

THRUST ASSEMBLY FOR PROPELLING A VESSEL AND VESSEL COMPRISING THE THRUST ASSEMBLY

The present disclosure pertains to the field of propulsion systems for vessels. The present disclosure relates to a thrust assembly for propelling a vessel and a vessel comprising the thrust assembly.

BACKGROUND

A vessel for towing, such as a tugboat or tug, is a secondary boat that is used for maneuvering other, typically larger, vessels by pushing or pulling them either by direct contact or by means of a tow line. Tugs typically move vessels that either are restricted in their ability to maneuver on their own, such as ships in a crowded harbor or a narrow canal, or vessels that cannot move by themselves, such as barges, disabled ships, log rafts, or oil platforms.

Tugboats are powerful for their size, are strongly built and typically have a high maneuverability. Tugboats are thus often equipped with fire-fighting (Fi-Fi) systems for use as firefighting vessels, thereby offering much-needed supplementary protection to the ships and ports served by the tugboats.

Tugboats are propelled by one or more main propulsion drives. The main propulsion drive may comprise a power unit, such as an engine or an electric motor, connected to a propeller, such as an azimuth thruster, for propelling the vessel. For safety reasons, tugboats often feature two main propulsion drives for redundancy.

Tugboats are typically rated by their engine power output and their overall bollard pull. Bollard pull is a conventional measure of the pulling or towing power of a vessel. The bollard pull is defined as the force, in tons or in kilonewton (kN), exerted by the vessel under full power, on a shore-mounted bollard through a tow-line, commonly measured in a practical test (but sometimes simulated) under test conditions that include calm water, no tide, level trim, and sufficient depth and side clearance for a free propeller stream. The largest commercial harbor tugboats, used for towing container ships or similar, typically have around 60 to 65 short tons-force (530–580 kN) of bollard pull, while smaller commonly used tugboats may have a bollard pull around 15 short tons-force (130 kN) below the number for the largest tugboats.

The fire-fighting systems of the tugboats typically comprise one or more fire monitors for delivering large water flows for fire-fighting purposes and a pump for feeding the fire monitors with a flow of water.

5 Fire-fighting systems according to FiFi class I are the most commonly used fire-fighting system with a fire monitor capacity of two times 1200 m³/h of water. The tugboat may e.g. comprise two fire monitors, each having a capacity of 1200 m³/h of water. In order to provide the required flow of water to the fire monitors, the pump may be driven by an engine.

10 The pump of the fire-fighting system may be driven by one of the power units of the main propulsion drive of the vessel, such as the tugboat. This solution is cost efficient, since the same engine may be used for propulsion and for driving the pump. However, the maneuverability of the tugboat may be negatively affected when one of the power units is driving the pump, since a significant amount of power from the power unit is directed from the propeller to the pump of the fire-fighting system.

15 The pump of the fire-fighting system may also be driven by a separate power unit, such as a separate engine or electric motor. This solution however involves high costs since an additional engine or electric motor is required.

SUMMARY

20 Accordingly, there is a need for a propulsion system, which mitigate, alleviate or address the shortcomings existing and provides a reliable, powerful and cost efficient propulsion system for a vessel.

Disclosed is a thrust assembly for propelling a vessel. The thrust assembly comprises a pump for generating a first flow of sea water. The pump comprises a pump inlet and a pump outlet. The thrust assembly further comprises an ejector comprising a suction inlet
25 configured for suction of a second flow of sea water, a motive inlet connected to the pump outlet for receiving the first flow of sea water from the pump, an outlet section comprising an ejector outlet configured for discharging a third flow of sea water, a nozzle arranged downstream the motive inlet, and a diffuser arranged in the outlet section downstream the nozzle. The outlet section is configured to mix the first flow of sea water with the second
30 flow of sea water to generate a third flow of sea water, the diffuser further being configured to increase a pressure of the third flow of sea water downstream the diffuser.

It is an advantage of the present disclosure that a simple, cost efficient and reliable thrust assembly can be provided. The ejector does not comprise any moving parts and thus the risk of failure of the thrust assembly is reduced compared to thrust assemblies comprising movable parts. Furthermore, since the ejector does not comprise any moving parts,
5 limited maintenance of the propulsion system is required. Thereby maintenance cost for the thrust assembly can be reduced. The thrust assembly is compact and easy to install which makes it easy to retrofit on a vessel.

Disclosed is a vessel comprising a thrust assembly for propelling the vessel as disclosed herein. The suction inlet of the ejector is arranged below a waterline of the vessel and in
10 fluid connection with sea water surrounding the vessel, so that sea water surrounding the vessel is sucked into the ejector through the suction inlet in the second flow. The outlet of the ejector is arranged below the waterline of the vessel and in fluid connection with the sea water surrounding the vessel, so that the third flow of sea water discharged through the ejector outlet creates a thrust force propelling the vessel. When the mass of water is
15 accelerated in the ejector an opposite reaction force from the mass of water will be generated, which acts on the vessel. The reaction force may, in combination with the lower pressure in front of the nozzle, such as at the suction inlet, propel the vessel. Thus, the ejector may create an area of lower pressure at the inlet of the ejector and an area of high pressure at the outlet, such that there is a pressure difference between the fore and
20 the aft of the vessel. The pressure difference between the fore and aft of the vessel may propel the vessel forward.

It is an advantage of the present disclosure that a simple, cost efficient and reliable solution for generating thrust force for propelling the vessel is provided. Since the ejector of the thrust assembly does not comprise any moving parts the risk of failure of the thrust
25 assembly is reduced compared to thrust assemblies comprising movable parts. Furthermore, since the ejector does not comprise any moving parts, limited maintenance of the ejector is required. Thereby maintenance cost for the vessel may be reduced. An inspection of the ejector may only be required during prescheduled drydocking, such as during special surveys, such as every fifth year.

30 It is an advantage of the present disclosure that the pump providing the first flow of sea water may be any pump configured to providing a required flow of water. Hence, a pump of a fire-fighting system of the vessel may be used for generating the thrust force propelling the vessel.

