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(54) Device and method for mixing a gas with a liquid or a liquid with a liquid

(57) This invention relates to a method for mixing a gas with a liquid or a liquid with a liquid, and a device designed to implement the said method.

The said device comprises a propeller (1) which contains a channel that places the upper surface of the blades (4) in communication with the environment containing a gas or liquid to be mixed with a liquid. The said device draws the gas, such as air, from the external en-

vironment (or a liquid) using the negative pressure generated on the upper surface of the propeller blades immersed in the liquid, such as water, when the propeller is rotated, the said negative pressure being sufficient to suck in the said air. The air thus aspirated will mix effectively with the liquid mass due to the effect of the vortex caused by the rotating propeller, which breaks up the air into a myriad of bubbles, thus greatly increasing the exchange surface.

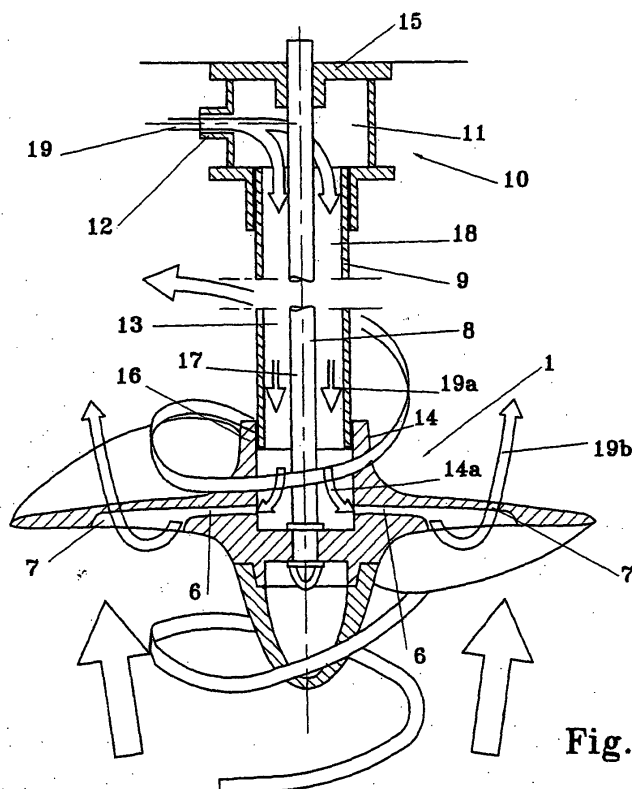


Fig. 4

Description

[0001] This invention relates to a device and the corresponding method for mixing a gas with a liquid or a liquid with a liquid.

[0002] The said device comprises a ship's propeller which contains a channel that places the upper surface of the blades in communication with the environment containing a gas or liquid to be mixed with a liquid.

[0003] The said device draws the gas, such as air, from the external environment (or a liquid) using the negative pressure generated on the upper surface of the propeller blades immersed in the liquid, such as water, when the propeller is rotated, the said negative pressure being sufficient to suck in the said air. The air thus aspirated will be effectively mixed with the liquid mass by the effect of the vortex caused by the rotating propeller, which breaks up the air into a myriad of bubbles, thus greatly increasing the exchange surface.

[0004] Processes which require two fluids, especially a gas and a liquid, to be mixed are used in various industrial systems (the chemical, food, water treatment and aquaculture industries, etc.).

[0005] Various systems are used to mix a gas with a liquid, which fall into three groups:

- o Air-blowing aerators: devices that comprise a compressor which conveys air through a pipe to the liquid mass through a porous diffuser into which the pressurised air passes. These systems are relatively complex, and require considerable maintenance because they are prone to clogging.
- o Mechanical aerators: these aerators create strong turbulence at the free surface, thus accentuating the natural exchange between the liquid surface and the gas. They comprise turbines which create a vortex that sucks in air and mixes it with water, breaking it up into bubbles, and rotating brushes which strongly agitate the surface of the water. These systems are very noisy and create a great deal of spray.
- o Aerators which use the Bernoulli principle: these aerators accelerate the liquid with pumps and ejectors or submerged turbines to create a negative pressure and draw the gas into a stream of liquid. These devices present the drawback that a large exchange surface is not formed between the liquid and the gas, resulting in less efficient mixing.

