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(54) **Static mixer for the treatment of exhaust gases and manufacturing method thereof**

(57) A static mixer (11) for the treatment of exhaust gases, including an annular support portion (13) and a plurality of radial vanes (15), which are radially arranged and have the rear ends (17) associated with said support portion (13) and the front ends (19) converging towards the centre ("C") of the mixer, wherein the vanes (15) have a shape twisted around the longitudinal axis ("R") of the vanes.

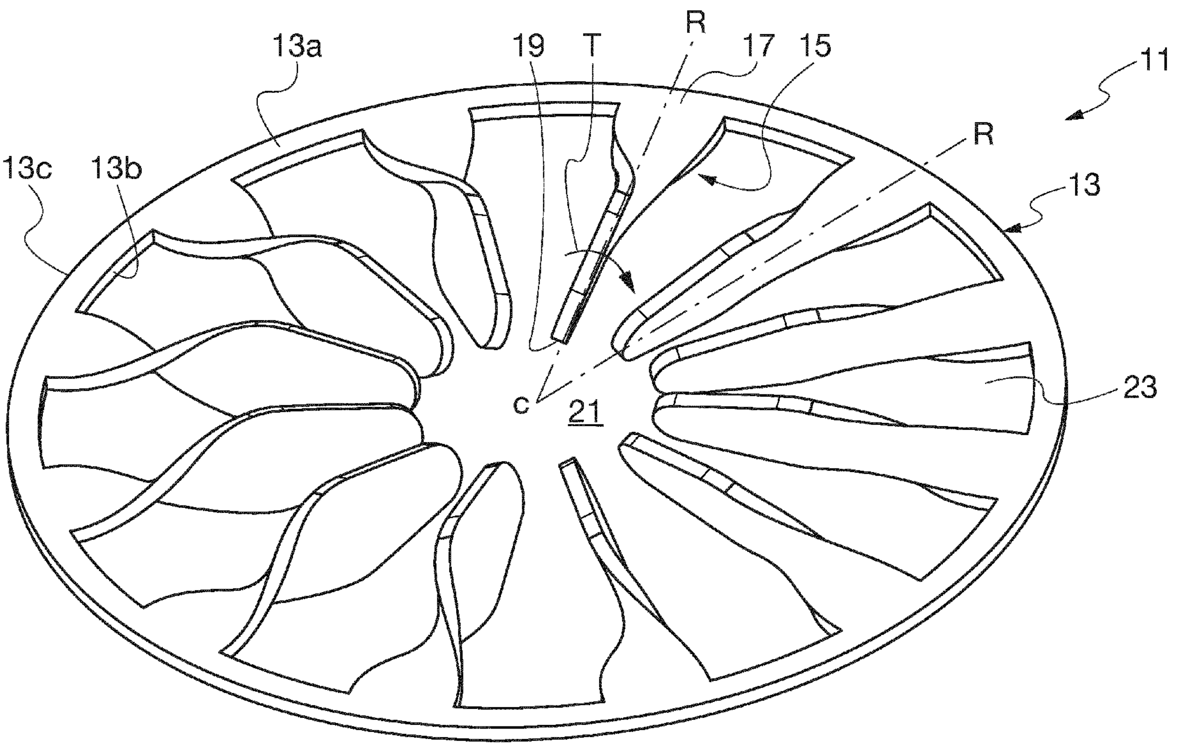

Fig. 1

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Description

Technical field

[0001] The present invention relates to a static mixer for the treatment of exhaust gases and to the manufacturing method thereof.

[0002] More precisely, the invention relates to a static mixer for the treatment of exhaust gases of internal combustion engines, which mixer can be incorporated in a system for the selective catalytic reduction (SCR) of nitrogen oxides.

Prior Art

[0003] Static mixers are commonly used in order to promote mixing of the exhaust gases with the reducing agent, introduced in gaseous or liquid state into the exhaust systems of the internal combustion engines.

[0004] In this context, the static mixer is mainly aimed at promoting the formation of a highly homogeneous mixture and causing the reducing agent introduced into the exhaust system to be as much as possible vaporised.

[0005] In order to meet this requirement, static mixers are at present produced, which comprise a set of vanes with various orientations inside the duct where the exhaust gases and the reducing agent mixture flow.

[0006] The vanes are generally associated with an annular frame intended to adhere to the internal walls of the duct housing the mixer, which generally is transversally arranged in the duct so that the exhaust gas flow is intercepted by said vanes.

[0007] The static mixer promotes mixing of the gases with the reducing agent, generally thanks to the increase of the turbulence phenomenon within the exhaust gas flow.

[0008] Yet, the provision of a static mixer in the region where gases flow causes a pressure increase inside the exhaust system. Such a pressure increase is a drawback, since it is of hindrance to the discharge of the exhaust gases and, generally, it may be more or less significant depending on the arrangement of the mixer and the exhaust system.

[0009] Moreover, the surface of a mixer can cause condensation of the reducing mixture, with the consequent formation of a liquid film that adheres to the vanes, thereby causing a reduction in the effectiveness of the same mixer.

[0010] Thus, two phenomena are to be contrasted when designing a mixer of the above mentioned kind.

[0011] The first phenomenon is the one determined by excessive pressure increases in the exhaust system housing the mixer. The second phenomenon is the one determined by the reduction of the mixing capability, resulting from the formation of condensate of the reducing agent onto the mixer surfaces.

[0012] In an attempt to achieve the best compromise between the opposed requirements of attaining a good mixing and preventing the occurrence of the above drawbacks, different solutions have been proposed hitherto.

[0013] Some solutions use a matrix of vanes of which the density, the inclination and the size are chosen by taking into account the above requirements. US 2007/0204751 discloses an example of such kind of mixer.

