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Fluid Structure Interaction (FSI) analysis on ballast tank in-line ejector

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Abstract. Ejectors are common devices on board liquid carrier vessels and meet on both cargo and ballast tanks. The "in-line" ejector presented in this paper is an original model that was designed with NX Siemens, using information and technical data from a worldwide supplier of high quality marine products. This paper presents a static analysis of fluid' influence which passing through an ejector on its metal structure using Ansys. From a previous work we took into account the data obtained with CFD (computer fluid dynamic) analysis. The pressure and fluid temperature fields were imported and applied to the meshed ejector model with finite elements, obtaining data on deformations and equivalent stresses and elastic strain.

1. Introduction

As we know the ejectors use the energy of some fluid jets to transfer fluids. Structural, the ejectors show as in figure 1 where the notations shown in the figure were made.

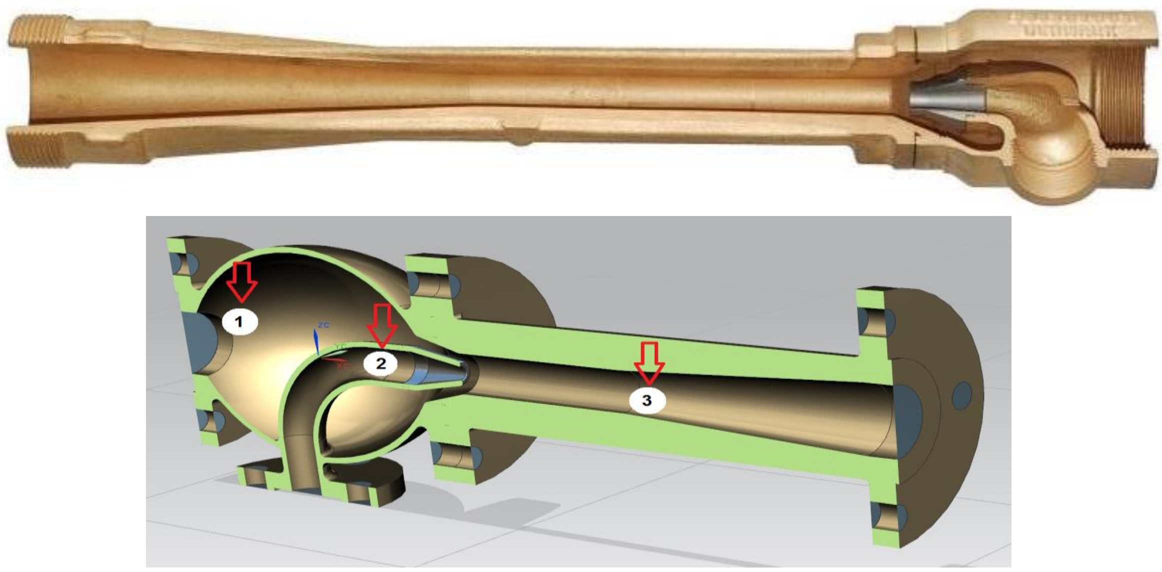

Figure 1. Sections viewing of 3D ejector assembly, [1].

The assembly NX cross section viewing from figure 1 contains the following parts:

- 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.

The working fluid energy is used to suck the transfer fluid, passing it through the house and the confusor part. This confusor part represents the conical side situated at the beginning of diffuser. For this purpose, the working fluid is introduced under pressure through the motive nozzle 2.

In the ejector nozzle there is an increase in kinetic energy, so a powerful jet is produced at the exit of the nozzle. The jet is mixed with the transfer fluid that enters in the house through the flange part. From this mixture results a transfer energy process from the jet to the transfer fluid.

For ejectors that have to perform high performance, very fine machining process of the interior surfaces is required, so that the energy losses are minimal.

Also, the centering of the jet to the house part has a great influence on the performance of these machines.

