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DESIGN AND FLOW ANALYSIS OF HYDROCYCLONE FOR FILTRATION OF METAL WORKING FLUIDS

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Abstract

Green manufacturing is an environmental friendly manufacturing mode of manufacturing. This includes the reduction of the wastage and to eliminate the particles causing the pollution of environment. The alternate way of reducing the waste is to recycle the identified contaminants. In mechanical manufacturing industry, each manufacturing industry spends their capital on the metal working fluids or cutting fluids.

Metal working fluid acts as coolant as well as lubricant for the work piece and cutting tool. It also increases the tool life of the cutting tool, degree of accuracy of the operation and surface quality of the finished product. During machining operation, the metal working fluids get contaminated when it comes in contact with oil, tramp oil, grease and metal chips. Hence the tool life of the cutting tool is reduced and surface finish of the work piece reduces and results in the increased consumption of the metal working fluids. Contaminated Metal working fluids are identified as the potential threat causing the degradation of environment, when it disposed untreated. In the present investigation the study was carried out to analyse the separation of the contamination in the metal working fluid by varying the flow velocity.

The separation of the trapped hydraulic oil in the metal working fluid (contaminants) was achieved through Hydrocyclone technique. The study was conducted by varying the fluid velocity at adequate rates. It was able to conclude that the separation of the contaminated particles was achievable by increasing the flow rate. The present investigation included the flow analysis of the newly designed system.

Keywords: *Metal working fluids, Hydrocyclone, flow analysis*.

1. Introduction

The machining process contaminates the metal working fluid when it comes in contact with oil, tramp oil, grease and metal chips due to this the tool life of the cutting tool is reduced and surface finish of the work piece is reduces. This can be avoided by filtration of metal working fluids and maintaining its coolant properties, quality and extending fluid service life, reducing the wastage and maintaining the ecological values.

Before draining into environment the metal working fluids has to undergo filtration as it allows for the reconditioning of cutting fluids to restore them to their peak condition. Various methods such as membrane filtration, hydrocyclone, Skimmer and Centrifugation are used for filtration of Metal working fluid (MWF).

Hydrocyclone are used in industry to separate two components of dissimilar density consisting a cylindrical and conical body section, inlet, overflow and underflow. In the Hydrocyclone, the cylindrical section is joined in to conical section. The metal working fluids from the machine is passed through the inlet opening of the Hydrocyclone in the tangential direction. The inlet which is in the upper portion of the cylindrical sector and, due to the tangential entry of the fluid, a huge swirling movement is produced inside of the Hydrocyclone which causes the fluids contain the oil to be discharge throughout a cylindrical hose which is set at the centre of the top and is expected into the cyclone through the outlet hose which is so call as the overflow tube. The left over fluids discharge through a circular opening at the bottom of the cone call as the underflow and in turn to the tank where the MWF settles. The reasons for the popularity of the Hydrocyclone are the high capacity, low maintenance and operating expenses, design and operational simplicity

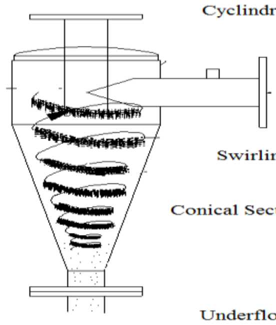


Fig1: Hydrocyclone

2. Methodology

2.1 Literature Survey

Rajendran Sripriya et.al [1] presented a paper on Hydrocyclone with design modification by suppressing air code that improves the performance efficiency. To check the efficiency of Hydrocyclone, it is very important to quantify presence or absence of air core in the Hydrocyclone. In the present study, Hydrocyclone design have been conceptualized and tested for its separation efficiency of particles which is based on gravity. Experimental investigation was carried out and results were analysed statically. The results showed that the suppressing of the air core improves the separation efficiency. It showed that the air core which has effect on particle separation is the relative density of the particle which approaches the fluid flow.

