4th Virtual International Conference on Science, Technology and Management in Energy
October 25-26, 2018

Analysis of an indirect evaporative air cooler

Matjaž Prek[1], Gorazd Krese[2], Žiga Lampret[3]

[1]University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia, matjaz.prek@fs.uni-lj.si
[2]Korona d.d., Ljubljana, Slovenia, gorazdkrese@gmail.com
[3]University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia, ziga.lampret@fs.uni-lj.si

Introduction

People spend in buildings between 80-90% of the time, which is why especially in recent decades, a lot of attention was paid to the comfort in the indoor environment. Air conditioning systems are becoming increasingly important in order to achieve the appropriate objectives of thermal comfort and air quality. Cooling demand in buildings is increasing as a results of global warming which represents a significant challenge in light of achieving the goals for reducing energy consumption. Evaporative cooling represents an efficient and economically feasible alternative method..

Performance of a counter-flow indirect evaporative air cooling device is analysed numerically. The device characteristic dimensions, inlet air temperature and humidity as well as inlet air velocity are investigated for the assessment of the thermal performance with the aim to determine the most influential design parameters.

Evaporative cooling

Evaporative cooling is a process of conversion of liquid water into vapour using the thermal energy in the air, which results in a lower air temperature. The energy required for evaporation of water comes from the sensible heat affecting the temperature of the air.

Evaporative cooling effect is used in various air cooling systems. Due to the simplicity and effectiveness of the process, devices using this effect achieve high cooling efficiency at low levels of primary energy consumption. There are two major types of evaporative cooling, i.e. direct and indirect.

Direct evaporative cooling is a process where cooled air is in direct contact with water (Figure 1) . The heat and mass transfer between air and water reduces the air temperature and increases its humidity at a constant wet-bulb temperature. Air temperature is limited with the wet-bulb temperature of the inlet air as the air moisture content reaches saturation point and the process of evaporation is concluded. Wet-bulb effectiveness of direct evaporative cooling systems ranges between 70% to 95%, depending on the configuration.

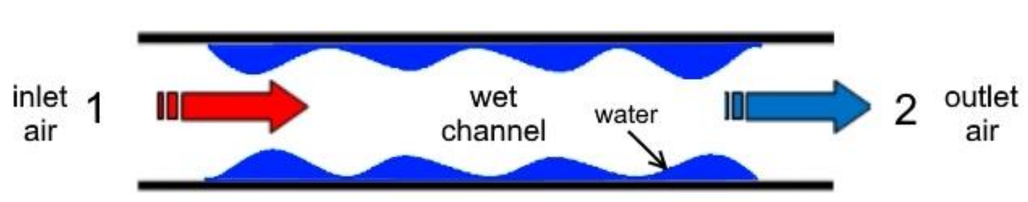

Figure 1: working diagram of direct evaporative cooling

Indirect evaporative cooling process is used in systems where airflows of the wet and dry channels are separated physically, so the inlet air is only cooled with no changes in moisture content. Product air flowing through the dry channel is in contact with the dry side of the wall, which is cooled by the working air flowing through the wet channel. In the wet channel evaporation of the water lowers the working air temperature and indirectly also the wall and consequently the product air (Figure 2). Efficiency of indirect evaporative cooling is limited by the working air wet-bulb temperature. Wet-bulb effectiveness of indirect evaporative cooling is typically in the range between 55% to 75%.