Typically, the ejectors encounter the ballast-bilge installation (water-jet ejectors), ship rescue systems with flooded compartments, and lately, even at oil chemical tankers.

Ejectors have the following benefits in operation:

- allow for high flow rates at high vacuum loads, thus having very good suction properties;
- are very simple from a constructive point of view;
- have low gauge and weights and have no moving parts.

No moving parts can be used to transfer non-homogeneous suspension liquids without leading to large wear. They are frequently used as auxiliary means for priming pumps.

2. Fluid Structure Interaction (FSI) analysis

In the previous paper [1] we specified that an in-line ejector with the dimensions 25 mm - inner diameter of motive inlet, 50 mm - inner diameter of suction inlet, 50 mm - inner diameter of discharge outlet has the best efficiency for ballast tanks and cargo tanks [2].

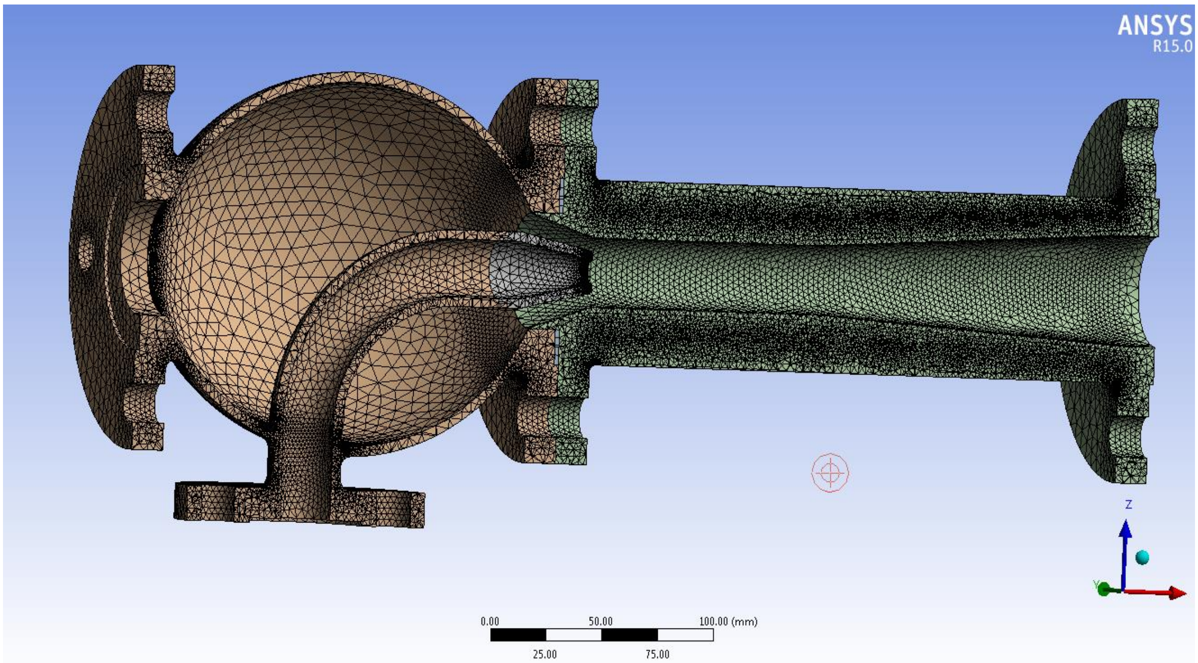

Figure 2. Section viewing of ejector mesh assembly.

The materials for the house ejector and diffuser were assigned copper alloy with mechanical properties, Yield Strength = 280MPa, Ultimate Tensile Strength = 430MPa and for motive nozzle, stainless steel with mechanical properties, Yield Strength = 207MPa, Ultimate Tensile Strength = 586MPa.

It is known that both materials have very good corrosion resistance in sea-water because of its principal constituents, copper and nickel. These alloys have excellent service under high-velocity conditions, where cavitation erosion is important. But stainless steel is a little more resistant to mechanical-wear than copper alloy due to the superior hardness.

