CFD Simulation of Pressure Differentials in a Cleanroom
Samuel Behrens K00255937

Aim of the Project

The aim of this project was to demonstrate an understanding of a Computational Fluid Dynamics simulation on the pressure differential within a clean room. The objectives for this project include:

- Research necessary information regarding CFD in clean rooms.
- Model a given cleanroom to run a simulation.
- Run two CFD simulations and review results.
- Review the pressure differentials for both simulations.
- Recommend future work.

Background

Computational fluid dynamics (CFD) is an advanced computational fluid mechanics that uses numerical methods to address complex fluid dynamics problems that come up in a variety of engineering fields, including chemical processing, biomedical engineering, and aerospace. Its ability to simulate fluid behaviour in extremely specific settings reduces the need for expensive and time-consuming physical testing, which is one of its main advantages.

Cleanrooms are an essential tool for engineers since they allow components to be manufactured under strict environmental requirements, which has a profound impact on manufacturing processes. High-Efficiency Particulate Air (HEPA) filters are carefully combined with modern HVAC (Heating, Ventilation, and Air Conditioning) systems in these settings to create an incredibly sterile and contamination-free atmosphere. Cleanrooms are known for their rigorous maintenance of positive pressure regimes to deter external pollutants.

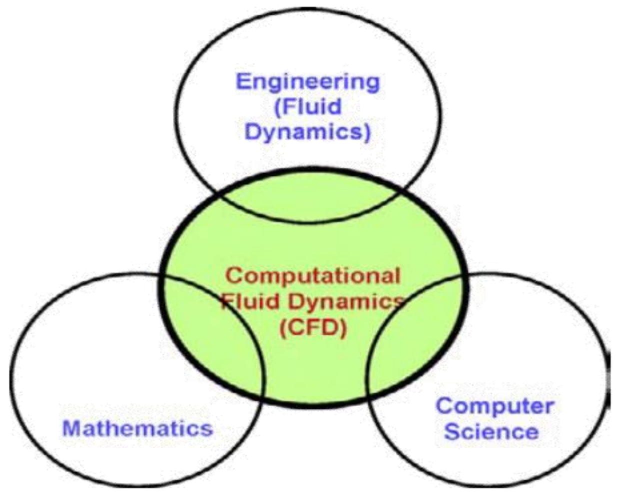

Figure 1: CFD Disciplines (Jiyuan Tu et al., 2013)

This dissertation attempts to demonstrate how the complex interactions between cleanroom design, HVAC systems, and pressure differentials can be meticulously simulated using CFD techniques, producing insights that closely resemble real-world scenarios through extensive research and comprehension of every aspect involved.

Model Setup

The simulations were carried out on cleanroom model whereby the dimensions were acquired by my supervisor Stephen Roughan. These dimensions were used to initially to create a detailed cleanroom model with accurate materials and thicknesses in Revit.

