

WATER TREATMENT APPARATUS FOR KILLING ORGANISMS AND
METHOD FOR TREATING SEAWATER

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The subject of the invention is a water treatment device comprising a water grinder and a pumping device, the water grinder having a rotor and a stator, the diameter of which increases in the direction of flow towards the outlet and the rotor and the stator forming an annular gap. In addition, the subject of the invention is a process for the treatment and processing of sea water, preferably ballast water on ships.

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Numerous processes are known for the processing of water. It is usual for the processing of water to be carried out mechanically, for example by filtration or ultrasound, chemically, for example by chlorine or oxygen, or biologically. Whilst chemical processes have the drawback that additional substances have to be used which for their part are in part environmentally harmful themselves, numerous mechanical processes are associated with a high outlay in terms of apparatus and a high energy input. As a result, the processes are frequently quite costly and can be carried out only in sectors in which space and the energy requirement are less relevant.

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Jyoti and Pandit describe a series of mechanical water processing methods in which the disinfection is carried out by cavitation (K.K. Jyoti, A.B. Pandit, Biochemical Engineering Journal, Vol. 7, 2001, pp. 201 to 212). In this case an efficient killing can be achieved by cavitation without the use of additional chemicals. Only with the use of high pressures of for

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example 69 to 689 bar, however, is a satisfactory result achieved, and this involves a corresponding
5 outlay in terms of apparatus and a high energy consumption.

As well as the water processing, for example in sewage treatment plants or in industry, this problem also arises for the processing of sea water, in particular ballast water. Organisms are taken in
10 together with the ballast water. When the ballast water is drained, these organisms are discharged again into the marine environment. On account of the international maritime traffic which has branched out
15 very widely in the meantime, an intense introduction of alien organisms into the marine environment takes place. In order to regulate the water exchange when taking on and draining ballast water, the International Convention for the Control and Management
20 of Ships' Ballast Water and Sediments has been adopted in the meantime. According to this, ballast water must be treated on board the ship before it is discharged again into the marine environment in order to prevent alien organisms from being introduced.

25 A process for the disinfection of ballast water is known from EP 1 975 130 A2. In this case the ballast water is conveyed through a homogenizer provided with a rotor and a stator. The micro-organisms contained in the ballast water are killed by
30 the shear forces arising there and by the cavitation. In this case, however, a loss of pressure occurs by way of a homogenizer, so that, depending upon the pressure applied, the flow velocity necessary for an adequate cavitation is no longer maintained.

The object of the invention is therefore to provide a device for the processing of water which is not subject to the drawbacks named above, and, in particular, even at low water pressures an adequate flow velocity leads to an effective killing of living creatures and organisms, in particular micro-organisms, without high amounts of energy having to be applied for this or additional substances which are environmentally harmful in part having to be used.

The object is attained according to the invention by a water treatment device comprising a water grinder and a pumping device, the water grinder having a rotor and a stator, the diameter d of which increases in the direction of flow towards the outlet, and the rotor and the stator forming an annular gap, characterized in that the toothing depth and the annular gap are reduced in the direction of flow towards the outlet, the annular gap at the outlet preferably has a width of from 2 μm to 20 μm , the rotor and the stator each have cross cut toothing on the surface which is arranged in opposite directions on the rotor and the stator, and the stator has a diffuser ring in the area of the outlet in place of the cross cut toothing.

In addition the object is attained by a process for water processing comprising at least the stages

- a. entry of the water into a storage reservoir,
- b. pumping of the water with a build-up of pressure to a pre-cleaning stage, preferably a filter,
- c. physical / mechanical pre-cleaning of the water in the pre-cleaning stage,

d. treatment of the water in a water treatment device according to the invention, wherein the organisms present in the water are killed, and

e. transfer of the water into a further storage reservoir.

Further embodiments form the subject matter of the sub-claims or are described below.

