Steam Pressure Characteristics on Converging-Divergent Injectors with Varying Suction Diameters

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Abstract. This study aims to determine the pressure characteristics of the convergent-divergent injector with varying suction diameter. Characteristic determination is done by simulation using ANSYS FLUENT software. The convergent-divergent injector has 28 mm suction chamber diameter dimensions, 14 mm nozzle input diameter, 58 mm suction chamber length, 5 mm nozzle output diameter, 130 mm mixing chamber length, 95 mm throat length, 130 mm diffuser length, and the output side diameter 40 mm injector. The primary nozzle used has a length dimension of 100 mm, an input diameter of 14 mm, and an output diameter of 5 mm. The injector suction was varied with successive diameters of 10 mm, 15 mm, and 20 mm. The results showed that the injector suction diameter has a significant effect on the vapor pressure characteristics of the convergent-divergent injector.

1. Introduction

For industries that need a power plant as well as a cooling system, the application of a combined heat and power (CHP) system is very appropriate. One technology that can be applied is a steam jet system (SJU) refrigeration machine. The SJU system uses convergent-divergent nozzles for the vacuum process. The nozzle converts pressure energy into kinetic energy so that it can evaporate water briefly and release it to the condenser (Pianthong, 2007). Low pressure or vacuum on the avaporator is very dependent on the design of the nozzle (injector). According to Mitchley (1998) one of the factors that influence the vacuum pressure of the evaporator is the geometry between the surface of the water and the side of the injector suction. Therefore, an appropriate injector design is needed for the application in a steam jet refrigeration engine. However, due to these geometry factors, the efficiency or performance (COP) of the steam jet refrigeration engine system is still very low. The problem with the low COP of a steam jet refrigeration system requires technological innovation to overcome it. The specific purpose of this study is to determine the pressure characteristics of the convergent-divergent nozzle with varying suction diameter. The working principle of the SJU refrigeration machine is that steam from the boiler is flowed to the evaporator or flash tank through a nozzle. The suction side of the nozzle is connected to the evaporator, while the output side is connected to the condenser.

Nozzles function to convert pressure energy into kinetic energy so that the vapor pressure will drop. The pressure drop causes the steam in the evaporator to be sucked and then flowed into the condenser. If these conditions continue, the water temperature will be lower too. This can be done until it reaches the desired water temperature. The process of absorption of heat from the refrigerant to the cooling load occurs in the evaporator. Therefore, the temperature or boiling point of the refrigerant must be lower than the temperature of the cooling load.

The performance of a steam jet (SJU) refrigeration system is very dependent on the efficiency of the nozzles. While the efficiency of the nozzle is influenced by the geometry and fluid pressure in the injector. Sahni [1] reported that COP steam refrigeration systems are influenced by nozzle geometry and pressure drop.

According to Mitchley [2] the influential factors in injector design are convection heat transfer below boiling temperature and the geometry between the water surface and the injector suction side. On the output side, the parameter that influences the injector efficiency is the pressure drop [1]. Other factors to consider are the critical pressure and shock waves on the injector. The ratio between the inlet pressure and critical pressure depends on the injector geometry and the thermal properties of the working fluid [3]. Another important thing to consider is the shock wave [4] report that the optimum geometry design of the steam injector is the inclination angle of 2o for convergent nozzles and 3o for divergent nozzles with 137 mm throat length.

2. Materials and method

Simulations were performed on convergent-divergent nozzles with 28 mm suction chamber diameter, 14 mm nozzle input diameter, 58 mm suction chamber length, 10-20 mm secondary fluid inlet diameter, 5 mm nozzle output diameter, 130 mm mixing chamber length, throat length 95 mm, diffuser length 130 mm, and injector output side diameter 40 mm, primary nozzles with length 100 mm, input diameter 14 mm, and output diameter 5 mm.

