formed in the three air intake ducts 410.

[0042] Here, the above-mentioned space forming member 220 is fabricated by injection molding of resin. Further, the first passage forming member 310 is fabricated by injection molding of resin. Further, the lid member 210 and the second passage forming member 320 are integrally fabricated by injection molding of resin. In this manner, the three air intake ducts 410 are not individually provided in the air cleaner 10 according to the present embodiment. The three air intake ducts 410 are formed by the combination of two components (the first passage forming member 310 and the second passage forming member 320). Further, the lid member 210 and the second passage forming member 320 are constituted by a single member. Therefore, facilitation of assembly of the air cleaner 10 is realized while an increase in number of components of the air cleaner 10 is suppressed.

(c) Regarding Intake Noise Generated in Air Cleaner 10

[0043] In general, the intake noise change rate of an air cleaner provided in a straddled vehicle is determined based on the number, shape and size of air intake ducts provided in the air cleaner. As described above, the inventors of the present invention have discovered that a rider can identify whether the rotation speed of the engine 5 is in the specific range by hearing an intake noise with an air cleaner including three or more air intake ducts. As such, in the present embodiment, the three air intake ducts 410 are provided in the air cleaner 10 such that the first intake noise change rate is larger than the second intake noise change rate.

[0044] Further, in the air cleaner 10 according to the present embodiment, the lengths of the three air intake ducts 410 are set to be different from one another. Specifically, as shown in Figs. 2 and 3, the air intake duct

410A is the longest and the air intake duct 410B is the shortest among the three air intake ducts 410. Here, in the present embodiment, the length of an air intake duct having an upstream opening and a downstream opening is the length of a central axis of an air intake passage of the air intake duct extending from the upstream opening to the downstream opening.

[0045] Each of the three air intake ducts 410 has a natural frequency corresponding to the length of the air intake duct. Therefore, the resonance frequency of an intake noise generated by resonance in the air intake duct 410A, the resonance frequency of an intake noise generated by resonance in the air intake duct 410B and the resonance frequency of an intake noise generated by resonance in the air intake duct 410C are different from one another. In this case, the pitches of the intake noises generated in the three air intake ducts 410 are different from one another. Basically, in air intake ducts, the larger the length of an air intake duct is, the lower the pitch of an intake noise generated from the air intake duct is, and the smaller the length of an air intake duct is, the higher the pitch of an intake noise generated from the air intake duct is.

[0046] Therefore, when the intake noises that have different pitches and are generated from the three air intake ducts 410 are simultaneously generated, a chord including the intake noises having three or more pitches is produced. Thus, the rider can have an improved driving feeling by hearing the chord including the intake sounds.

[0047] Here, letting the natural frequency of an air intake duct be "f," letting the sound velocity be "c" and letting the length of the air intake duct be "L," the natural frequency of the air intake duct can be expressed by the following formula (1).

$$f=c/2L... (1)$$

[0048] Therefore, the length of each of the above-mentioned three air intake ducts 410 can be set based on the above-mentioned formula (1) such that the intake noise having a desired resonance frequency is obtained. The natural frequencies of the three air intake ducts 410 are preferably set such that the three intake noises generated by resonance in the three air intake ducts 410 overlap with one another.

[0049] Further, in the air cleaner 10 according to the present embodiment, the aperture area of at least one of the upstream openings 411, 421, 431 of the three air intake ducts 410 is set different from the aperture area of another upstream opening.

[0050] Here, the level of the intake noise generated from an air intake duct depends on the rotation speed of the engine and the aperture area of the upstream opening of the air intake duct. Fig. 7 is a diagram for comparing the sizes of the upstream openings 411, 421, 431 of the three air intake ducts 410. As shown in Fig. 7, the aperture areas of the upstream openings 411, 421, 431 of the three air intake ducts 410 provided in the air cleaner 10 are different from one another. Specifically, the three upstream openings 411, 421, 431 are formed such that the aperture area of the upstream opening 411 is smaller than that of the upstream opening 421 and the aperture area of the upstream opening 421 is smaller than that of the upstream opening 431. That is, among the aperture areas of the three upstream openings 411, 421, 431, the aperture area of the upstream opening 411 of the air intake duct 410A is the smallest, and the aperture area of the upstream opening 431 of the air intake duct 410C is the largest.

[0051] In this case, the level of the intake noise generated from the air intake duct 410A is lower than the levels of the intake noises generated from the air intake ducts 410B, 410C. Further, the level of the intake noise generated from the air intake duct 410B is lower than the level of the intake noise generated from the air intake duct 410C. The upstream opening 421 of the air intake duct 410B is formed to be directed toward the head of the rider who rides the motorcycle 100. Therefore, an excessive increase in level of the intake noise that is output toward the rider can be suppressed.

[0052] Further, as shown in Fig. 7, each of the upstream openings 411, 421, 431 is substantially rectangular and has curved corner portions. With such a shape, a high flow regulating effect can be obtained in the upstream space US as compared to the case where each upstream opening 411, 421, 431 has corner portions that are bent at a right angle. Further, as described above, in a case where each of the upstream openings 411, 421, 431 is substantially rectangular, generation of dead spaces among the air intake passages P1, P2, P3 is reduced as compared to the case where the upstream openings 411, 421, 431 are circular. The upstream openings 411, 421, 431 may be circular.

[0053] Further, in the air cleaner 10 according to the present embodiment, the directions in which the upstream openings 411, 421, 431 of the three air intake ducts 410 are directed are different from one another. Thus, the direction in which the intake noise generated from the air intake duct 410A is output, the direction in which the intake noise generated from the air intake duct 410B is output and the direction in which the intake noise generated from the air intake duct 410C is output are different from one another. Specifically, as shown in Fig. 4, the upstream opening 411 of the air intake duct 410A is directed obliquely, rearwardly and rightwardly. Further, the upstream opening 421 of the air intake duct 410B is directed upwardly. Further, the upstream opening 431 of the air intake duct 410C is directed leftwardly. Thus, the intake noises generated from the air cleaner 10 is prevented from being concentrated in one direction to be output.

(d) Regarding Flow of Fluid Inside of Air Cleaner 10

[0054] As shown in Figs. 2 and 3, the downstream openings 412, 422, 432 of the three air intake ducts 410 are all directed downwardly inside of the air cleaner case 200. With such a configuration, the air flowing into the upstream space US of the air cleaner case 200 from the three air intake ducts 410 flows in the common direction, and the flow of air generated in the upstream space US is stabilized. Thus, an occurrence of turbulence in the upstream space US is suppressed as compared to the case where the downstream openings 412, 422, 432 are directed in different directions. Therefore, a reduction in output of the engine 5 due to an occurrence of turbulence in the air cleaner 10 is suppressed.

