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(54) VEHICLE EXHAUST SYSTEM

(75) Inventors: **Taisuke Sakurai**, Shizuoka-ken (JP); **Itsurou Hagiwara**, Shizuoka-ken (JP)

Correspondence Address:
KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614 (US)

(73) Assignee: **YAMAHA HATSUDOKI KABUSHIKI KAISHA**, Shizuoken (JP)

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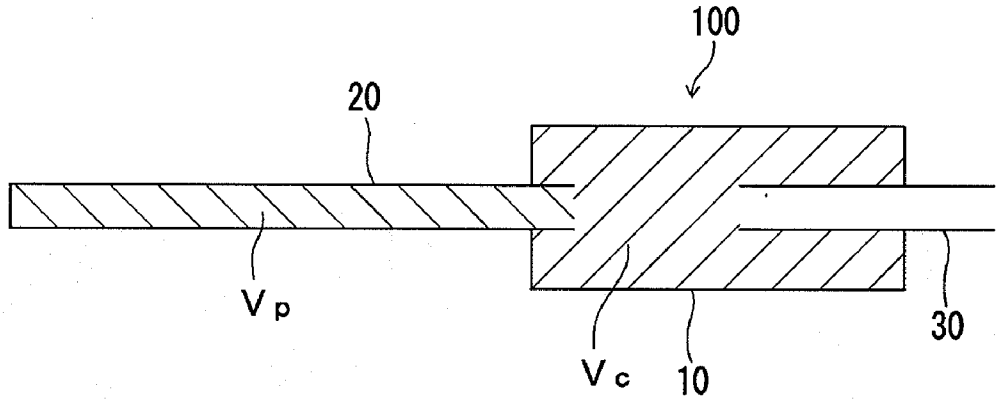
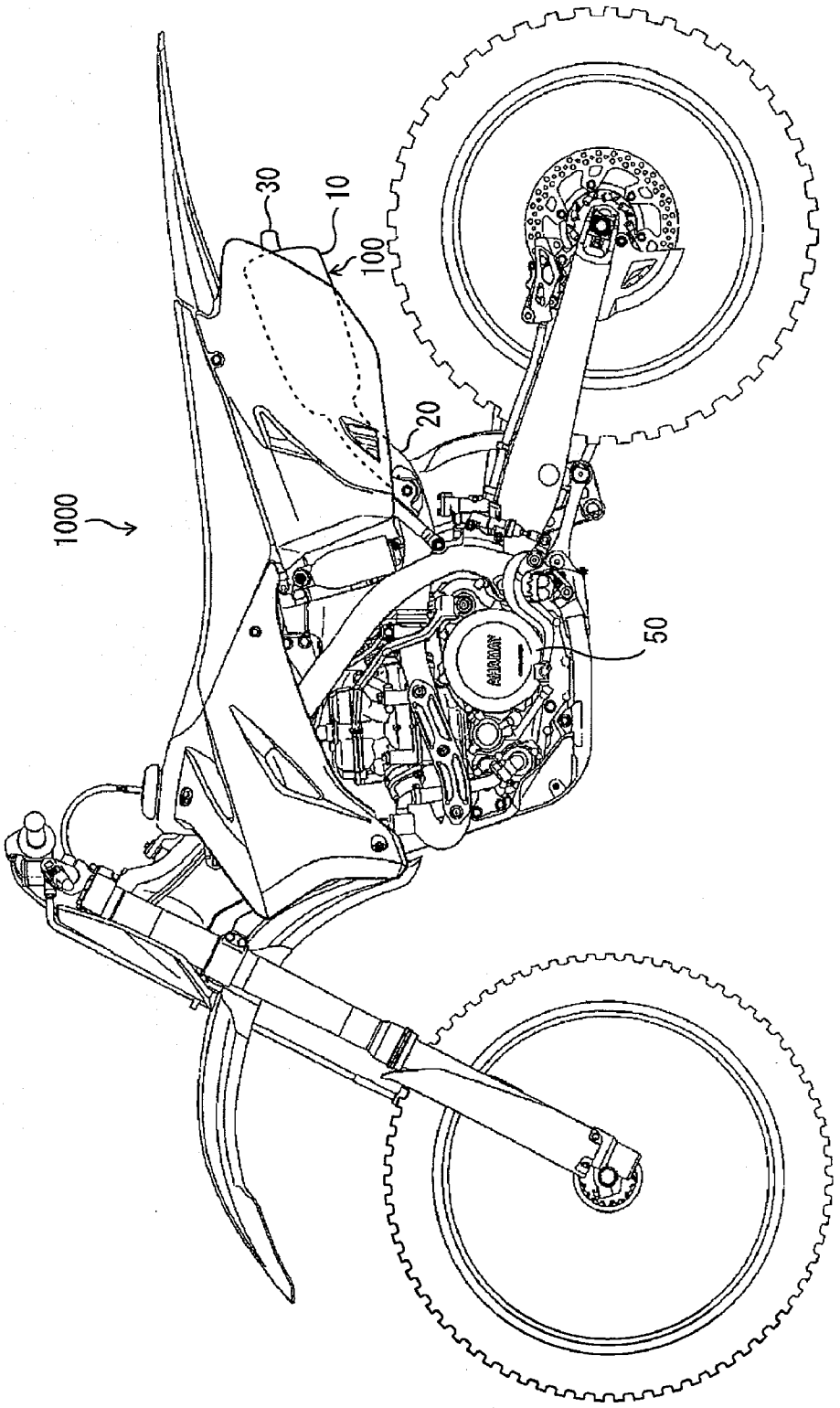
(57) **ABSTRACT**

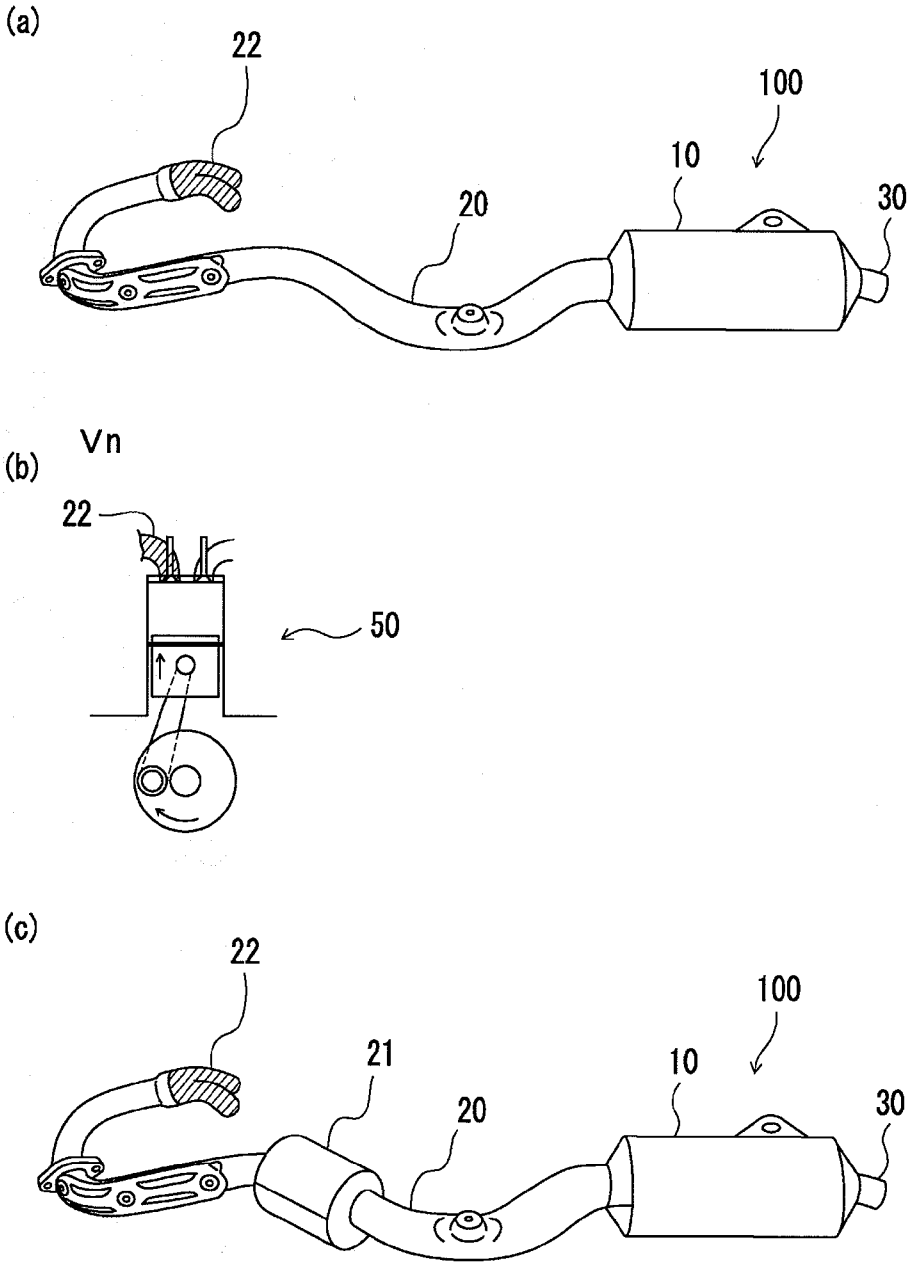
An exhaust system for a straddle-type vehicle, such as a motorcycle, that is compact while also reducing noise output. The exhaust system communicates with an engine of an associated vehicle. The exhaust system includes an exhaust conduit, which is at least partially defined by an exhaust pipe, communicating with a combustion chamber of the engine. The exhaust system also includes a silencer. A ratio of a volume of the silencer to a volume of the exhaust conduit is between about 0.7 to 1.4. In some arrangements, the volume of the silencer and the volume of the exhaust conduit are substantially equal to each other.