To visually see the fluid state in the nozzle with a simulation used ANSYS 16.0 which features the FLUENT system analysis feature. he simulation step starts with drawing CAD nozzle using solid works, then importing CAD Nozzle to Ansys using the geometry feature in ANSYS Next, import the geometry of the nozzle into the mesh, then import the mesh to the setup, then set the solver based on pressure and steady state problems at the time type. Activate the energy equation then set the inlet pressure and output pressure under boundary conditions, finally select the iterative solver and mixed initialization then run the program. This method is quite well applied for fluid flow analysis in nozzles with fairly accurate results [5] [6].

3. Result and discussion

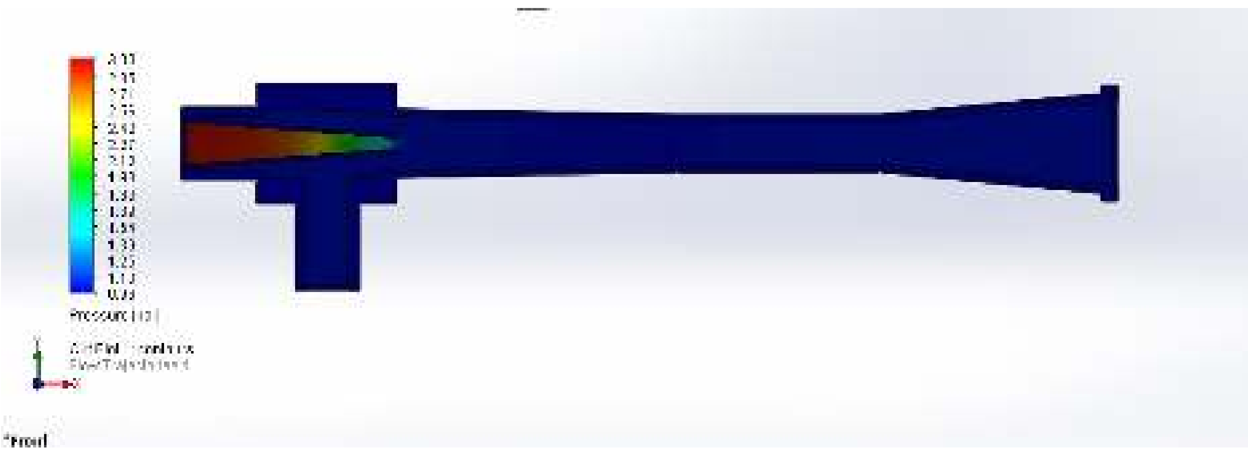

Figure1. Contour of nozzle with 10 mm suction inlet diameters

Figure 1 shows the pressure profile along the nozzle for the inlet side diameter of 10 mm. The highest pressure occurs at the inlet side of the primary nozzle by 3 bars then drops slowly to1 bar at the end of the nozzle.

