Optimizing the Flow through the Hydraulic Installation of a Port Crane

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Abstract: *The lifting installations with cranes have a much higher productivity than the big ones and come into operation without preliminary preparations, but compared to the big ones, they are constructively more complex and more expensive. They can have manual (very rare), electric (currently the most widespread) and electrohydraulic (with greater possibilities of adjusting the working speeds) actuation. The primary condition and the basis of the economic growth of the port activity is the provision of appropriate performances and in particular the activities of operating ships and handling goods, which constitute the main function of a port. As a result, the optimization of the flows through the hydraulic installations of the port equipment is very important in the operational processes. The current work presents the structural and operational characteristics of a harbour crane in order to optimize the performance of hydraulic installations.*

Keywords: *Crane, flow, harbour, optimization, plant, simulation*

1. Introduction about Port Cranes

Port cranes constitute the main means of trans-shipment of goods and are located along the mooring front. Superstructure works developed simultaneously with the progress made in shipbuilding. This is how specialized berths and maritime terminals appeared, equipped with the most modern operating installations, specialized in the operation of a certain type of cargo. At the same time, transport systems were developed, the most complex form of which is the door to door system. Following the analysis of the technical park in the Romanian maritime and river ports, it is found that in a general goods terminal the most common Port Operational Facilities (POF) are quay cranes.

Figures 1 and 2 show the most common port facilities, constituting the main means of trans-shipment of goods [1], [2], [3]. With the help of quay cranes, both general cargoes and some specialized ships are operated. Port practice demonstrates that in the vast majority of situations the use of quay cranes is characterized by a higher productivity than the equipment on board. Quay cranes are mainly intended for cargo handling operations from the ship to the terminal and vice versa. The lifting capacity of these cranes is variable, being dependent on the specialization or destination of the port operating berth [4].

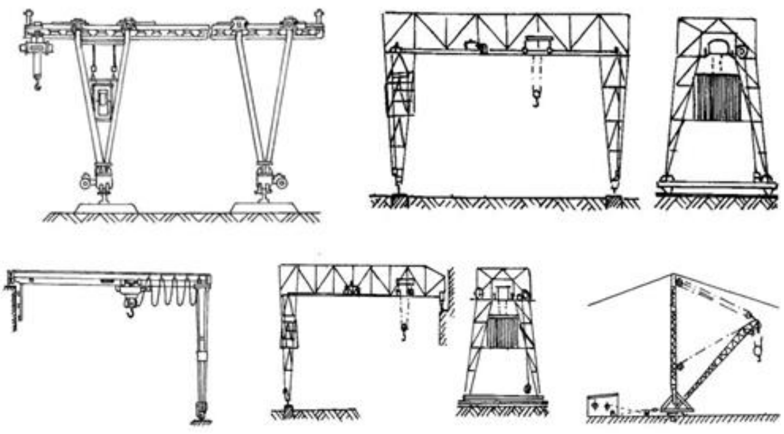

Fig. 1. Different types of port cranes [1]

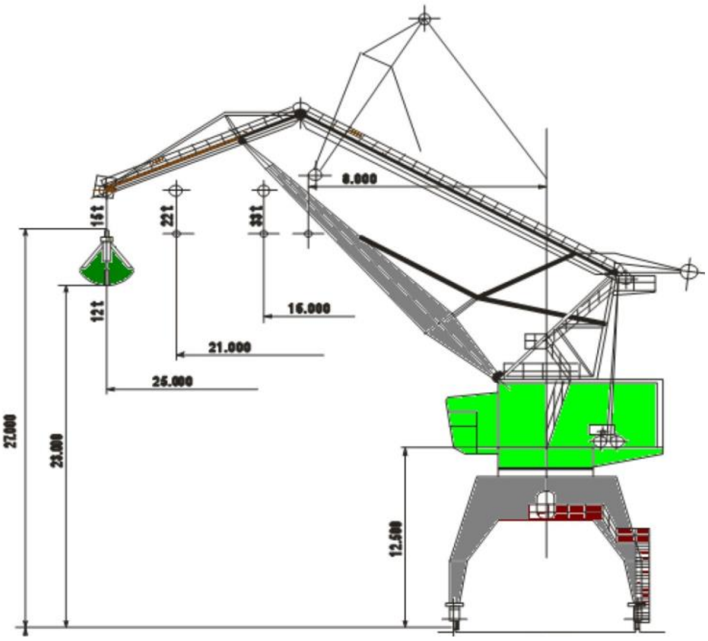

Fig. 2. Port crane with square jib [2]

Quay cranes can be classified into:

- gantry cranes
- semi-portal cranes.

In both types, the actual crane rests on a metal structure whose shape also gives the name of the respective type of crane. The rollers of the translation mechanism rest on a guide rail located along the magazine wall at a given height. The most widespread quayside cranes are the portal type (Fig. 3) [5].

