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Computational Study of Operating Parameters on Performance of Compound Hydrocyclone

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Abstract: The dynamics of hydro cyclones is complex, because it is a multiphase flow problem that involves interaction between a discrete phase and multiple continuum phases. The performance of hydro cyclones is evaluated by using Computational Fluid Dynamics (CFD), and it is characterized by the pressure drop, split water ratio, and particle collection efficiency. In this paper, a computational model to improve and evaluate hydro cyclone performance is proposed. Computational turbulence models (renormalization group (RNG) k-ε, Reynolds's stress model (RSM), and large-eddy simulation (LES)) are implemented, and the accuracy of each for predicting the hydro cyclone behavior is assessed. Four hydro cyclone configurations were analyzed using the RSM model. By analyzing the streamlines resulting from those simulations, it was found that the formation of some vortices and saddle points affect the separation efficiency. Furthermore, the effects of inlet width, cone length, and vortex finder diameter were found to be significant. The cut-size diameter was decreased compared to the Hsieh experimental hydro cyclone. An increase in the pressure drops leads to high values of cut-size and classification sharpness. If the pressure drop increases to twice its original value, the cut-size and the sharpness of classification are reduced to their initial values, respectively.
Keywords: Hydro-Cyclones, Velocity And Pressures, Epsilon, Eddy Simulations, Omega, Analysis.

I. INTRODUCTION

Hydro-cyclones are useful devices for removing particles from liquids via a centrifugal field. In general, larger particles are mostly trapped in the underflow, while the lighter ones go to the overflow with most of the working fluid exiting, as can be observed in Figure 1. Some advantages of these devices are the low operation and maintenance cost and no moving parts. They also have widespread applications in the mining and oil industry. In the past decade, the main challenge for these devices has been to minimize the pressure drop and maximize the separation efficiency to improve hydro cyclone performance. The d50 (cut size) parameter is a key factor in hydro-cyclone performance. The cut size is defined as the size at which a particle has a 50% probability of leaving the hydro cyclone through either the underflow or overflow. This factor is correlated with the collection efficiency, which indicates the number of particles that move toward the underflow. Finally, another critical factor is the pressure drop, which is an indicator of how much energy the hydro cyclone wastes, as a measure of the main system's loss.

The main assessment tools used to analyze hydrocyclone performance are laboratory measurements and numerical methods such as Computational Fluid Dynamics (CFD). Compared to experimental procedures, numerical methods cost less and save time. Moreover, CFD has proved to be a reliable tool when used with a suitable choice of turbulence models. The most accurate and frequently implemented models are renormalization group (RNG) k-ε [1], the Reynolds stress model (RSM), and large-eddy simulation (LES). Hsieh built a hydro cyclone prototype and proposed a computational model based on the finite difference method. This study is considered a benchmark for analyzing the role of pattern flows in particle classification, which makes it valuable for evaluating new work in this area. Later work such as that presented in used Hsieh's data for the validation of their numerical models. These studies concluded that only two turbulence models—RSM and LES—are able to model the anisotropy of the turbulent flow in hydro cyclones and thus accurately capture its flow dynamics. These two models, combined with the volume of fluid (VOF) multiphase model, can replicate the velocity profiles, air core diameter, and split water flow typically seen in a hydro cyclone. VOF tracks free surface or fluid interfaces. This technique is based on an Eulerian approach, and it is suitable not only for capturing the interface between the air core and the water in the hydro cyclone, but it is also less diffusive than other multiphase models such as the mixture model.

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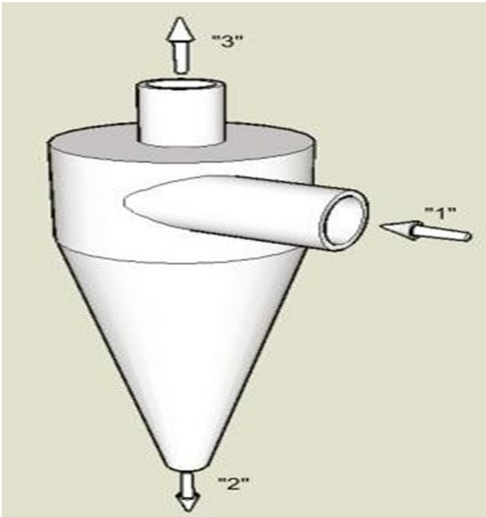
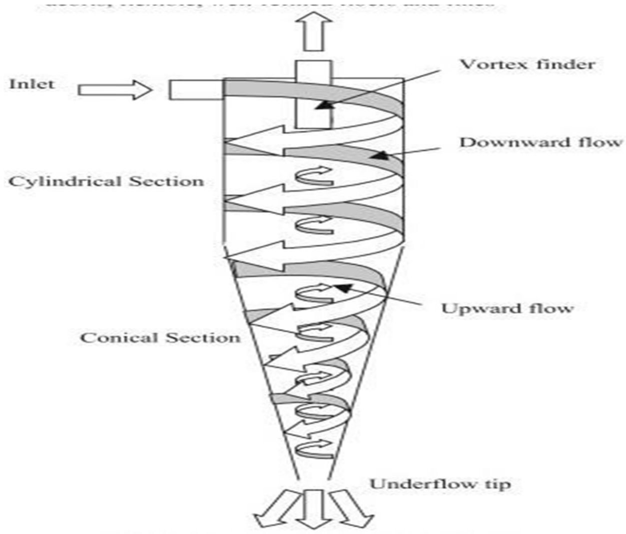


