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(54) Title: A TURBINE ARRANGEMENT COMPRISING A VOLUTE WITH CONTINUOUSLY DECREASING FLOW AREA HAVING A SUCCESSIVELY REDUCED VALUE

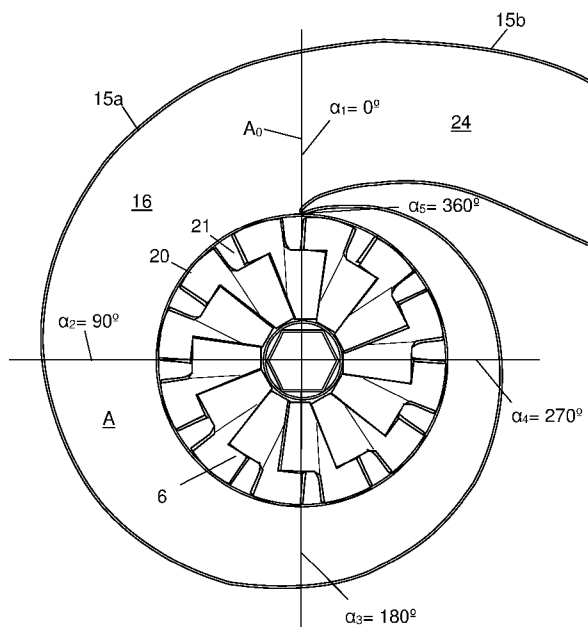


Fig 3

(57) Abstract: The present invention relates to a turbine arrangement driven by exhaust gases from a combustion engine (2). The turbine arrangement comprises a turbine housing (7), a turbine wheel (6) rotatably arranged in the turbine housing (7), a first volute section (15a) defining a curved flow passage (16) extending about 360° around the periphery of the turbine wheel (6), and an inner radial passage (20) directing exhaust gases radially inwardly from the flow passage (16) into a swept area (21) of the turbine wheel (6). The curved flow passage (16) has a cross section area (A) decreasing continuously in the flow direction of the exhaust gases from an initial area (A0) at an initial angular position (α1) of the curved flow passage (16) to an end angular position (αs). The flow area (A) decreases continuously with a successively reduced value from the initial angular position (α1) to an angular position (α) located at least 270° from the initial angular position.



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**A TURBINE ARRANGEMENT COMPRISING A VOLUTE WITH CONTINUOUSLY
DECREASING FLOW AREA HAVING A SUCCESSIVELY REDUCED VALUE**

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BACKGROUND OF THE INVENTION AND PRIOR ART

10 The present invention relates to a turbine arrangement according to the preamble of claim 1.

A turbine arrangement may comprise a turbine wheel arranged in a turbine housing designed with a volute receiving exhaust gases from a combustion engine. The volute comprises a curved flow passage distributing exhaust gases to the turbine wheel via an inner radial passage extending nearly 360° around the turbine wheel. In a conventional turbine arrangement, the curved flow passage has a cross section area which decreases linearly in the flow direction of the exhaust gases around the turbine wheel. A conventional turbine arrangement can also have a volute with a linearly decreasing Area/Radius ratio where the radius is defined as the radius to a position in the volute.

15 20 During steady flow conditions, such a curved flow passage provides a uniform distribution of the exhaust gases around the periphery of the turbine wheel and an optimum turbine efficiency.

The exhaust gases from a combustion engine are led to the turbine of a turbo charger via an exhaust gas manifold. In case the volume of the exhaust manifold is small enough in relation to the cylinder volume of the combustion engines, the opening of an exhaust valve will result in pressure pulses with high amplitude which reach the turbine wheel via the exhaust gas manifold. Such pressure pulses contain the majority of the energy available for the turbine wheel. This pulse is called “blow down pulse” and contain the majority of the residual gas energy left from the combustion and therefore very important to convert into mechanical power in the turbine as efficiently as possible to gain over all efficiency of the combustion engine

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WO 2015/099199 shows a turbine arrangement provided with a scroll section forming a flow passage extending substantially 360° around a turbine wheel. At least a first quarter of the flow passage having a greater reduction of the cross sectional area than a

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conventional flow passage in which the cross sectional area decreases linearly area wise or Area/Radius wise. In a second half of the flow passage, the cross section area decreases linearly.

5 SUMMARY OF THE INVENTION

The object of the present invention is to design a flow passage directing exhaust gases to a turbine wheel such that the turbine wheel provides a substantially optimum efficiency when it receives pulsating exhaust gases.

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This object is achieved by the turbine arrangement of the initially mentioned kind which is characterized by the features defined in the characterizing part of claim 1. The cross section area of the curved flow passage decreases continuously in the flow direction of the exhaust gases from an initial angular position to an end angular position located about 360° from the initial angular position. A graph can illustrate the cross sectional area as a function of the angular position of the curved flow passage. Furthermore, the flow area decreases continuously but with a successively reduced value from the initial angular position to an angular position located at least 270° from the initial angular position. This means that said graph obtains a continuously concave shape between said angular positions. Tests have been carried out verifying that it is possible to provide an optimum turbine efficiency with such a design of the curved flow passage when pulsating exhaust gases are directed to the turbine wheel.

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According to an embodiment of the invention, the flow area decreases continuously with a successively reduced value from the initial angular position to the end angular position. In this case, the cross section area decreases continuously with a successively reduced value in the entire curved flow passage. This means that said graph obtains a continuously concave shape between the initial angular positions and the end angular position.

