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CDF ANALYSIS OF WATER JET PUMP

ANALIZA CFD POMPY STRUMIENICOWEJ

Abstract

This paper presents a CFD analysis of Liquid Jet Liquid pump with the use of Ansys CFX CFD code. Simulations were conducted for various values of flow rate of motive fluid for both stages. On the basis of CFD analysis a pressure distributions and velocity as well were obtained. Furthermore, CFD simulations allowed to estimate head pressure of the jet pump for various working conditions.

Keywords: CFD analysis, jet pump

Streszczenie

W artykule przedstawiono analizę CFD pompy strumieniowej przy wykorzystaniu systemu Ansys CFX. Symulacje numeryczne zjawisk przepływowych przeprowadzono dla dwustopniowej pompy strumieniowej. Przeprowadzono obliczenia różnych wartości objętościowego natężenia przepływu dla strumienia głównego oraz dla przypadków, w którym są wykorzystywane jeden lub oba stopnie. Wyznaczono rozkłady prędkości oraz ciśnienia, jak również wyznaczono wysokość tłoczenia pompy strumieniowej w różnych warunkach pracy.

Słowa kluczowe: analiza CFD, pompa strumienicowa

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1. Introduction

Jet pumps are pumping devices that transfer momentum from one fluid (motive) to another one (driven or secondary). Motive fluid might be liquid or a gas as well, while secondary might be liquid, gas or a mixture. The basic structure of typical jet pump is presented in Fig. 1. The nozzle of jet pump (1) accelerates motive fluid to high velocity. Kinetic energy and momentum of motive fluid is gained at the cost of pressure energy. Pressure falls in mixing chamber (3) and secondary fluid is forced to flow into the motive fluid stream through the inlet (2). Mixed fluids than go to the discharge chamber (4), where fluids decelerate and gain pressure energy.
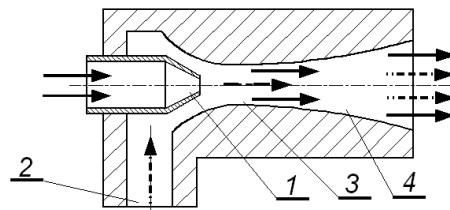

Fig. 1. Two stage jet pump: 1 – motive fluid nozzle, 2 – inlet to the jet pump,
3 – mixing chamber, 4 – discharge chamber

Rys. 1. Schemat pompy strumienicowej: 1 – dysza, 2 – wlot pompy strumienicowej,
3 – komora mieszania, 4 – dyfuzor

Jet pumps have a lot of advantageous, which the most important is no moving parts resistance for wear and lower production cost in comparison to other types of pump. The disadvantageous is low efficiency and low height of pumping.
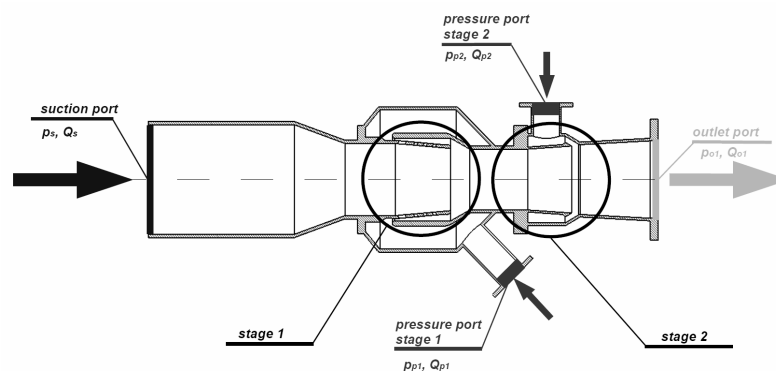

Fig. 2. Two stage jet pump

Rys. 2. Dwustopniowa pompa strumienicowa

It might be distinguished two main types of pump that are differ with nozzle of motive fluid which might be axial or circumferential. The main advantageous of circumferential nozzle is that there might be used for transport non liquid objects with limited dimensions.

The area of application for jet pumps is very wide from chemical and oil industry for nuclear engineering. There might be a lot of solutions for jet pumps [1]. Jet pump delivery and in consequences its dimensions may range from few millimeters to few meters.

The object of the work is a two stage liquid jet liquid (LJL) pump that is shown in Fig. 2. It is a prototype of two stage pump that was elaborated in cooperation between Bergen University College and Fjell Industries AS. It is a jet pump with circumferential motive nozzles with suction diameters 200 mm what significantly extends applications of this pump on a wide range of liquids and mixtures.

