Bulletin of the *Transilvania* University of Brasov • Vol. 11 (60) Special Issue No. 1 - 2018
Series I: Engineering Sciences

SIMULATION OF THE MICROCLIMATE IN A CHURCH DURING COLD SEASON

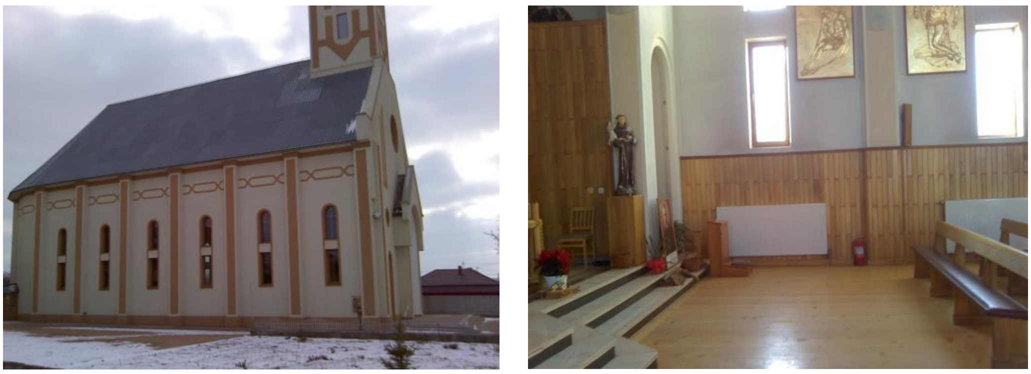
F.E. ȚURCANU[1] M. VERDEȘ V. CIOCAN I. ȘERBĂNOIU, A. BURLACU, M. C. BĂLAN

Abstract: *In the paper is presented a heating system installed in church and the interior climate generated. Thermal Comfort is the purpose of each designer, since the design stage and has to be ensure for the churchgoers, but even for the interior finishes. The heating system that uses hydronic radiators is evaluated trough the CFD modelling, in order to evaluate pro and contra arguments. The simulation has been made in a 3d simulation software environment, in Autodesk CFD with good results.*

Key words: *hydronic heating systems, indoor climate modelling, thermal comfort.*

1. Introduction

The indoor microclimate that's has been analysed is found in the church of Saint Cross Rising, in the village of Săbăoani, country of Neamț (Fig. 1a). The church has been built in the years of 2000, on a mixt structure of masonry and columns and girders of reinforced concrete. At the top the church has a dome made from reinforced concrete. The heating system is formed by a hydronic radiator systems and a boiler with the power of 40 kW, that burn wood. The heating systems is mounted on the exterior walls under the



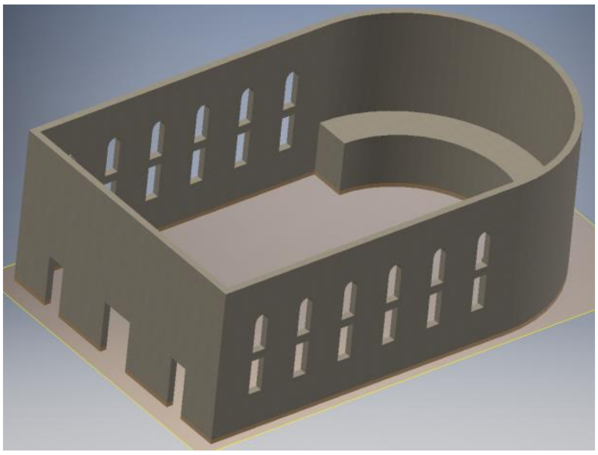
a) b)

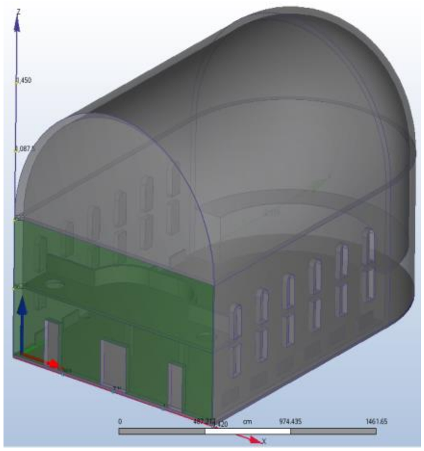
Fig. 1. *a) Exterior view of the studied church b) Existing heating system inside the church*

[1] Faculty of Civil Engineering and Building Services, University of Gheorghe Asachi from Jassy

windows (Fig. 1b).