With Ansys the meshing operation using finite elements generated a total of 242668 nodes and 1234214 elements in the whole ejector component assembly shown in figure 2.

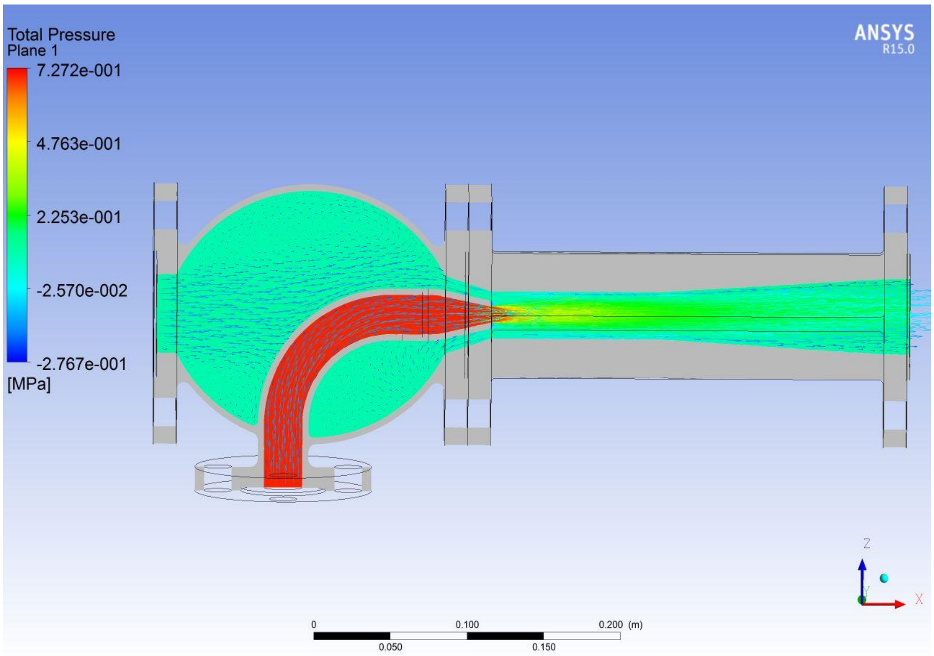

Figure 3. Section viewing of fluid total pressure distribution.

