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(54) **A propulsion unit**

(57) The propulsion unit comprises a shaft (10) with a hub (20) and a propeller (30) with propeller blades (40, 50) attached to the hub. An air distribution channel (141, 142) is positioned in a leading edge (LE) in each propeller blade. The air distribution channel extends from a root

(R0) towards a tip (T1) of the propeller blade and is provided with openings (151, 152). Air is supplied to the air distribution channels with an air supply arrangement (111, 121, 131; 112, 122, 132, 160, 170). The openings open into a pressure side (PS) of the propeller blade.

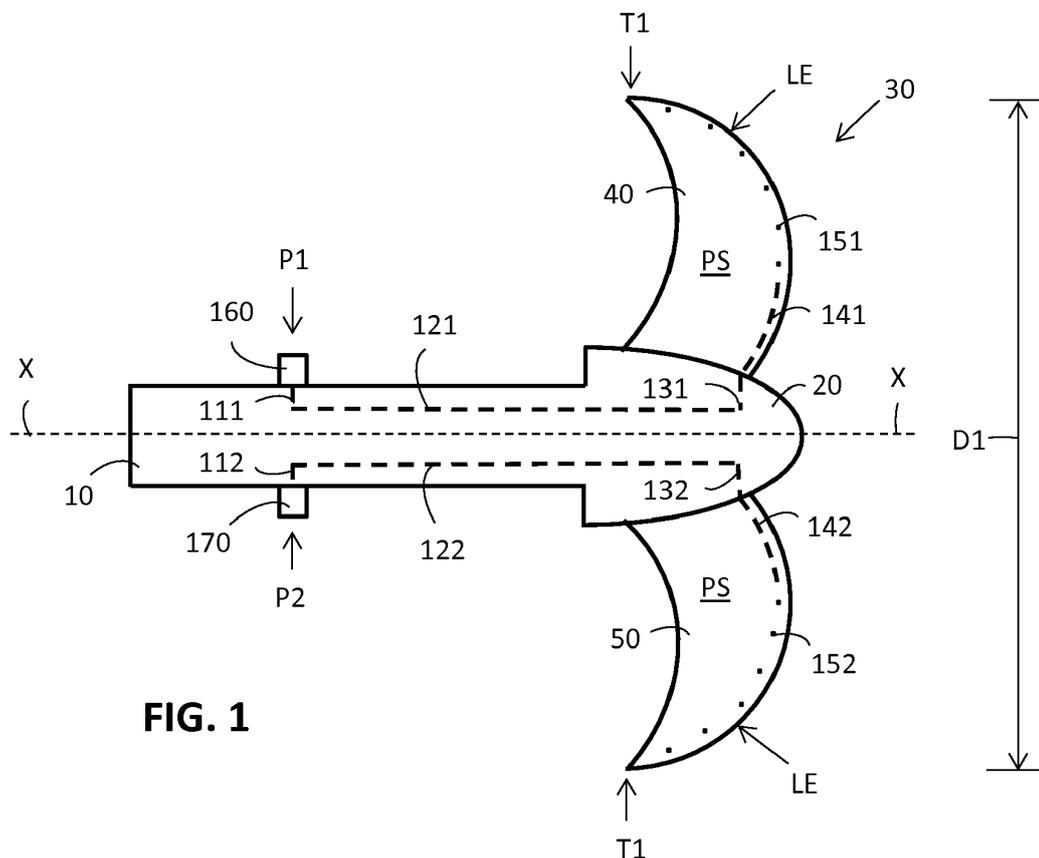


FIG. 1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a propulsion unit according to the preamble of claim 1.

BACKGROUND ART

[0002] US patent 4,188,906 discloses a method for decreasing the deleterious effects of cavitation on a ship propeller. The method is based on the idea to eject air from the suction side of the blades in the propeller when the ship speed and the propeller speed reach a predetermined point to thereby produce a cavity which extends from the leading edge of the blade to a point in water beyond the trailing edge of the blade and envelops the entire suction side of the blade. There is an axial bore in the shaft and a hollow cavity in the hub. A series of holes in the suction faces of the blades are connected to the hollow cavity in the hub. Air can thus be blown from the interior of the ship along the axial bore in the shaft to the holes in the suction faces of the blades.

