Sensitivity Analysis of the Location of Inlet and Outlet Air on the Particle Transmission in a Modeled Room Utilizing Taguchi Method and ANOVA

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ABSTRACT

In the present study, the sensitivity of particle dispersion within a room to the spatial position of the inlet and outlet air register was investigated using the Taguchi method and analysis of variance (ANOVA). For this purpose, a total of 86400 particles with a size of 1µm were uniformly injected from the inlet register into the room at equal time intervals. Different positions for the inlet register (32 positions) and outlet register (4 positions) on the ceiling and floor of the room were considered. Subsequently, the behavior of the particles, as well as the particle deposition and dispersion within the room over a 60-second time period, were examined using the multi relaxation time lattice Boltzmann method. By employing the Taguchi method and L16 orthogonal arrays, the required number of experiments was reduced by 1/8. All specified experiments which suggested by orthogonal array are simulated, and the number of suspended particles in the room were measured. Following the experiments, the effects of each parameter on the output of the problem were determined based on a factor called the signal-to-noise (S/N) ratio and analysis of variance. According to the obtained results, the longitudinal position of the inlet register had the highest impact on the number of suspended particles in the room, accounting for 84.42% contribution. Additionally, the vertical position of the outlet register had the least impact, contributing only 0.16%.

KEYWORDS

ANOVA, Taguchi method, Sensitivity analysis, Particle dispersion

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1. Introduction

Bhagat et al. [1] discussed the importance of airflow an building ventilation in estimating the risk of COVID-1 infection. Their results indicated that the transmission o the SARS-CoV-2 virus indoors appears to be mor significant than transmission in open spaces, due t longer exposure times and reduced air turbulenc indoors, which leads to decreased particle dispersio outside the room. Furthermore, building ventilatio plays a crucial role in the potential pathways for particl dispersion. Sajjadi et al. [2] investigated the impact o air inlet location on particle behavior within a building Their results showed that the air inlet locatio significantly affects particle dispersion, with larger particle (10 micrometers) output being greater when the inlet is located on the floor compared to when it is on the ceiling, resulting in better indoor air quality. Younesi et al. [3] examined the impact of various air outlet positions on indoor air quality within a two-dimensional square geometry. Falahat [4] investigated the sensitivity of the output parameters, including the heat transfer rate, to the input parameters, including the Reynolds number, using the Taguchi method with L_{16} orthogonal array and analysis of variance. The optimized model showed significant improvements in performance compared to the original model; So that an increase of 94.5% is observed for the Nusselt number. Also, the sensitivity analysis showed that the twist angle of small channels with 50.67% plays an important role in the entropy production number.

As it is shown in literature review, it is very important to investigate the effect of the location of air inlet and outlet registers on indoor air quality, and on the other hand, until now, the sensitivity measurement of air inlet and outlet location parameters on the amount of particle transfer in indoor environments has not been investigated. Therefore, in this research, for the first time, using the Taguchi method and analysis of variance, the sensitivity analysis of the particle transmission rate in indoor environments to the location parameters of the air flow inlet and outlet will be investigated.

2. Methodology

A view of the desired room and the geometrical parameters used to position the flow inlet and outlet are shown in Figure 1. L_i, D_i and H_i represent the longitudinal, transverse position and height of the current inlet, respectively, and D_o and H_o respectively represent the transverse position and height of the current outlet, which are shown in Table 1.

