

Meliha Delalić

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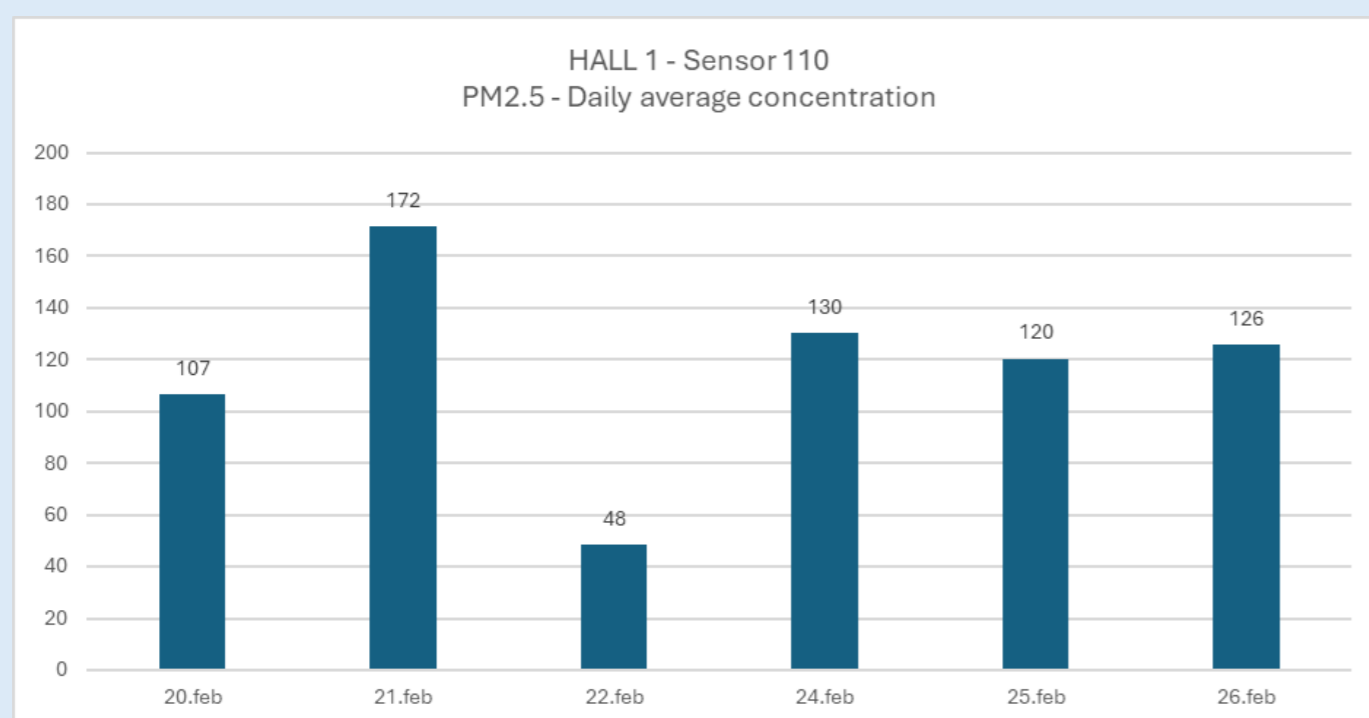
PROBLEM AND OBJECTIVES

Metal-processing operations in the investigated industrial hall generate high concentrations of $PM_{2.5}$ and PM_{10} particles due to grinding, cutting, and welding processes. Experimental measurements indicate frequent exceedance of recommended occupational exposure levels in the worker breathing zone ($C > 40 \mu g/m^3$). The existing ventilation system is unable to ensure effective pollutant removal due to non-uniform airflow distribution and insufficient capture of airborne contaminants.

MAIN GOAL: Reducing $PM_{2.5}$ and PM_{10} concentration by improving the existing ventilation system.