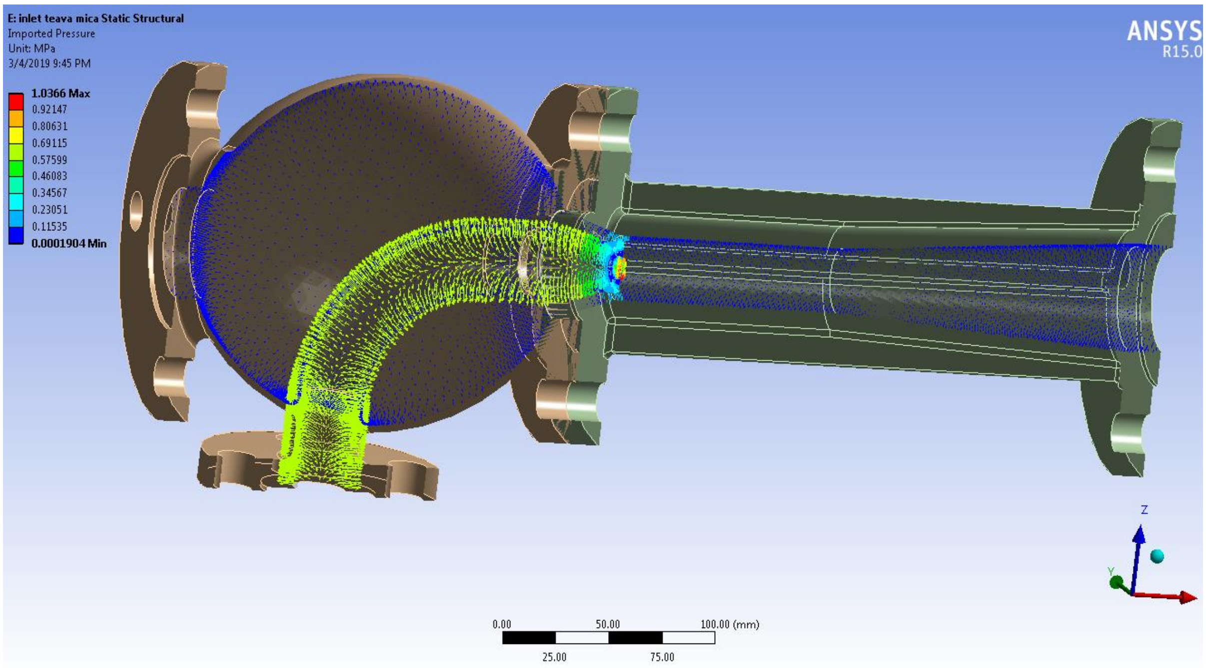

Figure 4. Section viewing of imported pressure at Static Structural module.

In-line ejectors are devices that are extensively required in ship ballast systems and are especially used to strip the tanks when finalizing de-ballasting operations. They are called in-line ejectors because the suction inlet and outlet discharge are in the same linear direction.

As we know from the previous work, seawater was used as a fluid with a temperature of 25˚C and a pressure of 7 bar at motive inlet. It is understandable why seawater has such a temperature because it is assumed that the ship performs the de-ballasting operation at a berth in a port where the water depth is small and the temperatures are raised during the summer.

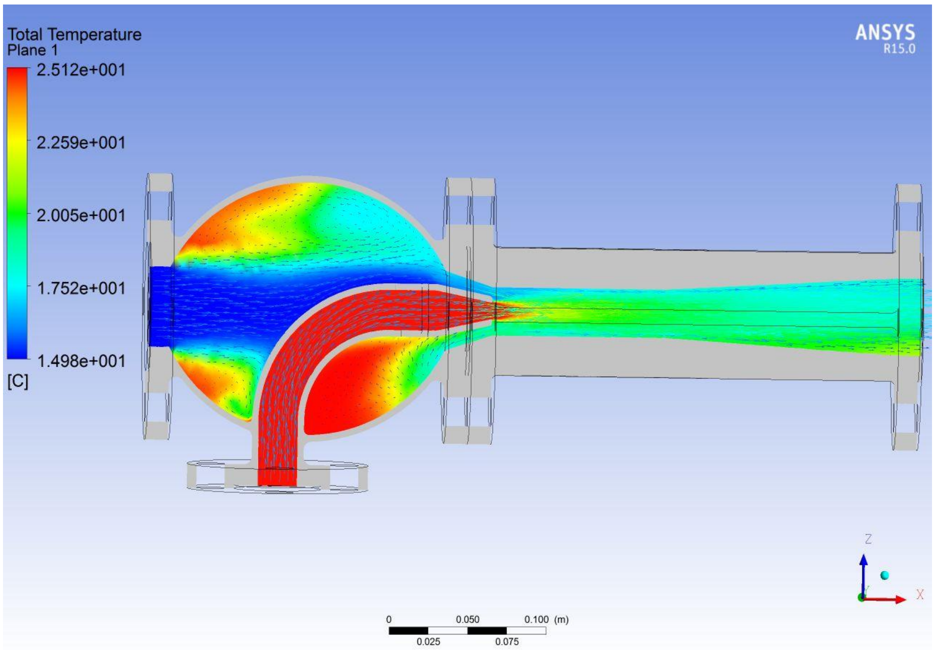

Figure 5. Section viewing of fluid total temperature distribution.