[0014] Other solutions use a set of vanes, which generally are radially arranged within the duct where the gases flow and are oriented so as to cause mixing of said gases with the reducing agent mixture. Static mixers of this second type are disclosed for instance in US 7,533,520, US 2009/0320453 and US 2009/0266064.

[0015] In all aforesaid solutions, the effort to find the best compromise between the requirements of mixing and free flow for the exhaust gases is clearly apparent.

[0016] Notwithstanding those efforts, the prior art mixers however do not wholly solve the problem of how to obtain the best mixing, while at the same time minimising the above drawbacks.

[0017] Moreover, the efforts made till now resulted in solutions that are more and more elaborate, complex and expensive to be manufactured.

[0018] In the field, there is therefore still a strong need to have at disposal a static mixer which is highly efficient, does not cause significant pressure increases, is scarcely prone to promote the formation of condensate and does not have the above drawbacks related to the manufacturing complexity and costs.

[0019] Thus, it is a first object of the invention to achieve such a result, by providing a static mixer device for the treatment of exhaust gases, which enables a better mixing with respect to the prior art devices and causes a reduced pressure increase and a reduced capability to form condensate.

[0020] It is another object of the invention to provide a static mixer of the kind discussed above, which can be industrially manufactured in simpler manner and at lower costs than the prior art mixers.

[0021] It is a further, but not the last obj ect of the invention to provide a mixer of the kind discussed above, which may be employed substantially in any exhaust system in which the selective catalytic reduction (SCR) technology is exploited.

[0022] The above and other objects are achieved by means of the static mixer for the treatment of exhaust gases and of the manufacturing method thereof as claimed in the appended claims.

Description of the invention

[0023] A first advantage of the invention results from the provision of a plurality of radial vanes, arranged inside an annular perimeter, converging towards the centre of the mixer and having a shape twisted around the longitudinal axis of the vanes.

[0024] Another advantage of the invention results from the feature that the width of the axial projection of the vane surface on the plane in which the vanes lie is greater than the thickness of the vanes. Advantageously, such a condition is met over the whole vane length.

[0025] A further advantage of the invention results from the feature that the vanes have a twisted shape of which the twist angle is preferably different from 90°. Indeed, thanks to such an arrangement, it is possible to obtain an effective mixing effect due to the turbulence which is created downstream the mixer, without causing an excessive pressure increase in the duct along which the exhaust gases flow.

[0026] Still another advantage of the invention results from the provision, in the mixer, of a free central portion, that is, a portion having no obstacles for the free flow of the exhaust gases, towards which the radial vanes converge. Thanks to such a free central portion and to the twisted shape of the vanes, it is possible to obtain an effective mixing effect of the exhaust gases with the reducing agent mixture. Such a mixing effect is promoted by the presence of such a central hole, which on the other hand contributes to preventing an excessive increase of the pressure due to the provision of the mixer. Indeed, in correspondence of the central hole, an increase in the gas speed and a consequent intense forward thrust of the gases occur, resulting in an advantageous turbulent motion downstream the mixer.

[0027] Still a further advantage of the invention results from the possibility of manufacturing the mixer by means of a succession of simple cutting and twisting and/or bending operations.

[0028] A further, but not the last advantage of the invention results from the possibility of manufacturing the mixer from planar bodies as well as from tubular bodies.

Brief Description of the Drawings

[0029] Some preferred embodiments of the invention will be described hereinafter with reference to the accompanying drawings, in which:

- Fig. 1 is a perspective view of the mixer;
- Fig. 2 is a plan view of the mixer shown in Fig. 1;
- Fig. 3 is a side view of the mixer shown in Fig. 1;
- Fig. 4 is a cross-sectional view taken along line IV-IV in Fig. 2;
- Fig. 5 is a schematic view of an exhaust system incorporating the mixer;
- Fig. 6 is a perspective view of the mixer, in an intermediate working step, in a first embodiment of the manufacturing method according to the invention;
- Fig. 7 is a plan view of the mixer in the working step shown in Fig. 6;
- Fig. 8 is a perspective view of the mixer, in an intermediate working step, in a second embodiment of the manufacturing method according to the invention;
- Fig. 9 is an enlarged view of a detail of Fig. 7.

Description of a Preferred Embodiment

[0030] Referring to Figs. 1 to 4, the static mixer for the treatment of exhaust gases according to the invention has been generally denoted by reference numeral 11.

[0031] Mixer 11 includes an annular support portion 13 and a plurality of substantially coplanar radial vanes 15, which are radially arranged and have their rear ends or bases 17 associated with said support portion 13 and their front ends or tips 19 converging towards centre "C" of the mixer.

[0032] More particularly, the rear end or base 17 is connected to said support portion 13 as shown in the accompanying drawings. Preferably the rear end or base 17 and the support portion 13 are made as a single piece, as it will be disclosed in detail hereinafter.

[0033] According to the invention, tips 19 of vanes 15 encircle a central portion 21 of the mixer. Said portion 21, which is substantially circular in the illustrated example, is free, that is, it is not occupied by the vanes or other mixer parts and it defines a passageway, free from interferences, for the exhaust gases.

[0034] Always according to the invention, vanes 15 have a shape twisted around longitudinal axis "R" of the vanes, i.e. the axis passing through centre "C" of the mixer, in the direction indicated by arrow "T".

[0035] Annular support portion 13 includes a crown 13a, preferably closed to form a ring, which in the illustrated example defines a circular internal perimeter 13b and a circular external perimeter 13c for mixer 11. Other embodiments will be however possible, in which the internal perimeter13b and/or the external perimeter 13c have a shape different from the circular one, for instance an octagonal, hexagonal, square or rectangular shape. In still other embodiments, vanes 15 may be directly associated with the inner wall of the duct of the exhaust system housing the mixer.