S.M.Mousaviam et.al [2] presented a paper on Hydrocyclone by influence of geometry on separation efficiency. It studied the gas-liquid-solid multiphase flouing of Hydrocyclone. The simulation has been done for the simulating air core and the multiphase model is compared in order to define (guess) the axial velocity and tangential velocity distribution. It main aim in identify an most favourable method and used to learn the efficient parameters, inlet flow, under flow, separation efficiency, pressure droplet, cone angle. Simulation has been done by means of large eddy simulation, Reynolds stress model and RNG K.E model. The outcomes that anticipated size classification are comparable in RSM, LES model. The model approval parametric studies have been done with the influence of velocity inlet particle amount and body measurement (cone angle, under flow and overflow).They predict that flow fluid in Hydrocyclone with different size and different length and which gives different performance.

J.G.Dueck [11] et.al presented a paper on Hydrocyclone by modelling of hydrodynamics and separation. Numerical studies for the run pattern and separation efficiency in a Hydrocyclone have been studied on the base of the Navier-stokes equations. Mathematical replica present to determine the separation characteristics and distributions of the particle velocity, pressure concentration is carried out in complex structure.

P.Rudolf [12] et.al presented a paper on simulation of multiphase flow in a Hydrocyclone. Swirling flow in Hydrocyclone is simulated for a multiphase gas-liquid-solid. Based on Hsieh's 75 mm Hydrocyclone they considered geometry and boundary condition for the multiphase model and these must be careful selection of interphase drag law. This approach fails for higher loading. Reynolds stress model is best selection for multiphase modelling of swirling flow on large grids. It results that velocity profiles and air core diameter can be simulated using RSM model, for large grid results by LES. Finally drag model choice is important in prediction of classification of particle flow of smaller particles should be modelled with gidaspow drag formula and large particle by Syamlal-O-Brain expression. Further study will be aimed on simulation of higher mass loading by using Eulerian model.

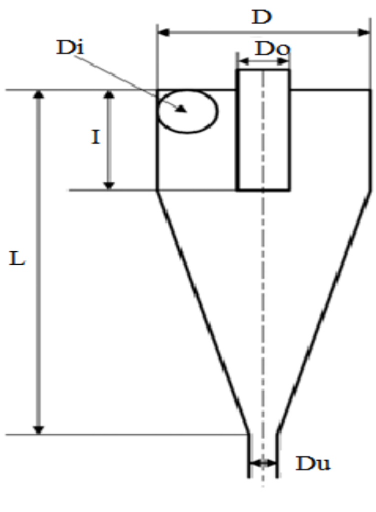
Maysam Saidi et.al [13] presented a paper on Numerical investigation of separation efficiency and cone angle effect on the flow field of deoiling Hydrocyclones. Simulation studies were done on the 35-mm deoiling Hydrocyclone with three dissimilar cone angles (A, B & C). Change in the different cone angle affected the pressure and velocity distribution in hydro cyclone and lead to change in the separation efficiency. Huge cone angle reduces the separation efficiency due to increases in the tangential velocity and force gradient within the hydro cyclone. Flow structure and reduction of oil droplet residence time in Hydrocyclone with a large cone angles are the main reasons for the decrease in the separation efficiency. The paper showed that study of different cone angles in deoiling hydro cyclone is conducted by LES approach. Due to high swirling flow in design (C) it creates a two separate recirculation zones, because of these zones which affects the separation efficiency of the hydro cyclone. As a result, the separation efficiency is decreased in deoiling hydro cyclones which is having large cone angles. Design (A) with a 6-degree cone angle has more separation efficiency in compare with the other different cone angles.