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According to an embodiment of the invention, the curved flow passage comprises a cross sectional area corresponding to three quarters of the initial area at an angular position in the range of 30°- 55° from the initial angular position. A conventional curved flow passage comprises a cross sectional area corresponding to three quarters of the initial area at an angular position of 90° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate

amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to three quarters of the initial area at an angular position of about 55° from the initial angular position. In case the turbine receives exhaust gases in the form of pulses with very high amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to three quarters of the initial area at an angular position of about 30° from the initial angular position. Thus, it is suitable to design the curved flow path depending on the intensity of the pressure pulses directed to the turbine.

- 10 According to an embodiment of the invention, the curved flow passage comprises a cross sectional area corresponding to half of the initial area at an angular position in the range of 70°- 130° from the initial angular position. A conventional curved flow comprises a cross sectional area corresponding to half of the initial area at an angular position of 180° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to half of the initial area at an angular position of about 130° from the initial angular position. In case the turbine receives exhaust gases in the form of pulses with very high amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to half of the initial area at an angular position of about 70° from the initial angular position.

- 25 According to an embodiment of the invention, the curved flow passage comprises a cross sectional area corresponding to a quarter of the initial area at an angular position in the range of 130°- 220° from the initial angular position. A conventional curved flow passage comprises a cross sectional area corresponding to a quarter of the initial area at an angular position of 270° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to a quarter of the initial area at an angular position of about 220° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with very high amplitude, it is suitable to design the curved flow passage such that it has a cross sectional area corresponding to a quarter of the initial area at an angular position of about 130° from the initial angular position.

According to an embodiment of the invention, the cross section area of the curved flow passage 16 is within a range of 40%- 60% of an initial cross section area at an angular position located 90° from the initial angular position. The cross section area of a conventional curved flow passage is 75% of an initial cross section area at an angular position located 90° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate amplitude, it is suitable to design the curved flow passage such that the cross section area is about 60% of the initial cross section area at an angular position located 90° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with very high amplitude, it is suitable to design the curved flow passage such that the cross section area is about 40% of the initial cross section area at an angular position located 90° from the initial angular position.

According to an embodiment of the invention, the cross section area of the curved flow passage 16 is within a range of 12%- 33% of an initial cross section area at an angular position located 180° from the initial angular position. The cross section area of a conventional curved flow passage is 50% of an initial cross section area at an angular position located 180° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate amplitude, it is suitable to design the curved flow passage such that the cross section area is about 33% of the initial cross section area at an angular position located 180° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with very high amplitude, it is suitable to design the curved flow passage such that the cross section area is about 12% of the initial cross section area at an angular position located 180° from the initial angular position.

According to an embodiment of the invention, the cross section area of the curved flow passage 16 is within a range of 3%- 14% of an initial cross section area at an angular position located 270° from the initial angular position. The cross section area of a conventional curved flow passage is 25% of an initial cross section area at an angular position located 270° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with moderate amplitude, it is suitable to design the curved flow passage such that the cross section area is about 14% of the initial cross section area at an angular position located 270° from the initial angular position. In case the turbine receives exhaust gases in the form of pressure pulses with very high amplitude, it is suitable to design the curved flow passage such that the cross

section area is about 3% of the initial cross section area at an angular position located 270° from the initial angular position.

5 According to an embodiment of the invention, the turbine arrangement comprises two curved flow passages arranged side by side delivering exhaust gases to the turbine from a respective divided exhaust manifold. Thus, the turbine arrangement may comprise a twin scroll turbine provided with two inlet for the exhaust gases. In this case, exhaust gases are alternatively delivered from the respective curved flow passages, via the inner radial passage, to the turbine wheel.

10 According to an embodiment of the invention, the turbine wheel is configured to receive exhaust gases from a number of cylinders of the combustion engine via an exhaust gas passage having a volume, wherein the ratio between the volume of said exhaust gas passage and the volume of one of the cylinders is smaller than 3. Pressure
15 pulses from the exhaust gases leaving a cylinders will be more or less damped in the exhaust gas passage before they enter the turbine wheel. In case the exhaust gas passage has a large volume, the amplitude of the pressure pulses entering the turbine wheel will be low. In this case, the ratio between the volume of said exhaust gas passage and the volume of one of the cylinders is larger than 3. In this case, the
20 turbine arrangement according to the invention will substantially not obtain a higher efficiency than a conventional turbine arrangement. In case this ratio is between 1 and 3, pressure pulses with moderate amplitude will enter the turbine wheel. In case the ratio is smaller than 1, pressure pulses with high amplitude will enter the turbine wheel. In the two latter cases, the turbine arrangement according to the invention will
25 obtain a significantly higher efficiency than a conventional turbine arrangement.

According to an embodiment of the invention, the curved flow passage is defined by stationary walls. In this case, no movable walls has to be used.

30 BRIEF DESCRIPTION OF THE DRAWINGS

In the following a preferred embodiments of the invention is described, as an example, with reference to the attached drawings, in which:

35 Fig. 1 shows a turbocharger including a turbine arrangement according to the present invention,

Fig. 2 shows the turbine arrangement more in detail,
 Fig. 3 shows a cross sectional view along the plane B-B in Fig. 2,
 Fig. 4 shows graphs defining the cross section area A of the flow passage as a
 function of the angular position α for three embodiments of the invention
 5 and
 Fig. 5 shows graphs defining the derivative $\Delta A/\Delta \alpha$ as a function of the angular
 position α for the three embodiments illustrated in Fig. 4.

