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(71) Applicant:
**SCHMID & WEZEL GmbH & Co.
D-75433 Maulbronn (DE)**

(72) Inventor: **Churakov, Alexander
Ashkelon 78151 (IL)**

(74) Representative:
**Dreiss, Fuhlendorf, Steimle & Becker
Gerokstrasse 6
70188 Stuttgart (DE)**

(54) **Double-sided centrifugal-centripetal turbine**

(57) A centrifugal-centripetal turbine which has a turbine wheel provided with circumferentially mounted blades on both its proximal side and its distal side. The radial and tangential components of the velocity of the working fluid are reversed in a chamber, radially beyond the outer edge of the turbine wheel that is separated from the turbine wheel by a barrier to inhibit frictional interaction between the working fluid and the turbine wheel. All parts of the turbine are designed to be fabricated by casting.

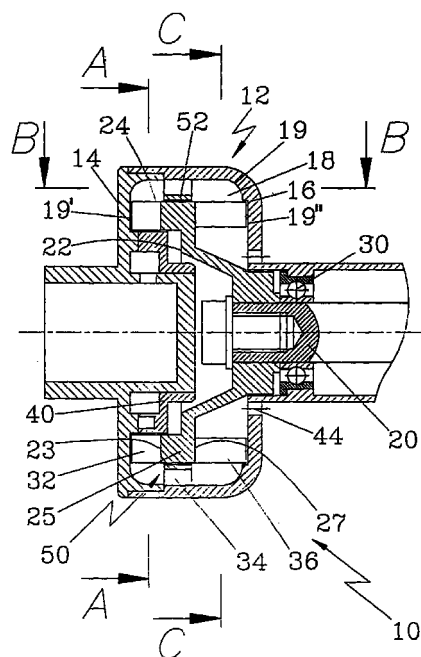


Fig. 1

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Description

FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention relates to turbines and, more particularly, to a double rimmed centrifugal-centripetal turbine, suitable for applications, such as hand-held pneumatic tools, in which space is at a premium, and which can be fabricated by casting.

[0002] In devices with small turbo drives, such as hand-held pneumatic tools, it often is necessary to minimize the maximum rotational (idling) speed. One conventional method of reducing a turbine's idling speed, increasing its diameter, is obviously not applicable to small turbo drives. In addition, small turbines have unique features relative to large turbines. Some of these features, such as large gaps between the inlet nozzle and the turbine wheel and above the turbine blades, relative to the overall dimensions of the turbine, and relatively large tangential length of the turbine blades, lead to a loss of efficiency because of leakage of working fluid. These features also make the use of jet stages and the use of multi-rimmed active velocity stages with more than three blade rims extremely complicated. Considering these limitations, the most efficient designs of small turbines are the radial-axial design, with centripetal entrance of working fluid and axial exit of working fluid; and the exclusively radial design, either centripetal or centrifugal, with energy transferred from the working fluid as the working fluid moves in a single plane.

[0003] Another significant difference between large turbines and small turbines is related to their manufacture. The rotors of small turbines preferably are manufactured in one piece. Most of the known manufacturing processes, such as electroerosion, or milling on a numerically controlled milling machine, are relatively expensive. It is with regard to manufacture that radial turbines have an advantage over axial and radial-axial turbines. The components of axial and radial-axial turbines cannot be manufactured by the relatively simple and inexpensive process of knock-down transfer casting without radical design changes that reduce the efficiency of these turbines. By contrast, radial turbine designs are known, for example, the single-rimmed design taught by Kirby in European Patent Application 0 353 856 A1, whose components can be produced by pressure casting in a knock-down transfer mold. In Kirby's design, the flow of the working fluid is either exclusively centrifugal or exclusively centripetal.

[0004] The most efficient method for reducing the idling speed of a turbine is by using double rimmed stages. This method can lower the idling speed of an axial turbine by as much as 40% to 50%. Double rimmed turbine velocity stages also are widely used in radial turbines. The double rimmed design has two disadvantages for radial turbines, as compared to axial turbines. In a centripetal radial design, the inlet nozzle

must be situated radially beyond the rotor, increasing the radial size of the design. In a centrifugal radial design, the main transfer of kinetic energy from the working fluid to the turbine rotor occurs at a smaller radius than in an axial turbine of similar outer dimensions, decreasing the torque available from this design. Thus, although ease of manufacture favors the radial design for small turbines, the incorporation of a double rimmed stage in such a turbine to reduce its idling speed is expected to carry a penalty in reduced efficiency.