[0055] In the air cleaner 10, the second passage forming member 320 is formed such that the downstream portions of the three air intake ducts 410 extend downwardly in the upstream space US. With such a configuration, even in a case where droplets of rainwater or the like enter any of the three air intake ducts 410, the droplets flow downwardly in the upstream space US. This prevents the droplets from directly adhering to the filter 501, so that a reduction in air intake efficiency due to the filter 501 being wet is suppressed. Further, the droplets that have entered the air cleaner 10 are prevented from being supplied to the engine 5. Further, because the air passing through the three air intake ducts 410 flows downwardly in the upstream space US of the air cleaner 10, a high flow regulating effect can be obtained.

[0056] As shown in Fig. 6, the second passage forming member 320 has the configuration in which three tubular portions 321, 322, 323 forming the other parts of the three air intake ducts 410 are integrated. Here, the lengths of the three tubular portions 321, 322, 323 of the second passage forming member 320 may be the same or different from one another. The degree of freedom in selecting the frequency of an intake noise generated from the air cleaner 10 is improved by individually setting of the lengths of the three tubular portions 321, 322, 323.

[0057] As shown in Fig. 5, the downstream opening 422 of the air intake duct 410B is located at a position farther downward than the filter 501 of the filter element 500 in the inner space of the air cleaner case 200. Further, similarly to the downstream opening 422, the downstream openings 412, 432 of the air intake ducts 410A, 410C are also located at positions farther downward than the filter 501 of the filter element 500. Further, a liquid drain 227 is formed in a portion of the air cleaner case 200 located at a position farther downward than the three air intake ducts 410. The liquid drain 227 of Fig. 5 is formed at a position farther upstream than the filter element 500. With such a configuration, in a case where droplets of rainwater or the like enter any of the three air intake ducts 410, the droplets are guided to the bottom portion of the inner space of the air cleaner case 200 and drained from the liquid drain 277.

[3] Effects

[0058]

(a) In the above-mentioned motorcycle 100, the air outside of the air cleaner 10 is guided to the upstream space US of the air cleaner case 200 through the air intake passages P1, P2, P3 of the three air intake ducts 410 during an operation of the engine 5. The air that has been guided to the upstream space US is supplied to the engine 5 through the downstream space DS of the air cleaner case 200 while being cleaned by the filter element 500. An amount of air supplied from the air cleaner 10 to the engine 5 changes according to the rotation speed of the engine 5. Thus, the level of the intake noise generated in each air intake duct 410 changes as the rotation speed of the engine 5 changes.
Here, as described above, the air cleaner 10 is configured such that the first intake noise change rate is larger than the second intake noise change rate. Thus, in the case where the rotation speed of the engine 5 changes from being in the non-specific range to being in the specific range, the resonance sounds generated from the three air intake ducts 410 overlap with one another. Thus, the level of intake noise increases abruptly. Therefore, the rider can easily identify a change in level of an intake noise generated from the air cleaner 10.
As a result, the rider can easily recognize an operating state of the engine 5 based on an abrupt change in level of intake noise by hearing the intake noise.

(b) In the above-mentioned air cleaner 10, the specific range corresponding to the first intake noise change rate may be set relatively low. In this case, because the level of intake noise changes largely in the relatively low rotation speed range as compared to a conventional air cleaner including one air intake duct, for example, the user can enjoy a feeling of acceleration of the vehicle.

(c) If a soft material such as rubber is used as a material for forming an air intake duct, an intake noise is likely to be absorbed by the air intake duct. In contrast, in the air cleaner 10, a rigid material having rigidity higher than that of rubber is used as the material of the three air intake ducts 410. In the present embodiment, the rigid material is resin. Thus, attenuation of the intake noise generated in the air cleaner 10 caused by absorption of the intake noise by each air intake duct 410 is suppressed. Therefore, the rider can accurately hear an intake noise to be output from the air cleaner 10 based on the design of each air intake duct 410.

[4] Experiment Regarding Intake Noise

[0059]

(a) The inventors of the present invention conducted an experiment to measure the relationship between the level of intake noise and the rotation speed of the engine 5 in regard to an air cleaner including one air intake duct. Further, the inventors of the present invention conducted an experiment to measure the relationship between the level of intake noise and the rotation speed of the engine 5 in regard to the air cleaner 10 of Fig. 2. These experiments are referred to as intake noise change rate confirmation experiments.

In the intake noise change rate confirmation experiments, the inventors of the present invention connected the air cleaner including one air intake duct to the engine 5, and measured the level of an intake noise output from the one air intake duct while increasing the rotation speed of the engine 5. Further, the inventors of the present invention connected the air cleaner 10 of Fig. 2 to the engine 5 and measured a combined value of the levels of the intake noises output from the three air intake ducts 410 while increasing the rotation speed of the engine 5.

Fig. 8 is a diagram showing the results of the intake noise change rate confirmation experiments. In Fig. 8, the results of the intake noise change rate confirmation experiments are shown by a graph. In the graph of Fig. 8, the ordinate indicates the level of intake noise, and the abscissa represents the rotation speed of the engine 5. Further, in Fig. 8, the result of experiment in regard to the air cleaner including one air intake duct is indicated by the thick one-dot and dash line. On the other hand, the result of experiment in regard to the air cleaner 10 of Fig. 2 is indicated by the thick solid line.

As shown in Fig. 8, in regard to the air cleaner including one air intake duct, the level of intake noise increases at a substantially constant change rate as the rotation speed of the engine increases. In contrast, in regard to the air cleaner 10 of Fig. 2, the level of intake noise changes abruptly when the rotation speed of the engine 5 is in the specific rotation speed range as indicated by the outlined arrow in Fig. 8. This is because the resonance sounds generated from the three air intake ducts 410 overlap with one another when the rotation speed of the engine 5 is in the specific rotation speed range.

From the above-mentioned results of experiments, it is found that the air cleaner 10 of Fig. 2 facilitates determination to be made by the rider based on an intake noise in regard to whetherthe rotation speed of the engine 5 is in the specific range or the non-specific range.

According to the results of experiments of Fig. 8, in the range in which the rotation speed exceeds the specific rotation speed range, the change rate of level of intake noise in regard to the air cleaner 10 of Fig. 2 is maintained higher than the change rate of level of intake noise in regard to the air cleaner including one air intake duct. Therefore, it is found that determination to be made by the rider based on an intake noise whether the rotation speed of the engine 5 exceeds the specific rotation speed range is also facilitated.

(b) In regard to the air cleaner 10 of Fig. 2, the inventors of the present invention conducted an experiment to confirm a difference in frequency of intake noises generated from the three air intake ducts 410 having different lengths. The difference in frequency of intake noises is generated due to a difference in natural frequency of the three air intake ducts 410. As such, this experiment is referred to as a natural frequency experiment.