10 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Fig. 1 shows a combustion engine 2 powering a schematically indicated vehicle 1. The vehicle 1 may be a heavy vehicle and the combustion engine 2 may be a diesel engine. In this case, the combustion engine 2 is provided with six cylinders 2a-f. Each cylinder
 15 2a-f comprises two inlet valves 3a which in an open state deliver charged air to the cylinders 2a-f and two exhaust valves 3b which in an open state deliver exhaust gases from the cylinders 2a-f to a first exhaust manifold 4 and a second exhaust manifold 5. The first exhaust manifold 4 receives exhaust gases from the cylinders 2a-c and the second exhaust manifold 5 receives exhaust gases from the cylinders 2d-f. The
 20 exhaust gases is led, via the respective exhaust manifolds 4, 5 to a turbine of a turbocharger. The turbine comprises a turbine wheel 6 rotatably arranged in a turbine housing 7. The exhaust manifolds 4, 5 and connected parts form an exhaust passage between the cylinders 2a-f and the turbine wheel 6. The turbine is designed as a twin scroll and provided with double inlet for the exhaust gases. The exhaust gases leaves
 25 the turbine housing 7 via an exhaust conduit 8.

The turbocharger comprises further a compressor wheel 9 rotatably arranged in a compressor housing 10. The compressor wheel 9 is driven by the turbine wheel 6 via a shaft 11. The compressor wheel 9 is with the compressor housing 10 arranged in a
 30 charge air line 12 directing charge air to the combustion engine 2. During operation of the compressor wheel 9, air is drawn from the surrounding, via a first part 12a of the charge air line, to the compressor wheel 9. The air leaves the compressor wheel 9 with an increased pressure and an increased temperature. The charge air line 12 comprises a
 35 second part 12b directing the charge air from the compressor wheel 9 to at least one charge air cooler 13. In this case, the charged air cooler is exemplified as an air cooled charge air cooler 13 arranged at a front position of the vehicle 1. The charge air is

cooled in the charge air cooler 13 by air of ambient temperature which is forced through the charged air cooler 12 and the radiator 13 by a not shown radiator fan and the ram air of the vehicle 1. The cooled charged air is directed via a third part 12c of the charge air line 12 to an inlet manifold 14 which directs the charge air to the
 5 cylinders 2a-f of the combustion engine 2.

Fig. 2 shows a cross section view of the turbine housing 7. The turbine housing 7 comprises a first volute 15 defining a curved flow passage 16 receiving exhaust gases from the first manifold 4 and a second volute 17 defining a curved flow passage 18
 10 receiving exhaust gases from the second exhaust manifold 5. The curved flow passages 16, 18 are arranged in parallel and they usually have a corresponding shape except that they are mirrored. The curved flow passages 16, 18 are divided by a radial wall 19. The exhaust gases leave the curved flow passages 16, 18 via an inner radial passage 20. The inner radial passage 20 extends nearly 360° around the periphery of the turbine
 15 wheel 6. The exhaust gases enter, via the inner radial passage 20, a swept area 21 of the turbine wheel 6 whereupon they expand through the turbine wheel 6. As a result, the turbine wheel 6 obtains a rotary movement which is transferred, via the shaft 11, to the compressor wheel 9. The exhaust gases leave the turbine housing 7, via an outlet portion 22 connected to the exhaust line 8. The turbine house 7 comprises further a
 20 connection portion 23 to be connected to the compressor housing 10. The turbine housing 7 and the compressor housing 10 for a housing of the turbocharger enclosing, for example, the shaft 11 connecting the turbine wheel 6 and the compressor wheel 9.

Fig. 3 shows a sectional view of the first volute 15. The first volute 15 comprises a
 25 curved volute section 15a forming the curved flow passage 16 and an initial volute section 15b forming an initial flow passage 24. The initial flow passage 24 may have a constant cross section area or a somewhat decreasing cross section area in the flow direction. The curved flow passage 16 extends substantially 360° around the periphery of the turbine wheel 6. A first initial angular position α_1 of the curved flow passage 16
 30 is indicated. In this angular position α_1 the cross section area A of the curved flow passage is A_0 . A second angular position α_2 of the curved flow passage 16 is located at an angular distance of 90° from the initial angular position α_1 . A third angular position α_3 of the curved flow passage 16 is located at an angular distance of 180° from the initial angular position α_1 . A fourth angular position α_4 of the curved flow
 35 passage 16 is located at an angular distance of 270° from the initial angular position α_1 . A fifth angular position α_5 of the curved flow passage 16 is located at an angular

distance of 360° from the initial angular position α_1 . The curved flow passage 16 has a continuously decreasing cross section area A in its flow direction from the initial angular position α_1 , where the cross section area $A = A_0$, to the fifth angular position α_5 where the cross section area $A = 0$.

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Fig. 4 shows a graph C defining the cross section area A as a function of the angular position α for a conventional curved flow passage 16. In this case, the cross section area A of the curved flow passage 16 decreases linearly with the angular position α .

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Fig 5 shows a graph C' defining the derivative $\Delta A / \Delta \alpha$ of the cross section area A for the same flow passage 16 with respect to the angular position α . Since the cross section area A of the curved flow passage 16 decreases linearly with the circumference position α , the derivative $\Delta A / \Delta \alpha$ is constant in all angular position α . During steady flow conditions, a curved flow passage 16 with such a decreasing cross section area A provides a uniform distribution of the exhaust gases around the periphery of the turbine wheel and an optimized turbine efficiency.

