Prototyping a 2-phase cooling system for electronic applications

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Abstract

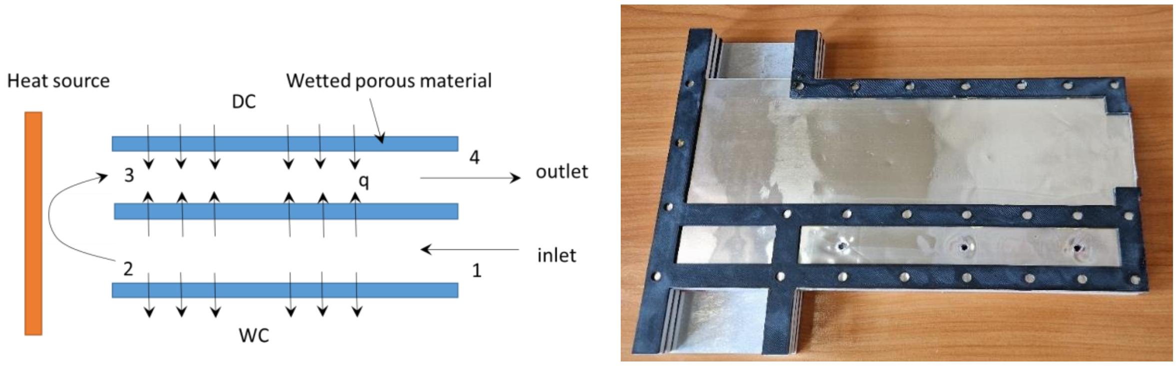
The paper presents cooling system based on the Indirect Regenerative Evaporative Cooling (IREC) concept. The prototype of the IREC system is developed for applications in electronics. Cooling relies on forced convection, where air is significantly cooled due to the phase-change – water evaporation. The system features two types of channels - dry and wet, through which the cooled air and moist air circulate. Water is supplied via porous membranes in the wet channels. The cooling system was tested in conditions of higher ambient temperature at the inlet.

1. Introduction

Among different heat dissipation systems, the Indirect Regenerative Evaporative Cooling (IREC) becomes attractive as if can sustain effecting in the high ambient temperature [1],[2],[3],[4]. It originates from the HVAC (Heating, Ventilation, and Air Conditioning) systems [2],[3][4]. In literature, the IREC system is known as M-cycle (Maisotsenko cycle) heat exchanger [2]. The innovation of our research involves both reducing the scale and directing all air from the dry channel to the wet channel to intensify evaporation. This mode of operation was named Full-Flow Return (FFR) [1]. The main advantage of IREC/FFR application in electronics is effective cooling at high ambient temperatures, even if the ambient temperature exceeds the temperature of the heat source.

2. Prototype of IREC system for electronic applications

The IREC/FFR system is typically implemented by 2 thermally coupled air channels: dry (DC) and wet (WC) as shown in fig. 1a. Dry air passing DC is cooled down significantly due to the evaporation process in WC. The heat source is placed at the end of DC and beginning of WC, where the airflow cools it down. This is the cooling area for an electronic device and the heating point for the dry air. Next, the heated dry air is directed to WC with wet walls made of the porous membranes sucking the water from the reservoir nearby. While air is flowing in WC, evaporation generates the cooling flux q as presented in fig 1a. Fig. 1b shows the wall of the dry channel during assembling the exchanger.

