Modeling the Flow through the Wastewater Installation Bioreactor

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Abstract: *The paper presents the wastewater treatment processes circulating on board cruise ship and modeling the flow through the wastewater installation bioreactor.*

Keywords: *Wastewater, modeling, bioreactor, oil separator, hydrocarbon, emulsion*

1. Introduction

Norwegian Joy is a cruise ship (Figure 1) [1].

Fig. 1. Norwegian Joy cruise ship

The characteristic data of the ship, as well as the installations and the afferent equipments are the result of the designer [2]. The total installed power of the ship is 76800 kW and is equipped with two MAN B & W 14V48 / 60CR engines of 16800 kW and three diesel generators of MAN B & W 12V48 / 60CR with a power of 14400 kW. The propulsion system is two ABB Azipod XO units with a total power of 40 MW. The power supply installation of the ship and the Azipod is divided into two large groups bow and stern, which allow the operation of the installations on the ship and the propulsion.
Regarding the wastewater treatment, on board the cruise ship is operated with the Scanship AWP system (Advanced waste purification) (Figure 2).

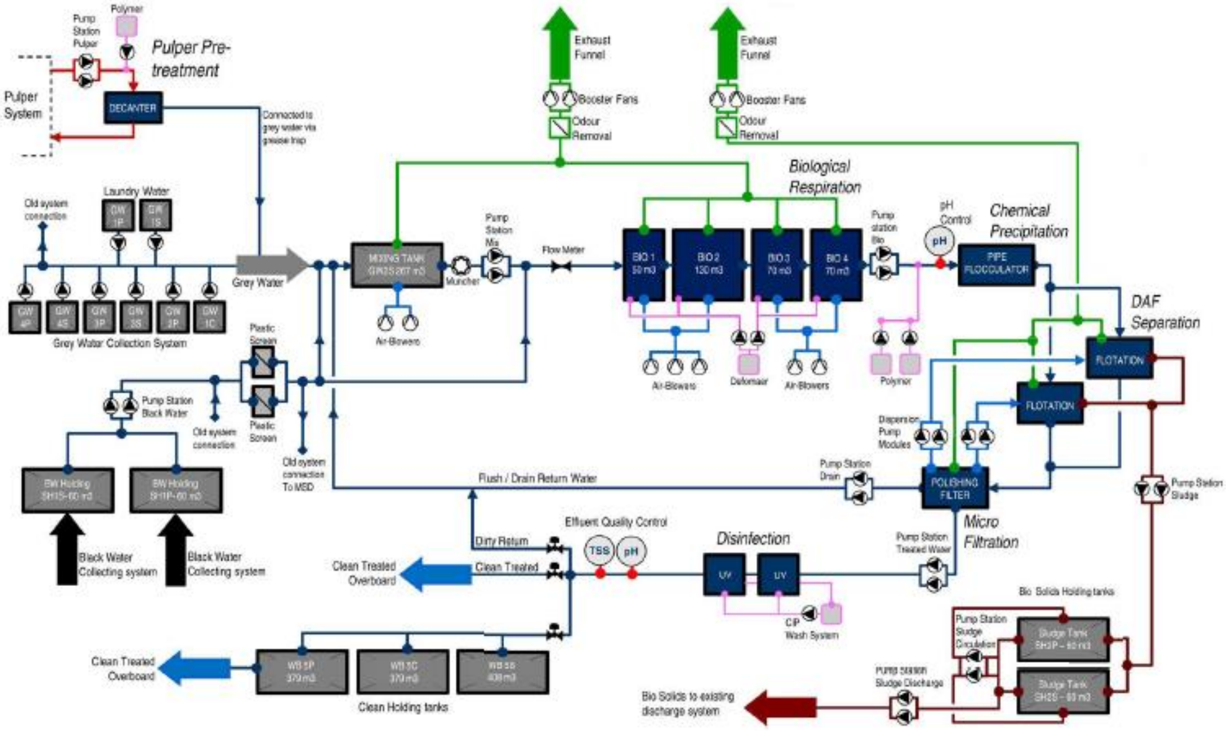

Fig. 2. Advanced waste purification system on cruise ship JOY

The wastewater treatment processes circulating on board of the JOY are shown in the diagram below (Figure.3) [1]:

