Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(1) (2021) 51-54
DOI: 10.22060/mej.2018.14584.5892

Effect of Air Curtain on Occupants Thermal Comfort and Indoor Air Quality in an Athletic Swimming Pool with Spectators' Stand

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ABSTRACT: In swimming pools with spectators' stand, due to differences in skin wetness, metabolic rates and clothing type of the swimmers and spectators, providing thermal comfort conditions for all residents is very difficult. Accordingly, using the air curtain to aerodynamically separate the pool hall and the spectators' stand is a reasonable idea to provide the mentioned different thermal comfort conditions. In the mentioned conditions, it is possible to use two different ventilation systems for these two parts. In the present study, an Olympic-size swimming pool with the spectators' stand is modeled and distribution of velocity, temperature, relative humidity, and chlorine concentration have been determined. Also, the results have been analyzed in both cases: using air curtain and without air curtain. The results show that the air curtain can significantly reduce the influence of chlorine pollutants on the spectators' section, so the concentration of chlorine at spectators' stand with the air curtain is about 0.00016 mg/m^3 less than the case without air curtain. In this study, 65 multi node local thermal comfort model has been used to determine the thermal comfort of individuals. In the case of using the air curtain, the standard deviation of thermal comfort index for first to third rows are 0.26, 0.25, and 0.28 respectively; and in the absence of air curtain, for first to third rows the standard deviation of thermal comfort index are 0.33, 0.39 and 0.35, respectively. These results indicate that using the air curtain can lead the thermal sensation to be more favorable and more uniform.

Review History:
Received: 2018-06-10
Revised: 2018-11-07
Accepted: 2018-12-03
Available Online: 2018-12-19

Keywords:
Swimming pool
Air curtain
Thermal comfort
Local sensation
Indoor air quality

1. INTRODUCTION

Indoor swimming pools are one of the spaces with special conditions such as high humidity, chlorine contaminant, and temperature variations. So in swimming pools with spectators' stand, it is important to provide the thermal comfort for all occupants. To achieve this aim, differences in skin wetness, metabolic rates and clothing type of the swimmers and spectators should be considered. A separation between the pool hall and spectators' stand with air curtain is a reasonable solution for using two distinct ventilation systems for these two parts.

In 2002, Shah [1] presented a correlation for evaporation in the swimming pools without a swimmer. In 2013, Randell and Sue-Chu [2] examined the effect of air quality on the athletes' respiratory system by measuring particles separated from their body in sports grounds and concluded that poor air quality in sports facilities causes many problems for athletes' respiratory system. In 2016, Zolfaghari et al. [3] investigated the interaction effects of evaporation, thermal sensation and concentration of contaminants in an indoor swimming pool without spectators stand using Gagge's two-node model [4]. On the other hand, many pieces of research have been conducted to investigate the use of air curtains in sports halls. In 1985, Haaz and Kamen [5] investigated the effectiveness of the annular air curtain to protect the stadium from the rain in the laboratory and reported the results dimensionless for use in real dimensions. In 2012, Gonçalves et al. [6] studied the effect of air curtain by using a gas detector on the reduction of mass and energy transfer between two spaces numerically and experimentally.

As mentioned before, using the air curtain in order to separate the pool hall and the spectators' stand. Therefore, the main aim of the present study is to evaluate the performance of the air curtain in aerodynamically separating of the mentioned two spaces.

2. METHODOLOGY

In the present study, as shown in Fig. 1, an Olympic-size swimming pool with the spectators' stand is numerically modeled and distribution of velocity, temperature, relative humidity, and chlorine concentration have been determined.

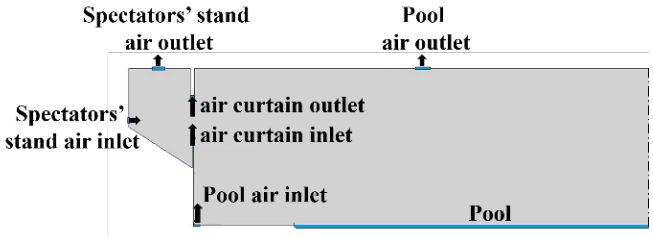

Fig. 1. Schematic view of the case study: a pool hall with spectators' stand and air curtain.