Hee-Soo Shin et.al [14] presented a paper on performance evaluation and design of Hydrocyclone for removing micron particles suspended in water. Hydrocyclone separates the particles from liquid on the basis of the density. Design and evaluating the performance of the high capability hydro cyclone for taking away different sized particle in liquids was carried out. The performance of three type of Hydrocyclone was evaluate and analysed with view to density of solid element with fly ash and coagulation sludge. The cut-size of particle decreases with reducing area of inlet and raising the inlet velocity in Hydrocyclone. The paper showed that Hydrocyclone was conducted to meet the set of fine particles in a hydrosol as an alternative of the conventional filler system. They were evaluated the experiment of the separation efficiencies of the fly ash and coagulated sludge through the density of 2,500 kg/m3 and of 1,030 kg/m3which is balanced in the water for the high-capability Hydrocyclone. The Hydrocyclone which is having the particle density of 2,500 kg/m3 has a high-quality performance. From this study it shows that the Hydrocyclone is an efficient method for removing the micron particle in a solid-fluid separation system.

From above the papers, it is observed that how the metal working fluids are managed to take away the metal chips (ferrous and non ferrous) and oil contaminants. The design parameters for the Hydrocyclone are explained. The main aim of filtration of metal working fluids is to reduce the elimination of fluid disposal, fluid usage, elimination of cost for buying new fluids, reduction in health and environmental hazards.

2.2 Design of Hydrocyclone:

Hydrocyclone is a technique of separating the fluids of different densities. It is designed for a volume of 25.3 litres consisting of the main body , cylinder and cone for the convergence of the fluid.



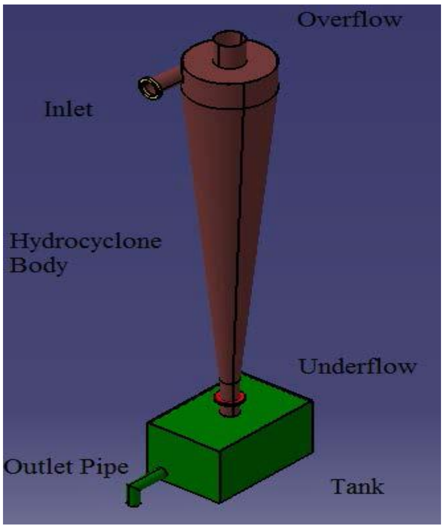


Fig 2: Schematic and 3 Dimensional Model of the Hydrocyclone assembly

Test procedure:

The following Hydro cyclone filtration system (Fig 2) consists of tank, cylindrical and conical body section, inlet, and underflow and overflow pipe. In the hydro cyclone, the cylindrical section is joined in to conical section. Fig 2 represents the 2-D drawings of Hydrocyclone body and the Fig 2 represents the schematic diagram of the Hydrocyclone. The metal working fluids from the machine after machining operation are passed through the inlet opening of the Hydrocyclone in a tangential direction. The inlet which lies in the upper part of the cylinder area and, due to the tangential entry of the fluids, an huge swirling movement is created inside the Hydrocyclone which causes the fluids contain the oil to be discharge throughout a cylindrical hose which is fixed at the centre of the top and is projected into the Hydrocyclone through the outlet tube which is so called as the overflow pipe. The remaining fluid leave or discharge throughout a spherical gap at the bottom of the cone so call as the underflow pipe and in turn to the tank where the MWF settles. Then the collected metal working fluids are free from metals and oil contaminants and the filtered MWFs passed in to the machine through pump for further operation.

3. Results and Discussion

3.1. Analysis for Hydrocyclone for different velocities

Hydrocyclone model was created in FE package; CATIA V5 and for analysing the fluid flow inside, the model was imported to other analysis FE package; ANSYS 14.5. Model is constrained for the boundary conditions having Inlet Diameter of18 mm, Overflow Diameter of 34 mm, Underflow Diameter of 20 mm.