Church is formed by a single shape nave, with the opening of 13.5 meters and a total height of 14 meters. Also the total length is of 23 meters, this numbers gives a total heating volume for the church of 3000 m^3 (Figure 2 a, b).





a) b)

Fig. 2. *a), b) View of the church from the modelling process*

Exterior walls have the weight of 0.4 meters, covered with a layer of 0.05 meters of polystyrene insulation and the exterior windows are made from insulated glass with woodwork made from PVC.

To create an indoor climate, distinct from the outside one, is the main purpose for almost all buildings and in our case for worship buildings. Also the climate created in the churches provides the thermal comfort for the churchgoers. By controlling the parameters that generate the indoor climate leads to an appropriate and sustainable use of the energy resources with a high cost-efficiency management [1, 2].

In the current practice of heating systems that lead to the creation of the indoor climate in churches, the technical solution are always a reference, meanwhile the real difficulties are choosing the criteria that form a suitable climate. That is why the literature refers to the following parameters when it comes to the indoor thermal climate of the places of worship: 1. Air temperature; 2. Surface Temperature; 3. Relative humidity; 4. Displacement of Air Currents [2].

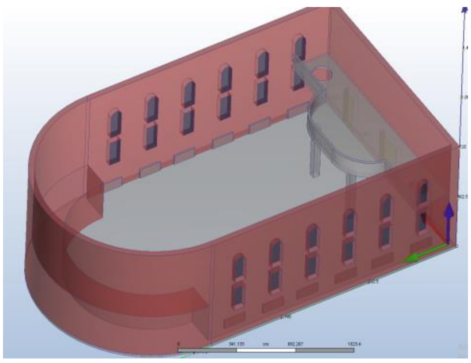
In order to understand how we can control the indoor microclimate in the places of worship, there is a need for a physical and also quantitative understanding of the complex interaction that exists between the above mentioned parameters [3].

2. Modelling Indoor Microclimate

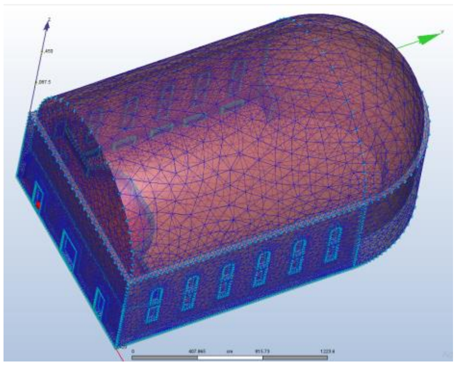
CFD modelling based on FVM (Finite Volume Methods) has opened the way for solving moment, mass and energy equations. Also, the k-e turbulence model and a standard model to define the wall flow, created the premises for dynamics simulations with a high degree of trust for thermal modelling of the interior climate, air movements etc. [4].

This paper analyses the hydronic heating of the air volume inside the church. The modelling allowed to identify the airflows patterns that are generated and theirs effect on the interior finishes as well as the thermal comfort of the churchgoers. The interior temperature that the heating system generate inside the interior volume has been evaluate as well [5].

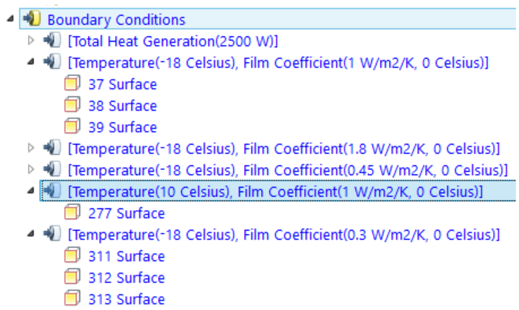
The church has been evaluated in a 3d environment in Autodesk Inventor, as faithfully as possible based on the construction plans. From Autodesk CFD the building has been exported in Autodesk CFD 2018 for further analysis (Fig. 3.a, 3.b). In this stage has been define the materials for all the surfaces that form the indoor heating volume. For all the surface have been imposed the limit condition. The exterior walls have a thermal resistance of R = 1.8 W/m^{2}K and the outside temperature is taken for measurements made outside during winter that has a maximum of T= - 18^{0}C (Fig. 3.c). Also the discretization have been made at a step of 0.5 meters resulting 4 million of elements (Fig. 3.d).



