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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) Exhaust system of an internal combustion engine

(57) Exhaust system (1) of an internal combustion engine (2); the exhaust system (1) is provided with: an exhaust duct (3) which originates from an exhaust manifold (4) of the internal combustion engine (2); at least one catalytic system (7; 5) arranged on the exhaust duct (3); a feeder device (8) which is connected to the exhaust duct (3) immediately upstream of the catalytic system (7; 5) to feed an additive into said exhaust duct (3); and at least one static mixer (9), which is arranged on the exhaust duct (3) in correspondence with the feeder device (8) and comprises a tubular body (10) which has a central axis of symmetry (11) and has two opposing annular edges (12); the static mixer (9) has at least one group (13) of tabs (14), which extend towards the outside of the tubular body (10) starting from a respective annular edge (12) of said tubular body (10), are arranged at a distance from one another so as to leave an empty space (15) between two successive tabs (14), and slope towards the central axis of symmetry (11) so as to converge towards said central axis of symmetry (11).

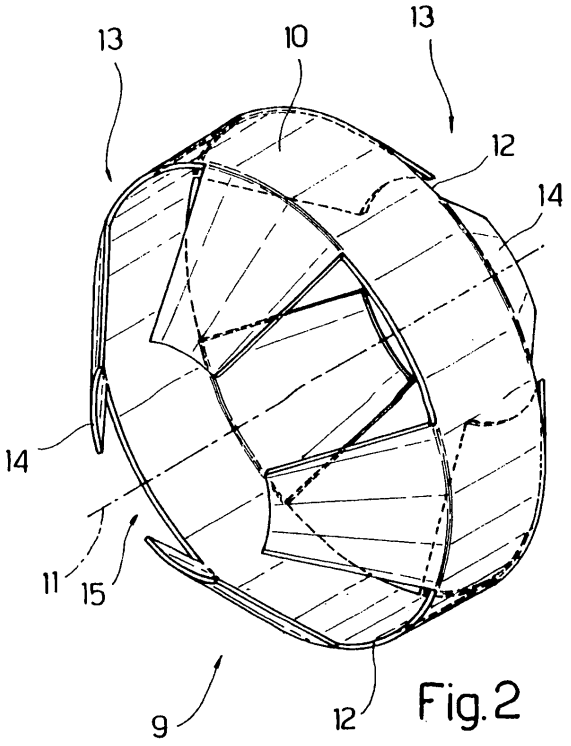

Fig.2

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Description

TECHNICAL FIELD

[0001] The present invention relates to an exhaust system of an internal combustion engine provided with an exhaust gas after-treatment arrangement.

[0002] The present invention is advantageously intended for use in an exhaust system of an internal combustion engine provided with an exhaust gas after-treatment arrangement to which the following description specifically refers but without loss of generality.

BACKGROUND ART

[0003] Next generation international standards limiting pollutant emissions by motor vehicles (the so-called "Euro5" and "Euro6" emission standards) will set very low thresholds for NO_x emissions.

[0004] Compliance with such limits is particularly critical especially for diesel engines; for this reason, a solution has been proposed which consists of providing exhaust systems of diesel engines with an additional NO_x SCR (Selective Catalytic Reduction) system suitable to convert molecules of NO_x (NO_2 or NO) into nitrogen (N_2), which is an inert gas, and water (H_2O). It is difficult to convert NO_x molecules into nitrogen (N) without the use of an adequate reducing agent. Ammonia (NH_3) is generally used for this purpose. The reducing agent must be introduced into the exhaust system and upstream of the SCR catalyst in order to mix with the exhaust gas before it enters the SCR catalyst.

[0005] However, storing ammonia inside a motor vehicle is not recommended for evident safety reasons relating to the fact that ammonia is toxic. Consequently, other solutions have been proposed which consist of storing and introducing an aqueous urea solution, as the urea is converted into ammonia due to the effect of the heat of the exhaust gas and also in part due to the catalytic effect.