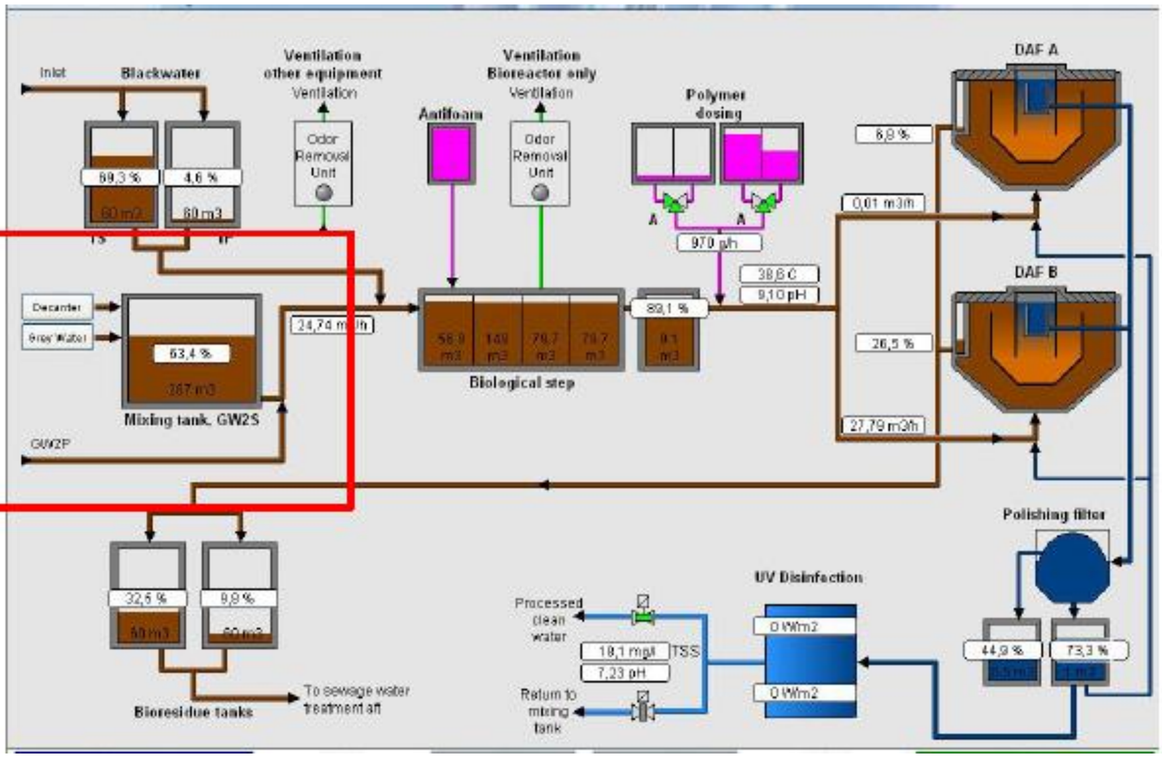

Fig. 3. JOY wastewater treatment processes

The wastewater comes from: the Engine room (ER), from the ER bilge, where the treatment of oil residues from the ship's facilities is done with the bilge separator, through an automated circuit and from all decks, crew cabins, passenger cabins, recreation rooms, gyms, swimming pools, restaurants, medical offices, shops, etc. In the ER, wastewater goes through several treatment processes:

- *Separation of residues by bilge separator type: 3SEP OWSF* (Figure 4) [2]

Fig. 4. JOY 3SEP OWS bilge separator

The elimination of hydrocarbon residues occurs in 3 points: tanks T_1, T_2 and T_3. The removed hydrocarbon residues are directed to the residue tank. In the first phase (tank T_1), the disposal of residues is controlled by a hydrocarbon sensor. The sensitivity of the sensor is adjustable to reduce the amount of bilge water removed from T_1. Hydrocarbons are accumulated at the top of tanks T_2 and T_3, the water coming from T_1. The removal of hydrocarbons from the filter tanks T_2 and T_3 occurs automatically. These hydrocarbons are removed by the pneumatically operated valves $V0_2$ (T_2) and $V0_3$ (T_3). The time interval between hydrocarbon removals for $V0_2$ and $V0_3$ is fixed. Hydrocarbons are removed from $V0_2$ every 5 minutes for a period of 20 seconds, which can be adjusted. Hydrocarbons removed from $V0_3$ every hour for a fixed period of 5 seconds. When the separator is switched on, automatic removal of hydrocarbons by $V0_2$ and $V0_3$ occurs for a fixed period of 3 seconds. This ensures that hydrocarbons that have accumulated at the top of the tanks while the separator has been turned off are removed.

- *Separation of residues through the JOWA type bilge separator*

The JOWA bilge separator is a two-stage separation system designed to separate and remove hydrocarbons from wastewater (Figure 5) [3].

In the first stage, the separator removes free hydrocarbons by gravity using coalescing plates. An adjustable hydrocarbon sensor controls the pneumatic valve for automatic discharge into the sludge tank or any dedicated tank. This sensor makes it possible to minimize the amount of water discharged into the waste tank. In the second stage the emulsified hydrocarbons are discharged into the two filter tanks and the value of the quantity in PPM (parts per million) is monitored by a PPM-meter also called ODM (oil discharge monitor) (Figure 6) [2], before the water is discharged overboard.

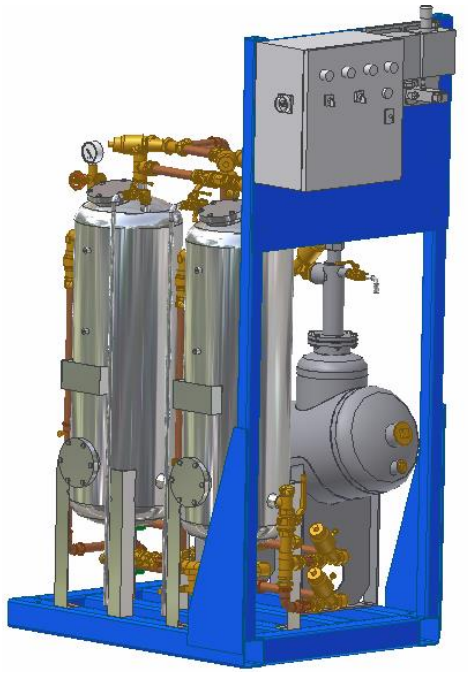

Fig. 5. JOWA bilge separator

Fig. 6. JOWA type separator control panel together with PPM meter

The free hydrocarbons collected at the top of each tank are automatically discharged into the waste tank at a predetermined interval. When the PPM meter alarm sounds, the separator automatically closes the overflow valve and recirculates the treated water into the bilge. When the degree of contamination drops below 15 ppm, the overflow discharge valve opens again without human intervention (Figure 7) [3].

