IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, May 2024

Design and Analysis of Fugitive Dust Emission Collector

K. Prabhakaran[1], M. Manoj[2], G. Pugalvendhan[3], R. Praveen[4], M. Dhinakaran[5]
Assistant Professor, Department of Mechanical Engineering[1]
Students, Department of Mechanical Engineering[2,3,4,5]
Anjalai Ammal Mahaligam Engineering College, Thiruvarur, India

Abstract: *This creative project explores the design and analysis of a novel fugitive dust emission collector, with a focus on its application in stone crusher units and crematorium facilities. Recognizing the detrimental health and environmental impacts of dust emissions, this project proposes a multifaceted approach. The core solution involves a combined system, this captures and removes larger dust particles through established methods like cyclones or bag houses. Dry fog dust suppression system, this technology utilizes atomized water droplets to suppress smaller fugitive dust particles, preventing their airborne spread. This project delves into the specific needs of stone crusher units and crematorium facilities. Utilizing CAD software, 3D models of the emission collector will be created, incorporating considerations like material selection, efficiency and airflow optimization, integration with existing infrastructure. Computational fluid dynamics (CFD) analysis by Simulating airflow patterns and dust capture efficiency within the collector. Assessing the collector's ability to withstand operational loads and environmental factors. This project aims to achieve, reduced fugitive dust emissions, enhanced environmental compliance, improved operational efficiency. Overall, this creative project showcases an innovative approach to fugitive dust control, potentially leading to improved environmental and public health outcomes in diverse industrial settings*

Keywords: SolidWorks 2021,Ansys 2022 R1, CAE,CFD

I. INTRODUCTION

Dust generation is a prevalent issue across various industries, including manufacturing, construction, and woodworking. These airborne particles pose significant health risks to workers, negatively impact product quality, and can even lead to potential explosions in certain environments. Therefore, effective dust collection systems play a crucial role in maintaining a clean and safe work environment. This project delves into the design, development, and analysis of a dust collector system. In an era increasingly mindful of environmental impact and industrial sustainability, the management of airborne particulate matter has become paramount across various sectors. Dust collectors play a pivotal role in this regard, serving as essential components in industrial processes to maintain air quality standards, ensure workplace safety, and mitigate environmental pollution.

This report presents a comprehensive analysis of a dust collector project, focusing on its design, implementation, performance evaluation, and impact assessment. By delving into the intricacies of dust collection technology, this document aims to provide insights into the functionality, efficiency, and effectiveness of the employed systems. Through meticulous planning, meticulous engineering, and rigorous testing, the project endeavours to address the challenges associated with particulate matter management in industrial settings. Additionally, it aims to contribute to the overarching objectives of sustainability, regulatory compliance, and operational excellence. By examining the methodologies, outcomes, and implications of the dust collector project, stakeholders can glean valuable insights into the critical role of dust collection systems in contemporary industrial operations. Moreover, this report aims to foster a deeper understanding of the principles, practices, and innovations driving advancements in air quality management and environmental stewardship.

II. LITERATURE REVIEW

Shree Ganesh & m. M Singh et al Air pollution, particularly in urban and industrialized areas, poses significant risks to public health and the environment. Particulate matter (PM) is one of the most concerning pollutants due to its adverse effects on respiratory health and overall air quality. In this review, we examine the existing literature on the concentrations of Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM) in low monitoring stations and their implications for environmental and human health. Numerous studies have documented elevated levels of RSPM and SPM in both industrial and residential areas, often exceeding the standards set by regulatory bodies such as the Central Pollution Control Board (CPCB). RSPM, also known as PM10, consists of particles with diameters less than 10 micrometres, while SPM encompasses a broader range of particle sizes. Both types of particulate matter originate from various sources, including vehicular emissions, industrial processes, construction activities, and biomass burning. In industrial areas, the concentration of RSPM and SPM tends to be higher due to the presence of heavy machinery, combustion processes, and emissions from industrial stacks. Studies by researchers have highlighted the significant contribution of industrial activities to particulate matter pollution, particularly in regions with high industrial density.

A.i. khan & m. Y. Bhuiyan et al Central dust collection systems play a crucial role in various industrial settings by efficiently capturing and controlling airborne particulate matter, thereby promoting workplace safety, equipment longevity, and environmental sustainability. In this literature review, we explore the economic considerations associated with adopting an improved design for central dust collection systems, which may entail higher initial costs but offer long-term benefits in terms of life cycle operation and other factors.