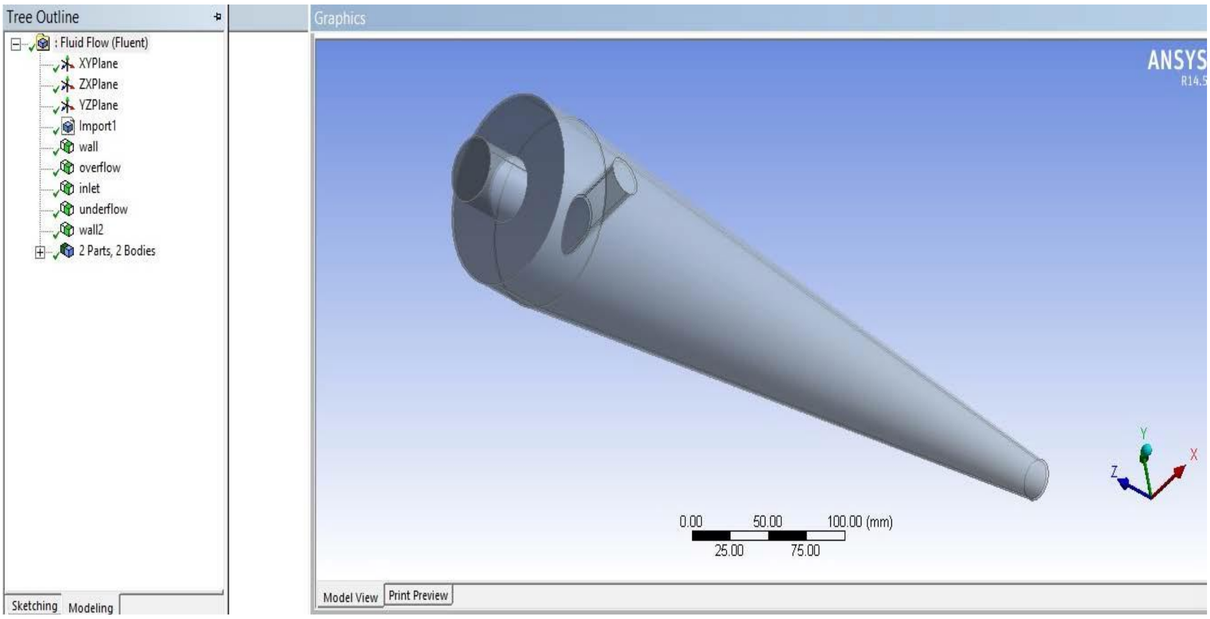


Fig 3: Hydrocyclone FEA model

Meshing was done for the Hydrocyclone model by using FE package ANSYS 14.5. Type of meshing selected for analysis was “Fine tetrahedral” for obtaining proper results for the fluid flow inside the Hydrocyclone as shown.