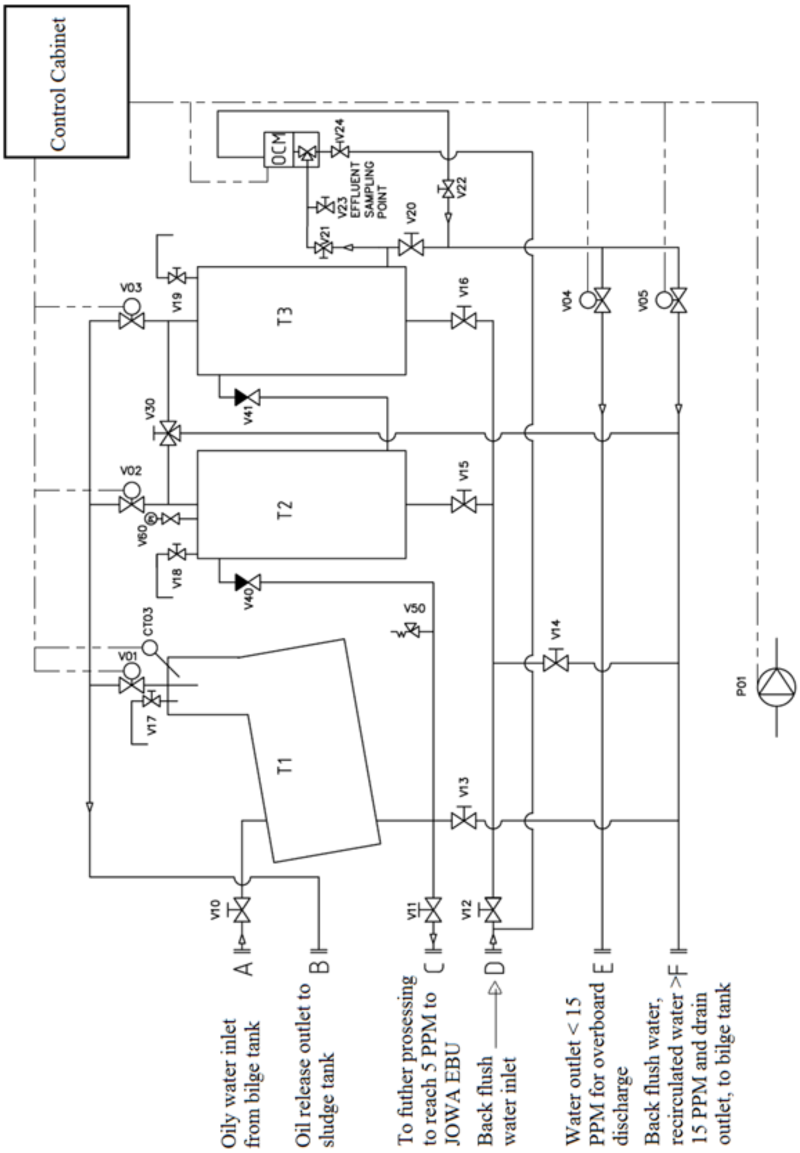

Fig. 7. Operating scheme of hydrocarbon separation

- *Anti-emulsion system. Constructive features of the separator - EBU*

The JOWA anti-emulsion system is designed to act as a pre-treatment of emulsions in bilge water before it enters the separator. The main function of the unit is to flocculate and remove hydrocarbon emulsions from bilge water (Figure.8) [4]. The EBU is specially designed to be connected to the bilge separator as a combined treatment system. When connected to the separator, the EBU system uses its own bilge pump [5].
The bilge pump of the EBU system ($P0_1$) is a screw or multi-screw type pump depending on the capacity of the treatment system 6m3 / 24h, 8m^3 / 24h, 10m^3 / 24h. It operates at a power of 0.55kW - 1.74kW with a current of 1.55A - 3.5A.
In addition to the bilge pump and two dosing pumps $P0_2$ and $P0_3$ are introduced into the system. These two pumps are diaphragm and operate with a power consumption of 16 W, at a working pressure of 0-2 bar.

