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Effect of nozzle position on water ejector efficiency

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Abstract

The aim of this experimental is to investigate the efficiency water ejector. The effect of nozzle position on its efficiency was investigated. Nozzle position varied the ratio of nozzle-to-throat spacing to throat diameter (X = L/D) with values of 0, 0.5, 1, 2 and 3 respectively. The maximum water ejector efficiency obtains for nozzle-to-throat spacing to throat diameter ratio is approximate 14 %. The experimental results were found in good agreement with the ESDU design guide.

Keywords: Water ejector, Nozzle position, Efficiency

1. Introduction

Ejector is a device to produce a vacuum. Due to simple design and lack of moving parts in system, installation costs and a little maintenance is required. It is widely used in many applications, such as air-conditioning systems [1-2] fuel cells [3] heating system [4] and vacuum drying [5]. Ejector consists of four main components: the nozzle, the suction chamber, the throat or mixing chamber and the diffuser as shown in Figure 1. It is based on the venturi principle and theory of jets. It operates by passing primary (motive) fluid at high pressure through a nozzle, that part of its potential energy (pressure) is converted into kinetic energy (velocity). The resultant jet of high velocity creates a low-pressure area in the suction chamber causing the secondary (suction) fluid to flow into this chamber. Then, the two streams combine in the mixing chamber or throat, where momentum and energy transfer takes place between the primary and secondary fluids. The fluids then pass through a diffuser in which the diameter of the pipe increases gradually and the velocity of the mixture is reduced. The reduction in the mixture velocity leads to the conversion of part of the kinematics energy to pressure, and further pressure recovery takes place. The high-pressure and low-pressure fluids leave the jet pump at an intermediate pressure between the high and low pressures.

The position of the nozzle has a greater on ejector performance than its design. Many researchers have been interested the optimum position of the nozzle in an ejector. Cunningham [6] reviewed the nozzle spacing and mixing throat lengths. He showed a detailed tabulation of literature recommendation for the ratio of nozzle-to-throat spacing to throat diameter (X). The results can be summarized by nozzle to throat spacing to nozzle diameter (X) should be of the order of 0.5 to 1.5. Although he showed this range, he suggested further study for the effect of (X) on the performance and the mixing process in the mixing chamber. El-Sawaf et al. [7] studied the experimental investigation of the water jet pump performance under the effect of nozzle to throat spacing to nozzle diameter (X). They concluded that the maximum efficiency is achieved at X=1. The ESDU design guide [8] suggested that the nozzle should be placed at a distance of 0 to 1 length of the mixing chamber's throat diameter upstream of the mixing chamber inlet.

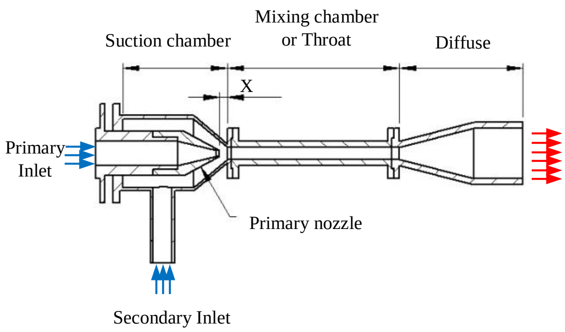

Figure 1 Schematic (not scaled) view of an ejector

Until now and to the author knowledge, the research work on the jet pump is limited to the effect of nozzle to mixing chamber distance on water ejector efficiency. Therefore, it is important to investigate the effect of nozzle-to-throat spacing to nozzle diameter ratio (X) on water ejector efficiency.

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2. Experimental set up

The experimental setup is schematically shown in Figure 2. The ejector test is designed so as to carry out experiments on water ejector under varying the nozzle position of the water ejector. The ejector test system consists of a water ejector, water tank, a centrifugal pump, rotameter, a pressure gauge and a piping system, are shown in in Figure 2. All geometries of the water ejector were designed to be easily fitted and interchanged with others.

The water ejector test rig was a continuous circulation system. Water is used as the motive fluid and air is used as the suction fluid. A centrifugal pump delivered water (motive flow) from a water tank passes through a control valve (V_1) for controlling the water (motive) pressure, and then water is divided into two branches. One of these branches passes through the bypass valve (V_2), which is used to control the water flow to the ejector. The other branch passes through a water rotameter, a bourdon type pressure gauge (P_m) and a water ejector. The Primary (water) flow rate (Q_p) is measured by a water rotameter at the exit of the centrifugal pump while the water pressure is measured using a pressure gauge. In the ejector, nozzle produces high-velocity jet and creates a vacuum in the suction chamber; hence, entrainment of secondary air from air chamber takes place. Secondary air pressure is measured by using vacuum pressure gauge (P_s). The secondary or suction (air) flow (Q_s) is measured with an orifice meter. Water and air mix thoroughly in the throat or mixing chamber. The diffuser converts the energy of this mixture partially from kinetic to pressure. Then the mixture returns to the water tank. The mixture pressure is measured by a bourdon type pressure gauge (P_d).