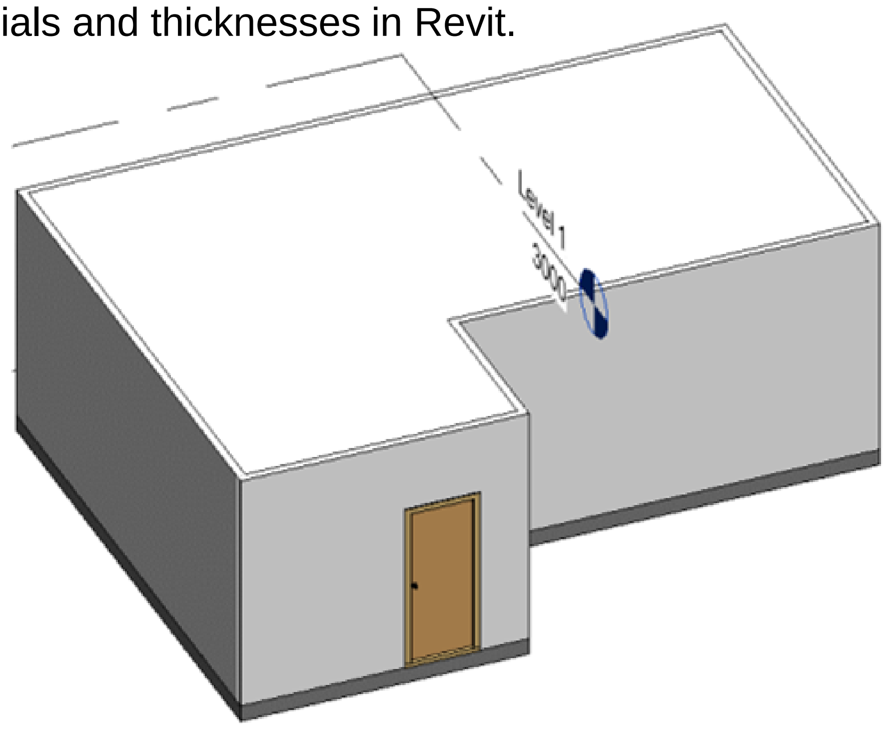

Figure 2: Revision 1 Revit Model

The model was then exported to SolidWorks to start the setup stages for the simulations. However, before the simulations could be setup, the model went through another revision to improve features such as the ceiling, doors, and vents. These changes had to be made in SolidWorks.

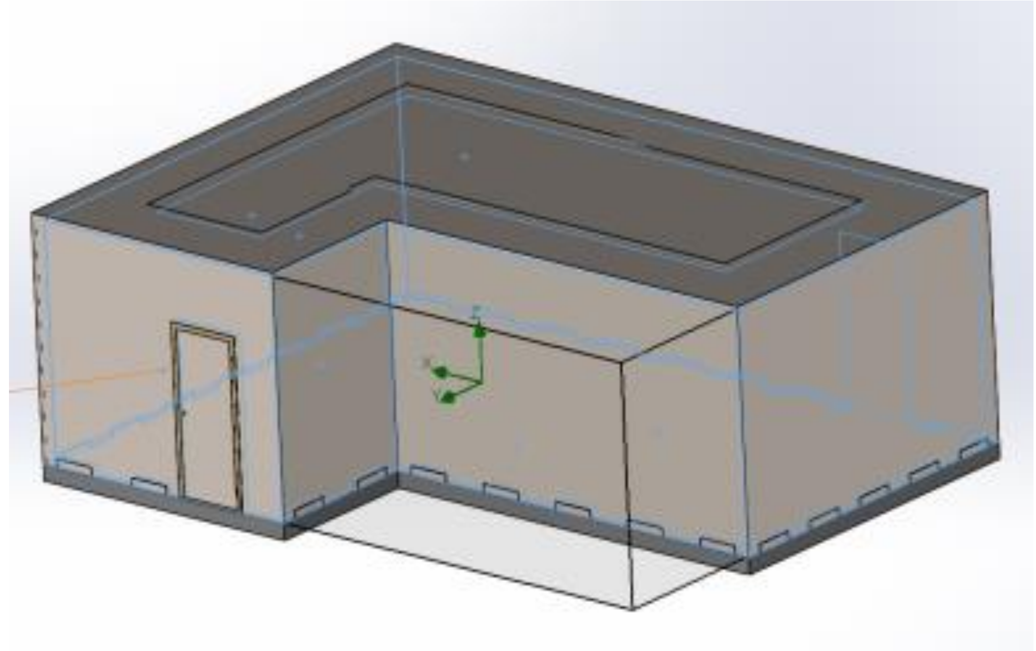

Figure 3: Final Revision SolidWorks Model

Simulations

Simulation 1

Simulation one was used as a base simulation and consisted of the pressures, leakage rates, and velocities received through research from the literature review. Boundary conditions were setup at the inlets and outlets. The outlet leakage rate was calculated using a leakage rate formula found by (Cheng et al., 2022) during the research stage of this project.