Hydro-cyclone



Swirling motion of hydro-cyclone

II. LITERATURE SURVEY

Most of these models are based on either fundamental or empirical and semi-empirical approaches. These models are also based on simplifying assumptions that can lead to significant differences between the estimated and measured results. none of them take into account all the factors that could influence the separation performances.

The majority of these studies used either the laser doppler anemometry (LDA) technique
or the particle image velocimetry (PIV) technique to obtain the fluid flow field. Others focused only on the measurement of pressure drop and separation efficiency.

Two relationships have been proposed to calculate the euler number and the cut-off diameter from already known values measured under the same operating conditions but at a different temperature. An empirical correlation derived by CFD was also proposed to estimate the euler number of hydrocyclones that are geometrically similar to the FR dorr-oliver hydrocyclones especially used for the enrichment of phosphate pulp at ambient temperature or generally used for other industrial processes operating at higher temperatures.

A. In a number of publications, we have proposed a mathematical model of the hydrocyclone based on the physics of fluid flow. The aim of this investigation is to examine the stability of the model with wide variations in device dimensions and thus confirm its validity.
B. Five hydro cyclones were the subject of this study, and in each case the velocity profiles of the fluid were measured by an LDV. The measured and predicted velocity profiles agree closely throughout each of the units.
C. In addition, the analysis of the measured velocity profiles sheds new light on the effects of variations in hydro cyclone dimensions. Most importantly, the classification efficiency curves of each hydro cyclone operated with dilute limestone slurries are also well predicted.
D. Particle size control is very important in the shield slurry separation. The structural parameters and separation efficiency of desilted separation efficiency were studied using numerical simulations.
E. In this study, slurry treatment process was designed firstly, and then the influence including the diameter of the overflow port, the size of the cone, the length of cylinder and the diameter of the bottom flow on the separation efficiency were studied.
F. In the hydro cyclone, the minimum tangential velocity occurs at the center of the cyclone, which makes it possible to separate materials more efficiently. The pressure distribution is consistent with the pressure characteristics of combined vortex motion. After obtaining the optimal design, the separation ability of the hydro cyclone was greatly improved.The 75 µm and 100 µm particles recycle efficiency increase 8% and 11% respectively. The results of this study provide a numerical basis for the optimization of hydro cyclone system.

III. MATERIALS

The particulate material used was pyrochlore (65% Nb2O5), which has a suitable density (rs = 4030 kg.m-3). The particle size distribution of the samples was determined by the gamma- ray attenuation unit. Am241 was the radioactive source utilized. The relationship between the beams counted by the equipment and the volumetric solids concentration (CV) in a given suspension may be derived from Lambert's equation, for example, was obtained for pyrochlore aqueous suspensions.

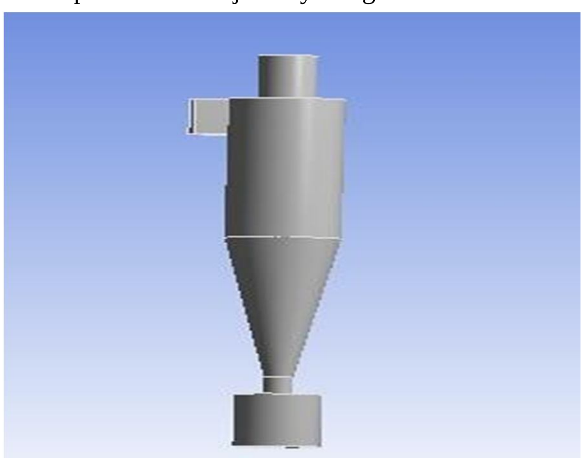
$$C_v = (42.74 \pm 0.55)\ln\left(\frac{I_o}{I}\right)$$

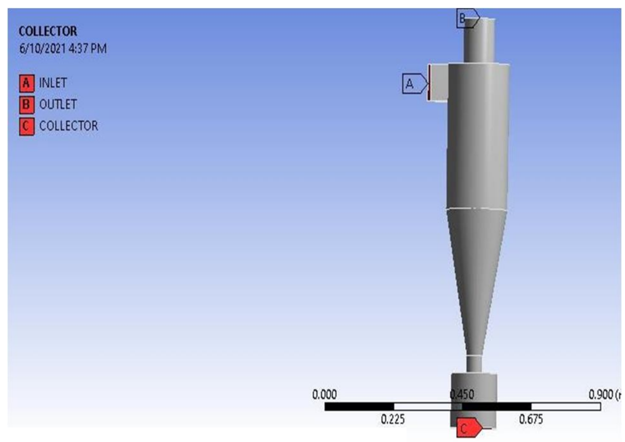
Where I is number of the gamma-ray beams counted for a uniform suspension and Io is the number of gamma-ray beams counted for pure water. With the aid of an axial stirrer, the slurry was made uniform and its concentration calculated according to. The particles were allowed to settle further this time gravitationally, and the Stokes diameters and the cumulative mass fractions could be obtained by means of, respectively. This procedure usually required approximately 25 minutes.