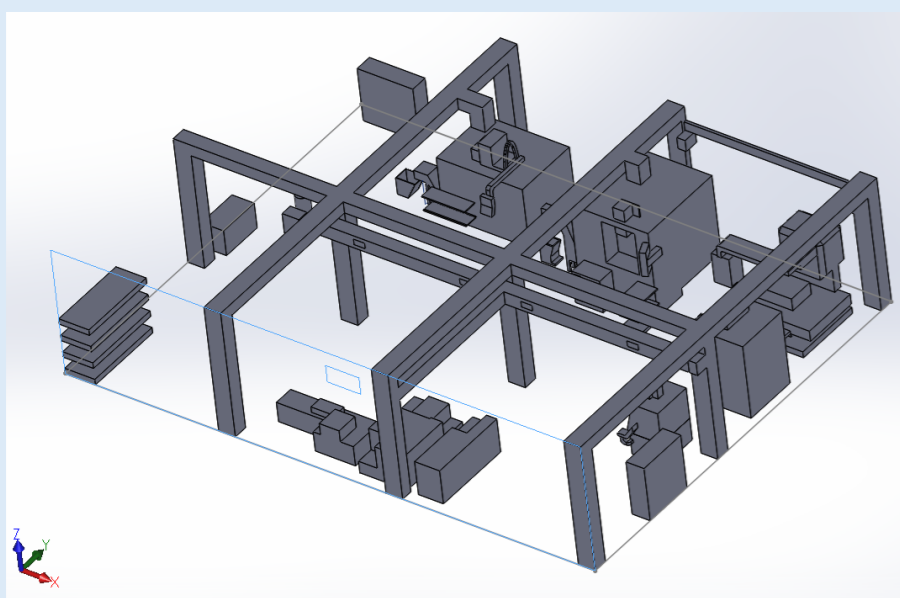
OBJECTIVES:

- CFD modelling of the industrial hall using real geometry and conditions
- Validation using experimental $PM_{2.5}$ measurements
- Assessment and optimization of LEV efficiency in the breathing zone



IMPLEMENTATION AND DESIGN

Turbulence Model: $k-\epsilon-\zeta-f$ elliptic-blending RANS model
Cell count: 402,023



- Geometry simplified and modeled as internal obstacles affecting flow and turbulence.
- Two local exhaust ventilation (LEV) hoods were added above the two largest emission sources.
- Walls: no-slip condition.
- Inlets: velocity/pressure-driven inflow with turbulence parameters.
- Outlets/symmetry: fully developed outflow without reflection.

