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Research Article

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Evaporation Cooling with Ceramics in Air-conditioning System

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Abstract Last years' climate change shows that the energy sources and energy supply security is very important in our life. Hot summers and variable weather put to test our adaptability. If the air temperature is over 35 °C it has a bad effect on the human body. Solar energy is one of the significant among the renewable energy resources, which can be utilized immediately for cooling, especially in summer. It has direct and indirect forms of use. We can use solar energy directly by solar cells or solar collectors for cooling systems. Indirectly for example by wind energy, which we can cool our buildings. Nowadays the low energy consumption is very important for the environmentally friendly cooling systems. Some coolant gases are harmful for ozone layer. In our paper the porous materials' cooling performance is discussed and shown that how water evaporation in air-conditioning system by using solar energy can be utilized.

Keywords climate change, evaporation cooling, ceramics, air-conditioning, experiments

1. Introduction

Mainly we use fossil fuels for comfortable life and work. The traditional air-conditioning systems work with electricity. These devices gain their energy from the electric grid, which can be overloaded in summer during hot period. It is a danger to the energy supply. If electrical energy comes from fossil fuel power plant it causes more greenhouse gas emissions in this period.

One of the environmental friendly ways is the solar energy utilization for cooling. Simple case is when the solar cells operate compression cooler. If we have solar heating system, we can combine this with an absorption or an adsorption cooling system [1]. The solar collector's operation temperature has an important role in choosing the sorption cooling system.

Next to the active system there are so many ways of passive cooling possibilities. The shadow causes significant temperature decrease, where we do not have to use energy. Simple and easy way of cooling is the evaporative cooling with water. These methods are direct or indirect cooling ways [2]. Direct way is when the drip coolers is used. Indirect way is the evaporation with porous dishes. During evaporation the fluid there are heat losses, so its temperature is decreasing [3-4].

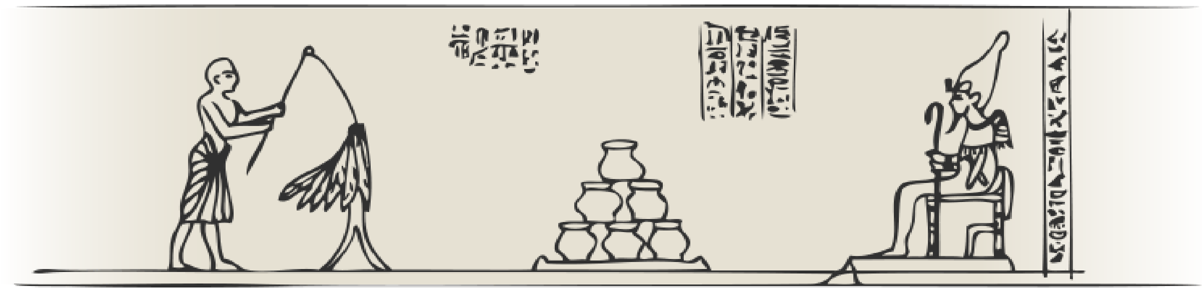

Figure 1: First application of evaporation cooling with ceramic pots [5]

There is a strong history of evaporating cooling [7]. The first picture of evaporation cooling came from the Ancient Egypt (Fig. 1), which shows the simple air-conditioning with pots. This was a direct evaporation cooling system with porous pots filled water. These pots were fanned to enlarge the evaporation speed.
By agricultural works the harvest pitcher (Fig. 2) was used, in which the water could be kept cold during a hot summer day. The water was colder about 10 ^oC than the actual air temperature. Such pots had not glaze, so the water could evaporate through the pot wall and it was cold.

Figure 2: Harvest pitchers [10] (left picture), [9] (right picture)

In the hot and arid regions, the inside air has to be cold and wet, so the direct evaporation cooling is a simple way for this. In the South-West States of America and Australia this type of evaporation cooling devices are used for air-conditioning, which can be seen in the Fig. 3. This device uses fan for air moving and a pump supply the water for a cellulose pad. The outside air is coming through the pad, so it cools down and the fan move the cold air to the inside space. The cooling pad has two functions: one is cooling down the incoming air, the second is filtrating the air before entering the rooms. By direct evaporative cooling the inside air is humidified.

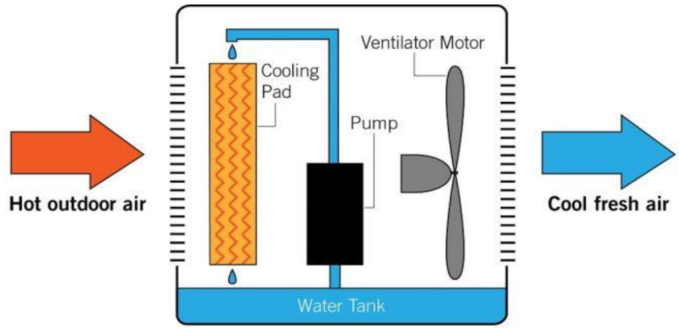

Figure 3: Evaporation cooling with cellulose pad using water [6]

Application of direct evaporation cooling with ceramic pots can be seen in the Fig. 4.