[0005] Kotlyar et al., in Russian patent 2,008,435, teach a compact double-rimmed centrifugal-centripetal radial turbine in which the rotor blades are near the periphery of the rotor, optimizing the energy transfer in the centrifugal stage, and the flow of the working fluid is transformed from centrifugal to centripetal by a circumferential shelf that is incorporated in the rotor. The geometry of this shelf, however, makes it impossible to fabricate the rotor by knock-down transfer molding.

[0006] To sum up, it has not been possible heretofore to combine efficiency, small size, ease of manufacture, and low idle speed in the same turbine.

[0007] There is thus a widely recognized need for, and it would be highly advantageous to have, a compact efficient turbine with a relatively low idle speed that is easy to manufacture.

SUMMARY OF THE INVENTION

[0008] According to the present invention there is provided a turbine for exchanging kinetic energy with a working fluid flowing therethrough with a velocity having an azimuthal component including: (a) a turbine wheel having a proximal side, a distal side and an outer edge, the proximal side having a first plurality of blades thereon; (b) a housing, the turbine wheel being rotatably mounted within the housing, the housing including a chamber extending at least partially circumferentially around the outer edge of the turbine wheel; and (c) a mechanism for directing the working fluid axially from the proximal side of the turbine wheel past the outer edge of the turbine wheel to the distal side of the turbine wheel via substantially all of the circumferential extent of the chamber while reversing the azimuthal component of the velocity of the working fluid.

[0009] The turbine of the present invention achieves high power by using a turbine wheel having blades on both its proximal side and its distal side and by directing the working fluid centrifugally on the proximal side of the turbine wheel and centripetally on the distal side of the turbine wheel. Both the radial component and the azimuthal component of the velocity of the working fluid are reversed at the outer edge of the turbine wheel. This is and of itself is not new, having been taught, for example, in UK Patent No. 252,706. Unlike the turbine of UK 252,706, however, which uses cored U-passages in the turbine housing adjacent to the outer edge of the turbine

wheel to redirect the flow of the working fluid, the present invention allows the working fluid to flow around essentially the entire extent of the outer edge of the turbine wheel, and uses guide vanes in a chamber circumferential to the turbine wheel to reverse the radial and azimuthal components of the velocity of the working fluid. Preferably, to minimize frictional losses as the moving working fluid and the moving turbine wheel pass each other in different directions, a barrier, attached to the guide vanes, is provided to keep the working fluid from contacting the outer edge of the turbine wheel. Preferably, the guide vanes are spaced and shaped, as described below, to allow all parts of the turbine of the present invention to be fabricated by casting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 is a central axial section through a turbine according to the present invention;

FIG. 2 is a proximal transverse section through the turbine of FIG. 1;

FIG. 3 is a peripheral axial section through the turbine of FIG. 1;

FIG. 4 is a distal transverse section through the turbine of FIG. 1;

FIG. 5A illustrates a portion of a guide vane assembly that cannot be fabricated by casting;

FIG. 5B illustrates a portion of another guide vane assembly that cannot be fabricated by casting.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The present invention is of a turbine, of high power and low idling speed, which can be used in applications such as the powering of hand-held pneumatic tools and whose parts can be fabricated by casting.

[0012] The principles and operation of a turbine according to the present invention may be better understood with reference to the drawings and the accompanying description.

[0013] Referring now to the drawings, Figure 1 is an axial cross section of a turbine **10** according to the present invention. Figures 2 and 4 are transverse cross sections of turbine **10** along cuts A-A and C-C respectively. Figure 3 is an axial cross section of turbine **10** along cut B-B.

[0014] The main parts of turbine **10** are a housing **12**, a turbine wheel **20**, a nozzle assembly **40** and a station-

ary axial guide vane assembly **50**. Housing **12** includes a proximal portion **14** and a distal portion **16**. Turbine wheel **20** is rotatably mounted within distal portion **16** of housing **12** on bearings **30**, and is rigidly attached to a shaft **28**. Turbine wheel **20** and shaft **28** together constitute the rotor of turbine **10**. Nozzle assembly **40** and guide vane assembly **50** are described in more detail below.

