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Production Optimization through Ejector Installation at ESA Platform Offshore North West Java Field

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Abstract**—**The offshore facilities condition of Pertamina Hulu Energi Offshore North West Java (PHE ONWJ) varies greatly from place to place, depending on the characteristics of the presently installed facilities. In some locations, such as ESA platform, gas trap is mainly caused by the occurrence of flash gas phenomenon which is known as mechanical-physical separation process of multiphase flow. Consequently, the presence of gas trap at main oil line would accumulate on certain areas result in a reduced oil stream throughout the pipeline. Any presence of discrete gaseous along continuous oil flow represents a unique flow condition under certain specific volume fraction and velocity field. From gas lift source, a benefit line is used as a motive flow for ejector which is designed to generate a syphon effect to minimize the gas trap phenomenon. Therefore, the ejector's exhaust stream will flow to the designated point without interfering other systems.

Keywords**—**Ejector, diffuser, multiphase flow, syphon effects.

I. Introduction

PHE ONWJ is an oil and gas company which handles offshore facilities from the north of Cirebon (West Java) to the east, up to Kepulauan Seribu (DKI Jakarta), Indonesia, 8300 km^2 in size [1]. PHE ONWJ itself engages in management, development, and production of oil and gas. Annual production improvements have become the company's strategy in delivering sustainable oil and gas production. To achieve this goal, company itself must manage and maintain a safe and reliable surface facility [1]. Using a simple rule of thumb, a top side facility's performance could be measured from how effective the facility delivers oil and gas production.

First of all, most wells in PHE ONWJ are artificial lift wells under gas lift application. Gas lift wells have a higher potential in generating multiphase flow (gas & liquid) under certain operational conditions that lead turbulence. The turbulence is difficult to determine its movement. The change in the turbulence intensity depends on the particle concentration which could lead flow complexity due to the effects of relative motion [2]. The problem arises when gas trap is centralized and accumulated on certain regions along the pipes or pipeline as vortices. Bubbles in a liquid flow tend to accumulate in the center of the vortices [2]. This phenomenon along main oil line can limit the oil production and cause backpressures followed by an increasing pressure of remote platforms pipeline. Instead of venting the gas trap to atmosphere, ejector installation will attract and recover gas trap to the production header.

A. Echo Flow Station and ESA Platform Profile

Echo flow station is part of PHE ONWJ production facilities which consists of: living quarter platform (echo service), processing platform (echo process/E-Pro), well platform (EA well), and compression system platform (E-Com). Echo flow station has 24 production remote platforms of Normally Unmanned Installation (NUI): 13 active NUI platforms, 4 NUI junction platforms, and others which are stated as in-active [3].

Currently, Echo flow station is one of the biggest oil producer with its base production of 15000 BOPD, compared with PHE ONWJ oil production of 38000 BOPD (at 2013). Echo flow station receives oil not only from its NUI, but also from Foxtrot flow station via 16 in pipeline (F-Pro → E-Com). On the other hands, the collected gas will be compressed under two stage compressors as gas lift, fuel gas, and residual gas [4].

ESA platform lies in the south east of Echo flow station, first operated in 1974, and it currently has several active gas lift wells. Gas lift injection at ESA platform is supplied by echo compressor under 6 in gas lift line through ETA platform with an operating pressure of 670 psig. Oil production of ESA platform flows to the production header prior to be delivered by export line of 12 in main gas line (MGL) pipeline to E-Com as 3 phase flow [3]. To be precise, ESA platform accommodate a daily production around 2414 BOPD for oil and 9.6 MMSCFD for gas [5]. Overview of Echo flow station and its production platforms are shown in Fig. 1.

B. Ejector

An early solution to reduce gas lock along main oil line is ejector installation. Ejector works using Bernoulli's principle. Ejector is an operating media entrains a suction fluid in the suction chamber whereby a two phase flow regime is discharged [6]. It has no moving parts; hence, routine maintenance is not required. Ejector is commonly used in various liquid heating and mixing applications [7]. The intimate contact between the motive media and the process liquid make the ejector ideal for mixing and heating application. Fig. 2 shows sectional drawing of an ejector.