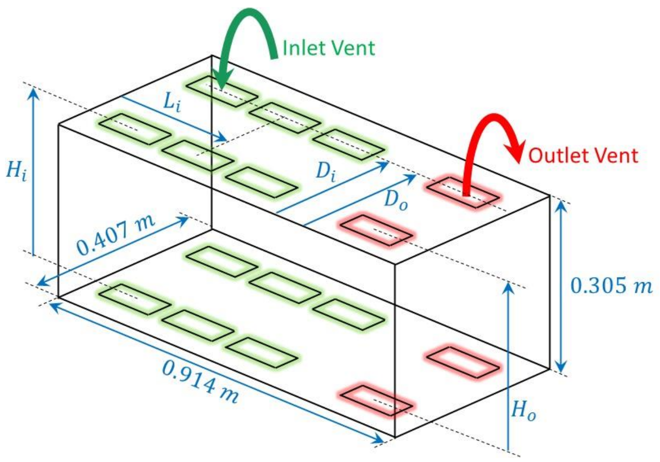

Figure 1. The case study geometry

Table 1: Coordinates of geometrical parameters of outlet and inlet register

D_o	H_o	D_i	H_i	L_i
$D_1 = 0.164\ m$	$H_1 = 0.305\ m$	$D_1 = 0.164\ m$	$H_1 = 0.305\ m$	$L_1 = 0.056\ m$
				$L_2 = 0.123\ m$
				$L_3 = 0.190\ m$
				$L_4 = 0.257\ m$
$D_2 = 0.392\ m$	$H_2 = 0.000\ m$	$D_2 = 0.392\ m$	$H_2 = 0.000\ m$	$L_5 = 0.324\ m$
				$L_6 = 0.391\ m$
				$L_7 = 0.458\ m$
				$L_8 = 0.525\ m$

To study the effects of the five introduced parameters, one of which has eight levels (longitudinal position of the inlet air) and the other four parameters each have two levels, there will be 8×2×2×2×2=128 possible combinations of experimental positions, that performing this number of tests is very time-consuming and not cost-effective. By using the L_{16} standard orthogonal array, which is suitable for designing experiments with five parameters and different levels, the number of experiments can be significantly reduced to 16.

3. Discussion and Results

Table 2 shows the amount of changes in the signal-to-noise ratio for different parameters. As the value of these changes enhances, the impact of this parameter on the output of the problem also increases. In Table 2, the row related to delta introduces the difference between the maximum and minimum values of the signal-to-noise ratio for each of the parameters, with a larger delta indicating greater influence. In this way, the parameters can be categorized based on their effectiveness, which is shown in the row related to rank.

Table 2: The importance of each of the parameters of the problem based on the number of suspended particles in the room

Level	L_i	D_i	H_i	D_o	H_o
1	91.97	92.19	92.3	92.52	92.39
2	92.06	92.5	92.39	92.18	92.31
3	93.22				
4	93.28				
5	92.87				
6	91.87				
7	91.73				
8	91.77				
Delta	**1.55**	**0.31**	**0.09**	**0.35**	**0.08**
Rank	**1**	**3**	**4**	**2**	**5**

Based on the data in Table 2, it was observed that the L_i parameter has the highest importance and the H_o parameter has the least importance in the problem of maximizing and minimizing the number of suspended particles in the room. D_o, D_i and H_i parameters are also in the next ranks in terms of importance and between these two parameters. Analysis of variance determines the contribution rate of each of the effective parameters in the problem on the objective function. In Analysis of Variance, the degree of freedom of each parameter is defined as one unit less than the number of levels of each parameter in the orthogonal array. Also, the variance of a parameter is determined by dividing the sum of squares by the degree of freedom, which determines how the response value depends on that variable; So that a parameter with more variance will have more influence. In addition, the contribution of each variable is defined as the ratio of the sum of squares of that variable to the sum of squares of all variables. Table 3 shows the results of analysis of variance.

Table 3: Results of analysis of variance for the number of suspended particles in the room

Source	DF	Seq SS	Adj MS	F	P (%)
L_i	7	6.159	0.880	50.867	84.42%
D_i	1	0.387	0.387	22.370	5.17%
H_i	1	0.031	0.031	1.792	0.19%
D_o	1	0.477	0.477	27.572	6.43%
H_o	1	0.029	0.029	1.676	0.16%
Residual Error	**4**	**0.069**	**0.0173**		
Total	**15**	**7.152**			

According to Table 3, the results of the analysis of variance and the order of influence of the parameters based on the level of participation confirm the findings of the Taguchi method. It is known that the L_i parameter with a share of 84.42% compared to other parameters has the greatest impact on the number of suspended particles in the room. The next parameters namely D_o, D_i, H_i and H_o are in the next rows of this importance with the share of 6.43%, 5.17%, 0.19% and 0.16% respectively.

4. Conclusion

In this study, using Taguchi optimization method and analysis of variance, the sensitivity analysis of indoor particle suspension to the location of air inlet and outlet register was investigated. The obtained results showed that changing the location of the registers affects the amount of suspended particles and the longitudinal position of the air inlet (L_i) with a share of 84.42% had the greatest effect on the amount of suspended particles in the room, the transverse position of the outlet (D_o) with a share of 6.43%, the transverse position of the inlet (D_i) with a share of 5.17%, the height position of the inlet (H_i) with a share of 0.19% and the height position of the outlet (H_o) with a share of 0.16% in the second, third, fourth, fifth and last category, respectively.

5. References

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