THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 1 - 2016, ISSN 1453 – 083X

DESIGN AND FLOW MODELLING OF BALLAST TANK IN-LINE EJECTOR

[1]Constantin DUMITRACHE, [2]Corneliu COMANDAR, [3]Bogdan HNATIUC
[1,3]Maritime University of Constanta, Romania, [2]"Ghe. Asachi" Technical University of Iasi, Romania
e-mail: ldumitr@yahoo.com

ABSTRACT

The purpose of this paper is to present the stages of designing a water in-line ejector used for ballast tanks stripping operation. The design operation was performed using NX Siemens CAD and ANSYS 15 for computer fluid dynamic analysis CFD. This ejector' design was based on descriptive drawings of component parts, all dimensions being chosen from a worldwide supplier of high quality marine products. Computer Fluid Dynamic analysis is based on the finite element method (FEM), meshing, boundary condition and loads. Finally, we reached important conclusions regarding velocities, pressure and temperature of the fluid.

KEYWORDS: in-line ejector, CAD NX Siemens, revolve, extrude, velocities, total pressure, temperature, CFD

1. Introduction

On board of commercial ships there are a lot of auxiliary devices, such as ejectors, emergency fire pumps, transfer pumps and electrical control, which are most used in maritime industries [1].

An ejector is a static piece of equipment with no moving parts (Figure 1). There are three major components of an ejector: the house with suction chamber (1), the motive nozzle (2) and the diffuser (3).

The operating principle of an ejector is to convert pressure energy of high pressure motive liquid into velocity. High velocity liquid emitted from a motive nozzle is then used to work on the suction fluid. This work occurs in the suction chamber and inlet diffuser.

The remaining velocity energy is then turned back into pressure across the diffuser. In simple terms, high pressure motive liquid is used to increase the pressure of a fluid that is at a pressure well below motive liquid pressure [2].

The ejectors are used in a large range of applications in maritime industry:

- stripping of bilges from the bottom of the vessel;
- filling and stripping of ballast tanks;
- stripping of all sorts of mediums from cargo holds includes oil, gas, water and sewage;
- stripping of bilge from chain lockers.

In the engine room ejectors, can both be used for stripping of bilge and for ventilation of exhaust or other gasses, and removal of ashes from incinerators.

Multiple use portable ejectors are designed for multiple suction purposes. These ejectors can be installed with hoses, in order to utilize the ejector various places on the ship. Portable ejectors are favorable to use where various suction quantities are low or where coarse vacuum cleaning are needed. Peak tanks are situated either in the front or the rear of the vessel. Ejectors can both be used for stripping and filling these tanks.

In the priming of centrifugal pumps the ejector creates vacuum which will initiate the function of pumps.

2. Construction of in-line ejector

All dimensions for the in-line ejector were presented in the supplier's technical documentation [1]:

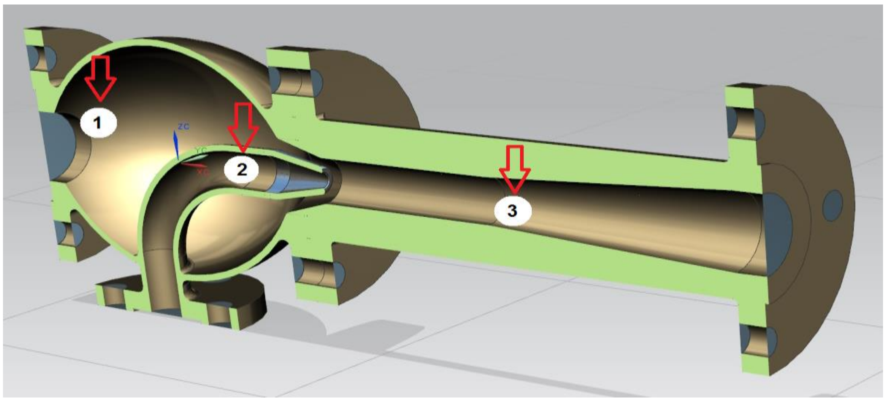


Fig. 1. *Assembly NX cross section viewing parts of in-line ejector; 1- the house, central part of ejector, containing suction and motive inlet; 2 - the motive nozzle is mounted in the house with the purpose of regulating motive liquid; 3 - the diffuser, contains the process of mixing and ejecting the motive and sucked fluid*

2.1. 3D Design of house ejector

The essential feature of the ejector is the house (1) presented in Figure 2.