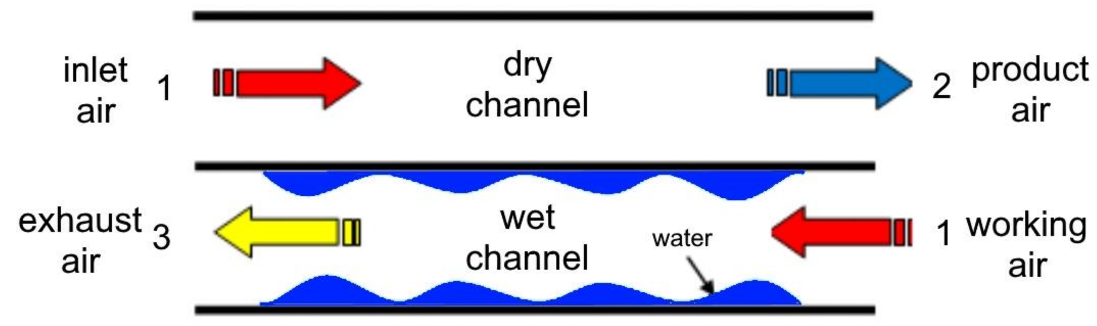

Figure 2: working diagram of direct evaporative cooling

Counterflow indirect evaporative cooling system

Counterflow indirect evaporative cooling system addresses some of the shortcomings of the described evaporative cooling systems. The device is composed of a series of parallel channels, wet and dry channels follow alternately (Figure 3). Inlet air enters the channel from the right side. At the end of the channel a part of the inlet airflow is used to cool the ambient while the residual airflow is diverted into a wetted channel where it comes in contact with the wetted surface. This air flows through the wet channel countercurrently to the primary air and is discharged at the end as waste air. During this process the inlet air can be cooled to the dew point temperature and not just the temperature of the wet-bulb temperature, because the secondary airflow is pre-cooled in a dry channel where dry-bulb and wet-bulb temperatures are reduced.

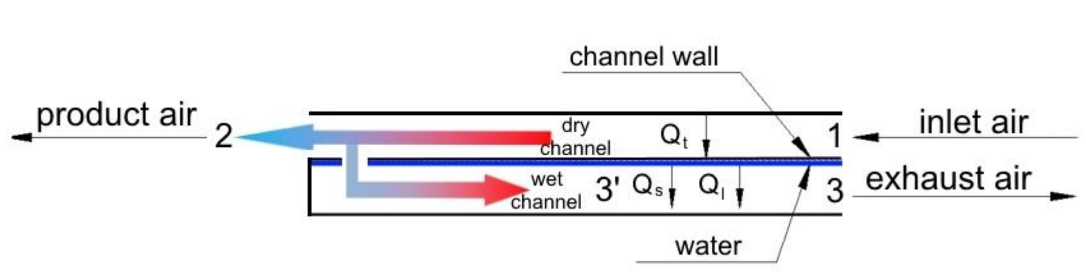

Figure 3: working diagram of direct evaporative cooling

Figure 4 shows the primary and secondary air transformation of the countercurrent evaporative cooling device. Inlet airflow is cooled without adding moisture (1-2 state change). Lowest possible temperature is the dew point temperature of the inlet air. Part of the inlet air diverted to the wet channel is subjected to direct evaporative cooling. Lowest temperature this diverted air can reach is the wet-bulb temperature (state 3'), where it reaches the saturation point. From this point on the evaporative cooling is stopped and the air is heated by the inlet air entering the dry channel.