Nargizolimova, renaalieva, sobirjonboboev, rashidkaldybaev et al Understanding the dynamics of dust flow motions and droplet trajectories within dust collection equipment is crucial for optimizing the performance and efficiency of these systems. In this literature review, we delve into existing research that explores the intricate interactions between dust particles, airflow patterns, and technical characteristics of dust collection chambers. Research on dust flow motions within collection equipment has revealed the complex nature of particle behaviour under various operating conditions. The interaction between droplets and dust particles within collection chambers, considering factors such as droplet size, velocity, and surface tension. These studies have provided valuable insights into the mechanisms governing droplet-particle collisions, coalescence, and removal efficiency in wet dust collectors. The technical characteristics of dust collection chambers, including chamber geometry, inlet configuration, filtration media, and exhaust design, significantly influence dust flow motions and droplet dynamics.

Junpeng li &qingchunqu et al The design and implementation of effective dust collection systems for ceramic dry edge grinding machines are critical for maintaining workplace safety, environmental compliance, and operational efficiency. In this literature review, we explore existing research and studies that focus on the design and experimental investigation of dust collection systems tailored specifically for ceramic grinding operations. Ceramic dry edge grinding processes generate significant amounts of airborne dust particles, posing health risks to workers and environmental concerns. Therefore, researchers and engineers have dedicated efforts to develop dust collection systems capable of efficiently capturing and removing particulate matter from the workplace environment. The importance of designing and implementing effective dust collection systems for ceramic dry edge grinding machines to minimize occupational hazards and environmental impact. By integrating innovative design approaches, experimental validation, and real-time monitoring technologies.

Muhammad i. Taiwo, mohammed a. Namadi&james, b. Mokwa et al Cyclone separators have long been utilized as cost-effective means of particulate matter removal in various industrial processes. However, their reputation as low-efficiency collectors has prompted extensive research into optimizing cyclone design to enhance performance. In this literature review, we delve into existing studies that explore the efficiency variations of cyclones across different particle sizes and designs, as well as advancements in cyclone design aimed at improving overall performance. Early studies on cyclone efficiency, the foundation for understanding the relationship between particle size and collection efficiency. These studies highlighted the inherent limitations of conventional cyclone designs in capturing fine particles due to their tendency to bypass the separator or re-entrain into the airflow. The evolution of cyclone design and optimization efforts aimed at overcoming the limitations of traditional designs and improving overall efficiency. By leveraging advancements in computational modelling, materials science, and system integration, researchers and engineers continue to push the boundaries of cyclone performance, making them indispensable components in modern industrial air pollution control systems.

J. Srinivas. Murugesan. Saravanan, m. Raghupathi et al Cyclonic separators have gained attention as cost-effective solutions for controlling particulate emissions from diesel engines while maintaining fuel economy. In this literature review, we explore existing research that examines the use of cyclonic separators and Computational Fluid Dynamics (CFD) simulations using ANSYS software to optimize their performance in mitigating particulate emissions from diesel engines. By leveraging CFD simulations and optimization techniques, researchers continue to refine cyclonic separator designs to achieve higher levels of particulate capture efficiency while maintaining fuel economy and operational reliability in diesel engine applications.

III. METHODOLOGY

Generate initial concepts for the dust emission collector based on the literature review and project objectives.Consider factors such as collection efficiency, pressure drop, ease of maintenance, and cost-effectiveness during the conceptualization phase.Utilize Ansys CAD software to create detailed 3D models of the proposed dust emission collector designs.Incorporate all relevant components and features, including inlet and outlet configurations, filtration media, housing structure, and any additional mechanisms for dust capture and containment.Incorporate all relevant components and features, including inlet and outlet configurations, filtration media, housing structure, and any additional mechanisms for dust capture and containment.Generate a high-quality mesh for the CAD model to ensure accurate simulation results.Optimize theDefine the boundary conditions, including inlet velocity, temperature, and particle size distribution. mesh density based on the complexity of the geometry and the requirements of the simulation.Specify the material properties of the dust particles and the collector components.Select appropriate turbulence models and solver settings for the simulation.Perform computational fluid dynamics (CFD) simulations to analyse the flow patterns, particle trajectories, and dust deposition within the collector.Evaluate the collection efficiency, pressure drop, and other performance metrics for each design iteration.Use the simulation results to identify areas of improvement and optimize the geometry and operating parameters of the dust emission collector.