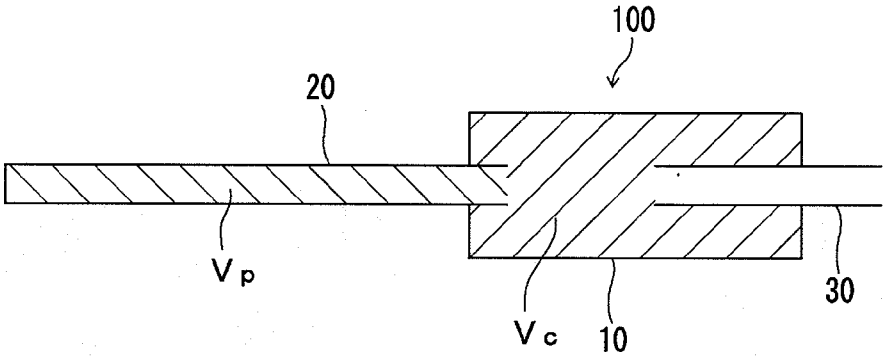
[Fig. 1]



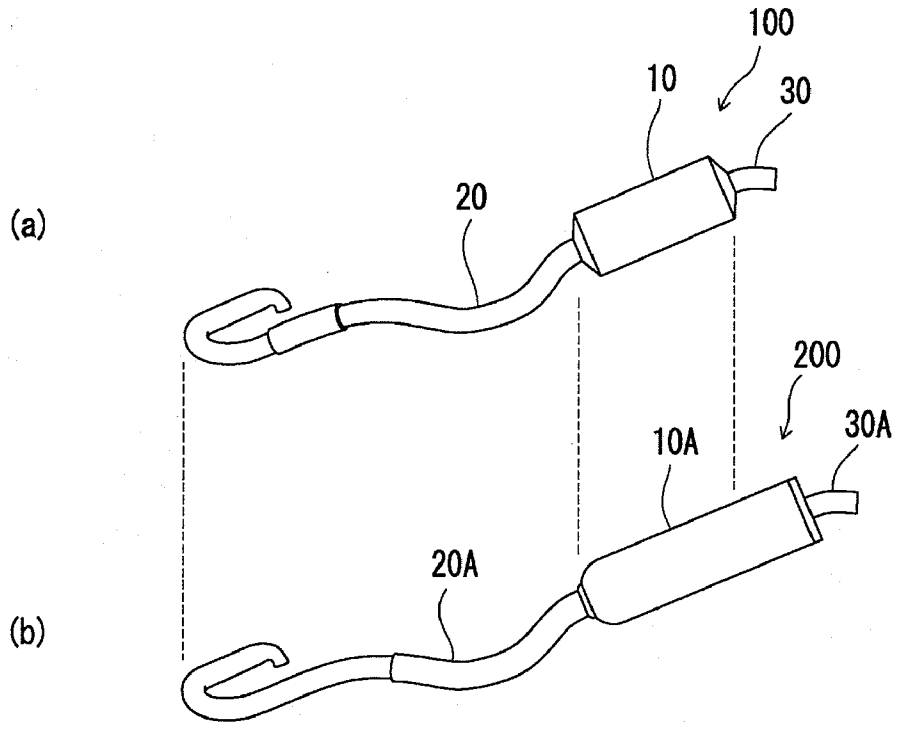
[Fig. 2]



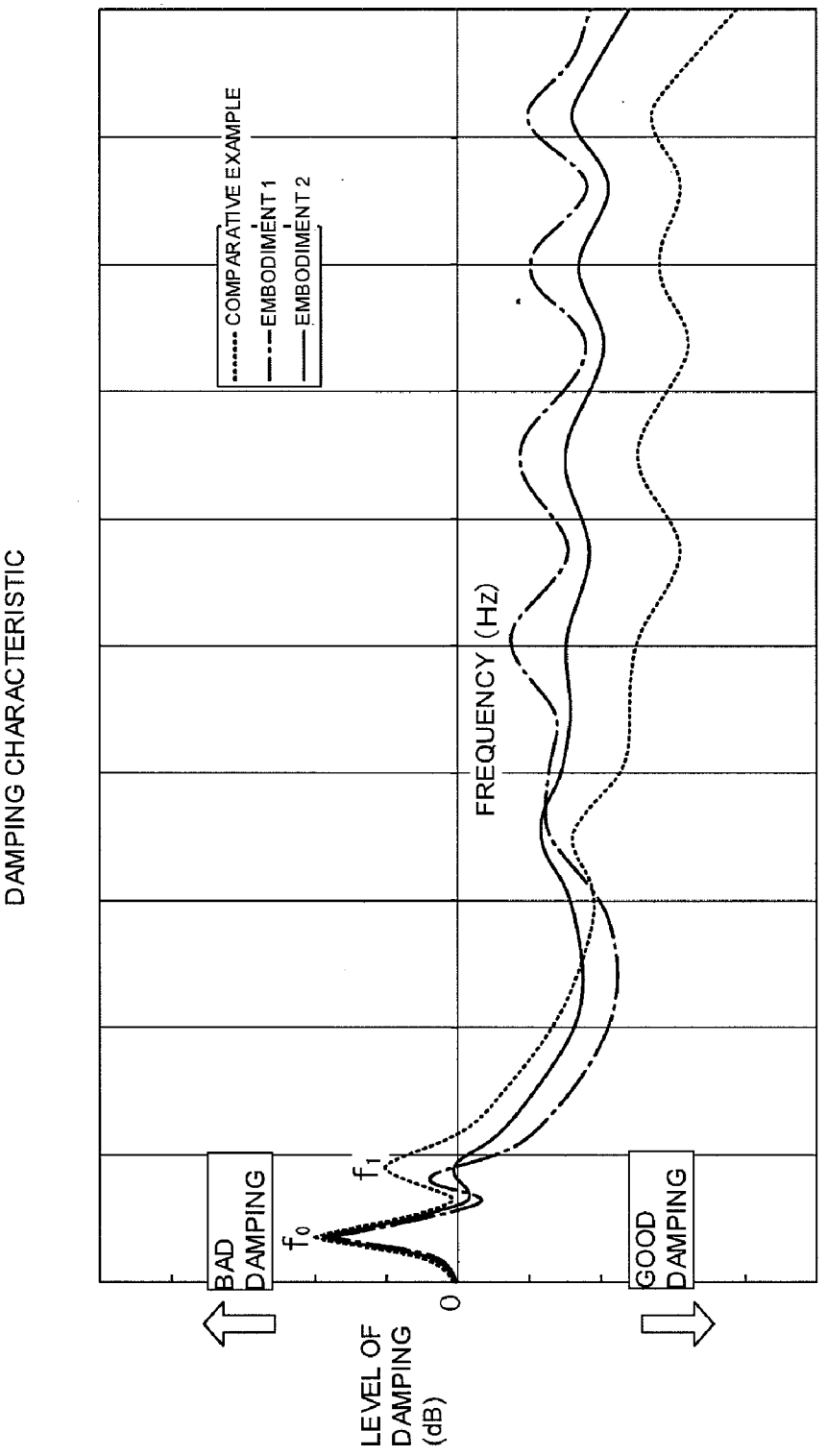
[Fig. 3]