[0003] US patent 4,696,651 discloses an apparatus for a propeller in a ship. The propeller strut is provided with a retrofit air pipe extending from the interior of the ship along the strut to the shaft of the propeller. An air feed sleeve is mounted on the propeller shaft. The air pipe is connected to a stationary part of the air feed sleeve and the rotating part of the air feed sleeve is connected to an air channel leading to the blades in the propeller. The leading edges of the blades are provided with holes. Pressurized air produced in the ship can thus be conducted to the holes in the blades by this arrangement. The air is then ejected from the holes to the water surrounding the blades in order to reduce cavitation of the propeller.

[0004] Drillings along the leading edge of the propeller, which are supplied with pressurized air, have been used e.g. in war ships for reducing propeller noise from cavitation. Air is pumped through the holes in the propeller in order to ventilate the vapor layer on the propeller. The effect is similarly to a surface piercing propeller and will reduce noise.

[0005] US patent 7,096,810 discloses a bow mounted vessel propulsion system. A boundary layer of air or air bubbles is produced at the bow of the vessel and, during forward motion, is superimposed upon the surface of the water as the vessel's hull passes over, reducing the frictional drag of the hull as it moves across the water. The vessel comprises a hull with a bow section, a stern section, a flat bottom surface, and propellers mounted on the bow section. The propellers are water surface-piercing propellers. This means that the propellers are positioned such that the upper portions of the propeller blades, as the propellers are rotating, are substantially above the surface of the water. Linear rail members run longitudinally along the lateral sides of the bottom sur-

face, whereby a channeled space is formed between the rail members. Since the propellers are partially operating above the water surface, they draw air into the ambient water. The air intermixes with the water to create air bubbles at the bow of the vessel. As the vessel travel forwards, bubbles travel rearwards directly under bottom surface and are confined within the channeled space by the rail members. This moving layer of air/air bubbles beneath the vessel materially reduces the frictional drag of the hull as it moves across and through the water.

[0006] JP patent publication 2010269643 discloses a bubble lubricating vessel. The vessel comprises a hull having a flat bottom at the longitudinal center of the vessel, keel boards disposed at both sides of the flat bottom, a bubble discharge port formed at the bottom of the bow of the vessel, and a bubble recovery port formed at the bottom on the stern of the vessel. Pressurized air is pumped from the bubble discharge port to the water and a part of the bubbles are recovered at the bubble recovery port.

BRIEF DESCRIPTION OF THE INVENTION

[0007] An object of the present invention is to achieve an improved propulsion unit.

[0008] The propulsion unit according to the invention is characterized by what is stated in the characterizing portion of claim 1. The propulsion unit comprises:

- 30 a shaft being rotatably supported and having an axial centre line,
- a propeller comprising propeller blades being attached to a hub on one end of the shaft, said propeller rotating with the shaft,
- 35 an air distribution channel positioned in a leading edge in each propeller blade, said air distribution channel extending from a root of the propeller blade towards a tip of the propeller blade,
- openings positioned along the air distribution channel,
- 40 an air supply arrangement in connection with the shaft for supplying air to the air distribution channels in the propeller blades,

45 **[0009]** The invention is characterized in that the openings open into an outer surface of a pressure side of the propeller blade.

[0010] Air can thus be pumped from the openings into the water surrounding the pressure side of the propeller blade. The air will after penetrating into the water from the openings pass along the surface of the pressure side of the propeller blade. The air passing on the pressure side of the propeller blade will form a lubrication layer between the water and the pressure side of the propeller blade. The air will thus reduce the friction between the water and the pressure side of the propeller blade. A lower friction will increase the efficiency of the propeller.

[0011] The power density of a propeller for a big ship

with a propulsion power in the order of megawatts is about 700 kW/m². This power density corresponds approximately to a pressure of 100 kN/m² with the ratio 0.15 kN/kW. The static pressure acting on a propeller blade is in the order of 0.3 to 1.5 bar depending on ship draft and blade position. The pressure of the air introduced into the pressure side of the propeller blade should be 1 to 2 bar higher than the static pressure leading to a pressure demand of 2.3 to 4.5 bar. Assuming that the whole pressure side of the propeller should be covered with a 5 mm layer of air and a new layer of air is needed for each revolution, we can calculate the amount of air needed for e.g. a 20 MW propeller having an area of 28 m² and a rotation speed of 120 rpm in the following way: $120/60 \text{ 1/s} * 28 \text{ m}^2 * 0.005 \text{ m} = 0.28 \text{ m}^3/\text{s} = 16.8 \text{ m}^3/\text{min}$ at a pressure of 2.3 to 4.5 bar. The power of a compressor producing an air flow of 17 m³/min at a pressure of 5 bar is about 80 to 100 kW.

