PUMPING EQUIPMENT EFFECTIVENESS INCREASE BY MEANS OF EJECTOR APPLICATION AS PRELIMINARY STAGE FOR HIGH-SPEED PUMP UNITS

Alexander Gulyi, Anastasiia Kobyzska

Sumy State University
Adres: Ukraine, 40007, Sumy, Korsakova St., 2. e-mail: kobyzska@mail.ru

Summary. The efficiency of ejectors application as preliminary stage for high-speed dynamic pumps is regarded in the given article. The research was carried out for two different types of pumps by simulation in Ansys CFX program package. It was concluded that main characteristics of pumps are improving when using ejectors as preliminary stage, i.e. these booster pumps application efficiency was proved.

Key words. Ejector, high-speed pump, booster pump, jet device.

INTRODUCTION

Cavitation control for pumps and other hydraulic machines is of great importance, because cavitation leads to fast destruction of hydraulic flow part elements and their reliability decrease. That is why cavitation problem and its overcome techniques appeared practically simultaneously with pump units appearance of the modern interpretation.

These techniques may be classified into three main groups for vane pumps [2]:

Geometric head increase before pump – fluid collectors lift or pump penetration from several meters to several dozens meters.

Pump modernization – inlet funnel expansion, preliminary screws installation, input flow partition into two parallel flows.

Additional preliminary pumps of different types installation at the inlet of the main pump.

As a rule, centrifugal pumps with reduced rotational speed and electro or turbo drive from pumping medium of the main pump outlet or its first stage are used as booster pumps [12]. The booster pump may be combined with the main pump in one casing for turbo variant.

PRIOR ART

Theoretically, jet pump (ejector) or jet device may be used as booster pump. The main advantages are simplicity, reliability and durability because of moving parts absence. The main disadvantage is low efficiency. That is why jet pumps are not widely used for different branches of industry.

However, according to some facts, jet pumps are used as booster pumps for power turbo-pump units in rocket technology and for borehole pump units of low productivity. Besides, there are volume theoretical works of this subject [10].

Effectiveness estimation of jet pump application as booster pump is presented by means of two centrifugal multistage pumps at this paper. One of them is a perspective analog of PE580-185 with rotational speed 9000rev/min, causing cavitational characteristic degradation and requiring additional 60m head back-up and another is an ammoniac ten-stage pump with parameters 10m^3/h and 100m for heat pump of 100kW with low geometrical height of condenser-pump column. Head back-up of 2 m is required for this pump.

JET DEVICE CALCULATION TECHNIQUE

The first part of the work consists of effectiveness analysis of the various booster pump feed circuits – turning on for total or partial head from intermediate stages. Calculations were carried out according to the technique [1], the results are given in the tables and in the figures.

Calculated values of necessary fluid circulation flow for the booster pump feed during head variation at the expense of different stages discharge connection are given at the following table.

Table 1. The Booster Pump Calculation for the Four-Stage Boiler-Feed Pump.

Fluid Bleeding Stage	Relative Head, m	Ejector Flow, m^3/h	Power, kW	Useful Power, kW	Ejector Efficiency
1	0,12	168	229	95	0,41
2	0,06	128	347	95	0,27
3	0,04	99	403	95	0,24
4	0,03	87	474	95	0,2

Obviously, flow of 168m^3/h is required for the first stage feed and flow of 87m^3/h is required for the last stage feed. However, energy effectiveness is worse for the last stage in spite of low flow. Required power equals 229kW and 474kW respectively. Intermediate results were obtained for intermediate stages. Thereby, booster jet pump connection to the first stage of the main pump is more effective for the given example. It is necessary to mention that useful hydraulic power of the jet pump equals 95kW, that corresponds to the efficiency higher than 40%. It is a bit lower than the efficiency of preliminary turbo pump unit, which equals about 50% for the pump and the turbine efficiency of 70%. Although losses will decrease by 40W (about 1%) for the given case.

Table 2. The Booster Pump Calculation Results for the Ten-Stage Ammoniac Pump.