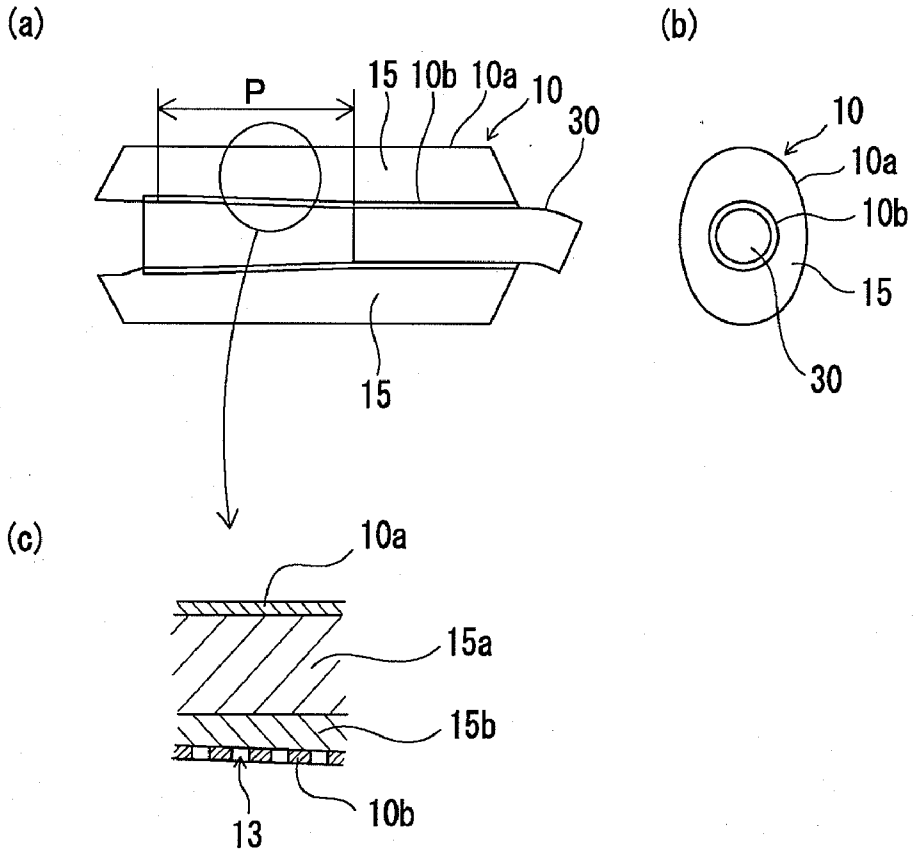
[Fig. 4]



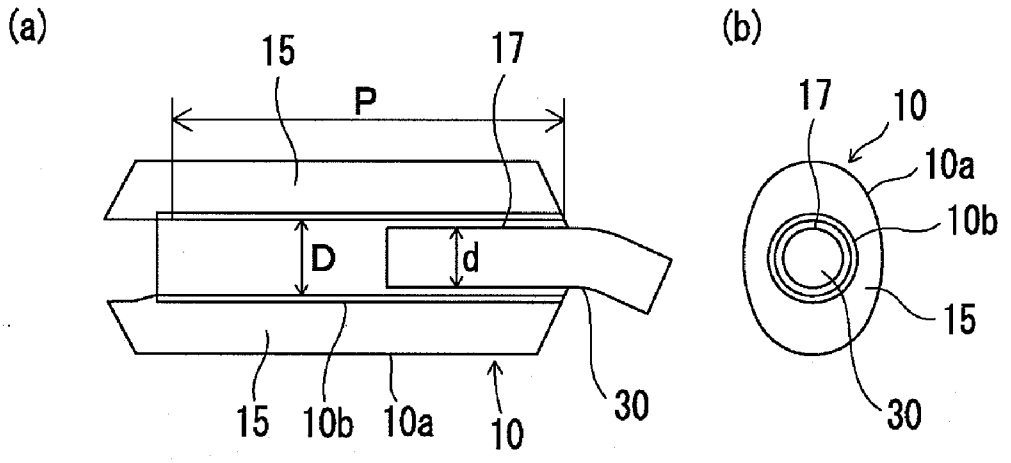
[Fig. 5]


DAMPING CHARACTERISTIC
COMPARATIVE EXAMPLE
EMBODIMENT 1
EMBODIMENT 2
FREQUENCY (Hz)
BAD DAMPING
GOOD DAMPING
f_0
f_1
0
LEVEL OF DAMPING (dB)

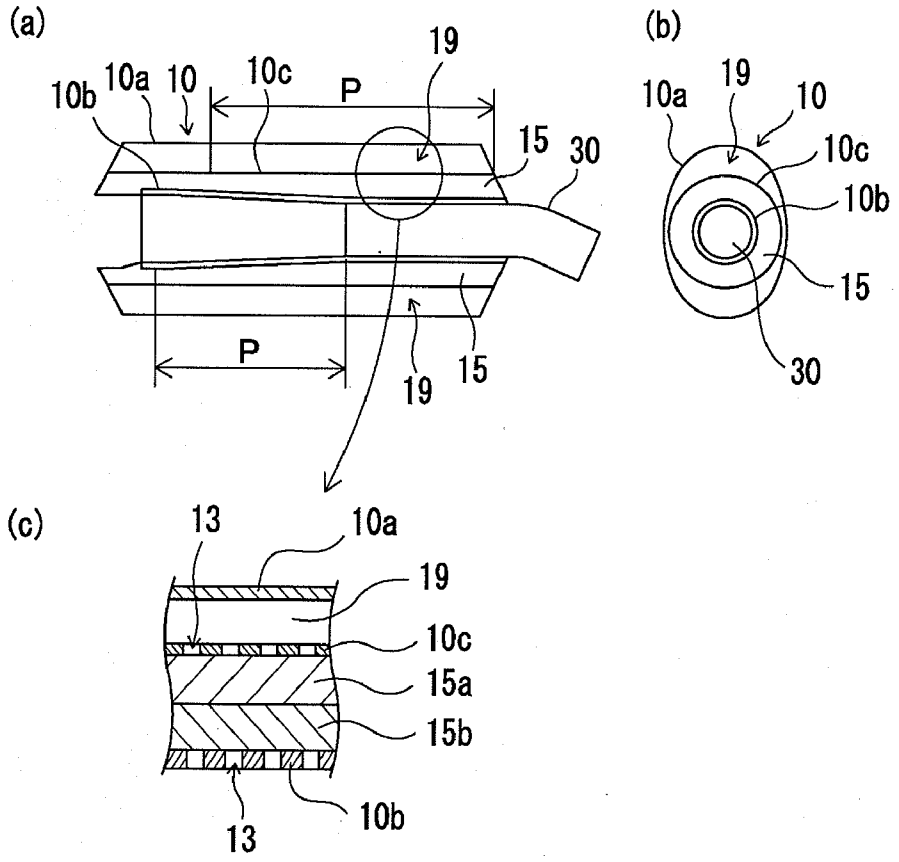
[Fig. 6]



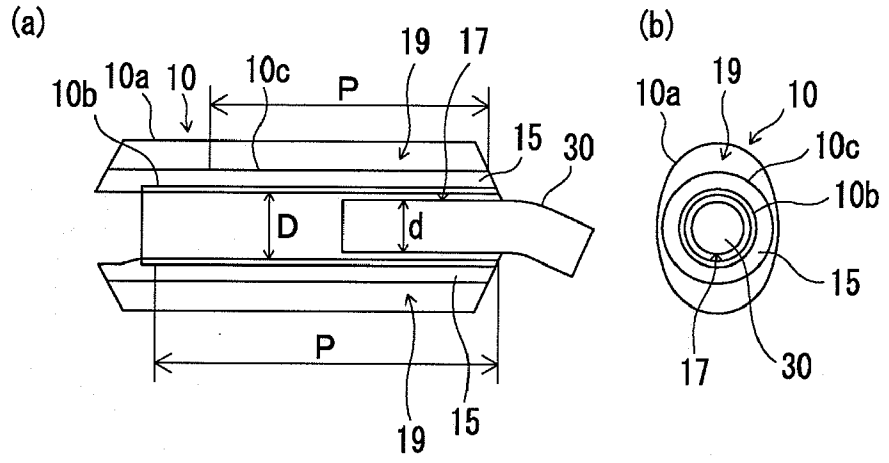
[Fig. 7]