[0036] According to a preferred embodiment of the invention, vanes 15 are angularly spaced apart in regular manner along internal perimeter 13b of annular support portion 13.

[0037] Always referring to a preferred embodiment of the invention, twelve radial vanes 15 are provided. The optimal number of vanes can however be chosen depending on the characteristics of the exhaust system into which the mixer is incorporated, and generally any number of vanes can be provided. Thus, other embodiments of the mixer will be possible, in which the number of vanes is different from twelve. A number of vanes ranging from eight to sixteen has proved to provide the best performance.

[0038] Moreover, in a preferred embodiment, the diameter of circular central portion 21 is about 1/4 the diameter of internal perimeter 13b of the mixer.

[0039] According to a preferred embodiment of the invention, vanes 15 have a shape twisted around longitudinal axis "R" of the vanes in such a way that the width of the axial projection of the vane surfaces on the plane in which the vanes lie is greater than the thickness of the vanes over substantially the whole vane length. Such a result is obtained by twisting the vanes by an angle different from 90°. The best results, as far as the mixing is concerned, have been achieved by means of a twist angle of the vanes indicatively ranging from 70 to 150°. Preferably, said twist angle exceeds 90° and more preferably is of about 110°.

[0040] In the whole, inside internal perimeter 13b, mixer 11 has a region occupied by a plurality of vanes 15 intercepting the exhaust gases and the reducing agent mixture, and a free region formed by the zones included between the vanes and denoted by reference numeral 23, as well as by central portion 21.

[0041] In a preferred embodiment of the invention, the area of the surface of the projection of the solid portions of the mixer, that is, the portions axially intercepting the flow of the gases and the reducing agent mixture, on the plane in which vanes 15 lie is in the whole about one half the area of the empty zones, that is, the zones left free for the flow of said gases and reducing mixture.

[0042] Referring to Fig. 5, there is schematically shown a unit 111 for the treatment of the exhaust gases of an internal combustion engine, where SCR technology is used. Said unit 111 comprises a set of ducts for the exhaust gases housed within a casing 113. Static mixer 11 according to the invention is housed in one of the ducts, denoted in the Figure by reference numeral 115, in which the exhaust gases flow in the direction indicated by arrow "F". In the example illustrated, mixer 11 is transversally arranged within duct 115, immediately downstream region 117 where the reducing agent mixture is introduced. Always with reference to the example illustrated, the reducing agent mixture is introduced by injection by means 119 preferably including a nozzle or a suitable valve, which means are axially arranged at the beginning of duct 115 in the direction of the exhaust gas flow. Said duct 115 further comprises, between means 119 and mixer 11, a radially oriented exhaust gas inlet 121, formed by a corresponding portion of duct 115 provided with radial holes 123.

[0043] In accordance with the above configuration, which corresponds to the preferred but non-exclusive arrangement, exhaust gases radially enter duct 115 and they are intercepted by the reducing agent arriving in axial direction, that is at 90° with respect to the gas inlet direction. Hence, the exhaust gas flow arrives in axial direction, i.e. deflected by about 90° with respect to the inlet direction into duct 115, at mixer 11, which substantially occupies the whole cross section of duct 115.

[0044] Advantageously, according to the invention, mixer 11 can be manufactured by means of a succession of simple mechanical cutting and twisting operations. According to this method of manufacture, preferably the mixer is obtained from a sheet metal body having a thickness preferably ranging from 0.8 to 2.0 mm, and more preferably of 1.5 mm. Vanes 15 will have therefore a laminar consistence.

[0045] In the alternative, the mixer could also be manufactured by other mechanical workings, for instance milling or electron discharge machining.

[0046] In a first embodiment of the method of manufacturing the mixer, the machining of a flat laminar metal body, for instance a foil of sheet metal, is performed.

[0047] In a second embodiment of the method of manufacturing the mixer, the machining of a tubular metal body is performed.

[0048] Referring to Figs. 6 and 7, there is shown the intermediate product obtained in accordance with the first embodiment of the method of manufacturing the mixer. Said intermediate product comprises a flat disc 11' obtained by cutting or shearing a flat foil sheet metal. Vanes 15 obtained in this way and shown in the Figures will be subsequently twisted around their longitudinal axis "R", for instance by means of a robotised manipulator, thereby obtaining the final product consisting of mixer 11 disclosed with reference to Figs. 1 to 4.

[0049] Referring to Fig. 8, there is shown the intermediate product 11" obtained in accordance with the second embodiment of the method of manufacturing the mixer. Said intermediate product comprises a tubular body on which vanes 15 are obtained by cutting or shearing. In the tubular body, vanes 15 are arranged with their longitudinal axes "R" along the generatrices of the cylinder defining said tubular body. Then, a bending at 90° of the vanes in correspondence of their bases 17 is performed to bring the vanes into a common plane. Said vanes 15 are subsequently twisted around their longitudinal axis "R", for instance by means of a robotised manipulator, thereby obtaining the final product consisting of mixer 11 disclosed with reference to Figs. 1 to 4. Always in accordance with the invention, in this second embodiment of the method the step of twisting vanes 15 can possibly precede the step of bending at 90°.

[0050] In the whole, the method according to the invention comprises the steps of:

- providing a laminar metal body;
- forming on said body of sheet metal a plurality of radial vanes radially arranged and substantially coplanar;
- twisting the vanes about their longitudinal axis thereby obtaining the mixer.