IV. COMPUTATIONAL FLUID DYNAMICS APPROACH

The effective control of fugitive dust emissions is crucial in various industries to mitigate environmental impacts and ensure regulatory compliance. In this study, we propose the design and analysis of a novel fugitive dust emissions collector utilizing a computational fluid dynamics (CFD) approach. By employing advanced CFD simulations, we aim to optimize the geometry and operational parameters of the collector to achieve efficient dust capture and containment. The CFD model will allow us to accurately predict the airflow patterns, particle trajectories, and capture efficiencies within the collector under different operating conditions. This comprehensive analysis will enable us to refine the collector design, enhance its performance, and minimize potential dust escape into the surrounding environment. Ultimately, the development of this innovative collector system promises to significantly reduce fugitive dust emissions, contributing to improved air quality and sustainable industrial practices.

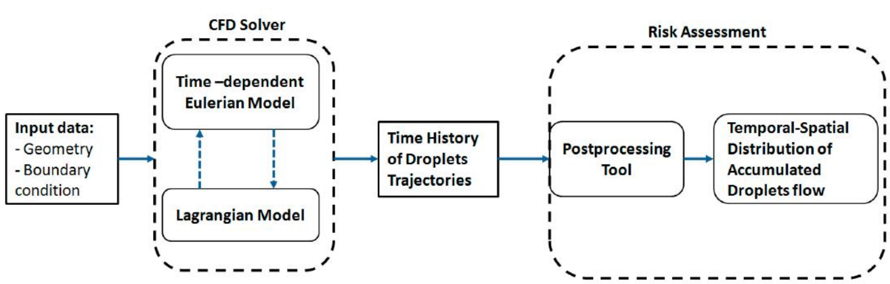

Fig. 1Flow chart for elements of cfd software

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, May 2024

V. PRE-PROCESSING

Starting with something new is not always easy. Especially, if it is something as complex as engineering simulation. As always, before starting with the actual task (in this case the simulation) it is crucial to prepare for the task in order to achieve the result you aimed for. The first step involves creating a detailed geometric model of the dust emissions collector using computer-aided design (CAD) software. This includes defining the dimensions, shapes, and features of the collector components, such as the inlet, outlet, ducts, baffles, and filters. The geometry should accurately represent the physical structure of the collector to facilitate precise simulation Once the geometry is finalized, the next step is to generate a computational mesh that discretises the geometry into small elements or cells. The mesh quality significantly influences the accuracy and convergence of the CFD simulations. Pre-processing activities here involve mesh refinement to ensure adequate resolution near critical areas such as the inlet, outlet, and regions of flow separation. Techniques like boundary layer meshing may be employed to capture boundary layer effects accurately. Assigning appropriate fluid properties and boundary conditions is crucial for simulating the flow of air and dust particles within the collector. This includes specifying parameters such as air density, viscosity, and temperature, as well as inlet velocity profiles and outlet pressure conditions. Additionally, the properties of the dust particles, such as size distribution and density, need to be defined for realistic particle tracking.

VI. MODELLING

Solid Works mechanical design automation software is a feature-based, parametric solid modelling design tool which takes advantage of the easy to learn Windows graphical user interface. You can create fully associative 3D solid models with or without constraints while utilizing automatic or user defined relations to capture designintent.