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A pressure pulse of the exhaust gases leaving an exhaust valve 3b of a cylinder 2a-f is transmitted to the turbine wheel 6 via an exhaust gas passage. In this case, the exhaust gas passage is defined by the inlet manifolds 4, 5 and connected exhaust parts

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upstream of the turbine wheel 6. The pressure pulse is more or less damped depending on the volume of the exhaust gas passage. In case the ratio between the volume of the exhaust gas passage and the volume of the cylinder 2a-f is larger than 3, the pressure pulse will be almost completely eliminated before it enters the turbine wheel 6. In case this ratio is between 1 and 3, pressure pulses with a moderate amplitude will enter the turbine wheel 6. In case this ratio is lower than 1, pressure pulses with a high amplitude will enter the turbine wheel 6. In case moderate or high pressure pulses entering the turbine wheel 6, the turbine efficiency will not be optimal with a conventional design of the curved flow passage 16.

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Fig. 4 shows a graph I defining the cross section area A as a function of the angular position α of a curved flow passage 16 according to a first embodiment of the invention. In this case, the turbine efficiency will be substantially optimal when pressure pulses of a moderate amplitude is directed to the turbine 6. The graph I has a continuously concave shape and it slopes downwardly from the first initial angular

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position $\alpha_1 = 0^\circ$ to the fifth end angular position $\alpha_5 = 360^\circ$. Fig 5 shows a graph I' defining the derivative of the graph I. Thus, the graph I' shows the derivative $\Delta A / \Delta \alpha$ of

the cross section area A as a function of the angular position α of the curved flow passage 16. It is to be noted that the graph I' slopes continuously downwardly but with a successively reduced value. Thus, the greatest reduction of the cross section area A is obtained in an initial part of the curved flow passage 16 close to the angular position $\alpha = 0^\circ$. The smallest reduction of the cross section area A is obtained in an end part of the curved flow passage close to the angular position $\alpha = 360^\circ$. Consequently, the flow area A of the curved flow passage 16 decreases continuously with a successively reduced value from the first initial angular position α_1 to the fifth end angular position α_5 .

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Fig. 4 shows a graph II defining the cross section area A as a function of the angular position α for a curved flow passage 16 according to a second embodiment of the invention. In this case, the turbine efficiency will be substantially optimal when pressure pulses of a high amplitude is directed to the turbine 6. The graph II slopes continuously downwardly from the first initiate angular position $\alpha_1 = 0^\circ$ to the fifth end angular position $\alpha_5 = 360^\circ$. The graph II has a more concave shape than the graph I. Fig 5 shows a graph II' defining the derivative of the graph II. Thus, the graph II' shows the derivative $\Delta A / \Delta \alpha$ of the cross section area A as a function of the angular position α of the curved flow passage 16 of the second embodiment. It is to be noted that the graph II' slopes continuously downwardly with a successively reduced value. The cross section area A of the curved flow passage 16 according to the second embodiment obtains a greater reduction in an initial part of the curved flow passage 16 close to the angular position $\alpha = 0^\circ$ than the cross section area A of the curved flow passage 16 according to the first embodiment.

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Fig. 4 shows a graph III defining the cross section area A as a function of the angular position α for a curved flow passage 16 according to a third embodiment of the invention. In this case, the turbine efficiency will be substantially optimal when pressure pulses of a very high amplitude is directed to the turbine 6. The graph III slopes continuously downwardly from the first initial angular position $\alpha_1 = 0^\circ$ to the fifth end angular position $\alpha_5 = 360^\circ$. Fig 5 shows a graph III' defining the derivative of the graph III. Thus, the graph III' shows the derivative $\Delta A / \Delta \alpha$ of the cross section area A as a function of the angular position α of the curved flow passage 16 of the third embodiment. It is to be noted that the graph III' slopes continuously downwardly with a successively reduced value. The cross section area A of the curved flow passage 16 according to the third embodiment obtains a greater reduction in an initial part of the

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curved flow passage 16 close to the angular position $\alpha = 0^\circ$ than the cross section area A of the curved flow passage 16 according to the second embodiment.

5 A suitable design of the curved flow passage 16 is defined by the area located between the graph I and the graph III in Fig. 4. Fig. 4 shows that a suitable curved flow passage 16 comprises a cross sectional area A corresponding to three quarters of the initial area A_0 at an angular position α in the range of 30° - 55° from the initial angular position α_1 . A suitable curved flow passage 16 comprises a cross sectional area A corresponding to half of the initial area A_0 at an angular position α in the range of 70° to 130° from the
10 initial angular position α_1 . A suitable curved flow passage 16 comprises a cross sectional area A corresponding to a quarter of the initial area A_0 at an angular position α in the range of 130° - 220° from the initial angular position α_1 . Fig. 4 shows that a suitable cross section area A of the curved flow passage 16 is within a range of 40 %- 60% of an initial cross section area A_0 at an angular position α_2 located 90° from the
15 initial angular position α_1 . A suitable cross section area A of the curved flow passage 16 is within a range of 12 %-33% of an initial cross section area A_0 at an angular position α_3 located 180° from the initial angular position α_1 . A suitable cross section area A of the curved flow passage 16 is within a range of 3 %- 14% of an initial cross section area A_0 at an angular position (α_4) located 270° from the initial angular position
20 α_1 .

The invention is in no way limited to the embodiments described with reference to the drawings but may be varied freely within the scopes of the claims.