[0015] Turbine wheel **20** includes an outer cylindrical portion **25**, the proximal surface of which is a first rim **23**, and the distal surface of which is a second rim **27**. On first rim **23** are mounted a first set of blades **32**. Similarly, on second rim **27** are mounted a second set of blades **36**. The radially outermost portion of housing **12** defines a chamber **18** whose peripheral circumference is defined by an inner circumferential surface **19** of housing **12**. The inner surface of chamber **18** also includes, in addition to circumferential surface **19**, a proximal surface **19'** and a distal surface **19''**. Adjacent to inner circumferential surface **19** and opposite outer edge **24** of turbine wheel **20** is guide vane assembly **50**, which includes a set of guide vanes **34** projecting radially inward from surface **19** and a circumferential barrier **52**, radially inward from guide vanes **34**, to which guide vanes **34** are rigidly attached and from which guide vanes **34** project radially outward. Note that barrier **52** surrounds, but does not contact, outer edge **24** of turbine wheel **20**.

[0016] Proximally to turbine wheel **20** and mounted on proximal portion **14** of housing **12** is nozzle assembly **40**. As best seen in Figure 2, nozzle assembly **40** includes three azimuthally pointing nozzles.

[0017] In operation, a working fluid such as air is introduced under pressure into proximal portion **14** of housing **12**. The working fluid flows through nozzles **42**, which, along with surface **19'**, direct the working fluid azimuthally and centrifugally at first blades **32**. In passing first blades **32**, the working fluid transfers some of its kinetic energy to turbine wheel **20**, causing turbine wheel **20** and shaft **28** to rotate. The working fluid proceeds into chamber **18**, where surface **19** and guide vanes **34** redirect the flow of the working fluid: surface **19** reverses the radial component of the velocity of the working fluid, and guide vanes **34** reverse the azimuthal component of the velocity of the working fluid. Barrier **52** intervenes between the working fluid in chamber **18** and outer edge **24** of turbine wheel **20**, inhibiting the loss of energy due to friction that would result if the working fluid were to flow directly past outer edge **24** of turbine wheel **20**. The working fluid now is directed by surface **19''** to flow centripetally past second blades **36**, thereby transferring almost all of the remaining kinetic energy of the working fluid to turbine wheel **20**. Finally, the working fluid leaves turbine **10** via exit ports **44** in distal portion **16** of housing **12**.

[0018] One important feature of turbine **10** is that both first blades **32** and second blades **36** are mounted on rims **23** and **27**, respectively, of outer cylindrical portion

25 of turbine wheel 20, adjacent to outer edge 24 of turbine wheel 20. Mounting blades 32 and 36 at the outermost possible radial positions on turbine wheel 20 minimizes the idling speed of turbine 10.

[0019] It will be appreciated that proximal portion 14 of housing 12, distal portion 16 of housing 12, turbine wheel 20 and nozzle assembly 40 all can be fabricated by knock-down transfer casting. Guide vane assembly 50 also can be fabricated by knock-down transfer casting, provided that any line, such as line 60 in Figure 3, that is drawn in the axial direction through guide vane assembly 50, intersects at most one guide vane 34, and intersects that guide vane 34 only once. This can be better understood with reference to the counterexamples in figures 5A and 5B, of guide vane assemblies that cannot be fabricated by casting. Figure 5A shows a portion of a guide vane assembly 50' whose guide vanes 34' overlap azimuthally, so that some axial lines 62 intersect two guide vanes 34'. Figure 5B shows a portion of a guide vane assembly 50'' whose guide vanes 34'' are sufficiently curved to be re-entrant in the axial direction, so that same axial lines 64 intersect the same guide vane 34'' twice. This ease of fabrication of guide vane assembly 50 is purchased at the expense of a certain loss of efficiency in the redirection of the working fluid in chamber 18; but because the purpose of guide vane assembly 50 is to redirect the flow of the working fluid, not to extract energy from the working fluid, this loss of efficiency is minimal compared to the efficiency that is lost in adapting the rotors of axial and radial-axial designs to manufacture by knock-down transfer casting. [0020] While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

Claims

1. A turbine for exchanging kinetic energy with a working fluid flowing therethrough with a velocity having an azimuthal component, comprising:
 - (a) a turbine wheel having a proximal side, a distal side and an outer edge, said proximal side having a first plurality of blades thereon;
 - (b) a housing, said turbine wheel being rotatably mounted within said housing, said housing including a chamber extending at least partially circumferentially around said outer edge of said turbine wheel; and
 - (c) a mechanism for directing the working fluid axially from said proximal side of said turbine wheel past said outer edge of said turbine wheel to said distal side of said turbine wheel via substantially all of said circumferential extent of said chamber while reversing the azi-

muthal component of the velocity of the working fluid.