[0006] A problem associated with introducing an aqueous urea solution into the exhaust system is that the decomposition of the urea also results in the formation of isocyanic acid (HNCO), which tends to thicken and polymerize, building up on the inside walls of the exhaust system and resulting in the formation of solid deposits that are difficult to remove. To prevent the polymerization of the isocyanic acid generated from the decomposition of the urea, there have been proposals to arrange a mixer in the exhaust system close to the point in which the urea is introduced. Said mixer generates turbulence in the exhaust gas flow which prevents the localized thickening of the isocyanic acid and thus prevents the polymerization of said isocyanic acid. The presence of a mixer that generates turbulence in the exhaust gas flow immediately before said exhaust gas flow enters the SCR catalyst clearly also improves the efficiency of the SCR catalyst since it results in a more uniform distribution of the reducing agent (i.e. the ammonia) in the exhaust gas.

[0007] Patent application EP1514591A1 describes a mixer, which is arranged in an exhaust system of an internal combustion engine immediately upstream of an SCR catalyst into which the hot exhaust gas mixed with reducing agents is fed. Similarly, patent applications EP1022048A1, DE10060808A1, WO0107763A1, WO9913972A1, WO9905402A1, WO9905401A1, EP1748162A1, DE10248294A1, WO0009869A1, WO2005073524A1, WO0112301A1, EP0526392A1, EP0894523A1 describe exhaust systems provided with mixers arranged close to reducing agent feeder devices.

[0008] However, the known mixers of the type described above have the drawback of not achieving an ideal balance between the opposing needs for effectiveness (i.e. to guarantee adequate mixing of the exhaust gas) and efficiency (i.e. to limit loss of pressure in the exhaust gas). In other words, known mixers of the type described above are either low in effectiveness (i.e. they do not guarantee adequate mixing of the exhaust gas) or low in efficiency (i.e. they cause high losses of pressure in the exhaust gas).

DISCLOSURE OF INVENTION

[0009] The purpose of the present invention is to provide an exhaust system of an internal combustion engine, said exhaust system overcoming the drawbacks described above and, in particular, being easy and inexpensive to produce.

[0010] According to the present invention an exhaust system of an internal combustion engine is produced according to that set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will now be described with reference to the attached drawings, illustrating some non-limiting embodiments thereof, in which:

- figure 1 is a schematic view of an exhaust system of an internal combustion engine provided with an exhaust gas after-treatment arrangement and produced according to the present invention; and
- figure 2 is a schematic perspective view of a mixer of the exhaust system of figure 1;
- figure 3 is a front view of the mixer of figure 2;
- figure 4 is a side cross-sectional view along the line IV-IV of the mixer of figure 2; and
- figure 5 is a schematic perspective view of an alternative embodiment of the mixer of figure 2;

PREFERRED EMBODIMENTS OF THE INVENTION

[0012] In figure 1, number 1 indicates an overall exhaust system of a "diesel" cycle internal combustion engine 2 (i.e. an engine that runs on diesel or similar types of fuel).

[0013] The exhaust system 1 discharges the exhaust gas into the atmosphere and comprises an exhaust duct 3 which originates from an exhaust manifold 4 of the internal combustion engine 2. An oxidation catalyst 5 and a particulate filter 6 are arranged on the exhaust duct 3; in figure 1 the oxidation catalyst 5 and the particulate filter 6 are arranged in series inside a single common tubular container.

[0014] Moreover, an SCR (Selective Catalytic Reduction) system 7 for after-treatment of NO_x (NO and NO_2) molecules is arranged on the exhaust duct 3 and downstream of the oxidation catalyst 5. The SCR catalytic system 7 can comprise a single SCR catalyst 7 as illustrated in figure 1, or a series of catalysts (usually three) that together optimize the SCR function for after-treatment of NO_x molecules.

[0015] Immediately upstream of the catalytic system 7, a feeder device 8 is connected to the exhaust duct 3, said device 8 being suitable to feed a reducing agent and in particular an aqueous urea solution (i.e. a solution of urea and water) into said exhaust duct 3. In use, due to the effect of the heat of the exhaust gas present in the exhaust duct 3, the urea fed into said exhaust duct 3 spontaneously decomposes into isocyanic acid (HNCO) and ammonia (NH_3), said ammonia acting as a reducing agent in the catalytic system 7 to facilitate the conversion of the NO_x molecules into nitrogen (N_2) and water (H_2O).

