EPJ Web of Conferences **269**, 01006 (2022) https://doi.org/10.1051/epjconf/202226901006
EFM 2019

Experimental tests of the air flowing out of a swirl diffuser

Marek Borowski[1], *Marek* Jaszczur[2*] *Michał* Karch[1], *Sławosz* Kleszcz[2]

[1] Faculty of Mining and Geoengineering, AGH University of Science and Technology, 30-059 Krakow, Poland
[2] Faculty of Energy and Fuels, AGH University of Science and Technology, 30-059 Krakow, Poland,

Abstract. The geometry of swirl diffusers affects the shape of the air stream injected into the rooms. In this work, the air flow from the swirl diffuser was tested using the Particle Image Velocimetry (PIV) method. The presented laboratory model was a simplification of the real object and was made at a geometric scale of 1:10. The swirl diffuser was tested with two vanes settings. The measured speed fields are shown. Normalized air velocity profiles obtained at different values of volume flow were compared. This will allow better understanding of the air flow from the swirl diffusers and better shape the air flow in the ventilated rooms.

1 Introduction

Ventilation of buildings should ensure adequate air quality in the rooms. The ventilation system is designed to bring the right amount of air and ensure the desired air distribution inside the rooms. Poor flow and too little air exchange in the room causes discomfort, it can also lead to a sick building syndrome. Poor climatic conditions affect the health of the users of the rooms as well as the construction of the building. Knowledge and forecasts of indoor air flow fluxes are therefore important for optimizing indoor climate. This has an impact on energy saving and environmental protection[1,2]. People in the indoors spend nearly 80% of their time during the day. Therefor indoor air quality is an important aspect of the indoor environment.

Swirl diffusers are intended for use in low- and medium-pressure ventilation systems. They are especially recommended for rooms with a height of 3 to 12 meters, where an important parameter is the exact setting of the final air speed to the occupied zone. The diffusers of this type are widely used in supply and exhaust systems in rooms requiring comfort, such as offices, shopping centers, restaurants, cinemas or so-called "Clean rooms" [3].

When choosing this type of diffusers, it is important to determine the coverage area of the air stream being blown. For this purpose, manufacturers of this type of diffusers present tables, nomograms or diagrams that show the range of the air stream depending of air flow. It can be noticed, however, that there are discrepancies between the data of the different producers in determining the range of the supply air stream. These discrepancies result mainly from the measurement methods used by manufacturers. Therefore, it is still a valid task to verify the results on an experimental way, adapting new measurement methods.

The air flow through swirl diffusers was analyzed by CFD methods by other authors [4,5]. Computational fluid dynamics is a very useful technique for predicting the distribution of air in a ventilated space. But the accuracy of CFD forecasts depends on the adopted and delivered boundary conditions. Simplifying the geometric model of the swirl diffuser is often used. This, together with inadequate turbulence modeling, can lead to a result that is far from real. In addition to the few items [6,7], the results of experimental research related to similar issues are missing in the literature. Therefore, an experimental investigation of the air velocity field flowing through the vortex diffusers was selected

In the presented work, Particle Image Velocimetry (PIV) was used. A laboratory model was made at a geometric scale of 1:10. He was a simplification of the real object. The flow conditions were adapted to the scale.

2 Experimental setup

Figure 1 shows a photograph of the measuring section of swirl diffusers. The aim of the research was to obtain velocity fields at the outflow from the diffuser. The measurement was carried out using the PIV Stereo method [6,8,9]. A model of the installation with a horizontal swirl diffuser was developed for the tests. The air flow was forced by a Venture MPB-K 200S radial fan. An inverter was installed, which enabled the fan speed control. The experimental setup consisted of a channel with a diameter of 50 millimeters and a length of 2 meters, to which the air was supplied by the stabilizing system of the air stream which had a length of 1.35 meters and consisted of a diffuser, a confusor and a

* Corresponding author: marek.jaszczur@agh.edu.pl

channel with a diameter of 0.2 meters. It equalized the air velocity distribution at the inlet to the tested diffuser.