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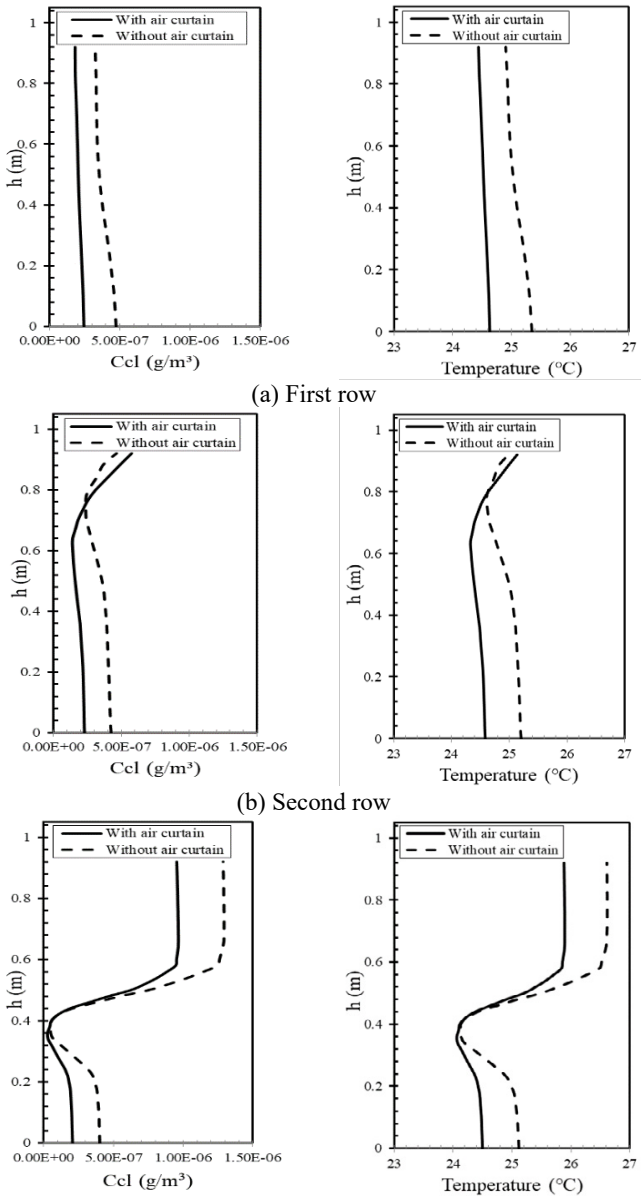
Also, the results have been analyzed in both cases, using the air curtain and without air curtain. In the spectators' section, there is different local thermal sensation due to temperature vertical difference of the air. To evaluate the local thermal comfort of spectators in this research, 65-point Tanabe [7] model had been used.

3. RESULTS AND DISCUSSION

In Fig. 2, the chlorine concentration and temperature distributions have been compared in the cases of using the air curtain and without utilizing the air curtain for the spectators' rows.

Fig. 3 shows the local thermal comfort of spectators using the Tanabe model [7], with and without air curtain in three