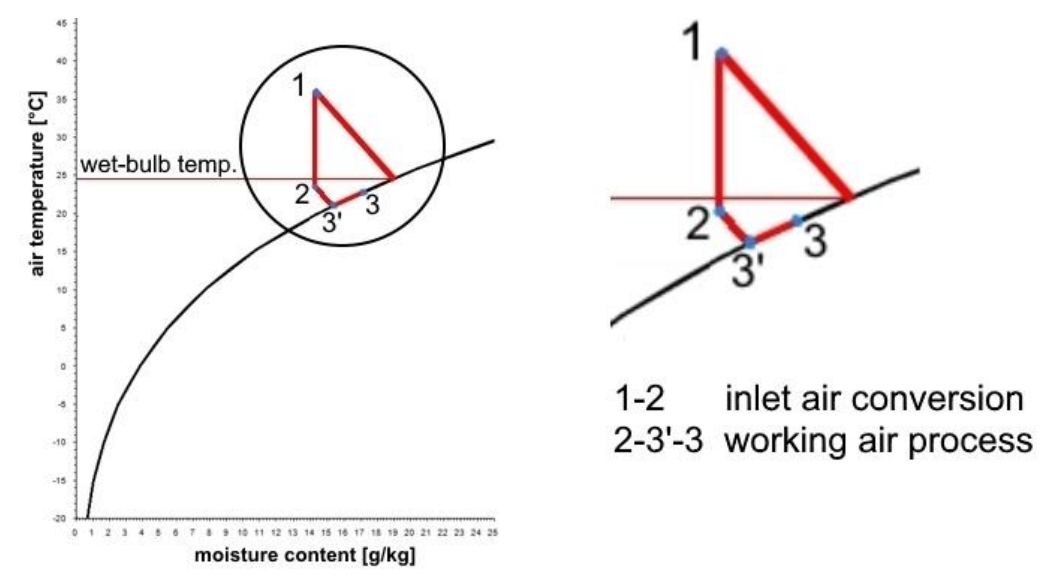

Figure 3: primary and secondary air conversion in the countercurrent cooling device

Results and conclusions

A numerical analysis of the proposed counter-flow device for indirect air evaporation was performed to better understand the changing temperature of the airflows and the water film in the device, and to determine the optimum dimensions of the device, from the effectiveness standpoint.

A number of parameters have been analysed to evaluate the effect on the device cooling effectiveness as well as on the cooling load. The influence of the length of flow path has shown that increasing the length of the device results in higher device effectiveness. Temperature and humidity of the inlet (outer) air were analysed, showing that both parameters have a key influence on the parameters of the generated cool air stream (Figure 4).

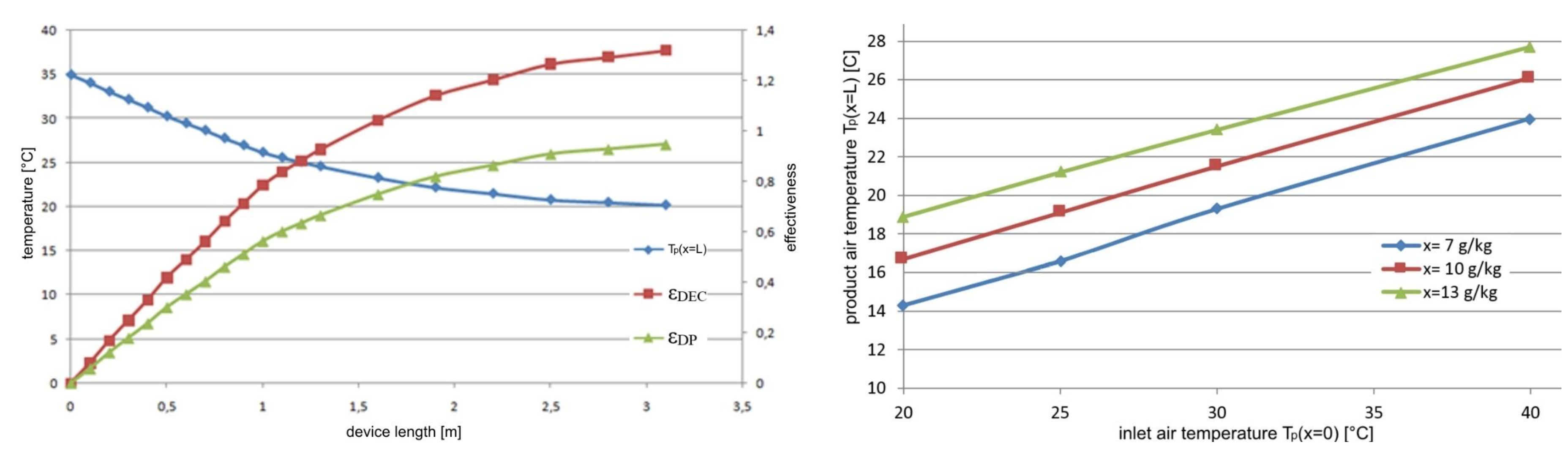

Figure 4: product air temperature, wet-bulb and dew point temperature effectiveness' for various device lenghts (left); product air temperature for different inlet air conditions (right)

