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Flow characteristics of injection pump with inclined suction pipe for basic design of cosmetics and paint production facilities

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Abstract

The injection pump is used to get pressure, and it has been applied to a lot of industry field like the cosmetics and paint production facilities. It can be manufactured with a simple structure irregardless of size of system, installed and used easily at places where fluid is flowing. This paper addresses the effect of velocity distribution and flux efficiency by CFD(Computational fluid dynamics) analysis by varying the angle with suction pipe of injection pump in three different ways. Analysis has been carried out using the commercial code as the experimental method. At the same fluid conditions, varying an angle with a suction pipe to 90°, 60°, and 45°, characteristics of mean velocity and flux efficiency through CFD analysis are as follows. In result, in the same flow condition, when a fluid flows through suction pipe to diffuser pipe, velocity vector shows laminar flow as a fluid recedes from the up-down walls of the pipe. And flux efficiency of suction pipe was the highest at an angle of 45 degrees.

Keyword : Injection Pump, Computational Fluid Dynamics, Production Facilities, Flux Efficiency

1. Introduction

The injection pump is used to get pressure, and it has been applied to a lot of industry field like the cosmetics and paint production facilities. As shown in [Fig. 1], injection pump consists of injection nozzle, suction pipe, and diffuser. The injection pump draws a fluid by vacuum-suction using the power by letting out the high-pressure pressurized fluid into the limited space through the nozzle. The structure of [Fig. 1] is so simple that it is used in industrial settings for vacuum dehydration, thickening, distillation, deodorization, crystal, exhaustion, impregnation, mixing, cooling, advection and so on because it rarely breaks down and is easy to operate and maintain [1]. Ji's [2] previous studies on injection pump with the design of injection nozzle identi-fied the internal pressure and suction performance with variations of nozzle shape and direction. Kim [3] made comparative analysis on the effect of flow characteristics based on the different nozzle length and diameter ratio and inhalation efficiency using

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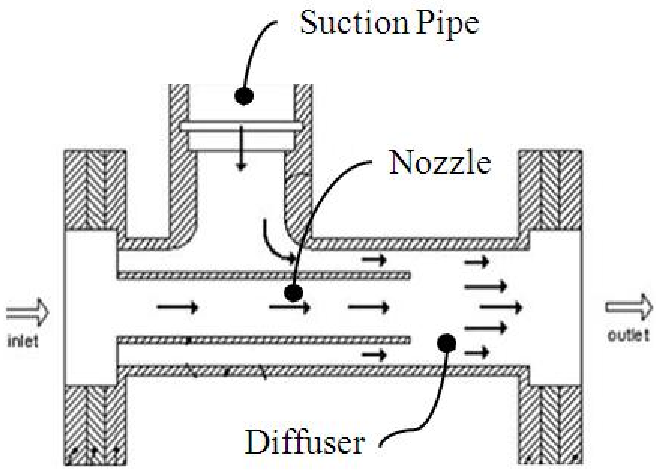
commercial code and the experiment. And he also made a study on injection pump with the design of diffuser through numerical analysis with Dutton's [4] diffuser shape. Lee [5] identified the correlation between mass flow and diffuser sectional area by building the corn-shape cylinder inside the injection pump system. As mentioned above, studies on injection nozzle and diffuser of injection pump are proceeding actively while the studies on flow characteristics of injection pump design with suction pipe are rare. So on this study, Joo [6], Sohn [7], Go [8][9] The injection pump is used to get pressure, and it has been applied to a lot of industry field like the cosmetics and paint production facilities. It can be manufactured with a simple structure irregardless of size of system. I found the value of velocity distribution after a derivation of the governing equation and liberalization by varying an angle with a suction pipe of a injection pump to 90°, 60°, and 45° using commercial code. And with continuity equation and momentum equation which is the governing equation, I had the discredited equation and obtained the data through finite volume method.