The thrust assembly may further be used in addition to a main propulsion system of the vessel to increase the bollard pull of the vessel. This allows the main propulsion system of the vessel to be downsized, since the maximum required bollard pull may be generated by the thrust assembly in combination with the main propulsion unit. Thus, smaller and/or
5 less powerful main engines and propellers may be used, which increases the energy and cost efficiency of the main propulsion unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present disclosure will become readily apparent to those skilled in the art by the following detailed description of
10 exemplary embodiments thereof with reference to the attached drawings, in which:

Fig. 1 illustrates an example of a thrust assembly according to this disclosure,

Fig. 2 illustrates an ejector comprising a nozzle according to one or more first embodiments according to this disclosure,

Fig. 3 illustrates an ejector comprising a nozzle according to one or more second
15 embodiments according to this disclosure, and

Fig. 4 illustrates an example of a vessel comprising the thrust assembly according to this disclosure.

DETAILED DESCRIPTION

Various exemplary embodiments and details are described hereinafter, with reference to
20 the figures when relevant. It should be noted that the figures may or may not be drawn to scale and that elements of similar structures or functions are represented by like reference numerals throughout the figures. It should also be noted that the figures are only intended to facilitate the description of the embodiments. They are not intended as an exhaustive description of the disclosure or as a limitation on the scope of the disclosure.
25 In addition, an illustrated embodiment needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular embodiment is not necessarily limited to that embodiment and can be practiced in any other embodiments even if not so illustrated, or if not so explicitly described.

The figures are schematic and simplified for clarity, and they merely show details which aid understanding the disclosure, while other details have been left out. Throughout, the same reference numerals are used for identical or corresponding parts.

5 A thrust assembly for propelling a vessel is disclosed. The thrust assembly comprises a pump for generating a first flow of sea water. The first flow of sea water may herein also be referred to as a flow of motive fluid.

The pump comprises a pump inlet and a pump outlet. The pump inlet may be configured to be in fluid connection with sea water surrounding the vessel, when the thrust assembly is arranged on the vessel. The motive fluid may thus be sea water. Sea water herein
10 refers to the water surrounding the vessel when the vessel is operating. In order to provide the desired thrust force, the capacity of the pump may be in the range of 2,000 to 3,000 m³/h and/or at a pressure of 9 to 11 bar. In comparison, portable fire pumps (which are referred to as Tragkraftspritzen in German) typically have a capacity of 800-2400 liter per minute (l/min), which corresponds to a capacity of 48-144 m³/h. Hence, portable fire
15 pumps are not able to provide the desired thrust force and are thus not suitable for use with the thrust assembly according to this disclosure.

The thrust assembly comprises an ejector for generating a thrust force for propelling the vessel.

The ejector is a jet device which uses the motive fluid provided to the ejector at a first
20 pressure to entrain a suction fluid at a second pressure and discharge the mixture of suction and motive fluids against a third pressure. The first pressure is higher than the second and the third pressure, while the third pressure is higher than the second pressure. The first pressure may thus be referred to as a high pressure, the second pressure may be referred to as a low pressure and the third pressure may be referred to
25 as an intermediate pressure. The operation of the ejector is based upon Bernoulli's Principle. Bernoulli's principle states that when the speed of a fluid increases its pressure decreases and vice versa.

The ejector comprises a suction inlet configured for suction of a second flow of sea water at the second pressure, a motive inlet connected to the pump outlet for receiving the first
30 flow of sea water from the pump at the first pressure and an outlet section comprising an ejector outlet configured for discharging a third flow of sea water at the third pressure.

The ejector comprises a nozzle arranged downstream the motive inlet and a diffuser arranged in the outlet section downstream the nozzle. The outlet section is configured to mix the first flow of sea water with the second flow of sea water to generate a third flow of sea water. The diffuser is configured to increase a pressure of the third flow of sea water downstream the diffuser. The pressure of the third flow of sea water creates a thrust force. The thrust force acts against the medium surrounding the vessel, such as the sea water surrounding the vessel, and thereby propels the vessel when the vessel is operating in the sea water. In other words, the diffuser is configured to increase the pressure of the third flow of sea water discharged from the ejector outlet is higher than the pressure of the second flow of sea water sucked into the ejector through the suction inlet.

The ejector may be shaped as an elongated body, such as a pipe, comprising three connections. The three connections are the motive inlet, the suction inlet, and the ejector outlet. The motive inlet is configured for receiving a first flow of motive fluid, such as the first flow of sea water, having a first pressure. The first flow of motive fluid having the first pressure may be provided by the pump. In other words, the pressure of the first flow of motive fluid may be generated by the pump. The first flow of motive fluid flows through the motive inlet towards the nozzle.

The nozzle provides a restriction in the motive inlet and thus a restriction in the flow path of the motive fluid. As the motive fluid passes through the nozzle, a pressure energy of the motive fluid upstream the nozzle is converted into kinetic energy. In other words, the flow of the motive fluid upstream of the nozzle has an inlet pressure and an inlet velocity and, when passing the nozzle, the velocity of the flow of the motive fluid increases and the pressure of the motive fluid reduces, such that the flow of the motive fluid has an outlet pressure and an outlet velocity when it leaves the nozzle. The inlet velocity of the motive fluid is thus lower than the outlet velocity of the motive fluid. Consequently, the inlet pressure of the motive fluid is higher than the outlet pressure of the motive fluid. The reduction of the pressure of the motive fluid over the nozzle creates an area of lower pressure and higher velocity downstream the nozzle than upstream the nozzle. Thus, the reduction of the pressure of the motive fluid creates a zone of negative pressure inside the ejector downstream of the nozzle. Negative pressure herein means that the pressure is lower than a pressure in surrounding zones of the ejector, such as being lower than the pressure at the suction inlet. The negative pressure generated when the motive fluid passes through the nozzle thus causes a second fluid to be drawn or sucked into the flow

of motive fluid. Thus, the negative pressure zone causes a flow of the second fluid into the ejector from the suction inlet of the ejector. The second fluid may be sea water drawn from the suction inlet into the flow of motive fluid. Thus, the ejector uses the flow of motive fluid provided by the pump to draw the second fluid into the ejector, thereby increasing the amount of fluid that is discharged through the ejector.

