Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(1) (2020) 1-3
DOI:

Optimal Layout of a Typical Telecommunication Center with the Help of Computational Fluid Dynamics and Artificial Neural Networks

H. Vozouhi, I. Mirzaee*, N. pormahmod Hesar, M. Abbasalizadeh
Department Mechanical Engineering, University of Urmia, Urmia, Iran

ABSTRACT: The present study investigates and simulates the status of cold air distribution in a microwave oven hall and proposes a new method to improve the room temperature. Initially, the present hall is simulated by computational fluid dynamics method and validated using empirical data measured by sensors used in rack output. A comparison of the simulation results and the available experimental data shows very good agreement between these data. Temperature measurement with error less than 1 degree indicates the correct choice of numerical solution method in the present study. In the computational fluid dynamics method, the effect of the arrangement of the racks was investigated by changing the arrangement. In the final step, using the computational fluid dynamics solution and neural network is proposed the best arrangement of racks. Based on the numerical simulation, the lowest and highest supply heat indexes are 0.456 and 0.631, respectively, and the lower the heat index, the higher the cooling efficiency. The average wall temperature of the racks has been used in optimization. The average temperature of the optimum alignment rack obtained from the neural network is 21.9°C which is 0.7°C lower than the best simulation.

Review History:

Received:
Revised:
Accepted:
Available Online:

Keywords:

Cooling
Optimization
Rack
neural networks
Computational fluid dynamics

1- Introduction

Today, high-tech cooling systems are invented and applied in a variety of models and locations. Sharma et al. [1] introduced two dimensionless parameters for the Supply Heat Index (SHI) and the Return Heat Index (RHI), which are used to evaluate the temperature of the data center. Herrlin [2] studied the effect of rack cooling. The Rack Cooling Index (RCI) indicator is a measure of how cool the equipment is and how compliant it is with the standards and guidelines. Chu et al. [3] investigated the thermal efficiency of an air distribution system for a dense data center using Computational Fluid Dynamics (CFD) simulations. Nakawa et al. [4] studied various data center cooling states using different ways. Patel et al. [5-6] were among the first to use CFD for modeling and studying airflow and temperature distribution at the false floor data center. Rambo and Jashie [7-8] developed CFD simulations using the Reynolds-Averaged Navier–Stokes (RANS) turbulence model and expanded the domain to consider inter-rack features in a multi-dimensional manner.

2- Methodology

In the present study, there are 40 racks inside the server hall, where the air enters through 6 paths and after passing through the racks, exits through one path. It should be noted that in all states, six inputs and one air outlet are embedded, and no change in the input and output boundary conditions will occur. Fig. 1 shows the schematic geometry of the rack halls. The main issue in the present study is to investigate the effect of the arrangement of racks on the center of cooling efficiency without changing the boundary conditions of input and output.

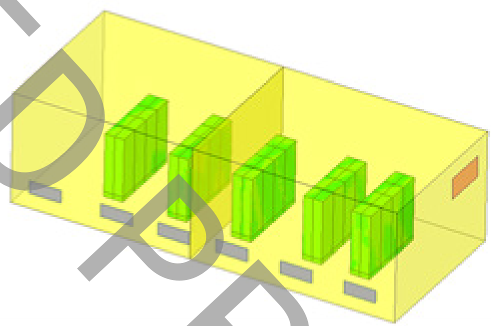

Fig. 1. Schematic geometry of the microwave hall

3- Results and Discussion

In the present simulations, there are 40 racks inside the server. The air enters through 6 paths with a flow rate of 1.15 kg/s and a temperature of 289.15 K, and then leaves through a path with a temperature of 293.15 K. It should be noted that in all cases, six inputs and one air outlet are embedded, and no change will occur in the input and outlet boundary conditions. Racks are in 10 columns and 4 rows. The distance between columns 1 and 2 with columns 3 and 4 is 0.9 meter, the distance between columns 3 and 4 with columns 5 and 6,

*Corresponding author's email: dr.iraj.mirzaee@gmail.com

is 1.6 meters, and the remaining columns have a distance of 1.4 meters.

In server halls, racks have a different power that makes their analysis more sensitive and important. Due to the type of equipment and the type of processing of each rack, their production capacity varies. Fig. 2 shows the power generation of each rack.

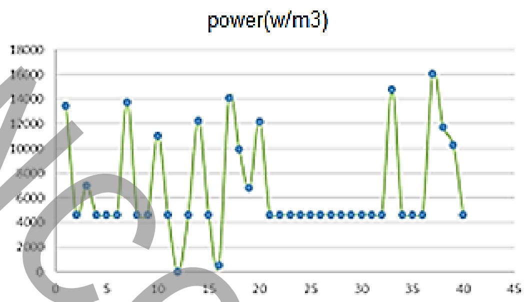

Fig. 2. Racks power generation

To validate the CFD simulation, experimental data that was measured at the racks outlet was used. Comparing the results of the numerical solution and the data of the racks outlet represents a very good match between the results of the numerical solution and the experimental results. Fig. 3 below shows the temperature contour in the four rows. In this contour, the higher temperatures of the racks result from higher input temperatures or higher power.

