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(54) Title: EXHAUST SILENCER FOR INTERNAL COMBUSTION ENGINE

(57) Abrégé/Abstract:
This is to provide a high-performance exhaust silencer in which a shell wall includes a shell outer plate, a shell inner plate, and a damping material to be inserted therebetween, wherein a space between the shell outer plate and shell inner plate of the exhaust silencer will be narrowed, the shell outer plate and the shell inner plate will not interfere with each other, and an outer shape will be small but expansion chambers will be large by surely securing an air space between the shell outer plate and the shell inner plate. For the above-mentioned damping material, a material obtained by stretchably weaving metal wire into mesh is used.
ABSTRACT OF THE DISCLOSURE

This is to provide a high-performance exhaust silencer in which a shell wall includes a shell outer plate, a shell inner plate, and a damping material to be inserted therebetween, wherein a space between the shell outer plate and shell inner plate of the exhaust silencer will be narrowed, the shell outer plate and the shell inner plate will not interfere with each other, and an outer shape will be small but expansion chambers will be large by surely securing an air space between the shell outer plate and the shell inner plate. For the above-mentioned damping material, a material obtained by stretchably weaving metal wire into mesh is used.
EXHAUST SILENCER FOR INTERNAL COMBUSTION ENGINE

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FIELD OF THE INVENTION
The present invention relates to an exhaust silencer for a four-stroke internal combustion engine to be mounted on a motorcycle or the like.

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BACKGROUND OF THE INVENTION
In a conventional exhaust silencer, a shell wall is fabricated by pressing and attaching wire cloth of a damping material to the inner side of a shell outer plate with a shell inner plate made of a punching plate. Since the wire cloth is relatively thick, it is necessary to widen a space between the shell outer plate and the shell inner plate, and there is a problem that the exhaust silencer becomes larger.

Moreover, in the above-mentioned method of attaching the damping material, a temporarily attaching process is necessary by using tape, spot welding or the like, and there is a problem that man-hours are increased. See for example, unexamined Utility Model Application Publication No. S61-94223.

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An object of the present invention is to provide a high-performance exhaust silencer which solves the above-mentioned problems of the prior art, narrows the space between the shell outer plate and shell inner plate of the exhaust silencer, allows the shell outer plate and the shell inner plate not to interfere with each other, and has a small outer shape but a
large combustion chamber by surely securing an air space between the shell outer plate and the shell inner plate.

Further, another object is to improve a damping material to be inserted between the shell outer plate and the shell inner plate as well as an attaching method thereof, whereby the improvement in working efficiency is attempted.

**SUMMARY OF THE INVENTION**

The present invention is characterized in that, in an exhaust silencer for an internal combustion engine in which a shell wall includes a shell outer plate, a shell inner plate and a damping material to be inserted therebetween, the above-mentioned damping material is a material obtained by stretchably weaving metal wire into mesh.

In the present invention, since a material made by weaving metal wire into mesh is used as the damping material and therefore stretchable, the damping material can be inserted with a thin thickness, whereby it becomes possible to make the shell wall thinner. Further, since an air space can be surely secured between the shell outer plate and the shell inner plate, it is possible to provide the exhaust silencer having a small outer shape but a large combustion chamber. That is, it is possible to prevent the shell wall of the exhaust silencer from vibrating, without reducing the capacity of the exhaust silencer but suppressing an increase in the weight thereof. The shell outer plate can be thermally insulated with air spaces in the mesh.

An aspect of the invention is characterized in that, in the exhaust silencer for an internal combustion engine according to the above, the above-mentioned metal wire is stainless steel wire. Thus heat-resistance properties of the damping material can be improved.

Another aspect of the invention is characterized in that, in the exhaust silencer for an internal combustion engine according to the above, both the shell inner plate and the damping material of woven mesh are fabricated into cylindrical shapes, and the damping material of woven
mesh is fabricated so that an inner diameter thereof is smaller than an outer diameter of the shell inner plate on natural length scales.