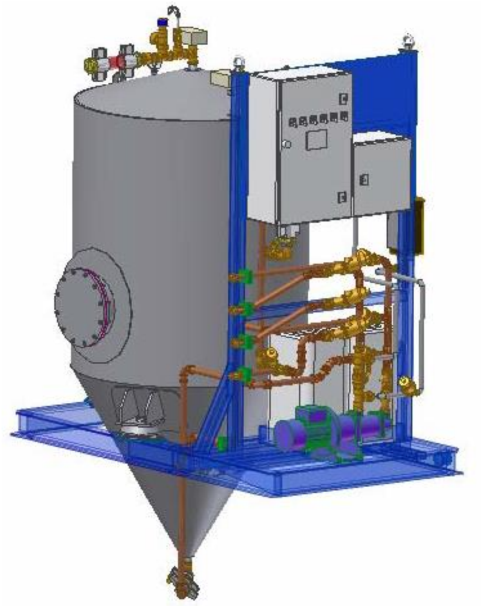

Fig. 8. EBU anti-emulsion system

The B01 storage tank has a volume of 1000 liters. The anti-emulsion system coupled to the separator removes up to 80% of the water from the emulsions, then this water called treated water is discharged into the separator.

2. Methods and researches

The ANSYS-FLUENT v13 program was used to simulate the process of separating hydrocarbons from water.

2.1 Drawing geometry

A two-dimensional model was created, a rectangle 0.1 m wide and 0.2 m long. This is the reservoir where the two fluids, water and hydrocarbon, will separate gravitationally. To make the geometry we used the program tools (Figure 9) and dimensioned the study system (Figure 10). In the end, the study model was generated in an axonometric system and with the units of measurement.

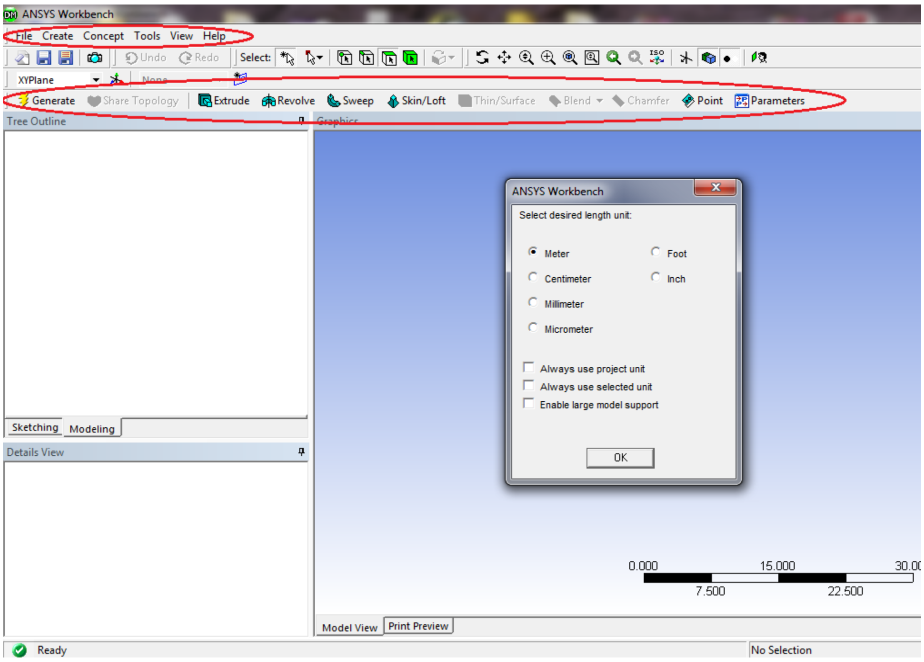

Fig. 9. Geometric module

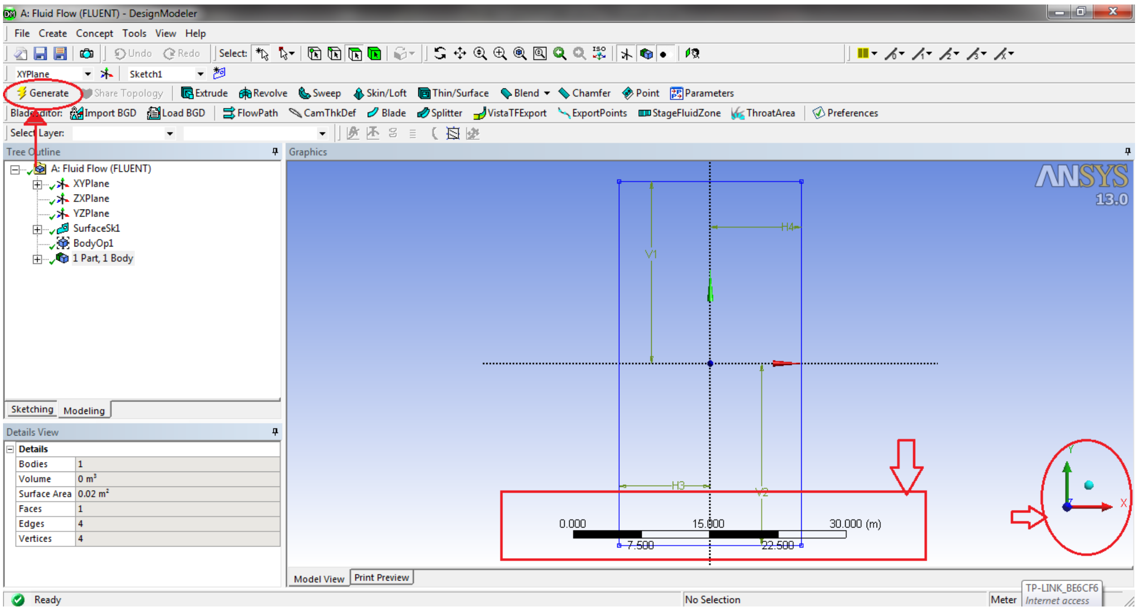

Fig. 10. Geometry completion

2.2. Profile discretization

At this stage, we have made the tank discretized. We discretized the tank into 5000 simple units, namely squares measuring 0.002 meters (Figure 11).