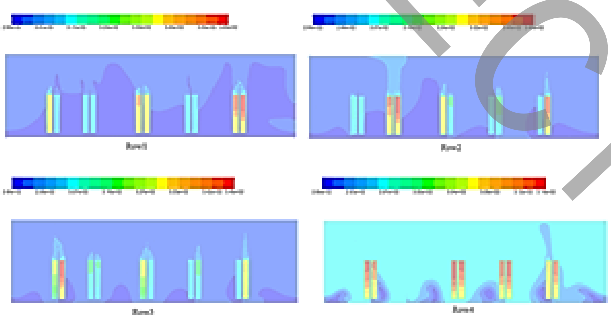

Fig. 3. Temperature contour in the intermediate planes of the Rows

Eq. (1) indicates the general equation of SHI.

$$SHI = \frac{\delta Q}{Q + \delta Q} \quad (1)$$

And also RHI is obtained from Eq. (2).

$$RHI = \frac{Q}{Q + \delta Q} \quad (2)$$

1In the above relations, Q is the total amount of heat dissipated inside the hall. The RHI diagram for different layouts is presented in Fig. 4.

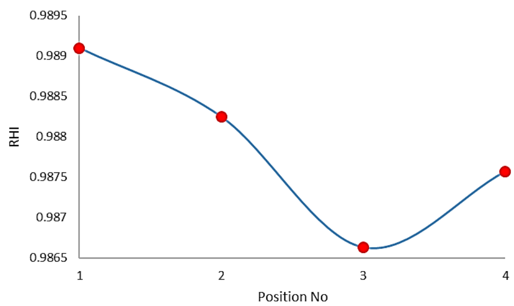

Fig. 4. RHI for different layout states

4- Optimization

At this stage, first, the location of each rack containing x and y from rack number 1 to rack number 5 with their temperature is extracted. For example, rack 1 is located in 8 different layouts and in these 8 layouts the temperature value is extracted. Using this data, it is supposed to implement a minimization function on each of the racks.

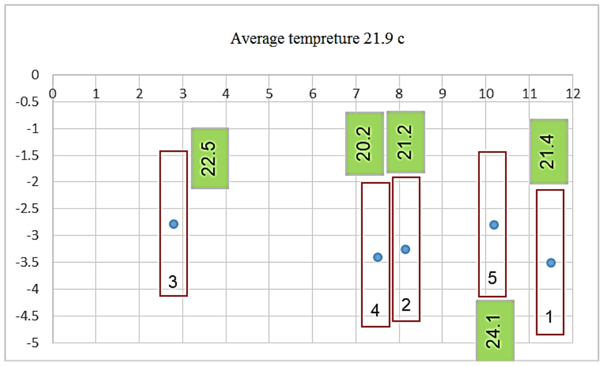

Fig. 5. Optimum rack layout to achieve the minimum average temperature and minimum temperature for each rack

The description of the minimization algorithm is provided in the next steps. Fig. 5 shows the layout and the minimum obtained the temperature of the racks. This is done using the code used in MATLAB software. In the optimum state, the average temperature of the neural network is 21.9°C which is less than 0.7°C in comparison with the best modeling mode and shows that the resulting positions provide the minimum temperature for each rack with the average temperature.

5- Conclusions

The results of CFD simulation for 8 numerical simulations indicate that the first layout is the best state. In this layout, SHI is equal to 0.456 and the worst case is the third layout which has an SHI of 0.631. Finally, the main objective is to obtain the optimal state using the genetic algorithm. It can be deduced from the optimization results that the lowest temperature is 20.2°C and the maximum temperature is 24.1°C.

6- References

[1] R.K. Sharma, C.E. Bash, C.D. Patel, Dimensionless parameters for evaluation of thermal design and performance of large scale data centers, in: Proceedings of AIAA2002-3091, American Institute of Aeronautics and Astronautics Conference, 2002.

[2] M.K. Herrlin, Rack cooling effectiveness in data centers and telecom central offices: the rack cooling index (RCI), ASHRAE Transactions 111 (2) (2005) 1–11.

[3] J. Cho, T. Lim, B.S. Kim, Measurements and predictions of the air distribution systems in high compute density (Internet) data centers, Energy and Buildings 41 (10) (2009) 1107–1115.

[4] Nakao, M., Hayama, H. and Nishioka, M., 1991, which cooling air supply system is better for a high heat density room: Under floor or overhead. Proceedings of International Telecommunications Energy Conference (INTELEC) 12(4), p. 393-400.

[5] C.D. Patel, C. Bash, C. Belady, L. Stahl, D. Sullivan. Computational fluid dynamics modeling of high compute density data centers to assure system inlet air specifications,

The Pacific Rim/ASME International Electronics Packaging Technical Conference.

[6] C.D. Patel, R. Sharma, C. Bash, M. Beitelmal. Thermal considerations in cooling of large scale high compute density data centers, Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, 2002, pp. 767e776.

[7] J. Rambo, Y. Joshi. Multi-scale modeling of high power density data centers, The Pacific Rim/ASME International Electronics Packaging Technical Conference and Exhibition, 2003, IPACK2003-35297.

[8] J. Rambo, Y. Joshi. Physical models in data cneters airflow simulations, ASME International Mechanical Engineering Congress and R&D Exposition, 2003, IMECE03-41381.