DESCRIPTION OF THE INVENTION

[0006] The purpose of this invention is to overcome the drawbacks of the known art by providing a device that is easy and cheap to instal, requires little maintenance, does not produce spray, is not prone to clogging, and guarantees excellent mixing of a gas or liquid with a liquid.

[0007] The method in accordance with the invention

can be conveniently used in all cases in which it is necessary to mix a liquid with a gas or another fluid, such as (by way of example but not of limitation) activated-sludge biological treatment plants for urban wastewater or uses in the chemical industry.

[0008] The invention will be better understood from the following description and the annexed figures, wherein:

- figures 1 and 2 show a propeller and the pressure trend on the blade profile
- figure 3 shows a propeller blade in a device in accordance with the invention, in cross-section
- figure 4 shows a possible embodiment of the device in accordance with the invention, in cross-section.

[0009] The specific case of mixing a gas with a liquid will be referred to herein, but the same inventive idea could obviously apply to the mixing of two liquids, while still remaining within the ambit of protection of this invention.

[0010] If the intersection of a ship's propeller (1) with various cylinders (2) having an axis coinciding with that of the said propeller is considered, cross-sections (3) of the profile (3a) of the blades (4) will be obtained.

[0011] When airfoil profiles move in a fluid, they generate a flow such that overpressure is created on the lower surface of the said profiles and negative pressure on the upper surface thereof. Lift is due to the combined effect of this overpressure and negative pressure.

[0012] The term "airfoil profiles" means any profile that generates negative pressure when it moves in a fluid.

[0013] A ship's propeller exploits the same effect, because the blade has a profile (3a) which generates the same type of flow in the liquid; when it rotates, it therefore creates negative pressure on the upper surface of the blades of the said propeller.

[0014] The present invention is based on exploitation of that principle.

[0015] If the upper surface of the said blades is placed in communication with an environment containing a gas via a pipe, the said gas will be aspirated as a result of the negative pressure created on the upper surface of the blades.

[0016] The gas aspirated in this way enters the stream of liquid and mixes with it, mixing being aided by the fact that the said gas is in a highly vortical fluid, with the result that the exchange surface is very large.

[0017] The diagram in fig. 2 shows the direction and magnitude of the forces which act on airfoil (3a) of the said cross-section (3) of blade (4) when the said blade advances in the liquid at velocity V, having an angle of attack α . The resultant F of the said forces can be broken down into a force P, which constitutes the propulsive thrust, and a force R, which constitutes the fraction due to generation of lift and resistance to the advance of the blade in the liquid (drag).

[0018] Another force R', due to the viscosity of the liquid, which has the same direction as R, also acts on the blade.

[0019] If the propeller is kept stationary, by reaction the said forces P and R' act on the liquid, causing a liquid flow and a vortex respectively, which are coaxial with the said propeller.

[0020] The diagram in fig. 3 shows the pressure trend along airfoil (3a) of the said cross-section (3), the said pressure trend being correlated with the force trend shown in fig. 2.

[0021] This figure demonstrates that a negative pressure of high value is regenerated on the upper surface of the blade.

[0022] If an opening (7) is made in an area (5) of the upper surface of the blade, and the said opening is placed in communication with the environment containing the gas by means of pipe (6) which runs along the blade, when the propeller is rotated the negative pressure generated in the said area (5) will have the effect of sucking in the gas, which is at a higher pressure.

[0023] A possible form of embodiment of a device in accordance with the invention, which is shown in fig. 4 by way of example but not of limitation, comprises:

- a propeller (1) fitted with a plurality of blades (4) which rotates on a bearing (16), pipes (6) and openings (7) in the said blades (4) allowing the liquid in which blades (4) are immersed to communicate with a cavity (14a) inside hub (14) of the said propeller (1)
- a tubular element or pipe (8) with axis (17) which also acts as load-bearing structure of the system, the first extremity of which is integral with a support (19), and the second extremity of which is fitted to the said bearing (16) on which propeller (1) rotates, the cavity (13) of the said pipe (9) communicating with the said cavity (14a)
- a drive shaft (8) located in cavity (13) of pipe (9) which causes propeller (1), connected to a motor (not illustrated), to rotate, the said drive shaft being centred at the first extremity by bearing (15) of support (10), and at the second extremity by hub (14) of the said propeller (1), the said hub (14) being centred on the said axis (17) by the said bearing (16), which is inserted between the said hub (14) and the said pipe (9)
- an opening (12) in support (10) which places the environment containing the gas in communication with a cavity (18) between the said pipe (9) and the said shaft (8).