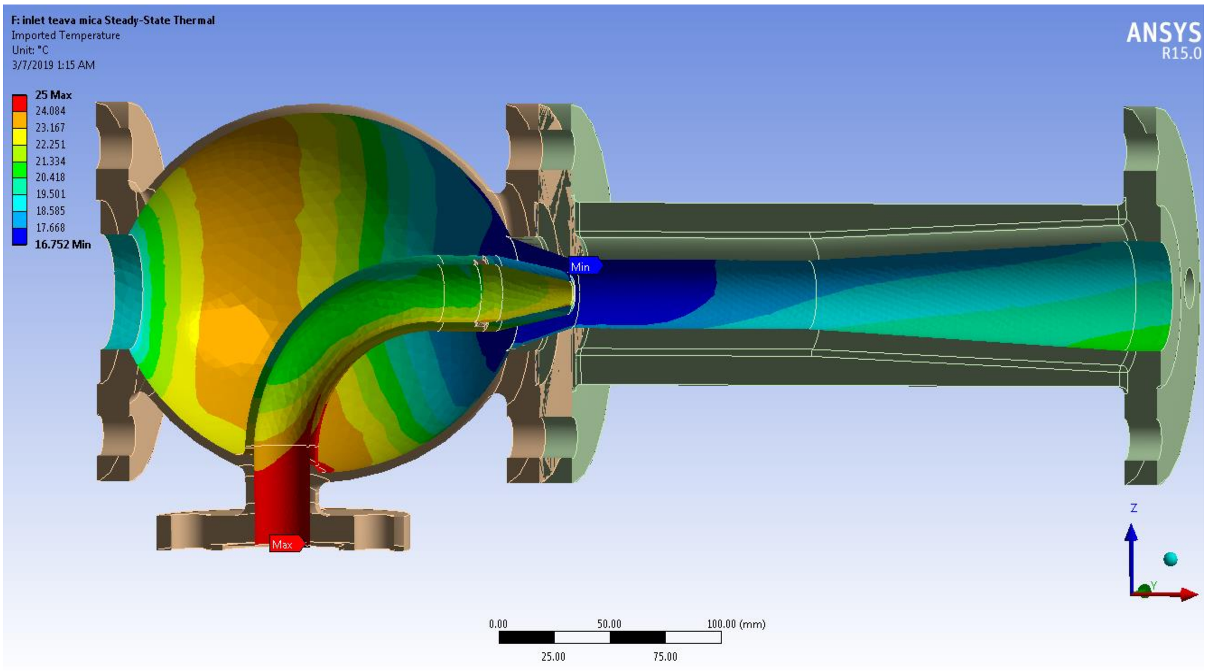

Figure 6. Section viewing of imported temperature at Steady-State Thermal module.

When the fluid enters the ejector with this high pressure, it will exert pressure on the material up to the motive nozzle, and after it the fluid will relax. The total pressure of the fluid determined in the previous paper is shown in figure 3. This pressure field was then imported at Ansys Static Structural module and distributed on the ejector' inner walls that come in contact with the fluid as in figure 4.