An outlet of the nozzle may be directed towards the outlet section of the ejector, such that the motive fluid flows towards the ejector outlet.

In the ejector, the flow of motive fluid and the flow of the second fluid are mixed to a third flow of fluid. Once the flows have been mixed, the third flow of fluid moves into the diffuser of the ejector. The diffuser comprises a diverging section which slows the mixture down and thereby increases the pressure of the third flow of sea water. This may be considered as the reverse of the process occurring in the nozzle, when the first flow of sea water passes through the nozzle. The diffuser thus enables the ejector to discharge the third flow of sea water at a pressure that is greater than the pressure of the second flow of sea water sucked into the ejector at the suction inlet.

In one or more example embodiments of the ejector, the nozzle may include a nozzle outlet being centrally mounted in the outlet section. The nozzle having a centrally mounted nozzle outlet is cheap and easy to manufacture. The nozzle may be prefabricated and inserted into the ejector through the motive inlet. Thus, the design and dimension of the injector may be adapted to provide different characteristics to the ejector. The nozzle may e.g. be adapted to provide different level of pressure reductions of the motive fluid. Thus, the suction capacity of the ejector may be adapted by changing the nozzle.

In one or more example embodiments of the ejector, the nozzle may be a ring nozzle including a nozzle outlet mounted around a circumference of the outlet section. The nozzle outlet may be integrated into the outer wall of the ejector. The ring nozzle thus allows the motive fluid to be evenly distributed around the circumference of the inner side of the ejector. The ring nozzle thus has the benefit that there is no central obstruction in the ejector, which improves the flow of second fluid through the ejector and thus allows a larger volume flow to be generated by the ejector.

The dimensions of the ejector may be up to implementation and may vary based on the requirements of a specific implementation. However, in the following some examples of

dimensions that may be suitable for generating the additional or auxiliary thrust for the vessel are provided.

In one or more example embodiments of the thrust assembly, an inner diameter of the suction inlet and/or the outlet section of the ejector may be in the range of 350-550 mm. In one or more example embodiments, the inner diameter of the suction inlet may be smaller than the inner diameter of the outlet section. In other words, the inner diameter of the outlet section may be larger than the inner diameter of the suction inlet.

In one or more example embodiments of the thrust assembly, a length of the ejector from the suction inlet to the ejector outlet may be in the range of 2000-3500 mm.

In one or more example embodiments of the thrust assembly, the pump may further be configured to provide a flow of sea water to a fire-fighting system of the vessel. In other words, the pump providing the first flow of sea water to the ejector may be a pump comprised in a fire-fighting system of the vessel. Since fire-fighting operations and towing operations typically are not performed simultaneously, one pump may be used for either fire-fighting or for creating a thrust force for propelling the vessel.

In one or more example embodiments of the thrust assembly, the thrust assembly may comprise a distribution valve, such as a first distribution valve, arranged at or in the pump outlet of the pump. The first distribution valve may be configured to allow the first flow of sea water to be directed towards the ejector and/or the fire-fighting system. The first distribution valve allows the pump to be used for fire-fighting purposes and/or for creating thrust force for propelling the vessel. Thereby, the fire-fighting system may be used to provide additional bollard pull to the vessel when the vessel is used for towing purposes. The first distribution valve may be configured to be remotely operated. This allows an operator to control the operation of the distribution valve from a remote location, such as from a wheelhouse or a bridge of the vessel.

Further, a vessel comprising the thrust assembly for propelling the vessel. The suction inlet of the ejector is arranged below a waterline of the vessel or connected to tubing or pipes with an inlet below a waterline of the vessel. Thereby, the suction inlet is in fluid connection with sea water surrounding the vessel, so that the sea water surrounding the vessel is sucked into the ejector through the suction inlet in the second flow. The outlet of the ejector is arranged below a waterline of the vessel and in fluid connection with the sea water surrounding the vessel, so that the third flow of sea water discharged through the

ejector outlet creates a thrust force on the sea water surrounding the vessel. The thrust force on the sea water surrounding the vessel causes the vessel to be propelled forwards.

The vessel may further comprise a main propulsion unit. The thrust assembly may be configured to operate as a secondary propulsion unit for providing additional or auxiliary thrust to the vessel. The additional thrust may be used to increase the bollard pull, for example when the vessel is performing towing operations. The main propulsion unit may comprise a first main engine and a first propeller. In one or more embodiments, the main propulsion unit may comprise a plurality of propellers and main engines, such as e.g. two propellers and two main engines. Thus, the main propulsion unit may in one or more exemplary embodiments comprise a first and a second main engine driving a first and a second propeller, respectively.

The ejector may be arranged inside a hull of the vessel, e.g. below a waterline of the vessel. The suction inlet, the pump inlet and the ejector outlet may be in fluid connection with the sea water via a respective opening in the hull. The ejector may be installed on the vessel with pipes of same or greater diameter than the connections of the ejector, such as the motive inlet, the suction inlet and the ejector outlet, of the ejector. The ejector may be arranged such that a longitudinal axis of the ejector is arranged in parallel, or at least substantially in parallel, with a longitudinal axis of the vessel.