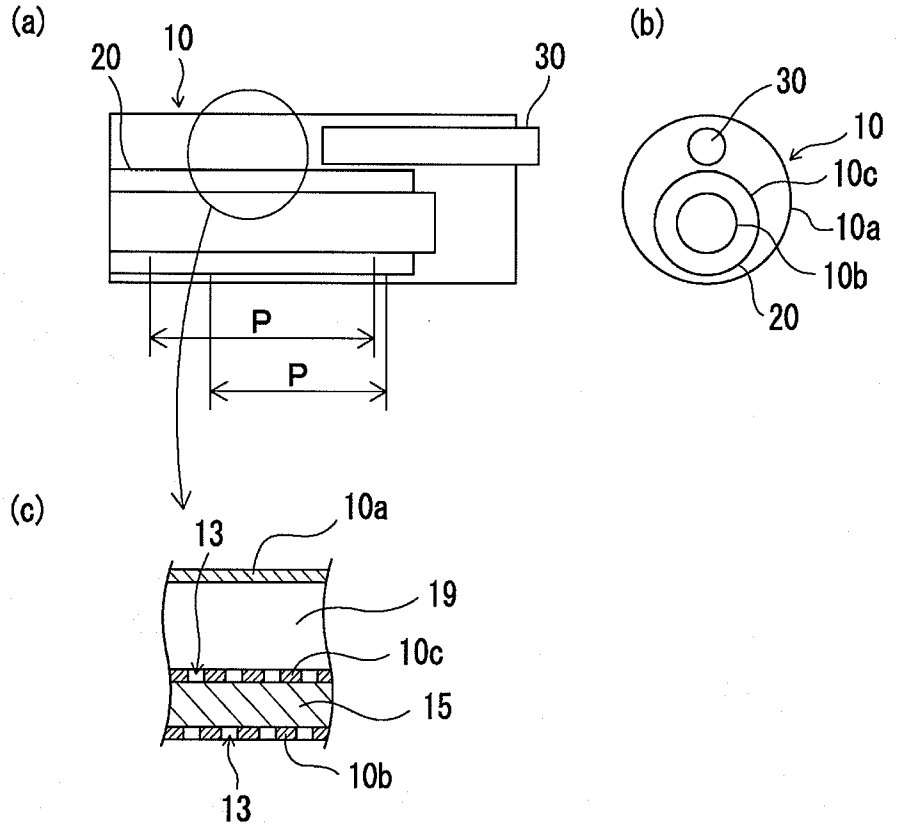
[Fig. 8]


(a)
10b
10a
10
10c
P
19
15
30
P
19
15
(b)
10a
19
10
10c
10b
15
30
(c)
13
10a
19
10c
15a
15b
10b
13

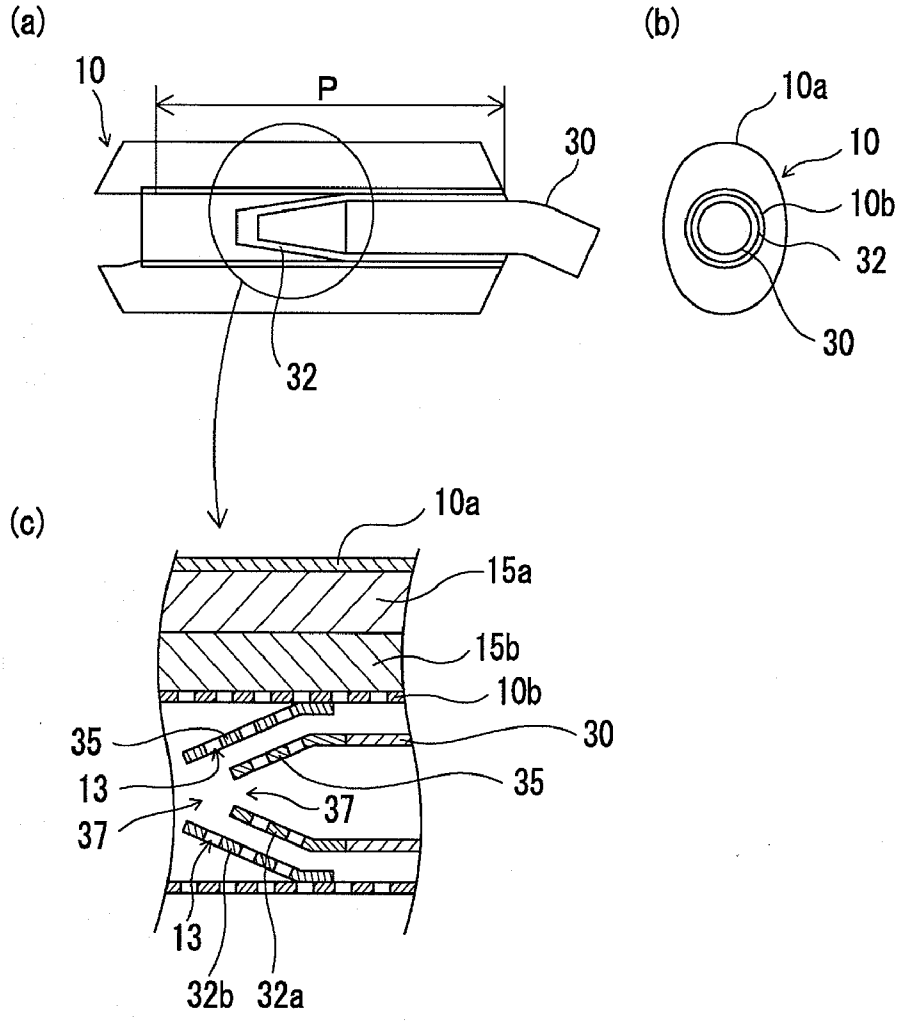
[Fig. 9]



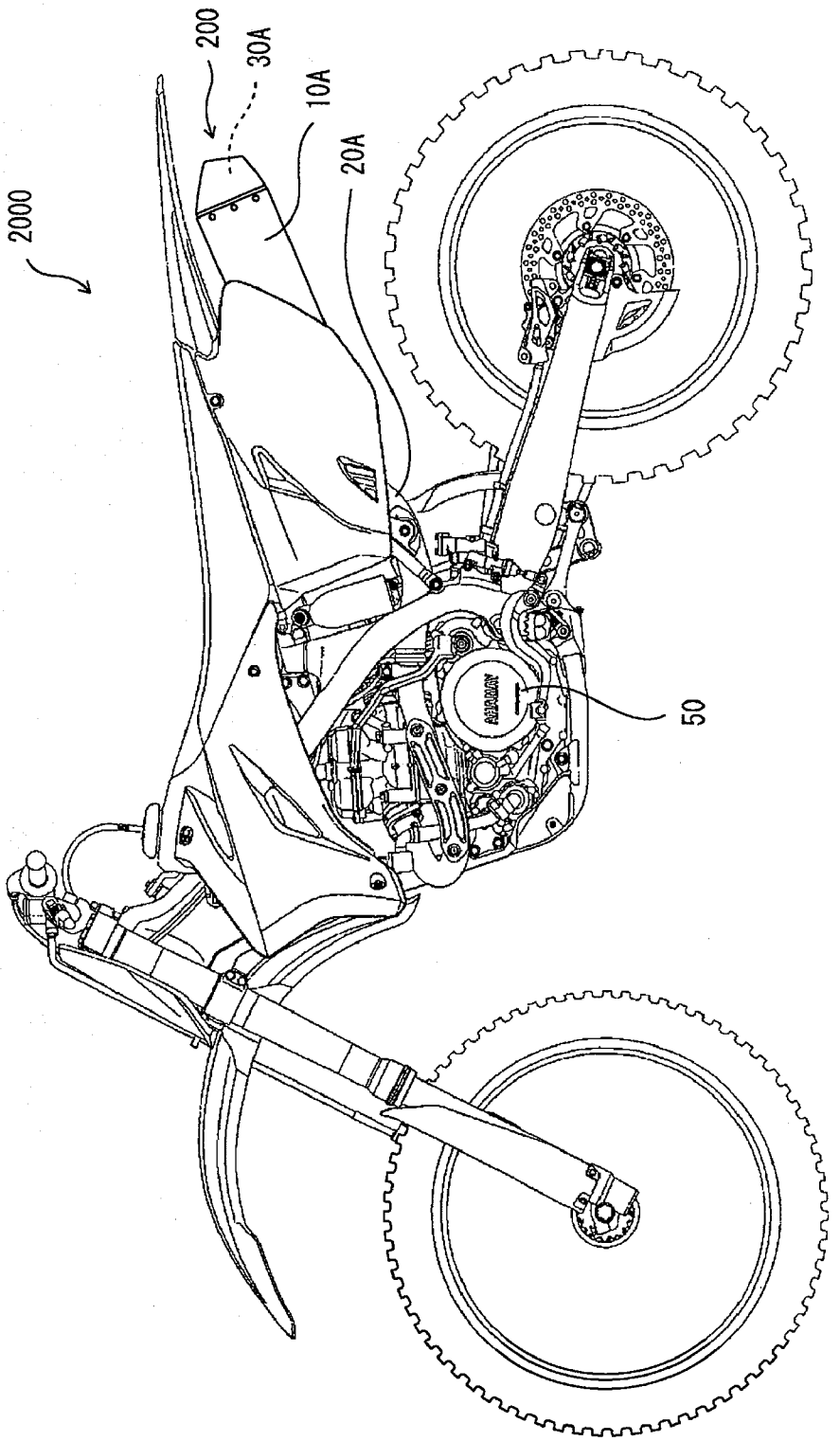
[Fig. 10]



[Fig. 11]


(a)
10
P
30
32
(b)
10a
10
10b
32
30
(c)
10a
15a
15b
10b
35
30
13
35
37
37
13
32b
32a

[Fig. 12]



VEHICLE EXHAUST SYSTEM

RELATED APPLICATIONS

[0001] This application is related to, and claims priority from, Japanese Patent Application No. 2007-031097, filed Feb. 9, 2007 and Japanese Patent Application No. 2006-092334, filed Mar. 29, 2006, the entireties of which are incorporated by reference herein and made a part of the present specification. Application Ser. Nos. _____ (Attorney Docket FY.53109US2A), _____ (Attorney Docket FY.53109US3A), and _____ (Attorney Docket FY.53109US4A), entitled VEHICLE EXHAUST SYSTEM, all filed on even date herewith, are also incorporated by reference herein in their entireties and made a part of the present specification.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention generally relates to an exhaust system for a vehicle. More particularly, the present invention relates to an exhaust system for a straddle-type vehicle and a straddle-type vehicle incorporating such an exhaust system.