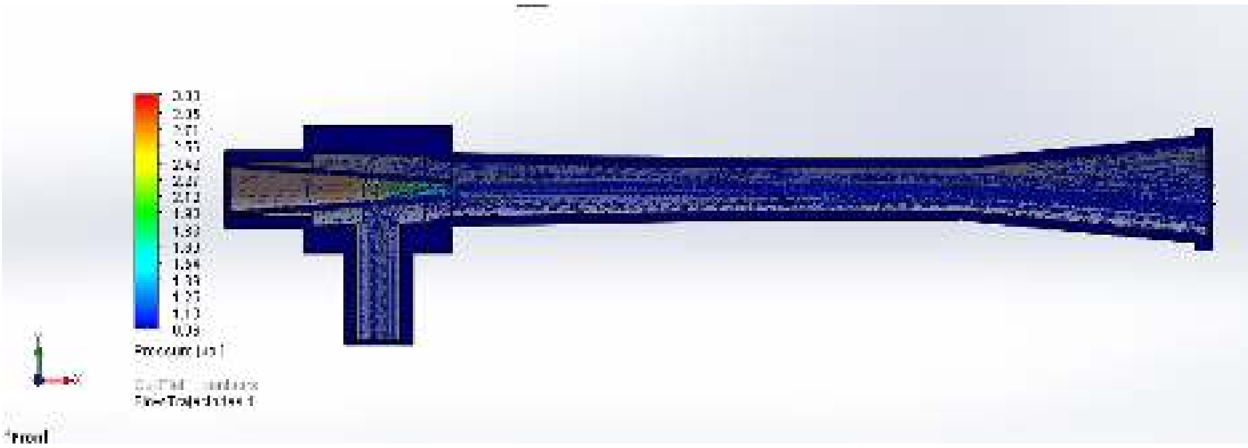

Figure 2. Streamline of nozzle with 10 mm suction inlet diameters

Figure 2 shows a uniform streamline on the nozzle indicating that the pressure in the mixer, throat, and diffuser is almost constant.

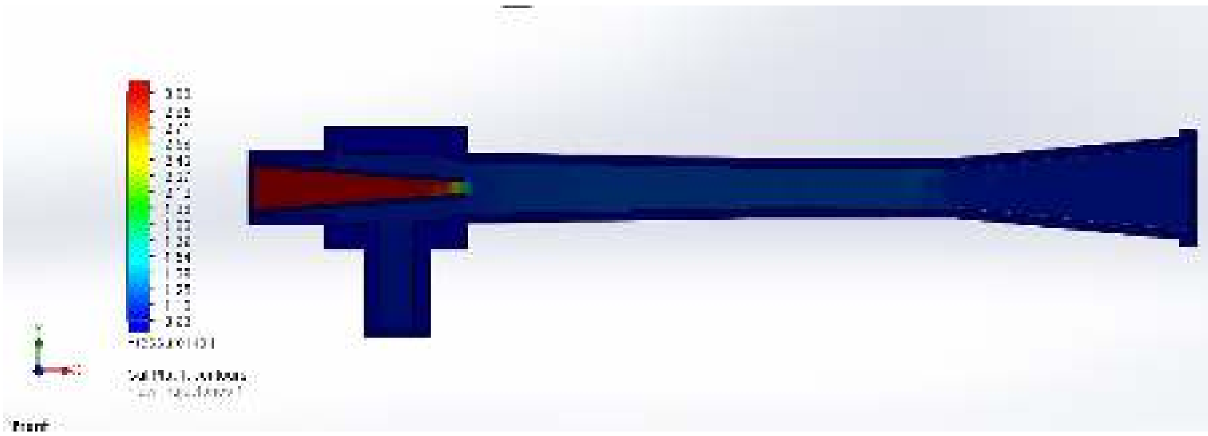

Figure 3. Contour of nozzle with 15 mm suction inlet diameters

Figure 3 shows the pressure on the inlet side of the 3 bar primary nozzle until it almost reaches the nozzle output end then comes out at 1 bar pressure.