[0060] In the natural frequency experiment, the inventors of the present invention input sounds having a plurality of frequencies to the three air supply ducts 800 of the air cleaner 10 of Fig. 2 and measured the relationship between a combined value of the levels of the intake noises output from the three air intake ducts 410 and the frequencies of the intake noises.

[0061] Fig. 9 is a diagram showing the result of the natural frequency experiment. In Fig. 9, the result of the natural frequency experiment is shown by a graph. In the graph of Fig. 9, the ordinate indicates the level of intake noise, and the abscissa indicates the frequency of intake noise. Further, in Fig. 9, the relationship between the combined value of the levels of intake noises and the frequencies of intake noises obtained by the experiment is indicated by the thick solid line.

[0062] As shown in Fig. 9, according to the result of the natural frequency experiment, peaks respectively corresponding to the air intake ducts 410A, 410B, 410C were confirmed at three different frequencies. In Fig. 9, the peak corresponding to the air intake duct 410A is indicated by the arrow PA, the peak corresponding to the air intake duct 410B is indicated by the arrow PB and the peak corresponding to the air intake duct 410C is indicated by the arrow PC. According to this result, in a case where the intake noises are simultaneously output from the three air intake ducts 410 having different lengths, a chord including intake noises having three or more pitches is generated.

[5] Other Embodiments

[0063]

(a) While the three air intake ducts 410 are formed by the first passage forming member 310 and the second passage forming member 320 in the air cleaner 10 according to the above-mentioned embodiment, the present invention is not limited to this. The air cleaner 10 may have the configuration in which three individually formed tubular air intake ducts 410 are attached to the air cleaner case 200. In this case, the three air intake ducts 410 may have the same length or different lengths. Further, the upstream openings of the three air intake ducts 410 may have different aperture areas. Further, the three air intake ducts 410 may be attached to three portions that are spaced apart from one another in the air cleaner case 200 (a portion directed forwardly, a portion directed rightwardly and a portion directed leftwardly in the air cleaner case 200, for example).

(b) While the portions that are formed by the second passage forming member 320 in the three air intake ducts 410 are arranged in the left-right direction LR without being spaced apart from one another in the air cleaner 10 according to the above-mentioned embodiment, the present invention is not limited to this. One of the three air intake ducts 410 may be provided to be spaced apart from the other air intake ducts 410. Alternatively, each of the three air intake ducts 410 may be provided to be spaced apart from the other air intake ducts 410.

(c) While the upstream openings 411, 421, 431 of the three air intake ducts 410 are directed in different directions in the air cleaner 10 according to the above-mentioned embodiment, the present invention is not limited to this. The three air intake ducts 410 may be provided such that the upstream openings 411, 421, 431 are directed in the same direction.

(d) While the air cleaner 10 according to the above-mentioned embodiment has the three air intake ducts 410, the present invention is not limited to this. The air cleaner 10 may have four or more air intake ducts 410.

(e) While the air cleaner 10 according to the above-mentioned embodiment has the three air supply ducts 800, the present invention is not limited to this. The air cleaner 10 may only have one air supply duct 800, may have two air supply ducts 800 or may have four or more air supply ducts 800.

(f) While the above-mentioned embodiment is an example in which the present invention is applied to the motorcycle, the invention is not limited to this. The present invention may be applied to another straddled vehicle such as a four-wheeled automobile, a motor tricycle or an ATV (All Terrain Vehicle).

[6] Correspondences between Constituent Elements in Claims and Parts in Preferred Embodiments

[0064] In the following paragraphs, non-limiting examples of correspondences between various elements recited in the claims below and those described above with respect to various preferred embodiments of the present invention are explained.

[0065] In the above-mentioned embodiment, the engine 5 is an example of an engine, the air cleaner 10 is an example of the air cleaner, the air cleaner case 200 is an example of an air cleaner case, the filter element 500 is an example of a filter element, the air intake passages P1, P2, P3 are an example of a plurality of air intake passages and a plurality of air intake ducts 410, 410A, 410B, 410C are an example of a plurality of air intake ducts.

[0066] Further, the upstream openings 411, 421, 431 are an example of a plurality of upstream openings, the downstream openings 412, 422, 432 are an example of a plurality of downstream openings, the motorcycle 100 is an example of a straddled vehicle, the filter 501 is an example of a filter, the liquid drain 227 is an example of a liquid drain, the first passage forming member 310 is an example of a first passage forming member and the second passage forming member 320 is an example of a second passage forming member.

[0067] As each of constituent elements recited in the claims, various other elements having configurations or functions described in the claims can be also used.

[0068] While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

Claims

1. A straddled vehicle (100) comprising:

an engine (5); and
an air cleaner (10) that is configured to clean air to be supplied to the engine (5),
the air cleaner (10) comprising:

an air cleaner case (200) having an inner space;
a filter element (500) that is stored in the air cleaner case (200) to section the inner space into an upstream space (US) and a downstream space (DS); and
a plurality of three or more air intake ducts (410A, 410B, 410C) respectively forming a plurality of three or more air intake passages (P1, P2, P3), wherein
the plurality of air intake ducts (410A, 410B, 410C) are provided in the air cleaner case (200) to respectively have a plurality of upstream openings (411, 421, 431) that open to outside of the air cleaner case (200) from the plurality of air intake passages (P1, P2, P3), respectively have a plurality of downstream openings (412, 422, 432) that open to the upstream space (US) from the plurality of air intake passages (P1, P2, P3) and are configured to guide air outside of the air cleaner case (200) to the upstream space (US) through the plurality of air intake passages (P1, P2, P3), and

the straddled vehicle is configured such that air that has passed through the plurality of air intake ducts(410A, 410B, 410C), the upstream space (US), the filter element (500) and the downstream space (DS) is supplied to the engine (5).

2. The straddled vehicle (100) according to claim 1, wherein
a length of one air intake passage out of the plurality of air intake passages (P1, P2, P3) is different from a length of another air intake passage out of the plurality of air intake passages (P1, P2, P3).

3. The straddled vehicle (100) according to claim 1, wherein
lengths of the plurality of air intake passages (P1, P2, P3) are different from one another.

4. The straddled vehicle (100) according to any one of claims 1 to 3, wherein
an aperture area of one upstream opening out of the plurality of upstream openings (411, 421, 431) is different from an aperture area of another upstream opening.

5. The straddled vehicle (100) according to any one of claims 1 to 4, wherein
a direction in which one upstream opening out of the plurality of upstream openings (411, 421, 431) is directed is different from a direction in which another upstream opening is directed.

6. The straddled vehicle (100) according to any one of claims 1 to 5, wherein
each air intake duct (410A, 410B, 410C) is formed of a rigid material.

7. The straddled vehicle (100) according to any one of claims 1 to 6, wherein
the plurality of downstream openings (412, 422, 432) are directed in a common direction.