The water treatment device according to the invention permits an effective killing of living creatures and micro-organisms, even at low water pressures. The organisms are ground mechanically or are damaged by the scraping or separation of the cell walls on the teeth of the rotor and stator in such a way that they die. In addition, a further killing is achieved by the cavitation at the outlet at the annular gap and the abrupt pressure release or implosion caused thereby.

Organisms are understood according to the invention as being the living creatures and micro-organisms which are present in water, in particular in sea water, such as for example algae, fungi, bacteria, single cell organisms, small fish, crustaceans and plankton organisms.

The water treatment device according to the invention has a water grinder comprising a rotor and a stator. The surfaces of both the rotor and the stator have cross cut or random toothing, preferably cross cut toothing. The toothing depth on the rotor is reduced preferably to zero in the direction of flow towards the outlet and on the stator preferably to zero in the direction of flow towards the diffuser ring. The number of teeth and the distance between the

teeth depend in this case upon the diameter. The distances are selected in such a way that the desired swirling occurs. A shearing gap is formed by the reverse toothing of the two surfaces, and the two sets of teeth intersect with one another in the aforesaid shearing gap upon each revolution. It is preferable for the toothing depth and the annular gap to be reduced in the direction of flow towards the outlet so that the water is constantly swirled in a turbulent manner by the altered swirling zone. As a result of the turbulent swirling the organisms present in the water are subjected to a cutting and tearing effect between the surfaces of both the rotor and the stator, the so-called grinding surfaces. They are both ground mechanically and cut and torn on the surfaces, in which case the cell wall is destroyed mechanically in such a way that the organisms die.

The diameter both of the rotor and of the stator is increased in the direction of flow towards the outlet, so that the rotor and the stator preferably have a conical shape. On account of the increase in the diameter the liquid is accelerated along the decreasing annular gap. The grinding faces form a narrowly tapering annular gap which at the outlet has a width of preferably from 2 to 20 μm , more preferably from 2 to 10 μm , and in a particularly preferred manner 5 μm . It is preferable for the rotor to have a drive shaft which is driven by way of an electric motor.

As a result of the shear forces acting upon the organisms the latter are destroyed mechanically during the flow through the water grinder. This effect is

amplified as the distance between the rotor and the stator is reduced to an increasing degree and thus as the width of the annular gap decreases. The flow velocity increases strongly along the annular gap and the pressure in the medium conveyed increases. Cavitation effects occur as a result of the high flow velocities and the high pressures acting at the point of the smallest distance between the rotor and the stator at the outlet and the directly following large increase in the cross-section in the region of the discharge plate.

The killing of the organisms is thus carried out by the mechanical grinding or scraping and separation respectively in the region of the rotor and the stator on the one hand and by the cavitation at the outlet at the annular gap on the other hand. The organisms are destroyed or at least damaged to such a degree that they die.

In addition, in the region of the outlet the stator has a diffuser ring on its surface. The diffuser ring is preferably formed by an impressed random pattern on the surface of the stator, and in a particularly preferred manner by point-wise raised portions on the surface. On account of the impressed close pattern with many irregularities in a small area on the surface, the diffuser ring ensures an additional amplified swirling which causes a further grinding of the organisms. Furthermore, the additional swirling assists the formation of cavitation at the outlet of the water grinder. The rotor preferably has no toothing or notching in the region opposite the diffuser ring.

At the outlet of the annular gap of the water treatment device according to the invention, preferably on the tear-off edge, the local velocities of the water droplets are increased to such a degree that they reach a supercritical speed. On account of the abrupt increase in the cross-section, which then occurs in the region of the discharge plate, the water droplets tear off and cavitate. Pressure waves of 20,000 Hz and above and with a high intensity of up to 1,000 W per cm² occur in the immediate surroundings. The water droplets and the organisms contained in them implode as a result of the high pressure gradient. The organisms are killed in this case or the cell walls thereof are damaged to such a degree that they die. This procedure is for example comparable with the effect which occurs with the abrupt emergence of a diver from a great depth of water.