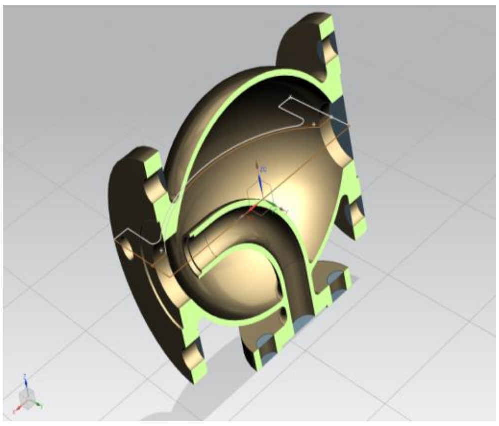


Fig. 2. *Section view of house ejector*

Achieving a 3D house representation starts with the sketch drawn with the yellow line in Figure 2 and goes on with the use of the *Revolve* option that gives the final shape with two flanges at the extremities.

The third flange, also known as motive inlet, is done initially in the form of sketch which is then extruded with the *Extrude* operation. The diameter pipe flange is crossing the ejector body and makes a rounded angle of 90 degrees that was done with the option *Sweep along Guide.*

2.2. 3D Design of motive nozzle

The easiest 3D part is motive nozzle constructed with 2D yellow sketch revolved with *Revolve* operation (Figure 3). The nozzle is considered the heart of the ejector because it converts the energy of pressure to velocity and directs the flow of motive liquid into the diffuser.

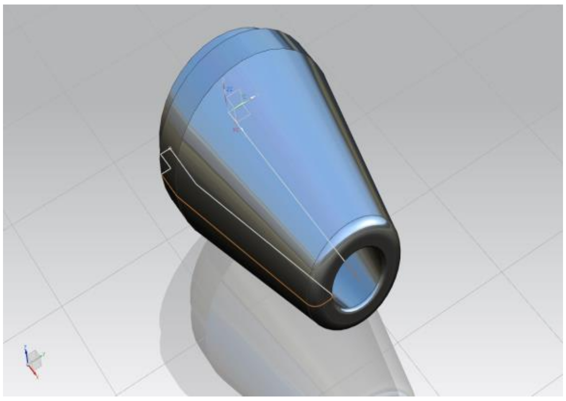


Fig. 3. *Main view of motive nozzle*

2.3. 3D Design of diffuser

The diffuser (Figure 4) is constituted of three parts:

- inlet diffuser;
- throat section;
- outlet diffuser.

Inlet diffuser provides a correctly shaped introductory section and converging diffuser section to handle the high velocity flow of fluids. It is in this section that entrainment and mixing of the motive and load fluids is completed and the energy of liquid velocity is converted to pressure.

The throat section is the transition piece between the converging inlet diffuser and the diverging outlet diffuser.

The outlet diffuser provides a correctly shaped diverging diffuser section for completing the conversion of velocity to pressure. The outlet diffuser section further reduces the fluid velocity to a reasonable level so as to convert practically all the velocity energy to pressure energy [3].