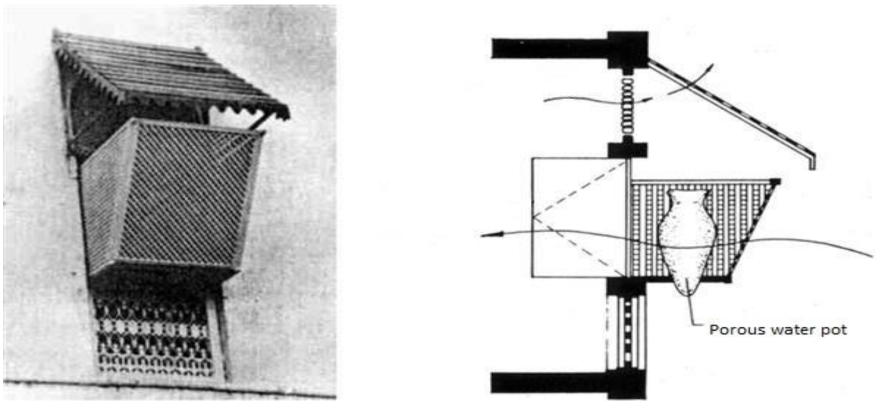

Figure 4: Ceramic cooling's application by buildings
(edited from the following source[8])

In the recent paper it is aimed at how the porous materials can be used for cooling how the water evaporation process can be utilized in air-conditioning system assisting by solar energy. Experimental approaches are to be used for that purposes.

2. Experimental and calculation procedures

For the analysis of evaporation cooling's possibilities in summer we used ceramic pots with water as working fluid. During the measurements some average ceramic (flower) pots and some individual ceramic pots were used. These pots were unpolished and had not glaze. They were filled with water. The temperature of the water (T_{w1}, T_{w2}), the outside air (T_{air}) and the surface (T_{s1}, T_{s2}) were measured by Pt1000 sensors. The data were collected by a computer. The air velocity (v_{air}) from fan was also detected with an anemometer. The air's relative humidity was measured, too. During the measurement we scaled the mass change of the pot (m_1, m_2) with digital scales, from which we could calculate the evaporated water quantity. The Fig. 5 and 6 show the experimental materials with devices.

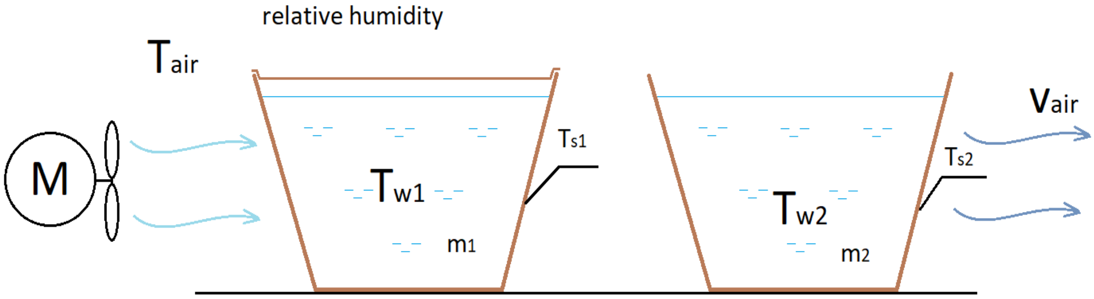

Figure 5: Experimental evaporation cooling with measuring parameters (closed and open pots filled with water)

Figure 6: Clay pot partly filled with water

As it can be seen in theFig.6 and 7, the evaporation process depends on the ceramic material. Where the ceramic wall can be more wet, there is more evaporation, so the cooling is stronger.

Figure 7: Clay pot with more porous (water drops)

The cooling performance can be determined from the following forms:

$$P_{cooling} = L_e \cdot \dot{m}$$

where L_e is the latent heat of evaporation [J/kg] and $\dot{m}$ is the mass flow [kg/s].