8. The straddled vehicle (100) according to any one of claims 1 to 7, wherein, in a state of the straddled vehicle (100) standing up to be perpendicular to a horizontal road surface,
the plurality of downstream openings (412, 422, 432) are located at a position farther downward than a filter (500) of the filter element in the inner space, and
a liquid drain (227) is formed in a portion located at a position farther downward than the plurality of air intake ducts (410A, 410B, 410C) in the air cleaner case (200).

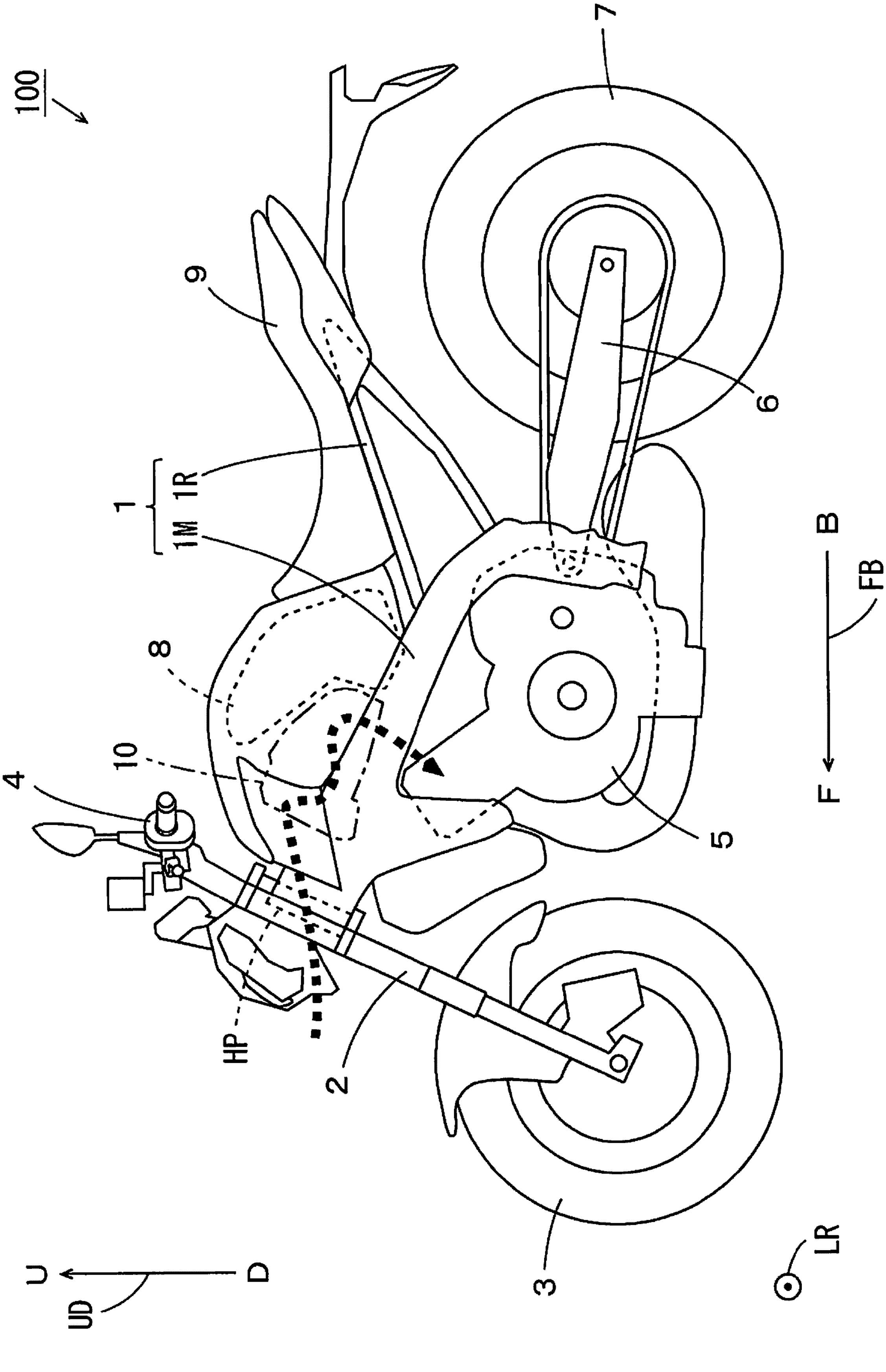
9. The straddled vehicle (100) according to any one of claims 1 to 8, wherein
the plurality of air intake ducts (410A, 410B, 410C) include
a first passage forming member (310) that is constituted by a single member and forms one portion of the plurality of air intake ducts (410A, 410B, 410C), and
a second passage forming member (320) that forms another portion of the plurality of air intake ducts (410A, 410B, 410C),
the air cleaner case (200) and the second passage forming member (320) are constituted by an integrally formed single member, and
the first passage forming member (310) is attached to the second passage forming member (320) such that the plurality of air intake passages (P1, P2, P3) are formed.

10. The straddled vehicle (100) according to claim 9, wherein
the second passage forming member (320) is formed such that the another portion of the plurality of air intake ducts (410A, 410B, 410C) extends downwardly in the inner space in a state of the straddled vehicle (100) standing up to be perpendicular to a horizontal road surface.

11. The straddled vehicle (100) according to claim 9 or 10, wherein
a portion of the second passage forming member (320) that is located in the inner space of the air cleaner case (200) has a plurality of tubular portions (321, 322, 323) that are formed to respectively correspond to the plurality of air intake passages (P1, P2, P3).