When the damping material fabricated as described above is extended in a diameter direction by utilizing the stretchability of the cylindrical mesh, put over the shell inner plate, and after put thereover, pulled in a longitudinal direction and contracted in the diameter direction, the damping material comes into tight contact with the shell inner plate. Since temporary attachment by using tape or temporary attachment by spot welding like conventional one is unnecessary for this working, the working is facilitated, and working efficiency is improved. Moreover, since the shell inner plate is tightly squeezed, a damping effect is also obtained.

A further aspect of the invention is characterized in that, in the exhaust silencer for an internal combustion engine according to the above, the damping material is woven using a bundle of a plurality of metal wires.

The strength of the damping material is increased by bundling the plurality of metal wires. Moreover, thermal-insulation properties are increased due to air spaces retained between the plurality of metal wires. Furthermore, the damping material with an adequate thickness can be obtained by changing the number of the wires to be bundled.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Preferred embodiments of the invention are shown in the drawings, wherein:

30 Fig. 1 is a longitudinal section of an exhaust silencer according to an embodiment of the present invention.

Figs. 2(a) and 2(b) are views of a spark arrester in use for the exhaust silencer, where Fig. 2(a) is a longitudinal section thereof and Fig. 2(b) is a view viewed from the rear thereof.
Fig. 3 is an outside view of wire mesh woven from stainless steel wire into a cylindrical shape.

Fig. 4 is a partially enlarged view of the cylindrical wire mesh.

Fig. 5 is an enlarged sectional view of a shell wall (portion A in Fig. 1) in the embodiment.

Fig. 6 is a view illustrating working of putting the cylindrical wire mesh woven from stainless steel wire over a shell inner plate.

Fig. 7 is an enlarged sectional view of a shell wall in an exhaust silencer according to a second embodiment of the present invention.

Fig. 8 is a longitudinal section of an exhaust silencer according to a third embodiment of the present invention.

Fig. 9 is a side view of a motorcycle equipped with an exhaust silencer of the present invention.

Fig. 10 is a side view of a four-wheel buggy equipped with an exhaust silencer of the present invention.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Fig. 9 is a side view of a motorcycle 40 equipped with an exhaust silencer 1 of the present invention. Across the center of a body frame 42 continued to a head pipe 41 of this motorcycle, hung is a power unit 45 in which an internal combustion engine 43 and a transmission 44 are integrated. The body frame 42 is constituted by connecting a plurality of members. A front fork 46 is rotatably supported by the head pipe 41, and the shaft of a handlebar 47 and the axle of a front wheel 48 are supported by the upper and lower ends of the front fork 46, respectively. The front end of a rear fork 49 is pivotally supported by a rear portion of the body frame 42 and capable of rocking in a vertical direction. Between the rear fork 49 and the body frame 42, a rear cushion 50 is placed. The axle of a rear wheel 51 is supported by the rear end of the rear fork 49. This rear wheel 51 is driven by a chain 54, which is wound around a drive sprocket 52 attached to a
shaft end of an output shaft of the power unit 45, and a driven sprocket 53 attached to the axle of the rear wheel 51. The output shaft is disposed in a crosswise direction of a body, in parallel with a crankshaft and the like. An exhaust pipe 55, continued to an exhaust port provided at the front side of the internal combustion engine 43, leads around the right side of the body to a rear portion of the body, where the exhaust pipe 55 is connected to the front end of the exhaust silencer 1. The exhaust silencer 1 is hung across a seat rail 56 the front end of which is connected to the body frame 42 and which extends rearward. On an upper portion of the body frame 42, a fuel tank 57 is installed, and on an upper portion of the seat rail 56, a seat 58 is mounted. The reference numeral 59 denotes a side cover.

Fig. 10 is a side view of a four-wheel buggy (rough-terrain vehicle of a saddle-riding type) 60 equipped with the exhaust silencer 1 of the present invention. This buggy 60 includes a pair of right and left wheels 62 and a pair of right and left rear wheels 63 at the front and rear of a body frame 61, respectively, and a power unit 66 in which an internal combustion engine 64 and a transmission 65 are integrated is supported by a center portion of the body frame 61. The power unit 66 is arranged so that a crankshaft 67 is oriented in a longitudinal direction of a body. The rotation of the crankshaft 67 is transmitted to an output shaft 68 through each shaft of the transmission 65. Each of these shafts is parallel with the crankshaft 67 and arranged to be oriented in the longitudinal direction of the body. The front wheels 62 is driven by a front wheel drive shaft 69 continued to the front end of the output shaft 68, and the rear wheels 63 are driven by a rear wheel drive shaft 70 continued to the rear end of the output shaft 68. An exhaust pipe 71, continued to an exhaust port provided at the front side of the internal combustion engine 64, leads around a side of the internal combustion engine 64 to a rear portion of the body, where the exhaust pipe 71 is connected to the front end of the exhaust silencer 1. The exhaust silencer 1 is hung across the body frame 61, between the body frame 61 and the rear wheels 63. On an upper portion of the body, a handlebar 72, a fuel tank 73, and a seat 74 are mounted in order from the front.