The suction inlet of the ejector and/or the pump inlet may be in fluid connection with the sea water, such as being connected to the sea chest, via one or more pipes. In order to increase a suction capacity of the ejector, the one or more pipes connecting the suction inlet to the seawater are preferably straight. Pipes having multiple bends in different planes on the suction side may cause a decrease in suction capacity due to friction, hence this is to be avoided. If the layout of the vessel requires one or more bent pipes to be used for installing the ejector, such as for connecting the suction inlet to the sea water, a straight pipe section having a length of ten times the diameter of the straight pipe section should be installed upstream the suction inlet of the ejector to prevent turbulence in the second flow of sea water sucked into the ejector. In some embodiments, the suction inlet of the ejector may be connected to a plurality of pipes connecting the suction inlet to the sea water, such as to a first pipe being connected to a first sea chest arranged on a starboard side of the vessel and to a second pipe being connected to a second sea chest arranged on a port side of the vessel. Thereby, two low pressure areas may be created in the fore of the vessel, such as at and/or around the first and the second sea chest.

On a discharge side of the ejector, such as at the ejector outlet, a straight pipe section having a length of at least three times its pipe diameter may be installed to connect the ejector outlet to an outlet in the hull of the vessel being in contact with sea water. Using a straight pipe section having a length of at least three times its pipe diameter may reduce wear in the pipe connected to the ejector outlet. In some embodiments, the ejector outlet may be connected to a plurality of outlets in the hull, such as to a first pipe being connected to a first outlet arranged on a starboard side of the hull of the vessel and to a second outlet arranged on a port side of the hull of the vessel. Thereby, two high pressure areas may be created in the aft of the vessel, such as at and/or around the first and the second outlets in the hull of the vessel.

In one or more example embodiments of the vessel, the vessel may comprise a plurality of thrust assemblies, such as two thrust assemblies. The two thrust assemblies may be arranged on opposite sides of a longitudinal axis of the vessel, such as on opposite sides of a keel of the vessel. The vessel may thus comprise a first thrust assembly arranged on a port side of the vessel and a second thrust assembly arranged on a starboard side of the vessel. The arrangement of the first and the second thrust assemblies on the vessel may mirror each other, such that the arrangement of the first and the second thrust assemblies is symmetric along a longitudinal axis of the vessel.

In some embodiments, the first thrust assembly may be arranged such that the suction inlet of the ejector of the first thrust assembly is arranged in the fore of the vessel and the outlet of the ejector of the first thrust assembly is arranged at the aft of the vessel, and the second thrust assembly may be arranged such that the suction inlet of the ejector of the second thrust assembly is arranged in the aft of the vessel and the outlet of the first ejector is arranged at the fore of the vessel. Thereby, the first and the second thrust assemblies may generate thrust in opposite directions, such as in a fore and an aft direction.

The first and the second thrust assembly may use a same pump or separate pumps for providing the first flow of sea water to the respective ejector. When the first and the second thrust assemblies are driven by the same pump, a distribution valve, such as a second distribution valve, which may be referred to as an ejector distribution valve, may be provided for directing the flow of motive fluid, such as the first flow of sea water, from the pump to the first and the second thrust assembly. By changing the ratio of the flow of motive fluid from the pump to the respective first and the second thrust assembly the

vessel may be turned. For example, by reducing the amount of motive fluid provided to the first thrust assembly arranged on the port side of the vessel and increasing the amount of motive fluid provided to the second thrust assembly arranged on the starboard side of the vessel, the vessel will perform a turn to port, and vice versa. The vessel may
5 thus comprise a plurality of distribution valves, such as the first and the second distribution valve, where the first distribution valve is configured for distributing the first flow of fluid, such as the first flow of sea water, between the thrust assembly and the fire-fighting system, and where the second distribution valve is configured for distributing the first flow of fluid, such as the first flow of sea water, between the first and the second
10 thrust assemblies. In some embodiments the first and the second distribution valves may be the same valve. In some embodiments the first and the second distribution valves may be separate valves arranged in a same valve body.

The vessel may further comprise a fire-fighting system. The pump may be configured to provide a flow of water to the fire-fighting system. Since fire-fighting operations and towing
15 operations typically are not performed simultaneously, a single pump may be used for either fire-fighting or propulsion purposes. In one or more example embodiments of the vessel, the vessel may comprise an auxiliary engine for driving the pump. The auxiliary engine may thus drive the pump for providing the first flow of sea water to the flow. By using the

20 In one or more example embodiments of the vessel, the inlet of the pump may be arranged below a waterline of the vessel and in fluid connection with the sea water surrounding the vessel, so that sea water surrounding the vessel is pumped to generate the first flow of sea water. The inlet of the pump may be a fixed inlet arranged in the hull of the vessel or may be a pipe or a hose that is placed into the water surrounding the vessel
25 when the pump is to be operated. The fixed inlet of the pump may be a fixed pipe connected to a sea chest of the vessel. The sea chest may be a rectangular or cylindrical recess in the hull of vessel that provides an intake reservoir from which the fixed pipe of the pump may draw raw water, such as sea water. The sea chest may comprise gratings, which may be removable, for preventing unwanted objects, such as large fish, nets,
30 garbage etc., from entering the sea chest and getting drawn or sucked into the pump inlet and/or suction inlet of the ejector. The sea chest may contain baffle plates to dampen the effects of vessel speed or sea state in order to ensure that sea water may be continuously drawn by the pump from the sea chest.

In one or more example embodiments of the vessel, the distribution valve, such as the first and/or the second distribution valve, may be remotely operable from the wheelhouse or a bridge of the vessel. The term wheelhouse herein means a room or a location on the vessel from which an operator may control the operation of the vessel, such as a bridge or
5 a control room. This allows an operator of the vessel to remotely control the distribution valve, such as the first and/or the second distribution valve, from the wheelhouse of the vessel. The operator may thus switch between using the pump to feed the fire-fighting system or using the pump to create additional thrust. The additional thrust may be used to increase the bollard pull of the vessel, which is beneficial when the vessel is operating as
10 a tow and/or a tugboat. In one or more embodiments, the distribution valve may be operable to be closed, fully open towards the fire-fighting system and closed towards the ejector, and/or fully open towards the ejector and closed towards the fire-fighting system. In one or more embodiments, the distribution valve may also be operable to control the flow going to either the fire-fighting system or the ejector, such that the amount of water
15 flowing through the valve can be continually adjusted to provide between 0 and 100% of the maximum flow provided by the pump. The operator may also remotely adjust the ratio of motive fluid going to the first and/or the second thrust assembly to control the thrust and/or the direction of movement of the vessel.