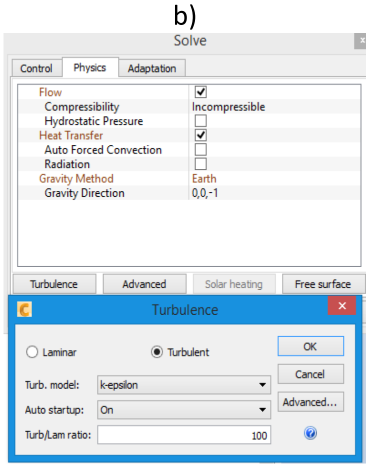
a)



b)



c)



d)

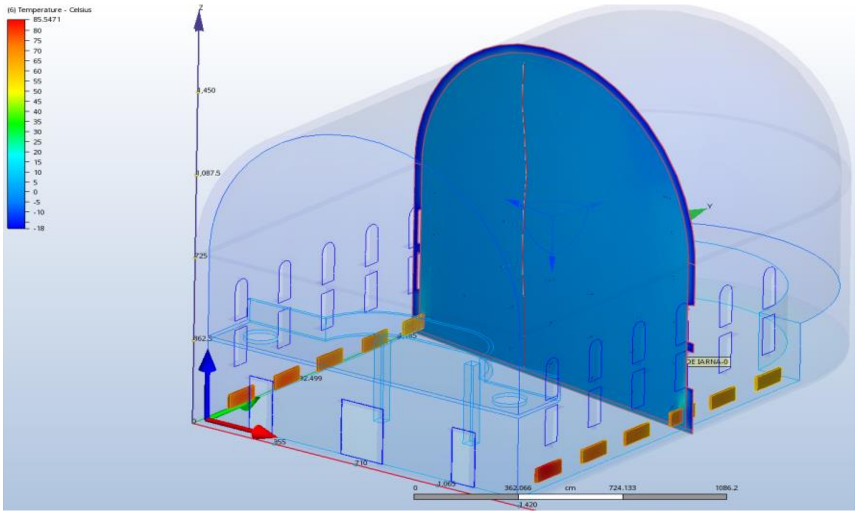
Fig. 3. a*) Defining the materials for the surface that form the interior volume b) Discretization of the interior volume c) Imposing the boundary conditions d) Defining the turbulence model along others parameters for running the analysis*

For numerical simulation of the indoor climate as well as for all simulations it is important to reduce numerical errors. Therefore, for volume simulations, meshing refinements were made by minimizing the size of the elements to achieve constant meshing [6, 7].

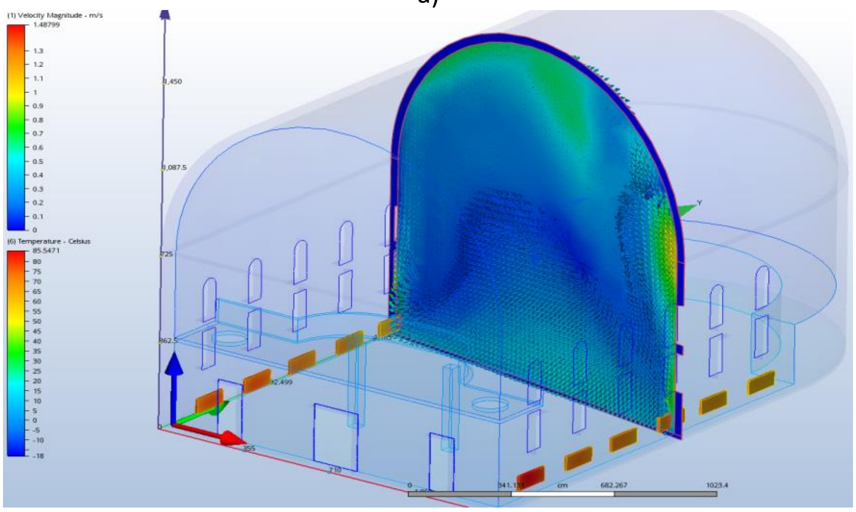
The transfer equations between the wall and the volume of air is solved by the k-e model equation at the wall, being the scalar equation type [8].

3. Conclusion

Hydronic heating system works on the basis of natural convection in large proportion (90%). The air enters the bottom, is heated due to the buoyancy phenomenon and it comes out at the top (Figure 4a, b).



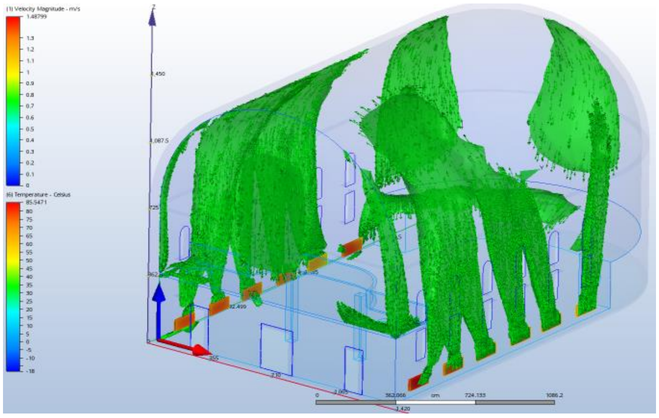
a)