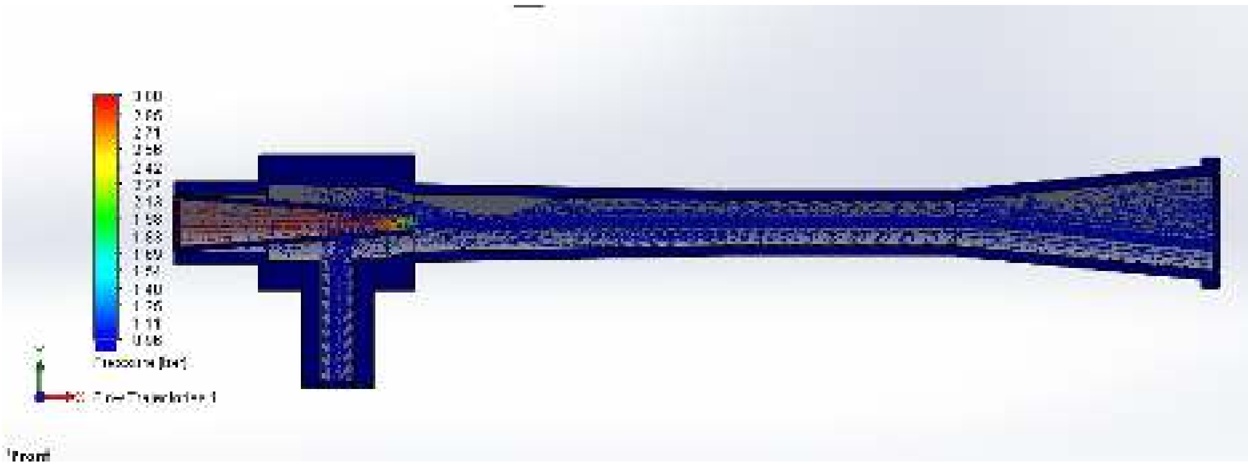

Figure 4. Streamline of nozzle with 15 mm suction inlet diameters

Figure 4 shows the stream line in the nozzle where there is shock on the mixing side and on the diffuser there is a vortex flow

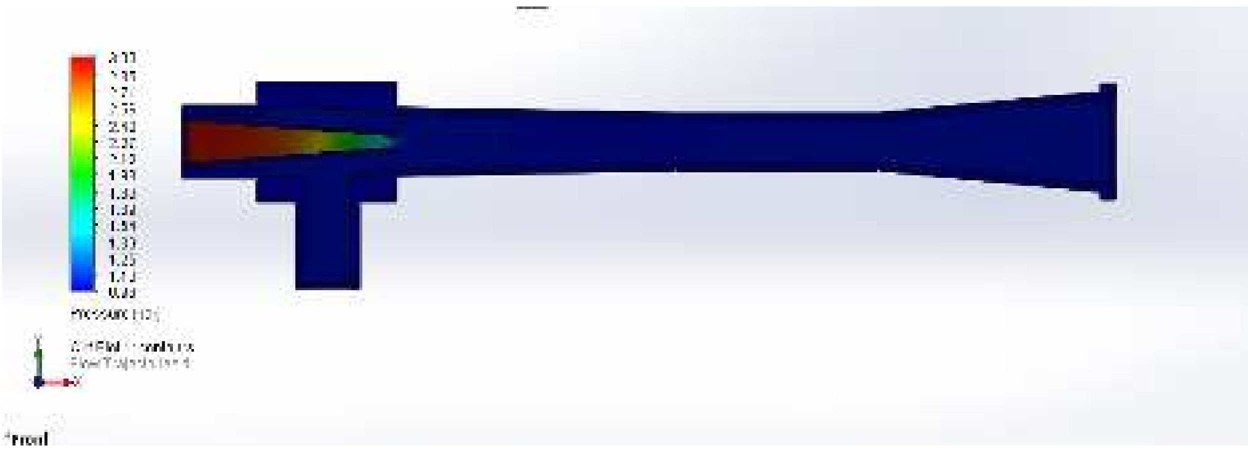

Figure 5. Contour of nozzle with 20 mm suction inlet diameters

Figure 5 shows the pressure characteristics in the nozzles with 3 bar pressure on the inlet side and down to about 1.93 bar pressure.

