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USE OF CFD ANALYSIS TO ACHIEVE ENERGY EFFICIENT DATA CENTER

Sevde Stavreva[1], Marko Serafimov[2], Igor Andreevski[3], Cvete Dimitrievska[4]

Summary: *Several parameters impacting airflow and the achievement of defined work conditions of datacom equipment have been analyzed in an existing data center. First, the necessary measurements were carried out in order to establish the features of the center, as well to use them to create the basis of the numerical model of the data center, via the program package PHOENISC. Simulating the numerical model of the data center, the temperature field, pressure field and velocities within the data center were being achieved. The results obtained by the simulations were compared with the measurements done, showing quite a high concurrence, and thereby confirming the model and becoming available for further data center analyses. The model includes several factors influencing the airflow. Analyzing the obtained results from the model simulations, hints were obtained how to implement changes in the data center, in order to comply with the recommended work conditions for the datacom equipment, and at the same time to achieve reduced energy costs.*
Keywords: *data center, datacom equipment, airflow, field, numerical model, simulation, heat load*

1. DATA CENTER FEATURES

The datacom equipment is positioned upon raised floor with size 18 m x 13 m. The ceiling height is 3 m, and the raised floor height is 0,4 m. The heat dissipation from the datacom equipment amounts to 111 kW, with additional 15 kW from outdoor sources and lighting system. The racks are ordered in rows, with cold/hot aisles layout, the width of the cold aisle being 1,2 m. The air-conditioning of the data center employs three CRACs with airflow of 54000 m^3/h, the CRACs being located in the next room. The conditioned air at 13°C is introduced into the raised floor, then through the perforated tiles on the floor, it is conducted into the cold aisles of the datacom equipment room. The exhaust hot air leaves the room through outlets located near the ceiling.

[1] Ass. MSc., Sevde Stavreva, Macedonia, Faculty of Tech. Sciences-Bitola, (sevde.stavreva@uklo.edu.mk)
[2] Prof.PhD, Marko Serafimov, Macedonia, Faculty of Mech. Engineering-Skopje, (marsersk@)ukim.edu.mk)
[3] Asist. Prof. PhD, Igor Andreevski, Macedonia, Faculty of Tech. Sciences, (igor.andeevski@uklo.edu.mk)
[4] Prof.PhD, Cvete Dimitrievska, Macedonia, Faculty of Tech. Sciences, (cvete.stefanovska@uklo.edu.mk)

The measurements in the existing center helped to create the center layout with the given datacom equipment and perforated tiles, as well as, to establish the heat dissipations from the datacom equipment according to its position and size.

The velocities and the temperatures of the air flowing through the perforated tiles of the raised floor were measured, as well as the air temperature at 1750 mm height from the floor and 50 mm off the front of the air inlets into the racks (ASHRAE 2004h)[3]. The airflow velocities through the perforated tiles of the raised floor are within the range from 0,6 m/s to 1,5 m/s. The temperature differences between the air on the floor level and the air flowing into the racks at 1750 mm height from the floor, average from 4 to 7°C. The temperatures of the return air to the CRACs were measured and compared to the data recorded by the CRACs sensors, the difference being insignificant. The return air temperatures to the CRACs range from 19°C to 24°C.

The measurements in the existing center were used for the numerical simulation of the center, as well as for comparison of the results obtained from the numerical model simulations with the actual measurements.

2. DATA CENTER MODEL

To simulate the airflow in the data center with the program package PHOENICS, the numerical model of the actual- size racks, as well as, the model of the heat dissipation were created, matching the installed equipment in the center. The installed racks have respective heat dissipation of 1,6 kW, 2,3 kW and 3,1 kW, depending on the size. Then, all other remaining elements of the data center, using parameters matching the real situation in the existing data center were numerically put together. Using the created data center model (Fig. 1), simulations employing computational grid with 193 x 216 x 58 cells have been carried out, the range being equivalent to the investigated center.

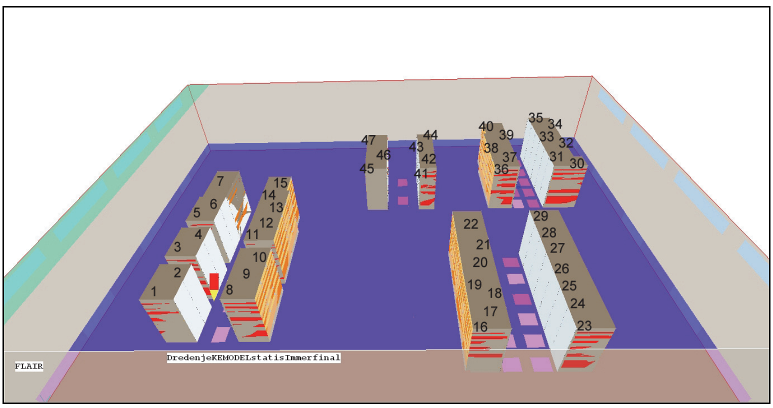

Fig. 1 *Data center model in PHOENICS*

The simulations yielded the temperature field, pressure field and velocities in the data centers, using the standard $k-\varepsilon$ model of turbulence. The temperature distribution in one plane of the center running parallel to the plane xOz, is shown on Fig. 2.