[0012] By assuming that the lubrication of the pressure side of the propeller blades with air could save 4% of the power we get that the saving is 20 MW * 0.04 = 800 kW. This means that the net saving could be in the order of 700 kW with the inventive arrangement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which:

Figure 1 shows an axial cross section of the shaft and a propeller according to the invention.

Figure 2 shows a radial cross section of the shaft of figure 1.

Figure 3 shows a cross section of the shaft and of one propeller blade.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Figure 1 shows an axial cross section of the shaft and a propeller according to the invention. The shaft 10 is part of a propulsion unit in a vessel. A hub 20 is attached to an outer end of the shaft 10 and a propeller 30 comprising propeller blades 40, 50 is attached to the hub 20. There are four propeller blades 40, 50 connected to the hub 20, but only two of these are shown in the figure. The propeller 30 has a diameter D1 measured from the tips T1 of the propeller blades 40, 50. Each propeller blade 40, 50 comprises a leading edge LE and a pressure side PS. Each of the propeller blades 40, 50 is provided with an air distribution channel 141, 142 extending along the leading edge LE of the propeller blade 40, 50. The air distribution channel 141, 142 is provided with openings 151, 152 opening into the pressure side PS of the propeller blade 40, 50. The shaft 10 is provided with an air supply arrangement for supplying air to the air distribution channels 141, 142 in the propeller blades 40, 50. The air supply arrangement comprises first radial

bores 111, 112, axial bores 121, 122 and second radial bores 131, 132. The first radial bores 111, 112 extend from the outer circumference of the shaft 10 to the interior of the shaft to a first end of the axial bores 121, 122. The axial bores 121, 122 extend in the axial direction X-X of the shaft into the hub 20. The second axial bores 131, 132 are positioned within the hub 20 and extend from the outer surface of the hub 20 to the interior of the hub 20 to a second opposite end of the axial bores 121, 122. The outer ends of the second radial bores 131, 132 are connected to the distribution channels 141, 142 in the propeller blades 40, 50. There are further air transfer sleeves 160, 170 extending around the circumference of the shaft 10. Air P1, P2 can be transferred from the air transfer sleeves 160, 170 and further via the air supply arrangement 111, 121, 131; 112, 122, 132 to the distribution channels 141, 142 in the propeller blades 40, 50.

[0015] Figure 2 shows a radial cross section of the shaft of figure 1. This air transfer sleeve is intended to be used for a propeller 30 with four blades 40, 50. The air transfer sleeves 160, 170 enclose the outer circumference of the shaft 10. A first air transfer sleeve 160 extends over a first half A1-A1 of the shaft 10. A second air transfer sleeve 170 extends over a second half A2-A2 of the shaft 10. Both air transfer sleeves 160, 170 extend in a sector of about 180 degrees. Each air transfer sleeve 160, 170 is sealed at both ends against the outer circumference of the shaft 10 with appropriate sealings 190. A first set of radial bores 111, 114 extends from the outer surface of the shaft 10 within the first air transfer sleeve 160 into a first end of corresponding axial bores 121, 124 within the shaft 10. A second set of radial bores 112, 113 extends from the outer surface of the shaft 10 within the second air transfer sleeve 170 into a first end of corresponding axial bores 122, 123 within the shaft 10. The axial bores 121, 122, 123, 124 are at a second end within the hub 20 connected to corresponding second radial bores 131, 132. Figure 1 shows only two second radial bores 131, 132, but there are naturally four second radial bores, one to each propeller blade 40, 50. The second radial bores 131, 132 are connected to corresponding air distribution channels 141, 142 in the propeller blades 40, 50.