[0016] A static mixer 9 is arranged on the exhaust duct 3, in correspondence with the feeder device 3. The function of said mixer 9 is to generate turbulence in the exhaust gas in the exhaust duct 3 in order to prevent the localized thickening of the isocyanic acid (which forms during the decomposition of the urea) and thus prevent the polymerization of said isocyanic acid and improve the efficiency of the catalytic system 7 by distributing the ammonia more uniformly in the exhaust gas. In the embodiment illustrated in figure 1, the static mixer 9 is arranged downstream of the feeder device 8 (i.e. between the feeder device 8 and the catalytic system 7); alternatively, the static mixer 9 could be arranged upstream of the feeder device 8. According to an alternative embodiment which is not illustrated, two static mixers 9 could be provided and arranged respectively upstream and downstream of the feeder device 8.

[0017] As illustrated in figures 2, 3 and 4, the static mixer 9 comprises a cylindrical tubular body 10, which has a central axis of symmetry 11 and two opposing annular edges 12, and two groups 13 of tabs 14 arranged on opposite sides of the tubular body 10.

[0018] In each group 13, the tabs 14 extend towards the outside of the tubular body 10 starting from a respective annular edge 12 of said tubular body 10, they are arranged at a distance from one another so as to leave an empty space 15 between two successive tabs 14, and slope towards the central axis of symmetry 11 so as to converge towards said central axis of symmetry 11. Each tab 14 of the static mixer 9 has substantially the shape of an isosceles trapezium with a longer base 16 arranged over the respective annular edge 12 of the tubular body 10 and a shorter base 17 which is free.

[0019] The two groups 13 of tabs 14 are staggered so that each tab 14 of one group 13 is longitudinally aligned along the central axis of symmetry 11 with an empty space 15 between two successive tabs 14 of the other group 13.

[0020] In correspondence with the respective annular edge 12 of the tubular body 10 each tab 14 extends for the equivalent of the extension of an empty space 15 between two successive tabs 14; for example in the embodiment that is illustrated there are four tabs 14 each having an angular extension of 45° and alternating with four empty spaces 15 each having an angular extension of 45°.

[0021] The ratio between the diameter D of the circumference defined by the longer bases 16 of the tabs 14 and the diameter d of the circumference defined by the shorter bases 17 of the tabs 14 is between 2 and 4 and preferably about 3. Moreover, each tab 14 forms an angle α of between 30° and 60° and preferably of approximately 45° with the tubular body 10. The tubular body 10 preferably extends longitudinally along the central axis of symmetry 11 by at least 10 mm.

[0022] In the preferred embodiment illustrated in the attached drawings, each group 13 has four tabs 14 (and thus four empty spaces 15 arranged alternately with respect to the tabs 14); more generally, each group 13 is made up of between 3 and 6 tabs 14.

[0023] According to an alternative embodiment which is not illustrated, the static mixer 9 only comprises a single group 13 of tabs 14 arranged along an annular edge 12 of the tubular body 10.

[0024] According to the alternative embodiment illustrated in figure 5, the static mixer 9 comprises a number of fastening brackets 18, which extend parallel to the central axis of symmetry 11 starting from an annular edge 12 of the tubular body 10 and are arranged in correspondence with the empty space 15 between two successive tabs 14. The fastening brackets 18 are welded or riveted to a side wall of the exhaust duct 3 so that the static mixer 9 is integral with the exhaust duct 3; according to the embodiment in figures 2-4 in which the static mixer 9 is not provided with the fastening brackets 18, the static mixer 9 is fastened to the exhaust duct 3 by welding or riveting the tubular body 10 to the side wall of the exhaust duct 3.

[0025] The static mixer 9 can be made by die-forming a flat metal sheet to define the tabs 14 (and, where applicable, the brackets 18), and then folding the die-formed sheet round a cylindrical core to give said die-formed sheet a tubular shape which is stabilized by means of welding or riveting; the tabs 14 are then folded towards the central axis of symmetry 11 to give them the shape described above. Alternatively, the static mixer 9 can be made by die-forming a tubular body of sheet metal to define the tabs 14 (and, where applicable, the brackets 18) and then folding the tabs 14 towards the central axis

of symmetry 11 to give the tabs 14 the shape described above.

