

TUBULAR AIR DEFLECTOR IN VENTILATION DUCTS

E. Smyk^{*}, D. Mrozi^k, S. Wawrzyniak^{*}, K. Peszyński^{*}

Abstract: *Flow stabilization in ventilations ducts is very important issue. This can affect the separation of the stream in the different type of fittings (e.g. T-shaped connectors). The use of perforated sheet or tubular deflector (thin-walled tubes arranged side by side in the duct) for faster flow stability is common practice in the industry. This elements are mounted especially near fan with ducts connection, although lack of studies proving the effectiveness of this methods. In this paper has been investigated the effect of tabular air deflector on flow stabilization with numerical simulation used.*

Keywords: Ventilations, Deflector, Air flow, Numerical simulation.

1. Introduction

One of the most important problem in investigation of different type of flows is its stabilization, in case of continuous flows. Usually it is recommended to use a straight section after a disturbance. This section should be 10 – 20 hydraulic diameters length. This solution is very problematic in case of ducts with a large diameter investigation, e.g. ventilation ducts (hydraulic diameter even up to 2 m or more). For these reason to investigation of different type of duct system are used analytical methods (Gan et al., 1996; Oliveira et al., 2006) and more often numerical methods (Maharudrayya et al., 2004; Parra et al., 2006). Experimental methods are used mainly in case of relatively small systems (Sippola et al., 2003) or existing and operated systems (Parra et al., 2006). However in case of determination of some non-linear phenomenon using of analytical methods is impossible and numerical methods aren't enough accurate. Then experimental method is necessary. In case of large duct system investigation them size is a big problem. For example the T-shaped connector investigation by hydraulic diameter equal 400 mm requires the use of duct 4 m length before each measure point. It reduces the effect of disturbances caused by the change in shape on measurements. Therefore we are looking for ways to faster flow stabilization.

The use of perforated sheet or tubular deflector (thin-walled tubes arranged side by side in the duct) for faster flow stabilization is common practice in the industry. However, the authors of this papers found any data to support the validity of this method. The aim of this work is to verify whether the tubular deflectors have an influence on the flow stabilization.

At this point it should also emphasize what is understood as stable flow. Stable flow is situation when velocity profile of stream is constant or varies slightly. As flow stabilization is the process when after a disturbance the velocity profile of this flow is changing and strives for some constant shape, which is dependent on kind and cross–area of the ducts, velocity etc.

^{*} Assist. Prof. Emil Smyk, MSc.:Faculty of Mechanical Engineering, UTP University of Science and Technology in Bydgoszcz (Poland), Al. Prof. S. Kaliskiego 7, Bydgoszcz; PL, emil.smyk@utp.edu.pl.

^{**} Dariusz Mrozi^k, BSc.: Faculty of Mechanical Engineering, UTP University of Science and Technology in Bydgoszcz (Poland), Al. Prof. S. Kaliskiego 7, Bydgoszcz; dariuszmrozi^k1@gmail.com.

^{***} Assist. Prof. Sylwester Wawrzyniak, PhD.:Faculty of Mechanical Engineering, UTP University of Science and Technology in Bydgoszcz (Poland), Al. Prof. S. Kaliskiego 7, Bydgoszcz; PL, sylwester.wawrzyniak@utp.edu.pl.

^{****} Assoc. Professor Kazimierz Peszyński, PhD., Faculty of Mechanical Engineering, UTP University of Science and Technology in Bydgoszcz (Poland), Al. Prof. S. Kaliskiego 7, Bydgoszcz; PL, kazimierz.peszynski@utp.edu.pl.

2. Methods

In order to verify the influence of tubular deflectors on the flow stabilization was used simulation method. To this aim a two channel models was modelled. One with deflector presented in the Fig. 1 and a second having the same dimensions but without deflectors. It is model of real part of ventilation system (connection of the fan with ducts). This connections causes severe flow disturbance due to the sudden change in cross- section. Ten meter long duct is installed after the deflector in order to stabilize the flow. Example real velocity profile measured on the exit of this system is showed in Fig. 2a (measured by hot- wire anemometer). As you can see after ten meter from deflector flow is stable but you should consider whether a ten meter length is necessary to flow satiation if the deflector is used.