2. The turbine of claim 1, wherein said chamber includes a circumferential surface, and wherein said mechanism includes a plurality of guide vanes extending radially inward from said circumferential surface.
3. The turbine of claim 2, wherein said mechanism for directing the working fluid axially includes a mechanism for isolating said outer edge of said turbine wheel from said working fluid.
4. The turbine of claim 3, wherein said mechanism for isolating said outer edge of said turbine wheel from said working fluid includes a circumferential barrier rigidly attached to said guide vanes between said guide vanes and said turbine wheel.
5. The turbine of claim 2, wherein any axial line through said chamber intersects at most one of said guide vanes.
6. The turbine of claim 5, wherein said axial line that intersects one of said guide vanes intersects said guide vane only once.
7. The turbine of claim 1, further comprising:
 - (d) a mechanism for directing the working fluid centrifugally at said first plurality of blades.
8. The turbine of claim 7, wherein said mechanism for directing the working fluid centrifugally at said first plurality of blades includes a plurality of nozzles, said first plurality of blades being positioned circumferentially around said nozzles.
9. The turbine of claim 7, wherein said mechanism for directing the working fluid centrifugally at said first plurality of blades includes a proximal surface, in said chamber, opposite said first plurality of blades.
10. The turbine of claim 1, wherein said distal side has a second plurality of blades thereon, the turbine further comprising:
 - (d) a mechanism for directing the working fluid centripetally at said second plurality of blades.