Fig. 2. Hercules model quayside crane [5]

The characteristics of the port crane are (Table 1):
- Model: HC-PT
- Type: Lifting platform
- Capacity: maximum 50 tons
- Working radius: 65 m
- Brand electrical parts: Siemens, Schneider, Chnt

Table 1: The characteristics of the port crane

Product specifications	Value
Lifting capacity, [t] Radius, [m]	Main hook : 50 45 24-33 24-60 Auxiliary hook: 20 28-65
Lifting height , [m]	60
Working radius, [m]	Max. 60... 65 Min. 24... 28
Mechanism speed ; Lifting speed , [m/min] Descent speed, [m/min] Rotation speed, [rot/min] Movement speed, [m/min]	Main hoo-: 7; Auxiliary hook- 15 ~ 10 0.24 30
Power source	3-phase A.C.60 Hz 440V
Track Gauge / abatement, [m]	13/16
Portal height, [m]	~13
Chassis rolling radius, [m]	~17
Wind pressure with the crane in operation, [N/m^2]	250
Wind pressure with the crane on standby, [N/m^2]	1000
Installed capacity, [kW]	125
Starting current, [A]	250

- Working environment: -20 + 45 degrees C
- Sling type: metal cables
- Power source: Electric
- Specifications: CE, CCC
- HS code: 84263000
- Certification: CE, ISO 900I: 2000
- Use: Port, constructions
- Name: Mobile jib crane
- Lifting height: 60 m
- Protection device: Limit Switch, main isolation switch
- Control mode: Cabinet / Remote Control.

The component elements of the port crane are (Fig. 3)[5]:

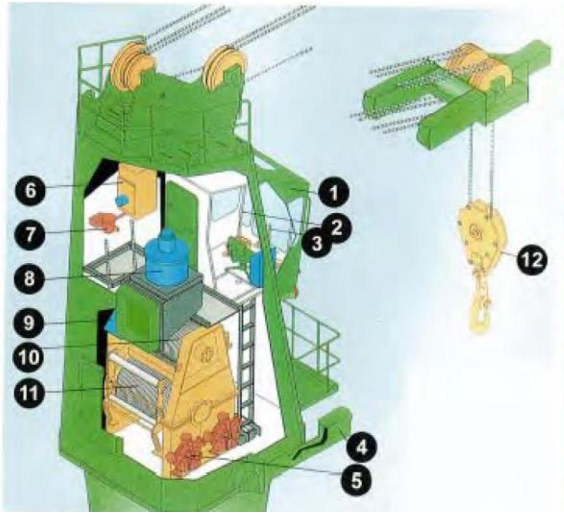

Fig. 3. Port crane-the components elements [5]

1. crane cabin
2. lever for arm movement and rotation
3. lift lever
4. arm
5. hydraulic motor
6. oil tank
7. oil filter
8. oil cooler
9. limit switch
10. lifting cable
11. lifting cable
12. locking pulley.

2. Method and research

The research consists of:
- presentation of the hydraulic actuation installation [2], [3], [4], [5], [6], 7], [8];
- flow optimization by using the ANSYS FLUENT simulation program [8], [9], [10].

2.1 Presentation of the general scheme and component parts

The reference crane is equipped with 2 drive cylinders (Fig. 4)[3],[6]

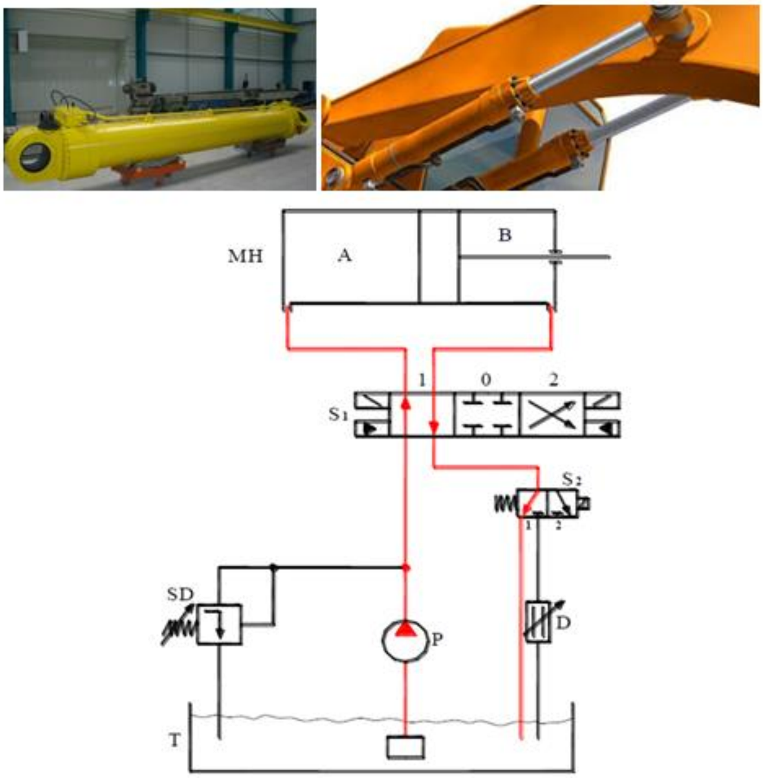

Fig. 4. Hydraulic cylinders and the general diagram of the operation of hydraulic cylinders [3], [6]

The diagram above comprises the hydraulic pump P, the pressure valve SD, the three-position hydraulic distributor with hydraulic steering S1, the hydraulic distributor S2, the hydraulic motor MH coupled to the working body, filters, pressure relays, throttle with flow regulator D and the tank T .