Fig. 1 is a longitudinal section of the exhaust silencer 1 according to a first embodiment of the present invention. This exhaust silencer is to be
connected to an exhaust pipe of a four-stroke internal combustion engine for a motorcycle or a four-wheel buggy. In the drawing, a shell 2 of the exhaust silencer includes a shell cylinder part 3, a conical front cap 4, and a rear end plate 5 having a large opening at a center portion thereof. The shell cylinder part 3 includes a shell outer plate 6, a shell inner plate 7, and a damping material 8 mounted therebetween. An introducing pipe 9 to be connected to the exhaust pipe of the internal combustion engine penetrates a top portion of the front cap 4, and an exhaust gas ejecting inlet 10 at the tip of the introducing pipe 9 opens inside the shell. The exhaust gas ejecting inlet 10 has a tip opening 11 of the introducing pipe 9 and many a small hole 12 bored in the side face at a tip portion of the introducing pipe 9, so that ejected gases are dispersed into the surroundings.

Inside the shell inner plate, a punching metal partition 13, a first separator 14, and a second separator 15 are provided in order from the front. A portion before the first separator 14 is a first expansion chamber C1, a portion after the second separator 15 is a second expansion chamber C2, and a portion sandwiched between the first separator 14 and the second separator 15 is a third expansion chamber C3. The ordinal numbers “first” to “third” for the expansion chambers agree with the passing order of exhaust gases. The punching metal partition 13 is a sheet metal partition plate perforated with many a small hole, through which the gases can freely pass. This partition 13 is for equalizing the rate of exhaust gases in the first expansion chamber C1, and thus preventing the retention of the gases.

A first communication pipe 16, penetrating through both the first separator 14 and the second separator 15, is fixed to these separators. A second communication pipe 17, penetrating through the second separator 15 only, is fixed to the second separator 15. It is designed to allow exhaust gases to flow from the first expansion chamber C1 to the second expansion chamber C2 through the first communication pipe 16, and further to flow from the second expansion chamber C2 to the third expansion chamber C3 through the second communication pipe 17. Incidentally, two first communication pipes 16 may be provided, with positional relationships similar to each other relative to the shell center line.
Penetrating through all of the first separator 14, the second separator 15 and the rear end plate 5, a spark arrester 18 is mounted. The spark arrester 18 is mounted by fixing a flange 20, which is welded to a rear end portion of a tail pipe 19 that is a core portion of the spark arrester 18, to the rear end plate 5 with a bolt 21.

Figs. 2(a) and 2(b) are views of the spark arrester 18, where Fig. 2(a) is a longitudinal section thereof, and Fig. 2(b) is a view viewed from the rear thereof. To the tail pipe 19 that is the core thereof, a tail pipe front cap 22, a supporting ring 23, and the flange 20 are welded in order from the front. The side face at a front end portion of the tail pipe 19 is perforated with many a gas-inflow small hole 24. Between the side faces of the tail pipe front cap 22 and of the supporting ring 23, a spark catching wire mesh 25 made of stainless steel for preventing sparks and soot from flowing out, is laid and spot-welded thereto.

In the exhaust silencer shown in Fig. 1, exhaust gases which have been discharged from the unillustrated internal combustion engine and, through the introducing pipe 9, ejected into the shell 2 of the exhaust silencer, travel though the first expansion chamber C1, the first communication pipe 16, the second expansion chamber C2, the second communication pipe 17, the third expansion chamber C3, the spark catching wire mesh 25, the gas-inflow small holes 24, and the tail pipe 19, and are discharged out to the open air. Through a process in which the exhaust gases repeat expansion and contraction by alternately passing through the expansion chambers each having a large capacity and the long communication pipes, the gas pressure of the exhaust gases is reduced and also the noise thereof is deadened. The exhaust gases are purified through the spark catching wire mesh 25, and discharged from the rear end of the tail pipe 19.