During the operation of a flow machine, as is present according to the invention in the form of the water grinder, pressure losses usually occur. These pressure losses are not desired since the remaining system pressure is in part no longer sufficient for the actual operation. In particular, only a low operating pressure of from 1 to 3 bar is available on board ships during the processing of ballast water.

In the case of the water treatment device according to the invention the pressure losses are compensated by a pumping device, in particular an internal pumping device. As compared with customary cavitation devices, for example nozzles, the water treatment device according to the invention has the advantage that there is no need for external jet pumps

with high pressure or ultrasonic generators which actively introduce ultrasonic energy into the liquid.
5 The electrical power which is very high for this for the energy input can thus be avoided and the outlay in terms of apparatus and energy for the water treatment device according to the invention is thus significantly lower than in the case of conventional
10 devices.

The internal pumping device preferably comprises an impeller wheel at the inlet of the water grinder and a discharge blade at the outlet of the water grinder. The impeller wheel is positioned as an
15 additional blade in the lower region of the rotor. As a result of the pumping action of the impeller wheel the pressure of the water entering is increased and the necessary flow velocity is achieved.

In addition, at the outlet of the water treatment
20 device a discharge blade is preferably fastened to the discharge plate, which compensates the drop in pressure which occurs downstream of the tear-off edge. The water grinder and the internal pumping device thus preferably form a structural unit.

25 The internal pumping device has the advantage that the water treatment device does not adversely affect the system pressure and no additional external pumps are required.

In the embodiment with the internal pumping
30 device the acceleration and generation of the desired pressure gradients are started at the entry to the grinder with the impeller wheel mounted on the rotor and further by the rotor and stator increasing in diameter in the form of a wedge as well as the axial

acceleration of the water at the ends of the notches. On account of the tothing of the rotor and the stator the water is braked when passing through the narrowing annular gap and it is accelerated again to a supercritical velocity and the following tearing and cavitation of the water at the outlet of the annular gap.

10 The necessary penetration and therefore the necessary low power density of the cavitation are low on account of the small gap of only a few μm . The intensity of the pressure waves is sufficient, however, to ensure that the organisms contained in the water are killed. Herein lies an advantage of the water treatment device according to the invention as compared with active ultrasonic generators. In the case of the latter very high power and therefore a high energy requirement are necessary in order to achieve a penetration approximately acceptable for killing the organisms. In many cases, however, such penetration is not achieved even at high power.

25 The water treatment device according to the invention and the process according to the invention can be used in a particularly effective manner in the case of sea water and, in particular, in the case of ballast water. When used on ships the water pumped through the physical / mechanical pre-cleaning stage frequently has only a low water pressure. The use of additional external pumps is frequently problematic since additional amounts of energy have to be made available for this. When the water treatment device according to the invention is used with an internal pumping device no additional pumps are necessary and

so no additional energy consumption also occurs on the ship.

5 It is preferable for the stator to be fastened to a base plate by at least one fastening means, the stator being fastened to the base plate in a radially displaceable manner. In order to be able to set the very narrow annular gap of a few μm , an exact
10 orientation between the rotor and the stator is necessary. This is implemented structurally by a radially displaceable stator against the rotor. The stator is positioned on a base plate and is first fixed on the latter only to the degree that it is
15 displaceable within certain limits. In a first step the stator is precisely centred by insertion of the rotor as far as the stop. The rotor then is lifted out axially by a defined length in a second step, so that very small annular gaps can also be made possible. The
20 stator is then finally fixed, so that no further displacement is possible. On account of this design, annular gaps as small as desired are possible which are dependent only upon the manufacturing accuracy of the components.

25 The process according to the invention is preferably used for the processing of sea water, in particular of ballast water. The sea water comes on board the ship in a sea container. It is then pumped in the direction of a physical / mechanical pre-
30 cleaning stage by means of a ballast water pump. Ballast water pumps on board ships work at low operating pressures of from 1.5 to 3 bar, preferably 2 bar. The water is filtered in order to free it from sediments and coarse particles. A pressure loss occurs

during the flow through the pre-cleaning stage, so that the water pressure downstream of the pre-cleaning is lower than upstream of the filter. In order that the pressure or the flow velocity of the water in the water treatment device is sufficiently high for cavitation to occur, an external pump or preferably an internal pump device is used, which conveys the water back to the appropriate flow velocity or the appropriate pressure respectively. The organisms present in the water are killed in the water treatment device.