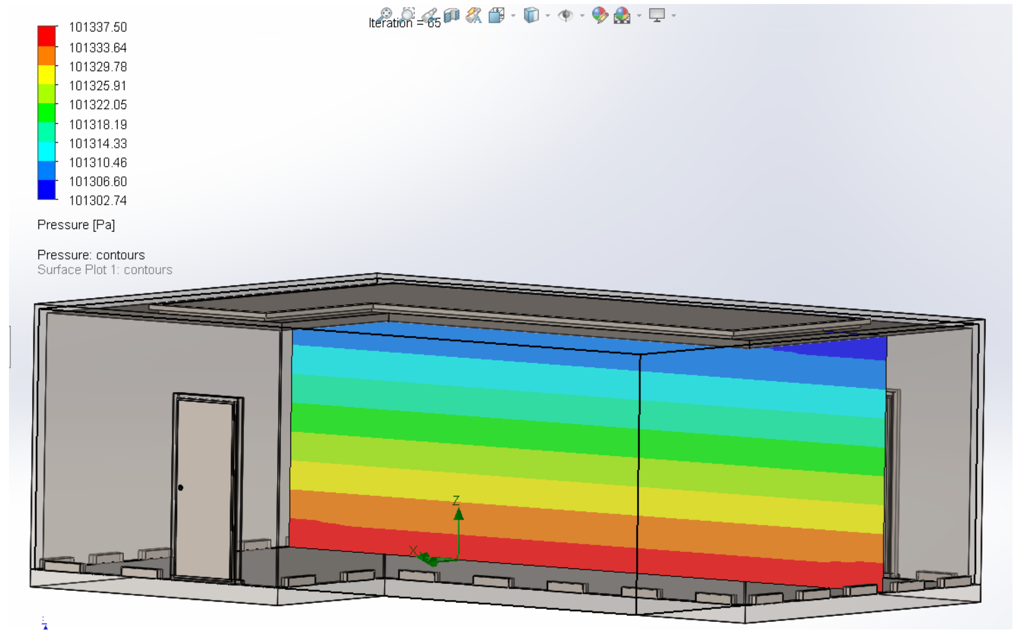

Figure 4: Simulation 1 Pressure

Simulation 2

The second simulation was conducted to imitate a door being opened. This was done by cloning the first simulation as the conditions of the inlet and outlets remained the same. To simulate a door being opened, a new boundary condition was applied to the rear door. This boundary condition specified that the door was exposed to 1 atm pressure or 101325 Pascals. This was done to show the changes that occurred in the simulation when the door was so called “opened.”