- *The destination of the hydraulic pump*

The hydraulic pump is designed to transform the mechanical energy received from the electric motor into the hydraulic energy of the fluid that is transmitted to the hydraulic system, namely the working body (Fig. 5) [4].

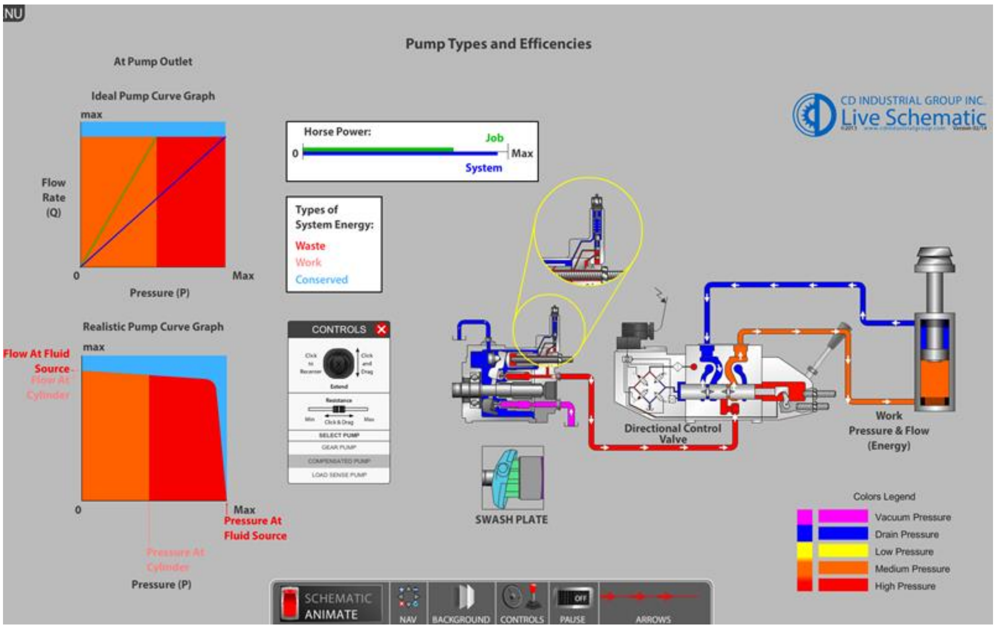

Fig. 5. Hydraulic pump [4]

- *The destination of the hydraulic motor*

The hydraulic motor is designed to transform the potential energy of the liquid into the mechanical energy of the working body (Fig. 6)[4].

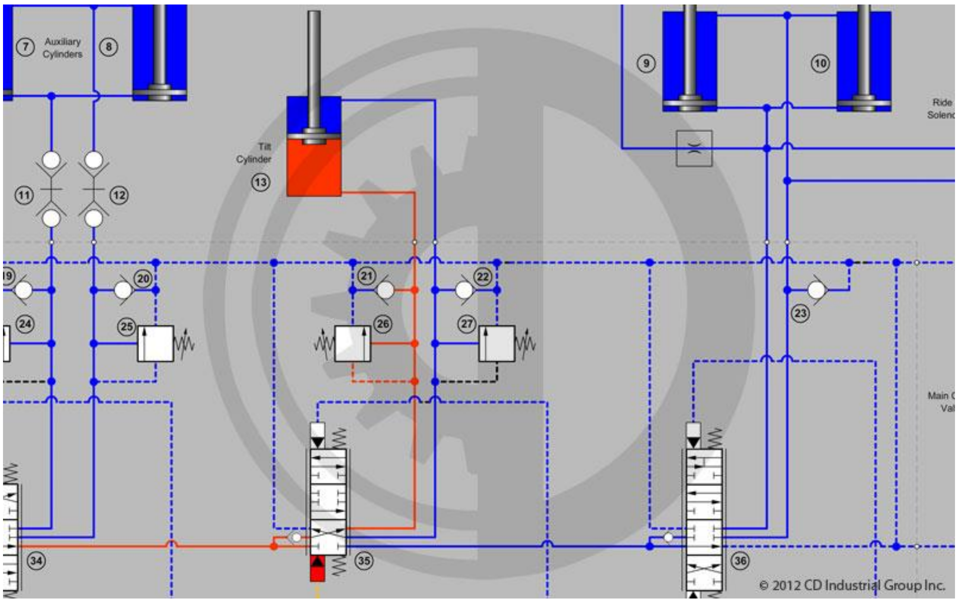

Fig. 6. Hydraulic motor [4]

- *The destination of distributors*

The hydraulic distributors are intended for discharging, stopping and starting the working bodies of the machine tools and the technological equipment which is performed by changing the direction of movement of the flow of the working fluid of the hydraulic system, opening and closing the system, changing the direction. The three-position hydraulic distributor (DH) is intended for starting and dumping the cycle (Fig. 7) [5].