The cooling power in an energetic system's can be determined by the material's surface. To complete this equation with evaporation surface we get a new formula for specific cooling performance, which dimension is W/m^2:

$$P_{sc} = \frac{L_e \cdot \dot{m}}{A_e}.$$

According to the (measured) evaporated water quantity we can determine the evaporation mass flow. This value shows how many square meters surface we need to achieve a required cooling performance:

$$A_e = \frac{L_e \cdot \dot{m}_e}{P_{sc}}.$$

Along with this information and using the mentioned equations we can calculate the water loss of the planned cooling system, as it is to be presented later in the paper. The evaporation mass flow mainly depends on the following parameters:

- air velocity,
- porous materials quantity,
- air humidity, and
- air pressure.

Finally, it can be simply concluded that if we reduce the humidity and the pressure the evaporation speed is able to increase.

3. Results and discussions

Fig. 8 shows the results of measured temperature distributions for two different experimental setups, when water and distilled water were evaporating in same size pots during the measurements. The relative humidity of the air was 45%. There was a small difference in the water temperatures (average 1.2 ^{o}C). The temperature between the air and the distilled water was an average of 5.9 ^{o}C.

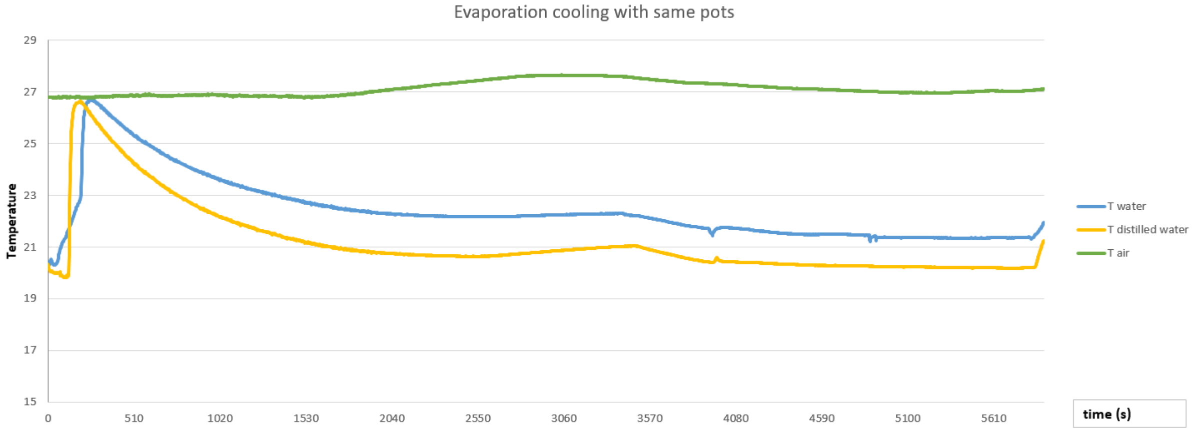

Figure 8: Evaporation cooling with same pots

From the measurements it can be concluded, that the usage of distilled water does not give significant difference to the usage of simple tap water, which is much easier available.

In the Fig. 9 the evaporation temperature changing effect can be observed (in ^{o}C). The picture was taken by a thermal image camera, measuring with the resolution of 0.1 ^{o}C.

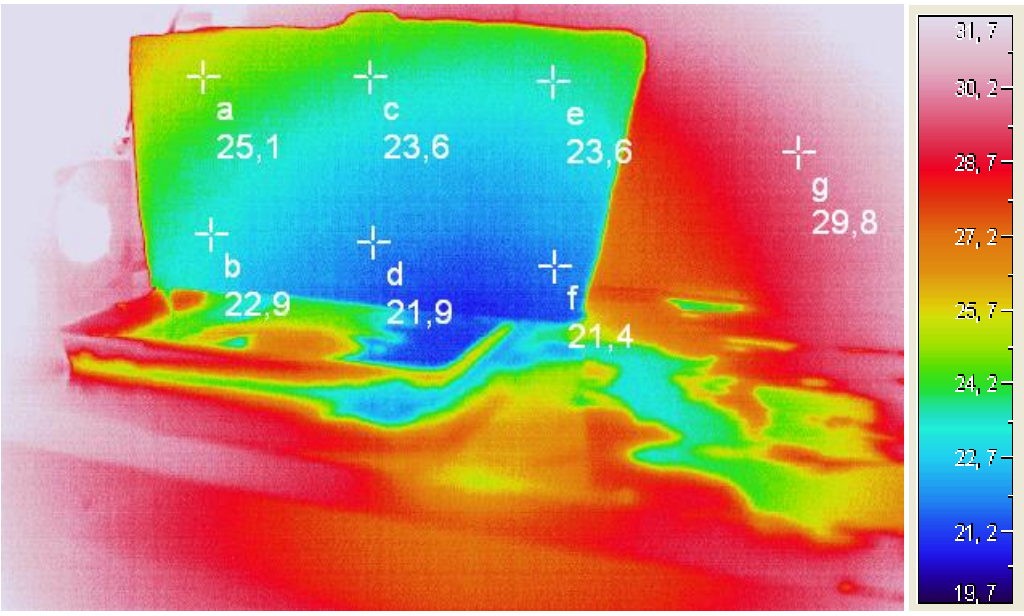

Figure 9: Infrared picture of an open individual ceramic pot (temperature values in °C)

The materials quality determines the cooling performance. The performance value is changing by evaporation mass flow, that can be seen fairly well in the Fig.10.