A. Space Claim

Space-Claim is a solid modeling CAD (computer-aided design) software that runs on Microsoft Windows and developed by Space-Claim Corporation. The company is headquartered in Concord, Massachusetts. Space-Claim Corporation was founded in 2005 to develop 3D solid modeling software for mechanical engineering. Its first CAD application was launched in 2007 and used an approach to solid modeling where design concepts are created by pulling, moving, filling, combining, and reusing 3D shapes. It was acquired by Ansys in May 2014, Inc, and was integrated in subsequent versions of Ansys Simulation packages as a built-in 3D modeler.

SpaceClaim Corporation markets SpaceClaim Engineer directly to end-user and indirectly by other channels. SpaceClaim also licenses its software for OEMs, such as ANSYS Flow International Corporation Catal CAD, and Ignite Technology which markets a version of SpaceClaim for jewelry design.



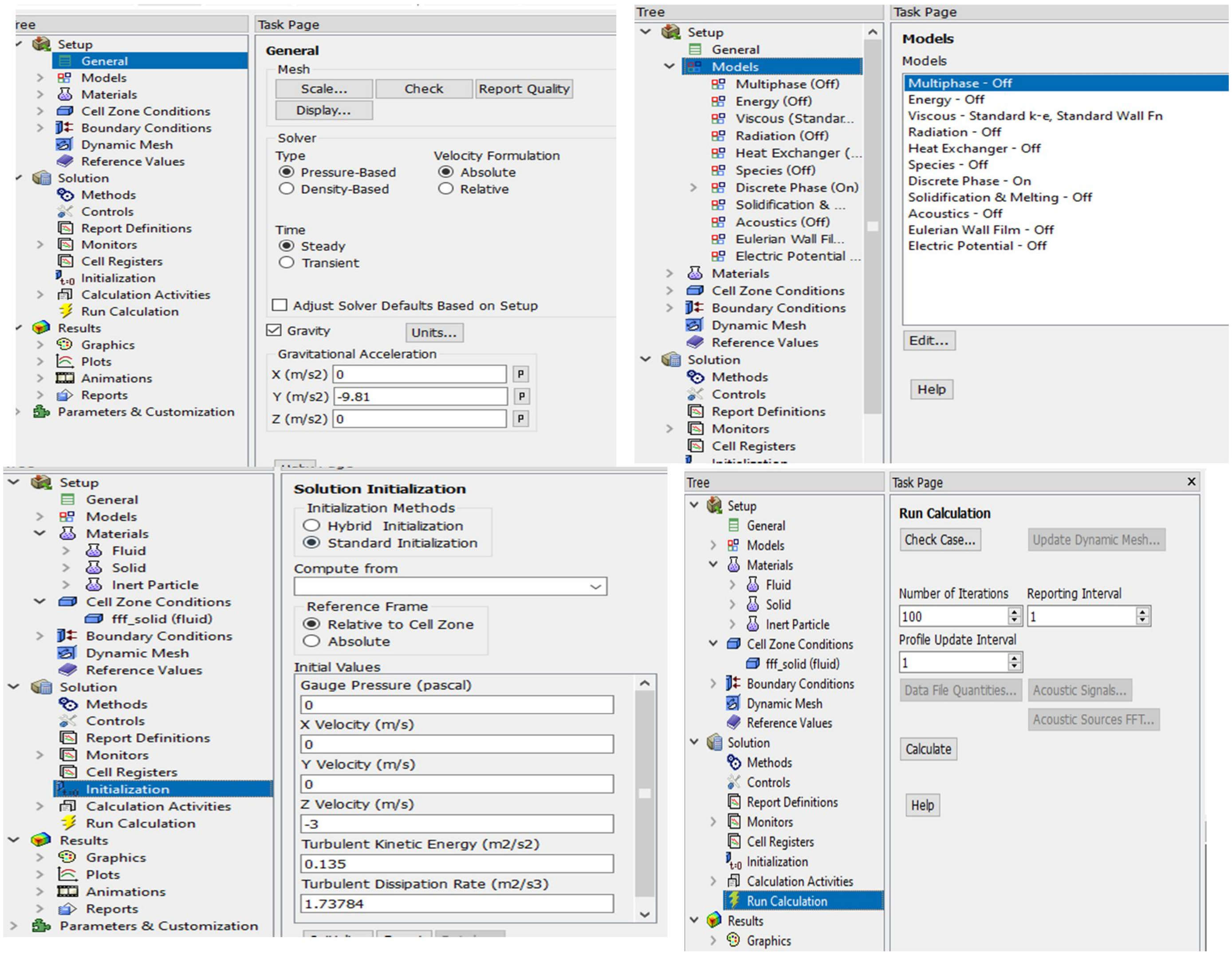


B. Computational Fluid Dynamics

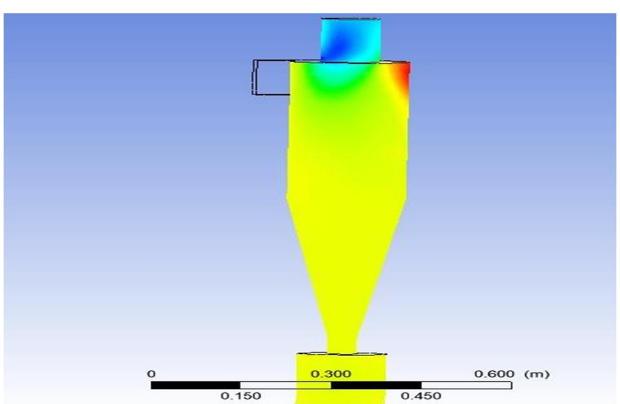
Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to analyze and solve problems that involve fluid flows. Computers are used to perform the calculations required to simulate the free-stream flow of the fluid, and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved, and are often required to solve the largest and most complex problems. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial validation of such software is typically performed using experimental apparatus such as wind tunnels. In addition, previously performed analytical or empirical analysis of a particular problem can be used for comparison. A final validation is often performed using full-scale testing, such as flight tests.

CFD is applied to a wide range of research and engineering problems in many fields of study and industries, including aerodynamics and aerospace analysis, weather simulation, natural science and environmental engineering, industrial system design and engine and combustion analysis.