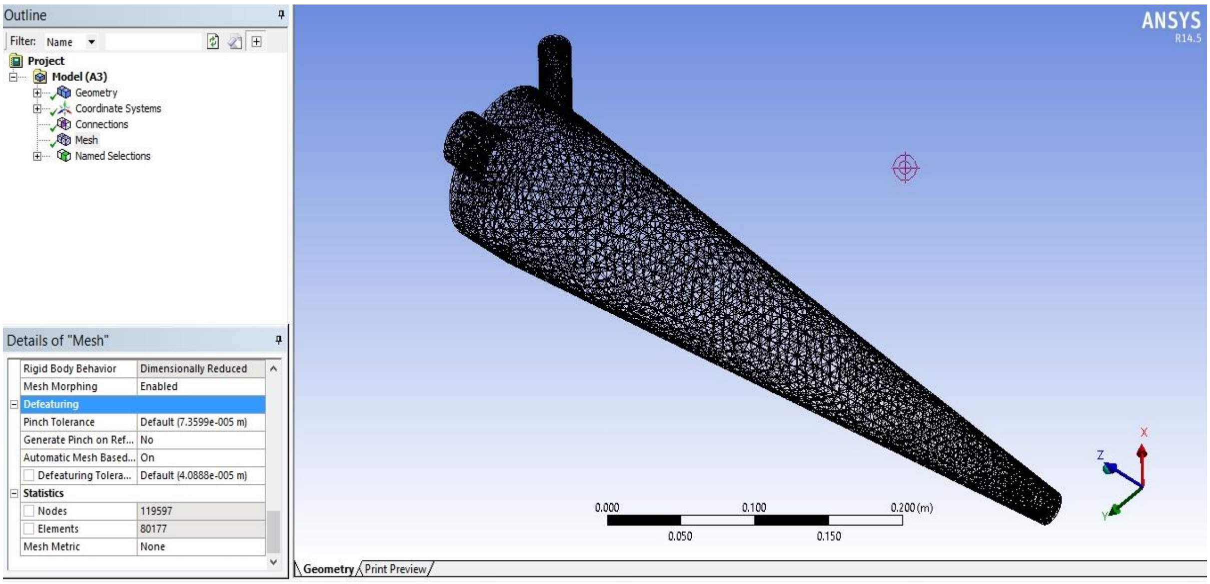


Fig 4: Meshed model of Hydrocyclone

Case 1: Velocity 0.106 m/s

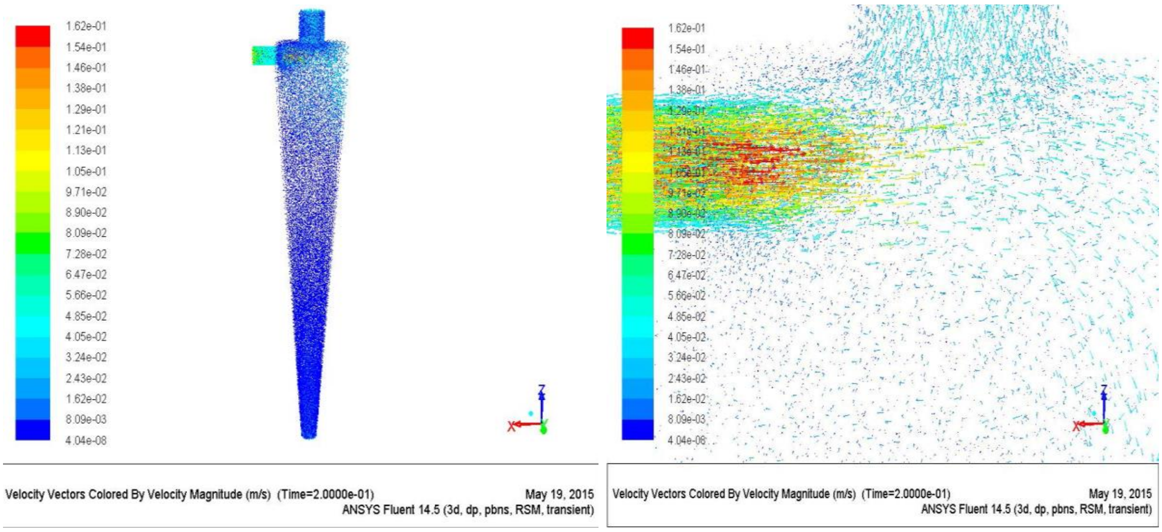


Fig 5: Velocity vector of Hydrocyclone at 0.106m/s velocity

At velocity of 0.106 m/s, the Hydrocyclone takes 0.3 sec time duration for completion of fluid flow. In the figure 5, the scale shows different particle traces in different colours indicating their time of flow inside the Hydrocyclone. The particle which remains inside the Hydrocyclone for least time is shown in blue and takes 2.86e-03 sec. The particle staying for core duration of time is shown in greenish yellow in the middle takes 7.87e-01sec and the particle which is staying till end is shown in red and takes 1.21e+00 sec for its flow completion. The particle which is having maximum velocity magnitude is shown is blue colour and taking 4.04e-08 sec. The particle having modest velocity is shown in greenish yellow in the middle takes 8.90e-02 sec

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and the particle which has least velocity magnitude is shown in red and takes 1.62e-01 sec for its flow completion.