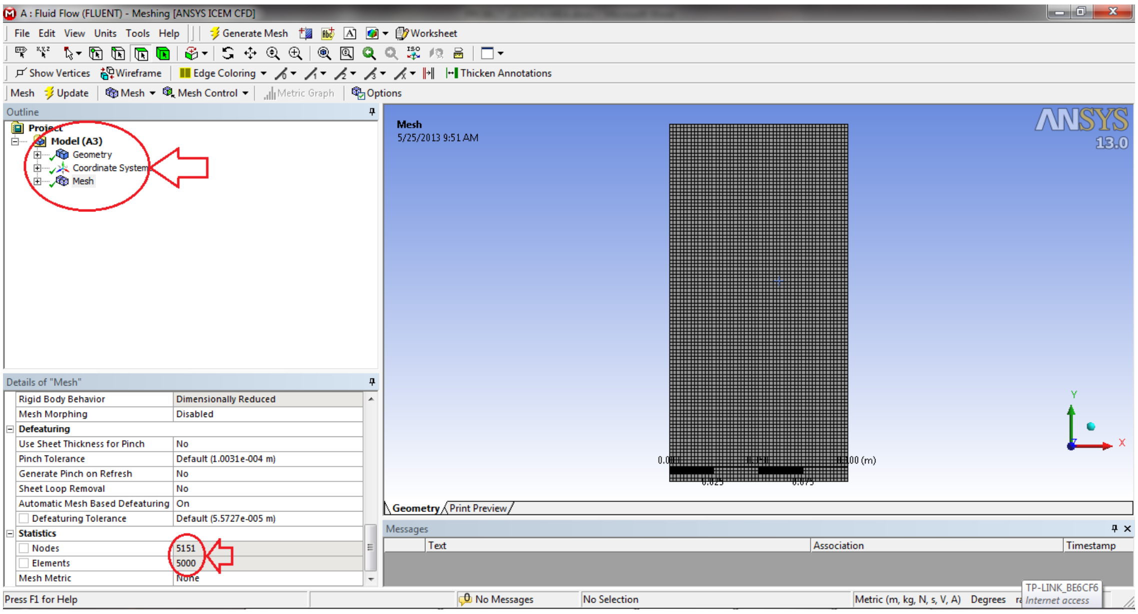

Fig. 11. Discretization of the field of study

2. 3. Calculation of fluid parameters

2.3.1. Using the Solution function

Opening the solution module leads to the window in Figure 12, where the parameters and settings are entered for a more suggestive display.

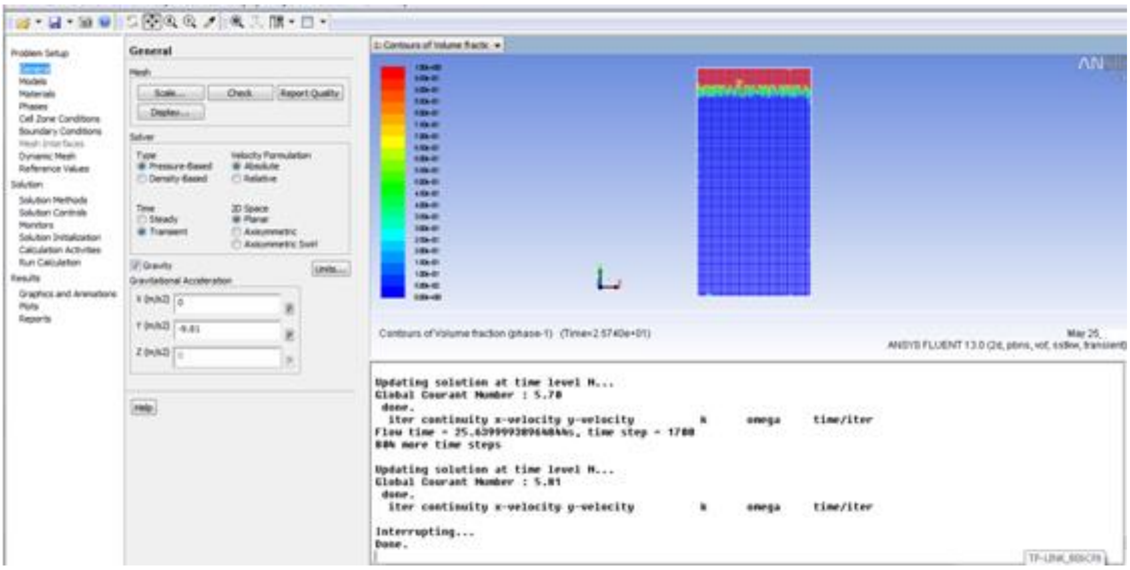

Fig. 12. Calculation of solutions

3. Results and interpretations

After initialization, an effective calculation is made, establishing for the first time 1000 iterations with the size of the iteration interval of 0.001 seconds (Figure 13).

