

# Numerical Analysis of Geometry Ejector for Boosting Low Pressure Natural Gas

Agus Eko Setyono<sup>1</sup>

<sup>1</sup>Magister Program on Energy,  
Diponegoro University, Indonesia

M.S.K Tony Suryo Utomo<sup>2</sup>

<sup>2</sup>Departement of Mechanical Engineering,  
Diponegoro University, Indonesia

Jaka Aminata<sup>3</sup>

<sup>3</sup>Faculty of Economics and Business,  
Diponegoro University, Indonesia

**Abstract**— Gas flaring is one of the main problems in the oil and gas production process which causes serious problems for the environment. Gas flaring with low pressure is generally used by a compressor to recover it, but the use of a compressor is quite expensive, so in this study it is proposed to replace it using an ejector system. In this study, the effect of the mixing tube length to diameter ratio (R) and primary nozzle exit position (NXP) geometry was analyzed using a numerical method. The results show that the larger the R value, the smaller the entrainment ratio and each R value has the optimum entrainment ratio at a motive pressure of 250 Psig. Meanwhile, the effect of NXP on the entrainment ratio shows a not large enough difference in the optimum value of the entrainment ratio. The flow contour shows that the smaller the R value, the shorter the length of the shock train and shock wave.

**Keywords**— Ejector; Numerical analysis; Entrainment ratio; Geometry; Natural gas.

## I. INTRODUCTION

One of the impacts of the use of oil and gas energy is the presence of gas burners in the flare stack or commonly called gas flaring [1]. Gas flaring is classified into 2, non-routine flaring and routine flaring. Non-routine flaring comes from the process system when conditions are abnormal, such as start-up, shutdown and other emergency conditions. Meanwhile, routine flaring comes from the process system for technical reasons, such as gas with too low a pressure [2]. Under these conditions, a compressor system is generally used to increase the gas pressure, but it costs a lot. Therefore, in several recent studies, it is proposed to use an ejector to increase the low gas pressure. The ejector has several advantages, including that it does not require additional power, its dimensions are small, there are no moving parts and low installation costs [3]. The main factor in the performance of the ejector is its geometric shape, so several studies have been carried out related to the analysis of the ejector geometry such as the effect of area ratio and NXP on ejector performance using various working fluids. Wang et al., (2018) analyzed the effect of area ratio and NXP on ejector performance using methanol working fluid [4], Varga et al., (2009) used R141b working fluid [5], Eames et al., (2007) used R245fa working fluid [6], Meyer et al., (2009) used steam working fluid [7], Jeon et al., (2017) used R141a working fluid [8], Yapici et al., (2008) used R123 working fluid [9]. From several studies conducted, it is still very rare to analyze the ejector system using natural gas

working fluid, so in this study we will analyze how the area ratio and NXP influence the entrainment ratio of the ejector. The results of the study of the ejector system are expected to be used to increase natural gas production from gas flaring.

## II. CFD MODELING

In this study, Ansys software is used in ejector modeling and simulation. The ejector is modeled in 2D axisymmetric geometry with a structured mesh type and a 38k quadrilateral element type as shown in Figure 1. The flow inside the ejector is made in a turbulent form (K-epsilon). The working fluid in the modeling is natural gas with specific heat properties, thermal conductivity, viscosity and molecular weight as shown in table 1. In the boundary conditions, primary and secondary flows are defined as “pressure inlet” conditions and discharge ejectors are defined as “pressure outlet” conditions.

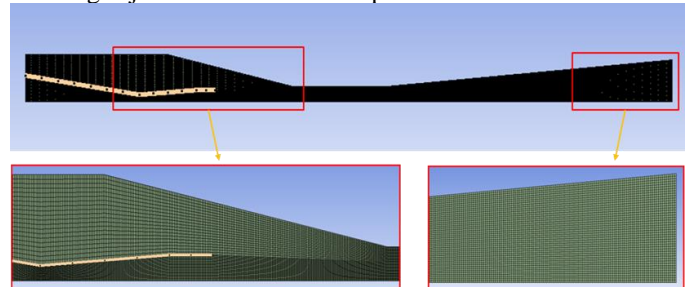


Fig. 1. Final mesh ejector.

Table 1. The properties of natural gas.