Fluid Bleeding Stage	Relative Head, m	Ejector Flow, m^3/h	Power, kW	Useful Power, kW	Ejector Efficiency
1					
2					
3	0,133	3,395	0,167	0,065	0,393
4	0,1	2,825	0,185	0,065	0,354
5	0,08	2,53	0,207	0,065	0,316
6	0,067	2,32	0,228	0,065	0,287
7	0,057	2,11	0,242	0,065	0,271
8	0,05	1,93	0,253	0,065	0,259
9	0,044	1,78	0,262	0,065	0,25
10	0,04	1,71	0,28	0,065	0,234

The same pattern is for the ammoniac pump too. Unfortunately, there is no necessary data for withdraw from the 1st, 2nd and 3rd stages calculation in the literature. Variant for the 3rd stage was calculated by means of extrapolation. Booster feed from the minimal stage (the 3rd stage) is the most effective according to the calculations. Preliminary stage efficiency equals about 40%. The given scheme is very effective because losses are about 0,1% of the heat pump power value in spite of the fact that power losses equal 100W or 5% of the pump power. The main requirements for the heat pump are high reliability, resource and minimal service.

The given device calculation technique by means of the Ansys CFX [4, 5] program package was developed and test calculation with optimization for both pump types was carried out, because jet devices application effectiveness was proved.

JET DEVICES FLUID FLOW NUMERIC SIMULATION TECHNIQUE

The prime target of numerical calculations is jet device inspection for cavitation absence, which was implemented by means of accurate probing of jet leaving nozzle and main fluid volume primary contact area. This work was implemented in several stages.

Fluid density was accepted as constant value for calculation. Stream line simulation was implemented by means of Reynolds equation and the range of turbulence models (k-ε, SST etc.) was applied for the calculation [18].

3D models of jet devices working fluid bodies for boiler-feed and ammoniac pumps correspondingly were created by means of SolidWorks Program Software on the first stage.

Calculation data preparation was implemented and computational grid (fig.1 and fig.2) was created by means of Ansys ICEM CFD Program Software [4, 5] on the second stage. The grid has the following parameters: global mesh size – 0.01mm, amount of all mesh elements – 4millions 600 thousand.

Prism mesh was created for necessary description of boundary layer near jet device solid walls. The prism mesh parameters are: the first prism mesh height – 0.001mm, geometric progression exponent – 1.2, amount of prism mesh layers – 5.

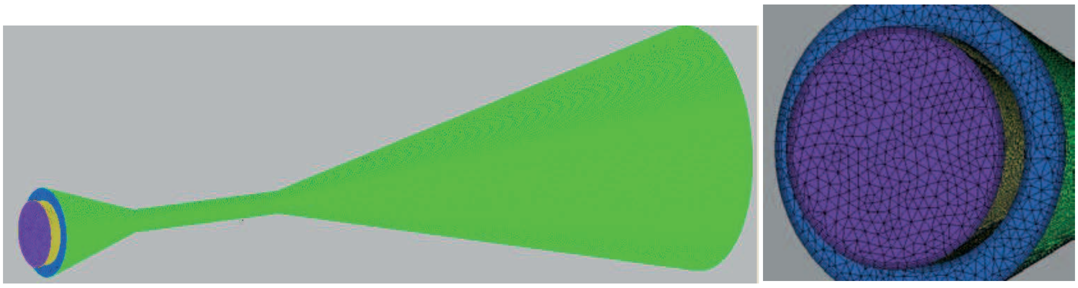

Fig. 1. Computational Grid of Jet Device Model for Ammoniac Pump.

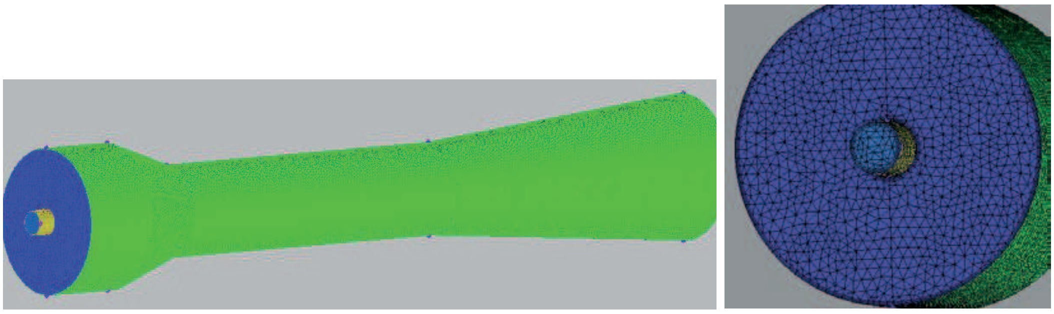

Fig. 2. Computational Grid of Jet Device Model for Boiler-Feed Pump.

