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Research Paper

On cold-aisle containment of a container datacenter

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HIGHLIGHTS

- Influences of layout, blockage, and containment on the performance of a container datacenter.
- The experiments are performed with a constant inlet temperature and 30 kW with 10 3-kW racks.
- Partial containment with enclosing door at the entrance of cold-aisle shows superior performance.
- A full cold-aisle containment with higher jet airflow pattern shows the worst performance.
- A full cold-aisle containment design without Coanda effect shows the best overall performance.

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ABSTRACT

In this study, influences of various blockage arrangements as well as cold-aisle containment on the overall efficiency of a container datacenter are reported. The test container datacenter contains ten racks and the cold air is supplied from drop ceiling. The experiments are performed with each rack equally delivering a power of 3 kW. Eight different layouts are examined. Appreciable hot air recirculation prevails especially at the entrance of cold aisle. Adding blockage plates to the computer room air handler (CRAH) at the entrance of computer racks only improve marginally the associated rack cooling index (RCI). Layout with enclosing the end of cold aisle while let open the entrance of cold aisle also performs poorly. Full containment of the cold aisle with high jet air flowrate from the supplied grilles gives the worst performance. Layout with enclosing at the entrance of cold aisle but let open the end of cold aisle shows a much superior temperature distribution and a rather high RCI of 99%. Higher supplied flow may induce jet airflow pattern, causing the Coanda effect to result in fluctuating behaviors of RCI and SHI alongside the cold aisle (zigzag phenomenon). A lower supplied air flowrate without Coanda effect for a full containment design give the best overall performance.

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1. Introduction

Datacenters are rooms containing array of racks, which comprise many servers for data storage, processing, and computing. With the advents of internet, the demand of computer server, IT equipment, and the need for datacenters is growing rapidly. Nowadays, most of the transactions, communications, computing, and storages that are processing in datacenters in association with almost every application such as banks, telecommunications, mobile phones, market transactions, universities, military service, government affairs and offices, and others special and private applications. According to the survey of Koomey [1] about the worldwide electricity used in datacenter, it appears that the aggregate electricity use for datacenters doubled worldwide for every five years (evaluated over the period 2000–2005). Yet the combined worldwide electricity consumption of datacenters has increased from 152 billion kW h per year (in 2005) to approximately 238 billion kW h per year (in 2010) [2], representing a growth of roughly 11% per year over the last decade as compared to the average 3% growth of electricity per year in whole sectors [3]. Notice that a large portion of this consumed energy (almost 50%) is necessary for cooling of servers to maintain their temperature within the allowable limits [4]. Hence, proper cooling management in datacenter would appreciably relax the cooling load of the chilling utilities. Consequently, a much more detailed understanding of airflow and temperature distributions for proper thermal management in datacenters is a vital issue subject to requirements of temperature limits while avoiding excessive use of cooling [5]. The layouts and features of all datacenters are similar; the most popular layout takes the form of a hot/cold aisle configuration to minimize mixing of hot and cold air. The cold air can be delivered from either drop ceiling or raised floor. For further minimizing the hot air re-circulation and cold air bypass, full

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Nomenclature

H	height, m
L	length, m
n	total number of intakes
Q	the total heat dissipation from all the racks in the data center, W
dQ	the rise in enthalpy of the cold air before entering the racks, W
RCI	rack cooling index, dimensionless
SHI	supplied heat index, dimensionless
T	temperature, °C
W	width, m

Superscripts

r	rack

Subscripts

Avg	average value
HI	high
in	inlet
LO	low
max	maximum value
max-*rec*	maximum recommended
max-*all*	maximum allowable
min-*rec*	minimum recommended
min-*all*	minimum allowable
out	outlet
ref	CRAH supply

containment of hot aisle or cold aisle can be adopted. In this study, efforts are focused upon the cold-aisle containment and relevant blockage arrangements.