Fig. 1. Set-up of the measurement section: 1- laser Nd:YAG, 2-camera CCD, 3-swirl diffuser.

The air was used as the experimental fluid in the channel, thus the equality of the Pr number was automatic. Having equal Re numbers ensures the averaged velocity fields are similar. The Reynolds numbers were equal to Re1=47000, Re2=85000, Re3=143000, Re4=183000. Particle Image Velocimetry (PIV) method was used to evaluate the velocity vector components. The particles were illuminated with a double-pulse Nd:YAG laser of energy of about 400 mJ per pulse. The digital images were acquired by 4 Mpx monochromatic CCD camera. In each experiment, 1000 double frame images were recorded with the camera recording at a frequency of 3 Hz, which resulted in an overall time of one measure of around 5 minutes. During the calculations, the size of interrogation windows that exhibit satisfying results was set to 32x32 px. The Davis 7 software was used to analyse the images and to find the velocity vector components.

The seeding for the PIV method was DEHS oil sprayed through an atomiser, to obtain a particle diameter of about 1 μm. The seeding particles were introduced to the inlet air stream, immediately behind the flow-stabilising section.

The measurements were performed for the steady and isothermal flow conditions.

The tested swirl diffuser was made in the 1:10 scale, in two variants differing in the arrangement of the vanes. The vanes were set at an angle of 60 and 75 degrees. Analyzed swirl diffusers are shown in Figure 2. The volume air flow was measured using a standardized measuring orifice. The experiment was carried out at four volumetric flow rates of the air:100, 185, 310, 380 m^3/h.

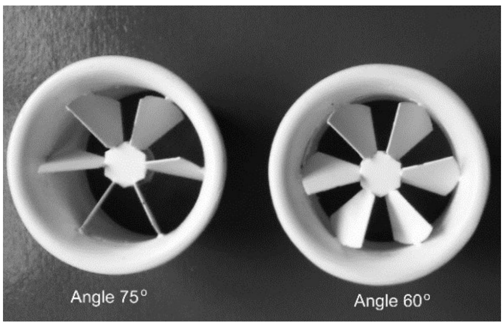

Fig. 2. Setting diffuser vanes: angle of 75 degrees and angle of 60 degrees.

3 Results

The measurement method used allows obtaining of a vector field velocity images throughout the tested area. On this basis, the flow velocity can be analyzed at any point in the area under test. Figures 3 and 4 shows the image of the measured velocity field. The results presented were obtained for 60° and 75° diffusers and for a flow of 380 m^3/h.

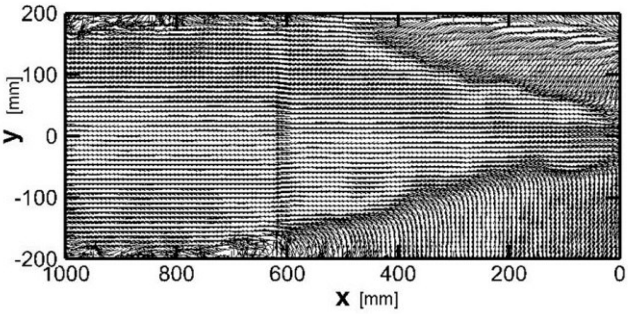

Fig. 3. The image of the measured velocity field. For the case: 60° diffuser and flow rate 380 m^3/h.

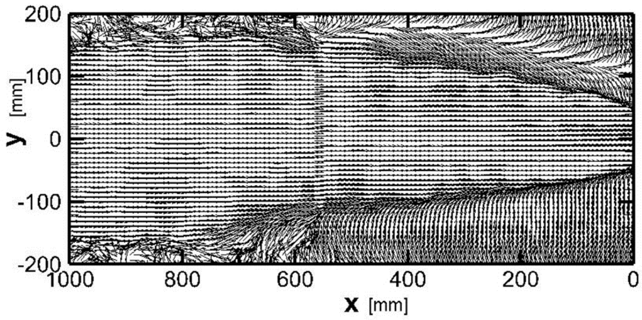

Fig. 4. The image of the measured velocity field. For the case: 75° diffuser and flow rate 380 m^3/h.