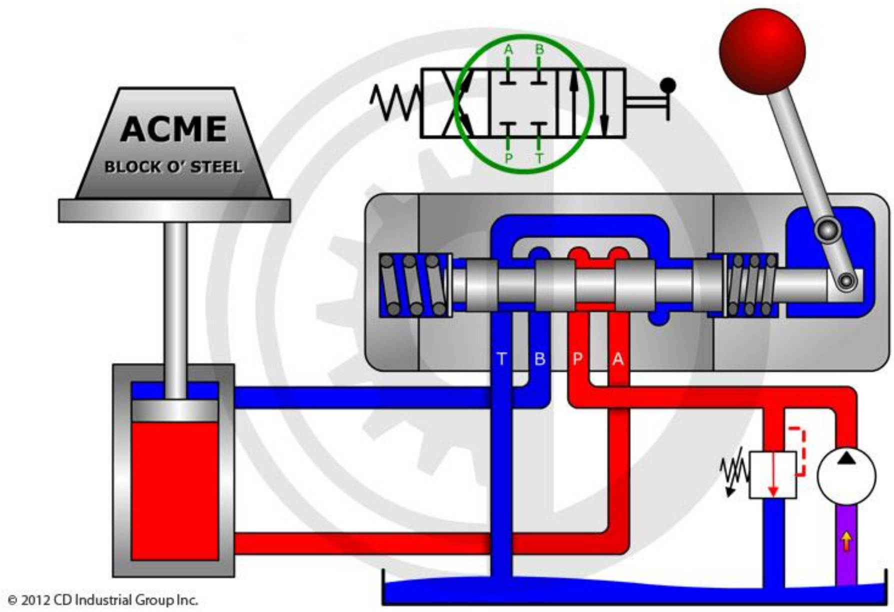

Fig. 7. Distributors [5]

- *The destination of the pressure device*

The pressure device is designed to protect the hydraulic system from overload and maintain a constant pressure (Fig. 8) [5].

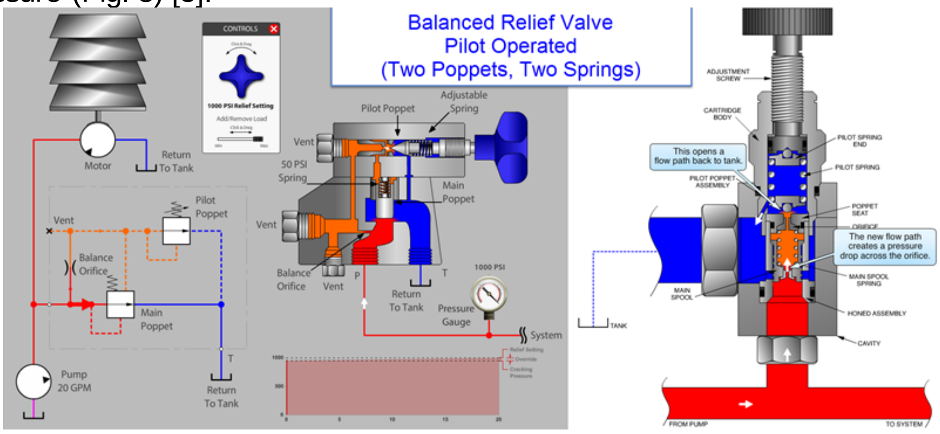

Fig. 8. Pressure valves [5]

- *The destination of throttles with regulator*

Throttles with regulator are designed to regulate the flow of liquid and keep it constant, therefore also the speed of the working body. In this case, chokes with a regulator are used and are installed at the output (Fig. 9) [5].

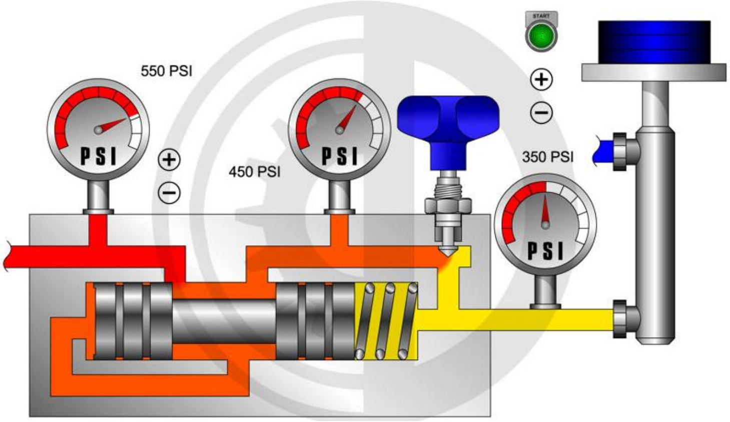

Fig. 9. Flow regulators [5]

- *The purpose of one-way valves*

Check valves are used in hydraulic systems to allow fluid to move through pipes in one direction only (Fig. 10) [5].