[Fig. 1] Schematic Diagram of Injection Pump

2. Numerical Analysis Modeling

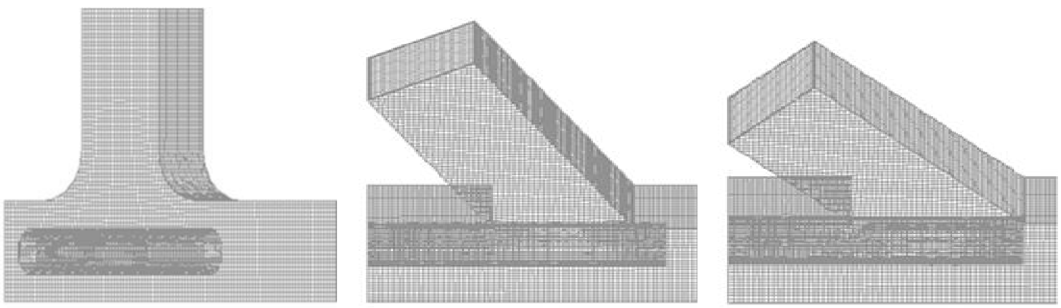
2.1 Analytical Model and Boundary Condition

In this paper, CFD(Computational fluid dynamics) commercial code was used as a method of fluid analysis. With the Analytical Model, [Fig. 1] Schematic Diagram of Injection pump, I have varied the suction pipe angle of an injection pump to 90°, 60°, and 45° and discussion on flow characteristics of angle variation in the suction pipe is made. I have established the flux and mesh number based on the angle 90°, 60°, 45° with suction pipe of injection pump and flow condition. The condition of this analysis is shown in [Table 1].

[Table 1] CFD Condition of Driving Flow

unit	V(m/s)	Q(kg/s)	Grid Number
90°	2	0.0015687	218,000
60°	2	0.0016347	176,000
45°	2	0.0018692	168,000

Heat transfer and compressibility were disregarded in flow condition, and the analysis has been carried out at the density kg/m3, viscosity coefficient N·S/m2, and by maintaining the static pressure of working fluid with 20°C water. Mesh is shown in [Fig. 2].



(a) 90°　　(b) 60°　　(c) 45°

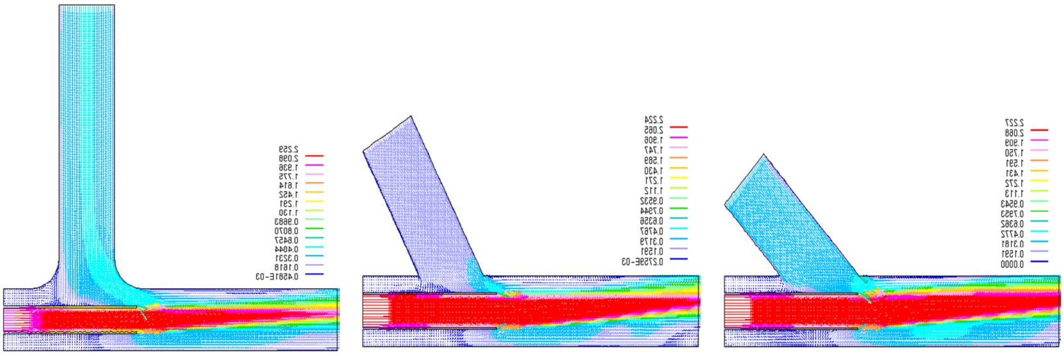
[Fig. 2] CFD Grid of Injection Pump

3. Result and Discussion

3.1 Velocity Distribution

The suction pipe in [Fig. 3] shows average velocity vector when the angle of the suction pipe is 90°, 60°, and 45° respectively. As motive fluid passes through the nozzle the pressure energy has reduces and the velocity energy increases, and as a result, the vacuum pressure is created. And as it draws the secondary fluid through the suction pipe, I have verified the flow pattern which is created when they meet at the diffuser and exchange momentum. The flux is 90°=0.0015 kg/s, 60°=0.0016 kg/s, 45°=

0.0018 kg/s respectively, and velocity vector goes down toward the suction pipe. As an angle of the suction pipe increases, the velocity vector of a diffuser pipe decreases. In addition, if the appropriate location of the drive pipe is selected, the flux suction would be evenly distributed. According to Hwang and others' paper, as high-pressured motive fluid passes through the nozzle, the negative pressure is created inside the injection pump, and high-pressured motive fluid flows into inside of the pump through the suction pipe.

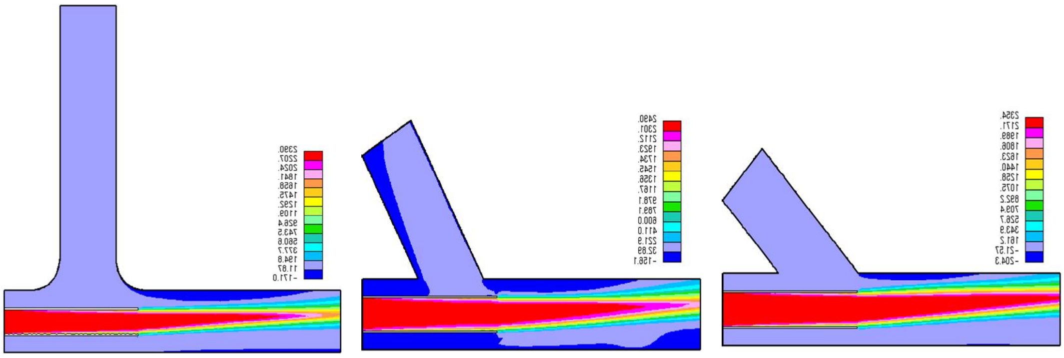


(a) 90° (b) 60° (c) 45°

[Fig. 3] Mean Velocity Vector Distribution (V=2m/s)

