NUMERICAL MODELLING OF FLOW IN THE EDUCTOR PUMP

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Rezumat. Lucrarea de față urmărește studierea proceselor care au loc în interiorul pompelor cu ejector în timpul funcționării acestora în scopul alegerii unei geometrii optime, care să ofere maximul de eficiență. Modelarea numerică este realizată cu ajutorul programului ANSYS Fluent. Stabilirea parametrilor domeniului de calcul, discretizarea acestuia și stabilirea condițiilor pe frontiere se realizează pentru un studiu comparativ a două geometrii diferite ale pompei cu ejector. Modelarea numerică se realizează utilizând metoda ecuațiilor Navier Stokes mediate în maniera Reynolds (RANS). Sunt prezentate apoi rezultatele, în funcție de care se alege geometria cea mai eficientă.

Abstract. The present paper focuses on eductor pumps processes during operation to find the appropriate geometry for achieving the highest efficiency. Numerical modelling is performed with ANSYS Fluent. In the numerical modelling process, computational domain parameters, as well as boundary conditions, were set for two eductor geometries under comparative analysis. Numerical modelling is performed using the Reynolds-averaged Navier–Stokes equations (RANS). Then the experimental results are presented and the most effective geometry is selected based on them.

KEYWORDS: *numerical modelling, eductor pump, fluid, suction, efficiency*

1. INTRODUCTION

Eductors are hydraulic systems that use a driving fluid to entrain another fluid. The driving fluid may be a liquid, steam or any other gas. The entrained suction fluid may be a gas or a liquid.

Eductors provide a wider range of applications even though their coefficient of performance (COP) is lower as compared with other pumps, ranging between 0.1 and 0.4 [1]. Nevertheless, eductors can reach performance coefficients similar to other systems provided enough attention is paid to their geometry design [2]. A major advantage of eductor pumps is that, without moving parts, they provide robust operation and require low maintenance cost [3]. Due to their relative simplicity and the absence of moving parts that may block or wear, the use of eductors has become quite common for evacuation of corrosive agents, sewage, slurry or corrosive particles in suspension. Eductor pumps are also used for fire fighting purposes, the motive fluid which is water entraining the foaming agent and yielding foam as a result of fluids mixture. Jet pumps are commonly used to extract water from water wells, as they do not require previous priming. Eductors are also widely used in different refrigeration systems.

2. THEORETICAL BACKGROUND

The operating principle is based on the transfer of energy from the fluid moving at high velocity (motive fluid) to the suction (entrained) fluid. Schematic diagram of the eductor and static pressure and fluid velocity profiles along eductor length are shown in figure 1 [3].

The high velocity of the motive fluid creates a low pressure zone that draws in and entrains the suction fluid in the suction chamber through the suction nozzle.

The eductor is a particular case and one of the practical applications of Bernoulli's principle:

$$p + \frac{\rho v^2}{2} + \rho g h = constant \qquad (1)$$

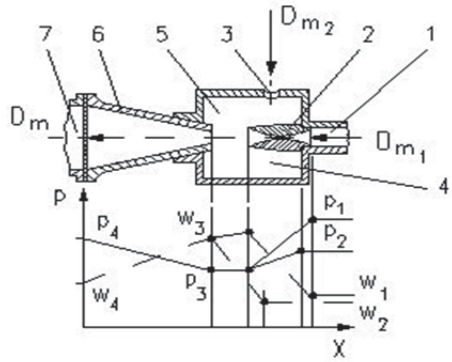

Fig. 1. Schematic diagram of the eductor**:** 1- driving nozzle 2- diffuser throat; 3 – suction nozzle; 4 – suction chamber; 5- mixing section; 6- diffuser; 7- converging-diverging outlet nozzle [3].

where: p – static pressure;

$\frac{\rho v^2}{2}$ – dynamic pressure;

$\rho g h$ - hydrostatic pressure.

The ejection coefficient is [3]:

$$u = \frac{Dm_2}{Dm_1} \qquad (2)$$

where: u – mass entrainment ratio;

Dm_2 – is the mass flow rate of suction fluid;

Dm_1 – is the mass flow rate of motive fluid.

A number of research studies have been carried to improve the overall eductor efficiency. Elbel and Hrnjak (2008) investigated experimentally the performance of eductor in operation, and found that the eductor performed with a higher efficiency when the high side pressure was relatively low [4].

Lucas and Koehler (2012) investigated experimentally the relationship between eductor efficiency and the high-side pressure. The results show that the eductor efficiency is decreasing with decreasing evaporation pressure as well as increasing gas cooler outlet temperatures [5].