Parameters	values	unit
Density	Ideal gas model	kg/m <sup>3</sup>
Specific heat	45490	J/(kg-K)
Thermal conductivity	0.02933	W/(m-K)
Viscosity	0.01139	kg/(m-s)
Molecular weight	22.55	kg/kmol

The shape of the ejector in this study is shown in Fig. 2 which consists of two different parts. The first part is the primary nozzle which is converging – diverging in shape and is used to expand the primary fluid, in the process converting potential energy into kinetic energy. The second part, commonly called the secondary nozzle, consists of three zones: the suction chamber, the mixing chamber or constant

area section, and the diffuser [10]. Ejector parameter values such as motive inlet diameter, mixing tube diameter, diffuser diameter and other parameters are listed in table 2.

Table 2. Dimension of ejector geometry.

Symbols	Parameters	Value (mm)
Dm-in	Diameter Motive Inlet	50
Dm-out	Diameter Motive Outlet	22
Dthroat	Diameter Motive Throat	13
Lm	Length of Motive	200
Lm-c	Length Motive Converging	120
Lm-d	Length Motive Diverging	60
Dconv	Diameter Converging	90
Dmix	Diameter Mixing Tube	29
Ddisch	Diameter Discharge	80
Lp-conv	Length Pre Converging	150
Lconv	Length Converging	130
Lmix	Length Mixing Tube	100
Ldiff	Length Diffuser	300

To determine the effect of NXP and R on the entrainment ratio, 50 ejectors were modeled with variable motive pressure (PM), NXP and R which were divided into 2 groups as shown in Table 3. Meanwhile, secondary flow pressure and ejector discharge pressure were set constant at 20 Psig and 50 Psig.

Table 3. The geometric variations of the ejector.

No	PM (Psig)	NXP (mm)	R
1	210 - 300	80	3.44, 3.57, 3.70
2	210 - 300	70, 80, 90	3.44

### III. RESULTS AND DISCUSSION

#### A. Validation

To validate the model, experiment data from Huang & Chang (1999) was used as a comparison [11]. The geometry nozzle used for validation is only serial number A, namely

throat diameter 2.64 mm and exit diameter 4.50 mm, while for the mixing section serial numbers B, D and G are used, each with diameters of 6.98 mm, 8.10 mm and 7.34 mm as shown in Table 4. The fluid used in the experiment is R141b with the same pressure and temperature Huang & Chang (1999). Fig. 3 presents a comparison of the entrainment ratio between the experiment and the simulation which shows that the deviation is not too large. Compared to the experimental results, the biggest difference in the simulation is less than 10%, therefore this model can be concluded as appropriate and has good accuracy.

Table 4. Dimension of ejector geometry Huang & Chang (1999).

Primary Nozzle			Mixing (Constant Area) Section	
Serial No	Troath Diameter (Dt)	Exit Diameter (D4)	Serial No	Diameter (D3)
A	2.64 mm	4.50 mm	A	6.70 mm
			B	6.98 mm
			C	7.60 mm
			D	8.10 mm
B	2.82 mm	5.10 mm	E	8.54 mm
			G	7.34 mm
			H	9.20 mm

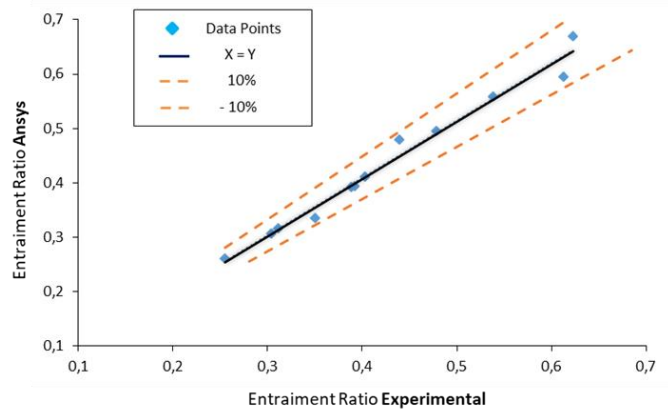


Fig. 3. Comparison of entrainment ratios between simulated results and experimental.

