# Ventilation study of a lecture classroom : Case D2

## 1. Introduction

The European HESE study (Health Effects of School Environments [1]) of the World Health Organization (WHO) has demonstrated that indoor air quality (IAQ) in the investigated schools and classrooms was poor, causing respiratory health effects. Especially after the outbreak of SARS-COV-19 virus it is therefore to supply fresh air to the building and dispose of heat, particles, humidity and other pollutants generated in the classroom. Consequently, the heat released by internal gains (i.e. the occupants and electronic devices) cannot easily be disposed of. Therefore, the air distribution system should be able to efficiently evacuate the old air, and ensure a homogeneous cooling/heating of the occupied zone. In this prospect, an integrated ventilation system is considered, with conditioned air blown through a trench heater and a ceiling fan. The experimental method aims at assessing ventilation efficiency by measuring the flow parameters in the occupied zone of the classroom. To carry out an analysis a quantitative analysis of some variables, defining the ventilation quality, is needed. One of them could be the air changes per hour (ACH), defined as the relation between the air flow rate entering the enclosed space and its volume, that is, the number of times per hour that a volume of air equal to the enclosed space volume is exhausted. The latter air can be outdoor air, coming from outside the room, or recirculated air from the same room. To ensure correct ventilation, it is not enough to achieve just the prescribed ACH of outdoor air. In HVAC, this parameter is called the age of air. The mean age of air in a point is defined as the mean time that the air particles contained in a differential volume around the point have stayed inside the room.

## 2. Modelling geometry and Meshing

A classroom at Hochschule Kaiserslautern is considered as an independent ventilation unit. The dimensions of the classroom are 10m length, 5.5m width, and 3.6m height. The room consists of 4 windows, 4 occupants, 4 desks, 2 doors, trench heaters, and a ceiling fan. Fresh air is supplied through supply air inlet with volume flux of 924 m3/h. Trench heater injects air vertically to the wall at a rate of 50m3/h. This air is a mixture of primary air with return air, the latter coming from the own room through the outlet of the trench heater at the same rate as 50m3/h. Air is exhausted from the room through a tiny slit located below 1.4m below the roof at the long end of the room wall opposite to windows. The occupants are place minimum 2m away from each other ensuring safe social distance is maintained to avoid any sort of contact in the time of corona outbreak.

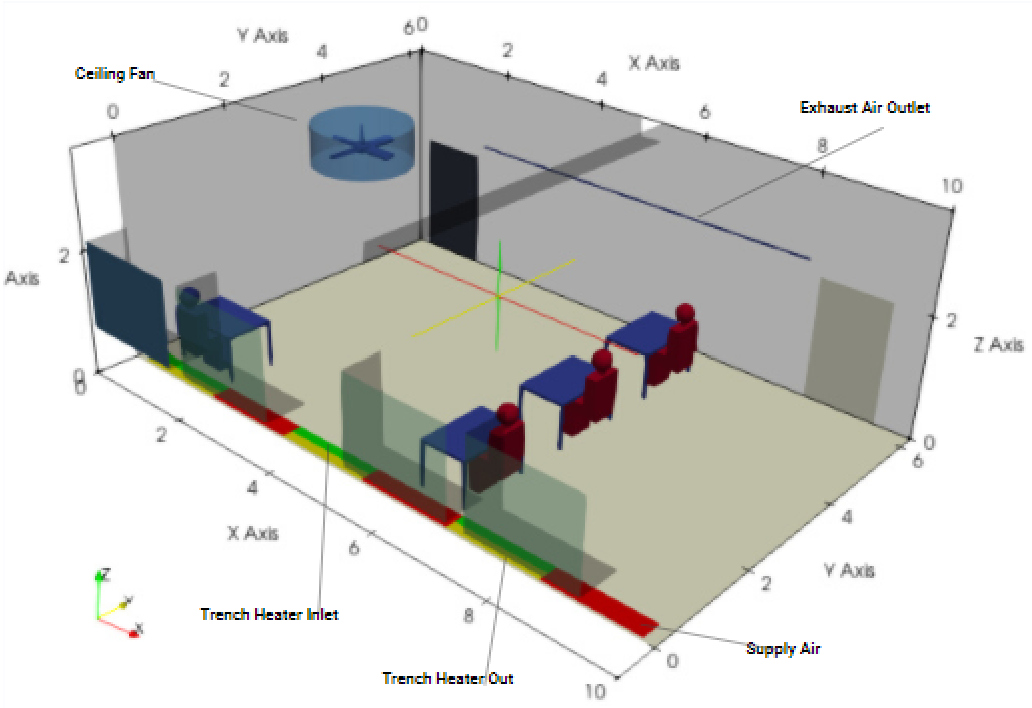


**Fig 1: Geometry of Case D2**

Meshing is done using snappyHexMesh. Refinement zones were added near inlet outlets and at ceiling fans with refinement boxes. After the sensitivity study of the mesh, the computational domain has around 1 million cells.