Using proper air distribution to reduce or to prevent the hot air recirculation and/or the cold air bypass is effective and to be efficient thermal management of datacenters. In practice, avoiding mixing of hot and cold air mixing is a key for efficient datacenter cooling strategies. Hence containment of hot-aisle or cold-aisle throughout the datacenter is an important thermal management and energy saving strategy. Arghode et al. [6] performed thermal field measurements of cold-aisle containment with a raised floor design, they concluded a significant improvement in the cold air delivery for the case with contained aisle as compared to open aisle. Takahashi et al. [7] experimentally investigated the performance of cold-aisle capping and hot aisle capping methods subject to raised floor design. They also reported cold-aisle containment delivers 15% lower fan power. Some previous computational investigations also reported the benefits of cold-aisle containment. For example, Schmidt et al. [8] and Gondipalli et al. [9] indicated that the deployment of cold-aisle containment can result in significant energy savings. Moreover, in the case of cooling failure, cold-aisle containment was suggested to result in reduced hot spot generation with time as compared to the case without containment. Note that the cold-aisle is a pathway in front of the computer rack to bring in the cold airflow into the server racks from the grilles. Hence, the major benefit of cold-aisle containment is the mitigation of server air inlet temperatures due to the minimum mixing of cold air with hot air. Hence, most energy efficient datacenters use some kind of containment system [6,9–11]. Although the foregoing studies had addressed the benefits of cold-aisle containment to some extent, however, these studies were conducted in comparatively large size data center and mainly applicable for raised floor door deign. In practice, small-scale datacenters (such as containers) using drop ceiling configuration may be easier to implement. Thus, the objective of this study is to experimentally investigate the relevant blockage layouts as well as cold-aisle containment on the overall efficiency of a datacenter within a typical container size datacenter. Yet it will be shown later on that a full cold-aisle containment does not necessary gives the best performance.

2. Test facility and measuring equipment

Fig. 1 shows the system layout of the datacenter simulation laboratory. The test facility contains a 30 refrigeration tons (RT) water chiller made by Yi-Guo refrigeration enterprise, a chilled water tank with 1500 L capacity, a computer room air handler (CRAH, Teco corp., model PHWP-K1500CUL1) with a controllable air flowrate ranging from 0 to 4 $m^{-3}\,s^{-1}$, a water pump (Liang Ghi Corp., model AEEP-PW, 2 hp with a maximum flowrate of 360 L/min), a simulation zone which contains 10 simulation racks. The evaporator of the chiller is installed within the water tank to control the setting temperature. Accordingly, the cooling water is circulated to CRAH to lower the return air temperature from hot aisle. Then the cold air is discharged into the cold aisle of container datacenter while the warm water from CRAH is circulated back to the tank. The racks are arranged in a two-row parallel fashion as shown in Fig. 1 and the space between the rack and ceiling are blocked to avoid short circuit of air flow. The simulation zone is of a typical container configuration with 20 ft container with dimensions being 6 m (L) × 3.1 m (W) × 2.3 m (H). It contains 10 simulation racks and the detailed dimensions and locations of the computer rack and CRAH are shown in Fig. 2. The size of each rack is 0.6 m (L) × 0.6 m (W) × 1.95 m (H), yet it is composed of five heating parts as depicted in Fig. 3. Each heating part consists of AC heaters with an adjustable heating power to 3 kW. The maximum heating power of a simulation rack is 15 kW. A total of 45 DC fans (Delta, model: AFB1212SH) are installed in front of the computer. The revolution of the DC fan is adjustable via programmable logic controller (PLC, model FBs-4DA) made by FATEK, yet each fan can deliver a maximum airflow rate up to 0.053 $m^3\,s^{-1}$. The inlet temperatures into each computer rack is measured by 225

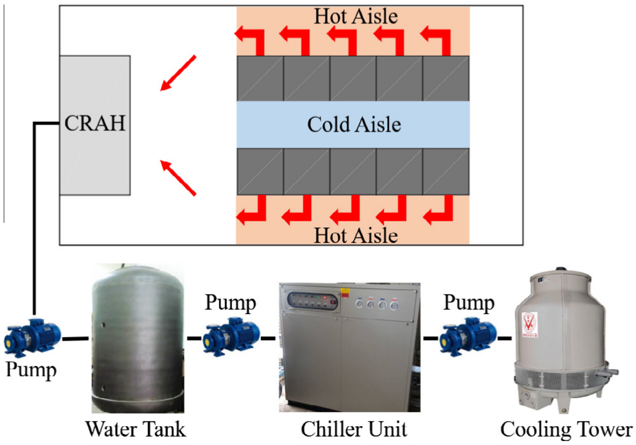

Fig. 1. Schematic of datacenter system and chilling utility layout.

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