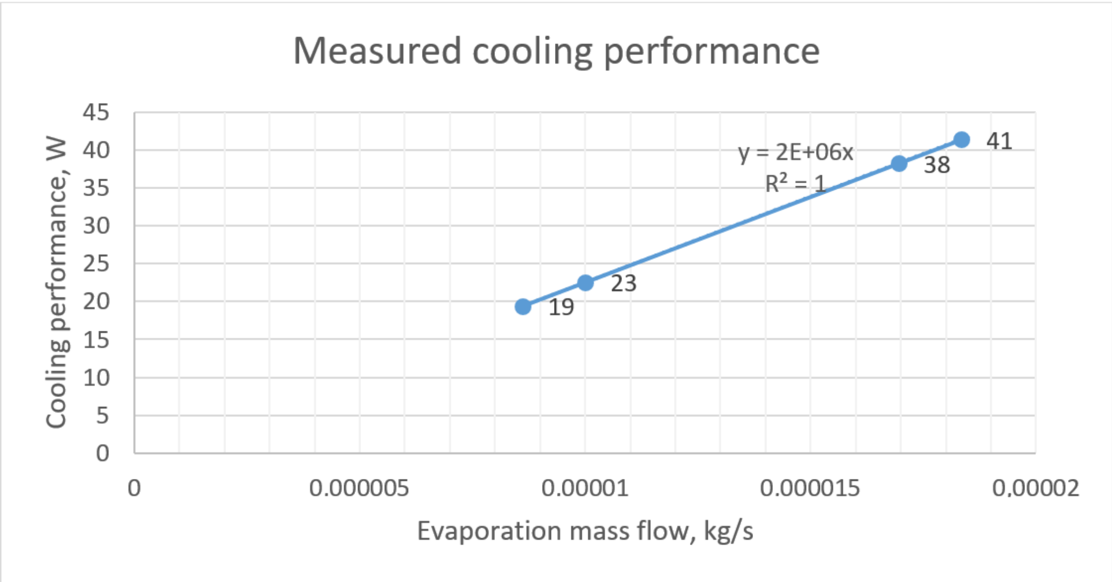

Figure 10: The cooling performance depending on evaporation mass flow

In order to calculate the temperature distribution vs time for evaporation cooling a parabolic type of model was applied along with the identification of its parameters:

$$T(t) = 0.000003\ x^2 + 0.0163\ x + 36.791.$$

The temperature distribution results yields by the model calculation for evaporation cooling it can be seen in the Fig. 11.

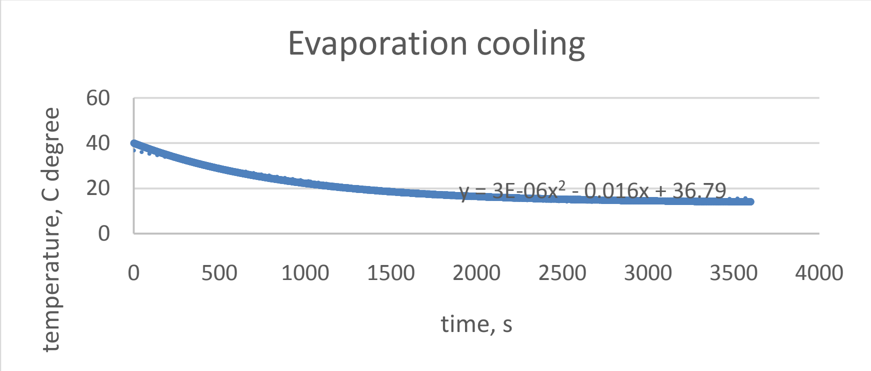

Figure 11: Cooling temperature by evaporation

According to the measurement data for a 2 kW power cooling system needs 2.5 m^2 ceramic surface. The calculated evaporated water, in this case, was 1234 g/m^2 hourly.

Conclusion

Evaporation cooling with ceramics is an environmentally friendly cooling technology, which we can use for a cooling system with low energy consumption and costs. In the paper the governing physical principles and their formulas were introduced. Based on the results of control measurements a quantitative calculation is presented for the surface and water need of a 2 kW power evaporation cooler unit.

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