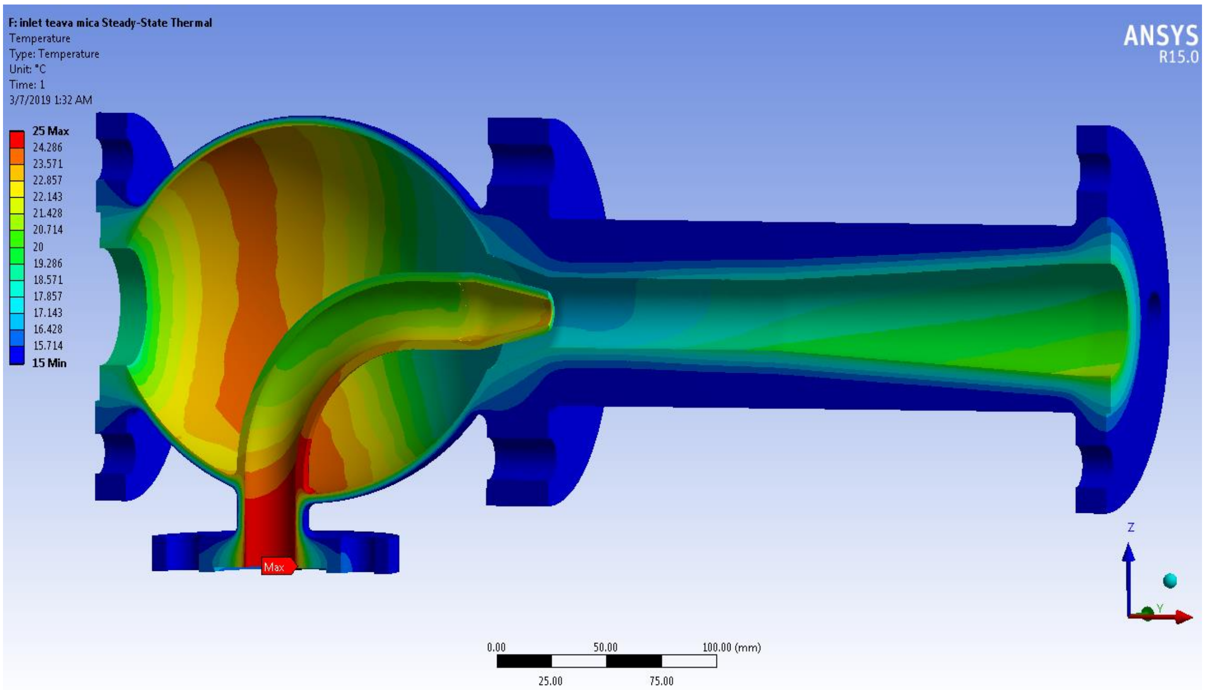

Figure 7. Section viewing of ejector body temperature at Steady-State Thermal module.