Numerical experiment was carried out on the third stage. Numerical experiment was carried out by means of stationary statement for single-phase fluid [15]. Pressure in the inlet and velocity in the outlet were set as boundary conditions. Fluid flow pattern, velocity and pressure distribution in the working fluid body were obtained by menas of the given calculation.

Obtained data analysis and visualization were the fourth stage. Nozzle position optimum parameters and ejector geometric sizes were defined by means of visualization and obtained static pressure.

Optimization problem of nozzle diameter and its axial position definition was solved within the scope of this problem. Optimum parameters are correspondingly: nozzle diameter – 16mm and it is 40mm remote from mixing chamber for ammoniac pump, nozzle diameter – 25mm and it is 200mm remote from mixing chamber for boiler-feed pump.

Streamlines in the working fluid body (fig.3 and fig.4) were obtained, besides hydrostatic pressure distribution contours of all construction elements for optimum variants of jet device for every pump type (fig.5 and fig.6) were obtained too.

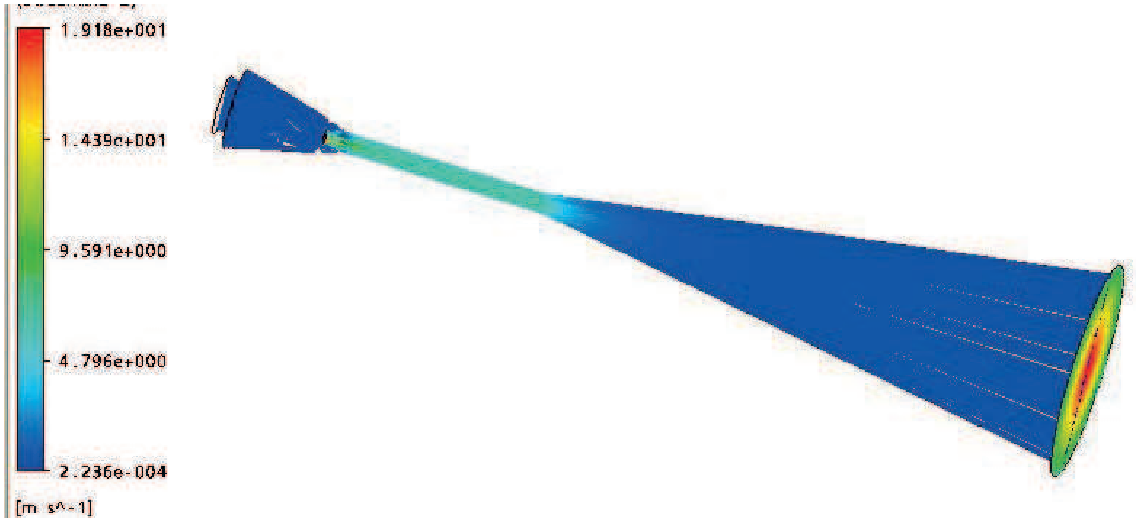

Fig. 3. Lines of Absolute Velocity Fluid Flow in Jet Device of Ammoniac Pump.

Fig. 4. Lines of Absolute Velocity Fluid Flow in Jet Device of Boiler-Feed Pump.