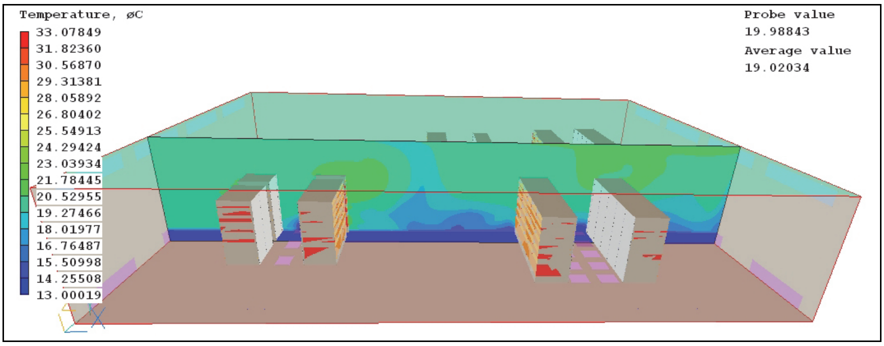

Fig. 2 *Temperature field in xOz plane for the investigated data center (standard $k-\varepsilon$ model)*

3. ANALYSIS OF OBTAINED RESULTS

The simulations yielded a temperature field of the data center, giving a distinct picture of the temperatures at any chosen point in the center, and not exclusively at the measured points. First, the results of the measurements with the results from the simulations at the measured points were compared, and it was established that the deviations were negligible. The air temperature analysis shows that the temperatures in the center in front of the racks, are within the recommended range, i.e. within class 1 (ASHRAE 2004 h)[3], with the total airflow matching the heat load. The causes of the temperature rise in front of the racks, have been analyzed as well, showing that the temperature rise is partly due to the flowing of the exhaust hot air back to the racks, which is especially conspicuous in the upper rack levels, and partly due to the perforated tiles distribution, through which the cold air is supplied to the racks. The possibilities for better and more evenly balanced cooling of the datacom equipment have been investigated.

The impact of the number and distribution of the perforated tiles, of the aisles` width, as well as, of the air velocity through the tiles upon the airflow through the racks and in the data center, was examined.

Analyzing the air temperature and the perforated tiles distribution, it was observed that the cold aisles with more perforated tiles (in front of each rack) provide better equipment cooling. For comparison, the next data center model included additional 27 perforated tiles in the cold aisles however the cold airflow from the CRACs remained the same. In reality, the replacement of an ordinary tile with a perforated one is a simple operation. The simulation results indicate temperature drop of the air in the center (Fig. 3). Detailed examination of the temperature field in the center (in several planes along x, y, z directions) indicates better temperature distribution, and more evenly balanced rack cooling.

Additional three models have been made for this center, the cold aisles` width ranging 1,3 m, 1,4 m and 1,5 m, matching each of the models. Analyzing the temperature fields in the center, and considering the results from the simulations of the three models, it could be concluded that the cold aisles` width does not impact significantly the temperature distribution in the center, since in each of the cases similar temperature fields were obtained as in the case of the cold aisle with width 1,2 m.

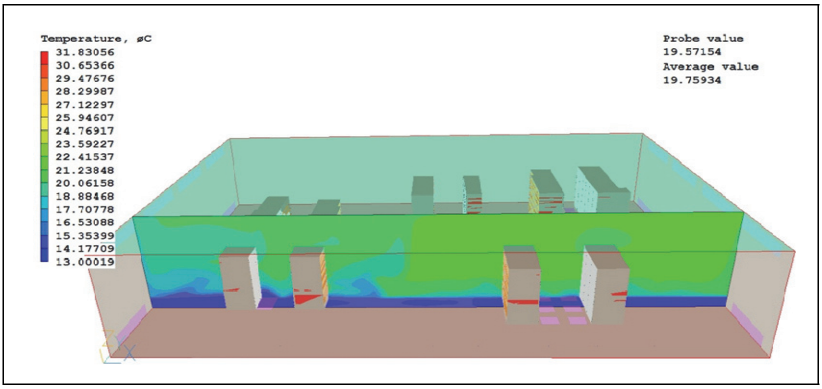

Fig. 3 *Temperature field in xOz plane for the data center with* additional perforated tiles *(standard $k-\varepsilon$ model*)

To explore the impact of the air velocity through the perforated tiles, upon the airflow in the center, additional two models of data centers were developed. In these models the previous distribution of the datacom equipment and the perforated tiles, as well as, the airflow and air temperature at the racks outlets were preserved, the only change being the air velocity through perforated tiles. In the first model the air velocity was reduced 50%, in the second model it was increased 50%, compared to the air velocity through the perforated tiles in the actual center where the measurements were performed. The simulations indicate an increase of 3,1^{o}C regarding the mean temperature in the center for the model featuring increase air velocity through the perforated tiles; the highest temperature in the center is also higher for 2,4^{o}C related to the actual center model. The model simulations with decrease air velocity through perforated tiles indicate that the mean temperature in the center, as well the highest temperature reached in it, are similar to those obtained by the actual center model.