[0026] According to an alternative embodiment which is not illustrated, the feeder device 8 is arranged upstream of the oxidation catalyst 5 to feed the fuel (for example diesel) into the exhaust duct 3, so that said fuel is burnt in the oxidation catalyst 5 to increase the temperature inside said oxidation catalyst 5 during a regeneration process of the particulate filter 6. In this case, the static mixer 9 is arranged upstream of the oxidation catalyst 5.

[0027] The static mixer 9 described above has numerous advantages, in that it is simple and inexpensive to produce, is particularly robust (and thus has a long working life and very low risk of breaking) and above all it achieves an ideal balance between the opposing needs for effectiveness (i.e. to guarantee adequate mixing of the exhaust gas) and efficiency (i.e. to cause limited loss of pressure in the exhaust gas). In other words, the static mixer 9 described above achieves high effectiveness (i.e. it guarantees adequate mixing of the exhaust gas) and high efficiency (i.e. it causes limited loss of pressure in the exhaust gas).

Claims

1. Exhaust system (1) of an internal combustion engine (2); the exhaust system (1) comprises:

   an exhaust duct (3) which originates from an exhaust manifold (4) of the internal combustion engine (2);
   at least one catalytic system (7; 5) arranged on the exhaust duct (3);
   a feeder device (8), which is connected to the exhaust duct (3) immediately upstream of the catalytic system (7; 5) to feed an additive into said exhaust duct (3); and
   at least one static mixer (9), which is arranged on the exhaust duct (3) in correspondence with the feeder device (8) and comprises a tubular body (10) which has a central axis of symmetry and two opposing annular edges (12);
   the exhaust system (1) being **characterized in that** the static mixer (9) comprises at least one group (13) of tabs (14), which extend towards the outside of the tubular body (10) starting from a respective annular edge (12) of said tubular body (10), are arranged at a distance from one another so as to leave an empty space (15) between two successive tabs (14), and slope towards the central axis of symmetry (11) so as to converge towards said central axis of symmetry (11).

2. Exhaust system (1) according to claim 1, wherein each tab (14) of the static mixer (9) has substantially the shape of an isosceles trapezium having a longer base (16) arranged over the respective annular edge (12) of the tubular body (10) and a shorter base (17) which is free.

3. Exhaust system (1) according to claim 2, wherein the ratio between the diameter of the circumference defined by the longer bases (16) of the tabs (14) and the diameter of the circumference defined by the shorter bases (17) of the tabs (14) is between 2 and 4.

4. Exhaust system (1) according to claim 3, wherein the ratio between the diameter of the circumference defined by the longer bases (16) of the tabs (14) and the diameter of the circumference defined by the shorter bases (17) of the tabs (14) is approximately 3.

5. Exhaust system (1) according to one of the claims from 1 to 4, wherein the static mixer (9) comprises two groups (13) of tabs (14) arranged along the two opposing annular edges (12) of the tubular body (10).

6. Exhaust system (1) according to claim 5, wherein the two groups (13) of tabs (14) are staggered so that each tab (14) of one group (13) is longitudinally aligned along the central axis of symmetry (11) with an empty space (15) between two successive tabs (14) of the other group (13).

7. Exhaust system (1) according to one of the claims from 1 to 6, wherein in correspondence with the respective annular edge (12) of the tubular body (10) each tab (14) extends for the equivalent of an empty space (15) between two successive tabs (14).

8. Exhaust system (1) according to one of the claims from 1 to 7, wherein each tab (14) forms an angle of between 30° and 60° with the tubular body (10).

9. Exhaust system (1) according to claim 8, wherein each tab (14) forms an angle of approximately 45° with the tubular body (10).

10. Exhaust system (1) according to one of the claims from 1 to 9, wherein each group (13) has between 3 and 6 tabs (14).

11. Exhaust system (1) according to claim 10, wherein each group (13) has 4 tabs (14).

12. Exhaust system (1) according to one of the claims from 1 to 11, wherein the tubular body (10) extends longitudinally along the central axis of symmetry (11) by at least 10 mm.

13. Exhaust system (1) according to one of the claims from 1 to 12, wherein the static mixer (9) comprises a number of fastening brackets (18), which extend

parallel to the central axis of symmetry (11) starting from an annular edge (12) of the tubular body (10) and are arranged in correspondence with the empty space (15) between two successive tabs (14).