Fig. 3 is an outside view of the damping material 8 to be mounted between the shell outer plate 6 and the shell inner plate 7. This is wire mesh made stretchable by weaving stainless steel wire into a cylindrical shape. Fig. 4 is a partially enlarged view of the cylindrical wire mesh. The arrow indicates an axis direction of the silencer shell on which this wire mesh is to be
mounted. Although a single piece of stainless steel wire 32, which is a material of this wire mesh, may be used, a bundle of a plurality of the stainless steel wires may be handled as if it were a single piece of wire, and woven. The cylindrical wire mesh of Fig. 3 is woven in a manner of weaving shown in Fig. 4 so that the whole shape thereof is made cylindrical. The cylindrical wire mesh woven from the stainless steel wire as described above is stretchable in a diameter direction. As for a manner of weaving, there is a variety thereof other than the above-mentioned one. A mesh density also can be selected from various ones. As another manner of weaving other than the above-mentioned one, a manner may also be used in which, while the direction of a stainless steel wire is slanted on a face of a cylinder relative to a longitudinal direction thereof, the stainless steel wire is woven and finished into a cylindrical shape. Fig. 5 is a longitudinal section of a shell wall (portion A in Fig. 1) on which the wire mesh woven as shown in Fig. 4 is mounted. The arrow indicates the axis direction of the silencer shell.

Procedures for mounting the damping material 8 between the shell outer plate 6 and the shell inner plate 7 are as follows. First, each of the shell outer plate 6, the shell inner plate 7 and the damping material 8 is made cylindrical. The inner diameter of the damping material is made smaller than the outer diameter of the shell inner plate 7 on natural length scales. The cylindrical damping material 8 thus made is widen in the inner diameter utilizing the stretchability of its mesh structure, whereby the damping material 8 is put over the outer face of the shell inner plate 7 from one end thereof. After the whole face is finished being covered, an integrated piece of the shell inner plate 7 with the damping material 8 is inserted into a central hollow portion of the shell outer plate 6, and both ends thereof are spot-welded, thus being fixed to each other.

Fig. 6 is a view illustrating working of putting the damping material 8 of the cylindrical wire mesh woven from the stainless steel wire over the shell inner plate 7. In order to skillfully perform this working, a wire mesh mounting jig 26 is fitted onto one end of the shell inner plate 7 in a cylindrical shape. This jig 26 is made from a metal plate and includes a spherical face portion 27 at the tip thereof, a conical face portion 28 continued to the rear end of the spherical face portion 27, a short cylinder
portion 29 smoothly continued to the rear end of the conical face portion 28, a circular flat plate portion 30 continued to the rear end of the cylinder portion 29, and a cylinder portion 31 continued to the inner edge side of the circular flat plate portion 30. The cylinder portion 31 is a portion to be fitted inside the one end of the shell inner plate 7. The circular flat plate portion 30 is a portion to be abutted onto the one end of the shell inner plate 7 to serve as a stopper.

When this jig 26 is used, first, the cylindrical damping material 8 having a smaller inner diameter than the outer diameter of the shell inner plate 7, is put on the front end of the jig 26 as shown in the drawing and pushed in the direction of the arrows, and then the damping material 8 is moved while being pushed and extended in the diameter direction on the surface of the conical face portion 30. The damping material 8 is further moved along the surface of the shell inner plate 7 and mounted thereon. If the damping material 8 is pulled in the axis direction on the surface of the shell inner plate 7, the damping material 8 is contracted in the diameter direction and comes into tight contact with the surface of the shell inner plate 7.