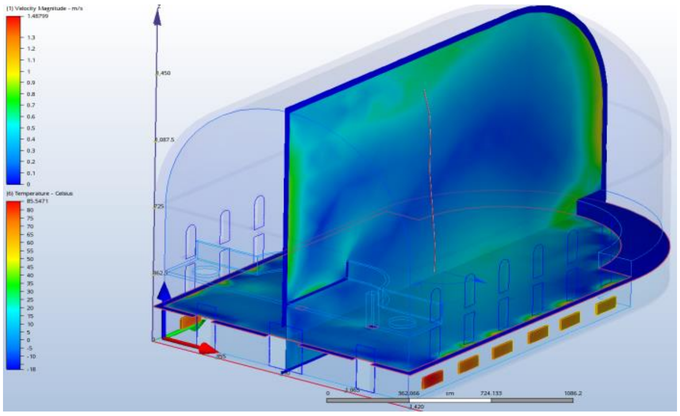
b)

Fig. 4. *a) Temperature in a transversal section plane b) Air velocity and temperature along a transversal plane*

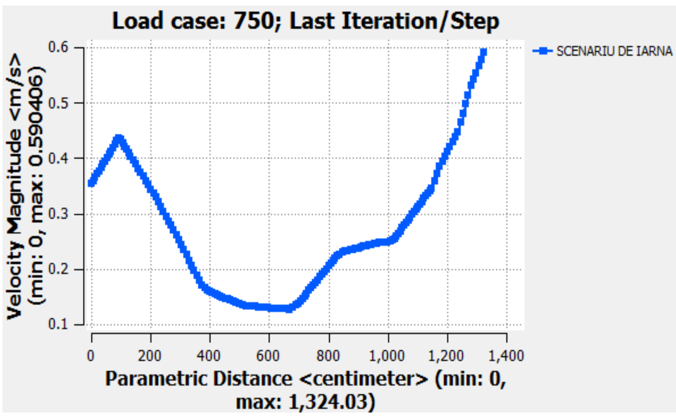
When it is in function, a radiator heating system causes air drying, so the RH% <, sometimes too low. This is especially true in areas with cold climate and when the system is in continuous operation. The system creates convection currents (air velocity exceeding 1 m/s, Figure 4. b) which drives the particles suspended from air and causing the surface that comes into contact with the air dust to blackening.



a)



b)



c)

Fig. 5. *a) Air currents movement b) Air and Temperature gradient along longitudinal section c) Air velocity along the line drawn in Figure 5. b.*

From the point of view of the internal thermal comfort, the system is efficient when is used without interruption (Figure 5 a, b, c), but also when the number of radiators is enough and the temperature of the heated volume is homogeneous, especially for small volumes of air.

From visual point of view the hydronic heating system brings discomfort both through the heating bodies and the pipes that are connected to each other and with the boiler.

References

1. Schellen, H., Lambertus, H.: *Heating Monumental Churches* - Indoor Climate and Preservation of Cultural Heritage. Eindhoven(NL): Technische Universiteit Eindhoven, 2002.
2. Şen, Z.: *Solar energy fundamentals and modelling techniques: atmosphere, environment, climate change and renewable energy*. London: Springer-Verlag Limited 2008.
3. Varas-Muriel, M., Martínez-Garrido, M., Fort, R.: *Monitoring the thermal–hygrometric conditions induced by traditional heating systems in a historic Spanish church (12th–16th C)*. In Energy and Buildings, 75(3), 2014, pp. 119-132.
4. Martinez Garrido, M. I., Fort, R., Varas Muriel, M. J.: *Sensor-based monitoring of heating system effectiveness and efficiency in Spanish churches*. Indoor and Built Environment, 21(1), 2016, pp. 156-165.
5. Liu, J., Yao, R., McCloy, R.: *A method to weight three categories of adaptive thermal comfort*. In Energy and Buildings, Volume 47 , 2012, p. 312–320.
6. Bratasz, Ł.; Kozłowski, R.; Camuffo, D.: Pagan, E. *Impact of indoor heating on painted wood: Monitoring the altarpiece in the church of Santa Maria Maddalena in Rocca Pietore, Italy*. Stud. Conserv. 2007, 52, 199–210.
7. M.I. Torres, V.P. Freitas: *Treatment of rising damp in historical buildings: wall base ventilation*. In Build. Environ. 42(1), 424–435 (2007)
8. Camuffo, D., Pagan, E., Schellen, H., Limpens-Neilen, D.: *A practical guide to the pros and cons of the various heating systems with a view to the conservation of the Cultural Heritage in Churches.* Results of the European Project Friendly Heating EVK4-CT-2001-00067.