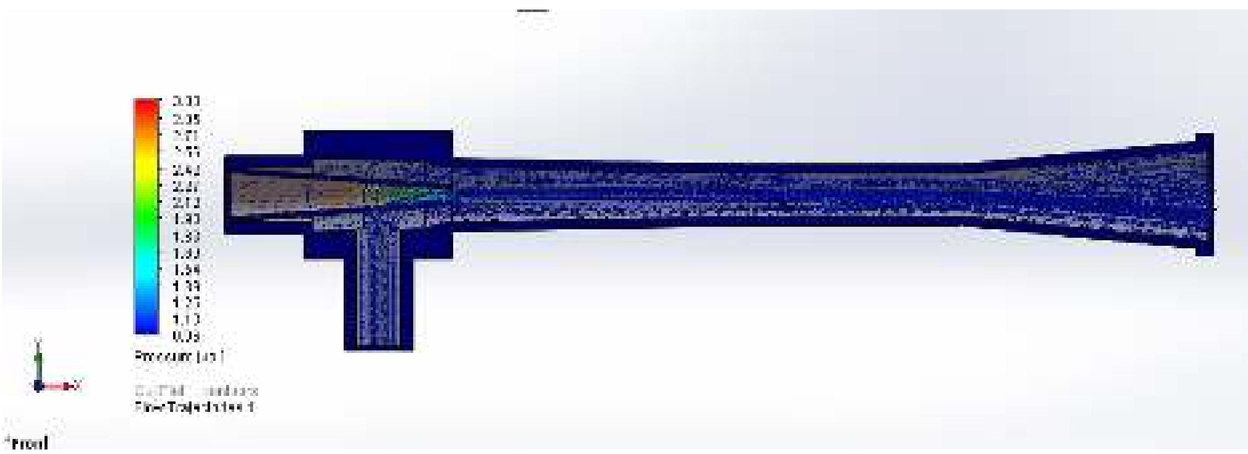

Figure 6. Streamline of nozzle with 20 mm suction inlet diameters

Figure 6 shows the streamline in the nozzle where there was no shock at the beginning of mixing, but there was still a vortex flow in the diffuser. Figures 1 to 6 how that at suction diameter of 15 mm and 20 mm vortex flow occurs in the diffuser area. This results in the occurrence of disturbance in the flow that affects the efficiency of the nozzles. These results are in line with the results of research conducted by Domanski [7] and Kshirsagar [8] the greater the suction side diameter the greater the flow losses that occur. Likewise opinion Pianthong [9] that the smaller the diameter of the suction pipe the better the efficiency of the nozzles.

4. Conclusion

The results showed that the injector suction diameter has a significant effect on the vapor pressure characteristics of the convergent-divergent injector. From the analysis it was found that the best suction side diameter is 10 mm for the divergent-divergent nozzles with dimensions as in this study.

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References

[1] Sahni, R. 2015. Ejector Expansion Refrigeration Systems Reaserch Inventy: International Journal of Engineering and science Vol. 5, Issue 2 (February, 2015) pp. 25-29.
[2] Mitchley, S.R. 1998. Vacum Boiling of Water in a Steam Jet Refrigeration System. Dissertation, Faculty of Engineering University of The Witwatersand, Johannesburg.
[3] Chunnannond, K., S. Aphornratana. 2004. Ejectors: Application in refrigeration technology. Renewable and Sustainable Energy; Reviews 8 (2004) 129-155.
[4] Elbel, S., P. Hanjak. 2008. Ejector Refrigeration: An Overview of Historical and Present Development with an Emphasis on Air- Conditioning Applications. International refrigeration and Air Conditioning Conference at Purdue, july 14-17, 2008 (2350, 1-9)
[5] Firman and Muhammad Anshar. 2018. Study on steam pressure characteristics in various types of nozzles. The 2nd International Conference on Sciences (ICOS 2017) 2 - 3 November 2017 Proceeding, Volume: 979, Journal of Physics: Conference Series
[6] Saengmanee, Ch., K. Pianthong. 2010. Design of a Steam ejector by co-operating the ESDU design method and CFD Simulation. The First TSME International Conference on Mechanical Engineering, 20-22 October, 2010, Ubon Ratchathani.
[7] Domanski, P.A. 1995. Minimazing Throthling Losses in The Refrigeration Cycle. 19th International Congres of Refrigeration 1995, proceeding volume IVb.
[8] Kshirsagar, S.D., M.M. Deshmukh. 2013. Combined Vapor Comparison-Ejector refrigeration

System: A Review. International Journal of Engineering Research and Development, Volume 6, Issue 1 (February, 2013), pp. 41-52.

[9] Pianthong, K., W. Seehanam, M. Behnia, T. Sriveerakul, S. Aphonratana. 2007. Investigation and Improvement of Ejector Refrigeration system Using Computational Fluid Dynamics Technique. Energy conversion & Manajement 48 (2007) pp. 2556-2564.