12. An air cleaner of the straddled vehicle according to any of the preceding claims.

FIG. 1



F I G. 2

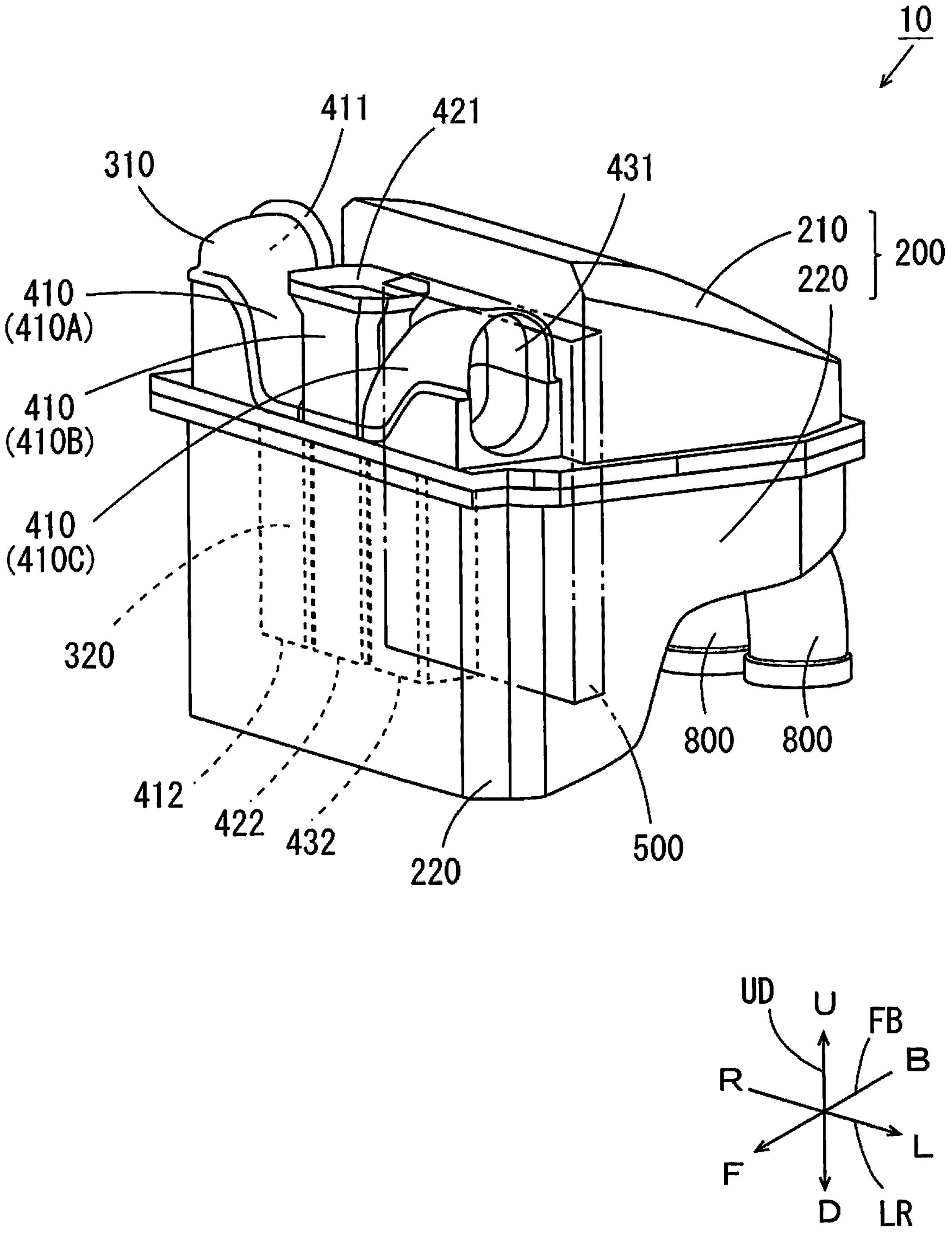

10
411
421
310
431
210
220
200
410
(410A)
410
(410B)
410
(410C)
320
800
800
412
422
432
220
500
UD
U
FB
B
R
L
F
D
LR

FIG. 3

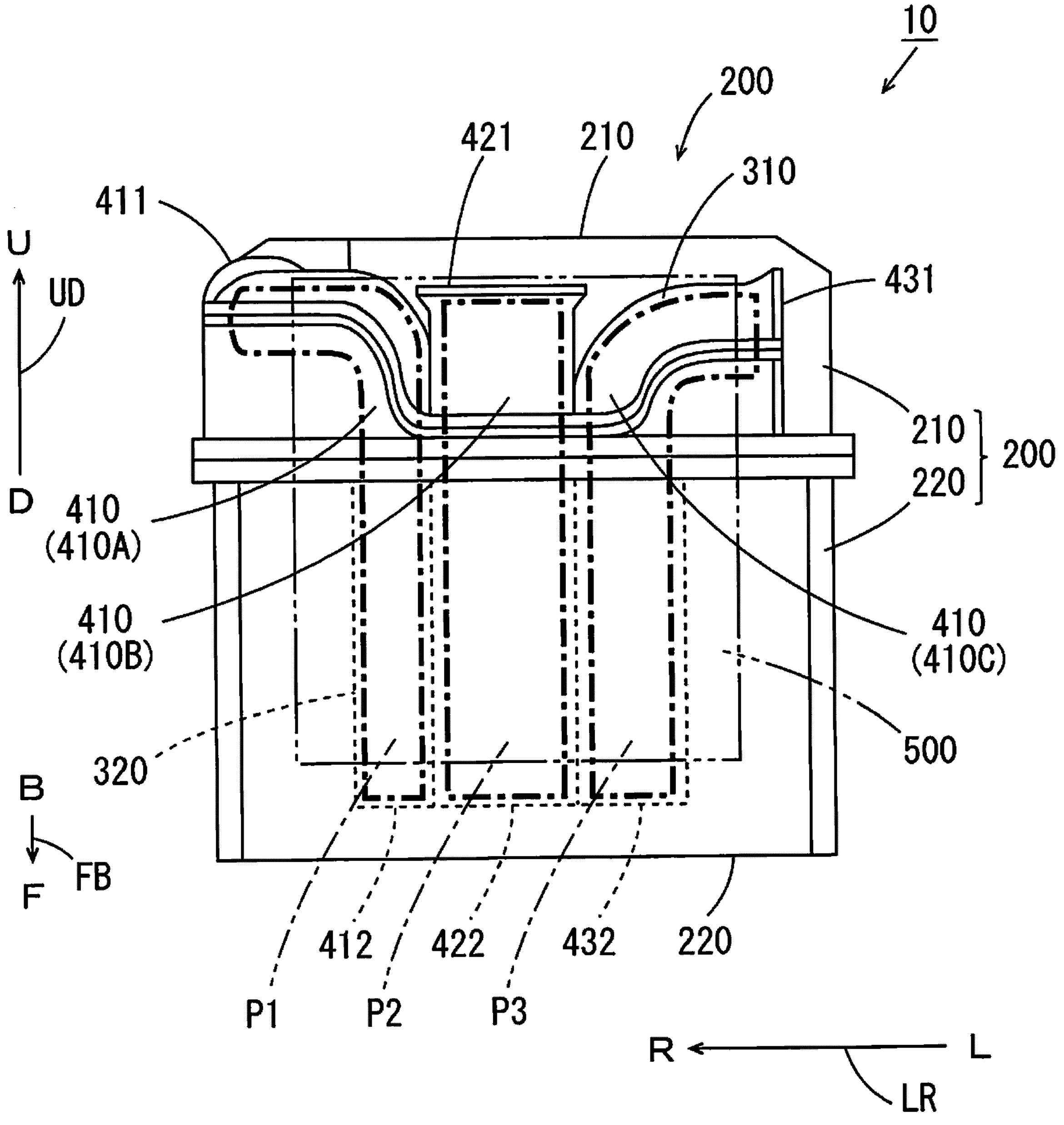

10
200
421
210
310
411
431
U
UD
D
210
220
200
410
(410A)
410
(410B)
410
(410C)
500
320
B
F
FB
412
422
432
220
P1
P2
P3
R
L
LR