[0024] With reference to the embodiment described, the gas follows the route indicated by arrows (19), (19a) and (19b), enters opening (12) in support (10) and reaches blades (4), then exits through openings (7), passing through cavity (18), cavity (14a) in hub (14) and pipes (6) in blades (4).

[0025] The gas follows the said route indicated by arrows (19), (19a) and (19b) due to the difference in pressure between the environment from which the said gas is drawn and area (5) of the upper surface of blade (4), the said pressure difference being due to the rotation of propeller (1), which receives the necessary power from drive shaft (8) which connects the said propeller (1) to the motor.

[0026] The liquid outside the propeller, which is subjected to force P (fig. 2) as a result of the pressure difference between the upper and lower surfaces of blades (4), follows a straight approach route (20) to propeller (1). Near the propeller, vortex (21), generated by viscous force R' caused by the movement of the said blades (4) relative to the liquid, is superimposed on the said straight movement (20).

[0027] The gas which exits from openings (7) in blades (4) mixes with the liquid in the area of greatest vorticity, and consequently breaks up into a myriad of bubbles which maximise the contact surface between liquid and gas.

[0028] The device to which the invention relates presents various advantages over the known art; in particular it is not prone to clogging and, as it operates totally immersed in the liquid and the gas passes through a pipe, without creating liquid-gas exchange surfaces in communication with the free surface, it does not create spray, and is also much quieter.

[0029] In terms of plant engineering it is easy to instal, and the mixing is so efficient that less power is required to produce the same effect.

[0030] The device in accordance with the invention could be used in all fields in which a gas needs to be mixed thoroughly with a liquid, as in the case of the water treatment industry.

[0031] An expert in the field could devise numerous modifications and variations, all of which should be deemed to fall within the scope of this invention.

Claims

1. Device for mixing a gaseous or liquid fluid with a liquid, **characterised in that** it includes an element immersed in the liquid which, by interacting with the said liquid, creates a negative pressure that sucks the gaseous or liquid fluid from an environment which contains the said gaseous or liquid fluid.
2. Device for mixing a gaseous or liquid fluid with a liquid as claimed in the preceding claim, **characterised in that:**
 - the said element which interacts with the said liquid is a blade with a cross-section having an airfoil profile (3a) which, when it travels in the said liquid, generates areas of negative pressure in correspondence with the upper surface

of the said airfoil (3a)

- the said areas of negative pressure are placed in communication via a channel with the said environment which contains the said gaseous or liquid fluid.

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which run inside the blade and its supports.

3. Device for mixing a gaseous or liquid fluid with a liquid as claimed in claim 2, **characterised in that:**

- the said blade, which has a cross-section with an airfoil profile (3a), is a blade (4) of a propeller (1)
- the said channel which connects the said negative pressure areas with the said environment containing the said gas comprises one or more openings (7) and pipes (6) in blades (4) of propeller (1), and a pipe which places pipes (6) in communication with the environment containing the gas.

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4. Device for mixing a gaseous or liquid fluid with a liquid as claimed in claim 1, **characterised in that** it includes:

- a propeller (1) which receives motion from a drive shaft (8) that rotates inside a tubular element (9) which constitutes a supporting structure for the said propeller (1) and the said drive shaft (8)
- one or more openings (7) in the upper surface of the blades of the said propeller
- pipes (6), (14a) and (18) in blades (4), hub (14) of propeller (1) and supporting pipe (9) respectively, which place the said openings (7) in blades (4) in communication with opening (12), which in turn places the device to which the invention relates in communication with the environment containing the gas to be mixed with the liquid.

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5. Method for mixing a gaseous or liquid fluid with a liquid, **characterised in that** at least one blade having an airfoil profile is caused to move in the said liquid and that the upper surface of the said blade is placed in communication with the environment containing the gas to be mixed with the liquid.