[0004] 2. Description of the Related Art

[0005] A exhaust system used in a straddle-type vehicle (for example, a motorcycle) is requested to meet two demands, that is, an exhaust efficiency, at which exhaust gases discharged from an engine should be efficiently discharged, and reduction of exhaust noise, which accompanies discharge of exhaust gases of high pressure and high temperature.

[0006] In particular, the demand for noise reduction or noise elimination has increased as noise regulations have been made more rigorous. Accordingly, it is increasingly desired that noise reduction or noise elimination be attained, while at the same time maintaining exhaust efficiency.

SUMMARY OF THE INVENTION

[0007] When design of an exhaust system is considered only in terms of exhaust efficiency, a muffler (exhaust system) is preferably extended straight. However, such an exhaust system is not well accommodated in a vehicle body of a motorcycle. Accordingly, in order to lessen an exhaust resistance, the exhaust system is extended toward the rear of a vehicle body in an attempt to avoid tight radius bends, which is difficult in many cases because of the front wheel of the motorcycle and a bank angle of the combustion chamber(s). Normally, a muffler having an ideal length in terms of engine performance is only seldom accommodated intact in a configuration of a motorcycle and, as compared with design of a muffler for four-wheel passenger cars, the design of a motorcycle exhaust system to meet both performance and physical constraints is significantly more challenging. That is, it is difficult in the context of a motorcycle exhaust system to achieve a length of the exhaust system that will both provide desired performance attributes and be accommodated within the space constraints of a motorcycle while maintaining a configuration that is as smooth as possible.

[0008] Also, not only an exhaust efficiency, but also a weight of a an exhaust system has a significant influence on the handling characteristics of a motorcycle. That is, because a motorcycle is relatively lightweight, even a weight of about one (1) kg has a great influence on the motorcycle. Moreover, because certain components of the exhaust system (e.g., the silencer) are usually located at a distance from a center of gravity of the motorcycle, the adverse influence of excess weight of the exhaust system on the handling characteristics of the motorcycle is increased.

[0009] On the other hand, in spite of any contrivance on a construction of the exhaust system, a certain silencer (or muffler) volume is needed to some extent to provide a noise reducing effect. In order to conform to regulations on noise, which are made increasingly rigorous, a silencer cannot but be made larger in many cases. Moreover, when a metallic sheet from which the silencer is constructed is thin, it vibrates thereby increasing noise. To avoid such a situation, the silencer is by all means liable to be relatively large in weight. An increase in the weight of the silencer results in undesired handling characteristics of the associated motorcycle.

[0010] In this manner, since a structure of an exhaust system for motorcycles is determined in terms of a variety of interrelated factors, it has been extremely difficult to realize an exhaust system in which miniaturization is achieved and a desired exhaust efficiency and noise-reduction characteristics are met.

[0011] At least some of the preferred embodiments of the present invention provide an exhaust system for straddle-type vehicles, such as motorcycles, in which miniaturization is achieved while a demand for noise reduction characteristics are met.

[0012] Certain preferred embodiments of the invention provide an exhaust system for a straddle-type vehicle, comprising an engine, and an exhaust system including an exhaust pipe connected to the engine and a silencer connected to the exhaust pipe. A volume of the silencer and a volume of the exhaust pipe have a ratio between about 0.7 and 1.4.

[0013] In a preferred embodiment, the exhaust system described above comprises a damping means for an improvement of a damping characteristic in a low frequency range, and a volume of the exhaust pipe and a volume of the silencer are substantially equal to each other to thereby realize the damping means. In some arrangements, the damping means decreases a level of a primary resonance frequency of an exhaust pipe length of the exhaust pipe in the exhaust part.

[0014] In a preferred embodiment, the exhaust system described above includes a tail pipe connected to the silencer, and the volume of the silencer is a volume obtained by subtracting a volume occupied therein by the exhaust pipe and the tail pipe from an inner volume of the silencer. In some arrangements, the volume of the exhaust pipe also includes a volume of a cylinder head exhaust port portion.

[0015] In a preferred embodiment, the silencer of the exhaust system described above comprises an outer housing and an inner core accommodated in the outer housing. Wherein at least a portion of the inner core includes a plurality of through-holes formed therein. In some arrangements, a sound absorbing material is positioned between an inner surface of the outer housing and an outer surface of the

inner core. In some arrangements, the sound absorbing material comprises at least one of glass wool and stainless steel wool.

[0016] In a preferred embodiment, the exhaust system described above includes a tail pipe connected to the silencer, and the tail pipe is radially offset relative to the exhaust pipe.

[0017] A preferred embodiment of the exhaust system described above includes a tail pipe connected to the silencer, wherein the silencer comprises an outer housing and an inner core accommodated within the outer housing. An outside diameter of the tail pipe is smaller than an inside diameter of the inner core of the silencer. In some arrangements, the inside diameter of the inner core is gradually decreased from a forward end to a rearward end, which meets up to a front end of the tail pipe. In some arrangements, an air layer is provided between the tail pipe and the inner core.

[0018] In a preferred embodiment, the silencer comprises an outer housing and an inner core accommodated in the outer housing. A sound absorbing material is positioned between an inner surface of the outer housing and an outer surface of the inner core. A first air layer, or air space, is provided between the inner surface of the outer housing and an outer surface of the sound absorbing material. In some arrangements, the exhaust system includes a tail pipe connected to the silencer. A second air layer, or air space, is provided between the tail pipe and the inner core, and the sound absorbing material is positioned between the second air space and the first air space.

[0019] In a preferred embodiment, a chamber is provided in the exhaust pipe, and a volume of the exhaust pipe also includes a volume of the chamber.

[0020] In a preferred embodiment, a conical member is provided in the silencer. Both ends of the conical member are open. At least a portion of a wall of the conical member is formed with a plurality of through-holes. In some arrangements, the silencer comprises an outer housing and an inner core within the outer housing. A tail pipe is connected to the inner core of the silencer, and the conical member is provided at an upstream end of the tail pipe. In some arrangements, a diameter of the upstream opening of the conical member is smaller than a diameter of the downstream opening.

[0021] In a preferred embodiment, the exhaust system includes a tail pipe connected to the silencer. A first conical member is connected to the tail pipe and a second conical member at least partially overlaps the first conical member and is connected to the inner core.

[0022] A preferred embodiment is a straddle-type vehicle incorporating any of the exhaust systems described in the above paragraphs. In some arrangements, the engine of the straddle-type vehicle operates on a four-stroke combustion principle. In a preferred embodiment, the straddle-type vehicle is an off-road motorcycle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] These and other features, aspects and advantages of the present invention are described below with reference to drawings of preferred embodiments, which are intended to illustrate, but not to limit the present invention. The drawings contain twelve (12) figures.

[0024] FIG. **1** is a side view showing a motorcycle comprising an exhaust system having certain features, aspects and advantages of the present invention.

[0025] FIG. **2**(*a*) is a perspective view showing the exhaust system according to the embodiment of the invention. FIG. **2**(*b*) is a view schematically showing an engine of the motorcycle of FIG. **1**. FIG. **2**(*c*) is a perspective view showing an exhaust system in which the exhaust pipe includes an expansion chamber.

[0026] FIG. **3** is a schematic view of the structure of an exhaust system according to the embodiment of the invention.

[0027] FIGS. **4**(*a*) and **4**(*b*) are perspective views showing the structures of the muffler according to the embodiment of the invention and a muffler of a comparative example.

[0028] FIG. **5** is a graph illustrating a comparison in damping characteristics between two embodiments of an exhaust system according to the invention and an exhaust system of a comparative example.

[0029] FIGS. **6**(*a*) to **6**(*c*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0030] FIGS. **7**(*a*) and **7**(*b*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0031] FIGS. **8**(*a*) to **8**(*c*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0032] FIGS. **9**(*a*) and **9**(*b*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0033] FIGS. **10**(*a*) to **10**(*c*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0034] FIGS. **11**(*a*) to **11**(*c*) are cross sectional views schematically showing examples of the exhaust system according to an embodiment of the invention.