For that purpose the velocity changes on the measurement axis was investigate with different Reynolds number. Arrangement of measurement axis is presented in the Fig. 2b. During the investigation, it was assumed that the flow is stable if the different between the final velocity (velocity on the end of ducts) and velocity at the some point is equal or less than 10 %, 5 % or 1 %. Distance between the first point that meets the above condition and beginning of duct is the length needed to stabilize the flow in specific axis. The maximum distance of flow stabilization from 13 axis with specific Reynolds number is the sought distance about which we can say that the flow is stable.

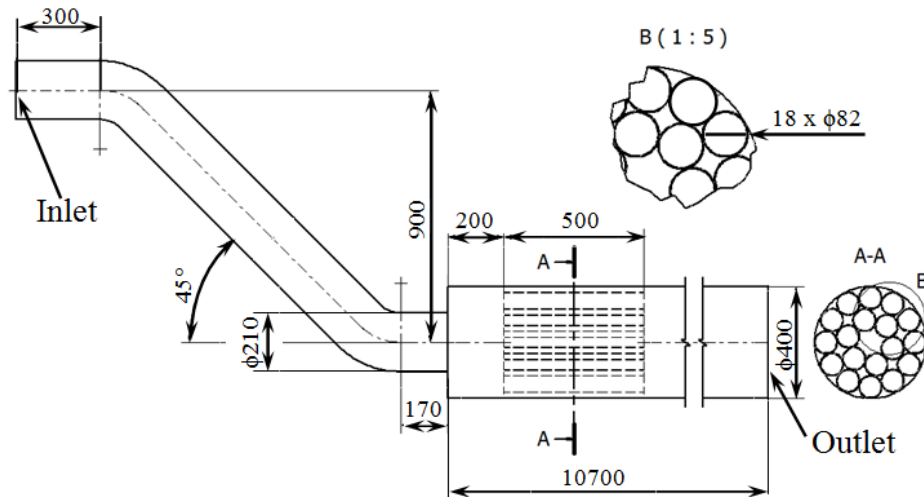


Fig. 1: Drawing of model with tubular deflector.

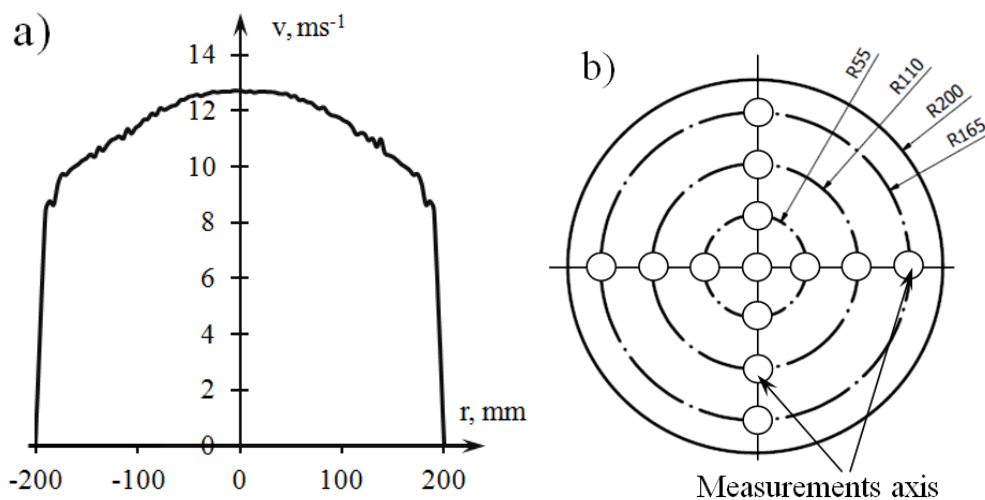


Fig. 2: a) velocity profile in real ducts system for $Re = 130\,000$; b) arrangement of measurement axis.