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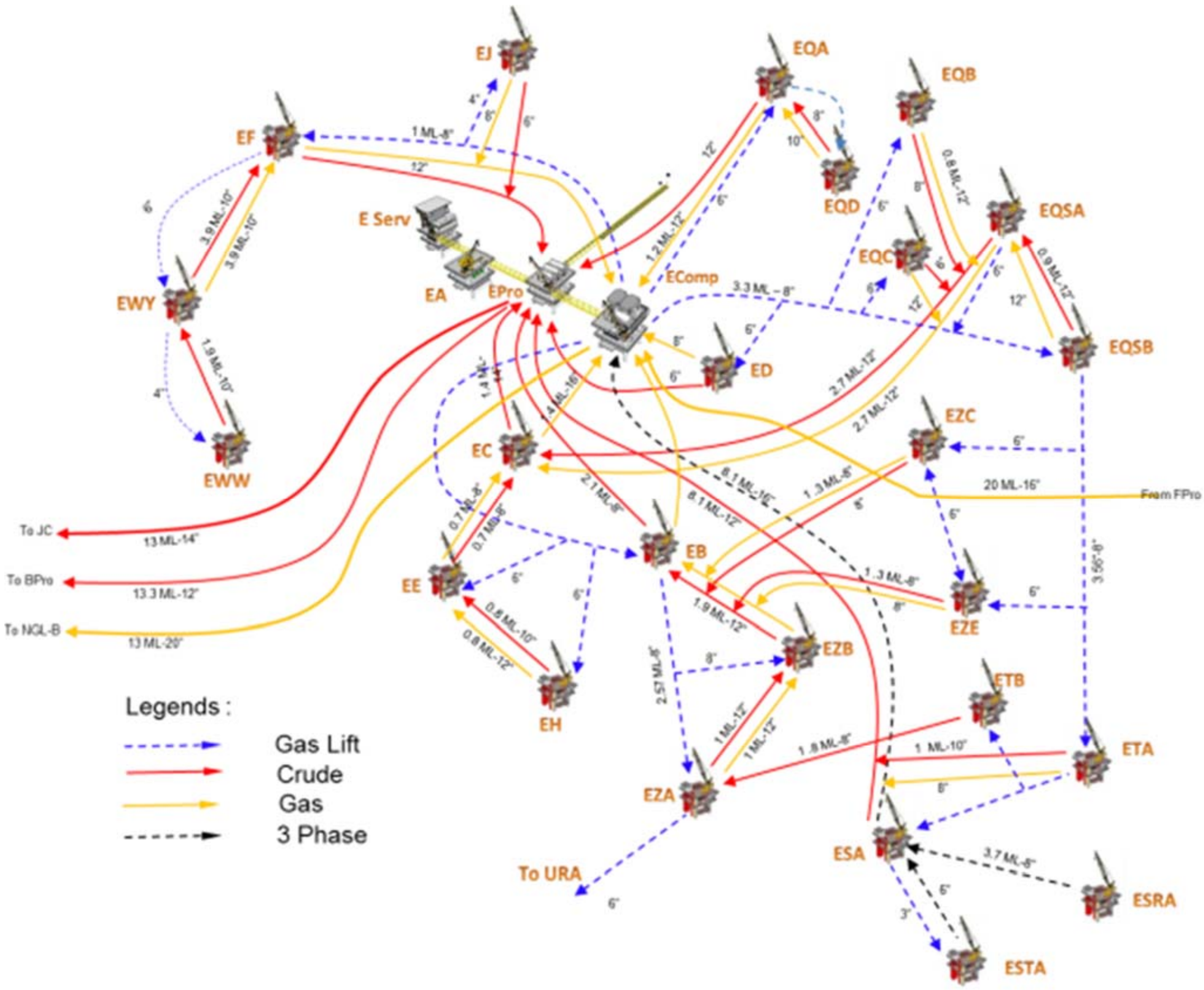


Fig. 1 Echo flow station and NUI network [3]

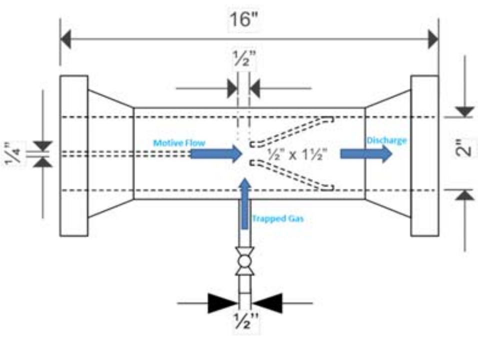


Fig. 2 Sectional drawing of ejector [8]

Ejector is composed by three basic parts: Nozzle, mixing chamber, and diffuser. Fig. 2 illustrates a typical ejector. A high pressure motivating fluid enters ¼ in tubing and expands through the diverging nozzle. The suction fluid enters ½ in pipe, mixes with the motivating fluid in the mixing chamber, and recompressed through the diffuser. A high pressure fluid converses into high velocity jet at the throat of the divergent nozzle which creates a low pressure at that point [9]. A sudden pressure loss draws the suction fluid into the divergent nozzle where it mixes with the motive fluid. The ejector installation is designed to decrease pressure outgoing of main oil line, which means a reducing gas lock effect. Fig. 3 shows ejector installation position in the working field.

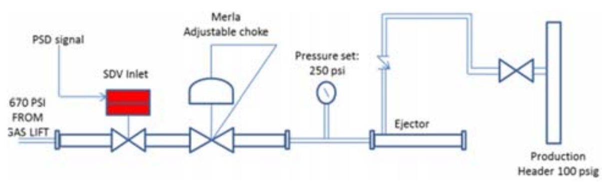


Fig. 3 Ejector installation at ESA platform [8]

II. Material and Method

A profound visualization of the following fluid dynamic along the ejector performed under the software of gambit to modelize the system and fluent to simulate the problem. Started with a drawing under Gambit, a complete discretized

2D model was created with a high refinement mesh. This condition is important to accommodate a myriad finite elements calculation due to delivering an improved simulation quality performance through fluent [10].