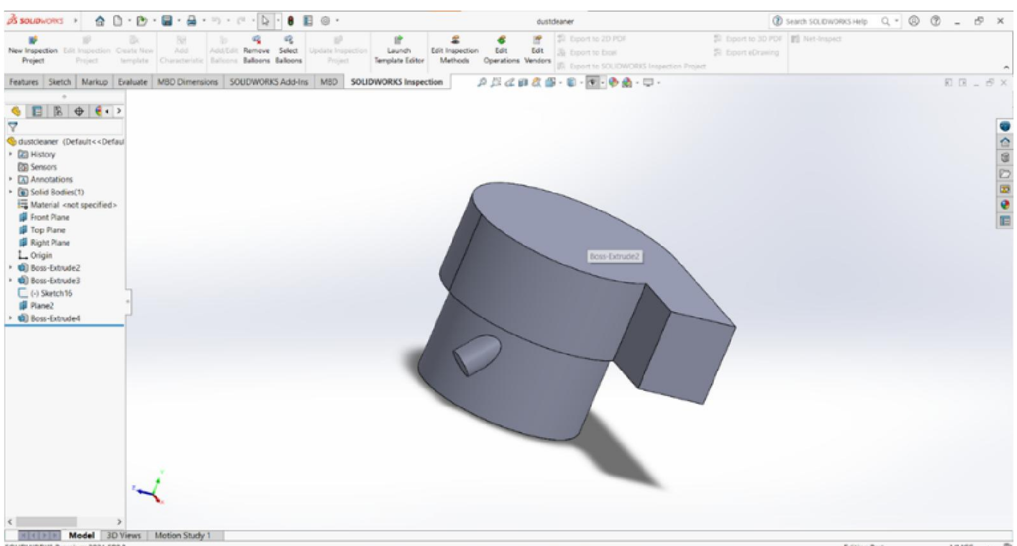

FIG 2: PERSPECTIVE VIEW OF 3D MODEL

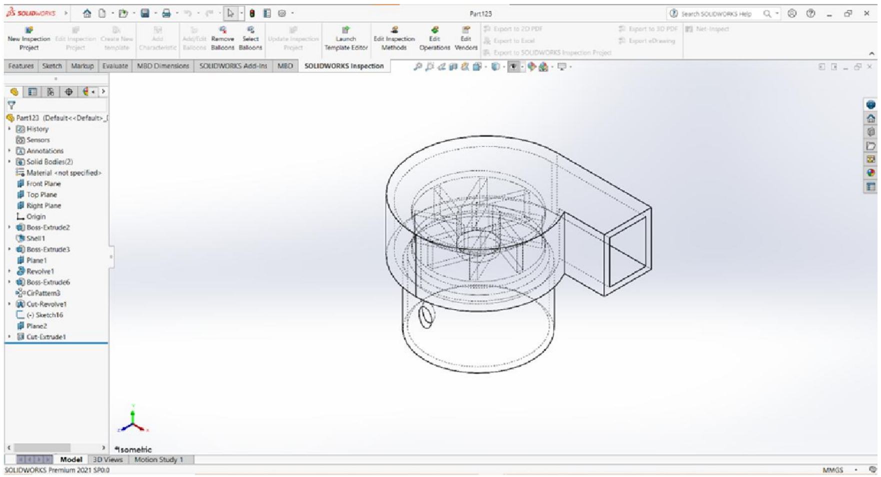

FIG 3: HIDDEN LINE VIEW OF 3D MODEL

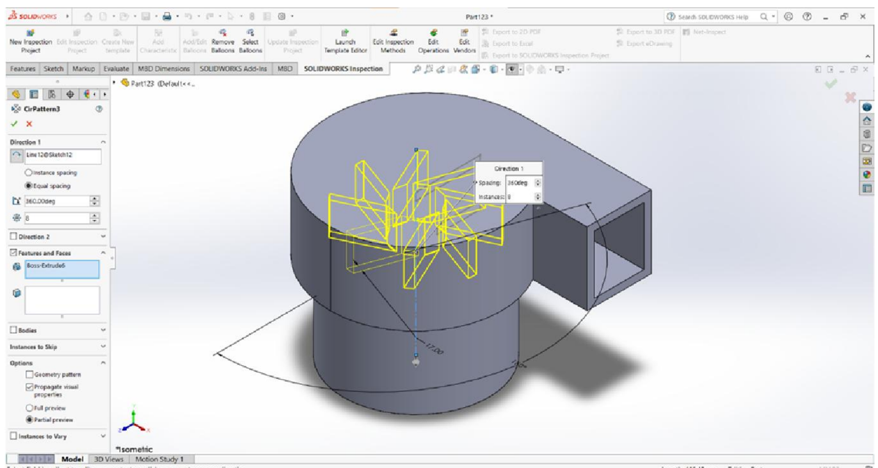

FIG 4: 3D VIEW OF IMPELLER

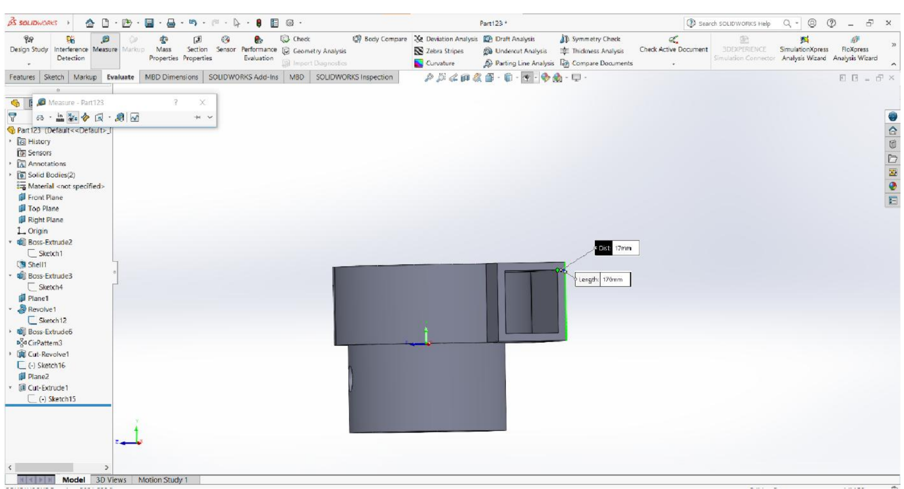

FIG 5: 3D VIEW OF INLET MODEL

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, May 2024

□. MESHING

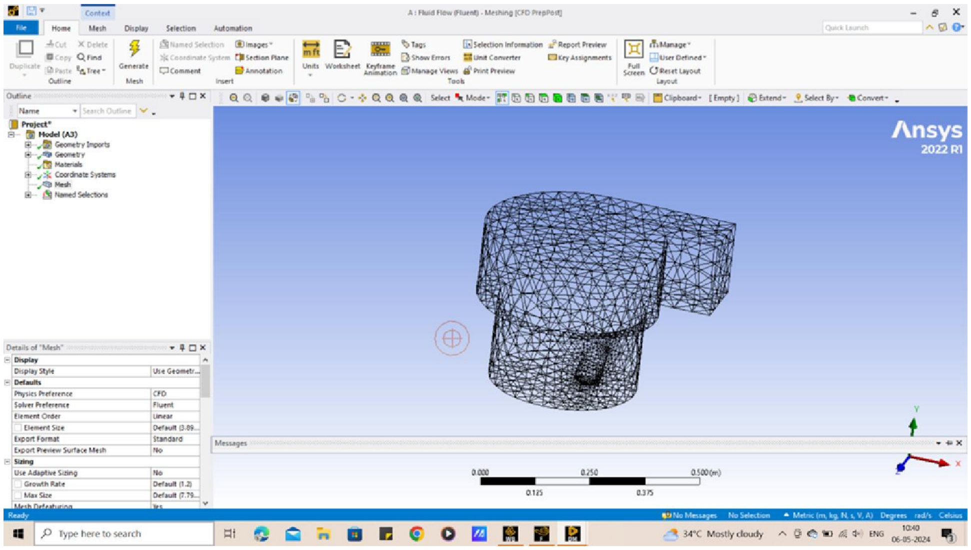

FIG 5: MESH SETUP

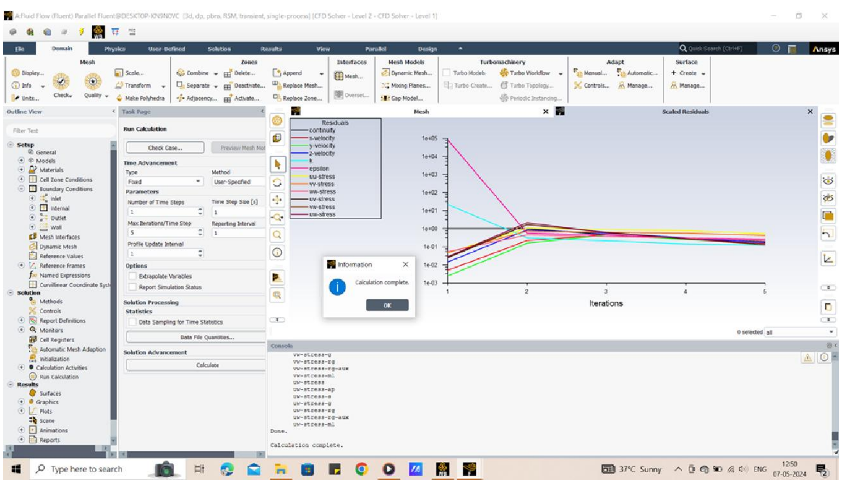

FIG 10 RESIDUALS

VII. TURBULENCE MODELS

Turbulence modelling in computational fluid dynamics (CFD) plays a crucial role in simulating turbulent flows accurately. Turbulence refers to the chaotic and unpredictable motion of fluid particles characterized by a wide range of spatial and temporal scales. Since resolving all the turbulent structures in a flow is computationally expensive, turbulence models are used to approximate the effects of turbulence on the fluid flow.