Nakagawa et al. (2010) presented an experimental investigation of eductor geometry, which shows that the eductor efficiency depends on the eductor geometry, the evaporation temperature and the gas cooler outlet temperature [6].

3. NUMERIAL MODELLING OF EDUCTOR PROCESSES

Numerical modelling is performed using the Reynolds-averaged Navier–Stokes equations (RANS) [7].

Numerical modelling of flow was performed with Fluent integrated in ANSYS Workbench Platform 16.1. This CFD software numerically solves the three-dimensional Reynolds-averaged Navier–Stokes equations by means of the Finite Volume method on a meshed geometry [8].

The geometry is generated with ANSYS Meshing Design Modeler and the meshing grid with ANSYS Meshing, which are pre-processing modules integrated in ANSYS Workbench 16.1 [9].

3. INPUT DATA

Two-dimensional computational domains are used for two different eductor geometries to fully capture the processes under analysis as well as to require minimal computational dynamics [10].

The mesh density was kept minimal not to require extensive computational effort but at the same time to get accurate modelling results. Thus, the discretization grid includes a number of 37,904 elements and 38,533 nodes. The flow is chosen *k*-ε, turbulent flow.

Two numerical simulations were performed on two geometries to determine which provides higher eductor efficiency.

A 52 cm long and 22 cm wide computational domain was selected. Computational domain area is 750 cm^2. These dimensions apply to both geometries analysed, the only difference being the suction fluid nozzle diameter for the second geometry.

Air is used both as driving fluid and suction fluid. For the first geometry (Fig. 2), diffuser throat diameter (D_1) is 2 cm and suction fluid nozzle (D_2) is 7 cm. In case of first geometry (Fig. 2) the suction fluid enters the mixing section perpendicular on the driving fluid. In case of second geometry (Fig. 3) suction fluid enters the mixing section parallel with the driving fluid. In this case, suction nozzle diameter is equal to the sum of the diameters of the two inlets/nozzles ($D_1 + D_2$).

The mass flow rate of driving fluid in the mixing chamber through the diffuser throat is 5kg/s.

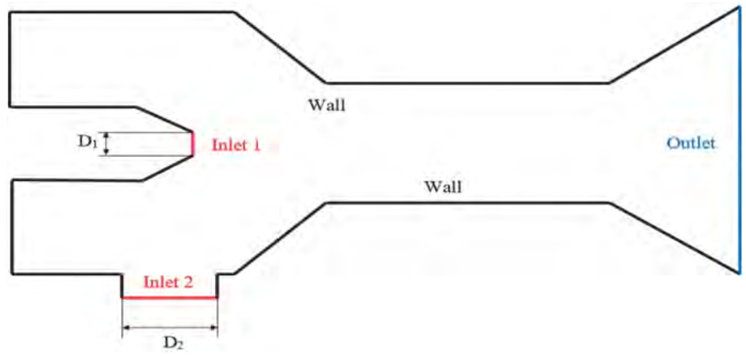

Fig. 2. Discretization for the first geometry model.

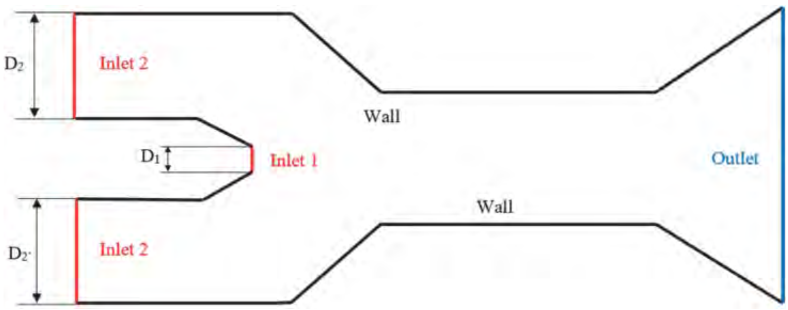

Fig. 3. Discretization for the second geometry model

4. RESULTS AND DISCUSSIONS

The same initial and boundary conditions are set for the numerical simulations for both geometries.

Figure 4 shows the velocity magnitude of the fluids in the eductor with the first geometry.

As Figure 4 shows, due to the position of suction nozzle perpendicular on the driving fluid, when the suction fluid is entrained in the suction chamber, driving fluid stream deviates to the upper part.