2. Mathematical model of a jet pump

Mathematical model of the jet pump consist of mass, momentum and energy conservation equations. When we assume a fixed in space volume Ω, bounded by close surface S, the mass conservation equation in general form is the following (according to [2]):

$$\frac{\partial}{\partial t}\int_{\Omega}\rho d\Omega+\oint_{S}\rho\mathbf{v}d\mathbf{S}=0 \tag{1}$$

where:
- ρ – fluid density,
- v – fluid velocity,
- t – time.

The momentum conservation equation in general form is as follows:

$$\frac{\partial}{\partial t}\int_{\Omega}\rho\mathbf{v}d\Omega+\oint_{S}\rho\mathbf{v}(\mathbf{v}\cdot d\mathbf{S})=\oint_{S}p\cdot d\mathbf{S}+\oint_{S}\boldsymbol{\tau}\cdot d\mathbf{S}+\int_{\Omega}\rho\mathbf{f_e}d\Omega \tag{2}$$

where:
- τ – shear stress tensor,
- f_e – vector of external forces,
- p – pressure.

The energy conservation equation in general form is as follows:

$$\frac{\partial}{\partial t}\int_{\Omega}\rho E d\Omega+\oint_{S}(\rho\mathbf{v}H-k\nabla T-\boldsymbol{\tau}\cdot\mathbf{v})\cdot d\mathbf{S}=\int_{\Omega}(\rho\mathbf{f_e}\cdot\mathbf{v}+q_H)d\Omega \tag{3}$$

where:

$E=e+\dfrac{\mathbf{v}^2}{2}$ – total energy,

e – internal energy,

$$H = E + \frac{p}{\rho} \quad - \quad \text{is enthalpy,}$$

$$W_f = \mathbf{f_e} \cdot \mathbf{v} \quad - \quad \text{is work of external forces,}$$

q_H –   is heat released by chemical reactions,
k –   is conductivity coefficient,
T –   is absolute temperature.

3. CFD simulation

Phenomena that occurs in the jet pump are complex and using models including equations presented above may not give very precise results (with assumed simplifications). Therefore in this work a CFD methods were applied to simulate fluid flow in the LJL pump. CFD analysis was carried out with following assumptions:

1. Flow is incompressible and homogenous.
2. There is no heat transfer between fluids and environment.
3. Roughness of walls was neglected.
4. Analysis was conducted for steady state conditions.
5. It was assumed the following fluid properties: density $\rho = 1000$ [kg/m^3], viscosity $\mu = 1.003e\text{-}3$ [Pa s].
6. The flow is turbulent, a Reynolds Stress Model was used.
7. Standard wall functions was used.

The CFD analysis was conducted for various flow conditions on inlet to the high pressure inlet as well as for the case when one or two stage operates. CFD model of LJL pump is shown in Fig. 3.
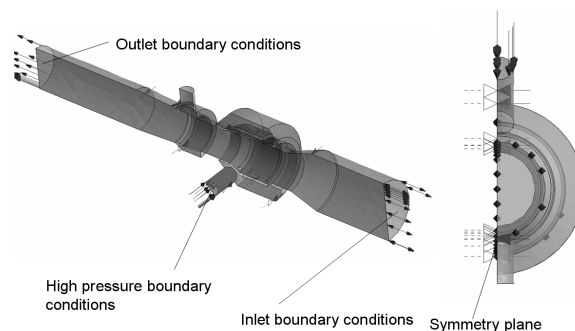

Fig. 3. CFD model of the jet pump, the case when only one stage operates

Rys. 3. Model CFD pompy strumieniowej, przypadek, w którym jeden stopień pompy jest wykorzystywany

Before the CFD model was prepared the grid was made in Ansys CFX mesh tool. The grid was prepared with mixed tetrahedral and prism cells. Prismatic cells were applied in vicinity at the walls. Figure 4 present a grid for a jet pump, which for the sake of symmetry was used only a half.
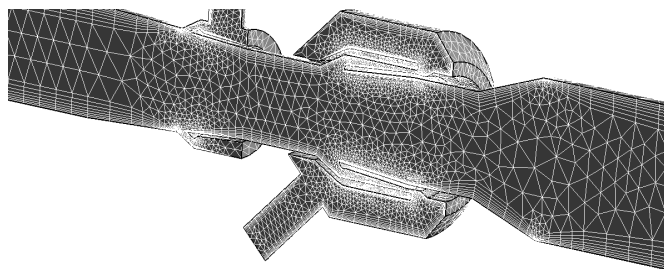
Fig. 4. Grid of the jet pump

Rys. 4. Model dyskretny pompy

3. CFD results

CFD simulations were conducted for various flow conditions on inlet and with one and both motive pressure operates. Below there are presented selected CFD results for the case when only first stage operates and at inlet there was applied flow rate 54 m^3/h.