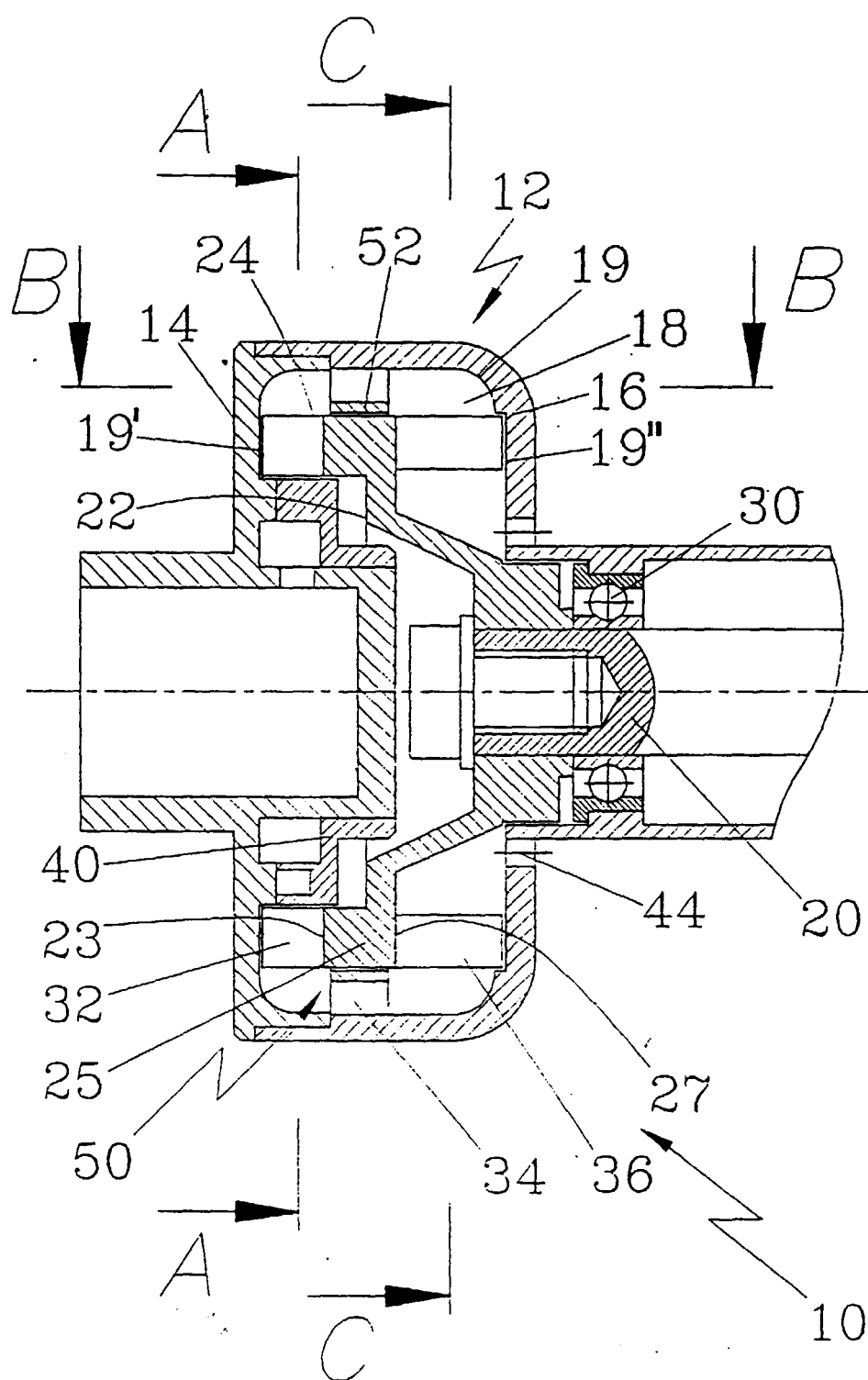


Fig. 1

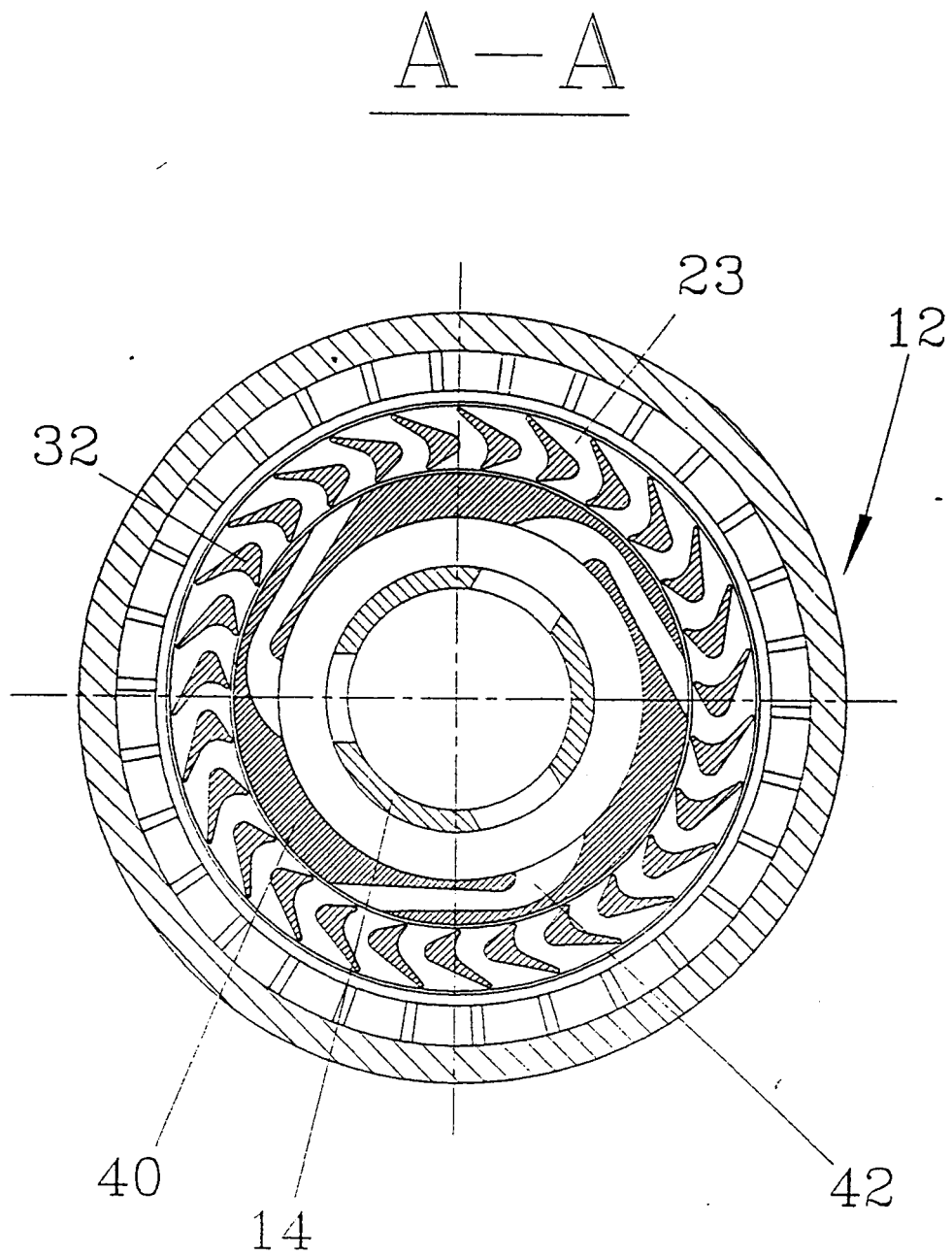


Fig. 2

B—B

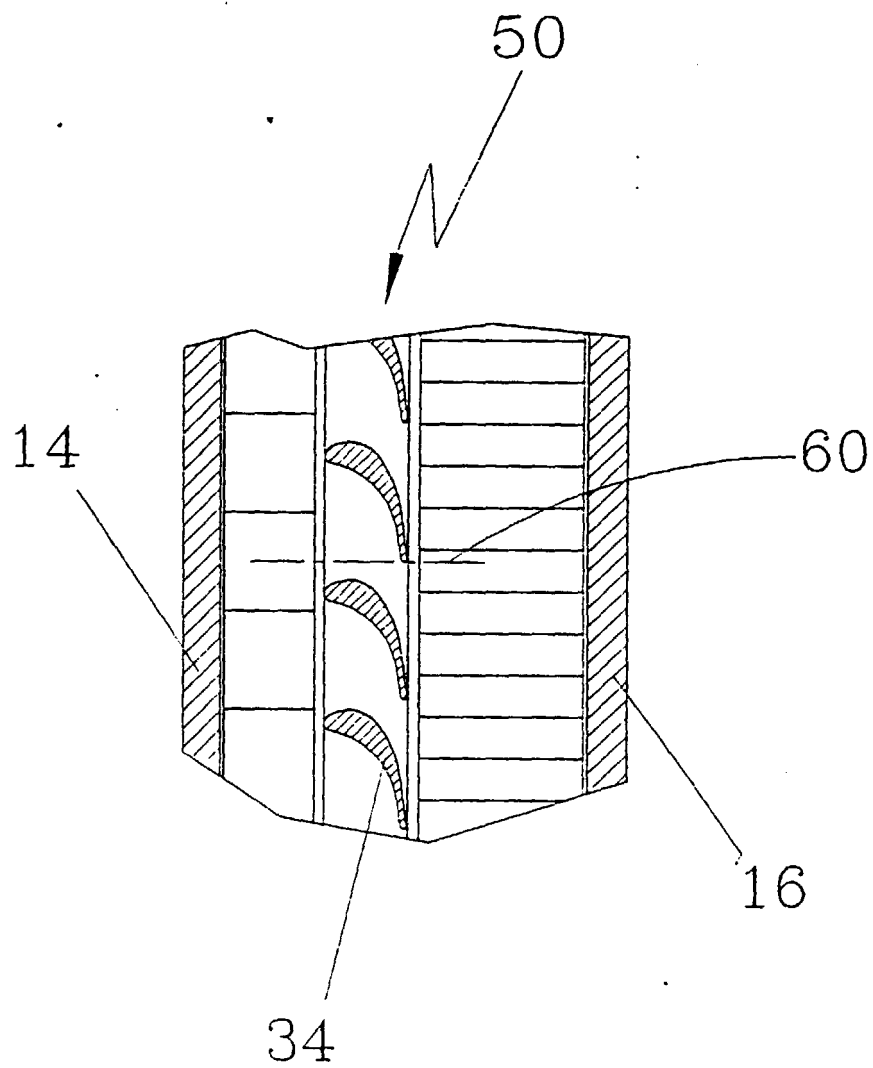


Fig. 3

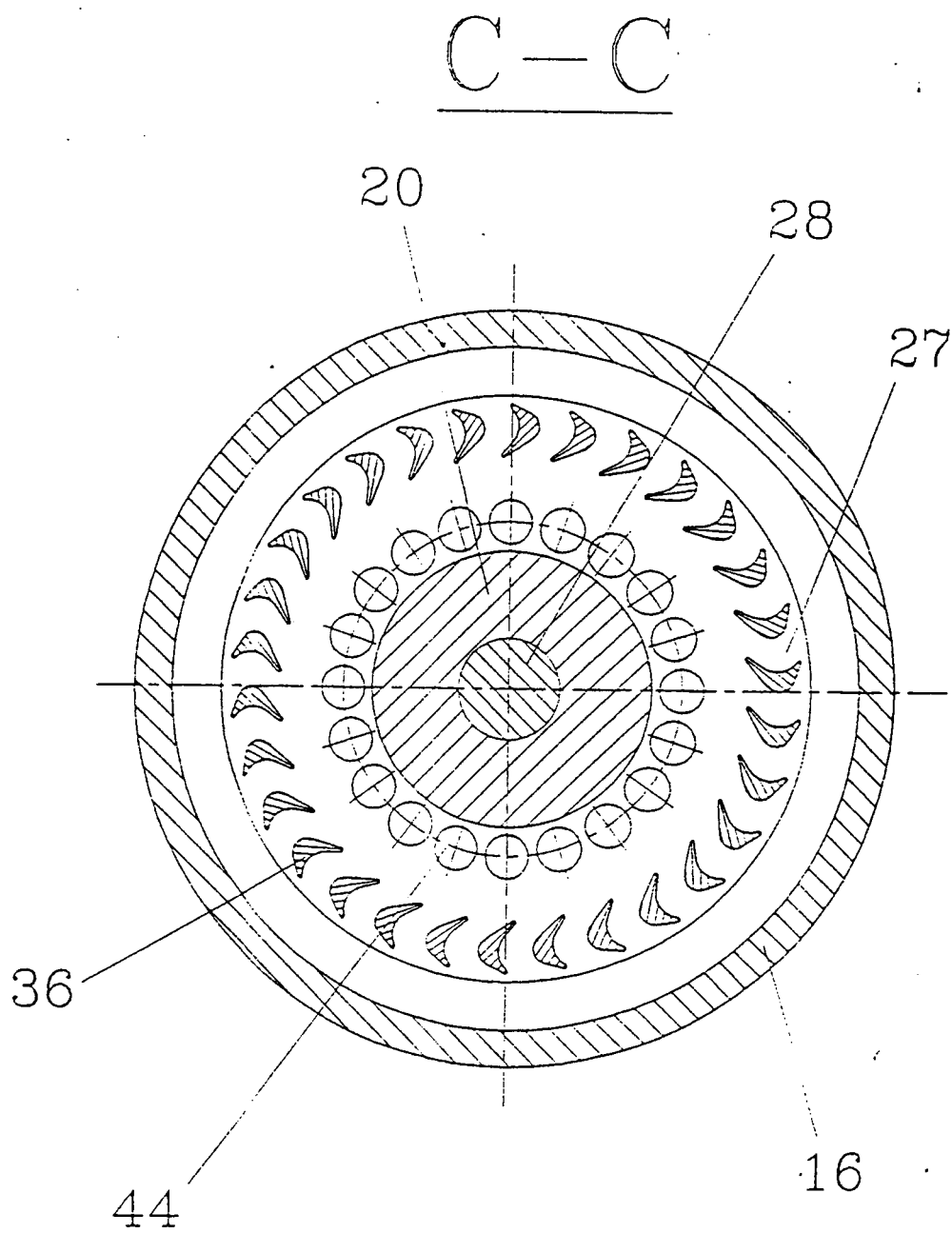


Fig. 4

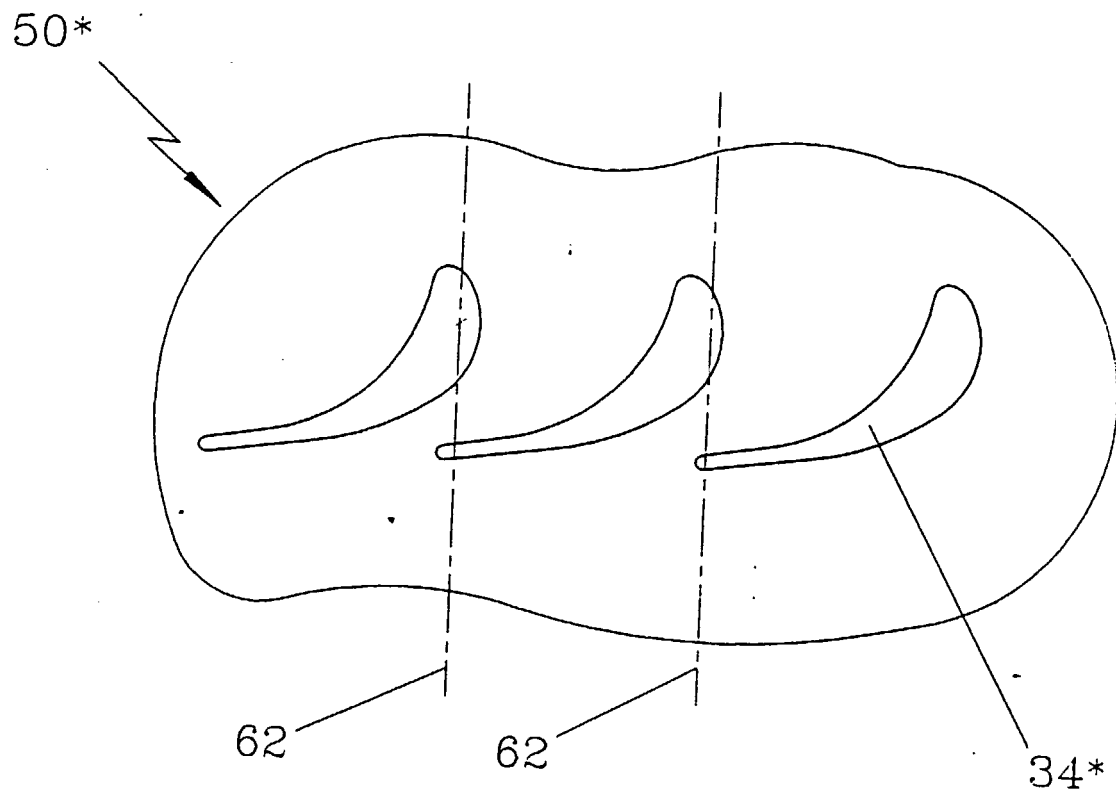


Fig. 5A

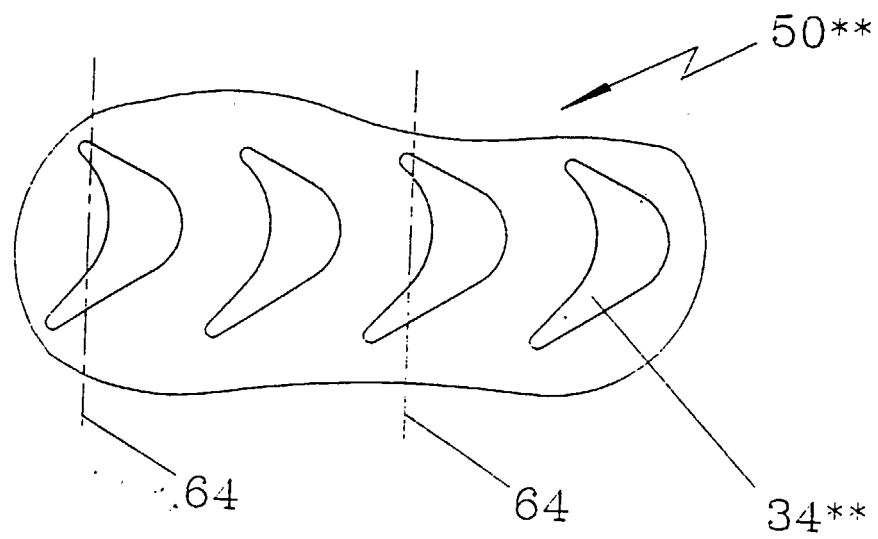


Fig. 5B



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EUROPEAN SEARCH REPORT

Application Number
EP 98 11 6484

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE 262 119 C (JOSSE & CHRISTLEIN) 7 July 1913	1,2,7-10	F01D1/06 F01D1/02 F01D15/06
Y	* claim 1; figures 1,6 * ---	3-6	
Y	GB 885 367 A (SVENSKA ROTOR MASKINER) 28 December 1961 * the whole document * ---	5,6	
A	US 1 470 219 A (RICHTMAN) 9 October 1923	1,2,7-10	
Y	* page 2, line 15 - line 36; figure 4 * ---	3,4	
A	US 2 837 309 A (HANSCHKE) 3 June 1958 * figure 2 *	1-4,7-10	
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F01D
Place of search	Date of completion of the search	Examiner	
THE HAGUE	28 January 1999	Iverus, D	
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 11 6484

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28-01-1999

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