The physical / mechanical pre-cleaning stage is preferably a filter, a filtration plant or a hydrocyclone. According to the invention, however, other devices can also be used which separate impurities and organisms from the water by physical / mechanical methods.

In one embodiment the water cleaned in the water treatment device is additionally cleaned in a further process step. The additional cleaning / after treatment can then take place by means of biological methods, such as for example UV radiation, chemical methods, such as the metering of germicidal agents or further mechanical methods. The water cleaned in this way is then conveyed into a further storage reservoir and, during the cleaning of sea water on board ship, into the ballast water tank.

The invention is explained in greater detail with reference to the figures. In the drawing

Figure 1 shows the design of a water treatment device according to the invention with an internal pumping device;

Figure 2 is a partial view of a water grinder according to the invention with a rotor drawn out of the stator, and

Figure 3 shows the course of the process according to the invention.

Figure 1 shows the water treatment device 1 according to the invention comprising a water grinder 2 and an internal pumping device 3. The water grinder 2 and the pumping device 3 form a structural unit in this case. The water passes along the arrow A into the water treatment device 1. There it is additionally accelerated by the impeller wheel 12 which is situated on the underside of the rotor 4, and is conveyed into the annular gap 8. The annular gap 8 is formed by the rotor 4 and the stator 5. It is evident that the annular gap 8 is reduced along the direction of flow of the water. At the end of the annular gap 8 the water flows over the tear-off edge 11. A cavitation occurs as a result of the great increase in the cross-section. The water is additionally accelerated in the direction of the outlet 9 by the discharge blades 13 which are fastened to the guide plate 14. The rotor 4 and the guide plate 14 are driven by way of a drive shaft 15. The water issues cleaned from the water treatment device 1 along the arrow B. The drive shaft 15 is connected to an electric motor (not shown). The fastening of the stator 5 to the base plate 16 is likewise not shown. The fastening can be carried out for example by screws which are inserted into the base plate 16 and which are mounted in elongate holes.

Figure 2 shows in detail an embodiment of the rotor 4 and the stator 5 of the water grinder 2. The

surface 6 of the rotor 4 and the surface 7 of the stator 5 have tothing in the form of notching in each case. It is evident that the tothing or notching respectively of the rotor 4 and the stator 5 are opposite in this case. The rotor 4 is shown here extracted out of the stator 5.

The upper end of the stator 5 has a diffuser ring 10. Numerous small, very fine notches, which are illustrated only diagrammatically here, are provided in the region of the diffuser ring 10. In the region opposite the diffuser ring 10 the rotor 4 has no notching or tothing since the tothing here has become zero. The tear-off edge 11 is situated in the region in which the rotor 4 and the stator 5 have the greatest diameter d.

Figure 3 shows the diagrammatic pattern of the process according to the invention. Sea water enters a sea container 20. The water is pumped by means of a ballast water pump 21 through a filter 22 and there it is freed of sediments and relatively large organisms. The water now enters at lower pressure the water treatment device 1 which is equipped in this case with an internal pumping device. There it is cleaned mechanically and the pressure is increased again to an operating pressure of 2 bar. The water is then subjected to an after treatment 23 for example here. After that, it is conveyed to the ballast water tank 24. Alternatively, the water can also be conveyed directly from the water treatment device 1 into the ballast water tank 24.