[0035] FIG. **12** is a side view showing a motorcycle comprising the exhaust system of the comparative example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036] According to preferred embodiments of the present invention, because a volume of the silencer and a volume of the exhaust pipe are selected to have a ratio between about 0.7 to 1.4, or to be substantially equal to one another, it is possible to improve the damping characteristics of the exhaust system in a low frequency range (in particular, a primary resonance frequency of an exhaust pipe length of the exhaust pipe in the exhaust system) whereby it is possible to achieve a decrease in the noise level of the exhaust system. Since an improvement in damping characteristic can be achieved by making a volume of the exhaust pipe and a volume of the silencer close to each other, rather than by increasing the volume of the silencer, it is possible to avoid an increase in weight of the silencer, so that it is

possible to realize a small-sized silencer for a straddle-type vehicle. As a result, it is possible to improve the handling characteristics of a motorcycle utilizing embodiments of the exhaust system.

[0037] While an exhaust system for a motorcycle is designed under various restrictions, conventional design philosophy is that a noise reducing effect cannot be actually produced unless the silencer is increased in volume. On the other hand, it is not possible to avoid a phenomenon in which an increase in volume of the silencer brings about an adverse affect on the handling characteristics of the motorcycle. In a muffler in, for example, present four-stroke motocross motorcycles (in particular, sports vehicles), a silencer is increased in volume whereby noise reduction and running performance are met, so that the muffler is large and heavy.

[0038] The present inventors have realize an exhaust device (muffler), which is small-sized and light while meeting performance criteria (exhaust property) and a noise characteristics. Embodiments of the invention are described below with reference to the drawings. In addition, the invention is not limited to the following embodiment.

[0039] FIG. **1** shows a motorcycle **1000**, on which an exhaust device, or exhaust system, according to an embodiment of the invention is mounted. The motorcycle **1000** includes an engine **50** and an exhaust system **100** connected to the engine **50**. The exhaust system **100** includes an exhaust pipe **20** and a silencer **10**. In addition, the exhaust system **100** including the silencer **10** is in some cases referred to as a "muffler" in the specification of the present application for the sake of convenience.

[0040] The muffler **100** includes the exhaust pipe **20** connected to the engine **50** of the motorcycle **1000**, and the silencer **10** connected to the exhaust pipe **20**. With a construction shown in FIG. **1**, a tail pipe **30** is connected to the silencer **10**.

[0041] A state, in which the muffler **100** is removed from the motorcycle **1000**, is shown in FIG. **2**(*a*). The exhaust pipe **20** and the silencer **10** of the muffler **100** shown in FIG. **2**(*a*) are formed with members for mounting to a vehicle body. The illustrated muffler **100** is one for four-stroke engines and the motorcycle **1000** shown in FIG. **1** is an off-road vehicle. In addition, in the exhaust pipe **20** shown in FIG. **2**(*a*), its end connected to the engine **50** mounts thereto a cylinder head exhaust port **22**.

[0042] The exhaust pipe **20** connects to an exhaust opening of the engine **50** as shown in FIG. **2**(*b*) to lead exhaust gases from the engine **50** to the silencer **10**. In an example as shown, the cylinder head exhaust port **22** of the exhaust pipe **20** is connected to the engine **50**. The silencer **10** has a noise reducing function to discharge exhaust gases led from the exhaust pipe **20** to the environment. In the case where the tail pipe **30** is connected to the silencer **10**, exhaust gases are discharged from the tail pipe **30**. In addition, an expansion chamber **21** can be further provided in the exhaust pipe **20** as shown in FIG. **2**(*c*). In this case, exhaust gases from the engine **50** are once expanded in the chamber **21** and then led to the silencer **10** to be discharged to the environment.

[0043] FIG. **3** schematically shows the structure of the muffler **100** according to the embodiment. The muffler **100** according to the embodiment is structured such that a volume (Vp) of the exhaust pipe **20** is substantially equal to a volume (Vc) of the silencer **10**.

[0044] The volume (Vc) of the silencer **10** is a volume obtained by subtracting a volume occupied therein by the exhaust pipe **20** from an interior of the silencer **10**. Also, in the case where the tail pipe **30** is connected to the silencer **10**, the volume (Vc) of the silencer **10** is a volume obtained by subtracting a volume occupied therein by the exhaust pipe **20** and the tail pipe **30** from an interior of the silencer **10**. In the case where the chamber **21** is formed in the exhaust pipe **20**, a volume of the chamber **21** constitutes a part of a volume occupied by the exhaust pipe **20**. Preferably, a volume (Vh) of the cylinder head exhaust port **22** also constitutes a part of a volume occupied by the exhaust pipe **20**. Thus, because an exhaust system is typically constructed for a specific vehicle, the volume of the exhaust port **22** will be known, and can be considered in the design of the exhaust pipe **20** and silencer **10**.

[0045] Since the muffler **100** is structured so that the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** are made substantially equal to each other, it is possible to improve a damping characteristic of a low frequency range of the muffler **100**, in particular, a primary resonance frequency fl. More specifically, a primary resonance frequency fl of an exhaust pipe length of the exhaust pipe **20**; referred below in some cases to as "a primary resonance frequency fl of a muffler" for convenience' sake. When a noise value in a low frequency range is decreased, sound waves having a large energy can be reduced in volume, so that the noise value can be decreased only by damping a noise value of a primary resonance frequency (f**1**) of the muffler. Specifically, damping can be achieved until noise regulations can be met.

[0046] With the illustrated arrangement, an improvement in damping characteristic can be achieved by making the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** close to each other instead of increasing the muffler **100** volume, so that it is possible to avoid an increase in muffler weight. That is, the muffler **100** according to the embodiment includes damping means for an improvement in damping characteristic in a low frequency range (in particular, a primary resonance frequency f**1**) and the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** are made substantially equal to each other to thereby realize the damping means, so that it is not necessary to make the muffler **100** larger in volume than needed and there is no need for any separately independent, new member as damping means, thus enabling a small-sized muffler **100** to be realized.

[0047] As a specific example, the structure of the muffler **100** according to the embodiment will be described with reference to FIG. **4**. FIG. **4**(*a*) shows a muffler **100** having a structure according to an embodiment of the invention and FIG. **4**(*b*) shows a muffler **200** as a comparative example.

[0048] Exhaust pipes **20** and **20**A shown in FIGS. **4**(*a*) and **4**(*b*) are substantially equal to each other in volume but silencers **10** and **10**A are considerably different in volume from each other.

[0049] The silencer **10**A shown in FIG. **4**(*b*) has a considerably larger volume than that of the exhaust pipe **20**A according to a typical design technique in order to obtain a

favorable noise reducing characteristic (damping characteristic). Specifically, the volume of the silencer **10**A exceeds twice the volume of the exhaust pipe **20**A, and more specifically, is about 2.5 times the latter.

[**0050**] On the other hand, the silencer **10** shown in FIG. **4**(*a*) has a volume near to the volume of the exhaust pipe **20** contrary to the typical design technique. Specifically, the volume of the silencer **10** is nearly 1.4 times or less the volume of the exhaust pipe **20**. More specifically, it is desired that the volume of the silencer **10** be in the range of 1.2 to 0.7 times the volume of the exhaust pipe **20**.

[**0051**] Making a comparison in weight between the both, the weight of the silencer **10** amounts only to around 60% of the weight of the silencer **10**A. A decrease in weight of the silencer **10** not only produces an effect of a decrease in total weight of the motorcycle **1000** but contributes much to an improvement in handling characteristics of the motorcycle **1000** since a member or members positioned distant from a vehicle body center (or, a center of gravity of a vehicle body) of the motorcycle **1000** can be reduced in weight.

[**0052**] FIG. **12** shows a construction, in which the muffler **200** of a comparative example shown in FIG. **4**(*b*) is mounted to a motorcycle. Making a comparison between both a motorcycle **2000** shown in FIG. **12** and the motorcycle **1000**, according to the embodiment, shown in FIG. **1**, it is possible to understand how small the muffler becomes in size and volume. As described above, it is an unexpected result that a small-sized and lightweight muffler **100** could be provide favorable performance and favorable noise reducing characteristics, in view of the convention design theory of increasing the volume of the muffler in order to obtain a favorable noise reduction.

[**0053**] Also, as described below, the muffler **100** is capable of decreasing a noise value further than the muffler **200**, which is large in muffler volume. This demonstrates that the muffler **100** according to the preferred embodiments produces excellent, and unexpected, technical results.

[**0054**] FIG. **5** is a graph illustrating damping characteristics of the muffler **100** and the muffler **200** of the comparative example. The damping characteristic of the muffler **100** according to the embodiment is indicated by plots in an Embodiment 1 and an Embodiment 2 while the damping characteristic of the muffler **200** is indicated by plots in the comparative example.