On the basis of the measurements made, for each diffuser a series of isolines with the same value of the velocity vector component Vx (axial) was plotted for subsequent values of the Reynolds number. Figure 5 shows the lines for 6 [m/s], 7 [m/s] and 8 [m/s] for the diffuser set with an angle of 60° plotted at Re2= 85000, Re3= 143000 and Re4= 183000. The range of the isoline understood as the coordinate x of the most distant point of the considered isoline from the outlet of the diffuser increases with the number of Re. At the same time, the isoline drawn for higher speeds have shorter and shorter ranges. The images of isolines is similarly presented for the other tested diffusor vanes settings.

Figure 6 shows the lines 9 [m/s], 11 [m/s] and 13 [m/s] for a diffuser with vanes set at an angle of 75° obtained at Re2= 85000, Re3= 143000 and Re4= 183000. Also here is the growing range of individual line with the increase in the value of the number Re.

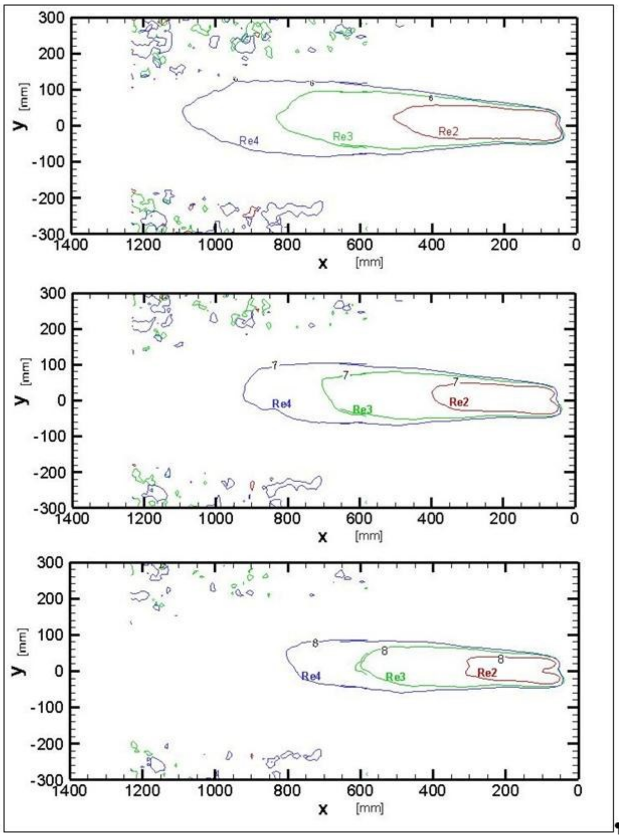

Fig. 5. The lines with the same value velocity vector axial component Vx at the air flow rate 385m3/h and for the 60 angle vanes.