Claims

1. A turbine arrangement driven by exhaust gases from a combustion engine (2), wherein the turbine arrangement comprises a turbine housing (7), a turbine wheel (6) rotatably arranged in the turbine housing (7), a curved volute section (15a) defining a curved flow passage (16) extending about 360° around the periphery of the turbine wheel (6), and an inner radial passage (20) directing exhaust gases radially inwardly from the flow passage (16) into a swept area (21) of the turbine wheel (6), wherein the curved flow passage (16) has a cross section area (A) decreasing continuously in the flow direction of the exhaust gases from an initial area (A_0) at an initial angular position (α_1) of the curved flow passage (16) to an end angular position (α_5), characterized in that the flow area (A) of the curved flow passage (16) decreases continuously with a successively reduced value from the initial angular position (α_1) to an angular position (α) located at least 270° from the initial angular position.
2. A turbine arrangement according to claim 1, characterized in that the flow area (A) decreases continuously with a successively reduced value from the initial angular position (α_1) to the end angular position (α_5).
3. A turbine arrangement according to claim 1 or 2, characterized in that the curved flow passage (16) comprises a cross sectional area (A) corresponding to three quarters of the initial area (A_0) at an angular position (α) in the range of 30°- 55° from the initial angular position (α_1).
4. A turbine arrangement according to claim any one of the preceding claims, characterized in that the curved flow passage (16) comprises a cross sectional area (A) corresponding to half of the initial area (A_0) at an angular position (α) in the range of 70°- 130° from the initial angular position (α_1).
5. A turbine arrangement according to claim any one of the preceding claims, characterized in that the curved flow passage (16) comprises a cross sectional area (A) corresponding to a quarter of the initial area (A_0) at an angular position (α) in the range of 130°- 220° from the initial angular position (α_1).
6. A turbine arrangement according to any one of the preceding claims, characterized in that the cross section area A of the curved flow passage 16 is within a range of 40

%- 60% of an initial cross section area (A_0) at an angular position (α_2) located 90° from the initial angular position (α_1).

5 7. A turbine arrangement according to any one of the preceding claims, characterized in that the cross section area A of the curved flow passage 16 is within a range of 12 %- 33% of an initial cross section area (A_0) at an angular position (α_4) located 180° from the initial angular position (α_1).

10 8. A turbine arrangement according to any one of the preceding claims, characterized in that the cross section area A of the curved flow passage 16 is within a range of 3 %- 14% of an initial cross section area (A_0) at an angular position (α_4) located 270° from the initial angular position (α_1).

15 9. A turbine arrangement according to any one of the preceding claims, characterized in that the turbine arrangement comprises two curve flow passages (16, 18) arranged side by side delivering exhaust gases from a respective exhaust manifold (4, 5) to the turbine.

20 10. A turbine arrangement according to any one of the preceding claims, characterized in that the turbine wheel (6) is configured to receive exhaust gases from a number of cylinders (2a-f) of the combustion engine (2) via an exhaust gas passage having a specific volume, wherein the ration between the volume of said exhaust gas passage and the volume of one of the cylinders (2a-f) is smaller than 3.

25 11. A turbine arrangement according to any one of the preceding claims, characterized in that the curved flow passage (16) is defined by stationary walls.

30 12. A combustion engine arrangement comprising a turbine arrangement according to claim 10.