Fig. 1 illustrates a thrust assembly 1 for propelling a vessel according to this disclosure.
20 The thrust assembly 1 comprises a pump 2 for generating a first flow f_1 of sea water. The pump 2 comprises a pump inlet 2a and a pump outlet 2b. The pump inlet 2a may be configured to be in fluid connection with sea water surrounding the vessel, when the thrust assembly 1 is arranged on the vessel. Sea water shall herein be understood as the water surrounding the vessel 1, when the vessel 1 is operating.

25 The thrust assembly 1 further comprises an ejector 3. The ejector 3 comprises a suction inlet 4, a motive inlet 5, an outlet section 6, an ejector outlet 6a, a nozzle 7 and a diffuser 8. The motive inlet 5 is connected to the pump outlet 2b for receiving the first flow f_1 of sea water from the pump 2. The suction inlet 4 is configured for suction of the second flow f_2 of sea water. The suction inlet 4 may further be configured to be connected to a sea
30 chest of a hull of the vessel, from where the suction inlet may draw the sea water. The outlet section 6 comprises an ejector outlet 6a configured for discharging a third flow f_3 of sea water. The nozzle 7 is arranged downstream the motive inlet 5. The diffuser 8 is arranged in the outlet section 6 downstream the nozzle 7. The outlet section 6 is configured to mix the first flow f_1 of sea water with the second flow f_2 of sea water to

generate a third flow f_3 of sea water. The diffuser 8 is further configured to increase a pressure of the third flow f_3 of sea water downstream the diffuser 8. In other words, the diffuser 8 increases the pressure of the third flow f_3 of sea water, and consequently reduces the velocity of the third flow of sea water f_3 , such that the third flow f_3 of sea water leaves the diffuser 8 with a higher pressure than when it enters the diffuser 8. A first part of the outlet section 6 arranged downstream the nozzle 7 and upstream the diffuser 8, may thus be configured as a mixing chamber for mixing the first flow f_1 of sea water with the second flow f_2 of sea water to create the third flow f_3 of sea water.

The nozzle 7 may be configured to reduce a pressure of the first flow f_1 of sea water, when the first flow f_1 of sea water passes through the nozzle 7. The nozzle 7 provides a restriction for the first flow f_1 of sea water provided by the pump 2. The restriction causes a pressure energy in the first flow f_1 available upstream of the nozzle 7 to be converted into kinetic energy, such as to a velocity of the first flow f_1 . When the velocity of the first flow f_1 increases the pressure of the first flow f_1 decreases, such that the first flow f_1 enters the outlet section 6 of the ejector 3 through the nozzle 7 with a pressure p_{out_1} being lower than the pressure p_{in_1} with which the first flow f_1 enters the motive inlet 5. In other words, a first outlet pressure p_{out_1} of the first flow f_1 in a section of the ejector 3 downstream of the nozzle 7 may be lower than a first inlet pressure p_{in_1} of the first flow f_1 upstream of the nozzle 7. The first outlet pressure p_{out_1} may be lower than a pressure p_{inlet} at the suction inlet 4, thereby causing the second flow f_2 of sea water to be sucked into the ejector 3 through the suction inlet 4. When the second flow f_2 of sea water reaches the outlet section 6 downstream of the nozzle 7, the second flow f_2 of sea water mixes with the first flow f_1 of sea water to create a third flow f_3 of sea water. A first part 6b of the outlet section 6 may thus be configured as a mixing chamber for mixing the two incoming flows f_1 and f_2 , such that a third flow f_3 is created.

Once the flows have been mixed, the third flow f_3 of sea water moves into the diffuser 8 of the ejector 3. The diffuser 8 comprises a diverging section which slows the mixture down and thereby increases the pressure of the third flow f_3 of sea water. This may be considered as the reverse of the process occurring in the nozzle 7, when the first flow f_1 of sea water passes through the nozzle 7. This diffuser 8 enables the ejector 3 to discharge the third flow f_3 of sea water at a pressure that is greater than the pressure of the second flow f_2 of sea water sucked into the ejector at the suction inlet 4. Thus, the ejector 3 is configured to compress or boost the pressure of the sea water entrained through the ejector 3. In other words, the diffuser 8 is configured to increase the pressure

of the third flow of sea water downstream of the diffuser 8, so that a pressure p_3 of the third flow f_3 of sea water discharged from the ejector outlet 6a is higher than the pressure of the second flow f_2 of sea water sucked into the ejector 3 through the suction inlet 4.

- 5 The capacity of the pump may be in the range of 2,000 to 3,000 m³/h at a pressure in the range of 9 to 11 bar, such as 10 bar. Hence, the motive fluid may be provided to the motive inlet 5 at a pressure in the range of 9 to 11 bar, such as 10 bar. The pump 2 may further be configured to provide a flow of sea water to a fire-fighting system 11 of the vessel 100. Thus, the pump 2 may be used for dual purposes, namely for fire-fighting
10 and/or for providing a thrust force for propelling a vessel. Since

The thrust assembly 1 may comprise a distribution valve 12 arranged in the pump outlet 2b of the pump 2. The distribution valve 12 may be configured to direct the first flow f_1 of sea water towards the ejector 3 and/or towards the fire-fighting system 11. The distribution valve 12 may be configured to be remotely operated, such as from a
15 wheelhouse of the vessel. Thereby an operator of the vessel may remotely control the distribution valve from the wheelhouse of the vessel. The operator may thus switch between using the pump 2 to feed the fire-fighting system or using the pump 2 to create additional thrust for propelling the vessel 100.

The inner diameter d_{i_inlet} of the suction inlet 4 and/or the inner diameter d_{i_outlet} of the outlet section 6 of the ejector 3 may be in the range of 350-550 mm. The inner diameter of
20 the suction inlet d_{i_inlet} may be smaller than the inner diameter d_{i_outlet} of the outlet section. In other words, the inner diameter d_{i_outlet} of the outlet section may be larger than the inner diameter d_{i_inlet} of the suction inlet.