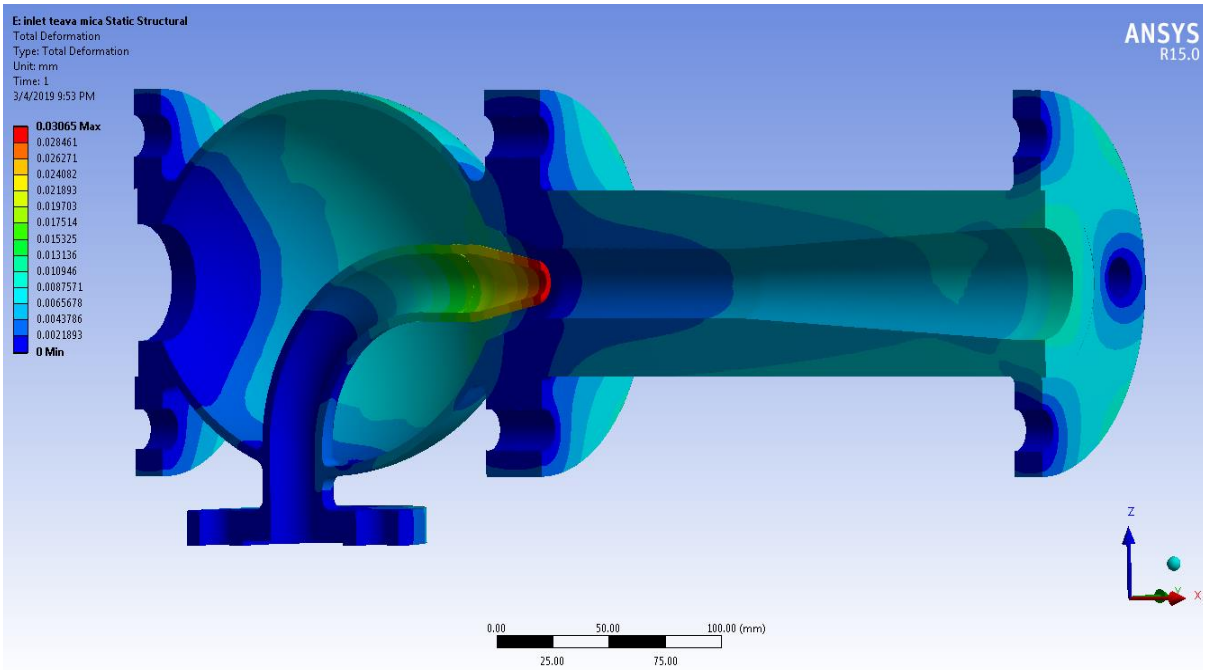

Figure 8. Section viewing of ejector total deformation at Static Structural module.

As mentioned, the fluid entering through the motive inlet has a temperature of 25˚C, and the inlet suction fluid has a temperature of 15˚C (figure 5), the same temperature with outer walls of the ejector. Due to the existence of this difference there will be a convection heat exchange on the outer walls of the ejector taking into account a convection coefficient of 10W/mm^2 C˚.

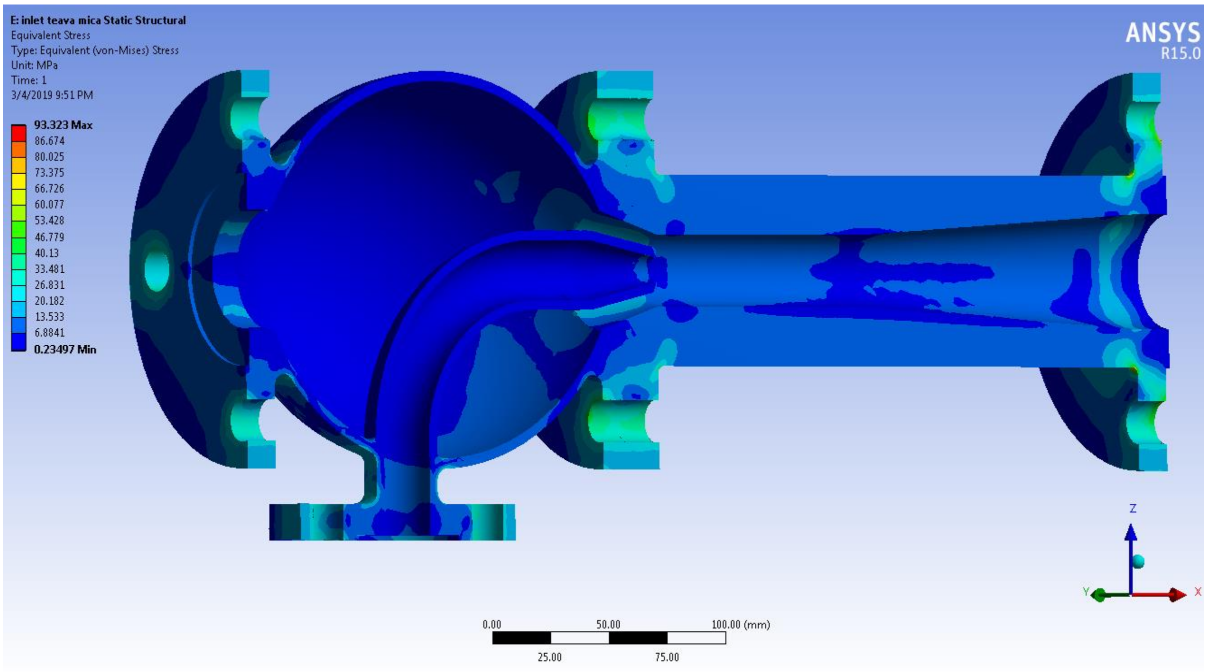

Figure 9. Section viewing of ejector Equivalent Stress at Static Structural module.