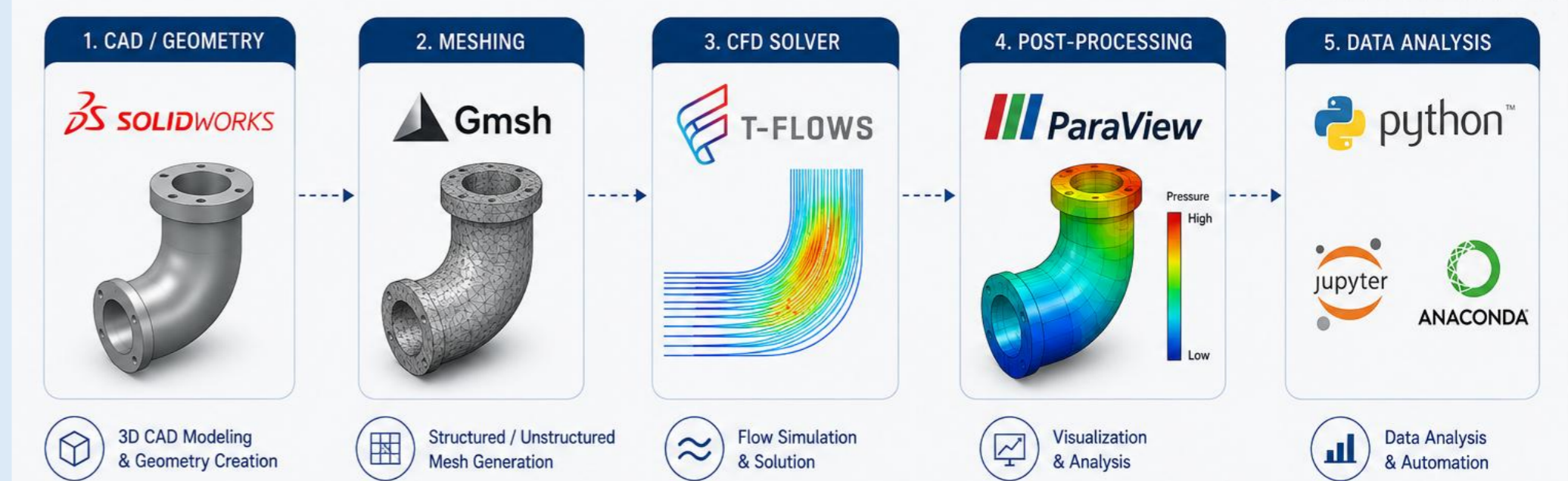
CONCLUSION

The combined CFD and experimental analysis showed that the ventilation system captures pollutant dispersion trends in the industrial facility, with quantifiable deviations highlighting model and system improvements.

References

- J. Qian, J. Wang, H. Liu, and H. Xu. 2020. CFD modeling of ventilation and dust flow behavior in polishing and the design of an innovative wet dust removal system. *International Journal of Environmental Research and Public Health* 17, 16 (2020), 6006. <https://www.mdpi.com/1660-4601/17/16/6006> (Accessed: 09 Apr 2026)
- European Commission. 2019. Commission Directive (EU) 2019/1831 establishing indicative occupational exposure limit values. <https://osha.europa.eu/en/legislation/directive/directive20191831-indicative-occupational-exposure-limit-values> (Accessed: 09 Apr 2026)