This paper also, as shown in [Fig. 3], has total pressure distribution. At a 45° angle of a suction pipe, pressure distribution shows larger range. At (a), (b), pressure distribution maintains without particular influence to the exit, but at (c), under the influence of suction and velocity scale, total pressure distribution shows wider range. According to Sohn and others' paper, when a fluid drawn from the rounding-treated suction pipe and a fluid at the main pipe area meet, the eddy flow is created and cause pressure loss at the upper wall. This paper also, at rounding-treated area, negative pressure and eddy flow is created. When a fluid is drawn from suction pipe to diffuser pipe, due to the change in velocity scale and velocity direction, the eddy flow attachment point is created. Among three conditions of pressure distribution the singularity of total distribution shows negative value under (c) the best condition, and as eddy flow is created largely, the curvature of a suction pipe with velocity condition is an important consideration. [Fig. 4] shows a nusselt number that was obtained when the angle variation conditions are 90°, 60°, and 45°, according to the point(L=0) where the drive pipe and diffuser pipe converge, with the point of 0mm, 90mm, and 180mm with entrance velocity condition and with the velocity distribution rate of each hight of a diffuser pipe

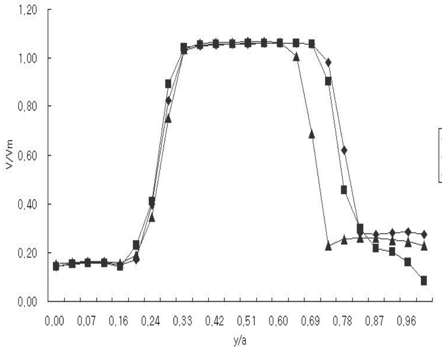
In [Fig. 4], velocity value increases sharply at $y/a > 0.3$, decreases sharply at $y/a > 0.6$ and recovers at y/a > 0.8. The gap between the upper and lower side of a diffuser pipe is created due to the suction of an angle variation in a suction pipe, and the reason of this is as follow. When velocity value near the wall is lower than the other side, and as the angle recedes from the wall, a velocity vector recovers to higher value and as a result, flux efficiency is increased. These phenomena are occurred as a fluid velocity of suction flow rate increases, the recovery section also increases. In [Fig. 4], analysis of the total pressure distribution through commercial code with the rate of total hight of a mixer pipe with diameter is shown. To find out a variation of pressure distribution as a fluid flows, according to the point where the drive pipe and diffuser pipe converge(L=0), total pressure distribution has been carried out at the points of 0mm, 90mm, and 180mm.



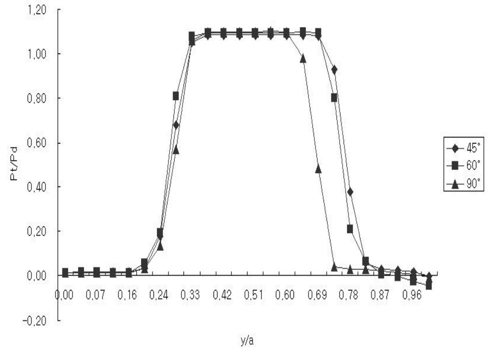
(a) 90° (b) 60° (c) 45°

[Fig. 4] Total Pressure Distribution (V=2m/s)