[0051] Reference is now made to Fig. 9, which shows an enlarged detail of one of the vanes shown in Fig. 7, generally corresponding however to any of the vanes in intermediate products 11' and 11", that is the vanes shown in Figs. 6, 7, 8. Said vanes 15, before twisting, has a rear portion 15a, close to base 17, with a carved shape, i.e. narrowing along the sides according a curved profile, and a tapered front portion 15b close to tip 19, i.e. a portion having a width progressively decreasing towards tip 19. Moreover, a connecting intermediate portion 15c is defined between said rear portion 15a and said front portion 15b. Preferably, the width of the projection of said connecting portion on the plane in which the mixer vanes lie will substantially correspond with the maximum width of vane 15.

[0052] Moreover, tip 19 is rounded in order to avoid the formation of sharp corners. According to the invention, vanes 15 are made so that their shape is twisted, in clockwise or counterclockwise direction, along their longitudinal axis "R", substantially in correspondence of the narrowed zone of carved portion 15a.

[0053] Several changes and modifications, included within the same inventive principle, can be made to the static mixer as described and shown.

Claims

1. Static mixer (11) for the treatment of exhaust gases, comprising an annular support portion (13) and a plurality of radial vanes (15) that are radially arranged with the rear end or base (17) associated with said support portion (13) and the front end or tip (19) converging towards the centre ("C") of the mixer, **characterised in that** the vanes (15) have a shape twisted around the longitudinal axis ("R") of the vanes.

2. Mixer according to claim 1, wherein the vanes have a carved rear portion (15a), proximal to the vane base (17), and a tapered front portion (15b) proximal to the vane tip (19).

3. Mixer according to claim 1 or 2, wherein the tips (19) of the vanes (15) encircle a free central portion (21) of the mixer.

4. Mixer according to claim 1 or 2 or 3, wherein the width of the axial projection of the vane surface on the plane in which the vanes (15) lie is greater than the thickness of the same vanes.

5. Mixer according to any of the claims from 1 to 4, wherein the angle of twist of the vane shape is comprised between 70° and 150°.

6. Mixer according to claim 5, wherein said angle is about 110°.

7. Mixer according to any of the preceding claims, wherein the vanes are angularly spaced apart in regular way.

8. Mixer according to any of the preceding claims, wherein eight to sixteen vanes are provided.

9. Method of manufacturing a static mixer according to any of the claims from 1 to 8, wherein there are provided the steps of:
   - providing a laminar body made of metal (11'; 11");
   - forming on said body a plurality of radial vanes (15), radially arranged and substantially coplanar;
   - twisting the vanes (15) around their longitudinal axis ("R") thereby obtaining the mixer.

10. Method according to claim 9, wherein there is provided a step of bending the vanes at 90° at their base (17), to bring the vanes in a common plane.

11. Method according to claim 9 or 10, wherein, before being twisted, the vanes have a carved rear portion (15a) proximal to the base (17) of the vanes and a tapered front portion (15b) proximal to the tip (19) of the vanes, a connecting intermediate portion (15c) being defined between said rear portion and said front portion, the width of the axial projection of said connecting portion on the plane in which the mixer vanes lie substantially corresponding to the maximum width of the vane (15).