A. Geometry Pre-Processing (Gambit Software)

Geometry pre-processing helps in delivering an accurate simulation of the geometry. This process is divided into some main steps:

1) Geometry's creation with available geometric hierarchy is provided by software of gambit such as: Vertices, edge, faces, and volumes (for 3D geometry). Starting by creating some vertices with the corresponding Cartesian coordinate system, straight and circular edge were needed to connect all of the spreading vertices into 2D plane. At the end, those edges formed a face-form which consists of several different edges.
2) Boundary layer for viscous flow creation under a viscous flow condition considering shear stress and boundary layer generation [4]. To begin to structure the mesh, a boundary layer was created first near the wall with certain thickness value [10].
3) Mesh geometry creation with the small size of domains and sub-domains. Well-meshed structures result a good solution from one sub-domain continuously across different interfaces of other sub-domain [10]. A better continuity between the mesh and a faster solution could be achieved under the software of fluent.
4) Set the type of boundary to address each part of geometry with the specific type of boundary condition based on its function and characteristics. The 2D axisymmetric shape was then divided into two different boundary types of pressure inlet and pressure outlet. By defining the type of boundary, some initial values would be inputted later on fluent software.
5) Mesh quality verification with a skewness value under 0.85-0.9. In order to have a fine mesh, a final verification was done under each element [10]. The option of "Export 2D (X-Y) Mesh" was chosen based on the 2D geometry and a new file was created to continue the fluid dynamic process in fluent software.

B. Computational Fluid Dynamics (Fluent Software)

Some governing equations were applied to solve the fluid dynamic problem under certain iteration steps. Several different variables were inputted and solved considering a convergence criteria as a stability parameter of our numerical scheme. Moreover, a residual calculation was performed at the end of the process to visualize the flow continuity problem. While entering interface part on fluent, an option of "2D" was chosen to simulate our 2D geometry. This step allowed the simulation to run under single-precision of 32 bits. The computational fluid dynamic is divided into five main steps:

1) Manage the grid to verify pre-processing phase which has done before. From this step, some information could be generated such as: size, memory usage, zones, and partition. Through the "display" toolbar, a visualization of the complete grid could be seen in detail containing several different surfaces based on the specified boundary types by gambit.
2) Define the model with several model solvers such as: pressure based solver, two dimensional spaces of geometry, implicit formulation, absolute velocity formulation, steady time, green gauss node based gradient, and superficial velocity. The simulation was done under a viscous flow condition.
3) Solve the problem and control the solution. We chose a condition under: simple pressure-velocity coupling and relaxation factors (pressure of 0.3, density of 1, body force of 1, momentum of 0.7, turbulent kinetic energy & dissipation rate of 0.8, and turbulent viscosity of 1).
4) Discretize the solution under: pressure condition to cover any swirl condition, second order upwind for momentum, turbulent kinetic energy to cover the compressible flow conditions which has a multi-dimension of linear reconstruction approach, and first order upwind for turbulent dissipation rate to have a faster solution.
5) Start the iteration using the default convergence criteria. We initialize the solution and compute from "all zone" with a reference frame of "relative to cell zone". The solution initialization led the solver to work and finish the corresponding governing equation under certain iteration process.

TABLE I
MASS FLOW OF EJECTOR'S REGION IN VARIOUS TRAPPED GAS PRESSURE (BASED ON FLUENT SIMULATION)

Trapped Gas Pressure	**50 psig**	**55 psig**	**60 psig**	**65 psig**	**70 psig**
Motive	11.2740	11.0467	9.8632	10.9239	9.0153
Trapped Gas	1.1690	1.5947	3.8077	2.3148	3.9891
Discharge	12.4425	12.6407	13.6716	13.2383	13.0085
Net	0.0005	0.0007	-0.0007	0.0004	-0.0040
Motive / Trapped Gas Ratio	9.6438	6.9271	2.5903	4.7192	2.2600
Trapped Gas Pressure	**75 psig**	**80 psig**	**85 psig**	**90 psig**	**95 psig**
Motive	8.6681	10.4863	8.2147	10.2458	10.0912
Trapped Gas	4.2670	3.4723	4.7286	4.1933	4.5342
Discharge	12.9375	13.9591	12.9453	14.4383	14.6251
Net	-0.0024	-0.0005	-0.0020	0.0008	0.0002
Motive / Trapped Gas Ratio	2.0315	3.0200	1.7373	2.4434	2.2256
Trapped Gas Pressure	**100 psig**	**105 psig**	**110 psig**	**115 psig**	**120 psig**
Motive	10.0001	7.8938	8.1844	7.6948	7.7352
Trapped Gas	4.8345	5.3566	6.1700	5.8361	6.0611
Discharge	14.8340	13.2533	14.3571	13.5335	13.8005
Net	0.0007	-0.0028	-0.0027	-0.0025	-0.0043
Motive / Trapped Gas Ratio	2.0685	1.4737	1.3265	1.3185	1.2762

III. RESULTS AND DISCUSSION

By using software of fluent, we define:

1) Motive flow pressure : 250 psig
2) Trapped gas pressure : 120 to 50 psig
3) Discharge pressure : 82 psig

The results are given by Table I and Fig. 4. From Fig. 4, it is known that mass flow of gas trap and discharge gas tend to decline along with the gas trap pressure, while mass flow of motive gas tends to incline. Fig. 7 shows the ratio of motive flow over net gas flowing out of the ejector.