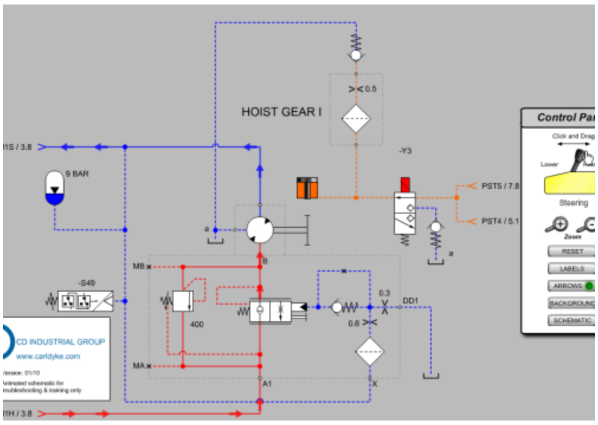

Fig. 10. Check valves [5]

2.2. Simulation of fluid flow on the hydraulic installation

To model the fluid flow system on the hydraulic installation, the Ansys program was used, namely Ansys-Fluent, the part that deals with the study of liquid flow.
With the help of the *Design Modeler* option offered by the Ansys Fluent program, the geometric construction of a sector of the hydraulic installation of the quay crane was realized (Fig. 11).

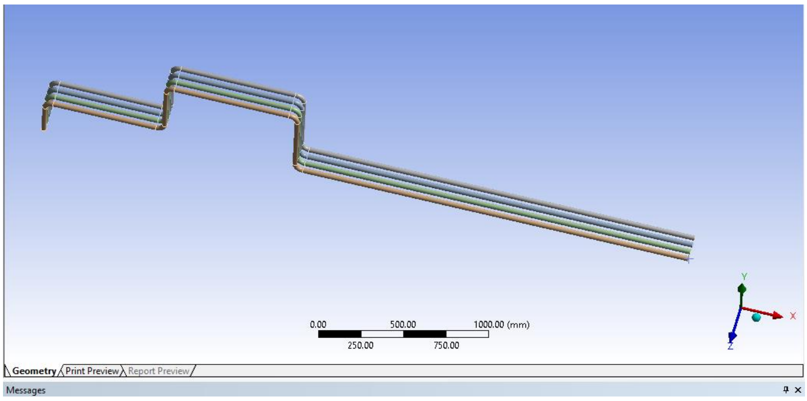

Fig. 11. Design of the crane hydraulic installation sector (Ox)

Given that it is equipped with 2 hydraulic lifting cylinders, we included the round-return installation sector with oil supply for the 2 cylinders (Fig. 12, Fig. 13).

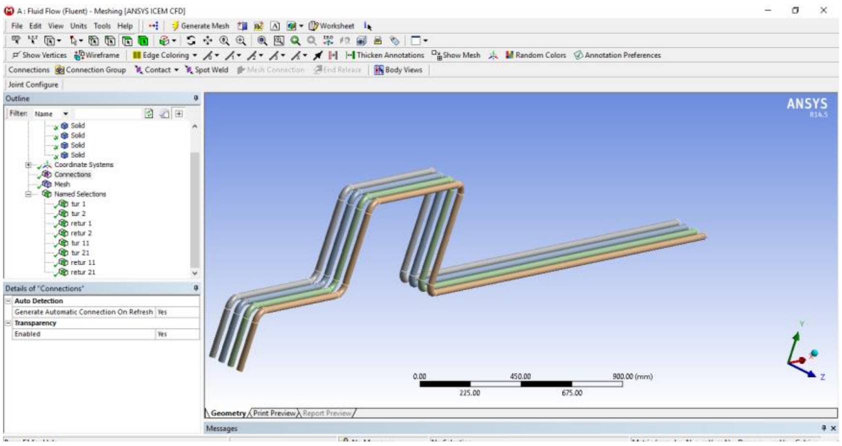

Fig. 12. Design of the crane hydraulic installation sector (Oy)