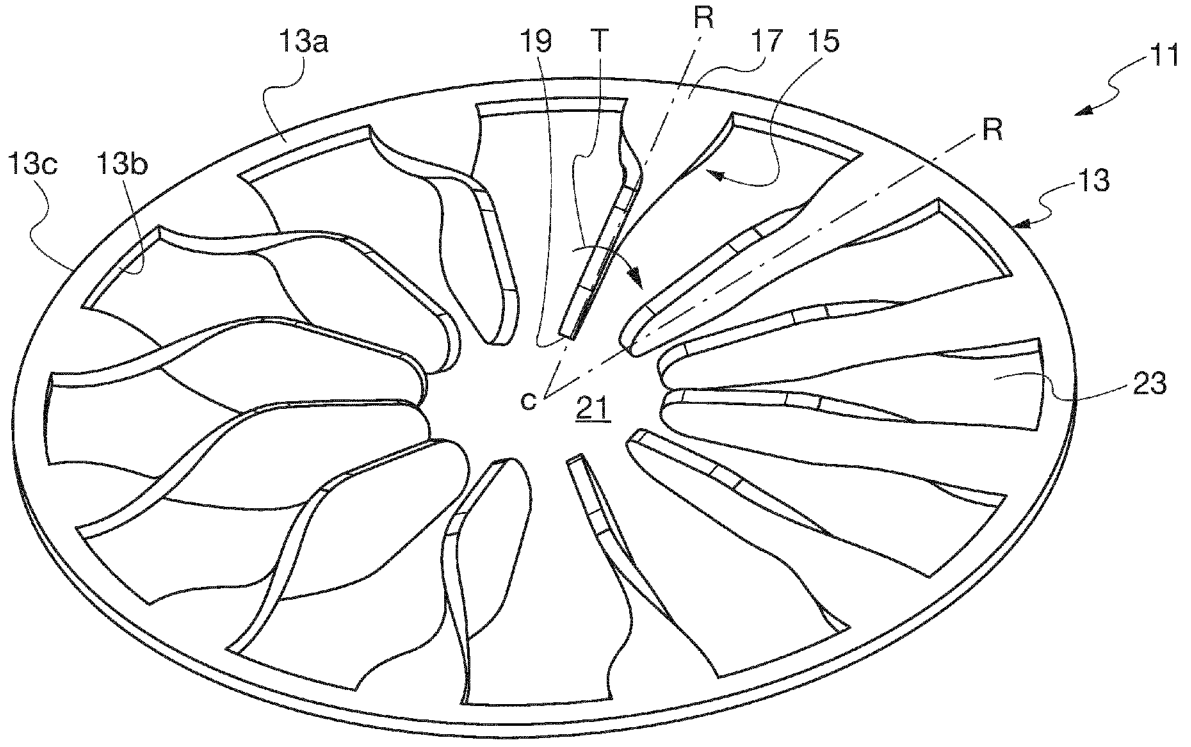

Fig. 1

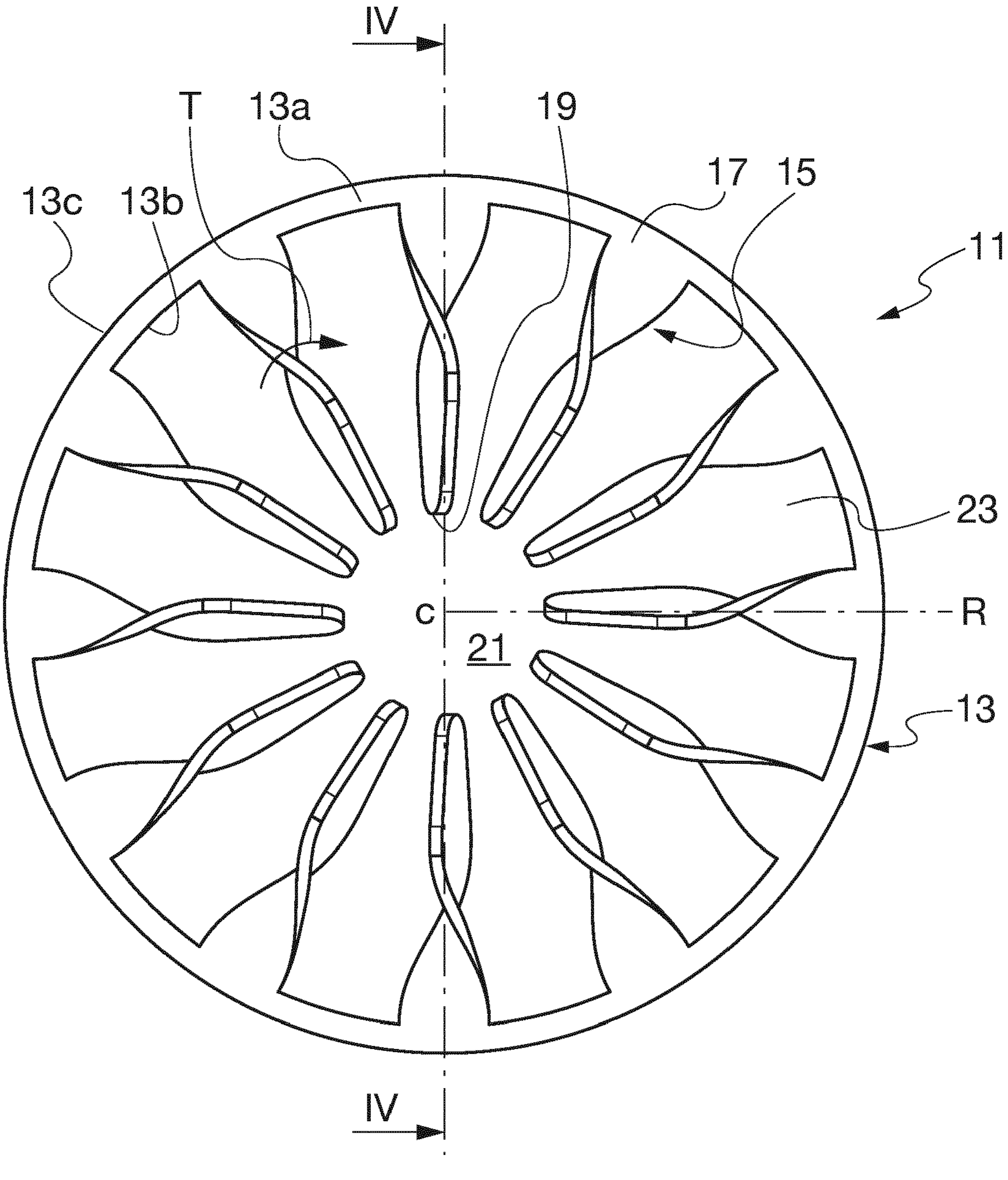

Fig. 2

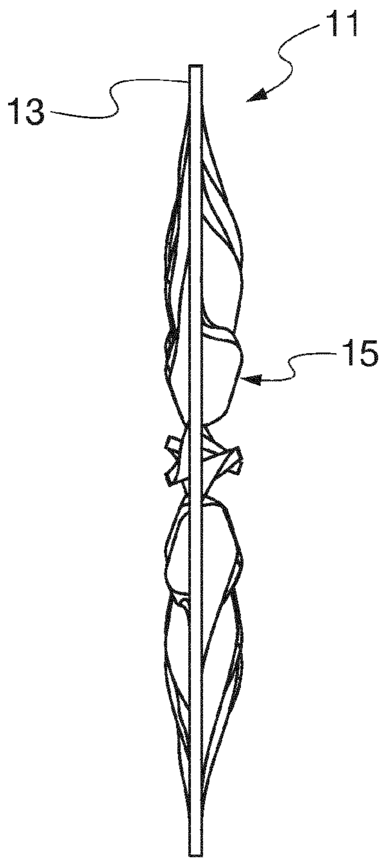

Fig. 3

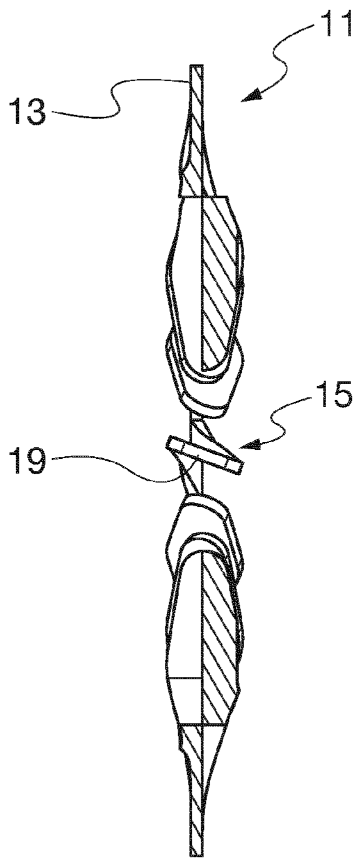

Fig. 4

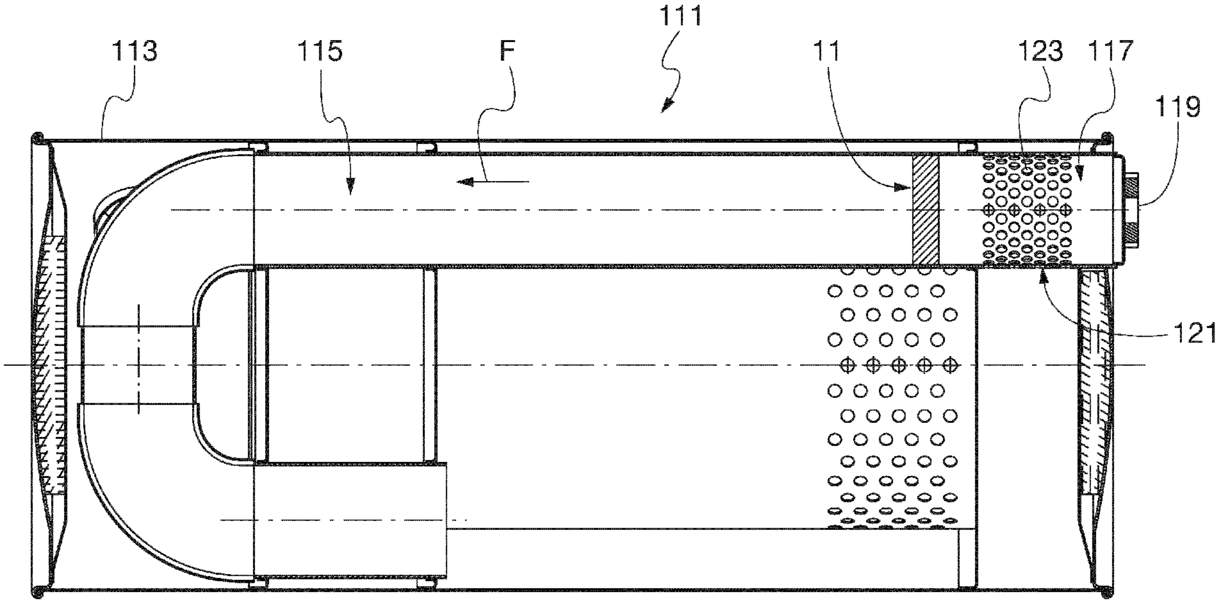

Fig. 5

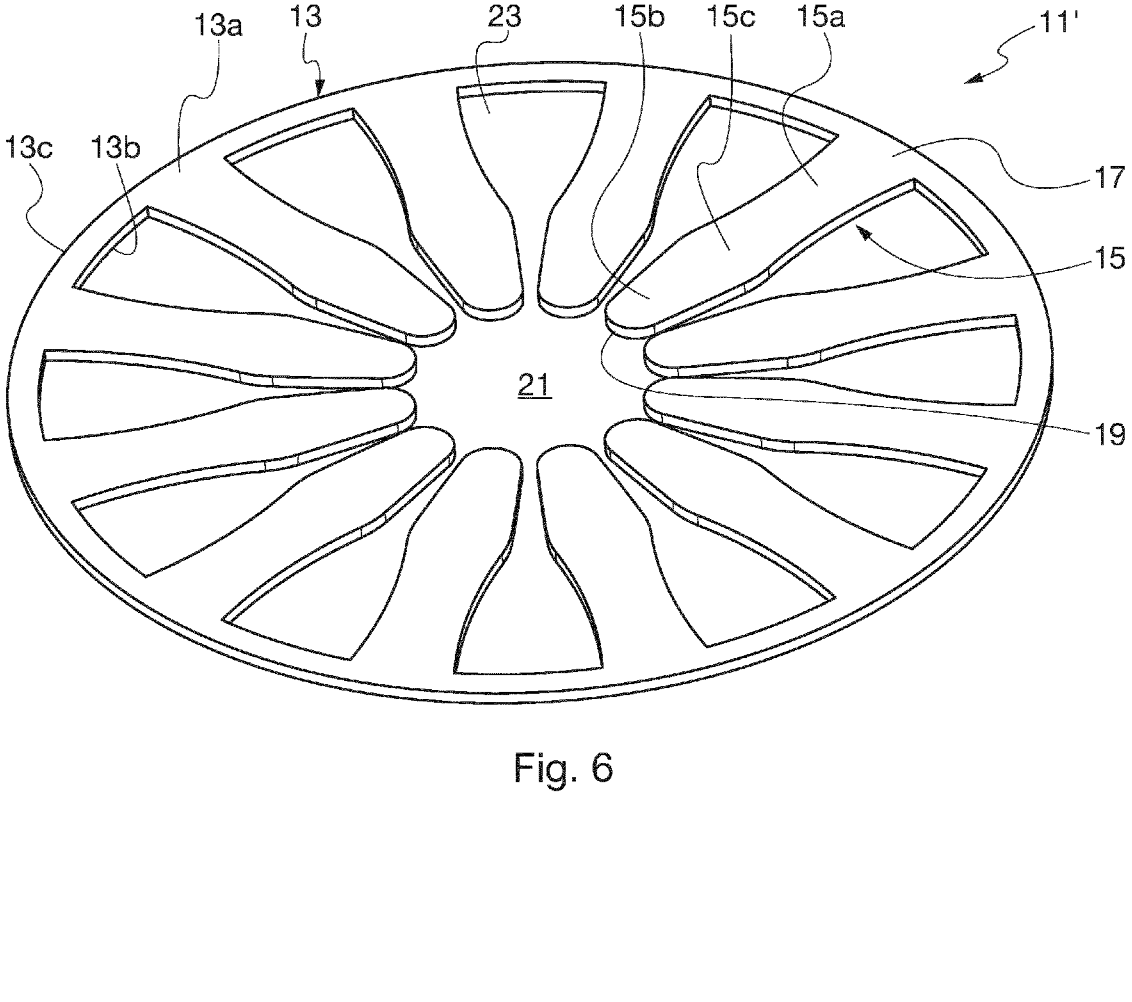

Fig. 6