Figure 5 shows fluid velocity on the Y-axis. It can be seen that suction air enters into the suction chamber at high speed, and makes the suction fluid flow deviate greatly.

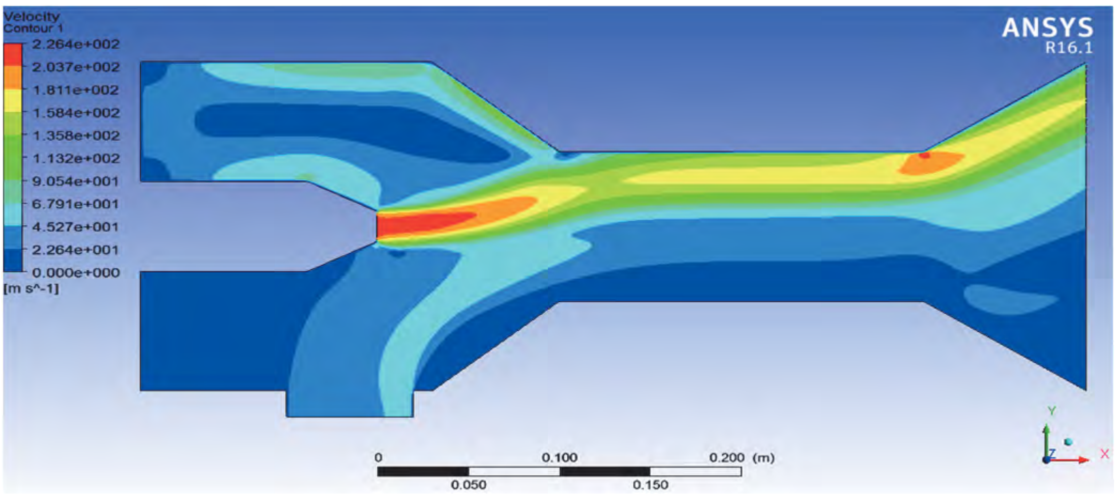

Fig. 4. Upward deviation of motive fluid stream determined by the fluid coming through the suction nozzle.

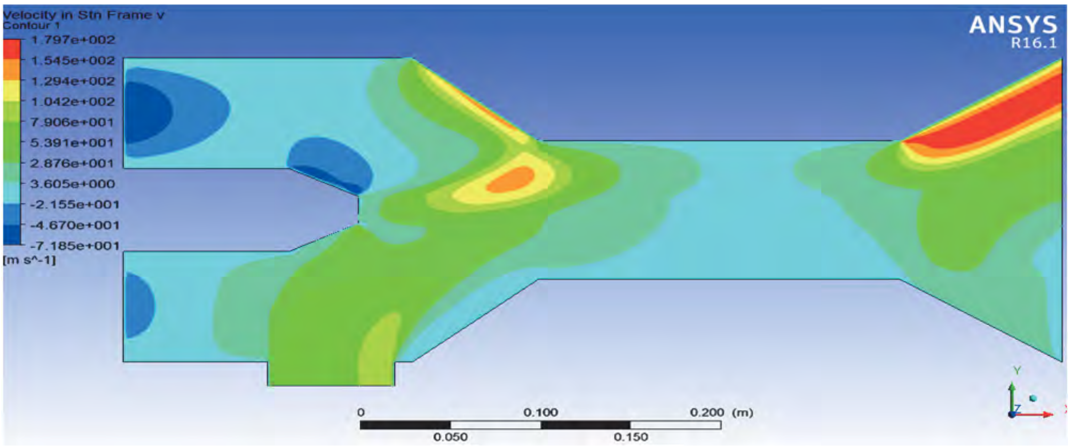

Fig. 5. Eductor fluids velocities on the direction of Y-axis.

If the suction nozzle is arranged so that suction fluid enters the suction chamber perpendicular to the direction of driving fluid, in the second geometry (Fig. 3), as shown in Fig. 6, then the driving fluid flow will no longer deviate.

Figure 7 shows eductor fluids velocities when the suction fluid enters the suction chamber parallel to the motive fluid (according to geometry shown in Fig. 3).