14. Exhaust system (1) according to claim 13, wherein the fastening brackets (18) are welded or riveted to a side wall of the exhaust duct (3).

15. Exhaust system (1) according to one of the claims from 1 to 14, wherein the catalytic system (7; 5) comprises:

an oxidation catalyst (5) arranged on the exhaust duct (3); and
an SCR catalytic system (7) arranged on the exhaust duct (3) downstream of the oxidation catalyst (5) and downstream of the feeder device (8).

16. Exhaust system (1) according to one of the claims from 1 to 14, wherein the catalytic system (7; 5) comprises an oxidation catalyst (5) arranged on the exhaust duct (3) downstream of the feeder device (8).

Amended claims in accordance with Rule 137(2) EPC.

1. Exhaust system (1) of an internal combustion engine (2); the exhaust system (1) comprises:

an exhaust duct (3) which originates from an exhaust manifold (4) of the internal combustion engine (2);
at least one catalytic system (7; 5) arranged on the exhaust duct (3);
a feeder device (8), which is connected to the exhaust duct (3) immediately upstream of the catalytic system (7; 5) to feed an additive into said exhaust duct (3); and
at least one static mixer (9), which is arranged on the exhaust duct (3) in correspondence with the feeder device (8) and comprises a tubular body (10) which has a central axis of symmetry and two opposing annular edges (12) and at least one group (13) of tabs (14), which extend towards the outside of the tubular body (10) starting from a respective annular edge (12) of said tubular body (10), are arranged at a distance from one another so as to leave an empty space (15) between two successive tabs (14), and slope towards the central axis of symmetry (11) so as to converge towards said central axis of symmetry (11);
the exhaust system (1) being **characterized in that**:
the static mixer (9) comprises two groups (13) of tabs (14) arranged along the two opposing annular edges (12) of the tubular body (10); and
the two groups (13) of tabs (14) are staggered so that each tab (14) of one group (13) is longitudinally aligned along the central axis of symmetry (11) with an empty space (15) between two successive tabs (14) of the other group (13).

2. Exhaust system (1) according to claim 1, wherein each tab (14) of the static mixer (9) has substantially the shape of an isosceles trapezium having a longer base (16) arranged over the respective annular edge (12) of the tubular body (10) and a shorter base (17) which is free.

3. Exhaust system (1) according to claim 2, wherein the ratio between the diameter of the circumference defined by the longer bases (16) of the tabs (14) and the diameter of the circumference defined by the shorter bases (17) of the tabs (14) is between 2 and 4.

4. Exhaust system (1) according to claim 3, wherein the ratio between the diameter of the circumference defined by the longer bases (16) of the tabs (14) and the diameter of the circumference defined by the shorter bases (17) of the tabs (14) is approximately 3.

5. Exhaust system (1) according to one of the claims from 1 to 4, wherein in correspondence with the respective annular edge (12) of the tubular body (10) each tab (14) extends for the equivalent of an empty space (15) between two successive tabs (14).

6. Exhaust system (1) according to one of the claims from 1 to 5, wherein each tab (14) forms an angle of between 30° and 60° with the tubular body (10).

7. Exhaust system (1) according to claim 6, wherein each tab (14) forms an angle of approximately 45° with the tubular body (10).

8. Exhaust system (1) according to one of the claims from 1 to 7, wherein each group (13) has between 3 and 6 tabs (14).

9. Exhaust system (1) according to claim 8, wherein each group (13) has 4 tabs (14).

10. Exhaust system (1) according to one of the claims from 1 to 9, wherein the tubular body (10) extends longitudinally along the central axis of symmetry (11) by at least 10 mm.

11. Exhaust system (1) according to one of the claims from 1 to 10, wherein the static mixer (9) com-

prises a number of fastening brackets (18), which extend parallel to the central axis of symmetry (11) starting from an annular edge (12) of the tubular body (10) and are arranged in correspondence with the empty space (15) between two successive tabs (14).

12. Exhaust system (1) according to claim 11, wherein the fastening brackets (18) are welded or riveted to a side wall of the exhaust duct (3).