FIG. 4

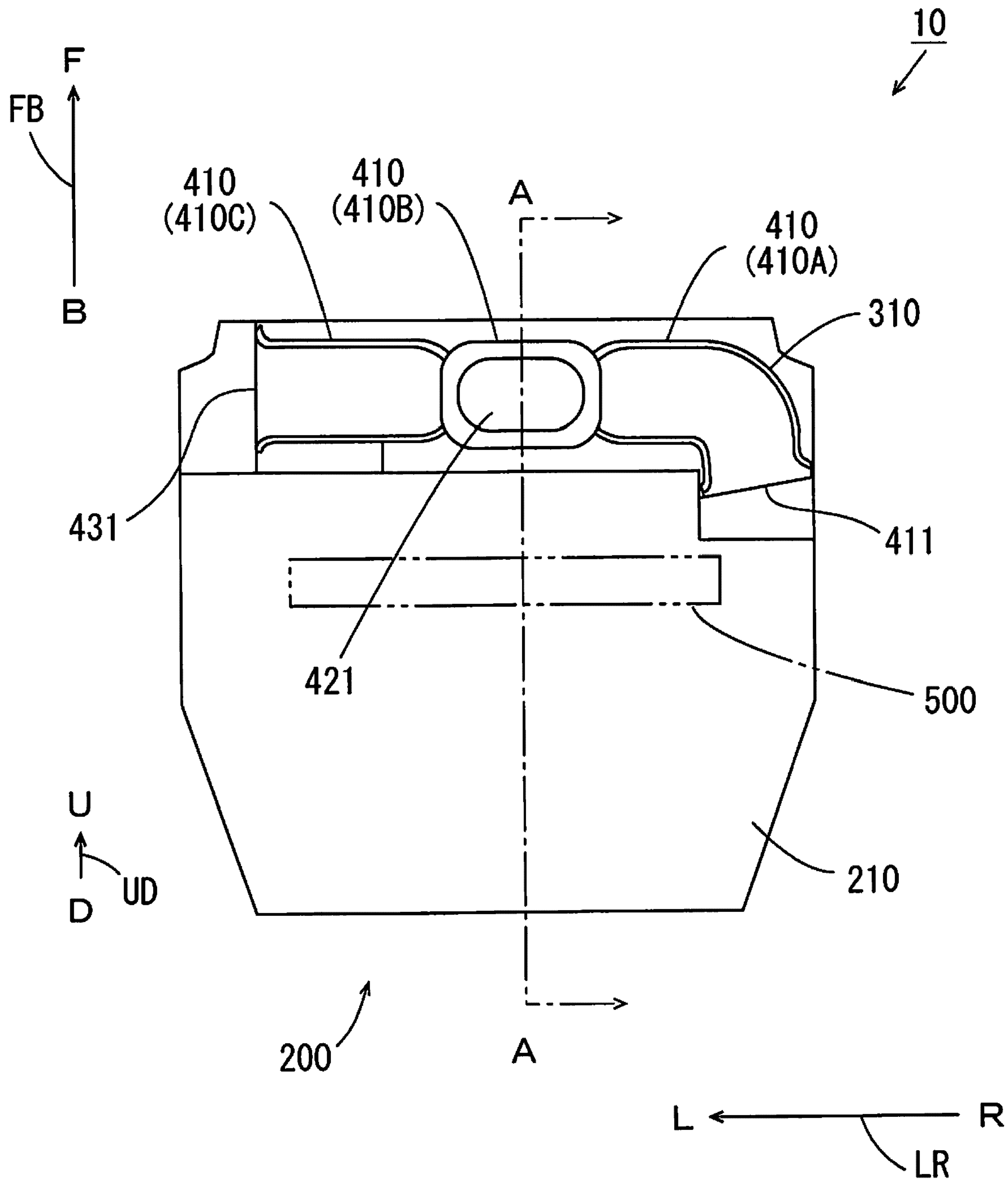

10
F
FB
B
410
(410C)
410
(410B)
A
410
(410A)
310
431
411
421
500
U
UD
D
210
200
A
L
R