[0016] A first air pressure P1 can be provided into the interior 162 of the first air transfer sleeve 160 through an inlet opening 161 provided in the first air transfer sleeve 160. A second air pressure P2 can be provided into the interior 172 of the second air transfer sleeve 170 through an inlet opening 172 provided in the second air transfer sleeve 170. The first air pressure P1 will propagate from the interior 162 of the first air transfer sleeve 160 through the first set of first radial air supply channels 111, 114 to the first set of axial air channels 121, 124 and further through the first set of second radial air supply channels 131 to the air distribution channels 141 in the propeller blades 40. The second air pressure P2 will propagate from the interior 172 of the second sleeve 170 through the second set of first radial bores 112, 113 to the second

set of axial air channels 122, 123 and further through the second set of second radial air supply channels 132 to the air distribution channels 142 in the propeller blades 50. The two radial bores 111, 114 in the first half A1-A1 of the shaft 10 are connected to the two blades 40 in the first half of the hub 20 and the two radial bores 112, 113 in the second half A2-A2 of the shaft 10 are connected to the two blades 50 in the second half of the hub 20. The shaft 10 rotates and the sleeves 160, 170 are stationary. This means that each propeller 30 blade 40, 50 is connected to the first sleeve 160 once the blade 40, 50 is in an upper position and to the lower sleeve once the blade 40, 50 is in a lower position. The air pressure P1 in the first sleeve 160 can be kept on a lower level compared to the air pressure P2 in the second sleeve 170. The higher pressure P2 in the second sleeve 170 will compensate for the higher hydrostatic pressure of the water acting on the propeller 30 blade 40, 50 in the lower position.

[0017] Figure 3 shows a cross section of the shaft and of one propeller blade. The air distribution channel 141 in the leading edge LE of the propeller blade 40 can be formed as an integral part of the propeller blade 40. This means that the air distribution channel 141 is formed when the propeller blade 40 is casted. The other possibility is that the air distribution channel 141 is formed as a separate part attached to the propeller blade 40. The air distribution channel 141 starts at the root R0 of the propeller blade 40. The openings 151 in the air distribution channel 141 open into the pressure side PS of the blade. Air can thus be pumped from the openings 151 into the water surrounding the propeller blade 40. The air will after penetrating into the water from the openings 151 pass along the surface of the pressure side PS of the propeller blade 40. The air passing on the pressure side PS of the propeller blade 40 will form a lubrication layer between the water and the pressure side PS of the propeller blade 40. The air will thus reduce the friction between the water and the pressure side PS of the propeller blade 40. A lower friction will increase the efficiency of the propeller.

[0018] The openings 151 begin at a first distance S1 from the axial centre line X-X of the shaft 10 of the propeller 30. The first distance S1 is in the range of 30% to 50% of the radius R1 of the propeller blade 40. The radius R1 of the propeller blade 40 is half of the diameter D1 of the propeller 30. The circumferential speed of the propeller blade 40 is low near the axial centre line X-X of the shaft 10 of the propeller 30 and increases towards the tip T1 of the propeller blade 40.

[0019] The openings 151 end at a second distance S2 from the tip T1 of the propeller blade 40. The second distance S3 is in the range of 5% to 30% of the radius R1 of the propeller 30. The circumferential speed of the propeller blade 40 is high near the tip T1 of the propeller 30 and decreases towards the axial centre line X-X of the shaft 10 of the propeller 30.

[0020] The openings 151 are advantageously posi-

tioned in those regions in the leading edge LE of the propeller blade 40 where the greatest benefit of the openings 151 is achieved. It seems that there might often be a lower pressure in the leading edge LE of the propeller blade 40 compared to other areas in the pressure side PS of the propeller blade 40. The area of relatively lower pressure in the leading LE on the pressure side PS seems to be between the first distance S1 and the second distance S2. Lubrication air from the openings 151 would thus help in raising the pressure in the leading edge LE on the pressure side of the propeller blade 40. This would raise the efficiency of the propeller 30.

[0021] The openings 151, 152 are at a third distance S11 from the leading edge LE of the propeller blade 40.

The third distance S11 is in the range of 0 to 15% of the total width S10 of the propeller blade 40.