13. Exhaust system (1) according to one of the claims from 1 to 12, wherein the catalytic system (7; 5) comprises:

an oxidation catalyst (5) arranged on the exhaust duct (3); and
an SCR catalytic system (7) arranged on the exhaust duct (3) downstream of the oxidation catalyst (5) and downstream of the feeder device (8).

14. Exhaust system (1) according to one of the claims from 1 to 13, wherein the catalytic system (7; 5) comprises an oxidation catalyst (5) arranged on the exhaust duct (3) downstream of the feeder device (8).

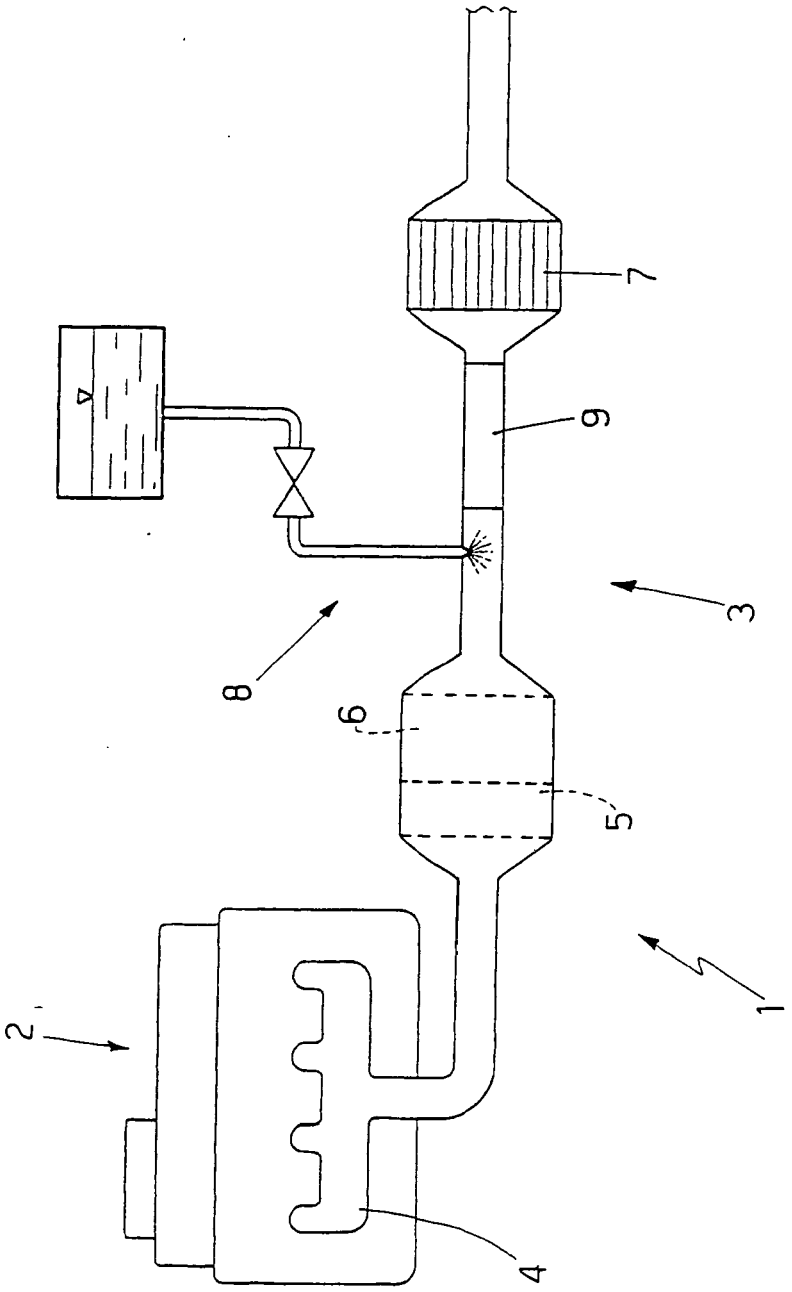


Fig.1

Fig.5

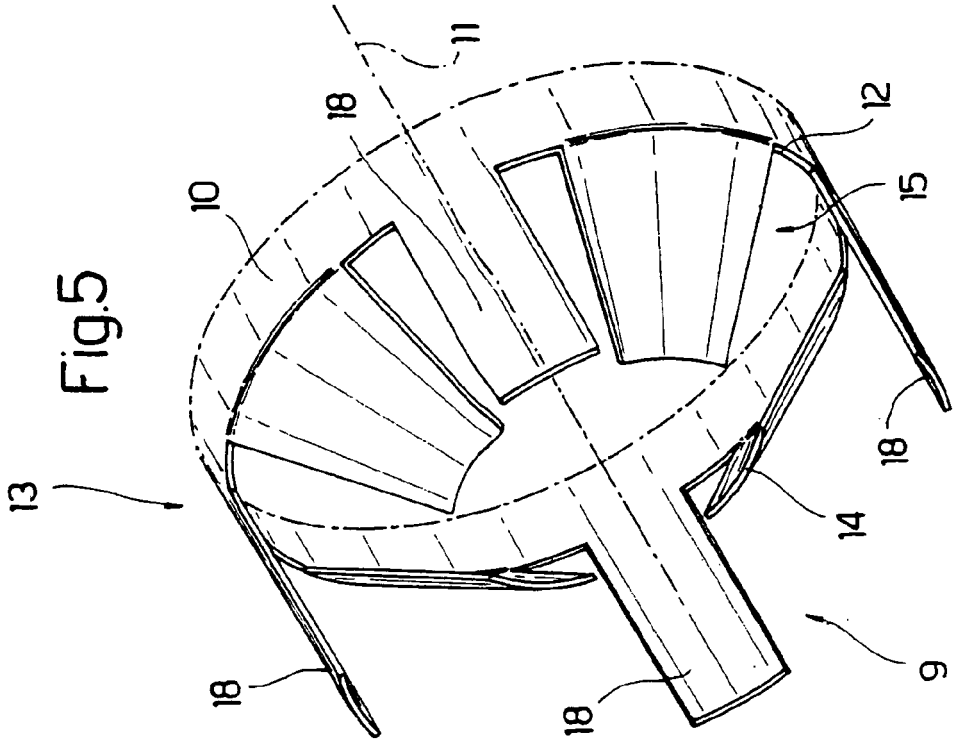
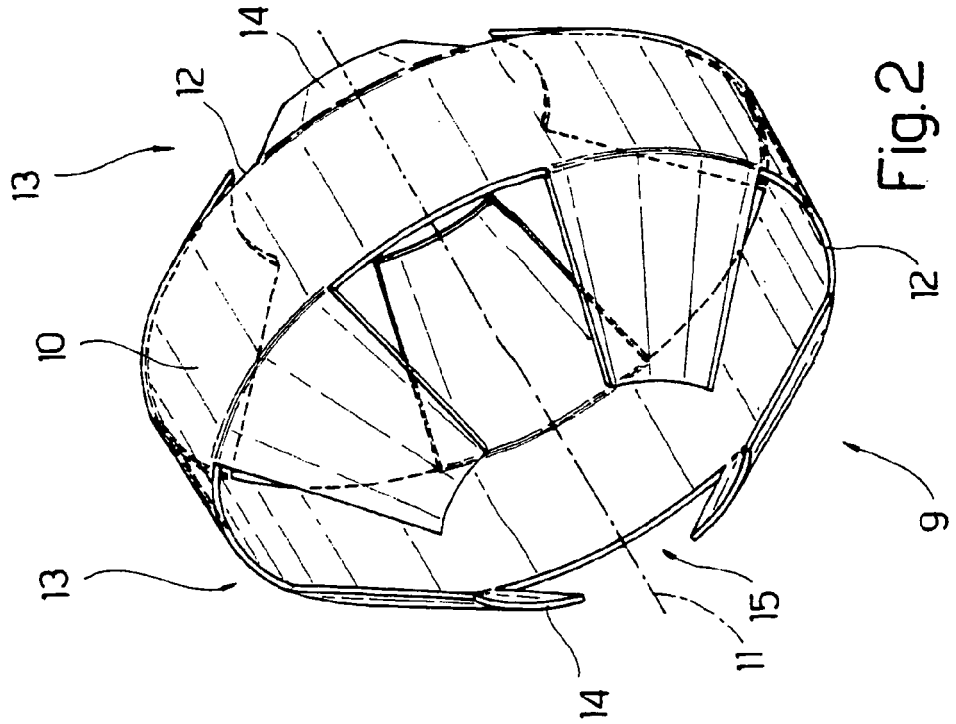