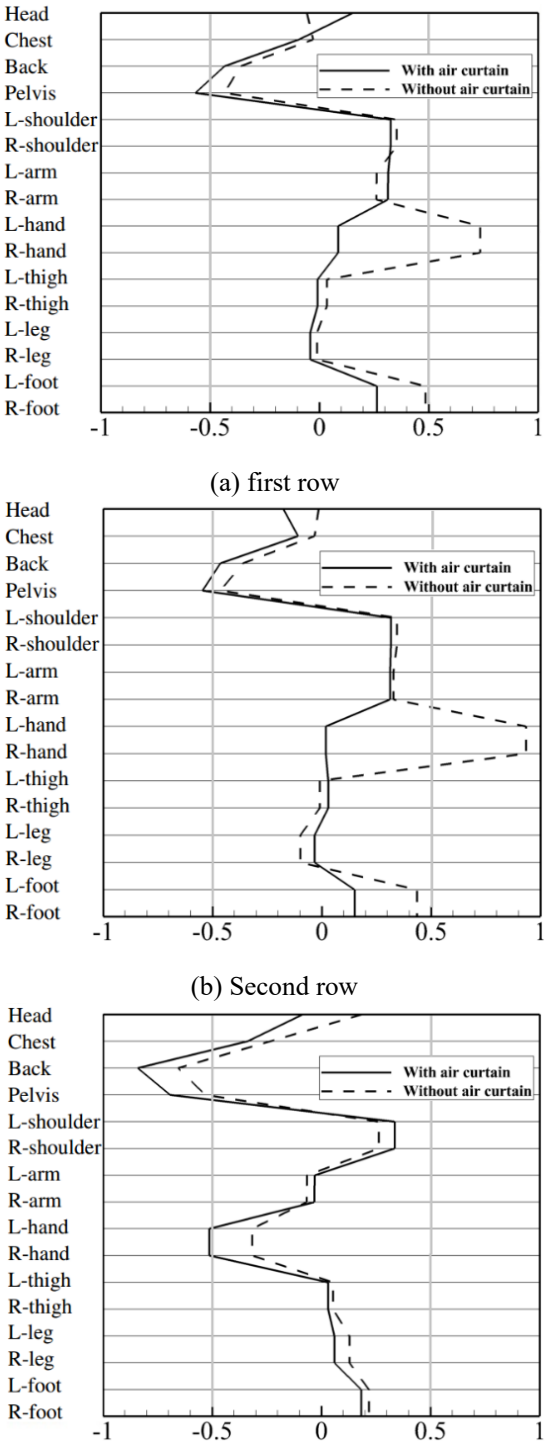


(a) First row

(b) Second row

(c) Third row

Fig. 2. Comparing the chlorine concentration and temperature distribution in two cases (with and without air curtain) for (a) first row (b) Second row (c) Third row



(a) first row

(b) Second row

(c) Third row

Fig. 3. Comparing the thermal comfort of different body members in two modes with and without air curtain for spectators: (a) first row (b) Second row (c) Third row

rows in spectators' stand. In this research -3 and +3 indicate very cold and very warm, respectively; and desirable range considered as the range between -0.5 to +0.5. In case that air curtain is used, except spectators in the third row and near the air inlet that their back experiencing cold sensation, in most

of the cases, the range of feeling in these three rows is from -0.5 to +0.5 which is suitable in terms of thermal comfort, but in the absence of air curtain, people have Non-uniform thermal sensation that this non-uniformity is more obvious in the middle row.

4. CONCLUSIONS

In the present study, an Olympic-size swimming pool with the spectators' stand is modeled and also, the results have been analyzed in both cases, using air curtain and without air curtain. The results show that if the air curtain is used, the average temperature in three rows of spectators' stands would be about $0.5\,^{\circ}C$ less than the average temperature when the air curtain didn't use. Also, using the air curtain reduces the influence of chlorine contaminant in the spectators' standby reduces the concentration of chlorine contaminant about 30%. In addition, the relative humidity in the spectators' stand is about 50%, which is suitable for indoor swimming pools. Also, using the results of local thermal sensation indicate that the presence of air curtain can reduce the standard deviation of the thermal sensation index compared to lack of air curtain. So using air curtains provides uniform thermal sensation in the swimming pool. The standard deviations of the thermal sensitivity index for the first to third row when using air curtain are 0.26, 0.25, and 0.28 respectively, and in absence of air curtain, these values are 0.33, 0.39 and 0.35 respectively.

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HOW TO CITE THIS ARTICLE

S.A. Zolfaghari, S. Azizi, S.M. Hooshmand, Effect of Air Curtain on Occupants Thermal Comfort and Indoor Air Quality in an Athletic Swimming Pool with Spectators' Stand, Amirkabir J. Mech Eng., 53(1) (2021) 51-54.

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