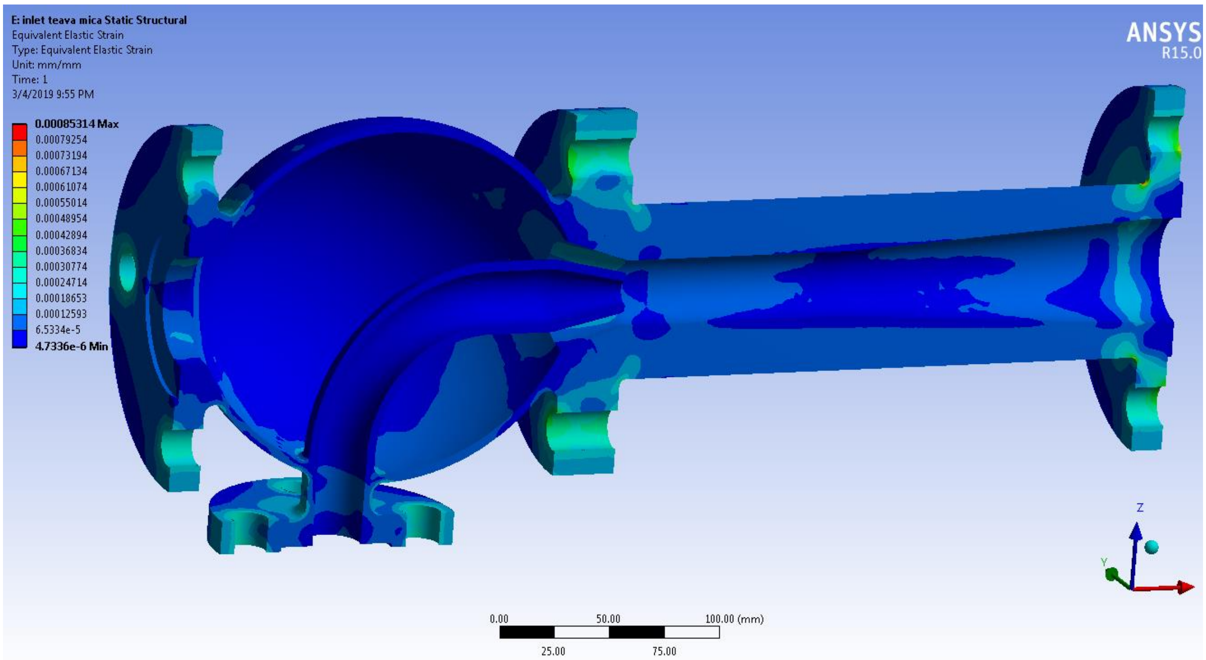

Figure 10. Section viewing of ejector Equivalent Elastic Strain at Static Structural module.

Fluid temperature is imported into the Ansys Steady State Thermal module and distributed on the ejector inner walls (figure 6). This temperature field will allow a heat exchange with the ejector material structure by determining the temperature distribution on the ejector body as in figure 7.

3. Conclusions

All these fields, pressure and temperature distributions are imported in the Static Structural module to determine the mechanical properties expressed by Equivalent Stress, Equivalent Elastic Strain and Total deformation.

As expected and confirmed by the previous work, the ejector works normally. The pressure at the outlet discharge does not fluctuate due to the fact that it is desired to have a constant pressure at the motive inlet during the ejector operation. We know that a variation in fluid pressure will cause the nozzle to pass less fluid. If this happens, however, the ejector will not produce enough energy by compressing the fluid, which will diminish the suction effect [3].

In figure 8 we note that total deformation is greater at the nozzle, which shows us that is the most suppresed element. Not accidentally this piece is made of stainless steel with good corrosion resistance and wear as presented in this paper. The equivalent stresses and equivalent elastic strain in figure 9 and 10 show that the highest values are found in the clamping holes in the flanges because fixed holes constraints have been applied to these holes.

4. References

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