[**0055**] In a low frequency range, Embodiment 1, Embodiment 2 and the comparative example are substantially the same in a damping characteristic of f**0** (damping level (dB)) but it is found that Embodiment 1 and Embodiment 2 are favorable in a damping characteristic (damping level (dB)) of f**1** (primary resonance frequency of an exhaust pipe length of the exhaust pipe in the exhaust part) as compared with the comparative example. In other words, Embodiment 1 and Embodiment 2 are low in noise value of fl as compared with the comparative example. The reason why the noise value of f**1** is small in Embodiment 1 and Embodiment 2 is that the volume (Vc) of the silencer **10** and the volume (Vp) of the exhaust pipe **20** have a ratio between about 0.7 and 1.4 and, in some arrangements, are substantially equal to each other.

[**0056**] With such a construction, the reason why the noise value in a low frequency range (in particular, f**1**) can be decreased is as follows. If a muffler were composed of only the exhaust pipe **20** (without the silencer **10**), f**1** would be a resonance frequency of ¼ wavelength determined by an exhaust pipe length and be suddenly changed into a resonance frequency, at which the both parts (**20**, **10**) were coupled together, in a configuration, in which the silencer **10** were added to the exhaust pipe **20**. Here, a strongest coupled state corresponds to the case where the both parts (**20**, **10**) are equal to each other in resonance frequency, which means in other acoustic terms that the both parts are equal to each other in volume. Moreover, when a sound absorbing material is filled in one of them in this state, it is possible to efficiently damp the frequency.

[**0057**] Also, when the resonance frequency f**1** is to be decreased, volumes (Vp, Vc) of the exhaust pipe **20** and the silencer **10** are influenced thereby, but even when the exhaust pipe **20** is bent, there is caused no substantial influence, which provides a design advantage in that the exhaust pipe **20** can be designed to fit within an available or desirable space of the associated vehicle.

[**0058**] In addition, as described above, even in the case where, for example, the chamber **21** is provided on the exhaust pipe **20** and a part of the exhaust pipe **20** is bulged, the volume (Vp) of the exhaust pipe **20** may include a volume of the chamber **21** and the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** are made close to each other. In addition, the same is also the case with a volume of the cylinder head exhaust port portion **22**.

[**0059**] In addition, a frequency f**0** (Hz) generated by resonance of the whole muffler can be found by, for example, the following formula in the construction shown in FIG. **3**:

$$f0=(c/2\pi)\cdot\{S/(V\cdot L)\}^{1/2}$$

[**0060**] Here, "c" indicates a velocity of sound, "V" indicates an exhaust system volume (that is, "Vp+Vc"), "L" indicates a length of the tail pipe **30**, and "S" indicates a cross sectional area of the tail pipe **30**.

[**0061**] When a ratio of the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** is ideally made 1:1 in the graph of damping characteristic shown in FIG. **5**, the noise value of f**1** in Embodiment 1 and Embodiment 2 can be further damped.

[**0062**] Since the exhaust pipe **20** is actually formed as shown in, for example, FIG. **4** to be bent in order to meet various design conditions and the size and weight of the silencer **10** is also determined in conformity to other conditions (vehicle body weight, vehicle body balance, etc.), however, it is unnecessary in many cases to maintain the ratio of the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** to an ideal 1:1 provided that an effect of a decrease in noise value is produced. That is, provided that a desired effect of a decrease in noise value is produced by making the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** close to each other contrary to conventional technical thought that it is desirable in a typical muffler design to make the silencer **10** large in volume (for example, Vc/Vp>2), it is possible to change a design of the exhaust pipe **20** and the silencer **10** in that range, in which such effect is produced (as an example, about 1.2 times to about 0.7 times, or about 1.4 times to about 0.7 times).

[0063] In the graph shown in FIG. **5**, it is found that the damping characteristic of the muffler in Embodiment 1 and Embodiment 2 is favorable (that is, noise can be decreased) in a low frequency range (for example, in the order of 600 to 800 Hz), and the comparative example demonstrates a favorable damping characteristic in a frequency range therebeyond. Accordingly, with the muffler **100** according to the embodiment of the invention, a decrease in noise component in a low frequency range is achieved by damping means (damping means for an improvement of a damping characteristic in a low frequency range), which is realized by making the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** substantially equal to each other, and a decrease in noise component in a frequency range therebeyond can also be achieved by other techniques.

[0064] Modifications of the muffler **100** according to the embodiment will be described below with reference to FIGS. **6** to **11**. The respective figures schematically show a structure of the silencer **10** in the muffler **100** according to various embodiments of the present invention, (a) being lateral, cross sectional views, and (b) being cross sectional views as viewed from the rear of a vehicle body. In addition, (c) are partially enlarged views in (a).

[0065] The silencer **10** shown in FIG. **6** comprises an outer housing, or cylinder **10***a*, and an inner core, or cylinder **10***b*, accommodated in the outer cylinder **10***a*. Through-holes **13** are formed in at least a part (region P) of the wall of the inner cylinder **10***b* of the silencer **10** and may be referred to herein as "punched holes," although the holes **13** may be produced by any suitable method.

[0066] The punched holes **13** are small holes formed in the silencer **10** (here, the inner cylinder **10***b*) and serve to enable energy of exhaust gases, which are introduced from the exhaust pipe **20**, to be led to the outer cylinder l0*a* through the small holes. In an example shown in FIG. **6**, a sound absorbing material **15** is positioned in a manner to come into close contact between an inner surface of the outer cylinder **1**Oa and an outer surface of the inner cylinder **10***b*.

[0067] The sound absorbing material **15** is a material capable of absorbing sound waves and can use, for example, glass wool, stainless steel wool (SUS wool), aluminum wool, ferrite, asbestos, etc. In this example, glass wool is used as the sound absorbing material **15**. The sound absorbing material **15** fairly absorbs a high frequency sound but is less effective in low frequency sound, so that a synergistic effect is produced when combined with the construction of the muffler **100** according to the illustrated embodiment.

[0068] In this example, a SUS wool **15***b* is provided on the outer surface of the inner cylinder **10***b* and a glass wool **15***a* is provided on an outer periphery thereof. In other words, the SUS wool **15***b* is provided on the outer surface of the inner cylinder **10***b* and the glass wool **15***a* is provided on the inner surface of the outer cylinder **10***a*. Also, the inner cylinder **10***b* is gradually decreased in inside diameter up to a front end of the tail pipe **30**. With a silencer **10** as shown in FIG. **7**, an air layer **17**, or air space, is formed between a tail pipe **30** and an inner cylinder **10***b*. Specifically, an outside diameter d of the tail pipe **30** is smaller than an inside diameter D of the inner cylinder **10***b* of the silencer **10**. In this example, punched holes (region P) are formed in as far as a region (a region, in which the air layer **17** is positioned), in which the tail pipe **30** is positioned. In addition, a cross sectional structure of the silencer **10** shown in FIG. **7** is substantially the same as that shown in the partially enlarged view of FIG. **6**(*c*).

[0069] The construction shown in this example can incorporate a damping characteristic in which noise elimination is achieved by varying (enlarging) a pipe (cylinder) in cross sectional area, and such combination makes it possible to regulate the damping characteristic of the muffler **100**. Specifically, the pipe (cylinder) is changed in cross sectional area to enable obtaining a damping characteristic, in which sounds mainly in a low frequency range are eliminated. Also, the provision of the air layer **17** enables producing both effects of noise reduction by the sound absorbing material **15** and noise reduction by pipe bulging, or an expansion chamber effect.

[0070] The silencer **10** shown in FIG. **8** has a structure similar to that in FIG. **6**, but a sound absorbing material **15** is arranged on an outer surface of an inner cylinder **1**Ob and an air layer **19** is present on an inner surface of an outer cylinder **10***a*, in which no sound absorbing material **15** is filled.

[0071] Here, the sound absorbing material **15** comprises a combination of SUS wool **15***b* and glass wool **15***a* in the same manner as that shown in FIG. **6**. In addition, as shown in FIG. **8**(*c*), a partition **10***c*, which supports the sound absorbing material **15** (**15***a*, **15***b*), is provided and punched holes **13** are formed on at least a portion of the partition **10***c*.

[0072] With such construction, it is possible to regulate a damping characteristic of the muffler **100** according to the embodiment owing to both effects of noise reduction by the sound absorbing material **15** and noise reduction by an expansion chamber effect.

[0073] A silencer **10** shown in FIG. **9** incorporates a feature of the structure shown in FIG. **7** into the structure shown in FIG. **8** such that an air layer **17** is formed between a tail pipe **30** and an inner cylinder **10***b*. Such a structural feature (that is, a structural feature that the sound absorbing material **15** is arranged between the air layer (first air layer) **19** provided between the inner surface of the outer cylinder **10***a* and the outer surface of the sound absorbing material **15** and the air layer (second air layer) **17** provided between the tail pipe **30** and the inner cylinder **10***b*) regulates a damping characteristic of the muffler **100**. In addition, a cross sectional structure of the silencer **10** shown in FIG. **9** is substantially the same as that shown in the partially enlarged view of FIG. **8**(*c*).