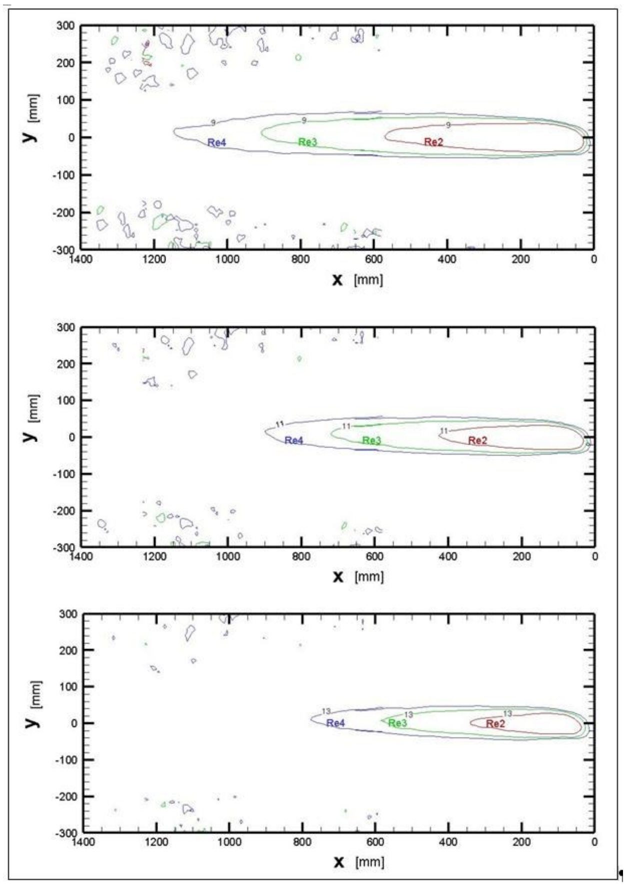

Fig. 6. The lines with the same value velocity vector axial component Vx at the air flow rate 385m3/h and for the 75 angle vanes.

The results of measurements in the form of normalized speed Vnor profiles are presented below:

$$Vnor = \frac{V}{V_{av}}$$

where:
V-the value of the air velocity at the point being analyzed,
Vav- the average speed value in the outlet cross-section of the tested swirl diffuser.

The speed normalization was done by dividing the local velocity values by the average velocity value at the outlet from the diffuser. The average velocity value was determined based on the measuring volumetric flow rate using a orifice. This operation is aimed at comparing speed profiles obtained at different values of the air flow through the diffuser.

Figure 7 shows normalized speed profiles in 100, 200, 300 and 400 mm from the diffuser outlet with vanes set at an angle of 60°, and Figure 8 with vanes set at an angle of 75°. You can see a large similarity of profiles obtained with different values of Re numbers. As the distance from the diffuser increases, the value of the normalized speed decreases. For the swirl diffuser, the speed profiles expand with the increasing distance from the diffuser outlet. The speed profiles for the diffuser with vanes at an angle 75 are thinner than at an angle 60°.

The degree of compliance of distributions of a given size c, for subsequent (i and i+1) numbers of Re, can be expressed in quantitative terms by the mean relative difference:

$$\alpha_w = \frac{\frac{1}{n}\sum_{i=1}^{n}\left|C_{Re_{i+1}} - C_{Re_i}\right|}{\frac{1}{n}\sum_{i=1}^{n}\left|C_{Re_{i+1}}\right|} \cdot 100\%$$

where:
C_{Rei} -value of the c-value measured for the i-th number Re_i: Re1= 47000, Re2= 85,000, Re3= 143000, Re4= 183000

The α_w index was calculated for the velocity vector values. The smaller the relative difference, the greater the degree of matching of distributions.
Table 1 shows the values of α_w calculated for a diffuser with vanes set at an angle of 60°. The measurements were made for the same values of the numbers Re as given above.

Tab. 1 Relative difference of velocity vector value distributions for diffuser with vanes at an angle of 60°.

Distances from the outlet of the diffuser	α_w	
	$Re_2 \rightarrow Re_3$	$Re_3 \rightarrow Re_4$
X=70mm	43,0%	20,6%
X=100mm	35,4%	17,2%
X=150mm	23,2%	15,0%
X=200mm	20,3%	11,8%
Average	30,5%	16,2%

For larger Re values, the index α_w decreases and its average value is 16,2%.