A length $L_{ejector}$ of the ejector 3 from the suction inlet 4 to the ejector outlet 6a may be
25 in the range of 2000-3500 mm.

Fig. 2 illustrates the ejector 3 according to one or more first embodiments herein. The nozzle 7 shown in Fig. 2 has a nozzle outlet 7a centrally arranged in the outlet section 6. The first flow f_1 of sea water is thus ejected centrally into the outlet section 6 of the ejector 3. The nozzle 7 having a centrally mounted nozzle outlet 7a is cheap and easy to
30 manufacture. The nozzle 7 may be prefabricated and inserted into the ejector 3 through the motive inlet 5. Thus, the design and dimension of the injector 7 may be adapted to provide different characteristics to the ejector 3. The nozzle 7 may e.g. be adapted to

provide different level of pressure reductions of the first flow f_1 . Thus, the suction capacity of the ejector 3 may be adapted by changing the nozzle 7.

Fig. 3 illustrate the ejector 3 according to one or more second embodiments herein. The nozzle 7 shown in Fig. 3 is a ring nozzle having a nozzle outlet 7b arranged around a circumference of the outlet section 6. The nozzle outlet 7b may be integrated into the outer wall of the ejector 3. The ring nozzle 7b thus allows the first flow f_1 of sea water to be evenly distributed around the circumference of the inner side of the ejector. The first flow f_1 of sea water enters the ejector through the motive inlet 5 with a pressure p_{in_1} and is then throttled through the ring nozzle at a high velocity and into outlet section 6 on the inside of the ejector 3 over a Coanda profile. A Coanda profile herein means a convex surface along which the flow of water may adhere due to the Coanda effect. The first flow f_1 of sea water clings to the Coanda profile as it enters the inside walls of the ejector 3 and thereby creates a low pressure area, having a pressure p_{out_1} lower than the pressure p_{in_1} , such as a vacuum, that induces sea water, such as the second flow f_2 of sea water, from the suction inlet 4 and converts the pressure difference between the low pressure area, such as the pressure p_{out_1} , and the ambient pressure, such as the pressure p_{inlet} , at the suction inlet 4 into an increased flow of sea water, such as flow comprising the flow f_2 and the flow f_1 and having a pressure p_2 , through the outlet section 6 of the ejector 3. The flow comprising the flow f_2 and the flow f_1 may herein also be referred to as the third flow f_3 of sea water. The diffuser 8 is configured to increase the pressure of the flow f_3 of sea water downstream of the diffuser 8, so that a pressure p_3 of the third flow f_3 of sea water discharged from the ejector outlet 6a is higher than the pressure of the second flow f_2 of sea water sucked into the ejector 3 through the suction inlet 4. As can be seen in Fig. 3 the ring nozzle 7b does not obstruct the flow path from the suction inlet 4 to the ejector outlet 6b, which improves the flow through the ejector 3 and thus allows the ejector 3 to generate a larger volume flow of sea water through the ejector 3.

Fig. 4 illustrates a vessel 100 comprising the thrust assembly 1 for propelling the vessel according to one or more example embodiments disclosed herein. The suction inlet 4 of the ejector 3 is arranged below a waterline 102 of the vessel 100 and in fluid connection with sea water surrounding the vessel 100, so that sea water surrounding the vessel 100 is sucked into the ejector 3 through the suction inlet 4 in the second flow f_2 . The suction inlet 4 may for example be connected to a sea chest comprised in the hull of the vessel 100, from where the suction inlet can draw sea water. The outlet 6a of the ejector 3 may

be arranged below the waterline of the vessel 100 and in fluid connection with the sea water surrounding the vessel 100. When the third flow f_3 of sea water discharged through the ejector outlet 6a into the sea water surrounding the vessel 100, a thrust force is created on the sea water surrounding the vessel 100. This thrust force causes the vessel 100 to be propelled through the surrounding water.

The ejector 3 may be arranged inside the hull of the vessel below a waterline 102. The suction inlet 4, the pump inlet 2a and the ejector outlet 6a may be in fluid connection with the sea water via a respective opening in the hull. The ejector 3 may be arranged such that a longitudinal centerline of the ejector 3 is arranged in parallel, or at least substantially in parallel, with a longitudinal axis of the vessel 100.

In one or more example embodiments of the vessel 100, the vessel 100 may comprise two thrust assemblies 1 arranged on opposite sides of a longitudinal axis of the vessel 100, such as on opposite sides of a keel of the vessel 100. The vessel 100 may thus comprise a first thrust assembly arranged on a port side of the vessel 100 and a second thrust assembly arranged on a starboard side of the vessel 100. The arrangement of the first and the second thrust assemblies on the vessel 100 may mirror each other, such that the arrangement of the first and the second thrust assemblies is symmetric along a longitudinal axis of the vessel 100. The first and the second thrust assembly may use the same pump or separate pumps for providing the first flow of sea water to the respective ejector 3.

The vessel 100 may further comprise a fire-fighting system 11. The fire-fighting system 11 may be configured for fighting fires occurring onboard the vessel 100 itself or may be configured to fight fires occurring on another vessel, such as for example on a towed vessel. The pump 2 may be configured to provide a flow of water to the fire-fighting system 11. The fire-fighting system may comprise one or more fire monitors, such as a starboard side fire monitor and/or a port side fire monitor, one or more deck hydrants, such as one or more starboard side deck hydrants and/or one or more port side deck hydrants, and one or more water spray nozzles.

The fire monitor is a water jet that can deliver large quantities of water to a source of fire from a distance. The fire monitor may be movably arranged on the vessel such that the fire monitor can be aimed towards the source of fire. In some embodiments, the fire monitor may be connected to a foam tank, such that foam may be mixed to the flow of water provided to the fire-fighting system 11 by the pump 2. The fire monitor may be

configured to be remotely and/or manually operated. The fire monitor may be configured to provide a flow of water in the range of 1000-1400 m³/h, such as 1200 m³/h and/or a flow of foam in the range of 200-400 m³/h, such as 300 m³/h.