Fig.2



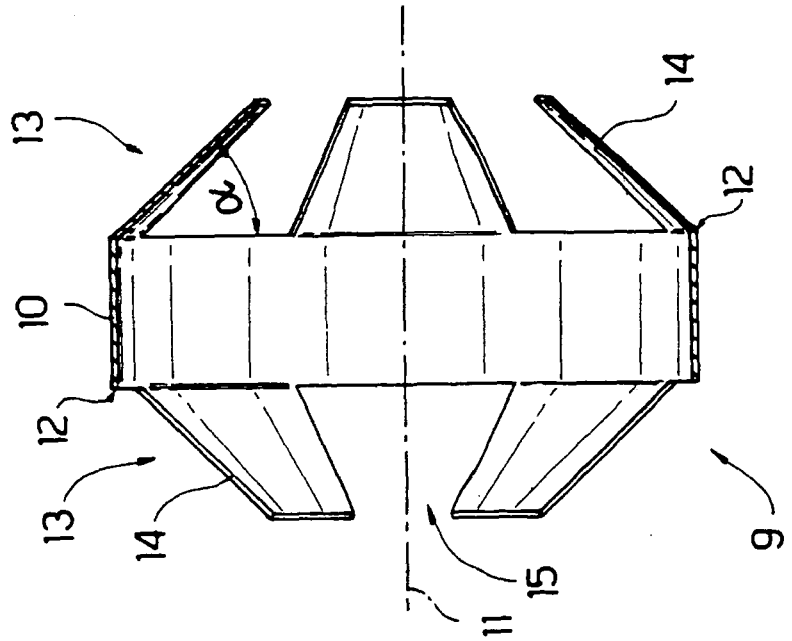


Fig.4

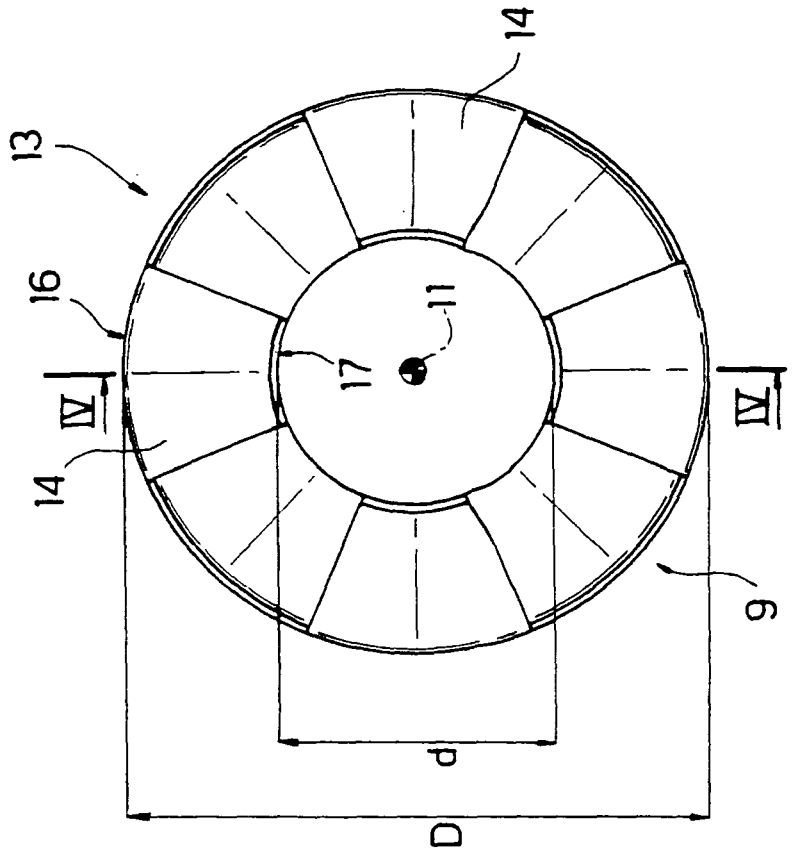


Fig.3

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EUROPEAN SEARCH REPORT

Application Number
EP 08 42 5083

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	30 July 2008	Tatus, Walter

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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