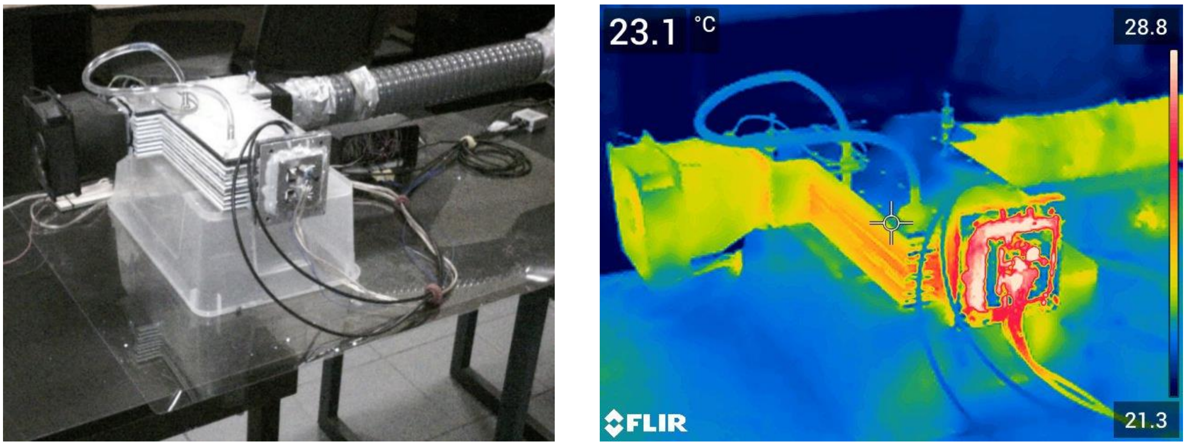


a) b)

Figure 1. a) – concept of IREC system and b) – the exchanger during the assembling

The mounted exchanger is presented in fig. 2 on the testing rig. This rig is equipped with numerous sensors in the different points to measure temperature T, relative RH and specific SH humidity, pressure p and air velocity v. As seen in fig. 2b on the thermal image, the heat is generated by a power elements in the front side of the exchanger.

There is a part of heat dissipated directly by natural convection to ambient. In order to reduce this leak of energy, the heat source was insulated by a box made of Styrofoam.



a) b)

Figure 2. a) The IREC system for electronic applications during operation b) a thermal image with the heat source in front

3. Preliminary results

The measurement results are gathered in table 1. The measurement points 1…4 referring to ambient/DC inlet, DC outlet, WC inlet and WC outlet correspond to the numbers presented in fig. 1. In the experiment, the ambient temperature was increased above 40°C by an external heater. The power P=12 W was dissipated in the electronic device generating the stabilised temperature T=45°C using the PID controller.

Table 1. Temperature, relative and specific humidity measured during the test

1 – ambient			**2 – DC outlet**			**3 – WC inlet**			**4 – WC outlet**		
T °C	**RH %**	**SH g/kg**	**T °C**	**RH %**	**SH g/kg**	**T °C**	**RH %**	**SH g/kg**	**T °C**	**RH %**	**SH g/kg**
41,22	13,30	6,55	**16,50**	**59,70**	**6.94**	23,16	39,10	6.94	24,58	55,18	11.42

The performance analysis of the developed heat exchanger is very convenient to analyse using the psychrometric chart – fig. 3.

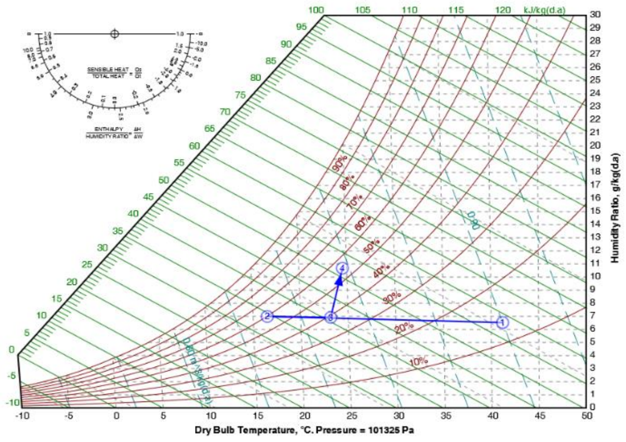


Figure 3. Thermodynamic processes in the IREC exchanger presented on the psychrometric chart [5]

Point (1) corresponds to the inlet of DC. Then air passes the DC being cooled down simultaneously – point (2). Next, the heat source increases the air temperature by almost 8°C – point (3). Finally, the slightly heated air with a higher specific humidity is discharges outside the WC – point (4). As can be seen the cooling of air in the DC is about 26°C reaching the value of 16°C.

4. Conclusions

A prototype of IREC/FFR heat exchanger was developed and measured in this research. It works according the expectation, cooling down air that was then used the absorb heat from an electronic system. A little amount of water is needed for moisturizing the porous thin layer during an operation. The system needs forced flow of air made by a fan, which consumes a little of electrical energy. The efficiency defined as the ratio of dissipated energy to energy consumed by the fan can reach a factor of 5-10.

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5. References

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