Investigation of Irreversibility in Data Centre Environment

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Abstract: IT equipment and systems, housed in data centres, consume a considerable amount of energy. As heat dissipation in data centres rises, thermal manageability and energy efficiency of the cooling infrastructure will be of significant concern. In this paper, a numerical analysis of flow and temperature distribution in a small raised-floor data centre is conducted. Subsequently, a detailed exergy analysis of the data centre is performed to get a better understanding of the room airspace irreversibilities.

Keywords: Data Centre, Computational Fluid Dynamics, Exergy

1 Introduction

A typical data centre consists of racks containing servers and IT systems, computer room air conditioning (CRAC) units, and air distribution systems to supply the cold air to the servers. As heat dissipation in data centres rises, thermal inefficiencies will have a significant impact on the thermal manageability and energy efficiency of the cooling infrastructure. Computational fluid dynamics (CFD) is an excellent tool to study the cooling issues in data centres [1]. In combination with CFD, the concept of exergy may be used to address the cooling inefficiencies in data centres, proposed by Shah et al. [2]. A second law assessment allows one to quantify the irreversibilities, the main source of inefficiencies in the data centre airspace. In this paper, a detailed irreversibility analysis of the data centre is performed to predict the locations of exergy losses with reasonable accuracy.

2 CFD Simulation

The prototype data centre studied here is modelled as a 3.4m × 3.2m × 6m enclosure located over a 60cm deep plenum, as shown in figure 1. There is one CRAC unit with a nominal cooling load of 80kW, which supplies cold-air at 15 ^{o}C with a fixed flow rate of 3m^3/s. The cold air is delivered to the front of the racks, and the resultant hot exhaust air from the racks is returned back to the CRAC. Regions in front and back of the racks are called cold aisle and hot aisle respectively, shown by red boundaries in figure 1. There are seven perforated tiles in the data centre placed in front of each rack, of 0.6m × 0.6m size, in the cold aisle. There is one row of seven racks, as shown in figure 1. Each rack is modelled as 0.6m × 2m × 1m cabinet consisting of five 1kW heat sources resulting in a heat load of 5kW per rack, considering a 10 ^{o}C temperature difference across the rack.

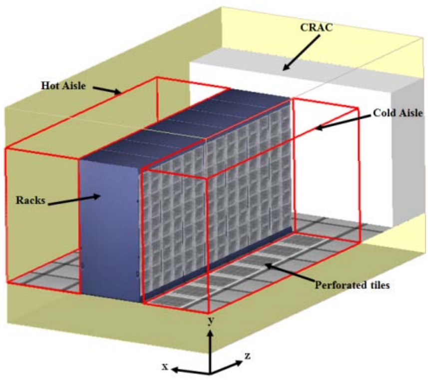


Figure 1: The schematic of the room

Steady state numerical solutions have been obtained using FloVENT v9.2 by Mentor Graphics Mechanical Analysis [3], employing a Cartesian grid and the standard κ–ε turbulence model.

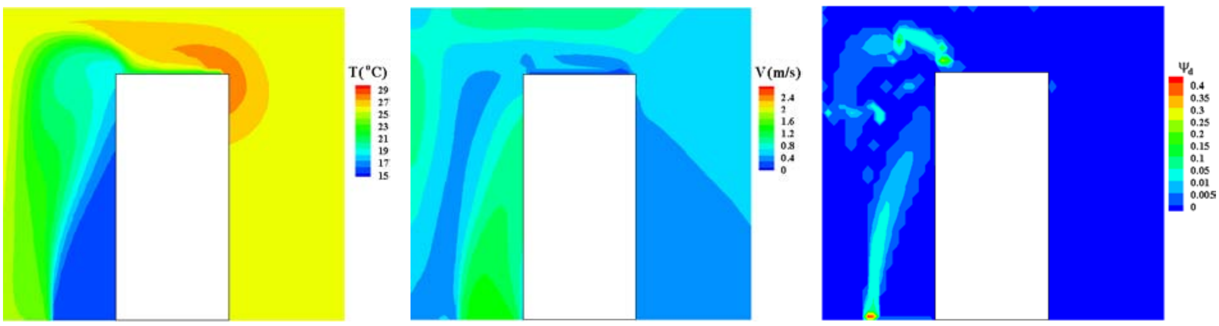
3 Irreversibility Analysis

From a second law analysis point of view, the mixing of hot and cold air streams in the room caused by hot air recirculation is an irreversible process, leading to wasted work potential in data centres. Any irreversibility in the data centre environment results in a decline in the quality of the energy. For calculating the irreversibility exergy destruction in the room airspace (excluding racks and CRAC), equation (1) has been applied, using the quantities obtained from the CFD analysis. For the i^{th} cell in the room, the exergy destruction is obtained by summing up the exergy flows on the corresponding j^{th} faces of the cell.

$$\dot{\Psi}_{d_i} = \sum_j \dot{m}_j \left[C_p(T_j - T_o) - T_o C_p \ln\left({T_j}/{T_o}\right) + {V_j^2}/{2}\right] \tag{1}$$

4 Results

Figure 2 shows thermal, velocity and exergy destruction fields in the room. The temperature and velocity fields show regions of high gradient where significant mixing and losses may be expected. The exergy destruction field shows the precise locations where the temperature and velocity combine to give high exergy destruction, allowing these regions to be targeted in the design of the system.



(a) (b) (c)

Figure 2: (a) Temperature, (b) total velocity and (c) Irreversibility maps, all at z=2.1m

5 Conclusion

In this paper, a detailed exergy analysis of the data centre is performed to get a better understanding of the room airspace irreversibilities. Results show that areas of irreversibility and loss may be precisely located using the exergy destruction than by considering only the temperature and velocity fields.

References

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