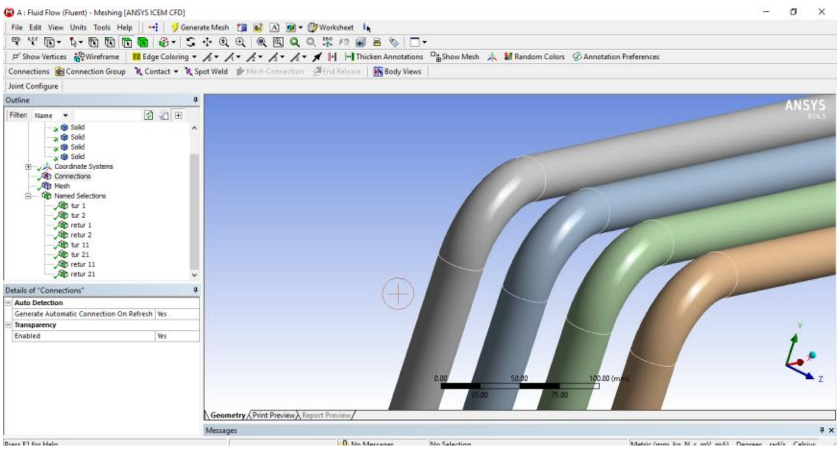

Fig. 13. Design of the crane hydraulic installation sector (Oz)

The fluid entry and exit points were established. Thus we noted 2 inputs and 2 outputs for the 2 actuation cylinders (Fig. 14).

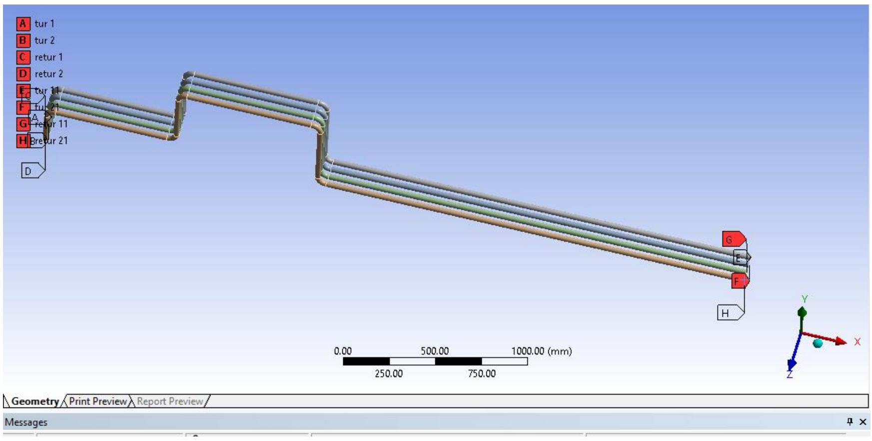

Fig. 14. The inlets and outlets in the hydraulic installation (return - return)

The next stage after the geometric construction, is the discretization of the installation. This process is a structural analysis of the entire pipeline segment, it being divided into a certain number of cells, with a view to the possibility of further development of the calculation on each cell, determining particular values of pressure and velocity.
The discretization was performed using the "Mesh" interface of the Ansys Fluent program. The structural analysis resulted in 1546512 cells and 243811 nodes (Fig. 15).