Case 2: Velocity 7.5 m/s

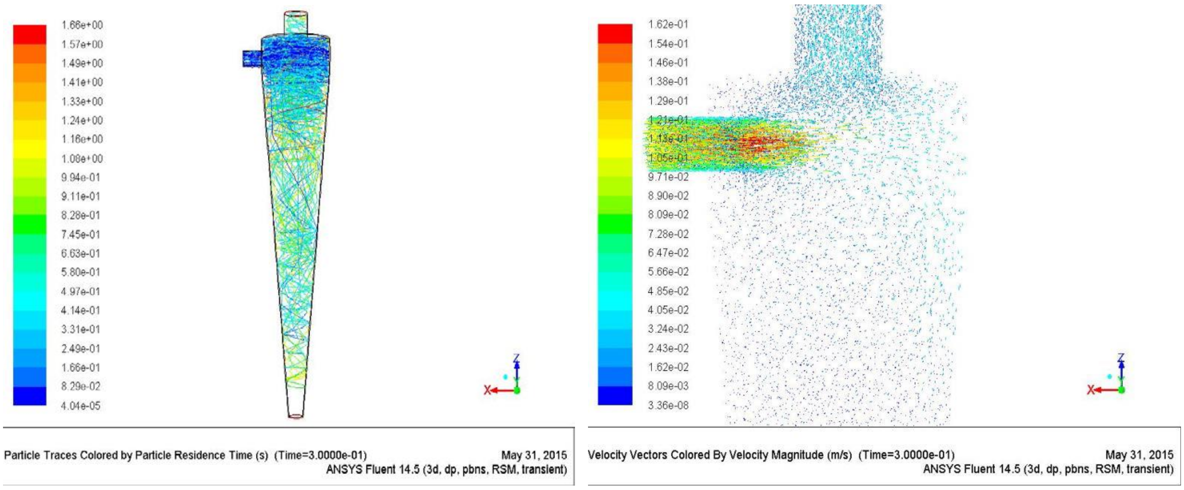


Fig6: Velocity vector of Hydrocyclone at 7.5 m/s velocity

At velocity of 7.5 m/s, the Hydrocyclone takes 0.3sec time duration for completion of fluid flow. In the figure 6, the scale shows different particle traces in different colours indicating their time of flow inside the Hydrocyclone. The particle which remains inside the Hydrocyclone for least time is shown in blue and takes 4.04e-05 sec. The particle staying for core duration of time is shown in greenish yellow in the middle takes 8.28e-01 sec and the particle which is staying till end is shown in red and takes 1.66e+00 sec for its flow completion.The particle which is having maximum velocity magnitude is shown is blue colour and taking 3.36e-08 sec. The particle shaving modest velocity is shown in greenish yellow in the middle takes 8.09e-02sec and the particle which has least velocity magnitude is shown in red and takes 1.62e-01 sec for its flow completion.

