Theoretical Approaches Regarding the VENTURI Effect

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Abstract: *In fluid mechanics there are situations when the fluid flow is carried out inside pipelines with different values of the main flow section. Based on the research works it was therefore demonstrated that when the fluid passes from a larger to a smaller section an increase in flow velocity is obtained together with a decrease of fluid static pressure. This phenomenon it is known as the VENTURI effect. This particular effect is based on both the fluid continuity principle, but also on the principle of conservation of mechanical energy, or BERNOULLI'S principle. This principle shows that inside a specific flow region, a decrease in static pressure appears when it is achieved an increase in fluid velocity. In this paper are presented the theoretical foundations regarding fluid flow inside a special model called the VENTURI tube where the effect can be emphasized. A three-dimensional model of the VENTURI tube was constructed with Solid Edge V20 and analyzed using ANSYS CFX for highlighting the fluid flow inside. The results are presented in terms of velocity and pressure of the working fluid.*

Keywords*: fluid flow, 3D modelling, computational fluid dynamics (CFD)*

1. Introduction

In the XVII century Isaac Newton published his works related to the laws of motion. He is considered the father of physics. Later in XVIII century Daniel Bernoulli published the fluid mechanics principle that describes mathematically how the static pressure changes when fluid flow rate is modifying in time. This principle describes an incompressible fluid flow and it is based on the conservation of energy law.
The Italian physicist Giovanni Battista VENTURI (1746-1822) had made research works in the field of fluid mechanics and published his results in 1797. These results are related to fluid flow inside a constricted tube where he observed that the fluid motion is achieved with a higher velocity in the region having small section area but in the same time with a smaller value recorded for static pressure. In the region with a greater section area the fluid velocity was smaller while the static pressure increased.

2. Daniel Bernoulli's principle

The theoretical approaches that led to the principle formulated by Daniel Bernoulli in 1700's are presented hereinafter.
Daniel Bernoulli published his research regarding fluid mechanics in 1738. He was a mathematician that created a formula that mathematically explains how an increase in a fluid's flow rate results in a decrease of static pressure exerted by that fluid. This equation is based on the Law of Conservation of Energy. In order for the fluid to increase its speed, it must convert its potential energy into kinetic energy. As kinetic energy (velocity) increases, potential energy (static pressure) decreases. [2]
In a permanent flow regime of an ideally, incompressible fluid, subjected to the action of conservative forces, Daniel Bernoulli's equation, as a load equation has the form: [4]

$$\frac{v^2}{2g}+\frac{p}{\gamma}+z=C \qquad (1)$$

Where:

- $\frac{v^2}{2g}$ - kinetic load;

- $\frac{p}{\gamma}$ - piezometric load;
- z - position load.

By multiplying equation (1) with fluid specific height and the fluid weight the pressure and energy equation are obtained.
The Bernoulli equation describing the pressure values within an ideal incompressible fluid can be written as: [4]

$$\frac{\rho v^2}{2} + p_{st} + \gamma z = C \tag{2}$$

The energy equation can be written as: [4]

$$G\frac{\rho v^2}{2} + Gp_{st} + G\gamma z = C \tag{3}$$

For a barotropic fluid (compressible), the Bernoulli equation as a load equation can be written as: [4]

$$\frac{v^2}{2g} + \int \frac{dp}{\gamma(p)} + z = C \tag{4}$$

Along a fluid streamline the total pressure can be assumed as: [4]

$$p_s + \frac{\rho v^2}{2} = p_t \tag{5}$$

Where:
p_s - static pressure;
$\frac{\rho v^2}{2}$ - dynamic pressure.

3. VENTURI tube model CFD analysis

A model is constructed for the VENTURI tube and analyzed using ANSYS CFX in order to emphasize the fluid flow parameters represented by air velocity and pressure.