[0022] The openings 151, 152 are at a suitable distance from each other. The distance between the openings 151, 152 must be such that the strength of the propeller blade 40, 50 is maintained at an adequate level. The distance between the openings 151, 152 need not be the same along the whole length of the leading edge LE of the propeller blade 40. There might be a need to have more openings 151, 152 closer to the tip T1 of the propeller blade 40, 50 in order to increase the amount of air closer to the tip T1 of the propeller blade 40,50.

[0023] The cross section of the openings 151, 152 could be elliptical in the direction into which air is blown from the openings 151, 152. All the corners in the openings 151, 152 are naturally rounded in order to reduce swirls.

[0024] The openings 151, 152 are in the figures positioned on a curved line on the leading edge LE of the propeller blade 40. The openings 151, 152 could, however, be positioned in any configuration of the leading edge LE of the propeller blade 40. The openings 151, 152 could e.g. be positioned on two curved lines running along the leading edge LE of the propeller blade 40 at a distance from each other, whereby a line drawn through the centre points of the openings 151, 152 would form a zigzag line.

[0025] The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A propulsion unit comprising:

- a shaft (10) being rotatably supported and having an axial centre line (X-X),
- a propeller (30) comprising propeller blades (40, 50) being attached to a hub (20) on one end of the shaft (10), said propeller (30) rotating with the shaft (10),
- an air distribution channel (141, 142) positioned in a leading edge (LE) in each propeller blade

(40, 50), said air distribution channel (141, 142) extending from a root (R0) of the propeller blade (40, 50) towards a tip (T1) of the propeller blade (40, 50), openings (151, 152) positioned along the air distribution channel (141, 142), an air supply arrangement (111, 121, 131; 112, 122, 132, 160, 170) in connection with the shaft (10) for supplying air to the air distribution channels (141, 142) in the propeller blades (40, 50), **characterized in that:**

the openings (151, 152) open into an outer surface of a pressure side (PS) of the propeller blade (40, 50).

2. A propulsion unit according to claim 1, **characterized in that** the openings (151, 152) begin at a first distance (S1) from the axial centre line (X-X) of the shaft (10) of the propeller (30), said first distance (S1) being in the range of 30% to 50% of the radius (R1) of the propeller blade (40, 50).
3. A propulsion unit according to claim 1 or 2, **characterized in that** the openings (151, 152) end at a second distance (S2) from a tip (T1) of the propeller blade (40, 50), said second distance (S3) being in the range of 5% to 30% of the radius (R1) of the propeller blade (40, 50).
4. A propulsion unit according to any one of claims 1 to 3, **characterized in that** the openings (151, 152) are at a third distance (S11) from the leading edge (LE) of the propeller blade (40), said third distance (S11) being in the range of 0 to 15% of the total width (S10) of the propeller blade (40, 50).
5. A propulsion unit according to any one of claims 1 to 4, **characterized in that** the air supply arrangement (111, 121, 131; 112, 122, 132, 160, 170) comprises:

two separate stationary air transfer sleeves (160, 170) being positioned around the rotating shaft (10),
two separate groups of air supply channels (111, 121, 131; 112, 122, 132), whereby:

a first group of air supply channels (111, 121, 131) connects a first air transfer sleeve (160) being positioned in a first half (A1-A1) of the shaft (10) to a first set of propeller blades (40) being positioned in a first half of the propeller (30), and
a second group of air supply channels (112, 122, 132) connects a second transfer sleeve (170) being positioned in a second half (A2-A2) of the shaft (10) to a second

set of propeller blades (50) being positioned in a second half of the propeller (30).

6. A propulsion unit according to claim 5, **characterized in that** each group of air supply channels (111, 121, 131; 112, 122, 132) comprises:

first radial air channels (111, 112) extending from the outer surface of the shaft (10) to the interior of the shaft (10) and being connected to a respective air transfer sleeve (160, 170) at the outer surface of the shaft (10),
second radial air channels (131, 132) extending from the outer surface of the hub (20) to the interior of the hub (20) and being connected to a respective air distribution channel (141, 142) at the outer surface of the hub (20),
axial air channels (121, 122) extending in the axial direction (X-X) within the shaft (10) and connecting each of the first radial air channels (111, 112) with a respective second radial air channel (131, 132).