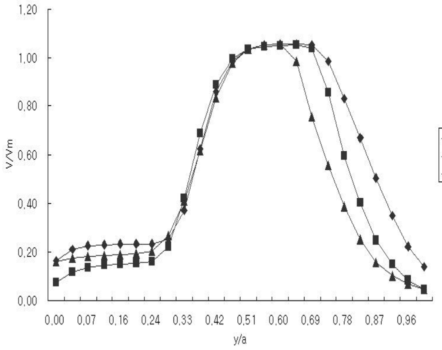
In [Fig. 5], at the point of L=0, pressure stribution is the smallest at a 90° angle, and the pressure increases sharply at y/a > 0.2, and decreases sharply at y/a > 0.6. And at a 60° angle, negative pressure is the lowest. At the point of L=90mm, the pressure is maintained low at y/a > 0.2, and at a 90° angle of a suction pipe, the pressure decreases sharply near y/a > 0.6. This singularity is created because at y/Dh > 0.5 of diffuser pipe near the Inclined Suction Pipe, dissipation rate is lower than the other part due to the suction but the larger the velocity and closer to the wall, the more negative pressure is created due to the intake of a fluid which causes eddy flow created by wall shear force. Because this phenomenon decreases efficiency of flux, when an appropriate location is selected after coming through a drive pipe, a nozzle shape can be implemented to a diffuser pipe, and as a result, the flow loss can be minimized.



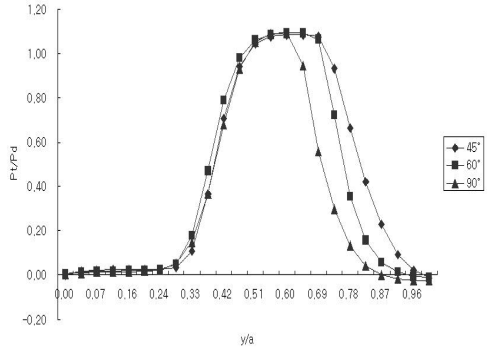
(a) Total Pressure Distribution (0mm)



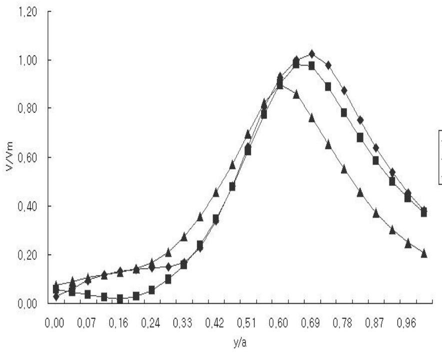
(a) Pressure distribution (0mm)



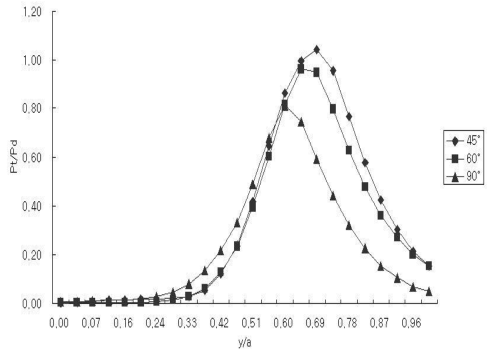
(b) Total Pressure Distribution (90mm)



(b) Pressure distribution (90mm)



(c) Total Pressure Distribution (180mm)

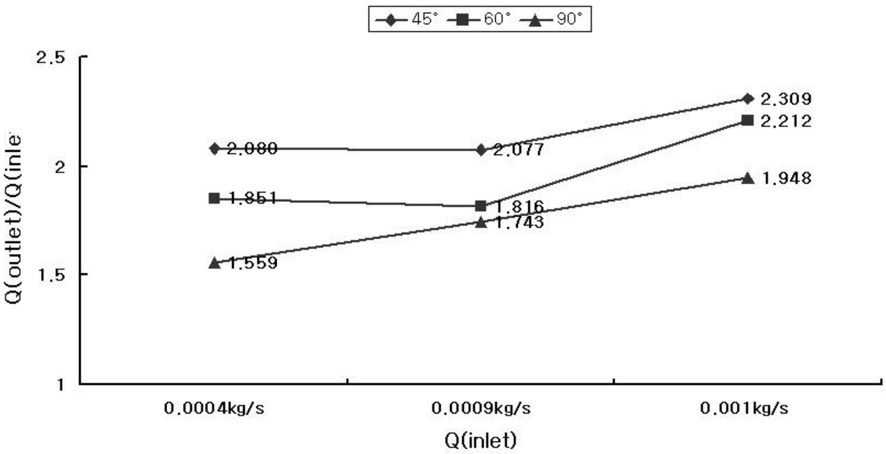


(b) Pressure distribution (180mm)

[Fig. 5] Total Pressure Distribution & Pressure distribution (V=2m/s)