As can be noticed, the highest velocity fluid reach in the motive nozzle having 16 m/s. Later entering the pump throat fluid velocity have almost a half of maximal velocity which is 7 m/s (Fig. 5). It can be also observed that fluid does not flows circumferentially to the pump but no uniformly. It is even better visible on Fig. 6 with path lines where the brighter lines indicate the motive fluid while the darkener the suction fluid.
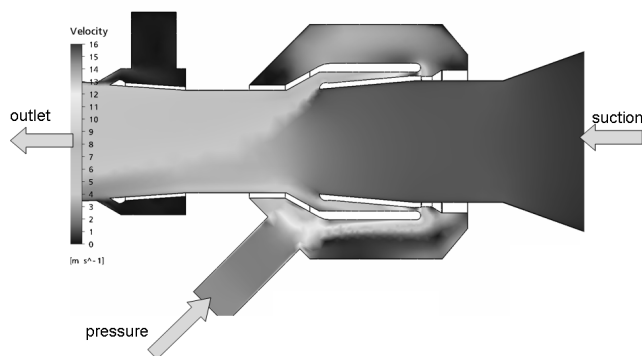

Fig. 5. Velocity distribution in m/s

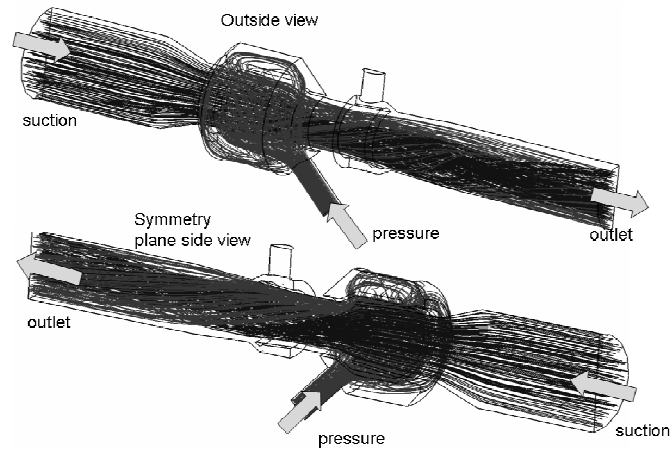Rys. 5. Rozkład prędkości cieczy w m/s

Fig. 6. Path lines

Rys. 6. Linie prądu

CFD model of jet pump allowed to investigated not only a phenomena that appears inside jet pump but also determine a pumping height. A set of simulations conducted for jet pump allowed to calculate pumping height and amount of liquid that may be transported by the pump. Figure 7 shows results of pumping height in function of flow rate of the jet pump. The simulations conducted for the first stage are marked by solid line while for both stages by dashed line. Presented below graph shows that using second stage allows to rise pumping height more than twice.
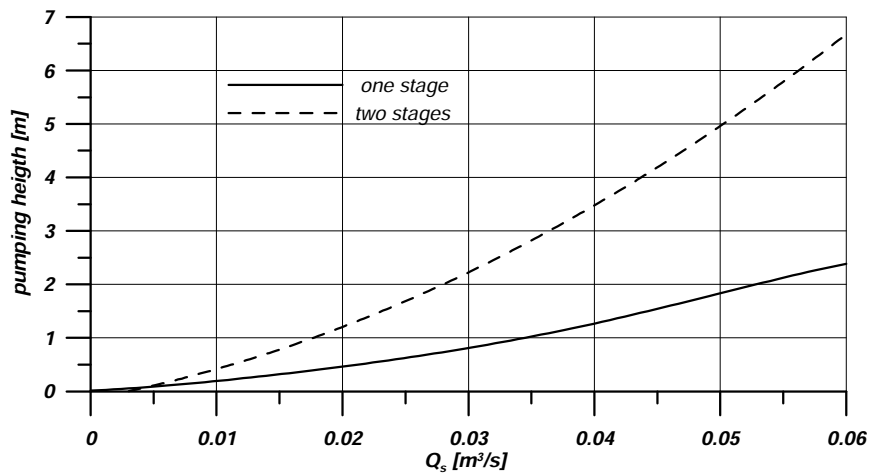

Fig. 7. Pumping heigth of LJL pump

Rys. 7. Wysokość tłoczenia pompy strumienicowej

4. Conclusions

This paper presents modelling of Liquid Jet Liquid pump with the use of CFD code Ansys CFX. Conducted computer simulations allowed to capture phenomena that appears in jet pump during operation as well as assess influence of both stages operating on pumping height. In the paper was presented selected CFD results for LJL pump as well as influence of implementation of second stage on value of pumping height.

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