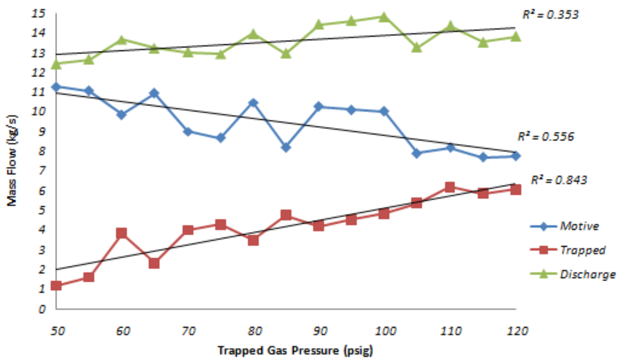


Fig. 4 Mass flow of each ejector's region in various conditions

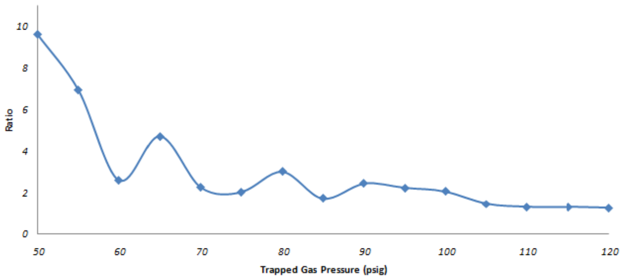


Fig. 5 Profile of trapped gas mass flow ratio profile towards trapped gas pressure

Fig. 5 shows ratio of motive gas over gas trap which indicates the effort or amount of motive gas needed to attract gas trap entering ejector. As gas trap pressure declines, the ratio of motive gas over trapped gas will increase. This indicates an increasing amount of motive gas needed to attract gas trap. Polymath software is used to obtain equation to predict amount of gas trap that can be taken by motive gas in actual condition. Based on polymath, the equation of motive/trapped gas ratio – trapped gas pressure relation is given as:

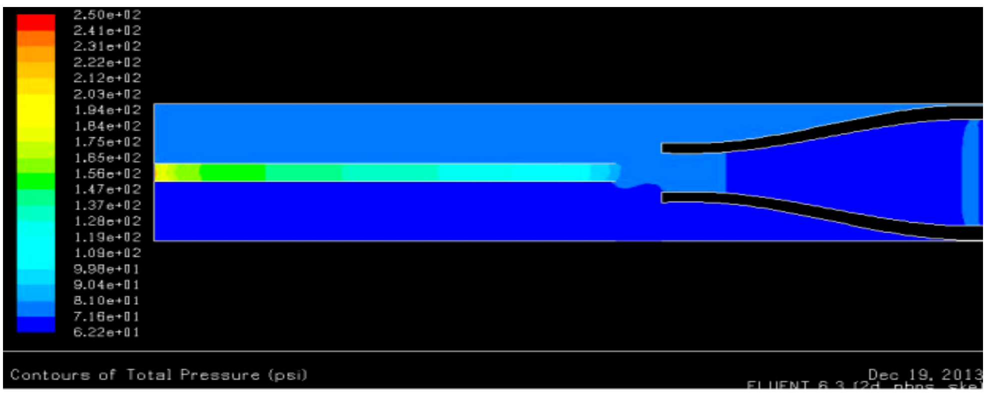
$$R = a_0 + a_1.P + a_2.P^2 + a_3.P^3 + a_4.P^4 + a_5.P^5 + a_6.P^6 + a_7.P^7 \quad (1)$$

Equation (1) is an equation of motive/trapped gas ratio (R) under certain trapped gas pressure (P) under variables of: a_0 (907.0249); a_1 (-65.4743); a_2 (2.053102); a_3 (-0.0360423); a_4 (0.0003809); a_5 (-2.41 x 10^{-6}); a_6 (8.402 x 10^{-9}); and a_7 (-1.238 x 10^{-11}). Based on actual condition, it is known that motive gas in amount of 451 MCFD was being used to attract gas trap resulting main oil line pressure decreases from 120 psig to 76 psig. In order to predict the amount of gas trap attracted by motive flow at 76 psig, we use (1) and after a set of solution arrangement we got 162.0099 MCFD.

To be in line with the idea of production optimization, instead of attracting 162.0099 MCFD, the ejector installation recovers around 28 BOEPD evidently, based on 2013 ESA well test [5]. This equivalency condition is relatively constant under a stable motif flow generation to attract gas trap accumulation along main oil line. An intermittent condition happened and captured by the simulation under fluent software with an operational condition sample as:

1) Motive flow pressure : 250 psig
2) Trapped gas pressure : 76 psig
3) Discharge pressure : 82 psig

The total pressure profile inside of ejector can be seen on Fig. 6.



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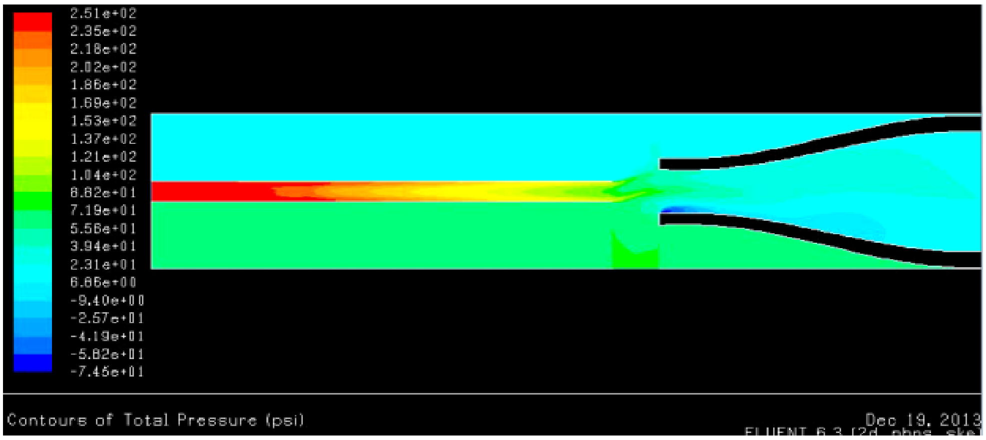