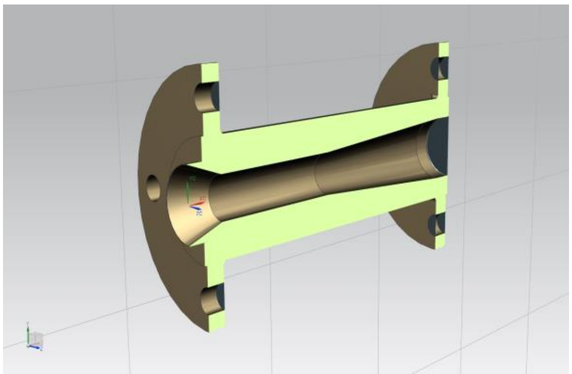


Fig. 4. *Section view of diffuser*

2.4. Assembly of component parts

Our in-line ejector is 25-50-50F type (25 mm - inner diameter of motive inlet, 50 mm - inner diameter of suction inlet, 50 mm - inner diameter of discharge outlet) and has the best efficiency for ballast tanks and cargo tanks [1].

All three parts of the assembly were added using touching (on flanges), infer center axis (on holes), concentric constraints. The final assembly is created when the component objects are added to the assembly part file, each component object being mated with the corresponding objects. The 3D Design of the ejector is presented in Figure 1.

Copper alloy was used for the house ejector and the diffuser, and stainless steel with mechanical properties presented in Table 1 was used for the motive nozzle.

Table 1. *Mechanical properties*

Material	**Yield Strength [N/mm²]**	**Ultimate Tensile Strength [N/mm²]**
Copper alloy	280	430
Stainless Steel	207	586

Both materials show excellent resistance to corrosion in sea-water because of main constituents, copper and nickel. This alloy has excellent service under high-velocity conditions, where cavitations erosion is important. But stainless steel is a little more resistant to mechanical-wear than copper alloy due to the superior hardness.

3. Computer fluid dynamics - CFD

CFD has become a powerful tool that can be employed either for pure/applied research or for industrial applications. Computational simulations and analyses are increasingly performed in many fluid-engineering applications, which include aerospace engineering (airplanes, rocket engines), automotive engineering, biomedical engineering (blood flow in artificial hearts), chemical engineering (fluid flow through pumps and pipes), civil and environmental engineering [4].

The first step in our CFD analysis is the creation of the geometry of the flow region using NX Siemens software (Figure 1). This assembly was imported in ANSYS 15 to extract the ejector flow region presented in section viewing in Figure 5.

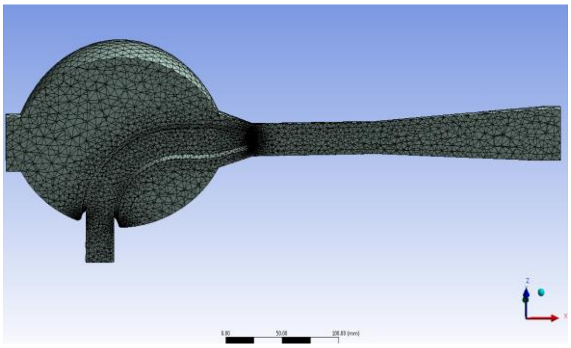
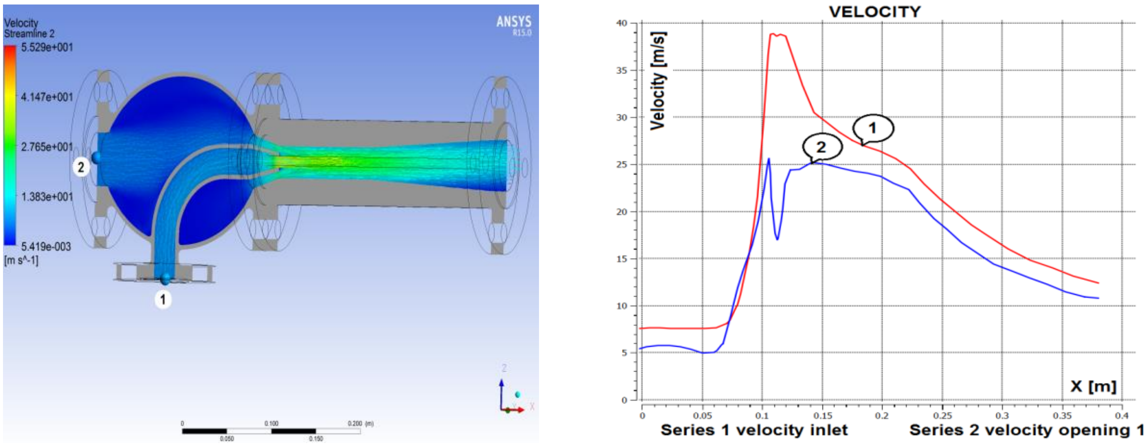


