HENDESE TEKNİK BİLİMLER ve MÜHENDİSLİK DERGİSİ
JOURNAL of HENDESE TECHNICAL SCIENCES and ENGINEERING
RESEARCH ARTICLE

Computational Fluid Dynamics Simulation of a Two-Phase Flow Model with a Cylindroconical Structure for Optimization of Liquid Flow

Umit DOGU[*1], **Fikret Kemal AKYUZ**[2], **Ahmet FEYZIOGLU**[3], **Sezgin ERSOY**[4]

*[*1,2]Festo Inc., Istanbul, TÜRKİYE*

[3,4]Faculty of Technology, Marmara University, Istanbul, TÜRKİYE

(**Received:** 18.09.2024, **Accepted:** 22.10.2024, **Published Online:** 27.10.2024)

Keywords
Cylindroconical Structure,
Fluid Dynamics Simulation,
Liquid Flow.

ABSTRACT

Hydrocyclone pumps are devices used in mining facilities to classify solid particles according to density or size differences or to separate them from a liquid. Hydrocyclones are manufactured in a cylindroconical structure that does not contain mechanical parts and are used to optimize liquid flow. Hydrocyclones heat up rapidly during operation and these high temperature values can cause wear and danger to hydrocyclone components. In order to prevent this, a cooling process must be carried out. This process reduces wear and extends the working life of the hydrocyclone. The viscosity of the liquid is reduced with the cooling process. Thus, it both ensures that the system operates in a better flow and creates a safe environment for employees. Regular cooling of hydrocyclone pumps used in mining facilities; ensures that the system operates more efficiently and has a longer life. An automation system can be created to guarantee the effectiveness of this cooling process. In this study, it is aimed to design an automation system for active cooling in hydrocyclone pumps.

Corresponding Author: umit.dogu@festo.com
Volume: 1 **Issue:** 2

Cite as: Dogu, U., Akyuz, F.K., Feyzioglu, A., Ersoy, S., "Computational Fluid Dynamics Simulation of a Two-Phase Flow Model with a Cylindroconical Structure for Optimization of Liquid Flow", Hendese, Vol. 1, Issue 2, Pages 98-101, 2024.

Doi: 10.5281/zenodo.13996532

1. INTRODUCTION

Hydrocyclone pumps are systems that provide the transportation of liquids or gases with mechanical power [1,2]. They move fluids using hydraulic power and provide flow with a rotary motion [3-7]. Hydrocyclone pumps are used in a variety of industrial applications such as water treatment plants, the oil and natural gas industry, mining and chemical processes [8-12].

In recent years, the focus of scientific developments on hydrocyclone pumps has been on more efficient and energy-saving designs [13-17]. These developments aim to provide advantages such as higher performance, lower energy consumption and longer durability.

Scientific studies on hydrocyclone pumps focus on the following (Table 1):

Table 1. Scientific studies on hydrocyclone pumps [18-25].

Scientific Studies	Explanation
Fluid Dynamics Simulations [18,19]	Computer-aided design and fluid dynamics simulations are used to better understand and optimize the internal flow characteristics of hydrocyclone pumps. These simulations are an important tool for evaluating design changes to increase pump efficiency and reduce energy losses.
Innovative Material Use [20,21]	The development of high strength and wear resistant materials is important to increase the durability and longevity of hydrocyclone pumps. New materials can reduce maintenance requirements and extend operating times by improving wear resistance.
Intelligent Control Systems [22,23]:	Intelligent sensors and control systems can continuously monitor and optimize the operating conditions of hydrocyclone pumps. These systems can monitor flow rate, pressure and other important parameters in real time, allowing the pumps to operate more efficiently.
Energy Efficiency Focused Designs [24,25]:	Various technological developments are being made to design more efficient hydrocyclone pumps. These developments focus on developing pumps that can provide higher flow rates with lower energy consumption, provide more efficient fluid transportation and reduce operational costs.

This study aims to use hydrocyclone pumps in a more sustainable and economical way. The results obtained in the study are to make hydrocyclone pumps advantageous in industrial areas where they will be used and to develop a system that will operate in the optimum operating range. Analysis and simulation techniques will be used to provide improvements in Separation and Filtration, High Efficiency, Low Maintenance Needs, Compact Design, Durability and Long Life. In addition, it is desired to reach a minimum outlet pressure of 8.5 bar for the system we want to design. Researcher contribution will be provided in the evaluation of simulation and analysis results and optimization of the system. It is aimed to make prototype production in line with the findings to be obtained and to carry out the study in a controlled environment. The main idea of this study will be to improve the separation and filtration of solids and liquids in hydrocyclone pumps with the product to be developed.