3.2 Flux Efficiency

In [Fig. 6] shows flux efficiency, using nudest number with the rate of the exit flux according to an angle variation in a suction pipe and flux variation with entrance conditions. When the entrance flux conditions are Q1=0.0004kg/s, Q2=0.0009kg/s, Q3=0.001kg/s respectively, at a 45° angle of a suction pipe, flux efficiency is =2.00, =2.07, =2.30. and at a 60° angle of a suction pipe, flux efficiency is =1.85, =1.81, =2.21. and at a 90° angle of a suction pipe, flux efficiency is =1.55, =1.74, =1.94. Therefore, at the same flux and the smaller the angle, the flux efficiency is the highest at a 45° angle a suction pipe. This is because as motive fluid passes through the nozzle, velocity energy increases and creates vacuum pressure. And secondary fluid is drawn through suction pipe and then exchange momentum at a diffuser part. Therefore, flow loss can be minimized with an angle of a suction pipe and appropriate location of a nozzle.



[Fig. 6] Flux Efficiency

4. Conclusion

At the same fluid conditions, varying an angle with a suction pipe to 90°, 60°, and 45°, characteristics of mean velocity and flux efficiency through CFD analysis are as follows.

(1) When a fluid is drawn from a suction pipe to a diffuser pipe, negative pressure is created at the rounding-treated part of the dividing pipe.

(2) The velocity gap between the upper and lower side of a diffuser pipe is created, and as recedes from the wall, velocity vector recovers to larger scale.

(3) At y/Dh > 0.5 of a diffuser pipe near the dividing pipe, influenced by suction total pressure creates negative pressure as velocity increases and closer to the pipe wall. This is because the in-taken fluid creates eddy flow by wall shear force.

(4) Take these phenomena into consideration, curvature design condition of suction pipe with velocity conditions should be considered as the design factors of a injection pump. And when the nozzle shape is implemented after selecting an appropriate location of a drive pipe and a diffuser pipe, flow loss can be minimized.

References

[1] J. W. Jang, W. H. Sin, Y. C. Park, "STUDY ON THE PERFORMANCE OF THE SHAPE OF THE AIR-LIQUID EJECTOR DIFFUSER", Journal of the Korea Academia-Industrial cooperation Society, vol. 15, no. 11, November 2014, pp. 6412-6418, doi: 10.5762/KAIS.2014.15.11.6412.

[2] M. k. Ji, P. H. Kim, K. T. Park, T. Utomo, H. S. Chung, H. M. Jeong, "Performance Characteristics of Air Driven Ejector According to the Position Changes and the Shape of Driving Nozzle," Journal of the Korean Society of Marine Engineering, vol. 32, no 4, May 2008, pp. 550-556, doi: 10.5916/jkosme.2008.32.4.550.

[3] Y. J. Kim, J. W. Park, L. S. Seo, "Effect of Nozzle Geometry on the Suction Flow Rate in a Ejector", Journal of the Fluid Machinery, vol. 12, no. 6, 2009, pp 13-17.

[4] J. C. Dutton, B. F. Carroll, "Optimized Ejector-Diffuser Design Procedure for Natural Gas Vapor Recovery", Journal of Energy Resources Technology, vol. 105, no. 3, September 1983, pp. 388-393, doi: 10.1115/1.3230934.

[5] J. H, Lee, H. D. Kim, "An Experimental Study of the Variable sonic/Supersonic Ejector System", Transactions of the Korean Society of Mechanical Engineers B, vol. 29, no. 5, May 2005, pp. 554-560, doi: 10.3795/KSME-B.2002.26.5.640.

[6] H. J. Joo, I. Y. Jung, S. K. Yun, H. Y. Kwak, "CFD Analysis on the Flow Characteristics of Ejector According to the Position Changes of Driving Nozzle for F.W.G", Journal of the Korean Solar Energy Society, vol. 31, no. 3, June 2011, pp. 23-28, doi: 10.7836/kses.2011.31.3.023.

[7] H. C. Sohn, G. M. Park, H. S. Go, H. N. Lee, "Flow Characteristics of Driven Nozzle Position Change in the Connected Injection Pump", Transactions of the Korean Society of Mechanical Engineers B, vol. 33, no. 4, April 2009, pp. 215-224, doi: 10.3795/KSME-B.2009.33.4.215.

[8] H. S. Go, C. G. Jung, H. N. Lee, "A Study on the Flow Characteristic of the Diesel Engine DPF", Journal of the Korean Society of Marine Engineering, vol. 36, no. 1, January 2012, pp. 109-117, doi: 10.5916/jkosme.2012.36.1.109.

[9] H. S. Go, "Flow Characteristics a Jet Pump by Inclined Suction Pipe", Master's thesis, Department of Mechanical Engineering, Chosun University Graduate School, Korea, 2007.