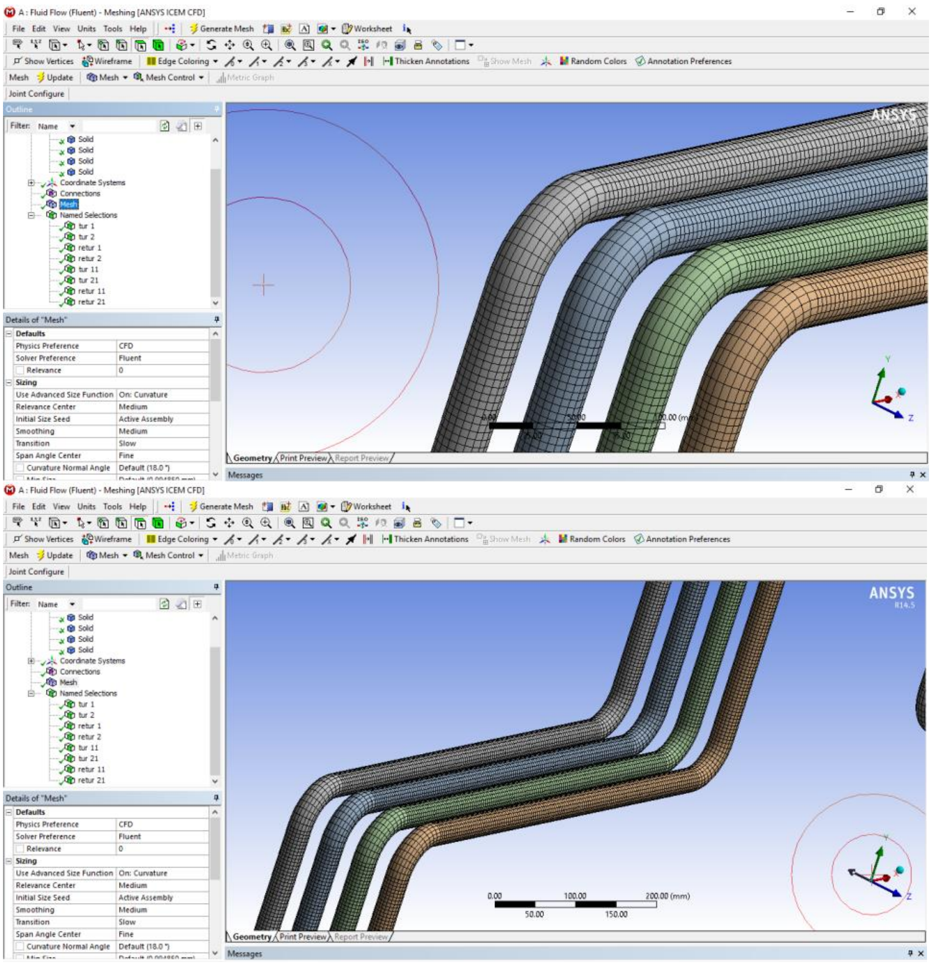

Fig. 15. Discretization of the installation

To visualize the results, the simulation program was run with the established working conditions.

3. Results and interpretations

After carrying out the simulation with the numerical program ANSYS FLUENT, the local pressure drops and speed variations on certain sectors, as well as on the entire installation, are presented in Fig. 16....Fig. 22.