Simulation was executed in ANSYS Fluent with used Spalart–Allmaras simulation model. The operating fluid was air. In the Fig. 1 are indicated boundary conditions – inlet and outlet, walls indescrivable surfaces were wall boundary conditions type. Outlet was pressure–outlet boundary conditions type and inlet was velocity–inlet boundary conditions type. Velocity on inlet was defined so as to obtain a specified Reynolds number in investigated duct (ϕ 400 mm).

3. Results

The result of simulation – distances of flow stabilization– are showed in the Fig. 3. In the Fig. 3a are showed results for model with tubular air deflector and in the Fig. 3b without. On charts are showed distances after with the flow was stable – from this distance the velocity hasn't changed, taking into account 10 %, 5 % or 1 % error. Distances was calculated by different Reynolds numbers and additionally on chart are indicated average values by lines for different errors.

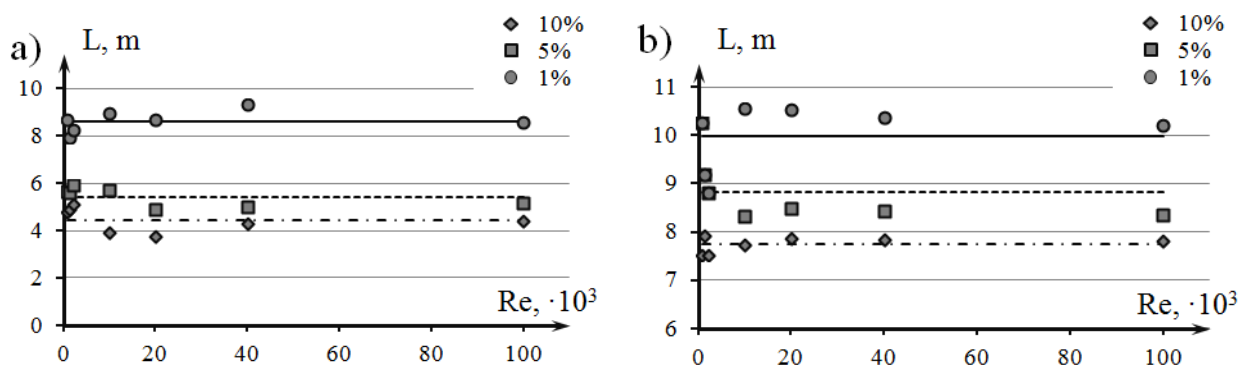


Fig. 3: Distances on which followed flow stabilization for different Reynolds number, error of stabilization for ducts model a) with tubular air deflector; b) without deflector with additionally average value of stabilization distance.