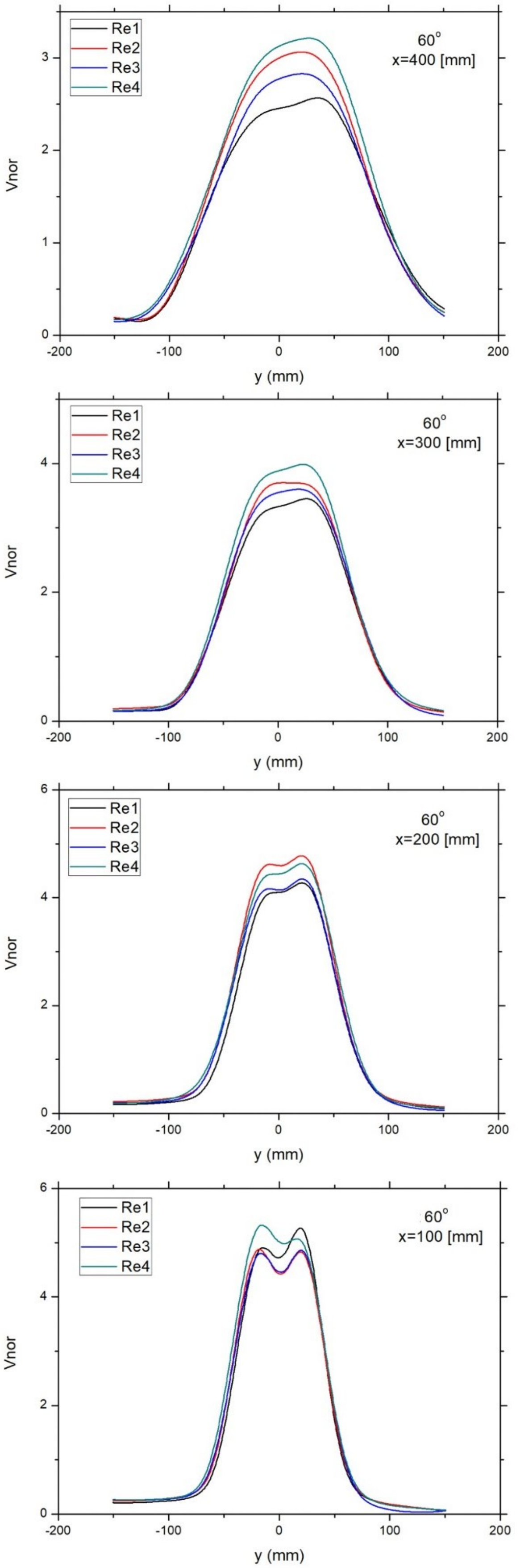

Fig. 7. Standardized profiles of air velocity flowing out of the diffuser with vanes directed at an angle of 60° at different distances (x = 100 ÷ 400mm) from the outlet of the diffuser.