VIII. K-OMEGA MODEL

The k-ω model solves two transport equations: one for turbulent kinetic energy (k) and the other for the specific rate of dissipation of turbulent kinetic energy (ω). The model aims to capture both near-wall behavior and free-stream turbulence effects, making it suitable for a wide range of flow scenarios. The k-ω model includes a built-in near-wall treatment to accurately predict the behavior of the turbulent boundary layer. This treatment adjusts the turbulence model coefficients near walls to account for the effects of wall proximity and wall shear stress. The k-ω model is

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, May 2024

commonly used in a wide range of applications, including internal flows (e.g., pipe flows, turbomachinery) and external flows (e.g., airfoils, automotive aerodynamics). Its ability to capture near-wall behavior and free-stream turbulence effects makes it suitable for simulating complex flows with boundary layer separation, adverse pressure gradients, and other challenging features.

IX. RESULTS AND DISCUSSION

Ansys fluent simulation:

Geometry and mesh:

Mesh size:

Cells	Faces	Nodes
13854	28712	2858

Mesh quality:

Name	Type	Min Orthogonal Quality	Max Aspect Ratio
Dust cleaner	Tet Cell	0.23871417	13.28981

Orthogonal quality:

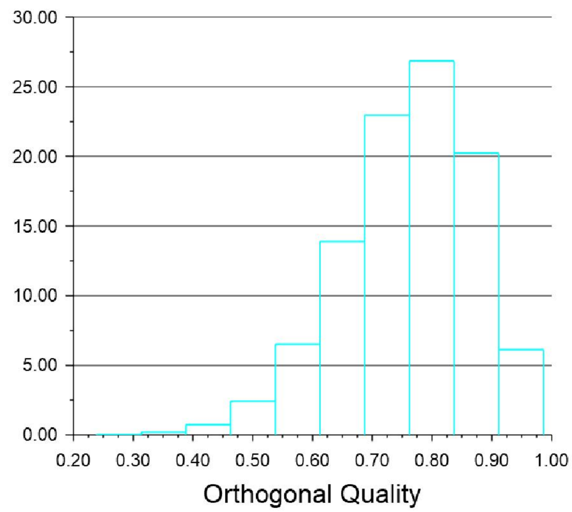

FIG 11 GRAPH VIEW OF QUALITY

Solver settings:

Flow	True
Turbulence	True
Reynolds Stresses	True
Absolute Velocity Formulation	True
Unsteady Calculation Parameters	
Number of Time Steps	1
Time Step Size [s]	1
Max Iterations/Time Step	5
Under-Relaxation Factors	

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, May 2024

Pressure	0.3
Density	1
Body Forces	1
Momentum	0.7
Turbulent Kinetic Energy	0.8
Turbulent Dissipation Rate	0.8
Turbulent Viscosity	1
Reynolds Stresses	0.5
Type	SIMPLE
Pressure	Standard
Momentum	Second Order Upwind
Turbulent Kinetic Energy	Second Order Upwind
Turbulent Dissipation Rate	Second Order Upwind
Reynolds Stresses	Second Order Upwind
Minimum Absolute Pressure [Pa]	1
Maximum Absolute Pressure [Pa]	5e+10
Minimum Temperature [K]	1
Maximum Temperature [K]	5000
Minimum Turb. Kinetic Energy [m^2/s^2]	1e-14
Minimum Turb. Dissipation Rate [m^2/s^3]	1e-20
Maximum Turb. Viscosity Ratio	100000

Solution:

	Value	Absolute Criteria	Convergence Status
continuity	0.4045886	0.001	Not Converged
x-velocity	0.008672179	0.001	Not Converged
y-velocity	0.00587785	0.001	Not Converged
z-velocity	0.008835553	0.001	Not Converged
k	0.01517085	0.001	Not Converged
epsilon	0.0224202	0.001	Not Converged
uu-stress	0.03796129	0.001	Not Converged
vv-stress	0.03635626	0.001	Not Converged
ww-stress	0.03197959	0.001	Not Converged
uv-stress	0.007179594	0.001	Not Converged
vw-stress	0.005496291	0.001	Not Converged
uw-stress	0.01229628	0.001	Not Converged