Velocity analysis showed the importance of choosing the optimal speed, since too low or too high air velocities in the channels can cause a decrease in the cooling power:

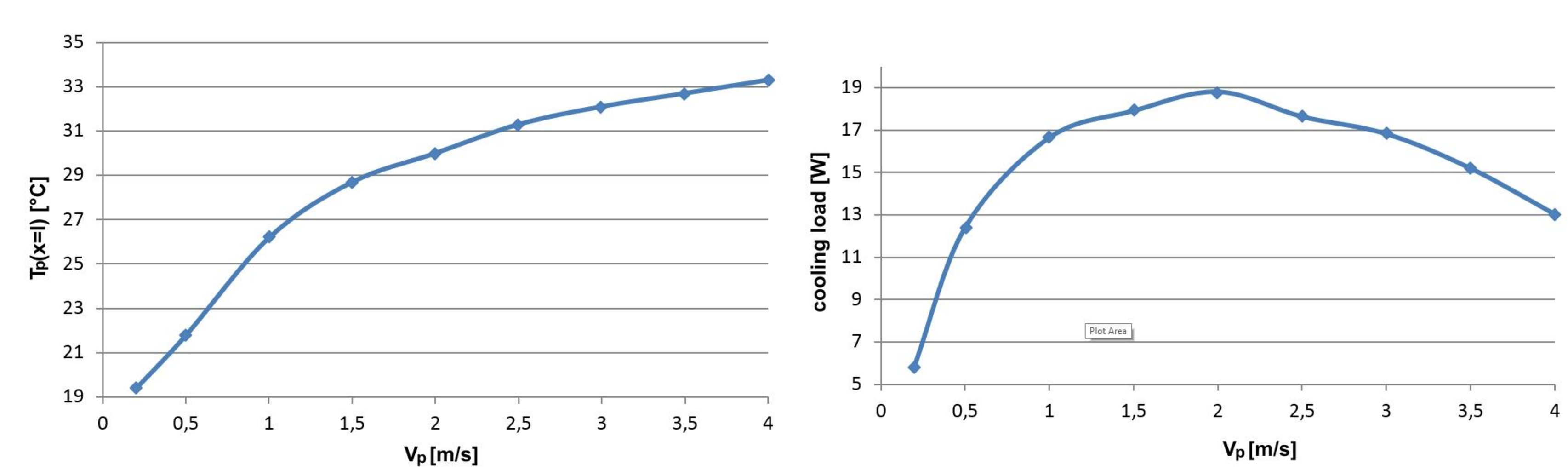

Figure 5: primary airflow velocity effect on the product airflow temperature (left); primary airflow velocity efefct on the device cooling load

For local climatic conditions, where the maximum air temperature in the summer time is approximately 35°C at 40% relative humidity, a device must be at least 1.5m in length for an appropriately tempered inlet air into the space where the outlet air temperature is approximately 23.5 °C. By extending the flow path further, lower temperatures can be reached, with a theoretical minimum temperature of 19.4 ° C.
The obtained results will be taken into account when designing a prototype device for counter-flow indirect evaporation cooling.

Literature

[1] Caliskan H, Hepbasli A, Dincer I, Maisotsenko V. Thermodynamic performance assessment of a novel air cooling cycle: Maisotsenko cycle. Int J Refrig 2011;34:980–90

[2] Zhiyin D. Investigation of a Novel Dew Point Indirect Evaporative Air Conditioning System for Buildings. University of Nottingham, 2011.

[3] Guo XC, Zhao TS. A parametric study of an indirect evaporative air cooler. Int Commun Heat Mass Transf 1998;25:217–26.