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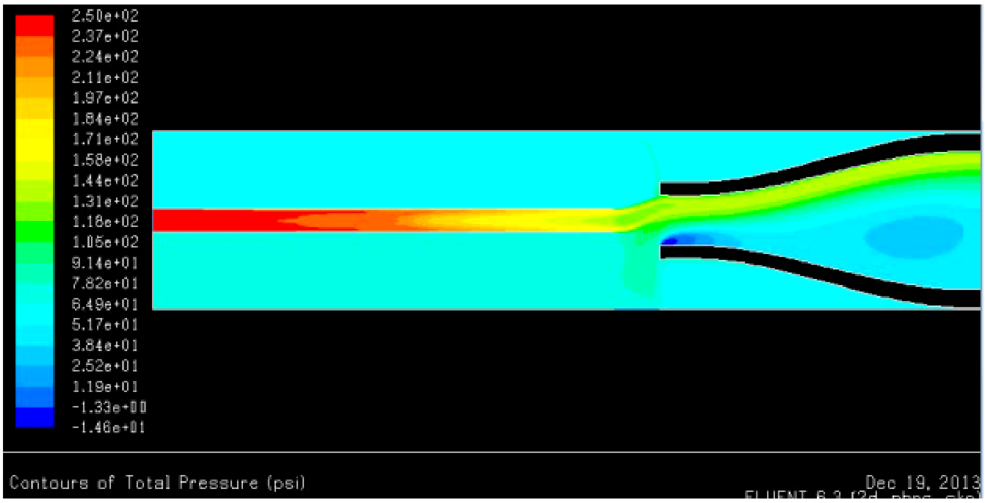

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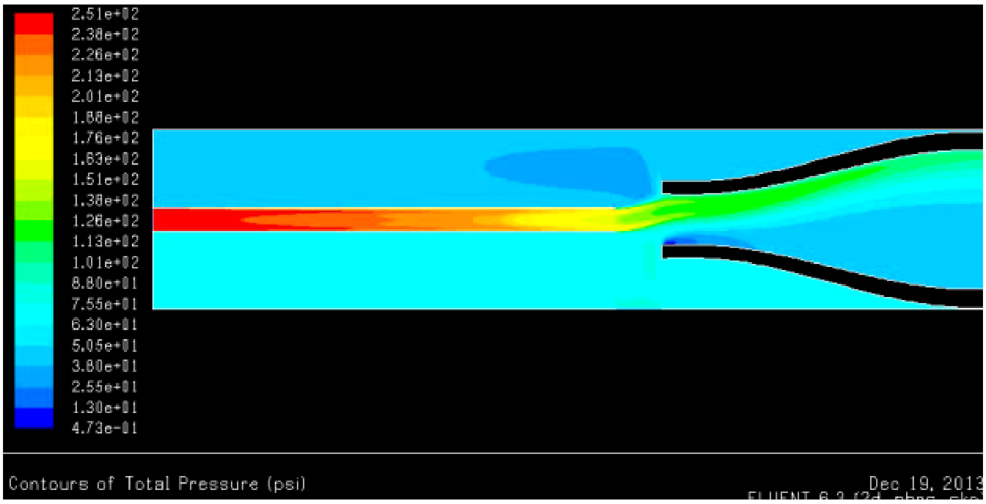

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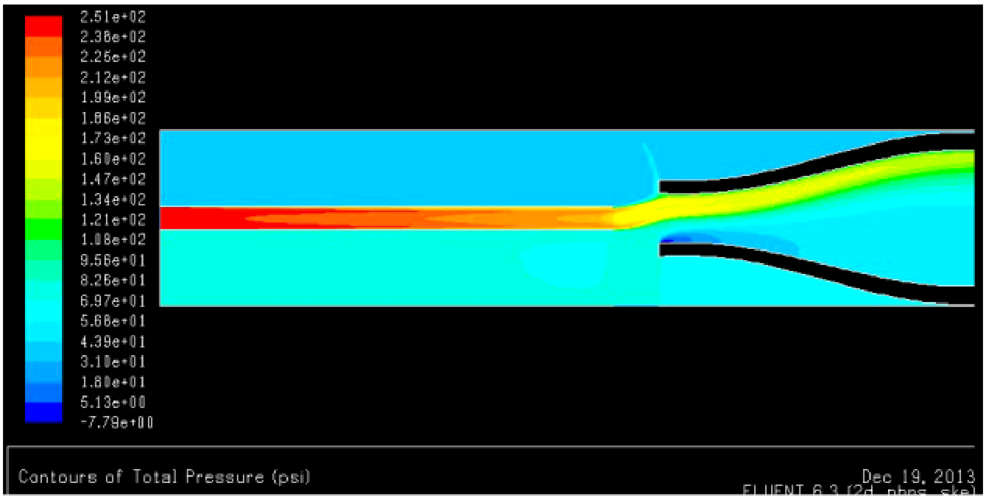