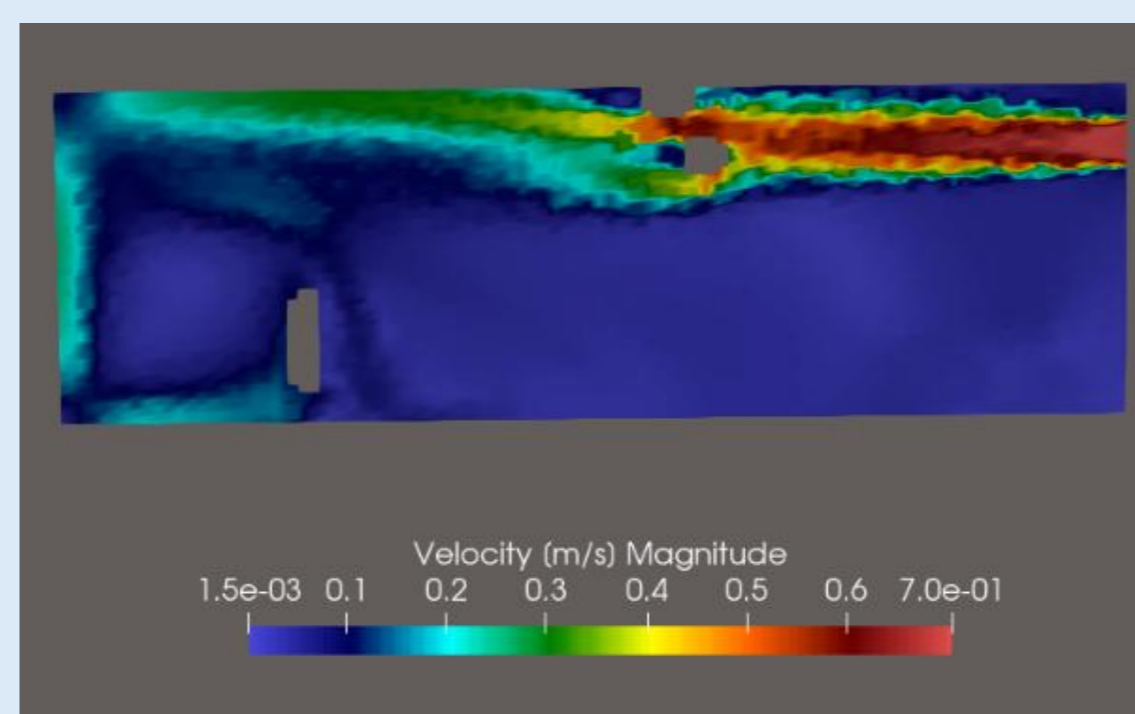
METHODOLOGY



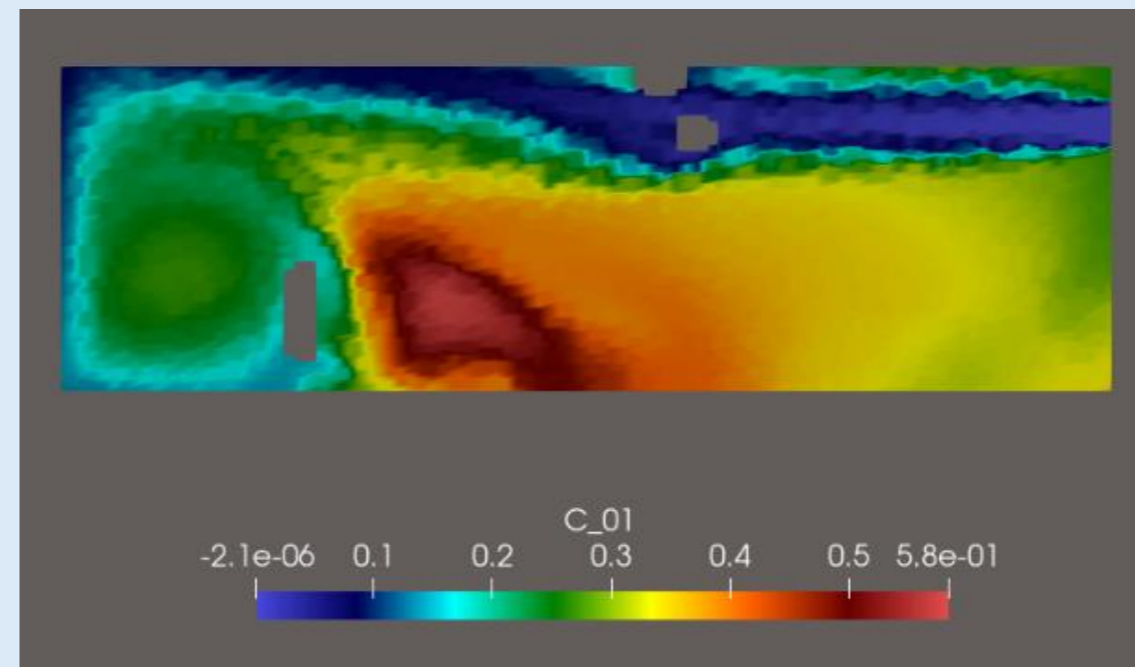
Experimental $PM_{2.5}$ and PM_{10} measurements were collected over multiple days in the facility using eight PMS5003 sensors. Later they were analyzed and used for validation and comparison against the CFD results.

As for CFD, key steps include 3D modeling, meshing, simulation, postprocessing and data analysis.