Fig. 5. *Section view of flow meshed region*

The second step is meshing operation (Figure 5) which generates 292884 nodes and 1496290 elements.

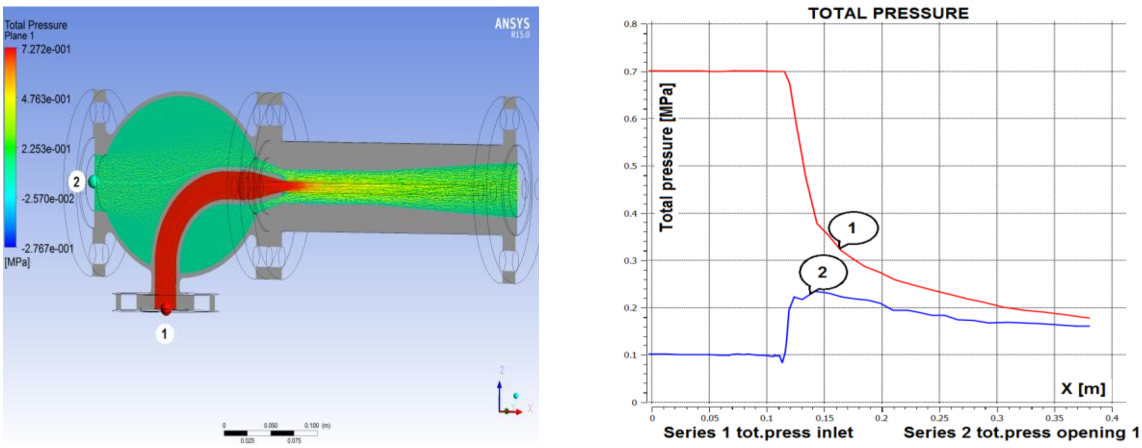
3.1. Boundary conditions

We considered that the ballast tank in-line ejector is assigned water as the fluid, with a 7 bar pressure at the motive inlet and a temperature of 25 °C. It is called “in-line” ejector because the suction inlet and outlet discharge are placed on the same line; both suction inlet and outlet have the atmospheric pressure and opening temperature 15 °C.