LR

FIG. 5

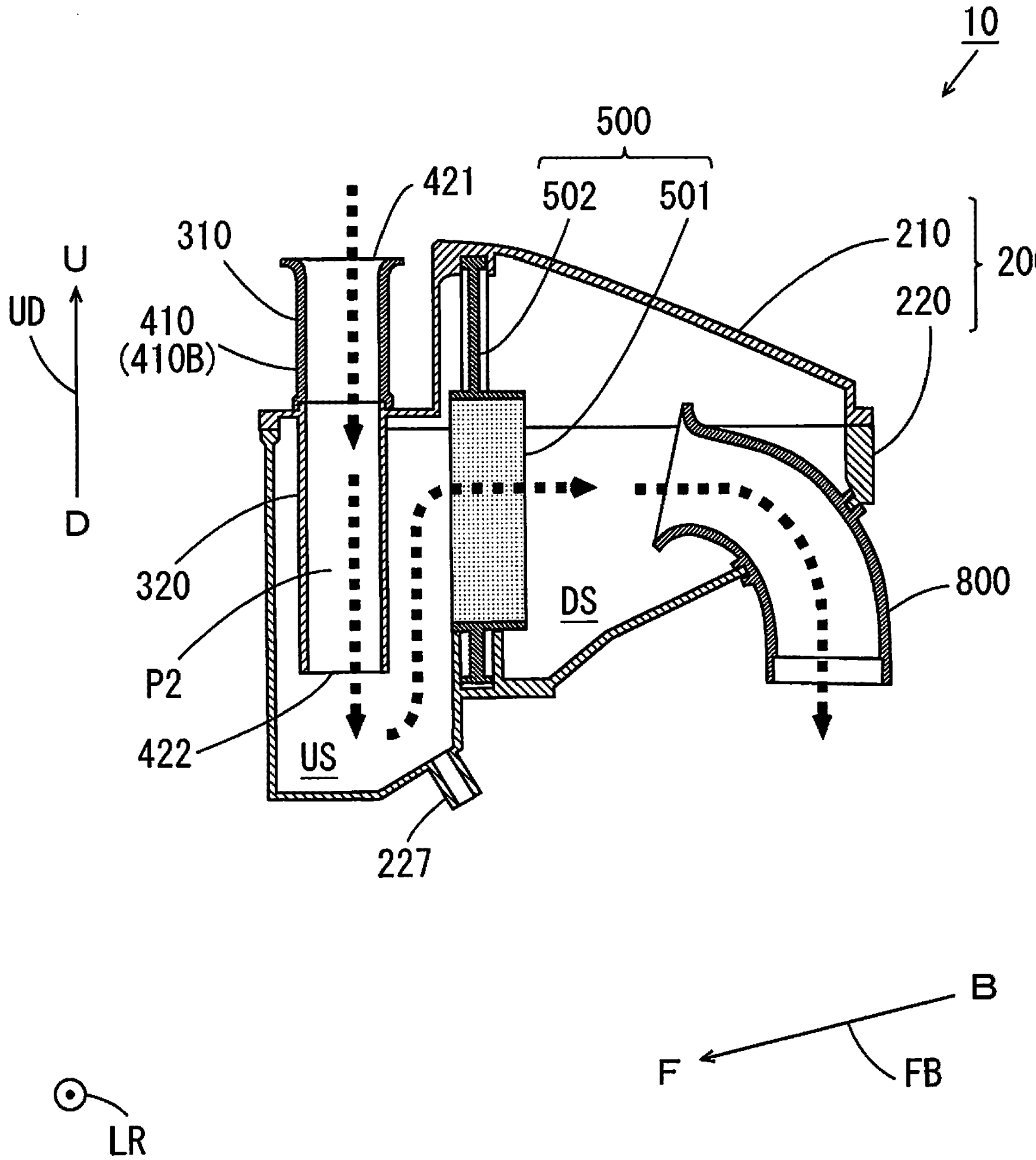
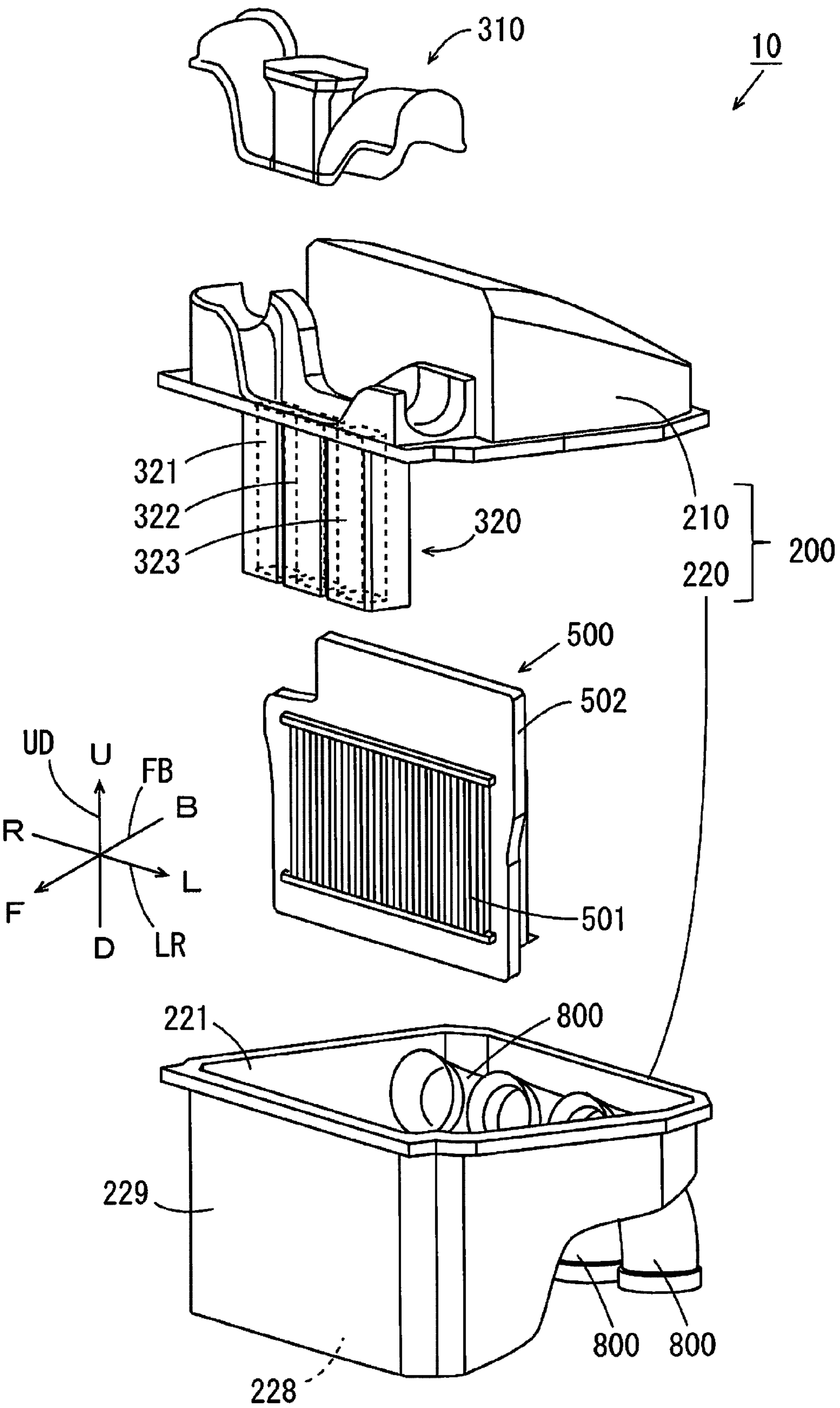
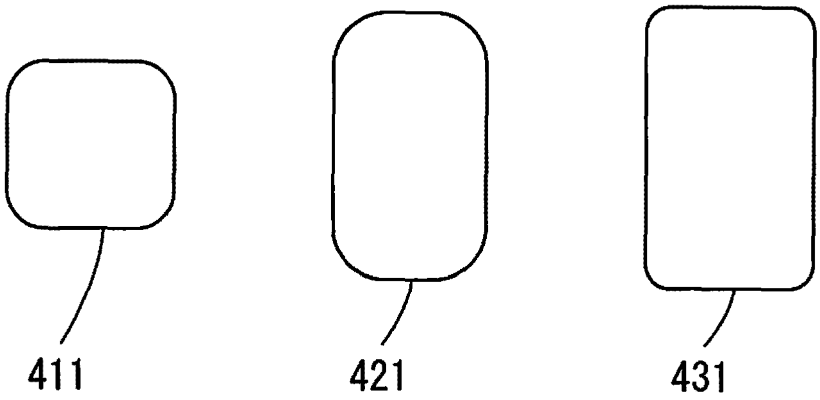