Case 3: Velocity 12.5 m/s

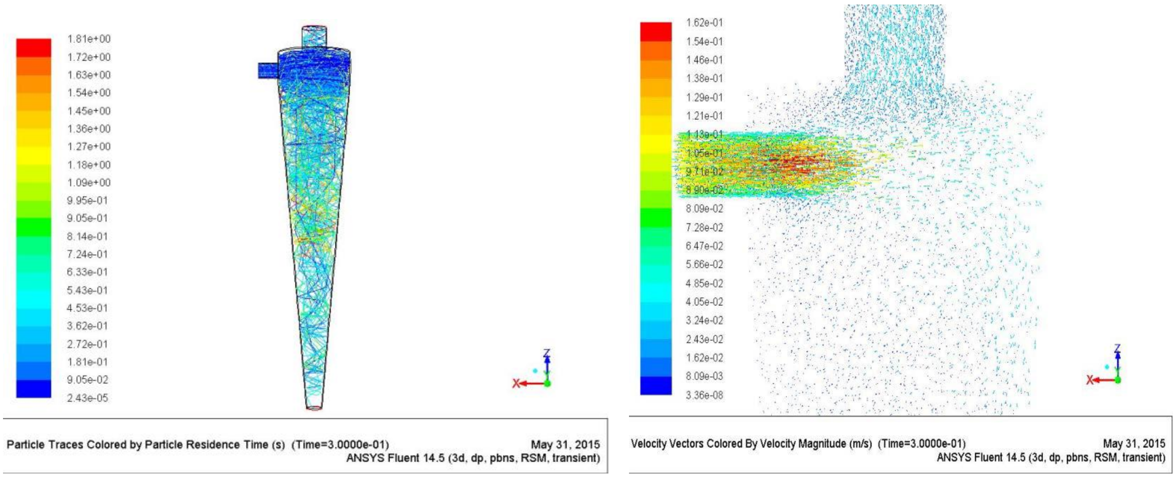


Fig 7: Velocity vector of Hydrocyclone at 12.5 m/s velocity

At velocity of 12.5 m/s, the Hydrocyclone takes 0.3 sec time duration for completion of fluid flow. In the figure 7, the scale shows different particle traces in different colours indicating their time of flow inside the Hydrocyclone. The particle which remains inside the Hydrocyclone for least time is shown in blue and takes 2.43e-05 sec. The particle staying for core duration of time is shown in greenish yellow in the middle takes 8.14e-01 sec and the particle which is staying till end is shown in red and takes 1.81e+00 sec for its flow completion. The particle which is having maximum velocity magnitude is shown is blue colour and taking 3.36e-08 sec. The particle shaving modest velocity is shown in greenish yellow in the middle takes 8.90e-02 sec and the particle which has least velocity magnitude is shown in red and takes 1.62e-01 sec for its flow completion.

4. Conclusion:

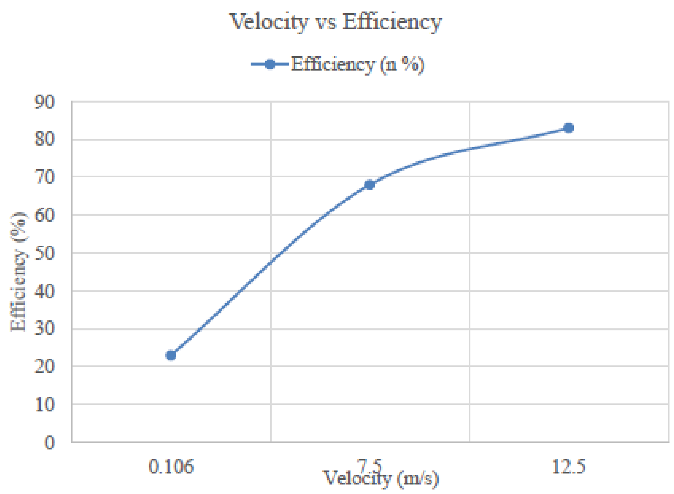
The conceptual design of the Hydrocyclone has been done. The analysis of Hydrocyclone for different velocities has been done. From the analysis of Hydrocyclone it is found that the separation efficiency increases by increasing in the velocity. The following are the separation efficiency obtained for different velocity

Formula for Separation Efficiency = Trapped/(Injected–Incomplete)

Case 1: For velocity 0.106 m/sec The particle are injected is 48, trapped is 4 and incomplete is 31, so the separation efficiency is **23%**

Case 2: For velocity 7.5 m/sec The particle are injected is 48, trapped is 11 and incomplete is 32, so the separation efficiency is **68%**

Case 3: For velocity 12.5 m/sec The particle are injected is 48, trapped is 15 and incomplete is 30, so the separation efficiency is **83%**



Graph 1: Velocity Vs Efficiency

From the graph (1), the efficiency and velocity were plotted with respect to x and y axis. It shows that the variation in separation efficiency with respect to different velocities. The separation efficiency increases by increasing in velocity. The efficiency of the designed system exhibited an improved efficiency with incremental velocity.

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