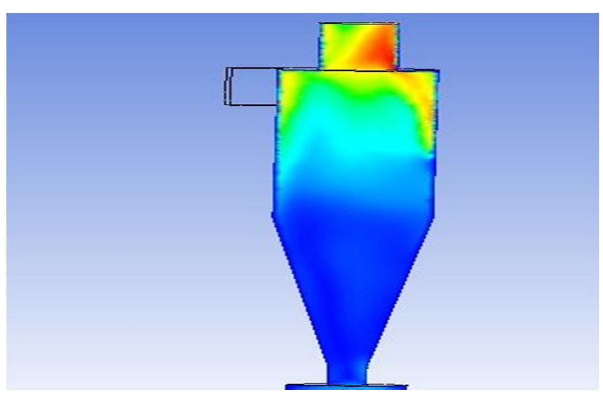
C. Boundary Conditions



IV. RESULTS



Inlet pressure & velocity of RSM of hydro cyclone



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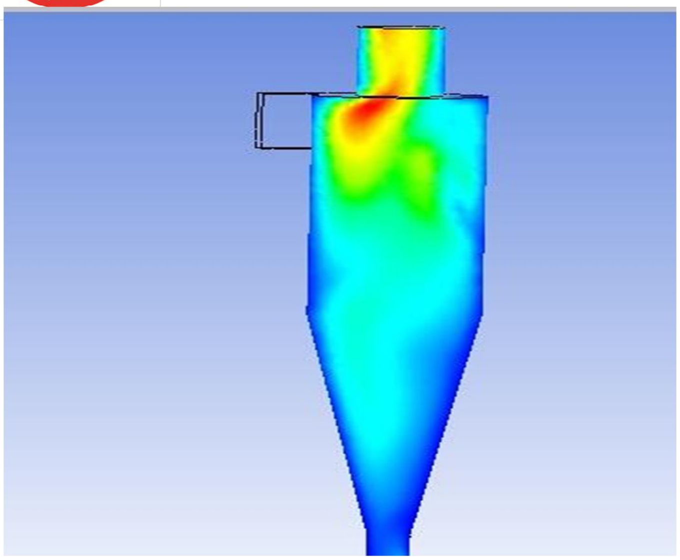
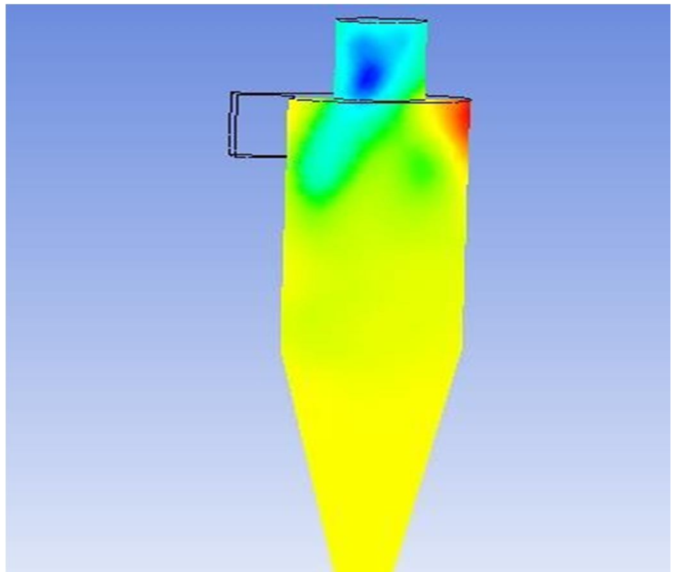
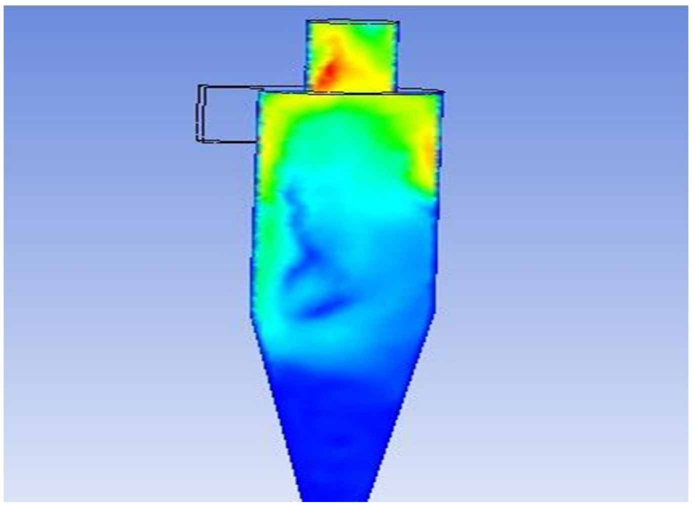