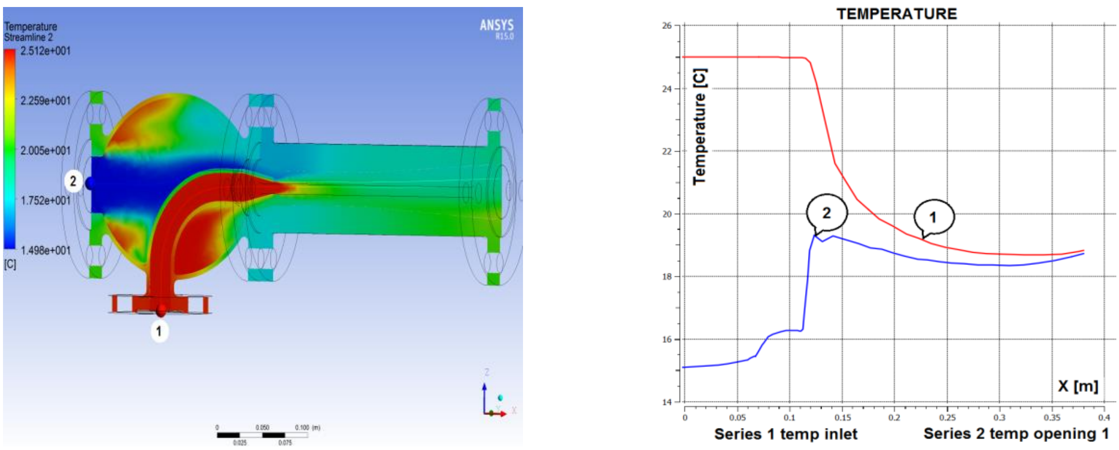
a b

Fig. 6. *Velocity distribution: a) ejector section plane; b) centered streamlines variation 1 (inlet) and 2 (opening 1)*



a b

Fig. 7. *Total pressure distribution: a) ejector section plane; b) centered streamlines variation 1 (inlet) and 2 (opening 1)*



a b

Fig. 8. *Temperature distribution: a) ejector section plane; b) centered streamlines variation 1 (inlet) and 2 (opening 1)*

4. Conclusions

As can be seen in Figure 7, motive liquid pressure is very important because it ensures the minimum pressure on the suction inlet. Generally, it is recognized that the manufacturer has designed the system to maintain stable operation with liquid pressures at or above a minimum liquid pressure. In our example, the motive inlet pressure is 7 bar and for this value the pressure at the suction inlet is around 1 bar. When the velocity of the fluid starts to increase at the motive nozzle, in the same time the suction velocity at opening 1 is increasing (Figure 6b). If the motive liquid supply pressure falls below design, then a motive nozzle will pass less liquid. When this happens, the ejector is not provided with sufficient energy to compress the suction fluid to the design discharge pressure. The same problem occurs when the supply motive liquid temperature rises above its design value, resulting in increased specific volume, and consequently, less liquid passes through the motive nozzle [2].

An ejector may operate unstably if it is not supplied with sufficient energy to allow compression to its design discharge pressure [5]. Unstable ejector operation is characterized by dramatic fluctuations in operating pressure. If the actual motive liquid pressure is below design or its temperature above design, then, within limits, an ejector nozzle can be rebored to a larger diameter. The larger nozzle diameter allows more liquid to flow through and expand across the nozzle. This increases the energy available for compression. If the motive liquid supply pressure is more than 20-30% above design, then too much liquid expands across the nozzle. This tends to choke the diffuser. When this occurs, less suction load is handled by the ejector and suction pressure tends to rise. If an increase in suction pressure is not desired, then ejector nozzles must be replaced with ones having smaller throat diameters or the motive liquid pressure corrected.

In conclusion, an ejector is designed to operate at exact motive pressure and motive capacity, any changes in motive flow can result in [1]:

- Varying motive flow will decrease ejector performance.
- Decreasing motive flow from the specifications might result in an insufficient or even non-performing ejector.
- Increasing motive flow might cause the ejector to malfunction.

Ejectors are designed for maximum suction capacity; therefore, increasing motive flow might not increase suction capacity.

References

[1]. Maritime Diesel Electric, *Marine Consulting, Engineering & Technical Purchasing*, www.mardiesel.com.

[2]. J. R. Lines, R. T. Smith, *Ejector system troubleshooting*, The International Journal of Hydrocarbon Engineering, UK, 1997.

[3]. F. Duncan Berkeley, *Ejectors*, Graham Manufacturing Company, Iinc., BATAVIA, N. Y., Reprinted from Petroleum Refiner, December 1958.

[4]. Jiyuan Tu, Guan-Heng Yeoh, Chaoqun Liu, *Computational Fluid Dynamics, A Practical Approach*, Second Edition, Butterworth-Heinemann is an imprint of Elsevier.

[5]. Yveline Marnier Antonio, Christelle Périlhon, et al., *Thermodynamic Modelling of an Ejector with Compressible Flow by a One-Dimensional Approach*, open access Entropy 2012, 14, p. 599-613, ISSN 1099-4300.