As results after the flow simulation were obtained:
- representation of water relative to hydrocarbon after 1 second (Figure 14);
- representation of water relative to hydrocarbon after 11 seconds (Figure 15);
- representation of water relative to hydrocarbon after 111 seconds (Figure 16);
- representation of the circulation speed of fluid cells (Figure 17)
- representation of the density of working fluids (Figure 18);
- representation of the turbulence of kinetic energy (Figure 19);
- representation of the dynamic pressure of moving fluids (Figure 20).

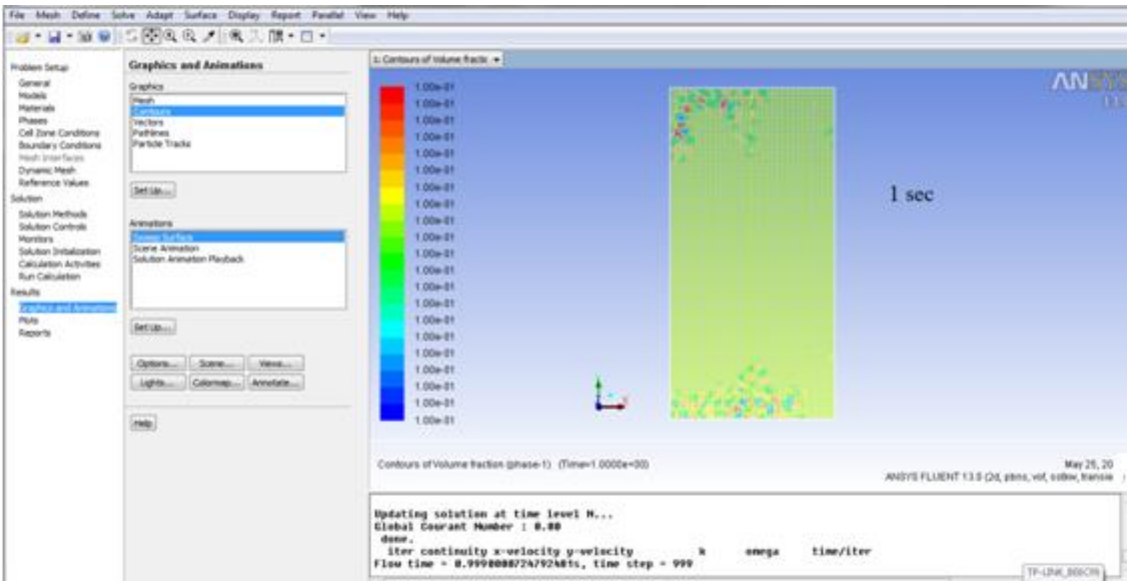

Fig. 13. Representation of water to hydrocarbon after 1 second

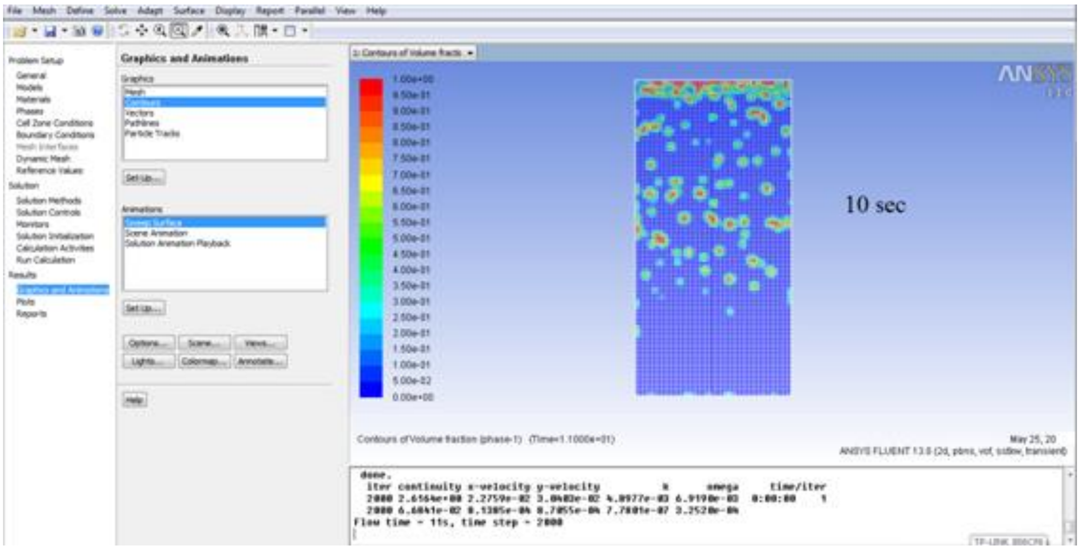

Fig. 14. Representation of water to hydrocarbon after 11 seconds

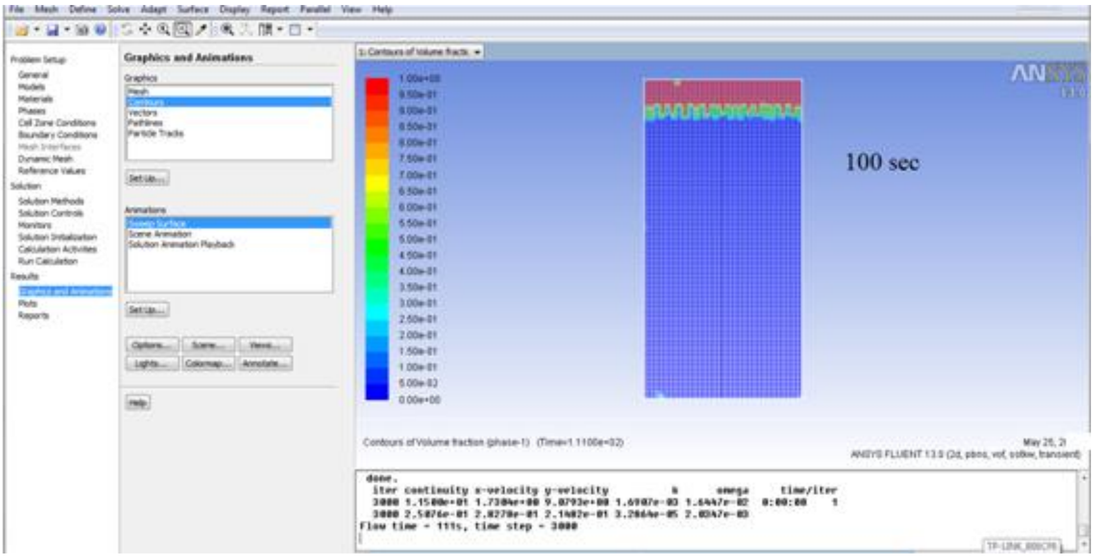

Fig. 15. Representation of water to hydrocarbon after 111 seconds

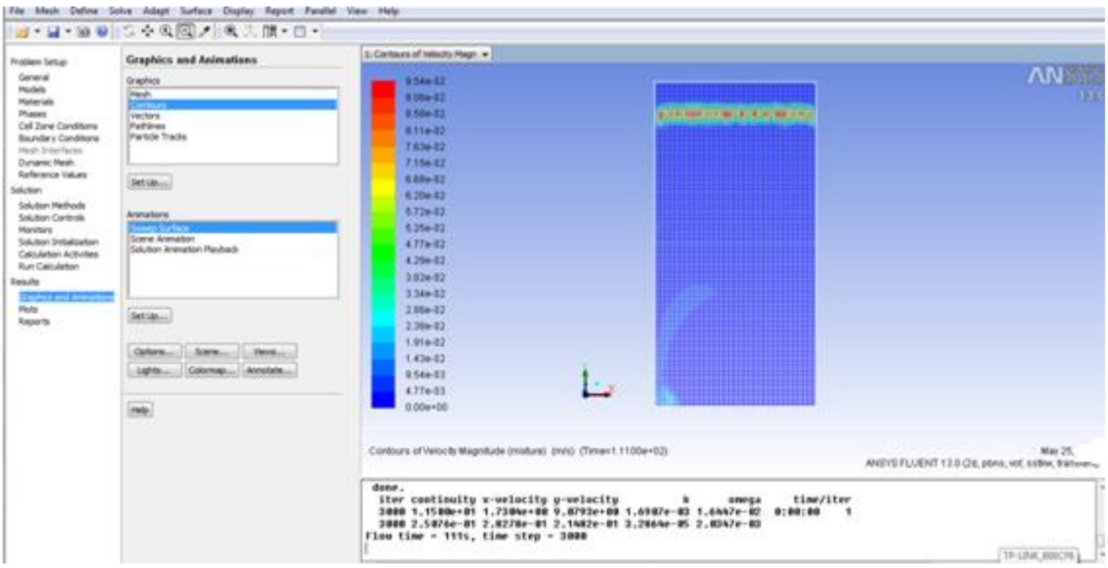

Fig. 16. Representation of the circulation speed of fluid cells

As one can see, the minimum value of the circulation speed of fluid cells is 0.0 m/s and the maximum value is $9.54*10^{-02}$ m/s.