13. A vehicle comprising a turbine arrangement according to any one of the preceding claims 1-11.

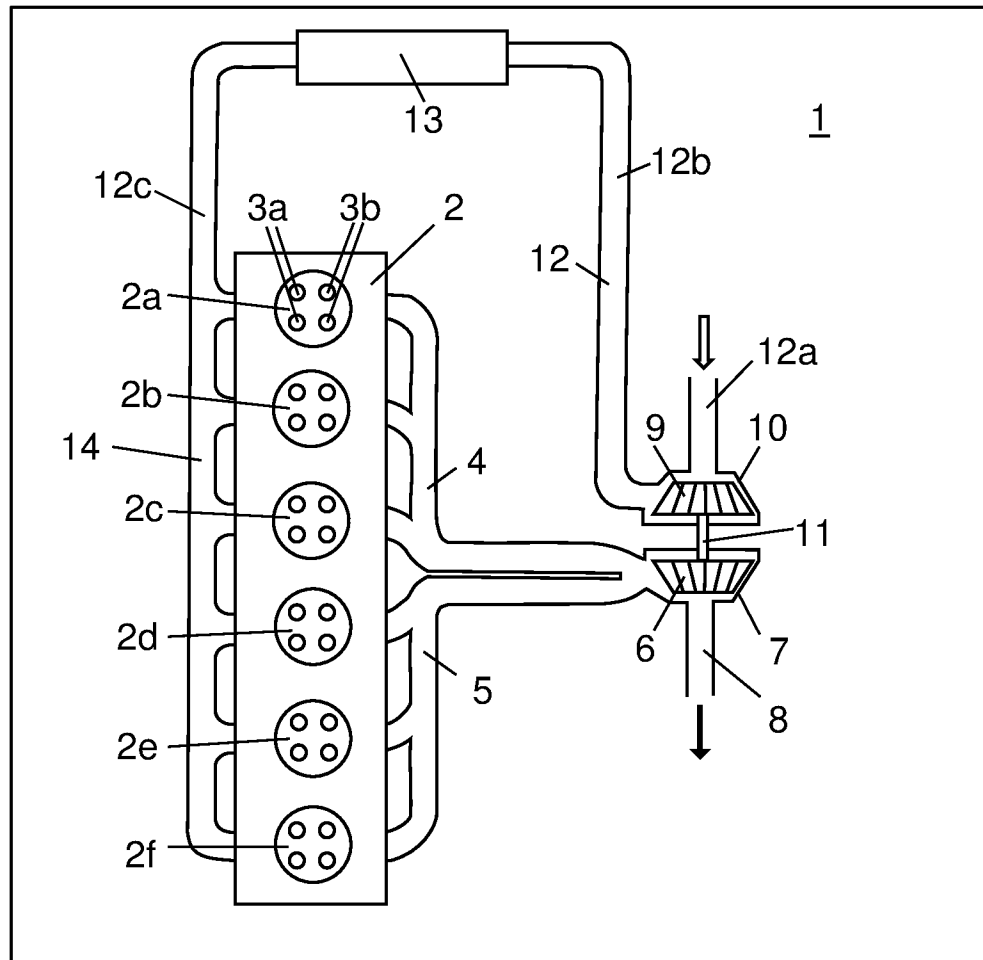


Fig 1

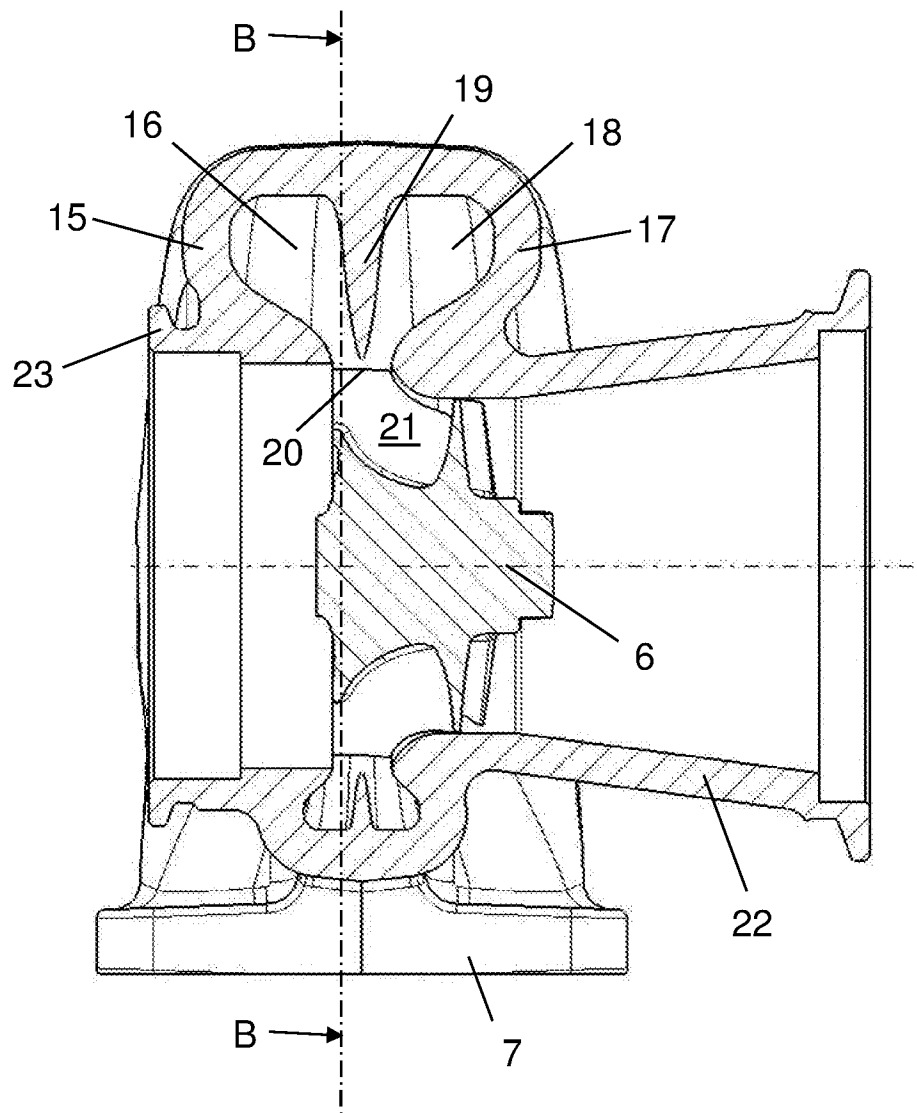