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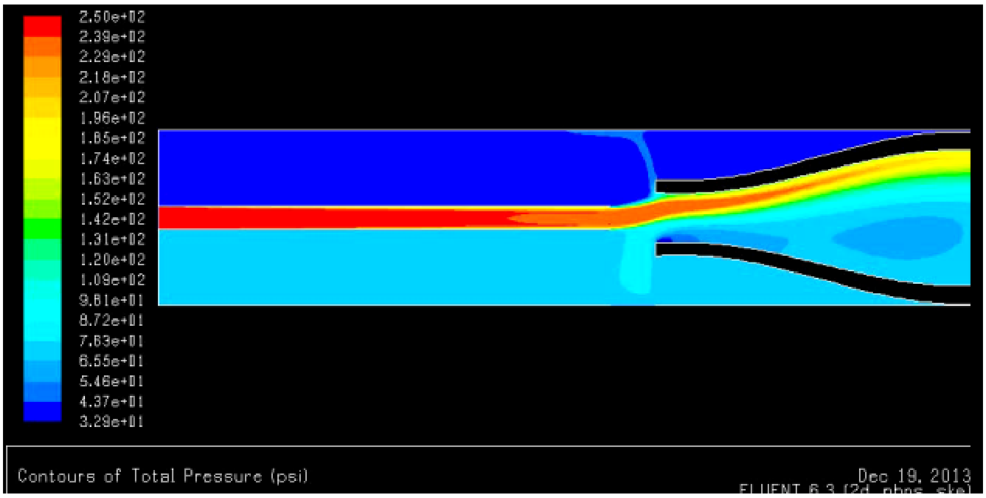
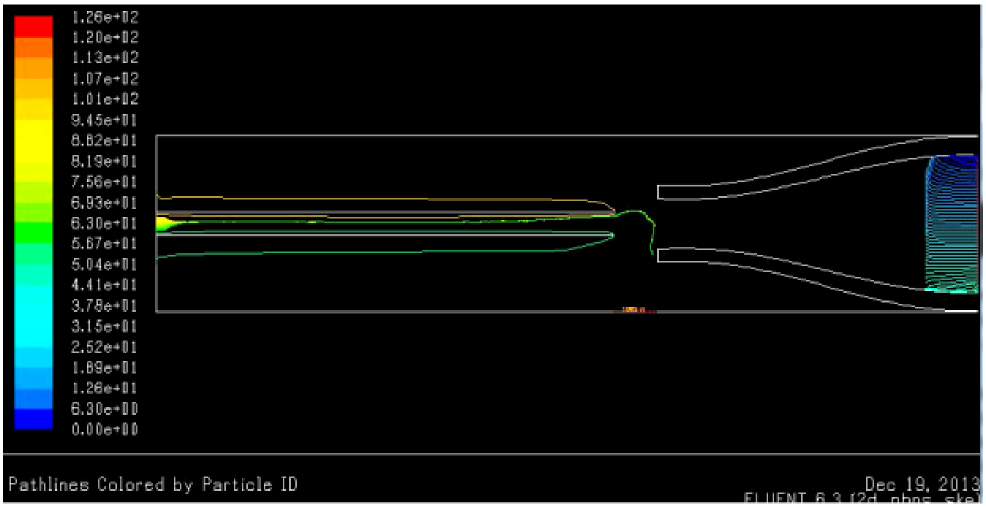


(f)

Fig. 6 Total pressure profile inside ejector from motive gas introduction (a) until gas settlement (f)