10
500
502
501
421
310
U
UD
410
(410B)
210
220
200
D
320
P2
422
US
DS
800
227
B
F
FB
LR

FIG. 6


310
10
321
322
323
320
210
220
200
500
502
UD
U
FB
B
R
L
F
D
LR
501
221
800
229
800
800
228

F I G. 7


411
421
431

F I G. 8

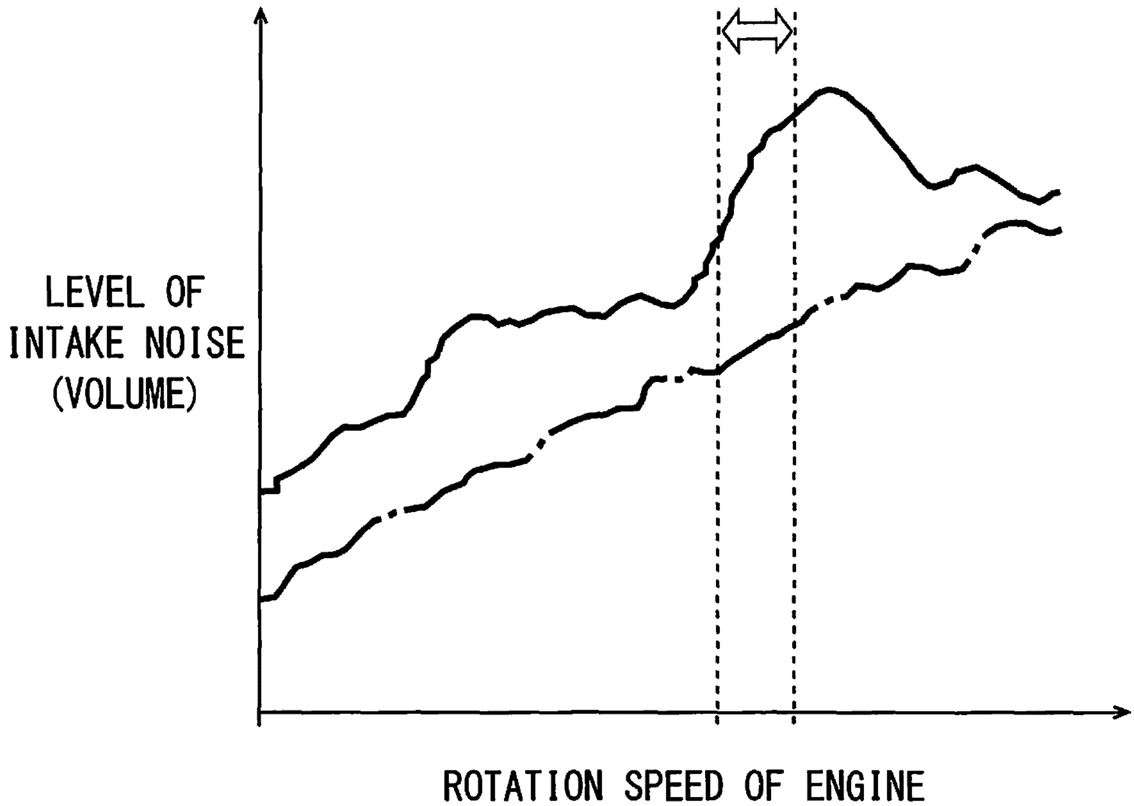
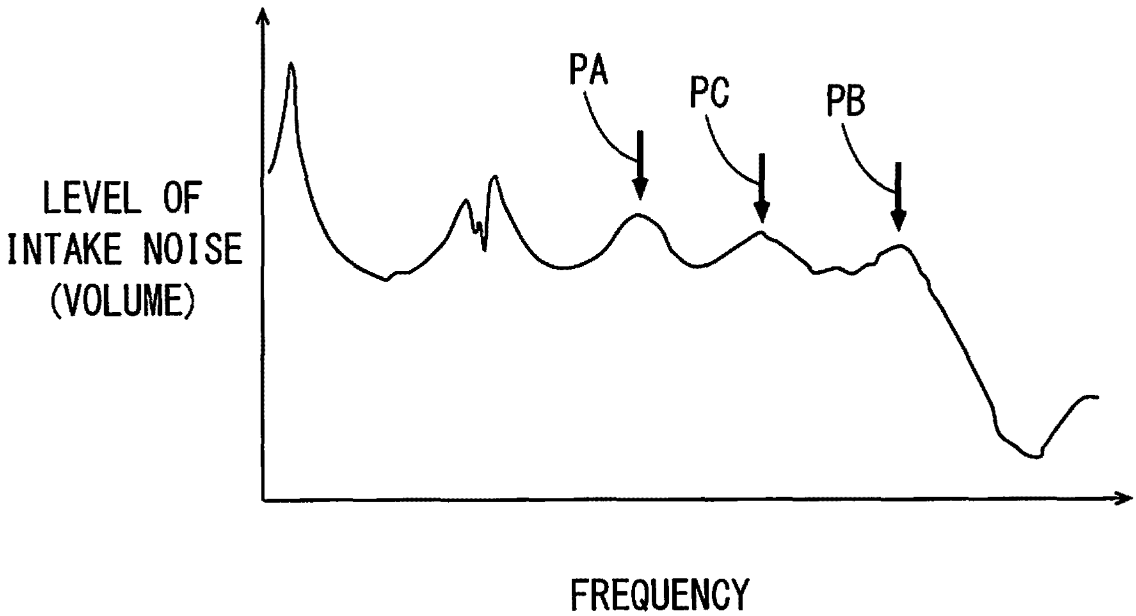

LEVEL OF
INTAKE NOISE
(VOLUME)
ROTATION SPEED OF ENGINE

FIG. 9



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 20 19 6189

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2005/098142 A1 (NAKAGOME HIROSHI [JP] ET AL) 12 May 2005 (2005-05-12) * the whole document * -----	1,4,6-9, 12 2-5	INV. F02M35/02 F02M35/16 F02M35/08 F02M35/10 F02M35/14
X	US 2008/121449 A1 (FUJIMURA KATSUMI [JP]) 29 May 2008 (2008-05-29) * the whole document * -----	1-3,5,6	
Y	EP 1 564 390 A2 (HONDA MOTOR CO LTD [JP]) 17 August 2005 (2005-08-17) * figure 2 * -----	2-5	
A	JP 2001 221113 A (KAWASAKI HEAVY IND LTD) 17 August 2001 (2001-08-17) * figure 3 * -----	10,11	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 November 2020	Kolodziejczyk, Piotr

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 19 6189

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-11-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005098142 A1	12-05-2005	DE 102004053119 A1	16-06-2005
		JP 4184923 B2	19-11-2008
		JP 2005139998 A	02-06-2005
		US 2005098142 A1	12-05-2005
US 2008121449 A1	29-05-2008	CN 101187331 A	28-05-2008
		EP 1925809 A2	28-05-2008
		JP 4846539 B2	28-12-2011
		JP 2008128153 A	05-06-2008
		US 2008121449 A1	29-05-2008
EP 1564390 A2	17-08-2005	CN 1657356 A	24-08-2005
		EP 1564390 A2	17-08-2005
		JP 4139394 B2	27-08-2008
		JP 2005231620 A	02-09-2005
		US 2005178598 A1	18-08-2005
JP 2001221113 A	17-08-2001	JP 3391379 B2	31-03-2003
		JP 2001221113 A	17-08-2001

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2011057131 A **[0002]**