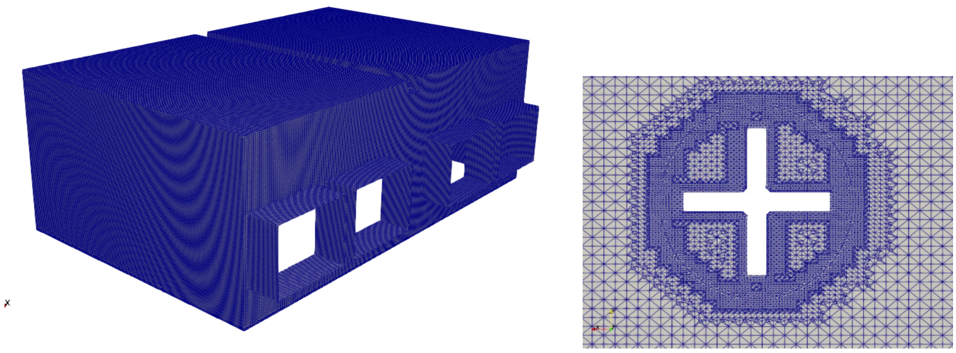

**Fig 2: Meshing of the geometries**

## 3. Boundary Conditions

Realistic boundary conditions have been defined for the CFD simulations, whose purpose is to give additional information on the airflow patterns inside the room. The boundary conditions for epsilon,k,e,p,p_rgh are standard. Temperature boundary conditions are fixed to 295K as the case is isothermal. Boundary conditions of U are following

| Patch | Type (U) | Value(U) |
|---|---|---|
| Supply Air Inlet | flowRateInletVelocity | 0.2567 |
| Trench Heater Inlet | flowRateInletVelocity | 0.04 (+ve Z direction) |
| Trench Heater Outlet | flowRateInletVelocity | 0.04 (-ve Z direction) |
| Exhaust Air Inlet | pressureInletOutletVelocity | Uniform (0 0 0) |
| Ceiling Fan | movingWallVelocity | Uniform (0 0 0) |
| Room,windows,occupants, walls | noSlip | - |

**Table 1**

## 4. Solver and methods

The case is solved with buoyantSimpleFoam solver which is a steady-state solver for buoyant, turbulent flow of compressible fluids, including radiation, for ventilation and heat-transfer. As the air introduced into the room is a mixture of return air and outdoor one, to set the value of the mean age of air at the inlet, the concept of the total age is used. The numerical model solves the mean age of the air conservation equation at the last timestep.

## 5. Results and Discussion

The aim of this study is to analyse the ventilation flow pattern in the room, that is, to find a feasible ventilation method that achieves efficient ventilation. To do so, the flow pattern of the initial configuration is analysed. Case B corresponds to the initial configuration and architecture of the classroom design. The air is introduced into the room by means of fresh air inlet and recirculated using trench heaters. All windows and doors are considered closed. In Case D2 , forced air circulation is provided by introducing a ceiling fan located 2.5m from the short end of the room. The ceiling fan is placed such that the occupants of the room are equidistant from the location of the ceiling fan. Rest of the operating conditions for this case remains the same as the initial case B.

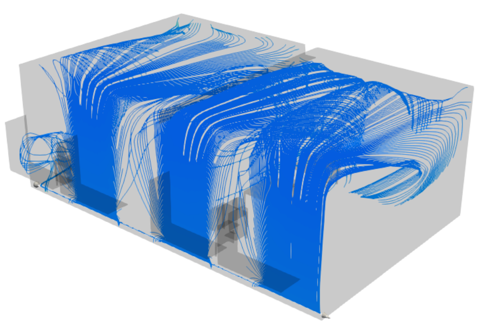

**Fig 3(A) Air flow streamlines Case B**

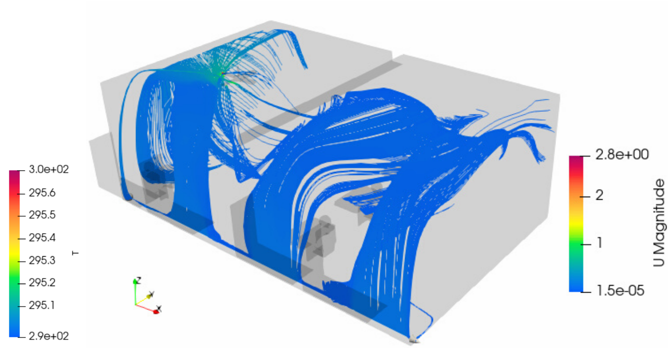


**Fig 3(B) Air flow streamlines Case D2**

Streamlines of both the cases can be seen in Fig 3. The computational investigation of streamlines flow pattern and age demonstrates that the addition of a ceiling fan results in better air circulation and reduces the mean age of air. As seen in Fig 4, mean age of air in the case D2. Table 2 summarizes the resulting ACH and mean age of air of both the cases.