Fig. 6 (a) shows ejector condition before any motive gas introduction. A phenomenon of turbulence occurred in space between nozzle and diffuser [11], shown by Fig. 6 (b). Pressure inside ejector gradually increases due to a significant pressure difference between motive gas and gas trap (Fig. 6 (c)), and it fluctuates for a moment awaits the motive gas entering diffuser (Fig. 6 (d)). A separation occurs in the attracted gas trap along diffuser (Fig. 6 (e)), due to an increasing adverse pressure gradient at discharge of ejector. At the end, a decrease in pressure at the entrance of diffuser leads the flow to find its stable condition (Fig. 6 (f)) with an increasing back pressure at diffuser or discharge of ejector. On the other hand, the path lines profile of gas particle inside ejector is shown by Fig. 7. This particle path line shows the movement of each particle along the ejector system. Those particles flow with others, generating a pattern called streamline under certain operating condition (pressure and velocity). The detailed movements of the streamlines from the inlet to ejector's outlet are as follows: Fig. 7 (a) shows particle's path lines after motive gas introduction. Gas particle flows and fills the system because of a significant pressure difference. As time goes by, gas trap is attracted to the diffuser (Fig. 7 (b)), and it enters a separation phase, (Fig. 7 (c)) indicated by a detaching flow the diffuser's surface. The separation becomes bigger with an increasing vortex (Fig. 7 (d)). Figs. 8 (e) and (f) show that gas trap tends to move upward inside diffuser and is suppressed by an increasing backflow.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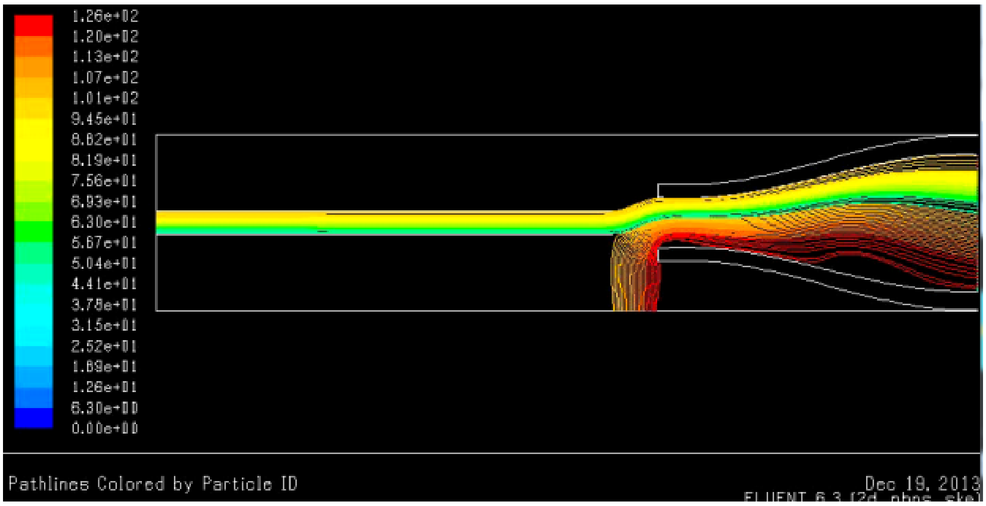
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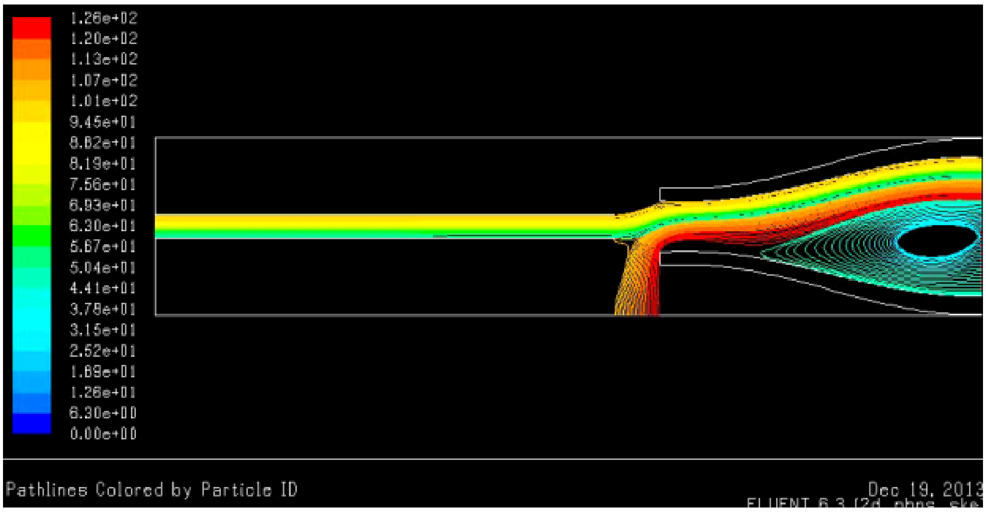
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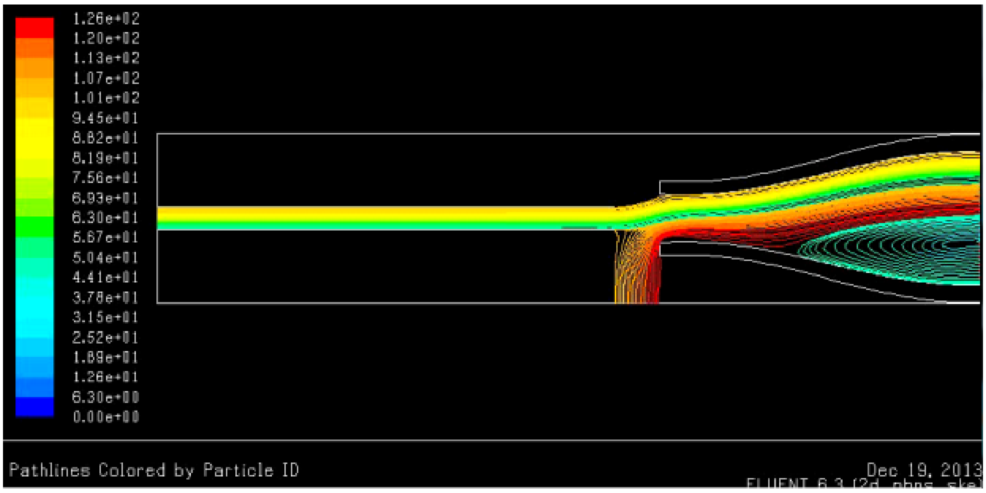

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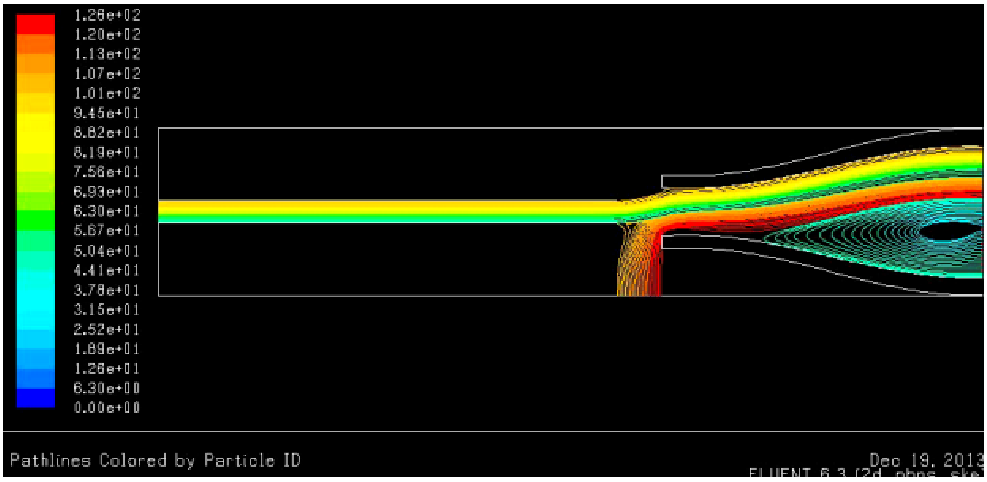