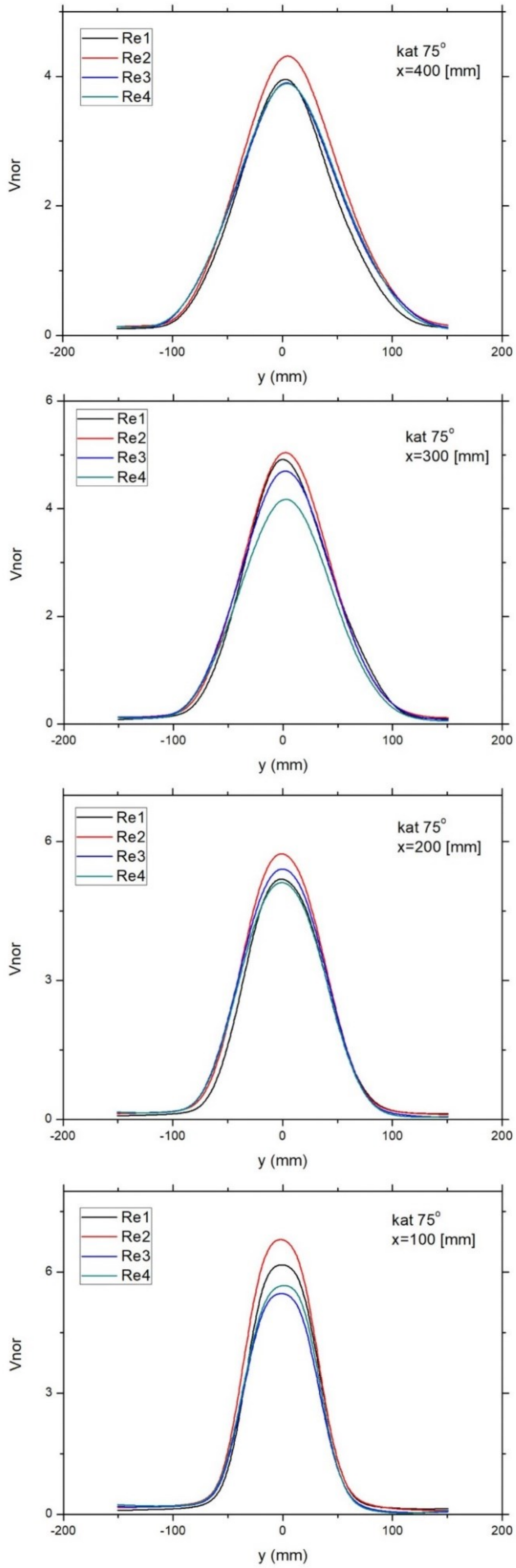

Fig. 8. Standardized profiles of air velocity flowing out of the diffuser with vanes directed at an angle of 75° at different distances (x = 100 ÷ 400mm) from the outlet of the diffuser.

Table 2 shows the values of α_w calculated for a diffuser with vanes set at an angle of 75°. Also in this example, the index α_w decreases for larger Re values, and its average value is 13,2%.

Tab. 2 Relative difference of velocity vector value distributions for diffuser with vanes at an angle of 75°.

Distances from the outlet of the diffuser	α_w	
	$Re_2 \rightarrow Re_3$	$Re_3 \rightarrow Re_4$
X=70mm	28,4%	20,0%
X=100mm	42,2%	13,8%
X=150mm	25,8%	9,9%
X=200mm	18,9%	9,2%
Average	28,8%	13,2%

4 Conclusions

The PIV method was used. This method allows simultaneous measurement in a large area of flow and allows the determination of velocity vectors at any point of this flow. The ability to determine the characteristic features of the diffuser, such as the shape and range of the air stream being formed, demonstrates the suitability of the measurement method used in the issues of ventilation. Information about the formed speed field has a decisive impact on the process of shaping the air flow in the room and thus on the efficiency of ventilation. That is, the rate of removal of gaseous pollutants, the spread of solid particles and microclimate in the zone people occupied.

Many speed profiles normalized in different cross-sections of the stream were compared. For them, a relative difference in the distribution of velocity vector values was calculated. This ratio decreases with the increase in the number of Re. The smallest values were obtained for flows with the Reynolds number above 143000. This means that with the increase in the number of Re, the degree of conformity of normalized distributions of velocity fields increases. In the tested laboratory model of a swirl diffuser, the turbulent flow for Re numbers above 143000 has the ability to self-model.

References

1. H. Awbi, 2003. Ventilation of buidings. London: Taylor and Francis.
2. A. Alfahaid, 2000. Effects of ventilation on human thermal comfort in rooms. Ph.D.Thesis. Norfolk: Old Dominion University.
3. A. Pełech, 2013. Ventilation and air conditioning. Basics. Wrocław: Wrocław University of Technology Publishing House.
4. K.C. Ng, K. Kadirgama, E.Y.K. Ng, 2008. Response surface models for CFD predictions of air diffusion performance index in a displacement ventilated office Energ. Buildings 40 774
5. R. Pandey, A. Kumar Rao, V. Yadav 2015 Comparison between simulation and experimental technique inside an air conditioned room to analyze the performance and flow characteristics of ceiling swirl diffuser under different operating and flow parameters, IJESRT 4 424
6. M. Jaszczur, R. Nowak, J. Szmyd, M. Branny, M. Karch, W. Wodziak 2011. An application of SPIV technique to experimental validation of the turbulence model for the air flow in the intersection of the mining face with the ventilation gallery J Phys Conf Ser. 318 5
7. B. Sajadi, A. Mohebbian, M.H. Saidi, Proc.of the 2nd Int. Conf. on Heating, Ventilation and Air-Conditioning, Tehran, Iran, June 1-3 (2010)
8. J. Westerweel, Digital particle image velocimetry: Theory and applications Delft University Press (1993)
9. LaVision Gmbh, Flow Master Manual for Davis 7.0 (2007)