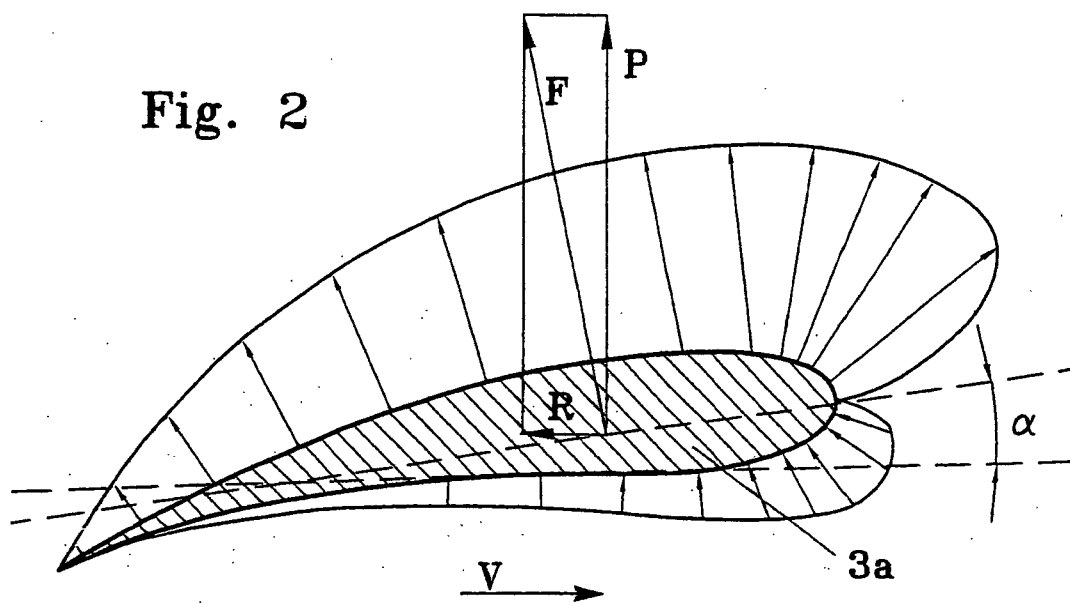
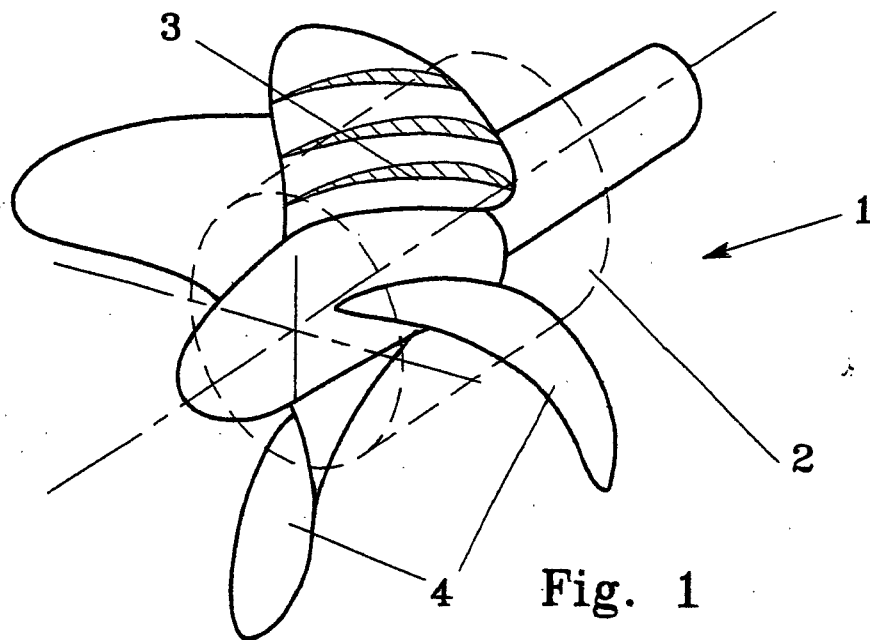
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6. Method for mixing a gaseous or liquid fluid with a liquid as claimed in claim 5, **characterised in that** a propeller immersed in the liquid is made to rotate and that the upper surface of the blades of the said propeller is placed in communication with the environment containing the gas to be mixed with the liquid.