2. MATERIAL AND METHOD

In this work, our purpose is to find pressure loss occurring in our two-way piping systems by using numerical simulation. First of all, fundamentals about pressure loss is given to grasp an idea how the pressure loss is classified and formulated. When we talk about straight piping system, pressure losses occur only due to major losses which is expressed by equation 1.

$$\Delta P = f\frac{L}{D}\rho\frac{V^2}{2g} \qquad (1)$$

ΔP=Pressure drop [Pa]
f =Darcy friction factor [-]
L=Length of the pipe [m]
D=Diameter of the pipe [m]
V=Averaged flow velocity [m]
g=Gravitational acceleration [m]

But if we have equipment's that changes or effect flow field, these equipment-like valves, filters etc creates extra pressure drop occurs which is called minor losses as expressed by equation 2.

$$\Delta P = K_L\rho\frac{V^2}{2g} \qquad (2)$$

KL=Minor loss coefficient [-]
These are two contributors of pressure drop in our system.

2.1. System Geometry

In numerical simulation methodology, we need only the geometry that fluid flows within. For this reason, flow domain is extracted within the flow equipment's given in Figure 1.

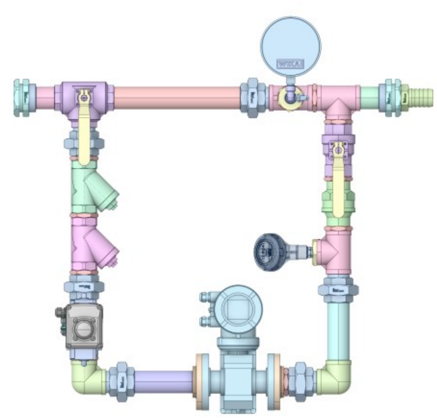

Figure 1. Flow equipment's.

Flow domain is given in Figure 2 and created in SpaceClaim

2021 R1 3D CAD modeling software.

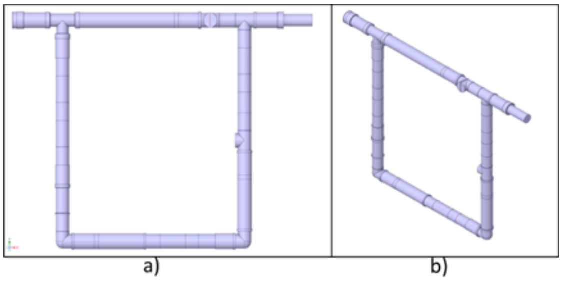

Figure 2. Flow domain a) front view b) isometric view

The piping system, one of the ways (upper way) is closed by a valve. For this reason, flow domain is cut not to allow flow pass through (Figure 3).

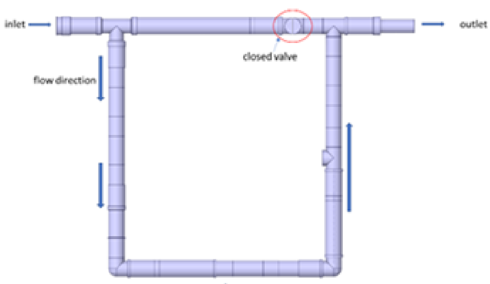

Figure 3. Direction of flow

2.2. Grid Generation

Generations of grid for this geometry were done in mesh modular in Ansys-Fluent version-21- a finite volume method based CFD software (Figure 4). The grid used for the problem is unstructured, having tetrahedral meshing. Quality of mesh is assessed by conducting grid independency test (GIT). To conduct an acceptable CFD simulation, changes in flow variables in the flow domain must be independent of number of grids. GIT as shown in Figure 4, the inlet pressure changes at 73250045 by 1 % percent. For this reason, 73250045 number of grids is chosen for the numerical calculations.