RESULTS AND VALIDATION

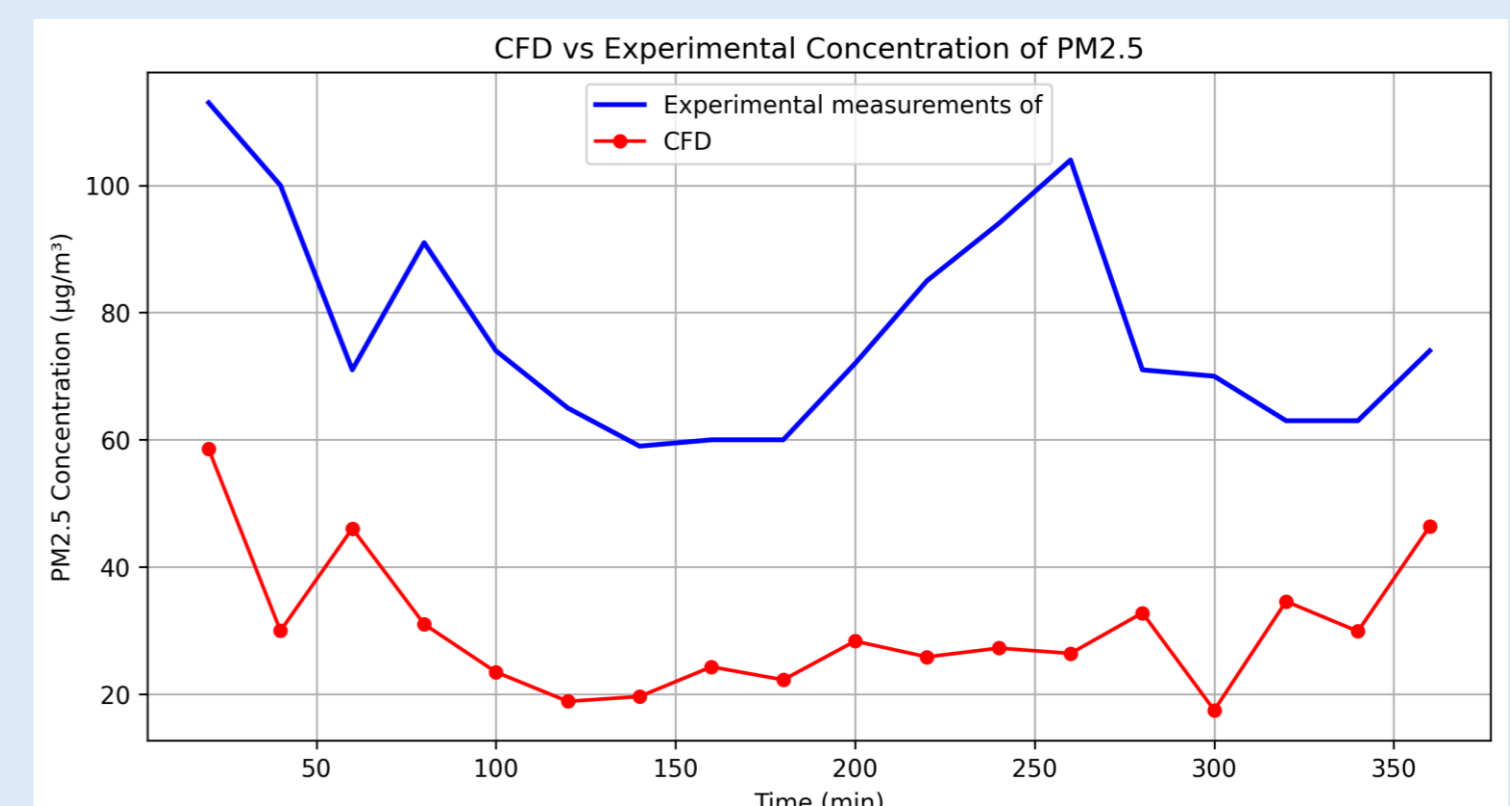


A high-velocity ventilation jet (0.4 - 0.7 m/s) dominates the upper-right domain, establishing a high-momentum convective path that keeps concentration levels negligible.



Machine geometry creates a massive fluid detachment zone in the lower-central region resulting in suppressed ventilation as velocity drops.

KEY RESULT > Proposed local exhaust system is predicted to decrease the average $PM_{2.5}$ concentration by 60.89%.



- CFD captures the temporal evolution of $PM_{2.5}$ very well, reproducing peak timings and overall trends.
- Systematic underprediction attributed to simplified boundary conditions and emission sources.

Keywords: Computational Fluid Dynamics (CFD), Local Exhaust Ventilation (LEV), Reynolds-Averaged Navier-Stokes (RANS), $PM_{2.5}$, PM_{10} , Industrial Space Air Quality, Industrial Ventilation, Airflow Simulation, Particle Dispersion, Mesh Generation, Worker Exposure, Ventilation Optimization, ParaView