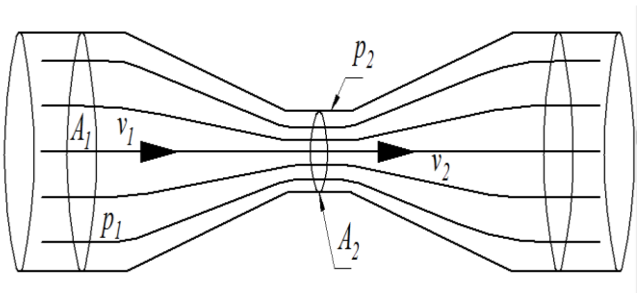


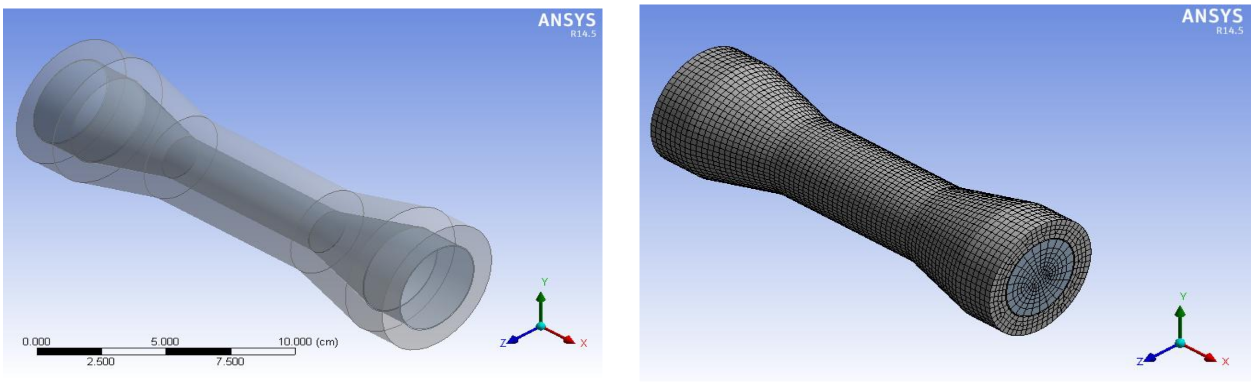
Fig. 1. VENTURI tube mathematical model

For the two main fluid regions can be written: [3]

$$\left(p_s + \frac{\rho v^2}{2}\right)_1 = \left(p_s + \frac{\rho v^2}{2}\right)_2 \tag{6}$$

It is expected that at the modification of fluid flow velocity through the tube interior pressure will change its value in a certain region.

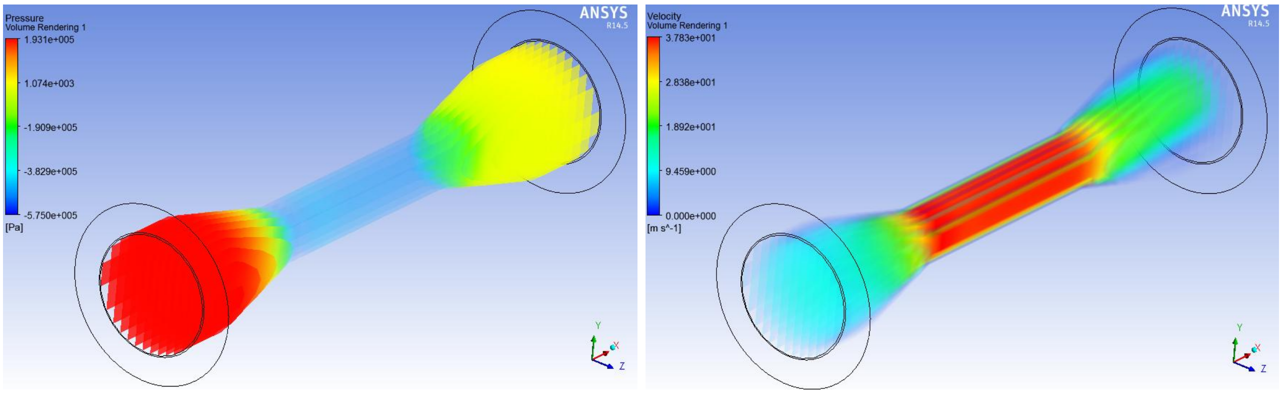
The VENTURI tube model constructed was launched into numerical analysis using ANSYS CFX software to observe the flow parameters of the working fluid (air) circulated through the tube. The results are presented in terms of pressure and velocity of the working fluid, specific values being recorded in different fluid regions within the analyzed model.



a) Imported model b) Model mesh

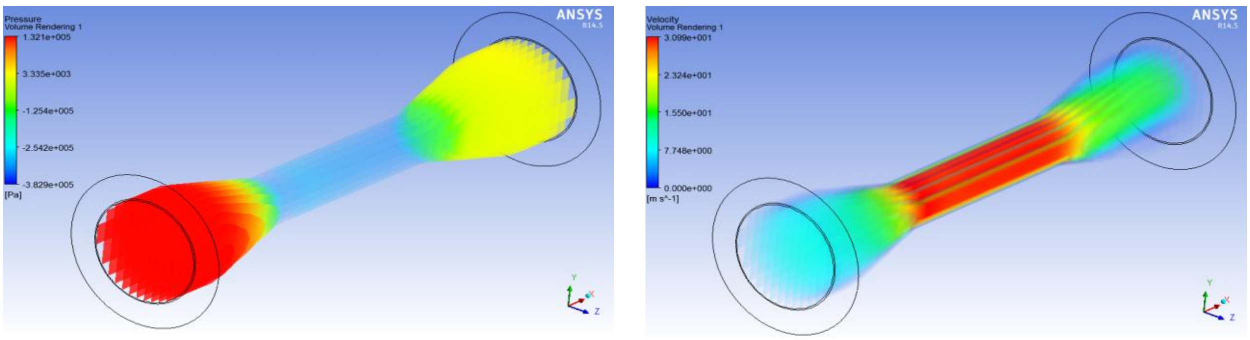
Fig. 2. The VENTURI tube three-dimensional model

A mesh was achieved for the three-dimensional model of the VENTURI tube having a total of 25987 nodes and 21987 elements of tetrahedral form.
The analysis of fluid flow through the VENTURI tube was made for the air at 25 degrees Celsius, with the declared static pressure value at the inlet in the range of (1.1, 1.3 and 1.9 bar), while the reference pressure was 1 atm.
Three sets of values were obtained for the parameters that describe fluid flow through the tube interior, being represented by pressure and velocity values on fluid regions. The obtained results are presented for the three cases in the following.