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, May 2024

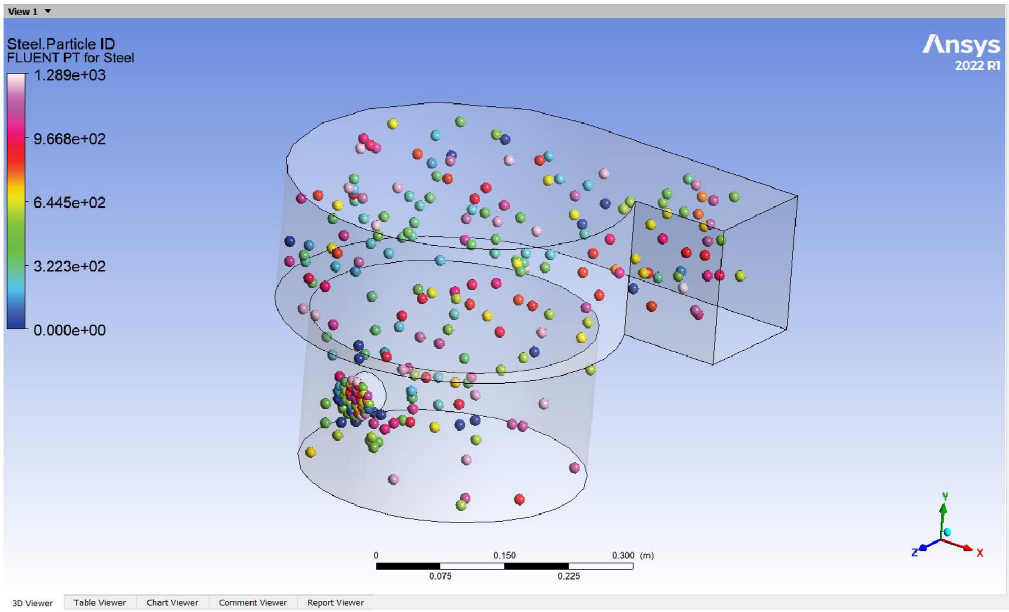

FIG 12 PARTICLE TRACKING

X. CONCLUSION

The design and analysis of fugitive dust emissions collectors represent a critical endeavor in environmental and industrial engineering aimed at mitigating the adverse impacts of airborne particulate matter on human health, environmental quality, and regulatory compliance. Through the utilization of advanced computational fluid dynamics (CFD) techniques, such as the simulation of turbulent flows and particle dispersion, researchers and engineers can develop innovative collector designs that effectively capture and contain fugitive dust emissions within industrial facilities.

By leveraging CFD simulations, engineers can optimize the geometry, operational parameters, and placement of dust emissions collectors to achieve enhanced dust capture efficiencies and minimize potential environmental contamination. The comprehensive analysis facilitated by CFD enables the refinement of collector designs to address specific industrial processes, airflow conditions, and particulate matter characteristics, thereby maximizing the effectiveness of dust mitigation strategies.

Furthermore, the integration of CFD-based analysis in the design process offers a cost-effective and efficient means of evaluating multiple collector configurations, assessing their performance under various operating conditions, and identifying potential design improvements without the need for costly and time-consuming physical prototyping.

REFERENCES

[1]. Shree ganesh& m. M Singh, “Impact of Stone Crusher On Ambient Air Quality And Human Health”,2020 IJRAR June 2020, Volume 7, Issue 2.
[2]. By A.I. Khan & M. Y. Bhuiyan, “Analysis of Design and Purchase Decision of Central Dust
[3]. Collection System”, Volume 13 Issue 1 Version 1.0 Year 2013.
[4]. Muhammad I. Taiwo. Mohammed A. Namadi. and James, B. Mokwa, “Design and analysis of cyclone dust separator”, Volume-5, Issue-4, pp-130-134,2016.
[5]. zaman bhuiyan, “Design analysis of Dust collection system,” BIOE 7200 ,2020.
[6]. Sairanen, Marjo; Rinne, Mikael; Selonen, O, “A review of dust emission dispersions in rock aggregate and natural stone quarries,” DOI:10.1080/17480930.2016.1271385,2018