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7. Method as claimed in claim 6, **characterised in that** the upper surface of the blade is placed in communication with the exterior by means of pipes



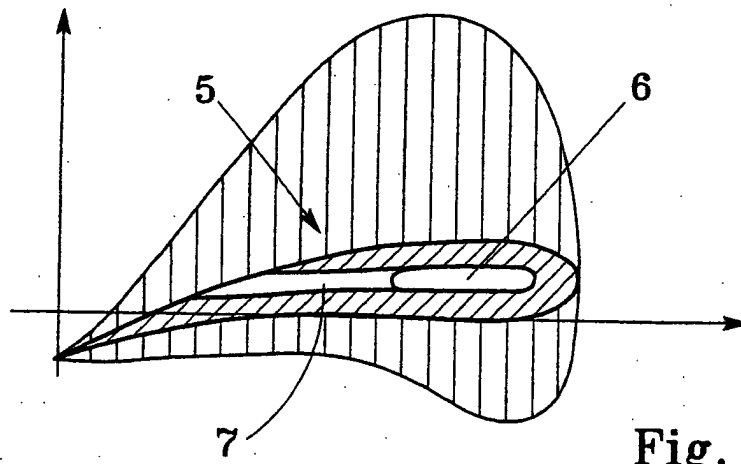


Fig. 3

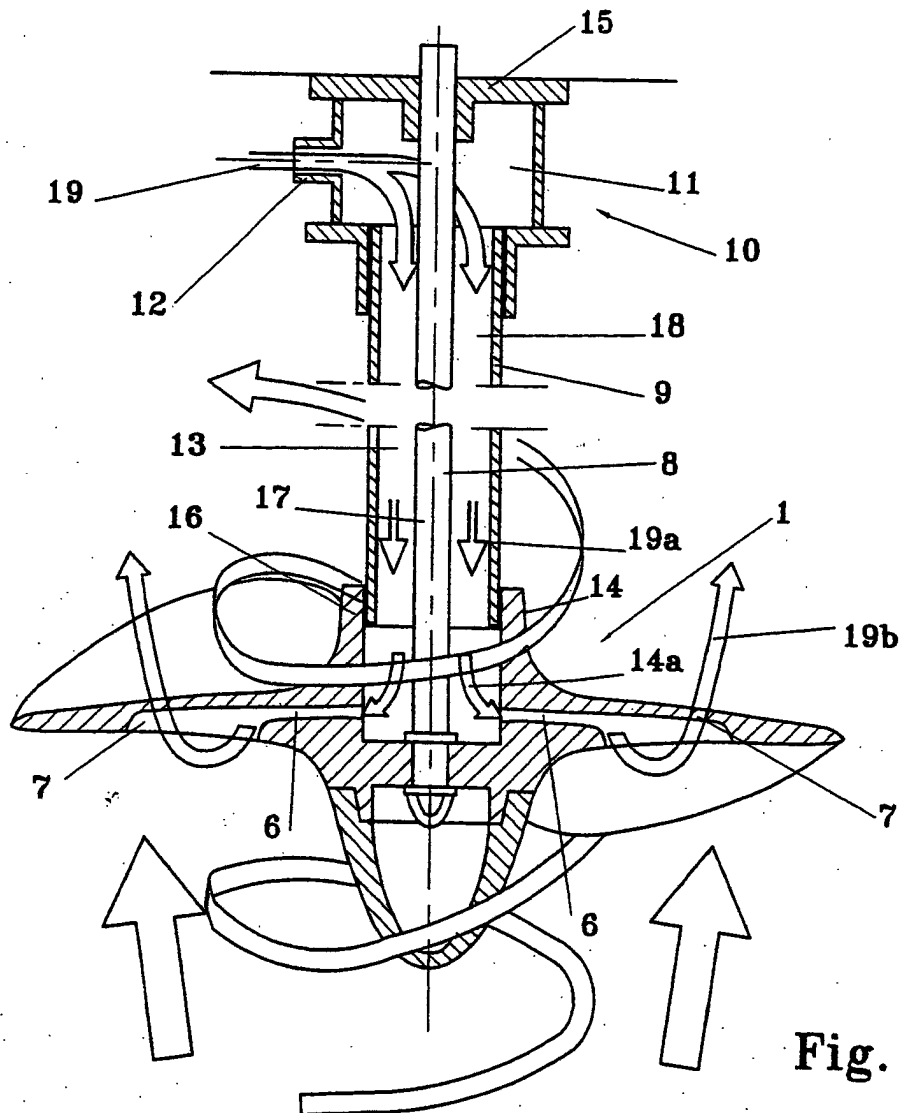


Fig. 4