5 The one or more fire hydrants are configured as attachment points for attaching a fire hose. The fire hoses may be manually operated by crew members. In order to allow the fire hoses to be manually operated, the fire hydrants may be connected to the pump 2 via a valve which reduces the pressure of the flow of water provided from the pump 2 to a pressure in the range of 4-6 bar, such as 5 bar. In some embodiments, the one or more fire hydrants may be connected to a foam tank, such that foam may be mixed to the flow
10 of water provided to the fire-fighting system 11 by the pump 2.

The one or more water spray nozzles may be configured to spray water onto the vessel 100 to fight fires onboard the vessel 100. The may be connected to the pump 2 via a valve which reduces the pressure of the flow of water provided from the pump 2 to a pressure in the range of 4-6 bar, such as 5 bar.

15 The vessel 100 may further comprise a main propulsion unit 10. The thrust assembly 1 may be configured to operate as a secondary propulsion unit for providing additional thrust to the vessel 100. The additional thrust may e.g. be provided when the vessel is operating as a towing vessel, such as when the vessel 100 is towing another vessel, and a high bollard pull is required. The main propulsion unit 10 may comprise a main engine
20 and a propeller. The additional thrust may be used to increase the bollard pull of the vessel 100. The thrust assembly 1 may be configured to add an additional bollard pull in the range of 4 to 6 tons, such as 5 tons. The main propulsion unit may comprise a first main engine and a first propeller. In one or more embodiments, the main propulsion unit may comprise a plurality of propellers and main engines, such as e.g. two propellers and
25 two main engines. Thus, the main propulsion unit may in one or more exemplary embodiments comprise a first and a second main engine driving a first and a second propeller, respectively.

Since fire-fighting operations and towing operations typically are not performed simultaneously, the pump 2 may be used for either fire-fighting or propulsion purposes. In
30 other words, when the vessel 100 is operating as a fire-fighting vessel, the flow of water f_1 from the pump 2 may be directed to the fire-fighting system 11 via the distribution valve 12. When the vessel is operating as a towing vessel, such as a tugboat, the flow of

water f_1 from the pump 2 may be directed to the ejector 3 via the distribution valve 12 to provide additional thrust to the vessel 100.

By using the pump 2 and the ejector 3 for providing additional thrust to the vessel 100, the main propulsion unit 10 of the vessel 100 are not required to provide the full power for generating the required bollard pull of the vessel 100. The main propulsion unit 10 may thus be downsized, such that a smaller and/or less powerful main propulsion unit 10 may be used. Downsizing of the main propulsion unit 10 may for example be achieved by reducing the size and/or the power of the main engine and/or the propeller. Smaller and/or less powerful engine are cheaper and are easier to maintain. Hence, downsizing the main propulsion unit 10 may lead to cost savings for manufacturing and maintenance of the vessel 100.

The vessel 100 may comprise an auxiliary engine or electric motor for driving the pump 2. By providing an auxiliary engine for driving the pump 2, the one or more main engines of the main propulsion unit 10 may be used exclusively for propelling the vessel 100. Thereby, the maneuverability of the vessel 100 is not affected when the pump 2 is in use. Furthermore, since the auxiliary engine is configured to drive the pump 2, which is configured to generate additional thrust for propelling the vessel 100, the main engines may be downsized, thereby saving costs for the main propulsion unit 10.

The inlet 2a of the pump 2 may be arranged below the waterline 102 of the vessel 100 and in fluid connection with the sea water surrounding the vessel 100, so that sea water surrounding the vessel 100 is pumped to generate the first flow f_1 of sea water. The inlet 2a may for example be connected to a sea chest in the hull of the vessel 100 by means of one or more fixed pipes.

The thrust assembly 1 may comprise the distribution valve 12 arranged in the pump outlet 2b of the pump 2 for directing the first flow f_1 of sea water towards the fire-fighting system 11 and/or the ejector 3 for providing additional thrust. The distribution valve 12 may be remotely operable from a wheelhouse 101 of the vessel 100. Thereby, an operator of the vessel 100 may control the additional thrust by controlling an opening and/or closing of the distribution valve 12.

It shall be noted that the features mentioned in the embodiments described in Figs. 1-4 are not restricted to these specific embodiments. Any features and components mentioned in relation to the thrust assembly of Figs. 1-3, such as dimensions of the

ejector and configurations of the nozzle, are thus also applicable to the vessel described in relation to Fig. 4.

It shall further be noted that a vertical axis, when referred to herein, relates to an imaginary line running vertically through the ship and through its center of gravity, a transverse axis or lateral axis is an imaginary line running horizontally across the ship and through the center of gravity and a longitudinal axis is an imaginary line running horizontally through the length of the ship through its center of gravity and parallel to a waterline. Similarly, when referred to herein, a vertical plane relates to an imaginary plane running vertically through the width of the ship, a transverse plane or lateral plane is an imaginary plane running horizontally across the ship and a longitudinal plane is an imaginary plane running vertically through the length of the ship.

Embodiments of products (thrust assembly for a vessel and vessel comprising the thrust assembly) according to the disclosure are set out in the following items:

- Item 1. A thrust assembly (1) for propelling a vessel (100), the thrust assembly (1) comprising:
- a pump (2) for generating a first flow (f_1) of sea water, wherein the pump (2) comprises a pump inlet (2a) and a pump outlet (2b), and
 - an ejector (3) comprising a suction inlet (4) configured for suction of a second flow (f_2) of sea water, a motive inlet (5) connected to the pump outlet (2b) for receiving the first flow (f_1) of sea water from the pump (2), an outlet section (6) comprising an ejector outlet (6a) configured for discharging a third flow (f_3) of sea water, a nozzle (7) arranged downstream the motive inlet (5), and a diffuser (8) arranged in the outlet section (6) downstream the nozzle (7),
- wherein the outlet section (6) is configured to mix the first flow (f_1) of sea water with the second flow (f_2) of sea water to generate a third flow (f_3) of sea water, the diffuser (8) being configured to increase a pressure of the third flow (f_3) of sea water downstream the diffuser (8).
- Item 2. The thrust assembly (1) according to Item 1, wherein the nozzle (7) includes a nozzle outlet (7a) centrally arranged in the outlet section (6).