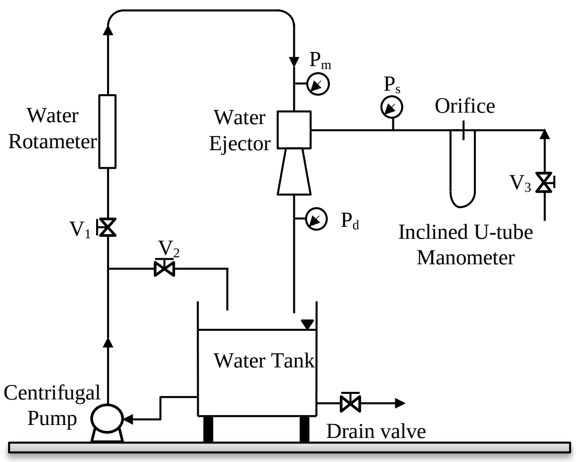

Figure 2 Schematic diagram of the water ejector test set up

In this study investigate the influence of nozzles position on the water ejector efficiency. The nozzle positions were fabricated with four different nozzle-to-throat spacing to throat diameter ratio "X" with values of 0, 0.5, 1, 2 and 3 respectively while the body of the ejector and other dimensions of the nozzle not including nozzle position were fixed. The nozzle exit diameter, throat diameter, throat length were 6 mm, 12.7 mm and 177 mm respectively. The primary flow pressure remains at 40 psig. Flow ratios ranging from 0 to 2.

The efficiency of ejector is generally considered to be a function of the parameters design is following [8]:

Flow ratio, M is calculated by secondary flow over primary flow:

$$M = \frac{Q_s}{Q_p}$$

where; Q_p is the primary (motive) flow rate , Q_s is the secondary (suction) flow rate.

In a specific situation, when the primary and secondary fluids have the same density, the volume flow ratio is the same as the mass flow ratio, *M*.

Pressure ratio, N is calculated by secondary flow pressure rise/primary flow pressure drop

$$N = \frac{P_d - P_s}{P_m - P_d}$$

where; P_m is primary (motive) pressure, P_s is secondary (suction) pressure, and P_d is discharge pressure.

Ejector efficiency (always less than 1), overall efficiency for the ejector pump η is found by:

$$\eta = \frac{\text{The total energy increase of suction flow}}{\text{The total energy increase of driving flow}} = M \times N$$

$$\eta = \frac{Q_s}{Q_p} \times \left(\frac{P_d - P_s}{P_m - P_d} \right)$$

3. Results

The relation between the flow rate ratio (M) and Pressure ratio (N) are shown in Figure 3. The flow ratio increases also with the pressure ratio is decreased, this agrees with the trend of similar curves of other researchers' results [7-8]. Figure 4 shows the comparison of various nozzle positions as the relationship between the flow rate ratio M and the efficiency η for the changing of nozzle position. The maximum water ejector efficiency obtain for nozzle-to-throat spacing to throat diameter ratio is X = 0 and driving pressure of 276 kPa.g is approximate 14 % at a flow ratio of 0.66.

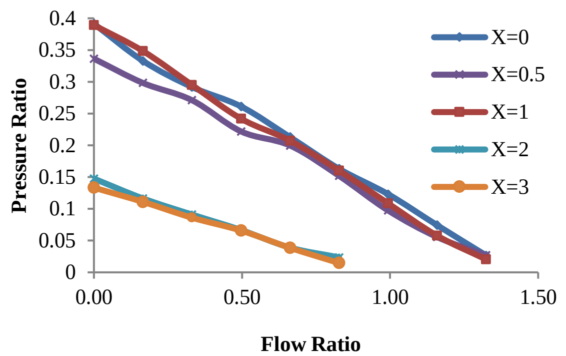

Figure 3 Relationship between the flow rate ratio M and pressure ratio N for different nozzle position

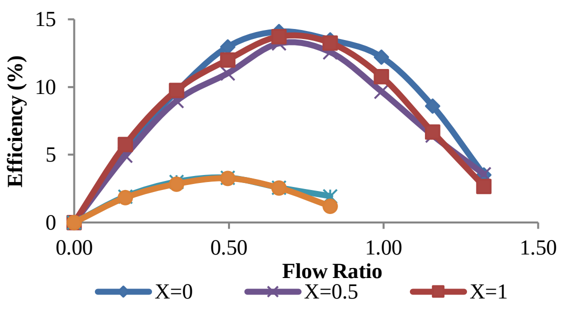

Figure 4 Relationship between the flow rate ratio M and the efficiency η for various nozzle positions

4. Discussion

The results show that the flow ratio is inversely proportional to the pressure ratio. The probable explanation of the significant jet pressure reduction at high pump driving pressure is the increase in the pressure loss in the ejector which cause swirl and eddy losses inside the water ejector. The pressure ratio decreases the efficiency increase. The curve presents a parabolic form. Increasing nozzle-to-throat spacing to throat diameter ratio (X) appropriately can increase the efficiency of the ejector. However, the increase is too large so they will decrease the ejection efficiency. It appears from this investigation that the maximum ejector efficiency is achieved at small distances between the primary nozzle exit and the throat inlet. Nozzle-to-throat spacing to throat diameter ratio (X) should be placed at a distance of 0 to 1. The experimental results were found in good agreement with the ESDU design guide [8].

5. Conclusions

In this study, investigations were done based on the water ejector efficiency. Tests are carried out at four different nozzle-to-throat spacing to nozzle diameter ratio “X” with values of 0, 0.5, 1, 1.5, 2 and 3 respectively.

The following points are summarizing the important conclusion.

1. The optimum value of “X” that gives the maximum efficiency is X = 0.

2. Increasing the value of “X” Increases the flow ratio.

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