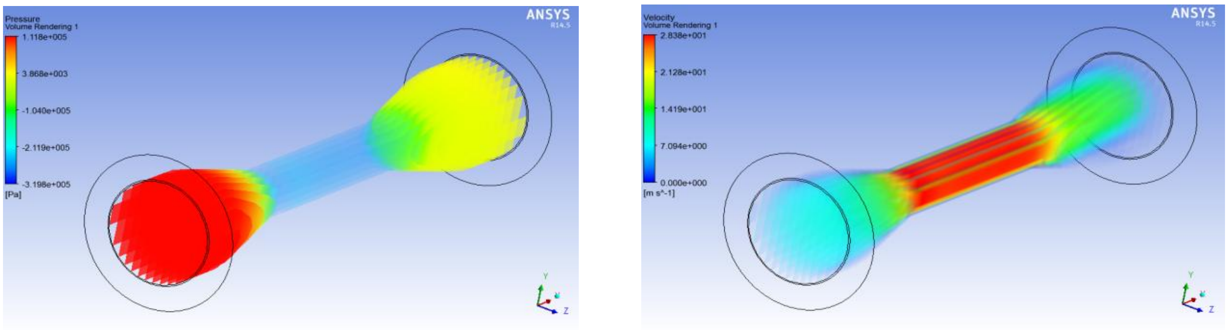
a) The values for static pressure b) Velocity values

Fig. 3. The obtained results for Case 1



a) The values for static pressure b) Velocity values

Fig. 4. The obtained results for Case 2

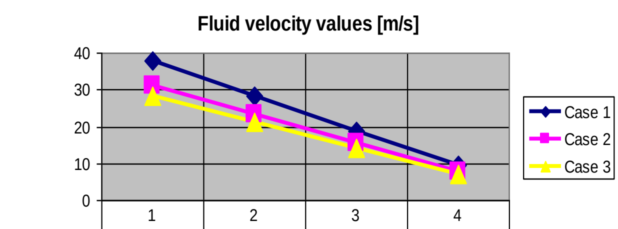


a) The values for static pressure b) Velocity values

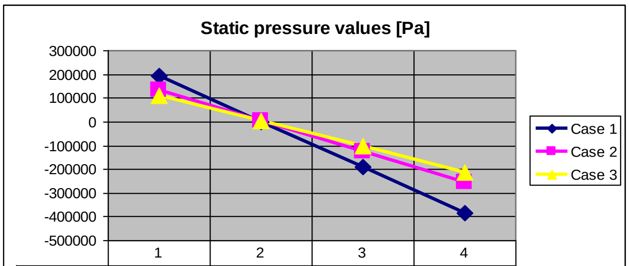
Fig. 5. The obtained results for Case 3

In Figures 3-5 are shown the values recorded for the static pressure and flow velocity of the working fluid inside the tube being noted the high levels of the inlet pressure for the large diameter section and the fluid velocity values are low. In the middle section the fluid velocity achieve high values while the static pressure reaches low values.

TABLE 1: Diagrams of the fluid velocity and static pressure values for the three cases



	1	2	3	4
Case 1	37.83	28.38	18.92	9.459
Case 2	30.99	23.24	15.5	7.748
Case 3	28.38	21.28	14.19	7.094



	1	2	3	4
Case 1	193100	1074	-190900	-382900
Case 2	132100	3335	-125400	-254200
Case 3	111800	3868	-104000	-211900

In Table 1 are presented the results diagrams for the three analyzed cases highlighting the maximum and minimum static pressure and velocity values of fluid flow through the tube.

4. Conclusions

A three-dimensionally model of a VENTURI tube was achieved and analyzed in this paper. This model can provide a solution to determine the fluid flow rate in a hydraulic or pneumatic installation using manometers mounted on different sections of the tube. Based on different pressure values recorded can be determined the flow rate for the working fluid circulated through the respective section.
Also by means of the VENTURI tube can be achieved the mixture of two different fluids due to the low pressure values recorded in the middle section where the fluid flow velocity values are high, and as a result a fluid (which may be a liquid or gas) may be absorbed and transported further into the hydraulic system circuit.
This property of making the mixture of two different fluids is used in automobile carburettors where is realized the mixture of liquid fuel and air, or the development of the ejectors also using the mixture of the two fluids.

References

[1] https://www.comsol.com/blogs/exploring-the-venturi-effect/
[2] https://answers.yahoo.com/question/index
[3] http://www.grc.nasa.gov/WWW/K 12/airplane/bern.html
[4] Vasilescu, Al., A., Mecanica fluidelor, Ministerul Educatiei și Învățământului, Universitatea din Galați, Galați, 1979