Fig 2

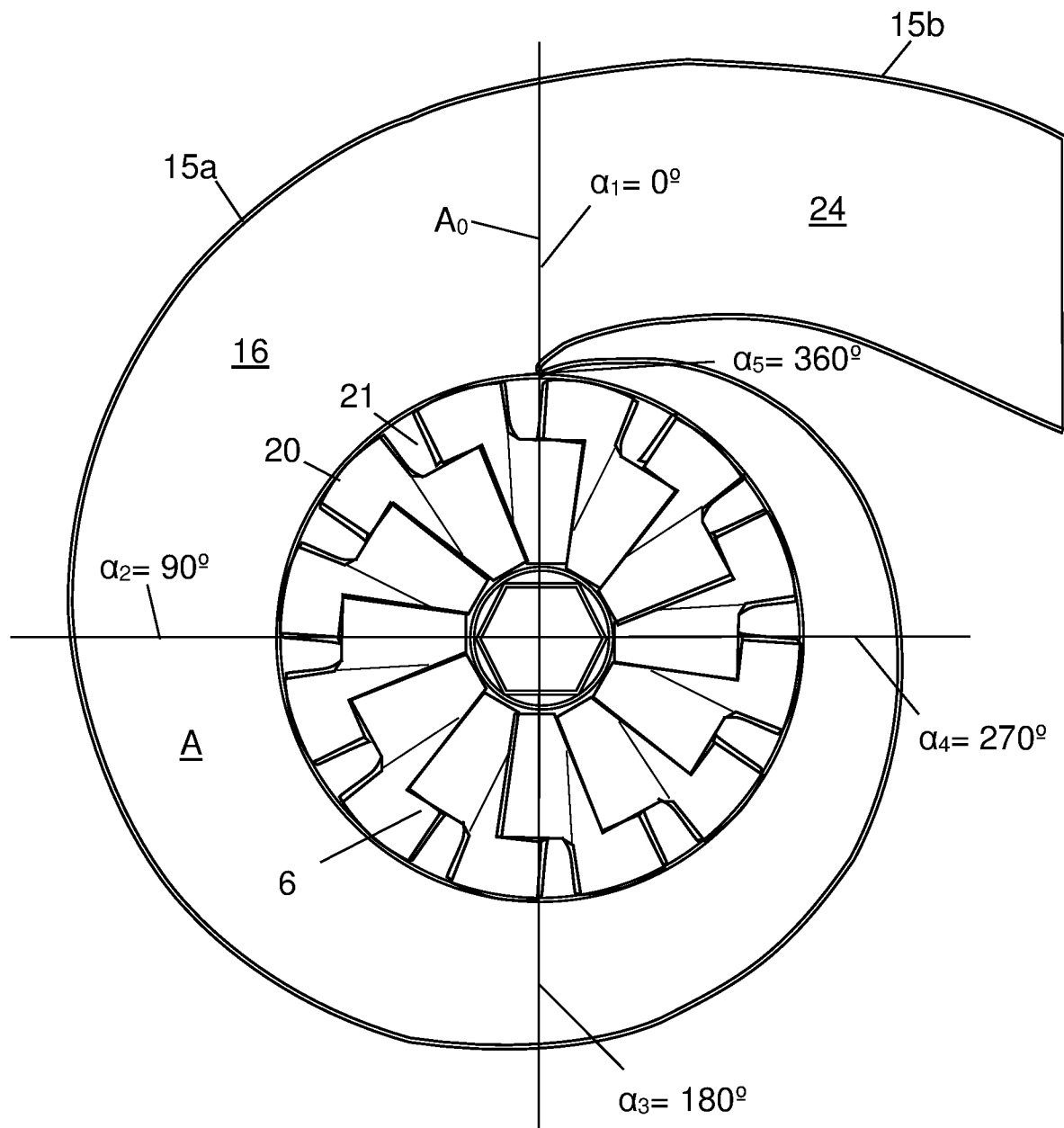


Fig 3

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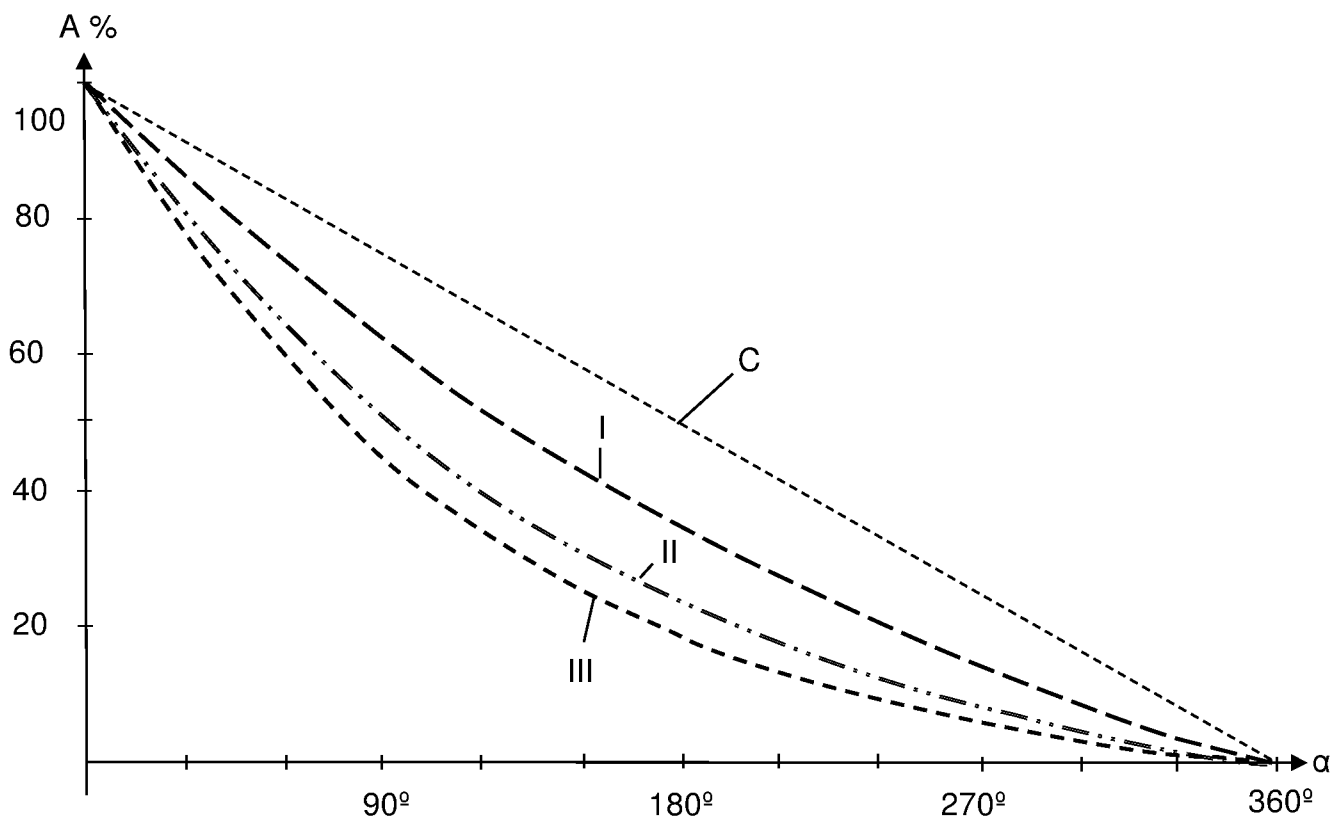