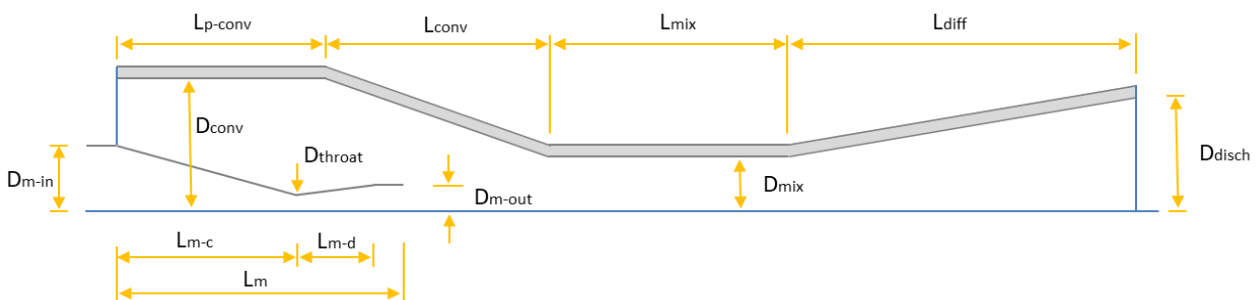


Fig. 2. Schematic of ejector.

**B. Effect of mixing tube length to diameter ratio on the ejector entrainment ratio**

Fig 4. shows the relationship between motive pressure and entrainment ratio with variations of mixing tube length to diameter ratio (R). At a motive pressure of 210 Psig, each R value will not produce a syphon effect or reversed flow from natural gas will occur. The ejector will be able to suck natural gas if it uses a motive pressure above 220 Psig. The first entrainment ratio will increase to its optimum point at a motive pressure of 250 Psig before falling again. The larger the R value, the smaller the optimum entrainment ratio will be. The optimum entrainment ratio at values of R = 3.44, 3.57, and 3.70, is 0.29, 0.24 and 0.19, respectively. Fig. 5. shows the difference in flow contours produced by varying the value of R. At the value of R = 3.44 it has the longest shock train and the farthest shock wave distance is measured from the nozzle output position. As the value of R gets smaller, the length of the shock train gets shorter and so does the shock wave.

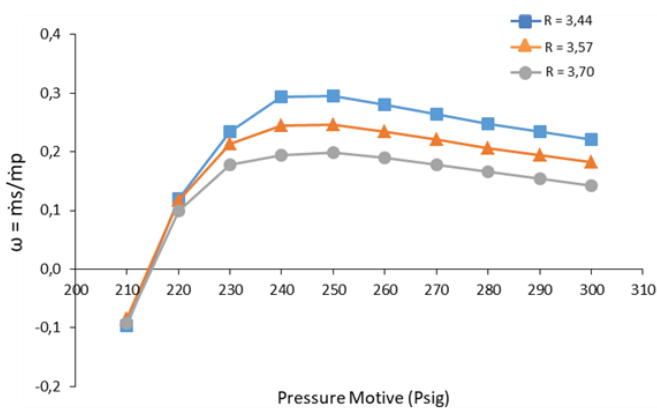


Fig. 4. Variation of R and motive pressure on entrainment ratio.

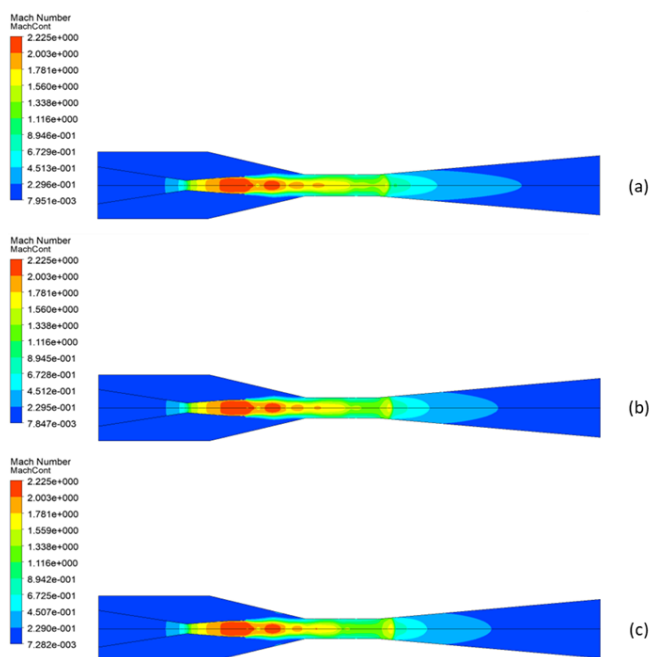


Fig. 5. Internal ejector flow structure (a) R=3.44, (b) R=3.57, (c) R=3.70.