The mesh of stainless steel wire woven into a cylindrical shape by the way of weaving shown in Fig. 4 has different sliding properties between in the surface and in the back face. Fig. 4 is a view of the wire mesh viewed from the surface side thereof. In Fig. 5, the surface side of the wire mesh is on the top of the drawing, and the back side of the wire mesh is on the bottom of the drawing. On the surface side of the wire mesh, since the stainless wire 32 is oriented approximately in the shell axis direction as shown at the portion X in Fig. 5, the wire mesh easily slides in the shell axis direction. On the back side, since the stainless steel wire 32 is oriented approximately in a direction orthogonal to the shell axis direction as shown at the portion Y in Fig. 5, the wire mesh is hard to slide in the shell axis direction. When the mesh of the damping material 8 of the embodiment described above is put over the shell inner plate 7, since the mesh is put thereover using the jig 26 shown in Fig. 6 while the inner diameter is extended, the sliding properties do not much matter. However, when a piece obtained by putting the mesh of the damping material 8 over the shell inner plate 7 is mounted inside the shell outer
plate 6, since the piece is inserted therein by allowing the surface of the damping material 8 to slide, good sliding properties are required. Therefore, when weaving the cylindrical wire mesh from the stainless steel wire, it is necessary to weave the wire mesh while taking it into account that the surface side of the wire mesh will be the outer face of the cylindrical damping material.

Fig. 7 is an enlarged sectional view of a shell wall 3 (portion equivalent to the portion A in Fig. 1) in an exhaust silencer according to a second embodiment of the present invention. In this, although the shell outer plate 6 and the damping material 8 are the same as those of the above-mentioned first embodiment, punching metal having many a small hole 33a thereon is used for a shell inner plate 33. When such punching metal is used, with a sound absorption effect attributable to air spaces in the mesh of the wire mesh damping material, acoustical properties are produced in the shell wall of the exhaust silencer. Other configuration than the above-mentioned part is the same as that of the exhaust silencer 1 of the first embodiment.

Fig. 8 is a longitudinal section of an exhaust silencer 35 according to a third embodiment of the present invention. This is an example in which the damping structure used for the shell walls of the above-mentioned first and second embodiments, is used as a damping structure for other part, where outlet portions of a first communication pipe 36, a second communication pipe 37 and a tail pipe 38 are each of a double-wall structure, and between the double walls, the cylindrical wire mesh which is woven from stainless steel wire and used in the above-mentioned embodiments is mounted, thereby preventing the vibration of these pipes. Since other part than the above is the same as that of the exhaust silencer 1 of the first embodiment, corresponding members are designated by the same reference symbols and numerals.

Hereinbefore, the various embodiments have been described in detail. Each of these is to be connected to an exhaust pipe of a motorcycle or of a four-wheel buggy as shown in Figs. 9 and 10, respectively. In the present invention, since the cylindrical wire mesh made by weaving a metal wire is used as a damping material, it is possible to prevent the shell wall of the
exhaust silencer from vibrating, without reducing the capacity of the
exhaust silencer but suppressing an increase in the weight thereof.
Moreover, it is possible to thermally insulate the shell outer plate with air
spaces in the mesh. Since stainless steel wire is used as a material for the
damping material, heat-resistance properties of the damping material are
high.

When the damping material is mounted, the damping material is
extended in the diameter direction by utilizing the stretchability of the
damping material formed into cylindrical mesh, put over the shell inner
plate, and after put thereover, pulled in the longitudinal direction, and
contracted in the diameter direction, whereby the damping material comes
into tight contact with the shell inner plate. Accordingly, since temporary
attachment by using tape or temporary attachment by spot welding like
conventional one is unnecessary, working is facilitated, and efficiency is
improved. Moreover, since the shell inner plate is tightly squeezed, a
damping effect is also obtained.

When the wire mesh is woven from a bundle of a plurality of metal wires
as a material, the strength of the damping material is increased.
Moreover, thermal-insulation properties are increased due to air spaces
retained between the plurality of metal wires. Furthermore, by changing
the number of the wires to be bundled, it is possible to obtain the damping
material with an appropriate thickness. The above-described damping
material of the wire mesh can be applied not only to the shell inner plate
but also to the outlets of the communication pipes and the tail pipe, to
prevent the vibration. When punching metal is used for the shell inner
plate, acoustical properties are produced in the shell wall.