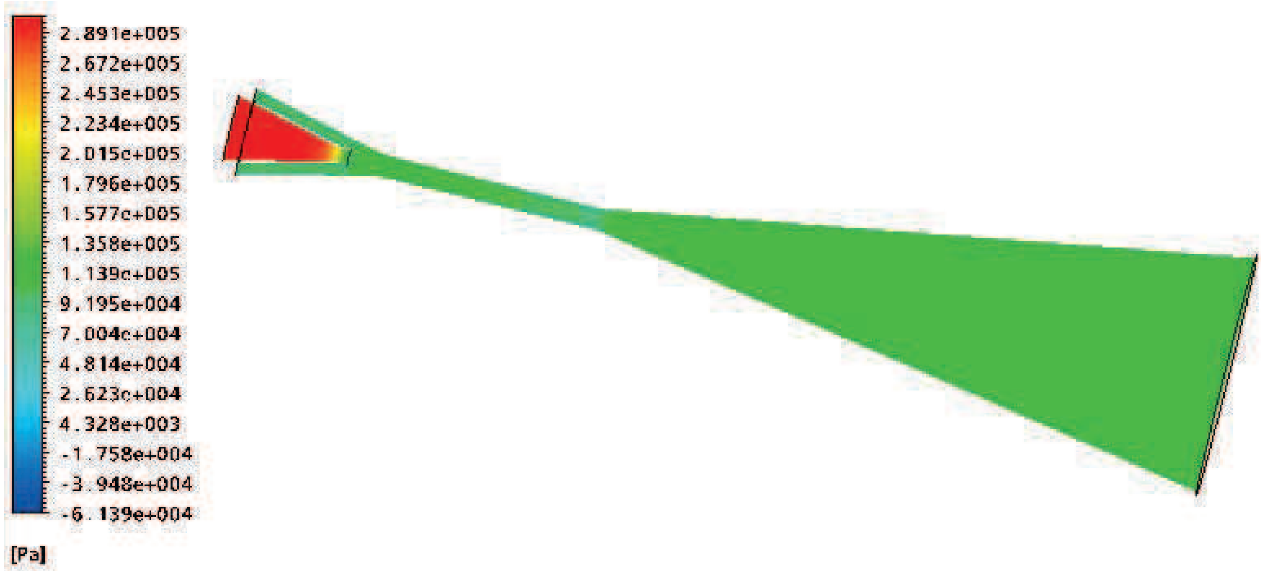

Fig. 5. Hydrostatic Pressure Distribution Pattern in Jet Device of Ammoniac Pump.

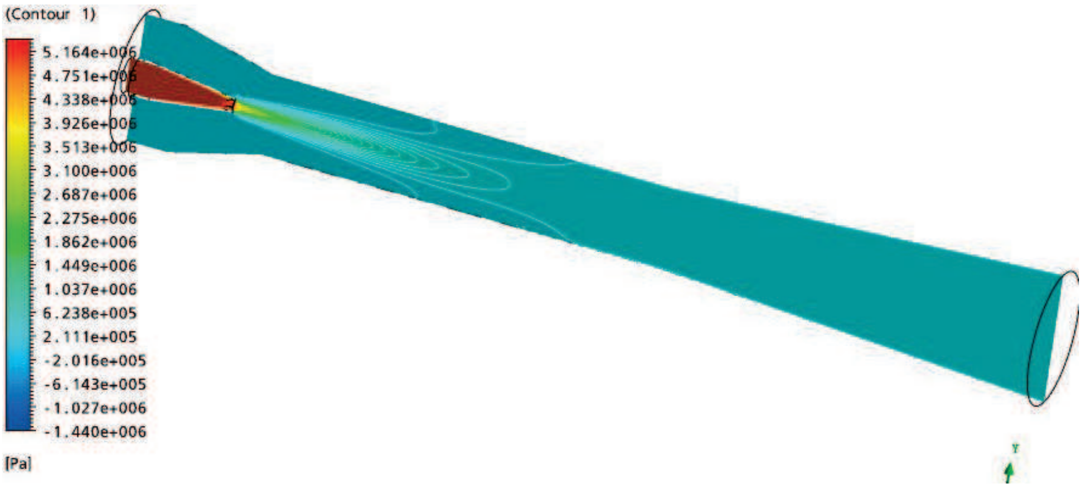

Fig. 6. Hydrostatic Pressure Distribution Pattern in Jet Device of Boiler-Feed Pump.

CONCLUSIONS

Obtained integral results comparison with analytical and experimental researches results, obtained by B. Lyamayev [1] and Y.Sokolov [3], allows to draw a conclusion about developed calculation technique adequacy and possibility of its introduction to computational-engineering practice. Jet device geometrical parameters optimization possibility was inspected for the highest effectiveness achievement using the given technique. Nozzle diameter and its axial location were optimized as the first approximation. Multifactor optimization is a very labour-intensive task and will be solved in the following researches.

According to the above-mentioned material, it is obvious that the work continuation with numerical and physical experiment implementation is reasonable.

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ НАСОСНОГО ОБОРУДОВАНИЯ ПУТЕМ ПРИМЕНЕНИЯ ЭЖЕКТОРОВ НА ПОДВОДЯЩИХ ПАТРУБКАХ ВЫСОКОСКОРОСТНЫХ НАСОСОВ

Аннотация. В данной статье рассматривается эффективность эжекторных подводов в качестве предварительная ступеней в быстроходных динамических насосах. Исследование осуществлялось для двух различных видов насосов моделированием в пакете программы ANSYS CFX. Было заключено, что главные характеристики насосов улучшаются, при использовании эжекторов в качестве предварительной стадии.

Ключевые слова: Подвод, быстроходный насос, эжектор, реактивное устройство.