- Item 3. The thrust assembly (1) according to any one of the previous Items, wherein the nozzle (7) is a ring nozzle including a nozzle outlet (7b) arranged around a circumference of the outlet section (6).
- 5 Item 4. The thrust assembly (1) according to any one of the previous Items, wherein a capacity of the pump (2) is in the range of 2,000 to 3,000 m³/h at a pressure of 9 to 11 bar.
- Item 5. The thrust assembly (1) according to any one of the previous Items, wherein an inner diameter of the suction inlet (4) and/or the outlet section (6) of the ejector (3) is in the range of 350-550 mm.
- 10 Item 6. The thrust assembly (1) according to any one of the previous Items, wherein a length of the ejector (3) from the suction inlet (4) to the ejector outlet (6a) is in the range of 2000-3500 mm.
- Item 7. The thrust assembly (1) according to any one of the previous Items, wherein the pump (2) is configured to provide a flow of sea water to a fire-fighting system (11) of the vessel (100).
- 15 Item 8. The thrust assembly (1) according to Item 7, wherein the thrust assembly (1) comprises a distribution valve (12) arranged in the pump outlet (2b) of the pump (2), wherein the distribution valve (12) is configured to allow the first flow of sea water (f₁) to be directed towards the ejector (3) and/or the fire-fighting system (11).
- 20 Item 9. The thrust assembly (1) according to Item 8, wherein the distribution valve (12) is configured to be remotely operated.
- Item 10. A vessel (100) comprising a thrust assembly (1) for propelling the vessel (100) according to any one of the Items 1 to 9, wherein
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- the suction inlet (4) of the ejector (3) is arranged below a waterline of the vessel (100) and in fluid connection with sea water surrounding the vessel (100), so that sea water surrounding the vessel (100) is sucked into the ejector (3) through the suction inlet (4) in the second flow (f₂), and

- the outlet (6a) of the ejector (3) is arranged below the waterline of the vessel (100) and in fluid connection with the sea water surrounding the vessel (100), so that the third flow (f₃) of sea water discharged through the ejector outlet (6a) creates a thrust force on the sea water surrounding the vessel (100).
- 5
- Item 11. The vessel (100) according to Item 10, wherein the vessel (100) comprises a fire-fighting system (11) and wherein the pump (2) is configured to provide a flow of water to the fire-fighting system (11).
- Item 12. The vessel (100) according to Item 10 or 11, wherein the vessel (100) comprises a main propulsion unit (10), and wherein the thrust assembly (1) is configured to operate as a secondary propulsion unit for providing additional thrust to the vessel (100).
- 10
- Item 13. The vessel (100) according to Item 12, wherein the main propulsion unit (10) comprises a main engine and a propeller.
- Item 14. The vessel (100) according to any one of the Items 10 to 13, wherein the vessel (100) comprises an auxiliary engine for driving the pump (2).
- 15
- Item 15. The vessel (100) according to any one of the Items 10 to 14, wherein the inlet (2a) of the pump (2) is arranged below a waterline of the vessel (100) and in fluid connection with the sea water surrounding the vessel (100), so that sea water surrounding the vessel (100) is pumped to generate the first flow (f₁) of sea water.
- 20
- Item 16. The vessel (100) according to any one of the Items 10 to 15, wherein the thrust assembly (1) comprises a distribution valve (12) arranged in the pump outlet (2b) of the pump (2) and the distribution valve (12) is remotely operable from a wheelhouse (101) of the vessel (100).
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The use of the terms “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. does not imply any particular order, but are included to identify individual elements. Moreover, the use of the terms “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. does not denote any order or importance, but rather the terms

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"first", "second", "third" and "fourth", "primary", "secondary", "tertiary" etc. are used to distinguish one element from another. Note that the words "first", "second", "third" and "fourth", "primary", "secondary", "tertiary" etc. are used here and elsewhere for labelling purposes only and are not intended to denote any specific spatial or temporal ordering.

- 5 Furthermore, the labelling of a first element does not imply the presence of a second element and vice versa.

It is to be noted that the word "comprising" does not necessarily exclude the presence of other elements or steps than those listed.

- 10 It is to be noted that the words "a" or "an" preceding an element do not exclude the presence of a plurality of such elements.

- Although features have been shown and described, it will be understood that they are not intended to limit the claimed disclosure, and it will be made obvious to those skilled in the art that various changes and modifications may be made without departing from the scope of the claimed disclosure. The specification and drawings are, accordingly, to be regarded
15 in an illustrative rather than restrictive sense. The claimed disclosure is intended to cover all alternatives, modifications, and equivalents.

LIST OF REFERENCES

	1	thrust assembly
	2	pump
	2a	pump inlet
5	2b	pump outlet
	3	ejector
	4	suction inlet
	5	motive inlet
	6	outlet section
10	6a	ejector outlet
	7	nozzle
	7a	centrally mounted nozzle outlet
	7b	ring nozzle
	8	diffuser
15	100	vessel
	101	wheelhouse
	102	waterline
	f_1	first flow
	f_2	second flow
20	f_3	third flow
	p_in_1	pressure of first flow upstream the nozzle
	p_out_1	pressure of first flow downstream the nozzle
	p_inlet	pressure at suction inlet
	p_3	pressure of third flow at ejector outlet
25	L_ejector	length of ejector
	d_i_inlet	inner diameter of suction inlet
	d_i_outlet	inner diameter of ejector outlet