List of References

5	1	water treatment device
	2	water grinder
	3	pumping device
	4	rotor
	5	stator
10	6	surface of the rotor
	7	surface of the stator
	8	annular gap
	d	diameter
	9	outlet
15	10	diffusor ring
	11	tear-off edge
	12	impeller wheel
	13	discharge blade
	14	guide plate
20	15	drive shaft
	16	base plate
25	20	sea container
	21	ballast water pump
	22	filter
	23	after treatment
	24	ballast water tank

Claims

- 5 1. Water treatment device (1) comprising a
water treatment grinder (2) and a pumping device (3),
where the water treatment grinder (2) has a rotor (4)
and a stator (5), the diameter d of which increases in
the direction of flow towards the discharge opening,
10 and where rotor (4) and stator (5) form an annulus,
characterised in that
- the depth of engagement of the gears and the
annulus (8) become reduced in the direction of flow
towards the discharge opening (9),
 - 15 - the rotor (4) and the stator (5) each have a
surface with cross cut
 gearing on the surface (6,7) that runs in
opposite directions on the rotor (4) and the stator
(5) or a random surface pattern (6, 7), and
 - 20 - that the stator (5) has a diffuser ring (10)
in the area of the discharge opening in place of the
cross cut gearing or the random pattern.
- 25 2. Water treatment device (1) in accordance
with Claim 1, characterised in that the diffuser ring
(10) has a surface (7) with an embossed, random
pattern, preferably in the form of point-like
projections on the surface (7).
- 30 3. Water treatment device (1) in accordance
with Claim 1 or 2, characterised in that the water
treatment grinder (2) has a tear-off edge (11) after
the annular gap (8).

4. Water treatment device (1) in accordance
with one of the preceding claims, characterised in
5 that the annular gap (8) has a width at its outlet (9)
of 2 μm to 20 μm , preferably 2 μm to 10 μm .

5. Water treatment device (1) in accordance
with one of the preceding Claims. characterised in
10 that the stator (5) is fastened to a base plate by at
least one means of attachment, where the stator (5)
fastening on the base plate is such that the stator
can slide in radial direction.

15 6. Water treatment device in accordance with
one of the preceding Claims,
characterised in that the pumping device (3) is
an external or internal pumping device or a
combination of the two, preferably exclusively an
20 internal pumping device.

7. Water treatment device (1) in accordance
with Claim 6, characterised in that,
the internal pumping device consists of an
25 impeller wheel (12) at the inlet and/or a discharge
blade (13) at the outlet (9), where this discharge
blade (13) extends over the periphery of the discharge
plate (14).

30 8. Water treatment device (1) in accordance
with one of the preceding Claims,
characterised in that, at the rotor (4) the depth
of engagement of the gearing tapers to zero in the
direction of flow towards the discharge opening (9)

and/or, at the stator (5), tapers to zero in the direction of flow towards the diffuser ring.

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9. Water treatment device in accordance with one of the preceding Claims,

characterised in that the rotor (4) has a drive shaft (16) and is driven by a drive motor, preferably an electric motor (15).

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10. Process for water treatment comprising at least the stages

- a. water entry into a storage reservoir,
- 15 b. pumping of the water with a build-up of pressure to a physical/mechanical pre-cleaning stage,
- c. physical/mechanical pre-cleaning of the water in the pre-cleaning stage,
- d. treatment of the water in a water treatment
- 20 device in accordance with one of Claims 1 to 9, when the organisms present in the water are killed, and
- e. water transfer into a further storage reservoir,

25 11. Process in accordance with Claim 10, characterised in that, in an additional stage f. preceding the water transfer (e.) into the storage reservoir, a physical, chemical and/or biological post-treatment process of the water takes place.

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12. Process in accordance with one of Claims 10 or 11, characterised in that sea water, in preference ballast water, is treated.

13. Process in accordance with one of Claims 10,
11 or 12, characterised in that in stage **a.** the water
5 is transported into a sea container and in stage **e.**
into a ballast water tank, or in stage **a.** into a
ballast water tank and in stage **e.** into a sea
container.

10 14. Process in accordance with one of Claims 10
to 13, characterised in that the physical/mechanical
pre-cleaning stage consists of a filter, a filtration
plant or a hydrocyclone.