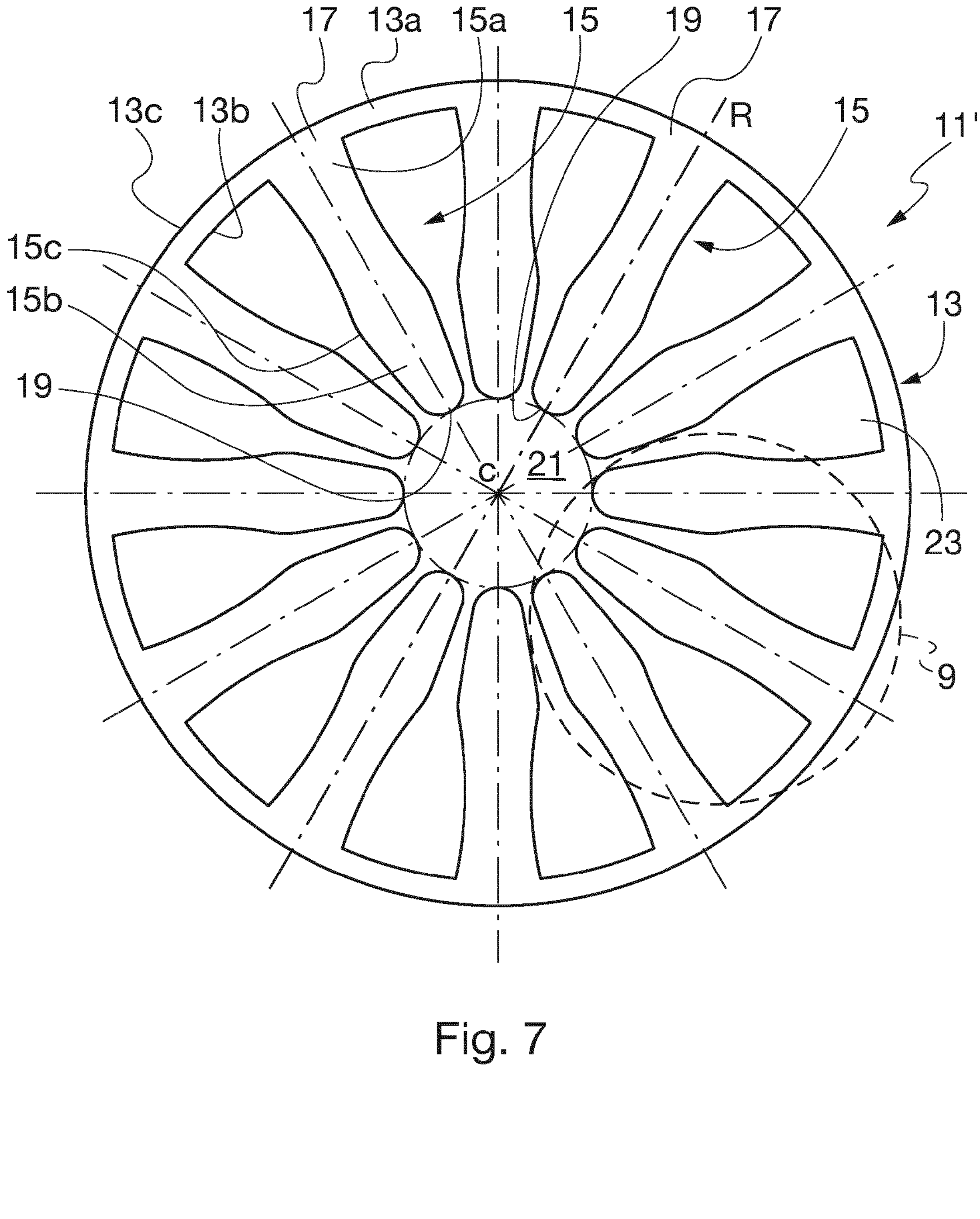

Fig. 7

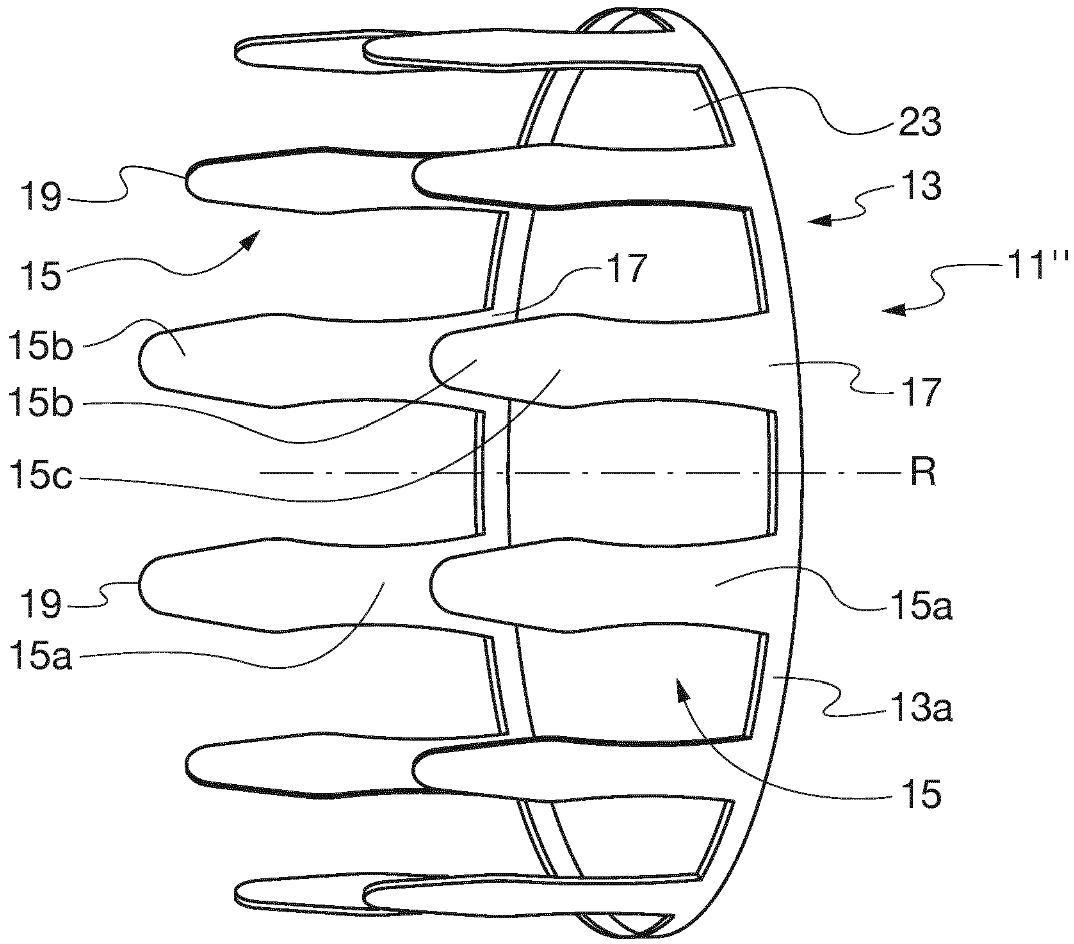

Fig. 8

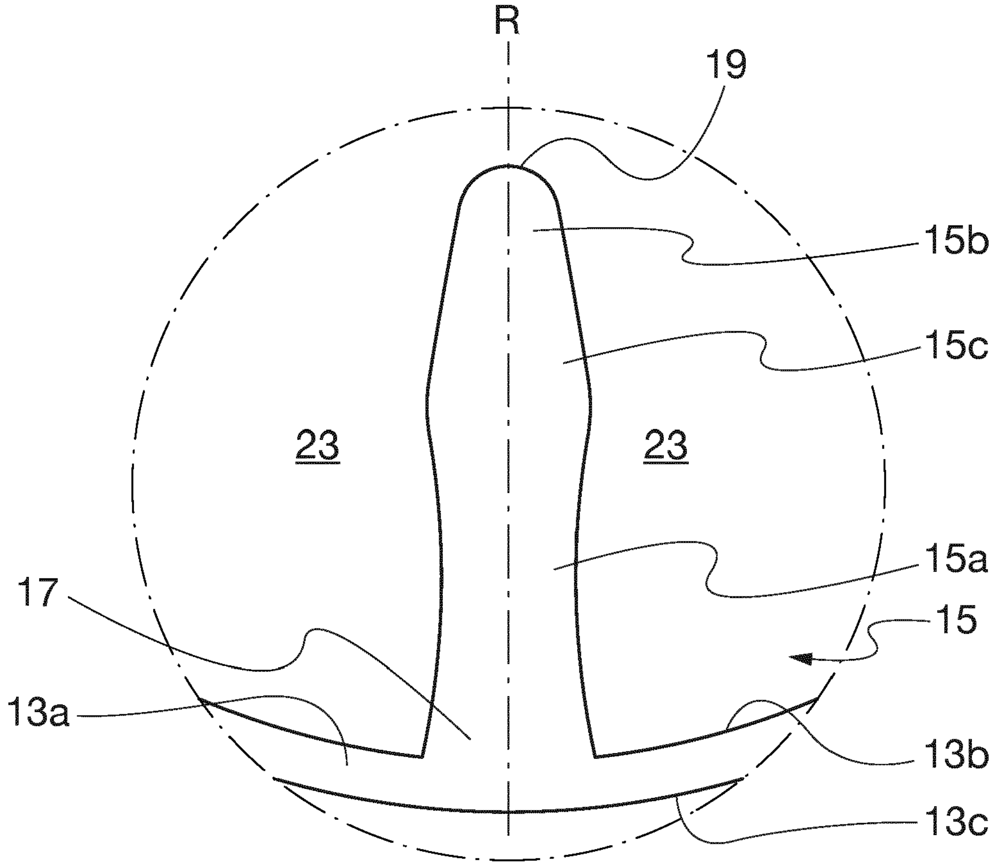

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 4926

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 35 36 315 A1 (SUEDDEUTSCHE KUEHLER BEHR [DE]) 16 April 1987 (1987-04-16) * column 4, line 60 - column 5, line 38 * * column 6, line 27 - line 36; claim 2; figures 1-3 * -----	1-9	INV. F01N3/28
X	FR 2 937 692 A3 (RENAULT SAS [FR]) 30 April 2010 (2010-04-30) * page 7, line 13 - page 8, line 2; figure 3 * -----	1-7	
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TECHNICAL FIELDS SEARCHED (IPC)

F01N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	2 April 2012	Zebst, Marc

CATEGORY OF CITED DOCUMENTS

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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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