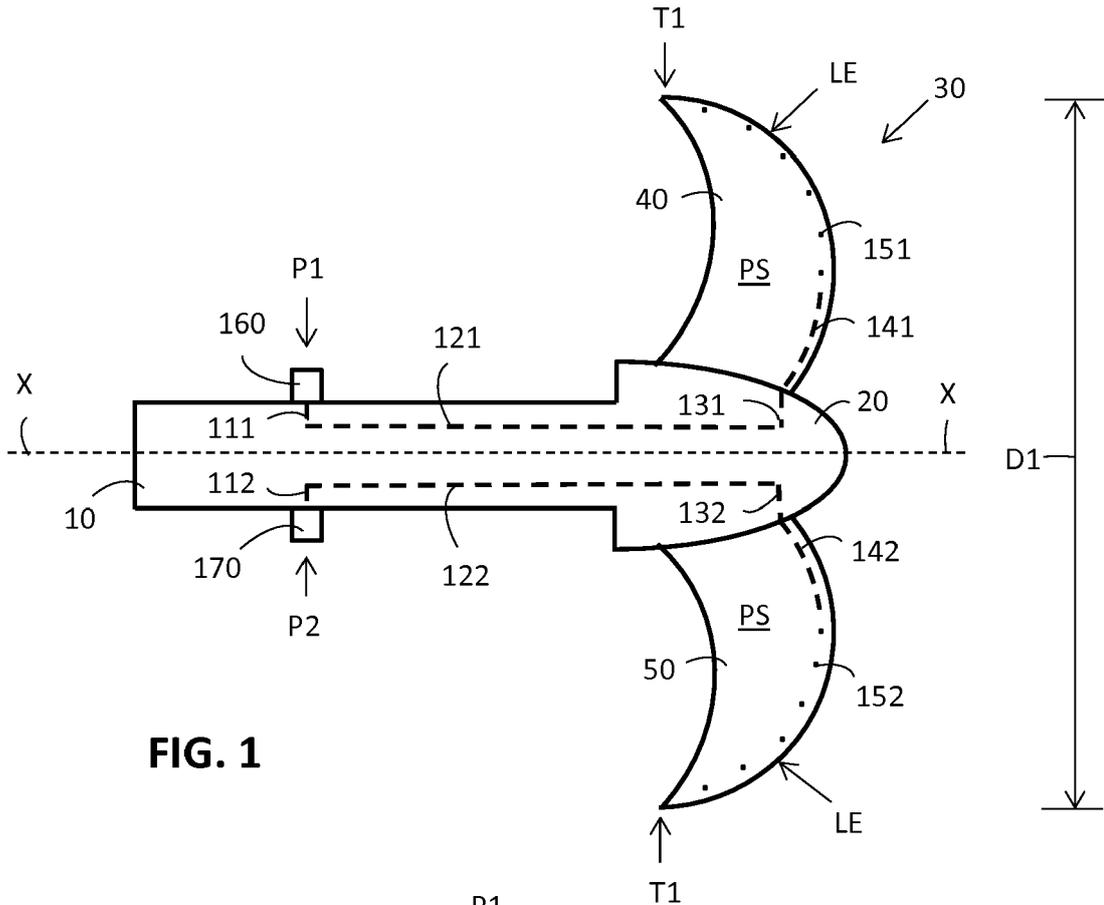


FIG. 1

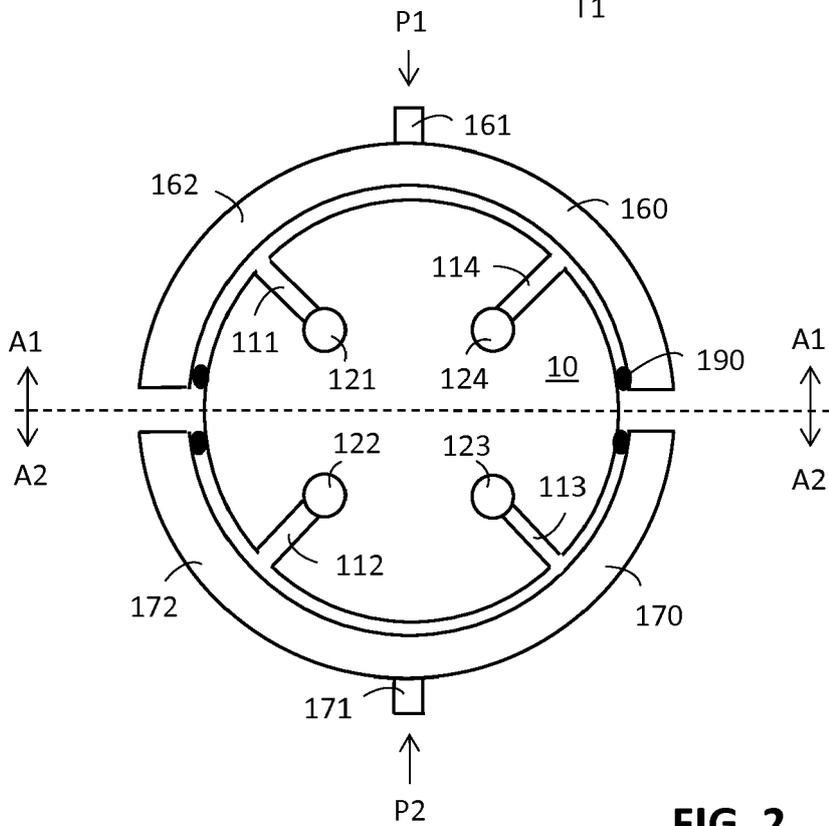


FIG. 2

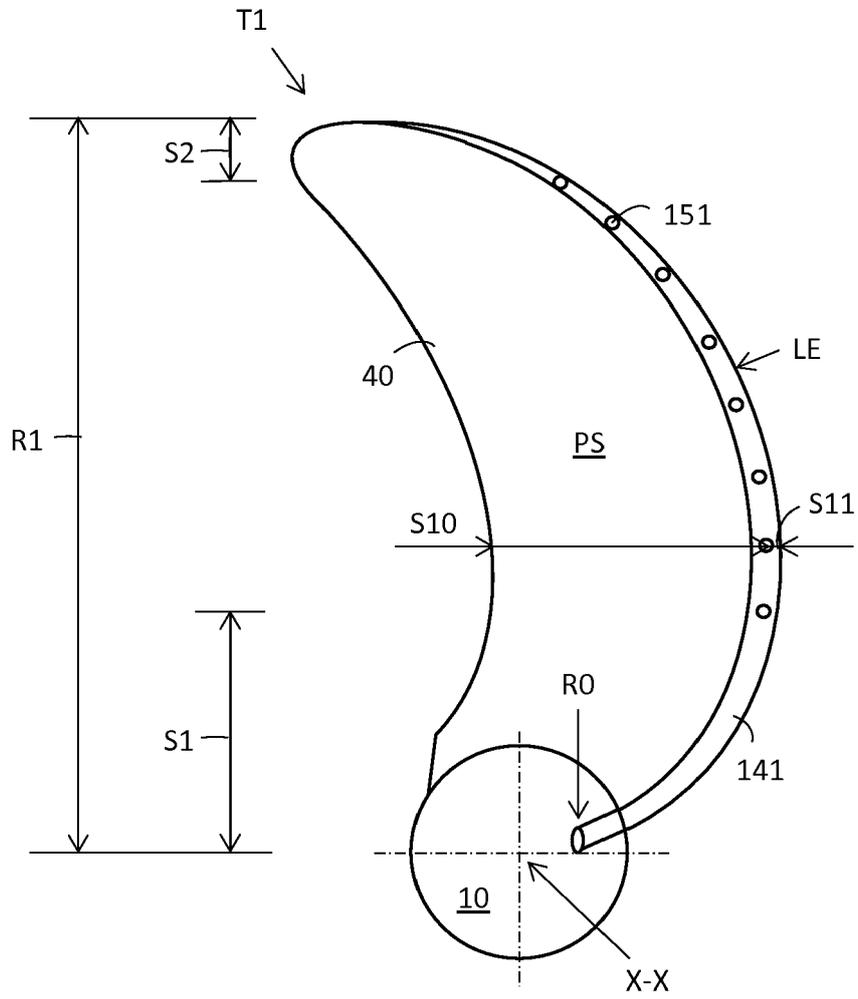


FIG. 3



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Application Number
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ANNEX TO THE EUROPEAN SEARCH REPORT
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