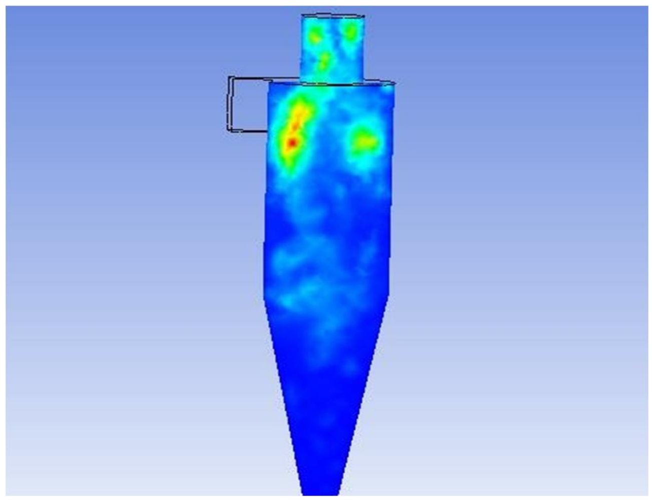




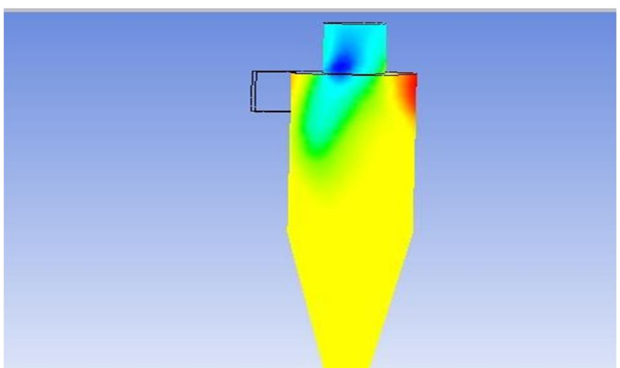
Collector pressure and velocity of RSM of inlet   inlet pressure and velocity of large eddy simulations hydrocyclone of hydrocyclone



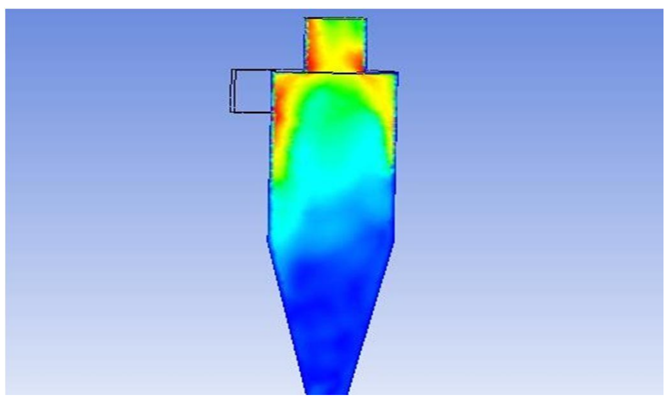
Outlet pressure and velocity of large eddy simulations of hydro cyclone