Although various preferred embodiments of the present invention have
been described herein in detail, it will be appreciated by those skilled in the
art, that variations may be made thereto without departing from the spirit
of the invention or the scope of the appended claims.
THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An exhaust silencer for an internal combustion engine, in which a shell wall includes a shell outer plate, a shell inner plate and a dampening material to be inserted therebetween, characterized in that the dampening material is a stretchably woven metal wire mesh, the metal wire mesh is maintained on said shell inner plate by a compressive force of said mesh exerted on said shell inner plate.

2. The exhaust silencer for an internal combustion engine according to claim 1, characterized in that the metal wire is stainless steel wire.

3. The exhaust silencer for an internal combustion engine according to claim 1, characterized in that both the shell inner plate and the dampening material of woven mesh are fabricated into cylindrical shapes, and the dampening material of woven mesh is fabricated so that an inner diameter thereof is smaller than an outer diameter of the shell inner plate on natural length scales.

4. The exhaust silencer for an internal combustion engine according to claim 1, characterized in that the dampening material is woven using a bundle of a plurality of metal wires.

5. The exhaust silencer for an internal combustion engine according to claim 1, wherein the shell inner plate includes an enlarged first end for mating with an inner surface of the shell outer plate and an enlarged distal end for mating with the inner surface of the shell outer plate with an intermediate portion extending therebetween.
6. The exhaust silencer for an internal combustion engine according to claim 5, wherein said dampening material is positioned on at least a portion of said intermediate portion.

7. The exhaust silencer for an internal combustion engine according to claim 1, wherein the dampening material is cylindrical and the mesh is stretchable in a diameter direction.

8. The exhaust silencer for an internal combustion engine according to claim 1, wherein a direction of metal wire of the mesh is slanted on the shell inner plate relative to a longitudinal direction of the exhaust silencer.

9. The exhaust silencer for an internal combustion engine according to claim 1, wherein the mesh is oriented approximately in an axial direction of the shell for facilitating the positioning of the mesh on the shell inner plate.

10. The exhaust silencer for an internal combustion engine according to claim 9, wherein a back side of the mesh is orientated approximately in a direction orthogonal to the axial direction of the shell for inhibiting the sliding of the mesh in the axial direction of the shell.

11. A shell for use in forming an exhaust silencer for an internal combustion engine comprising:
    a shell outer wall;
    a shell inner wall disposed within said shell outer wall; and
    a dampening material inserted between the shell outer wall and the shell inner wall;
    wherein the dampening material is a stretchably woven metal wire constructed into metal mesh for providing a thermal-insulation between the shell
outer wall and the shell inner wall, the metal mesh contacting an inner surface of
the shell outer plate and an outer surface of the inner plate and exerting a
compressive force on said inner plate.

12. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 11, wherein the metal wire is stainless steel
wire.

13. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 11, wherein both the shell inner wall and the
dampening material of woven mesh are fabricated into cylindrical shapes, and the
dampening material of woven mesh is fabricated so that an inner diameter thereof
is smaller than an outer diameter of the shell inner wall.

14. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 11, wherein the dampening material is
woven using a bundle of a plurality of metal wires.

15. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 11, wherein the shell inner wall includes an
enlarged first end for mating with an inner surface of the shell outer wall and an
enlarged distal end for mating with the inner surface of the shell outer wall with an
intermediate portion extending therebetween.

16. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 15, wherein said dampening material is
positioned on at least a portion of said intermediate portion.

17. The shell for use in forming an exhaust silencer for an internal
combustion engine according to claim 11, wherein the dampening material is cylindrical and the mesh is stretchable in a diameter direction thereof.

18. The shell for use in forming an exhaust silencer for an internal combustion engine according to claim 11, wherein a direction of metal wire of the mesh is slanted on the shell inner wall relative to a longitudinal direction of the exhaust silencer.

19. The shell for use in forming an exhaust silencer for an internal combustion engine according to claim 11, wherein the mesh is oriented approximately in an axial direction of the shell for facilitating the positioning of the mesh on the shell inner plate.

20. The shell for use in forming an exhaust silencer for an internal combustion engine according to claim 19, wherein a back side of the mesh is orientated approximately in a direction orthogonal to the axial direction of the shell for inhibiting the sliding of the mesh in the axial direction of the shell.
Fig. 7

**SHELL AXIS DIRECTION**