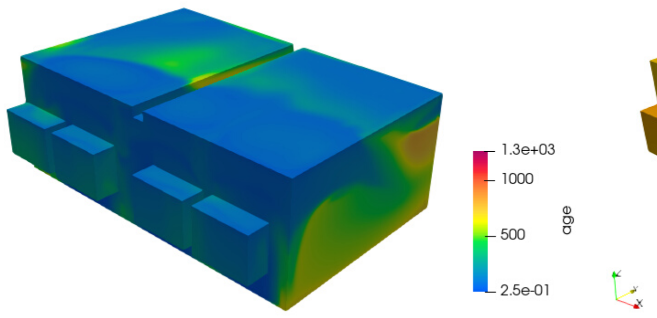


**Fig 4(A) Age of air: Case B**

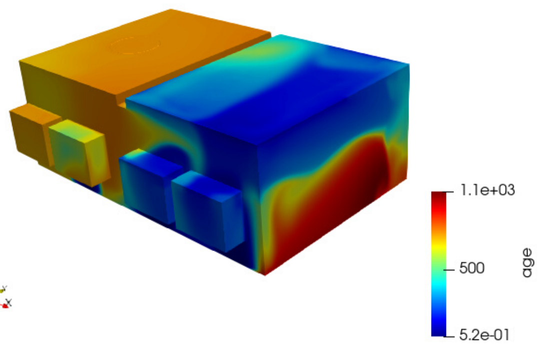


**Fig 4(B) Age of air : Case D2**

There is a difference in the age of air between the long and short ends of the classroom. This indicates that the location of trench heaters and exhaust air outlet modifies the flow pattern.

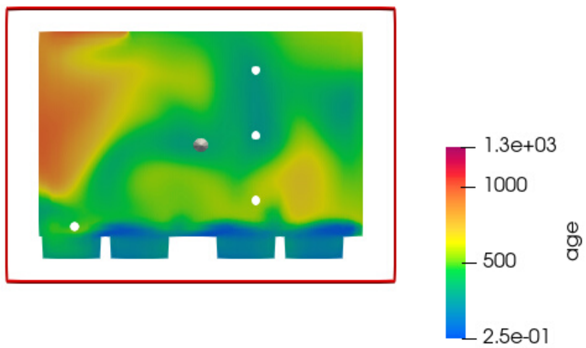


**Fig 5(A) Age of air at breathing level: Case B**

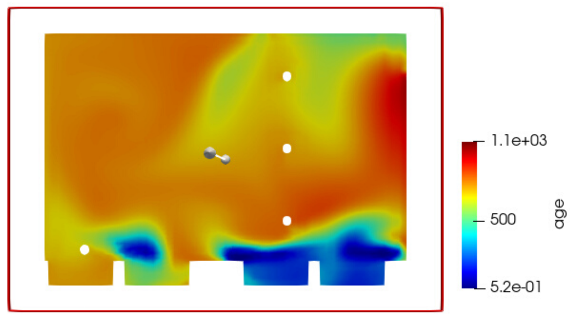


**Fig 5(B) Age of air at breathing level: Case D2**

The analysis of the age of air in Fig. 5 shows the mean age of air in a horizontal plane at a height of 1.35m below the roof, which is, approximately the height of breathing region of occupants which are in the classroom. The numbers represent the age of air in seconds. The initial configuration Case B has much higher ages than the other Case D2.

| Case | Maximum Age (exhaust air) seconds | Average Age (exhaust air) seconds | Air changes per hour ACH |
|---|---|---|---|
| Case B | 1300 | 845 | 4.2 |
| Case D2 | 1100 | 882 | 4.1 |

**Table 2**

## 6. Conclusion

The viability of the ventilation systems has been demonstrated. A better indoor environment quality has been obtained in the Case D2. there is not really a significant amount of difference between the ACH of both the cases. However, the youngest air will be found at outdoor air inlets, while the oldest air can be found at any other point, not necessarily at the outlets. This point is carefully observed in the Fig 5, which is the age of the air at the breathing region of the occupants in the room. Thus it can be inferred that the addition of a ceiling fan in the room results in better ACH in the horizontal plane of breathing region. The location of trench Heaters in respect to the location of the exhaust air plays a major role in the airflow in the room. It is also observed that slight modifications of geometry can bring about improvements in the efficiency of the ventilation flow pattern. For example change in the position of occupants or change in the location of ceiling fan or exhaust air outlet has a great effect on the air flow pattern. It was also seen that it is difficult to establish general standards, because the geometry of enclosed spaces and the presence of furniture/occupants modifies the air flow pattern as well as the mean age of air. This means that an individual study of each specific configuration case is necessary in order to determine the suitable position of occupants, inlet, outlets in the room to achieve much better air flow pattern which is suitable in the time of Covid-19 pandemic.

## 7. References


1. World Health Organization. School Environment: Policies and Current Status; WHO Regional Office for Europe: Copenhagen, Demark, 2015.
2. A.D. Gosman, P.V. Nielsen, A. Restivo, J.H. Whitelaw, The flow properties of rooms with small openings, J. Fluids Eng. 102 (1980) 316–323.
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