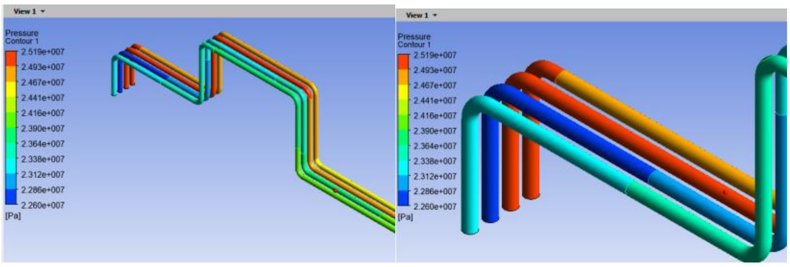

Fig. 16. The pressure on the contour-view 1 stream line on wall

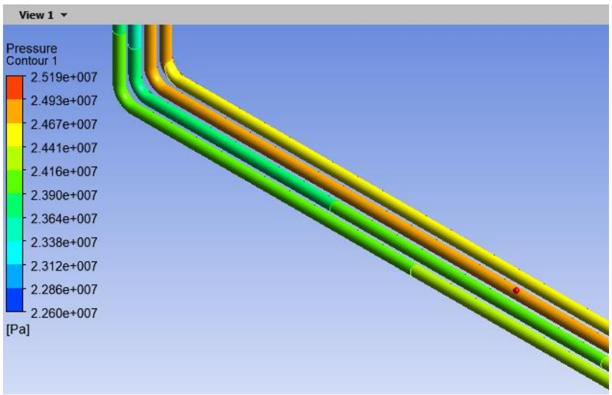

Fig. 17. The pressure on the contour-view 2 wireframe

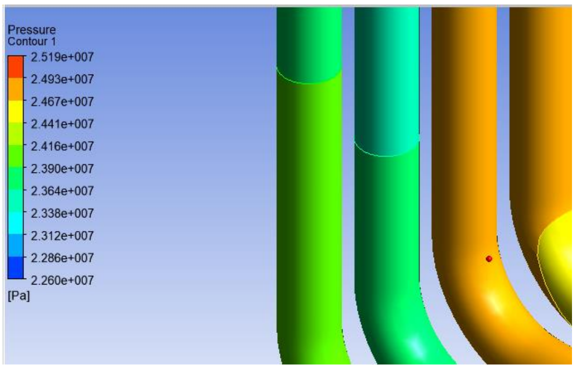

Fig. 18. The pressure on the bends of the installation

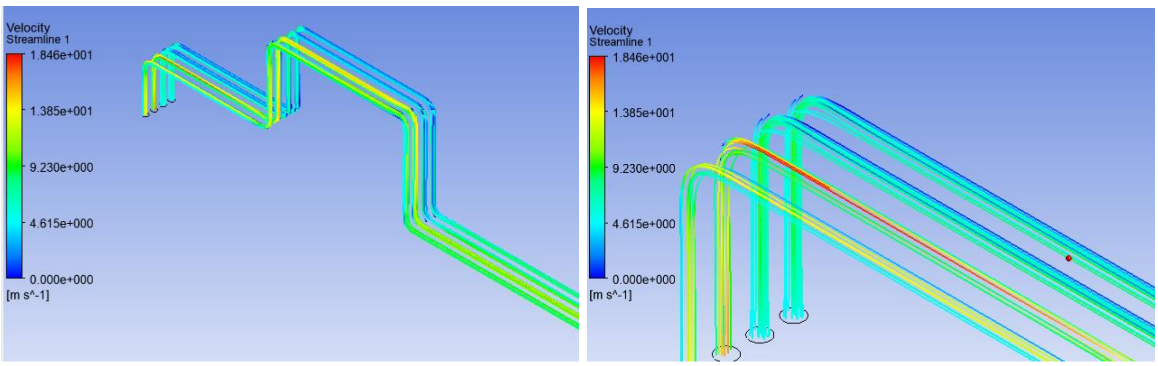

Fig. 19. The velocity on streamline 1

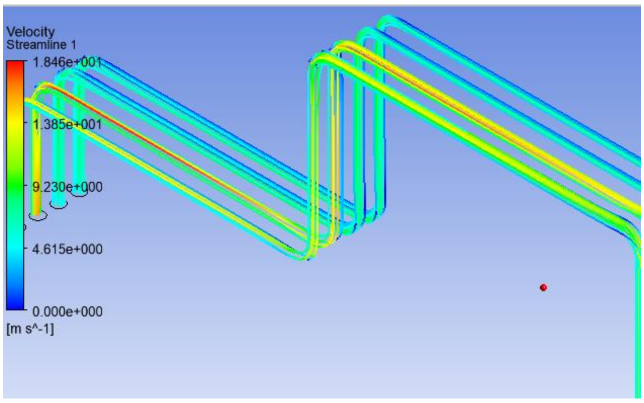

Fig. 20. The distribution of velocity on the frame

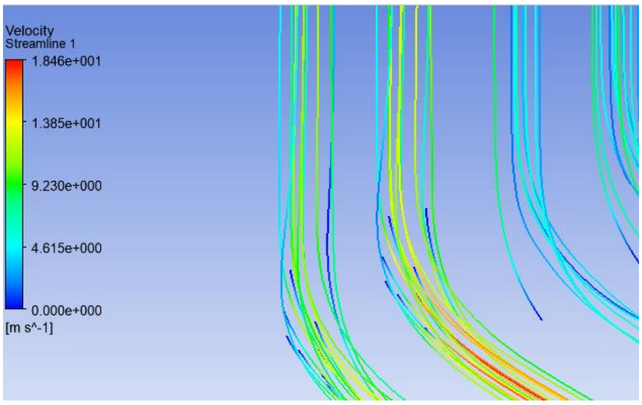

Fig. 21. The distribution of velocity on the bends of the installation

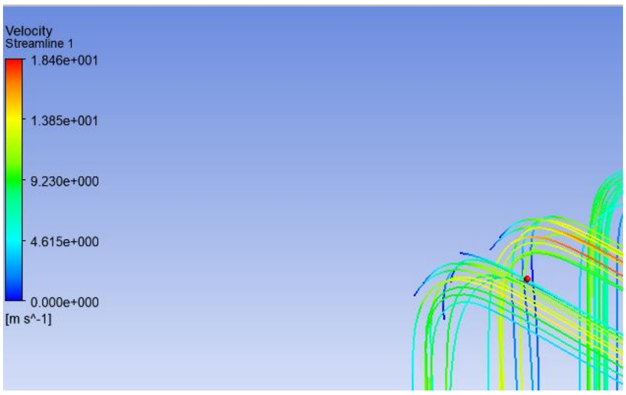

Fig. 22. The distribution of velocity- limit values

The main results obtained from the simulation were:

- pressure on the installation (cylinder 1 stroke): max 2.519 $\cdot 10^7$ Pa, min 2.441 $\cdot 10^7$ Pa;
- pressure on the installation (cylinder 2 stroke): max 2.519 $\cdot 10^7$ Pa, min 2.467 $\cdot 10^7$ Pa;
- pressure on the installation (return cylinder 1): max 2.441 $\cdot 10^7$ Pa, min 2.286 $\cdot 10^7$ Pa;
- pressure on the installation (return cylinder 2): max 2.441 $\cdot 10^7$ Pa, min 2.312 $\cdot 10^7$ Pa.

To optimize the design of hydraulic plant of crane, one must choose an uniform distribution of velocities during all frames [6,7,8].

4. Conclusions

The main quay cranes used in the naval industry were presented.
The quay cranes are the main means of trans-shipment of goods and are located along the mooring front. The actual capacity of quay cranes is not always their nominal capacity; for

example, a crane of 3-5 tf capacity can theoretically make 40 cycles/hour, which gives an average of 4.5 x 40 = 180 t/hour unloaded cargo. But for general goods, an unloading rate of 15t/h/team is quite a high average. Such cranes have a large range of action and a very small theoretical cycle, being very efficient in the operation of ships. The working cycle of the crane is the essential element in assessing the productivity of the port facility.
The quay crane with the main characteristics was presented:
- maximum load: 50 tons;
- lifting height: 60 m;
- installed power: 125 kW;
- type: Hercules.

The optimization of the flow was carried out with the help of the Design Modeller option offered by the ANSYS Fluent program: the optimization of the geometric construction of a sector of the hydraulic installation of the quay crane was analysed. Given that it is equipped with 2 hydraulic lifting cylinders, the round-return installation sector with oil supply for the 2 cylinders was included. The fluid entry and exit points were established. Thus, 2 inputs and 2 outputs were noted for the 2 actuation cylinders and the distribution of speeds on the routes of the installation was followed so that there were no discontinuities in the distributions of the current lines. Finally, the routes of the structures with the uniform hydrodynamic spectrum of speeds were chosen.

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