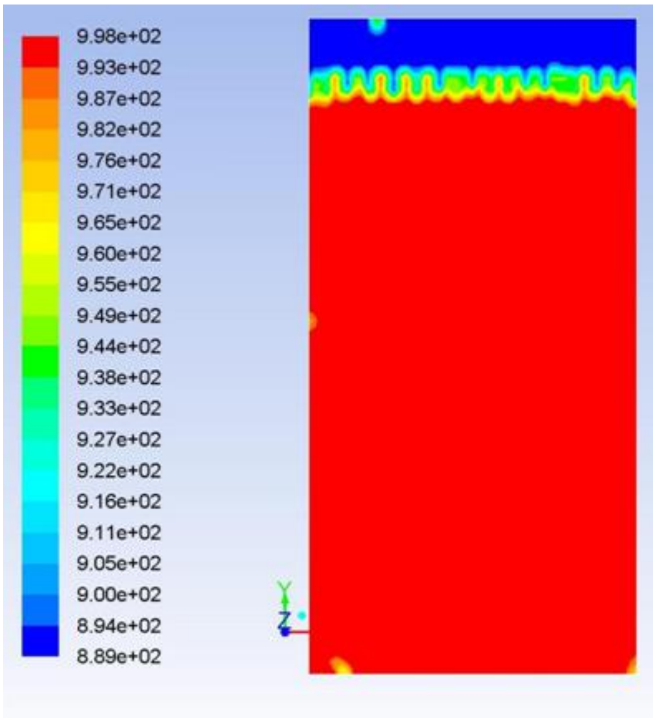

Fig. 17. Representation of working fluid density

As one can see, the minimum value of working fluid density is $8.89*10^{+02}$ kg/m^3 and the maximum value is $9.96*10^{+02}$ kg/m^3.

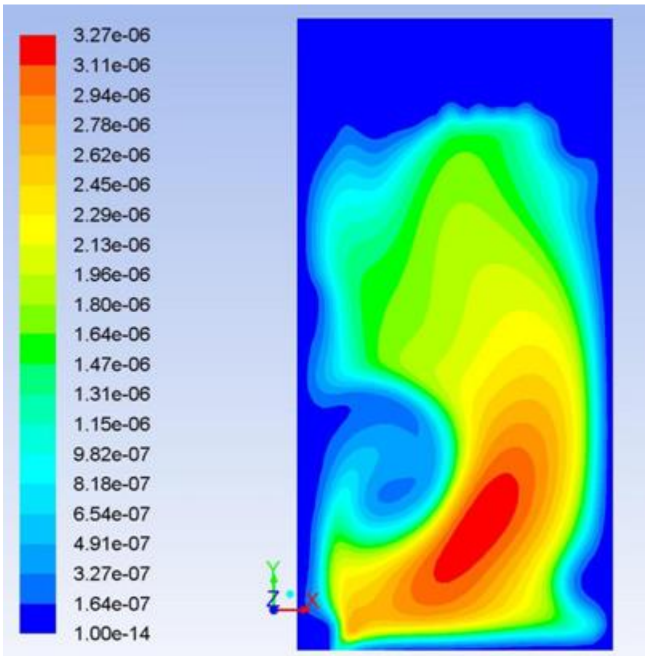

Fig. 18. Representation of kinetic energy turbulence

As one can see, the minimum value of kinetic energy turbulence is $1.00*10^{-14}$ J and the maximum value is $3.27*10^{-6}$ J.

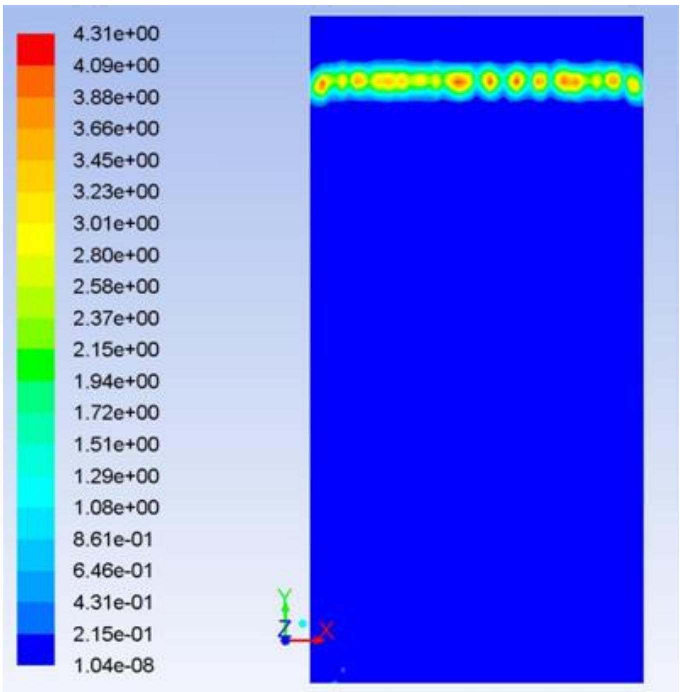

Fig. 19. Representation of the dynamic pressure of moving fluids

As one can see, the minimum value for dynamic pressure of moving fluids is $1.04*10^{-8}$ Pa and the maximum value is 4.31 Pa.

4. Conclusions

Marine oil pollution due to the carelessness and unpreparedness of seafarers is becoming an increasingly harsh reality. However, the interventions, measures and limitation of these actions are up to us. The violation of the rules by the navigators of the sea transport companies imposed the appearance of new combat provisions. Part of these is the security of all facilities and means by which crimes can be committed and the mode of operation. The start of the separation installation, respectively of the bilge separator is done by noting in the Logbook. Opening the overboard valves (which are sealed) and not only is also done by noting in the Logbook. All these measures were taken as a result of the increase in crime.

The water in the bilge tanks can also come from leaks through the glands of the shut-off valves and the etambou tube, purging the level bottles, condensation on the side of the water vapor in the air, washing the decks below the waterline, extinguishing fires and much more.

Technological availability allows us to design and build increasingly efficient bilge installations with a high degree of automation.

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