Fig 4

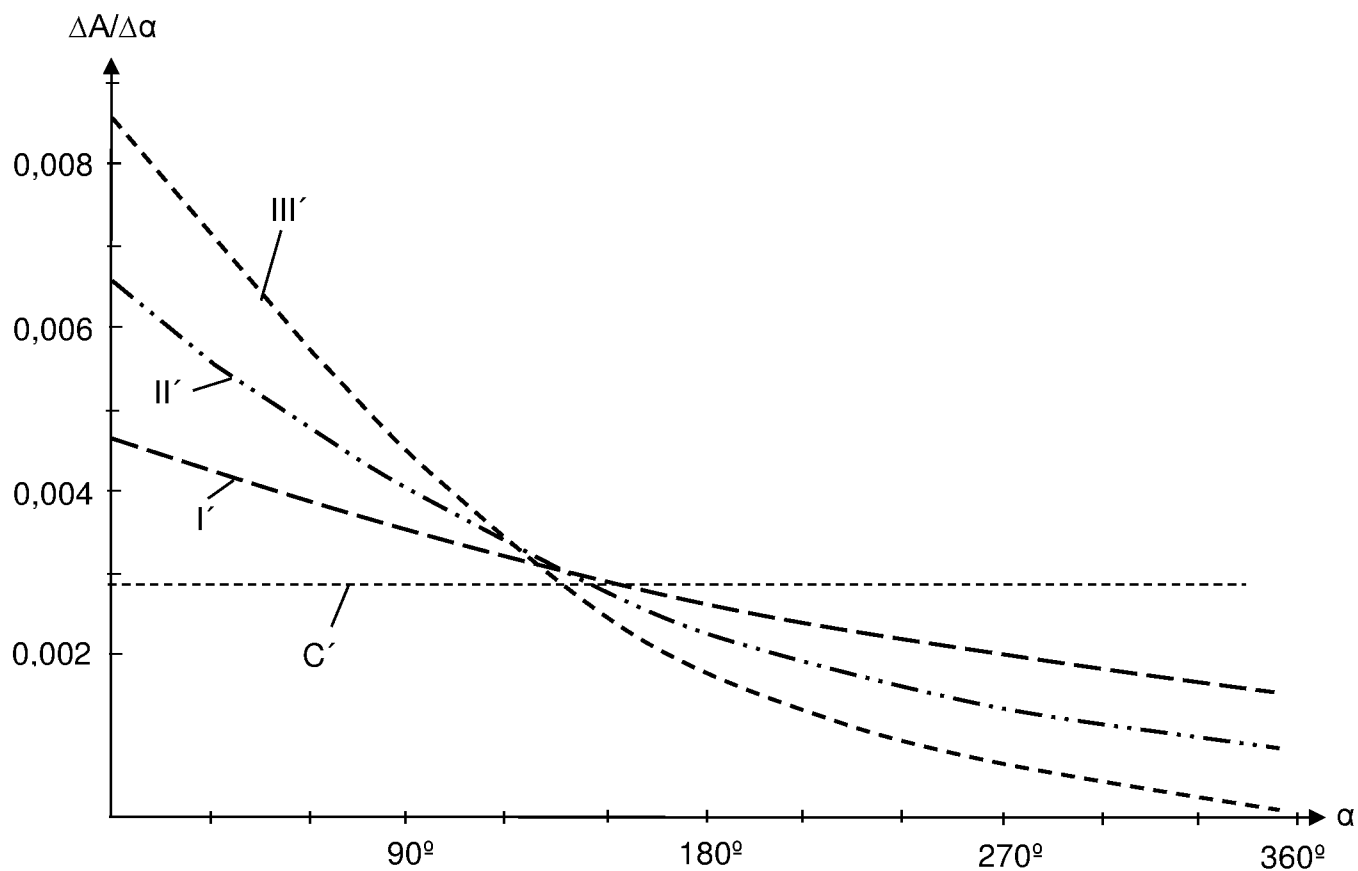


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/050243

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F01D, F02B, F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Yang M. et al. "Influence of volute cross-sectional shape of a nozzleless turbocharger turbine under pulsating flow conditions" 2014 Proc. ASME Turbo Expo 2014; Turbine Technical Conference and Exposition, pages 1-12; Abstract; bottom paragraph on the right on page 1; bottom paragraph on the left, second and bottom paragraphs on page 2; figure 2c; "Conclusions" on pages 9-10 --	1-13
A	WO 2015092373 A1 (CUMMINS LTD), 25 June 2015 (2015-06-25); page 22, line 20 - line 25; figures 2, 5 --	1-13
A	JP 2009221919 A1 (IHI CORP), 1 October 2009 (2009-10-01); whole document; figure 1 --	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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INTERNATIONAL SEARCH REPORT

International application No.
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International Patent Classification (IPC)

F01D 9/02 (2006.01)

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F02B 37/02 (2006.01)

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