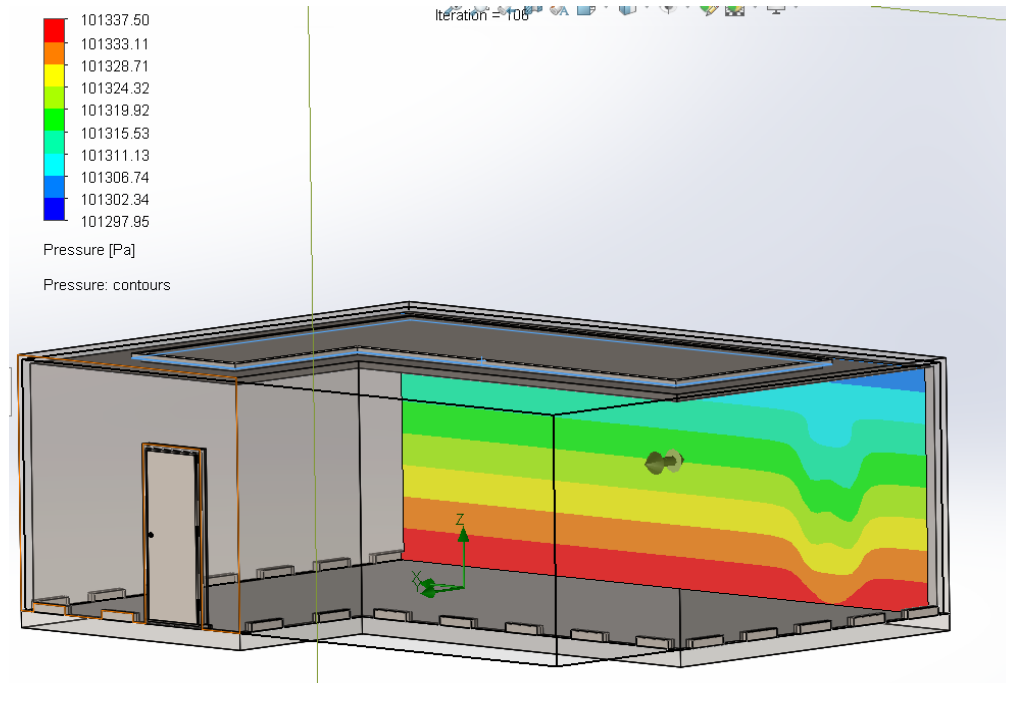

Figure 5: Simulation 2 Pressure

Conclusion

The results for the project simulations were both satisfactory. The first simulation that was created showed steady pressure and velocity parameters. The second simulation displayed disrupted parameters. It was also noted that the flow trajectories were significantly disrupted due to the pressure reduction produced in the second simulation.

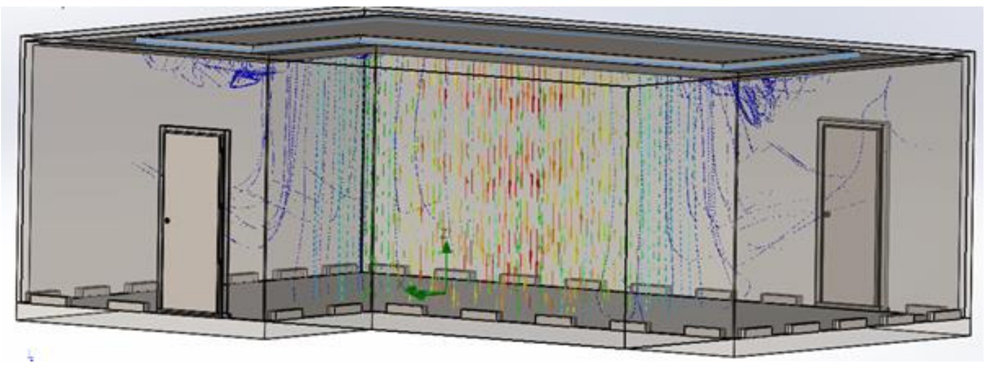

Figure 6: Simulation 1 Flow Trajectories

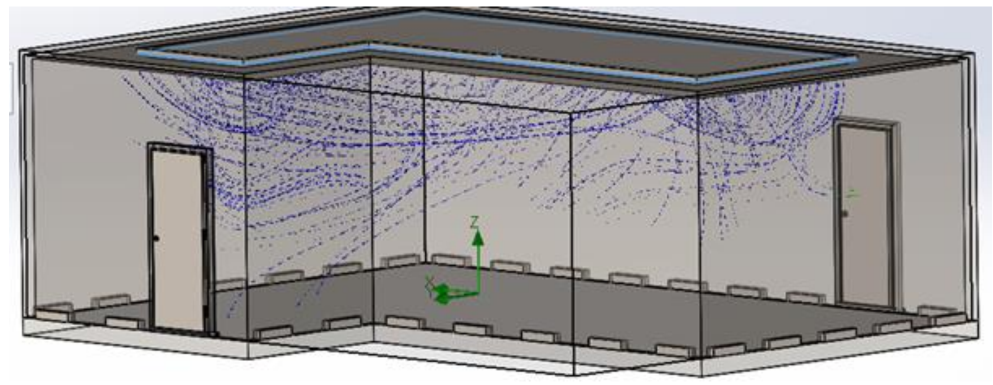

Figure 7: Simulation 2 Flow Trajectories

References

Cheng, X., Li, C., Ma, X., & Shao, X. (2022). Differential pressure control method for pharmaceutical cleanrooms under variable air supply conditions. Building and Environment, 213, 108849. https://doi.org/10.1016/J.BUILDENV.2022.108849.

Jiyuan Tu, Guan Heng Yeoh, & Chaoqun Liu. (2013). Computational Fluid Dynamics : A Practical Approach. In Computational Fluid Dynamics : A Practical Approach (Vol. 2).