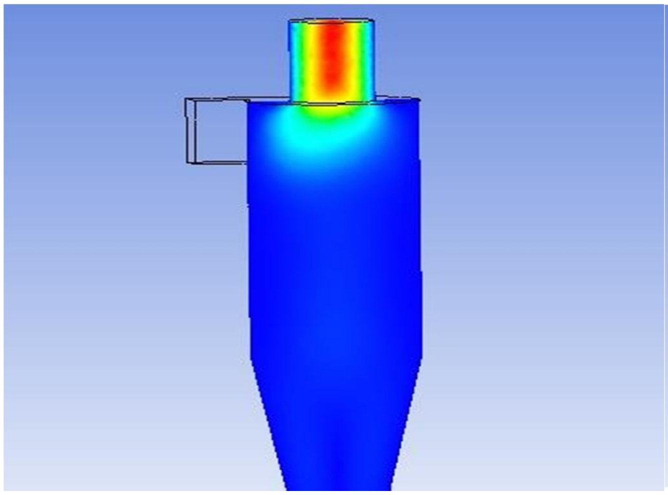
Collector pressure and velocity of large eddy simulations of hydro cyclone



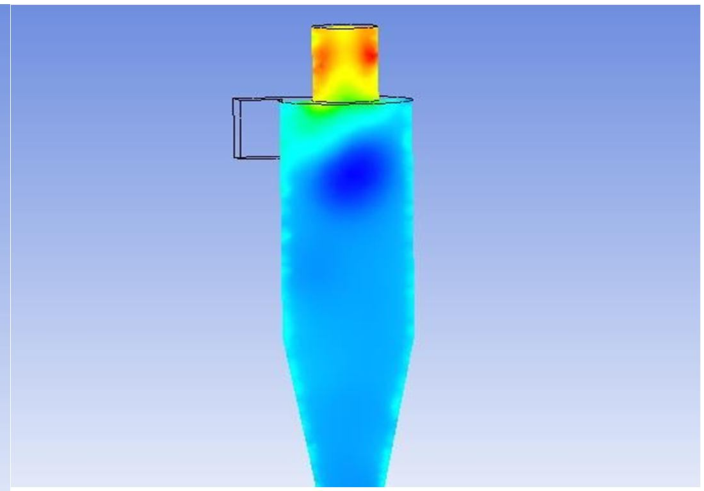
Inlet pressure and velocity of RNG K-omega of hydro cyclone



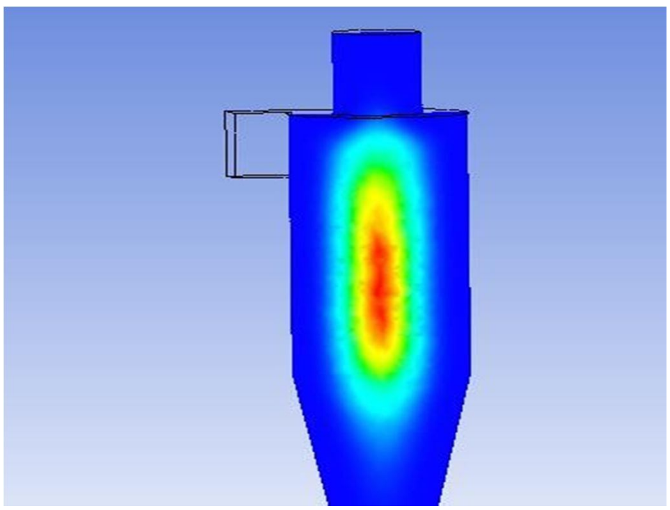
outlet pressure and velocity of RNG K-omega of hydro cyclone



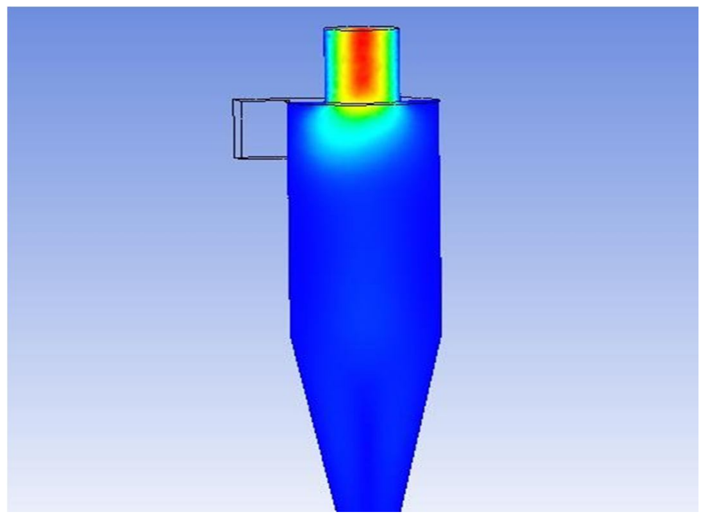
Outlet pressure and velocity results of RNG K-e(epsilon) of hydrocyclone