The impact of the ceiling height upon the airflow in the center was also investigated. Several different ceiling heights were examined, and the results showed that the distance between the upper rack and the ceiling should be at least 1m. The hot air, having a relatively small velocity and flowing toward the ceiling, should easily reach the hot air inlets (the plenums above the CRACs), which are located near the ceiling.

A model of the most optimal center was created, taking into consideration the layout of the racks and perforated tiles, the ceiling height and the cold aisles width. The temperature of 17^{o}C for the conditioned air introduced into the raised floor, but not the temperature of 13^{o}C prevailing in the actual center, were assumed. The temperature field obtained by the simulation, indicates that despite the increased temperature of the supplied cold air, the work conditions of the datacom equipment remain in the recommended range for class 1 (ASHRAE 2004h)[3]. The air temperatures at the rack inlets do not exceed 24^{o}C, which is also within the recommended range for class 1. Figure 4 shows a temperature field in a vertical plane for the optimal data center, while figure 5 displays the velocities` profile in one vertical plane of the center. The increased temperature of the supplied cold air contributes to energy saving. The recommended conditions for datacom operation, were attained without jeopardizing the safety of operation, and at the same time reduces the costs.

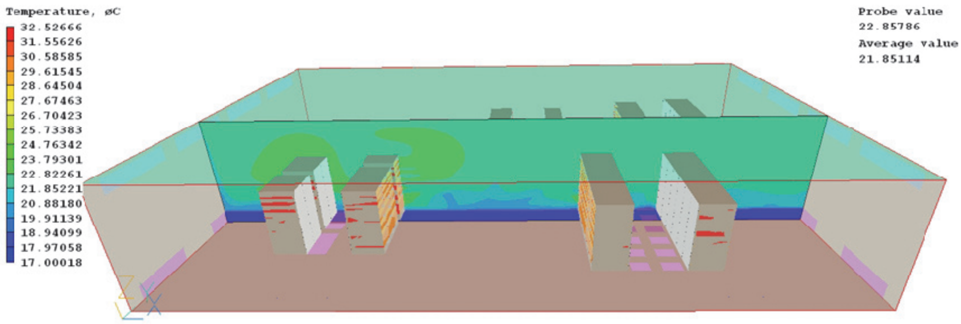

Fig. 4 *Temperature field of the optimal data center, in vertical plane (standard $k-\varepsilon$ model)*

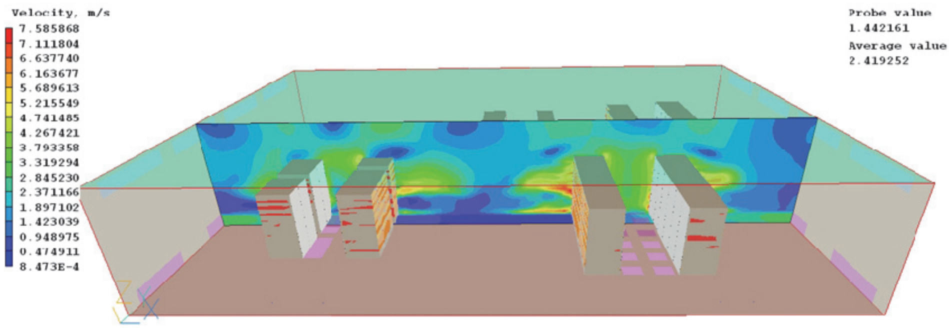

Fig. 5 *Velocity field of the optimal data center, in vertical plane (standard $k-\varepsilon$ model)*

4. CONCLUSION

Data centers are big energy consumers, tending to further increase the energy consumption. The increased energy consumption in data centers is due to the increased capacity of the datacom equipment, as well as to the environmental requirements within defined parameters. Worldwide, great attention is dedicated to the feasible reduction of energy consumption in data centers.

The investigated data center works non-stop 24 hours a day, seven days a week, resulting in three-fold increase of working hours in relation to other administrative buildings; thus rendering each energy savings very important.

Via the models created by program package PHOENICS, the impact of the racks and perforated tiles layout, the air velocity through perforated tiles, the cold aisles width, the distance between the upper racks and ceiling, were investigated; all in order to target the defined parameters for the air at the rack inlets, and at the same time striving to reduce the costs. By optimizing the above discussed parameters, an admissible increase in the temperature of the supplied conditioned air was achieved, thereby accomplishing significant energy savings.

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