[0074] In addition, the silencer **10** according to the embodiment is not limited to a structure, which comprises the outer cylinder **10***a* and the inner cylinder **10***b* accommodated in the outer cylinder **10***a*, but can adopt a structure shown in FIG. **10**. That is, it suffices to design a muffler **100** having a desired damping characteristic by the use of further means, which combines with damping means in a low frequency range, which is realized by making the volume (Vp) of the exhaust pipe **20** and the volume (Vc) of the silencer **10** substantially equal to each other, to enable reinforcing the damping means. Here, the sound absorbing material **15** in FIG. **10**(*c*) comprises, for example, SUS wool, or glass wool, or a combination thereof.

[0075] Also, with a silencer **10** shown in FIG. **10**, an axis of the tail pipe **30** is radially offset relative to an axis of the

portion of the exhaust pipe **20** connecting with, or positioned within, the silencer **10**. With such a structure, even when an air layer about the exhaust pipe **20** is decreased in cross sectional area by a sound absorbing material **15**, such a decrease can be compensated for by a cross sectional area of the tail pipe **30**.

[**0076**] A construction, in which at least one conical member **32** is arranged in a silencer **10** as shown in, for example, FIG. **11**, can be adopted as an example of such a further means to create a damping effect. The conical member **32** comprises a member, which is in the form of a cone with a tip end thereof opened and formed with punched holes **13** in a sidewall **35** of the conical member **32**. The provision of such a conical member can produce an effect of noise reduction or elimination and a directly transmitting sound of exhaust noise can be decreased.

[**0077**] An opening **37** provided on the conical member has an opening diameter at an upstream end thereof, which is made smaller than an opening diameter at a downstream end thereof. Thereby, it is possible to prevent direct transmission of noise, thus enabling improving a damping effect. It is possible to arrange one or plural conical members **32** within the silencer **10**. According to the embodiment, the conical members **32** are provided in two locations (**32***a*, **32***b*) on the inner cylinder **10***b* and an upstream end of the tail pipe **30**. In addition, it is possible to provide only one conical member **32** instead of several in number and to provide three or more conical members.

[**0078**] In addition, "upstream" side and "downstream" side referred to in the specification of the present application mean an upstream side and a downstream side, respectively, in a direction, in which exhaust gases in the muffler flow. In other words, "upstream" side is that side, on which an engine is arranged, and "downstream" side is that side, on which exhaust gases are discharged to the environment.

[**0079**] In the example shown in FIG. **11**, the conical member **32** is provided at an end of the tail pipe **30**. Specifically, the conical member includes a first cone **32***a* connected to the tail pipe **30** and a second cone **32***b*, which covers (i.e., at least partially overlaps) the first cone **32***a* and is connected to the inner cylinder **10***b*. By providing a plurality (**32***a*, **32***b*) of the conical members **32**, it is possible to further improve a damping effect.

[**0080**] In addition, while FIG. **1** shows an off-road motorcycle as an example of the motorcycle **1000**, the motorcycle **1000** may be constructed for on-road use as well. Also, "motorcycle" or "straddle-type vehicle" in the specification of the present application refers to a motorcycle and also means any vehicle, which includes but is not limited to a bicycle with a motor (motorbike) and a scooter and other vehicles that can turn with a vehicle body inclined. Accordingly, a three-wheeler/four-wheeler, at least one of a front wheel and a rear wheel of which has two or more wheels and which is three, four (or more) in the number of tires, is also intended to be included in the definition of a "motorcycle" or "straddle-type vehicle." Thus, applicability of the present invention is not limited to a motorcycle but to other vehicles capable of making use of the effect of the invention, for example, a so-called straddle-type vehicle, which includes four-wheeled buggies, ATV's (All Terrain Vehicle's), and snowmobiles.

[**0081**] While the invention has been described with respect to preferred embodiments, such descriptions are not limitative but various modifications are of course possible. According to preferred embodiments of the invention, it is possible to provide a muffler for a straddle-type vehicle, which achieves miniaturization while meeting a demand for a noise reducing characteristic.

[**0082**] Although this invention has been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the present invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof. In particular, while the present exhaust system and vehicle incorporating the exhaust system have been described in the context of particularly preferred embodiments, the skilled artisan will appreciate, in view of the present disclosure, that certain advantages, features and aspects of the system may be realized in a variety of other applications, many of which have been noted above. Additionally, it is contemplated that various aspects and features of the invention described can be practiced separately, combined together, or substituted for one another, and that a variety of combination and subcombinations of the features and aspects can be made and still fall within the scope of the invention. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims.

What is claimed is:

1. An exhaust system for a vehicle, comprising:

an exhaust conduit having a first end communicating with a combustion chamber of an engine of the vehicle; and

a silencer, a second end of the exhaust conduit communicating with the silencer;

wherein a ratio of a volume of the silencer to a volume of the exhaust conduit is between about 0.7 and about 1.4.

2. The exhaust system of claim 1, wherein the ratio between the volume of the silencer and the volume of the exhaust conduit is selected to improve a noise damping characteristic of the exhaust system in a low frequency range.

3. The exhaust system of claim 1, wherein a portion of the exhaust conduit is defined by an exhaust pipe and the ratio between the volume of the silencer and the volume of the exhaust conduit is selected to decrease a level of a primary resonance frequency of the exhaust pipe.

4. The exhaust system of claim 1, further comprising a tail pipe communicating with the silencer, wherein the volume of the silencer is defined by an interior volume of the silencer minus a volume of the tail pipe that is within the interior volume of the silencer.

5. The exhaust system of claim 4, wherein the volume of the exhaust conduit includes a volume of an exhaust port of the engine of the vehicle.

6. The exhaust system of claim 1, wherein the volume of the silencer and the volume of the exhaust conduit are substantially equal.

7. The exhaust system of claim 1, wherein the silencer comprises an outer housing and an inner core accommodated within the outer housing, and wherein at least a portion of the inner core includes a plurality of through-holes.

8. The exhaust system of claim 7, wherein a sound absorbing material is positioned between an inner surface of the outer housing and an outer surface of the inner core of the silencer.

9. The exhaust system of claim 8, further comprising a tail pipe communicating with the silencer, wherein an axis of the tail pipe is radially offset from an axis of the second end of the exhaust conduit that communicates with the silencer.

10. The exhaust system of claim 8, wherein the sound absorbing material comprises at least one of glass wool and stainless steel wool.

11. The exhaust system of claim 1, further comprising a tail pipe connected to the silencer, the silencer comprising an outer housing and an inner core within the outer housing, wherein an outside diameter of the tail pipe is smaller than an inside diameter of the inner core.

12. The exhaust system of claim 11, wherein the inside diameter of the inner core gradually decreases from a forward end toward a rearward end, wherein the rearward end meets up with a forward end of the tail pipe.

13. The exhaust system of claim 11, wherein an air space is provided between the tail pipe and the inner core.

14. The exhaust system of claim 1, wherein the silencer comprises an outer housing and an inner core within the outer housing, and wherein a sound absorbing material is positioned between an inner surface of the outer housing and an outer surface of the inner core, further comprising a first air space between the inner surface of the outer housing and an outer surface of the sound absorbing material.

15. The exhaust system of claim 14, further comprising a tail pipe connected to the silencer, wherein a second air space is provided between the tail pipe and the inner core, and the sound absorbing material is positioned between the second air space and the first air space.

16. The exhaust system of claim 1, wherein a chamber is provided in the exhaust conduit, and a volume of the exhaust conduit includes a volume of the chamber.

17. The exhaust system of claim 1, further comprising at least one conical member within the silencer, wherein a plurality of through-holes are formed in a wall of the conical member and each end of the conical member is open.

18. The exhaust system of claim 17, wherein the silencer comprises an outer housing and an inner core within the outer housing, and wherein a tail pipe is connected to the inner core, the at least one conical member being positioned at an upstream end of the tail pipe.

19. The exhaust system of claim 18, wherein an upstream opening of the at least one conical member is smaller than a downstream opening of the conical member.

20. The exhaust system of claim 17, wherein the exhaust system includes a tail pipe connected to the silencer, the at least one conical member comprising a first conical member connected to the tail pipe and a second conical member connected to the inner core, wherein the second conical member overlaps at least a portion of the first conical member.

21. A straddle-type vehicle, comprising:

an engine comprising at least one combustion chamber;

an exhaust conduit having a first end communicating with the combustion chamber; and

a silencer, a second end of the exhaust conduit communicating with the silencer;

wherein a ratio of a volume of the silencer to a volume of the exhaust conduit is between about 0.7 and about 1.4.

22. The straddle-type vehicle of claim 21, wherein the volume of the exhaust conduit includes a volume of an exhaust port of the engine.

23. The straddle-type vehicle of claim 21, wherein the engine operates on a four- stroke principle.

24. The straddle-type vehicle of claim 23, wherein the vehicle is an off-road motorcycle.

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