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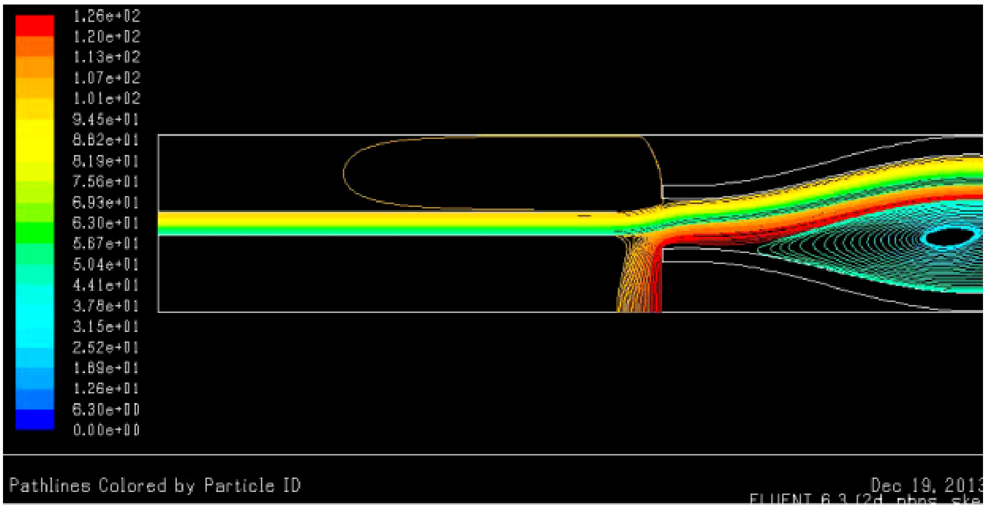

(f)

Fig. 7 Gas particle path lines profile inside ejector from motive gas introduction (a) until gas settlement (f)

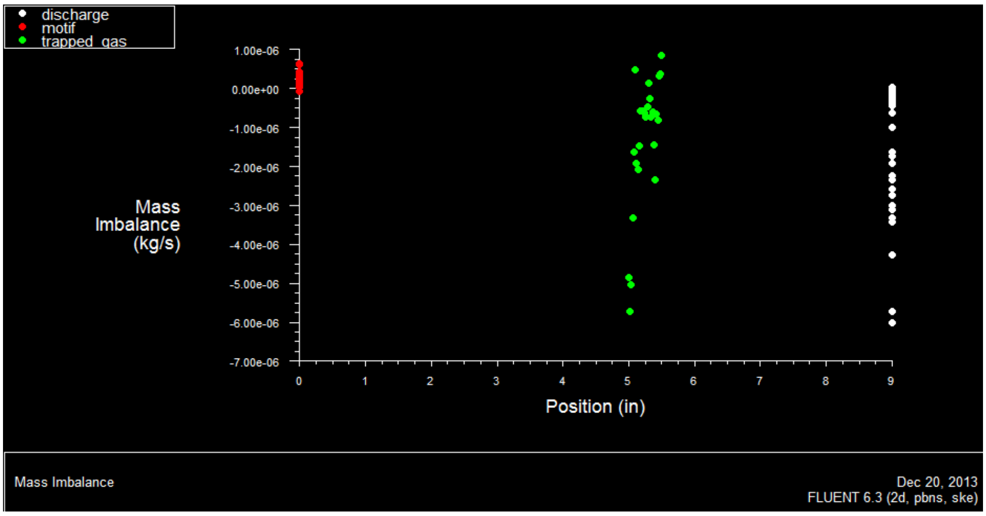

Fig. 8 Mass imbalance at motif entrance, gas trap entrance, and ejector discharge

Both pressure and particle path lines profiles show an intermittent flow condition along the ejector system (Fig. 6 (a)) where the initial discharge pressure is less than 80 psig. As the motive flow increases and compresses the system, the flow inside ejector ramps up and against the far field condition of ejector's downstream [11]. Based on actual condition, gas trap pressure declines from 120 psig and stabilizes at around 76 psig.

The intermittent condition is also indicated under the mass balance inside ejector, shown in Fig. 8. The figure shows that mass imbalance fluctuates around position 5 in for gas trap region and 9 in for ejector discharge region. The intermittent condition also represents a discontinuity of the flow along ejector.

IV. Conclusion

The blocking effect caused by gas trap accumulation along main oil line has been minimized by installing an ejector on the system. Benefited from the gas lift line, a motive flow is generated and adjusted under "Merla valve" (flow regulator). During the operational condition, pressure of gas trap will reduce from 120 to 76 psig. The phenomenon is as follows:

1) An increasing motive flow is followed by a reduction in attracted gas trap.
2) Trapped gas is being attracted intermittently by certain motive flow injection due to ejector limitation in generating a discharge pressure against its downstream pressure of 100 psig (header pressure).

V. Recommendation

For further analysis, some recommendations are available to improve the existing design, such as:

1) A study in flow continuity along ejector is still important to be done holistically.
2) To increase the syphon effect (attract gas trap accumulation) along the ejector, a diffuser performance could be increased by minimizing the flow separation from its entrance to egress region.

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