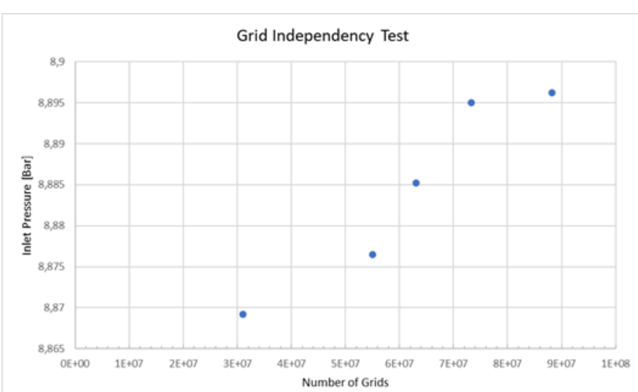

Figure 4. Grid Independency Test

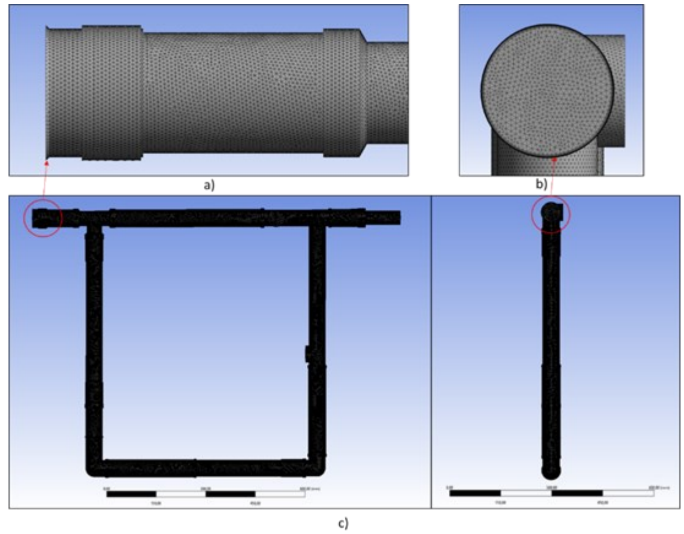

Figure 5. Meshing details, a) Face meshing at the inlet b) Inflation layer near the wall c) Volume mesh of flow domain.

As given in Figure 5, flow domain is meshed by adopting tetrahedral meshing. As can be seen from Figure 5, to resolve flow properties near the wall, inflation layers is created in a way that y+ value is kept below 1.

2.3. Boundary Conditions and Model

Fluid pressure the outlet was taken as 8,4 bar with the turbulent intensity of 1% and hydraulic diameter of 42 mm. At the inlet, fluid(water) volume flow rate was taken to be 360 lt/dk. The wall of the pipeline is taken as hydrodynamically smooth with no slip condition.

Pressure based CFD solver with the SST-k-ω turbulence model is adopted. To get the pressure distribution along the pipe, SIMPLE- pressure velocity coupling was used because it converges faster. Convergence criteria are set at 10-5. A second order upwind scheme is used for pressure, momentum, turbulent kinetic energy and turbulent dissipation rate.

3. RESULTS AND DISCUSSION

CFD allows us to make detailed analysis of flow field. In Figure 6a we can see that pressure gradually decreasing with the direction of the flow which is naturally expected flow behavior and from the T junction near the inlet to the closed valve position where flow stops, the pressure almost the same as expected since there is no flow.

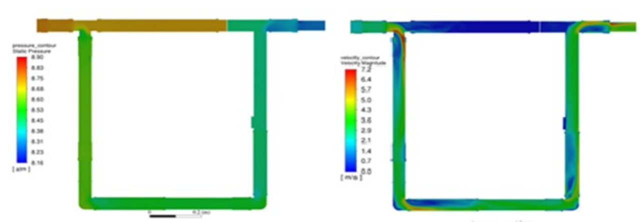

Figure 6. (a) Pressure distribution along the pipe, (b) Velocity distribution along the pipe

In Figure 6b., velocity distribution along the pipe is shown. There are 4 bends with 90° angle, in this areas flow, flow separation occurs and much of the pressure losses takes place in these areas. Maximum flow velocity was found to be 7,2 m/s while passing T junction near the inlet. Total pressure loss was found to be 8,8954 bar.

4. CONCLUSIONS

In this study, a flow model with a liquid fluid and a cylindrical cone structure with one and two phases was calculated. In addition, the computational flow dynamics of the flow model was simulated. According to the analysis and flow dynamics simulation, the total pressure loss in the pipe system was determined as 8.8954 bar. The maximum speed occurs near the inlet T connection and at approximately 7.2 m/s. In order to reduce the total pressure loss along the pipe, the chances in the cross section of the flow field can be reduced and the bending angle can be increased. As a result, an accurate design and modeling was made for our desired minimum 8.5 bar outlet pressure value

ACKNOWLEDGEMENTS

This work was carried out with FESTO R&D facilities.

REFERENCES

[1] Senfter, T., Neuner, T., Bachmann, C., Berger, M., Mayerl, C., Kofler, T., Pillei, M., "An Empirical Study on the Upcycling of Glass Bottles into Hydrocyclone Separators", Separations, Vol. 11, Issue 8, Pages 230-239, 2024.

[2] Mohanty, Shuvam., "Computational fluid dynamics analysis of a novel axial flow hydrocyclone", PhD Thesis, UNSW Sydney, Sydney, 2023.

[3] Kalashnikov, A. A., "Regulation of hydrocyclone parameters to improve the quality of water purification on drip irrigation systems", Caspian Journal of Environmental Sciences, Vol. 21, Issue 4, Pages 787-799, 2023.

[4] Gonçalves, S. M., Kyriakidis, Y. N., Ullmann, G., Barrozo, M. A. D. S., Vieira, L. G. M. "Design of an optimized hydrocyclone for high efficiency and low energy consumption", Industrial & Engineering Chemistry Research, Vol. 59, Issue 37, Pages 16437-16449, 2020.