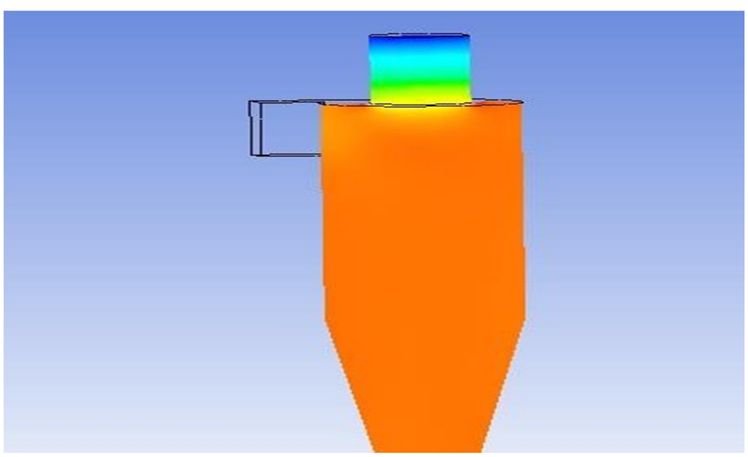
INLET pressure and velocity results of RNG K- e(epsilon) of hydrocyclone



Inlet pressure and velocity results of RNG K-omega of hydrocyclone



Outlet pressure and velocity results of RNG K-omega of hydrocyclone



Collector pressure and velocity results of RNG K-omega of hydrocyclone

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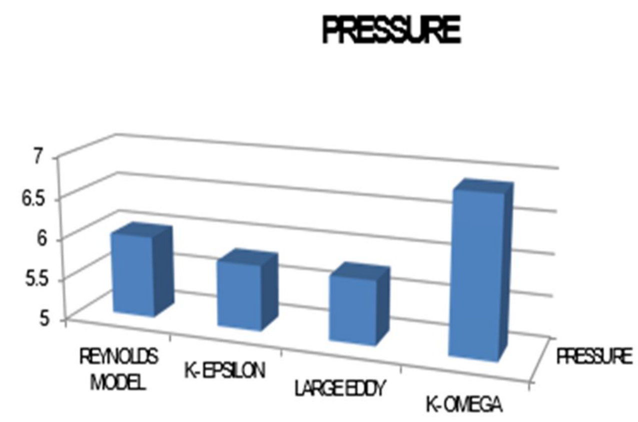
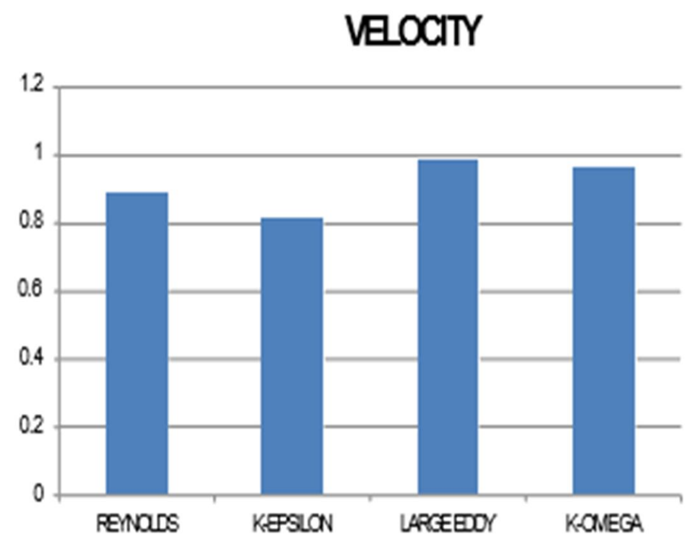
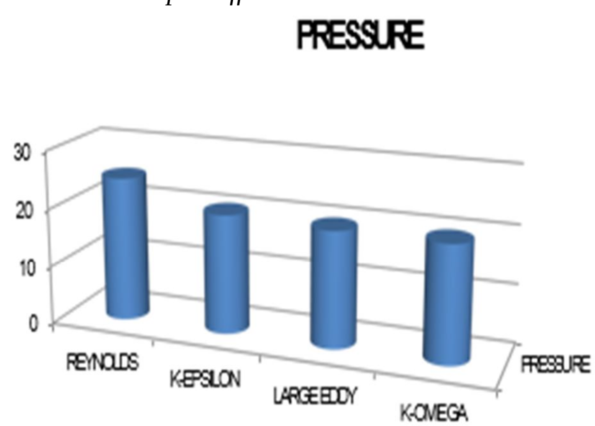
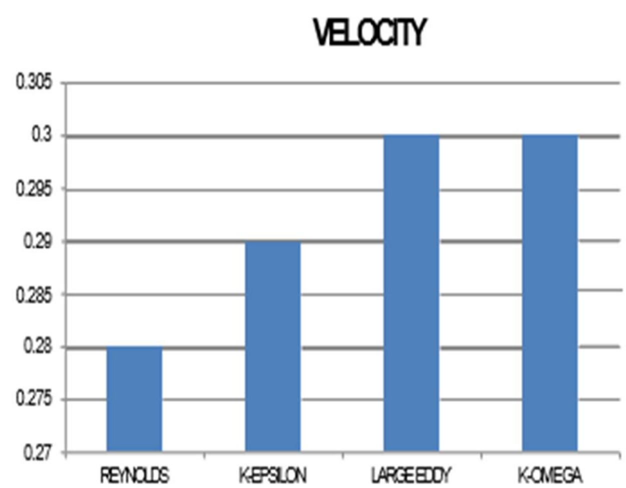
A. Discrete Phase Graphs On





B. Discrete Phase Graphs Off





V. CONCLUSION

In the development of the computational model, four turbulence models were evaluated. It was found that k-omega can reproduce most of the flow patterns of the continuous phase at a relatively low computational cost. Discrete phase on process was more time consuming than the phase off due to the several fields resolved per iteration in the former, but it was able to more accurately predict the main variables of interest. On the other hand, LES will require a finer grid to reach convergence and it is overall a more computationally expensive model. The phase on method took more time for LES. It was also found that discrete method can predict the classification curve in hydrocyclones point by point, making it suitable for the characterization of hydrocyclone performance.