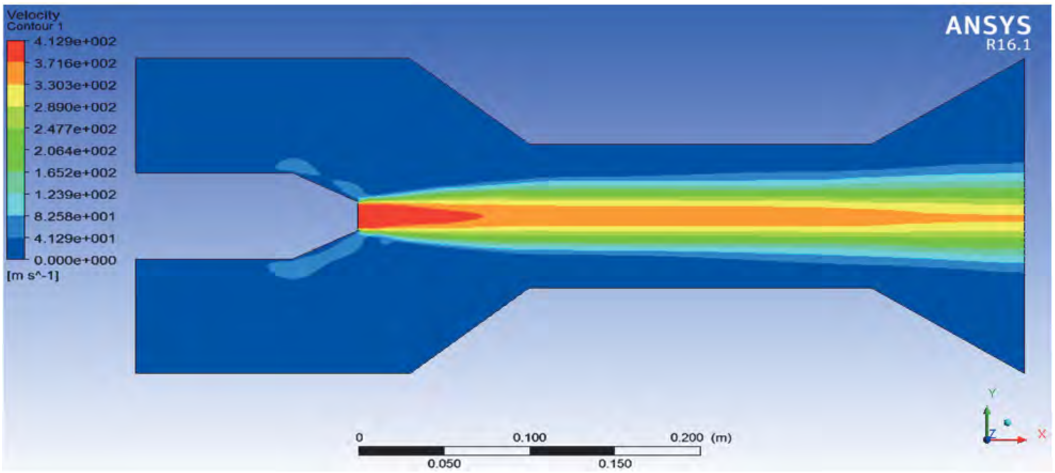

Fig. 7. Flow of driving fluid stream for the second geometry.

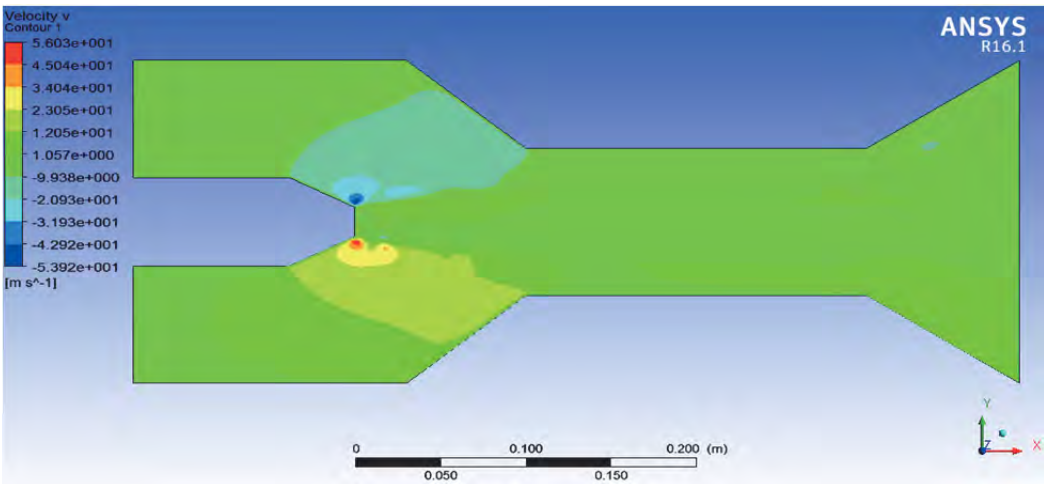

Fig. 8. Eductor fluids velocities on the direction of Y-axis for the second geometry analysed.

5. CONCLUSIONS

Following the numerical modelling of eductor flows corresponding to the two geometries, it can be observed that eductor model corresponding to the second geometry is more efficient, even though this study is a purely theoretical approach and the result is influenced by using of a 2D computational domain instead of real life 3D case.

The fact that suction fluid is entrained in the suction chamber perpendicular on the driving fluid leads to its deviation to the upper part. This induces additional frictions in the mixing section as well as a lower coefficient of performance (COP) for this eductor type.

In addition to a low eductor coefficient of performance, the mixing process of the two fluids is no longer properly achieved which clearly points out that eductors should not be used for mixing purposes.

When using the second geometry eductor, it can be obviously seen that, entrainment of suction fluid into the suction chamber parallel to the driving fluid does not lead to driving fluid stream deviations, so that it does not induce additional energy consumption by friction with eductor walls.

This analysis is purely theoretical, in real life the process is much more complex, and eductor efficiency is obtained by superimposing of several conditions whether related to its geometry or other factors.

Impact of eductors geometries on their efficiency improvement has been the study of many studies.

Some experimental investigations have been conducted to assess the effect of eductor geometry on its performance, such as the diffuser throat shape and arrangement (Aphornratana and Eames 1997; Eames el al., 2007) [11], [12].

From the numerical simulation results analysis it can be concluded that numerical modelling is a reliable tool for analysis of fluid flow processes.

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