[5] Lee, H., Park, J., Lee, J. C., Ko, K., Seo, Y., "Development of a hydrocyclone for ultra-low flow rates", Chemical Engineering Research and Design, Vol. 156, Pages 100-107, 2020.

[6] Bram, M. V., Jespersen, S., Hansen, D. S., Yang, Z., "Control-oriented modeling and experimental validation of a deoiling hydrocyclone system", Processes, Vol. 8, Issue 9, Page 1010, 2020.

[7] Tian, J., Ni, L., Song, T., Olson, J., Zhao, J., "An overview of operating parameters and conditions in hydrocyclones for enhanced separations", Separation and Purification Technology, Vol. 206, Pages 268-285, 2018.

[8] Li, F., Liu, P., Yang, X., Zhang, Y., Zhao, Y., "Effects of inlet concentration on the hydrocyclone separation performance with different inlet velocity", Powder Technology, Vol. 375, Pages 337-351, 2020.

[9] Bergström, J., Hannes V., "Experimental hydrocyclone flow field studies", Separation and Purification Technology, Vol. 53, Issue 1, Pages 8-20, 2007.

[10] Svarovsky, L., "Hydrocyclones", in Solid-Liquid Separation, Butterworth-Heinemann, Pages 191-245, 2001.

[11] Zhang, L., Xiaohua X., Jiangfeng Z., "Improving energy efficiency of cyclone circuits in coal beneficiation plants by pump-storage systems", Applied Energy, Vol. 119, Pages 306-313, 2014.

[12] Zhao, X., Zhao, K., Zhang, X., Gao, Y., Liu, H., "Structure Optimization and Performance Evaluation of Downhole Oil–Water Separation Tools: A Novel Hydrocyclone", Journal of Energy Resources Technology, Vol. 146, Issue 2, Pages 023001-023012, 2024.

[13] Ekechukwu, O. M., Taimoor A., Haval K. H., "Recent Developments in Hydrocyclone Technology for Oil-in-Water Separation from Produced Water", Energies, Vol. 17, Issue 13, Page 3181, 2024.

[14] Lee, H., "Development of a hydrocyclone for ultra-low flow rates", Chemical Engineering Research and Design, Vol. 156, Pages 100-107, 2020.

[15] Tian, J., Ni, L., Song, T., Olson, J., Zhao, J., "An overview of operating parameters and conditions in hydrocyclones for enhanced separations", Separation and Purification Technology, Vol. 206, Pages 268-285, 2018.

[16] Gonçalves, S. M., "Design of an optimized hydrocyclone for high efficiency and low energy consumption", Industrial Engineering Chemistry Research, Vol. 59, Issue 37, Pages 16437-16449, 2020.

[17] Ovchinnikov, A. S., "Modernization of structural elements of a hydrocyclone to improve the efficiency of irrigation water treatment", IOP Conference Series: Earth and Environmental Science, Vol. 965, No. 1, IOP Publishing, 2022.

[18] Padhi, M., Mayank K., Narasimha, M., "Understanding the bicomponent particle separation mechanism in a hydrocyclone using a computational fluid dynamic model", Industrial & Engineering Chemistry Research, Vol. 59, Issue 25, Pages 11621-11644, 2020.

[19] Zhao, Z., Zhou, L., Liu, B., Cao, W., "Computational fluid dynamics and experimental investigation of inlet flow rate effects on separation performance of desanding hydrocyclone", Powder Technology, Vol. 402, Pages 117363, 2022.

[20] Ullmann, G., Gonçalves, S. M., Kyriakidis, Y. N., Souza Barrozo, M. A., Vieira, L. G. M., "Optimization study of thickener hydrocyclones", Minerals Engineering, Vol. 170, Page 107066, 2021.

[21] Jokovic, V., Robert, M., Daniel A., "Can the performance of semi-inverted hydrocyclones be similar to fine screening?", Minerals Engineering, Vol. 146, Page 106147, 2020.

[22] Song, W., "Intelligent Control and Energy Conservation of Ball Mill", 2020 2nd International Conference on Artificial Intelligence and Advanced Manufacture (AIAM), IEEE, 2020.

[23] Zou, G., Zhou, J., Song, T., Yang, J., Li, K., "Hierarchical intelligent control method for mineral particle size based on machine learning", Minerals, Vol. 13, Issue 9, Page 1143, 2023.

[24] Khatri, N., Kamal K. K., Abhishek S., "Enhanced energy saving in wastewater treatment plant using dissolved oxygen control and hydrocyclone", Environmental Technology & Innovation, Vol. 18, Page 100678, 2020.

[25] Beaulac, P., Issa, M., Ilinca, A., Lepage, R., Martini, F. "Improving the energy efficiency of cyclone dust collectors for wood product factories", Open Journal of Energy Efficiency, Vol. 10, Issue 3, Pages 97-119, 2021.