These stagnation points are responsible for the low efficiency volume inside hydrocyclones. In order to ensure better performance, it is necessary to work with slender hydrocyclones, lower inlet diameters, and a lower vortex finder diameter. With this, it is also guaranteed that the momentum interchange remains in the axial direction. Consequently, the particles can leave the domain through the spigot. Finally, with these geometric variations, it is possible to build more compact hydrocyclones that meet the space limitation in any hydraulic system.

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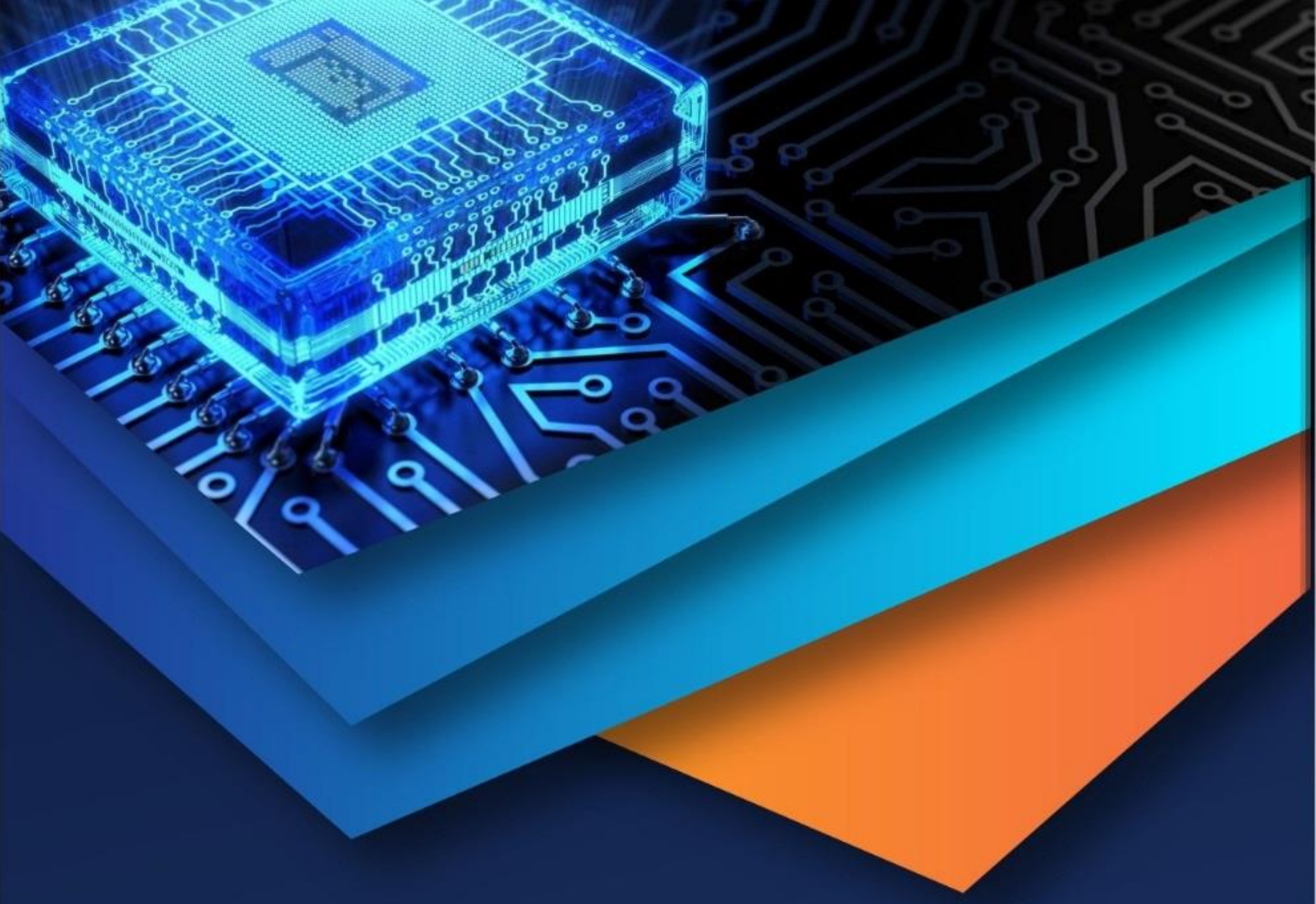

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