**C. Effect of primary nozzle exit position on the ejector entrainment ratio**

Fig. 6 shows the relationship between the motive pressure to entrainment ratio with variations of NXP. It can be seen that at a gas motive pressure of 210 Psig, the entrainment ratio value of each NXP has a fairly large difference, then along with the increase in motive pressure. Each NXP value has an optimum entrainment ratio at 250 Psig gas motive pressure with the highest value of 0.29 at 80 mm NXP. Meanwhile, the optimum entrainment ratio NXP = 70 and 90 has almost the same magnitude, namely 0.285 and 0.280, respectively. Fig. 7 shows the velocity contour M>1 of the output variation with a motive pressure of 250 Psig. It can be seen that NXP = 70 mm has the longest shock train and the larger the NXP the shorter the shock train.

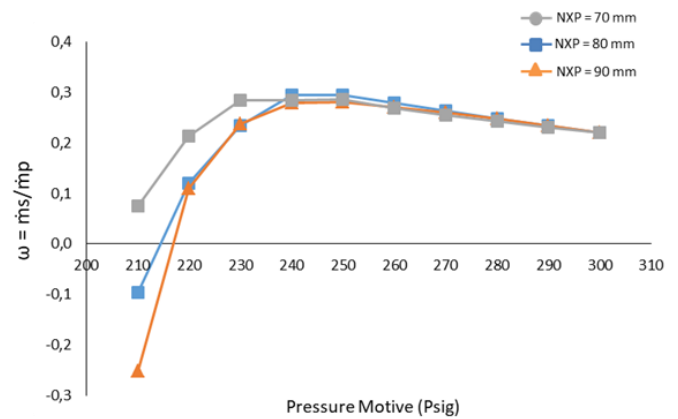


Fig. 6. Variation of NXP and motive pressure on entrainment ratio.

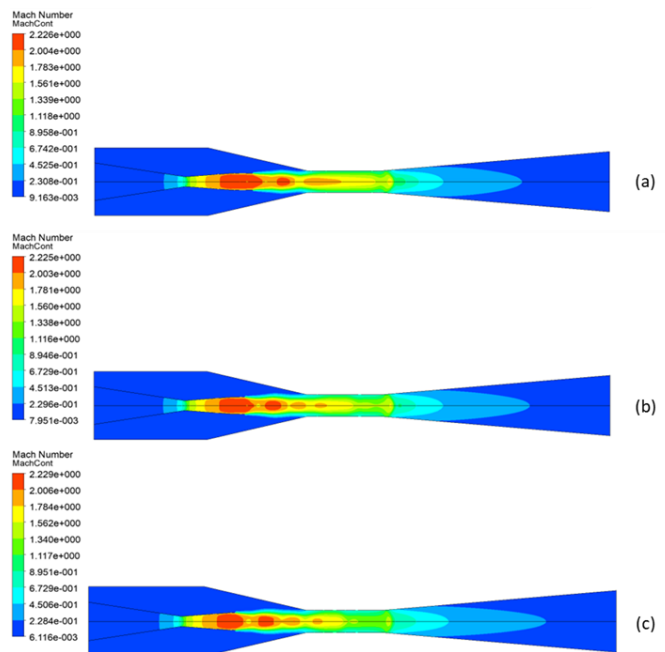


Fig. 7. Internal ejector flow structure (a) NXP=70 mm, (b) NXP=80 mm, (c) NXP=90 mm.

**IV. CONCLUSION**

In this study, the ejector geometry was investigated for increasing natural gas pressure by numerical analysis method. The effect of the geometry factor of mixing tube length to diameter ratio (R) and primary nozzle exit position (NXP) is modeled and simulated to determine its effect on the

entrainment ratio. The results show that the greater the R value, the smaller the entrainment ratio and each R value has the optimum entrainment ratio at a motive pressure of 250 Psig. The flow contour shows that along with the smaller R value, the length of the shock train is getting shorter and so is the shock wave. Meanwhile, the effect of NXP on the entrainment ratio shows a not large enough difference in the optimum value of the entrainment ratio. From the three NXPs, the entrainment ratios are 0.285, 0.290 and 0.280. The ejector flow contour shows that the larger the NXP, the shorter the shock train. Based on the studies conducted, the magnitude of R and NXP must be chosen properly to obtain optimal ejector operation in increasing the natural gas pressure.

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