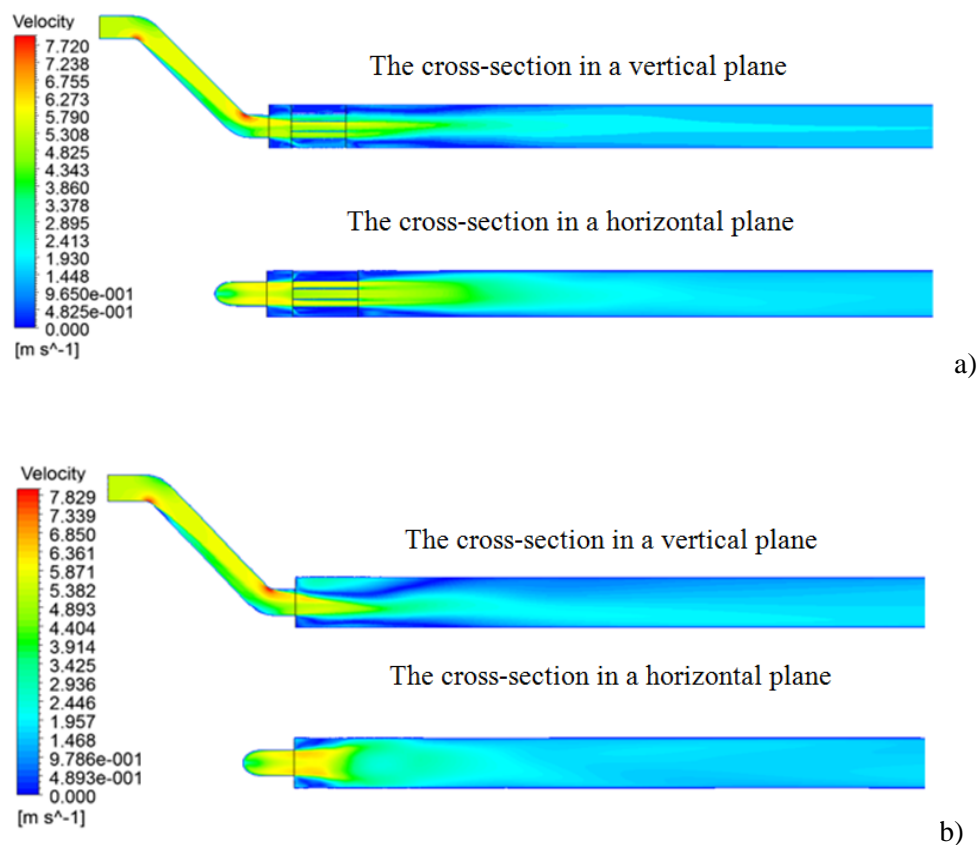


Fig. 4: Example contours of velocity on vertical and horizontal cross-section, first 4 m of ducts ducts a) with, and b) without tubular air deflector.

Results for model with air deflector are lower than for model without deflector. However the differences between them are different depending on error. By 10 % error the distances of flow stabilisation by case with deflector is almost twice lower then by case without deflector. If the accuracy is increasing, the difference diminishes but doesn't disappear.

Surprising is the fact that the distance of flow stabilization is not dependent on Reynolds number. The simulation was made by different Reynolds number from 1 000 to 100 000. We expected that the stream stabilization distance is dependant from Reynolds number what is exhibited in some article (Maharudrayya et al., 2004), but in our case this relationship doesn't exist. The stabilization distance is almost constant.

In the Fig. 4 is showed velocity count contours on vertical and horizontal cross-section. The used of deflector increase influence of disturbances caused by channels located before main duct. Additionally after changing the cross-sectional area occurred expansion of stream (Fig. 4b, horizontal plan). In case with tubular air deflector this expansion isn't so sudden and violent. It means that used of deflector can reduce disturbances caused by preceding its elements.

Modelled deflector are real and operates in ventilation system. In this point we should consider what is its coefficient drag and how influence on flow stabilisation its dimensions (length, diameters an number of pipes). Additionally conducted numerical analysis should be confirmed by experimental methods.

4. Conclusions

Analysis of stabilisation flow distances and velocity contour in ducts with and without tubular deflector revealed that deflectors have influence on flow stabilization, and they can reduce disturbances caused by elements located near before them.

Additionally next research objectives have been designated.

Acknowledgement

Scientific work financed from the budget for science in the years 2015/2018 as a research project within the program under the name "Diamond Grant ".

Authors thank the company Nucair Technologies Sp. z o.o., Solec Kujawski, Poland, for the opportunity to carry out the measurements and access to the test bench.

References

- Gan, G. and Riffat, S.B. (1996) Measurement and computational fluid dynamics prediction of diffuser pressure-loss coefficient. *Applied Energy*, 54(2), pp. 181-195.
- Maharudrayya, S., Jayanti, S. and Deshpande, A.P. (2004) Pressure losses in laminar flow through serpentine channels in fuel cell stacks. *Journal of Power Sources*, 138(1-2), pp. 1-13.
- Oliveira, P.J. and Pinho, F.T. (2006) Pressure drop coefficient of laminar Newtonian flow in axisymmetric diffusers. *International Journal of Heat and Fluid Flow*, 27(2), pp. 319-328.
- Parra, M.T., Villafruela, J.M., Castro, F. and Mendez, C. (2006) Numerical and experimental analysis of different ventilation systems in deep mines. *Building and Environment*, 41(2), pp. 87-93.
- Sippola, M.R. and Nazaroff, W.W. (2003) Modeling particle loss in ventilation ducts. In *Atmospheric Environment*. pp. 5597-5609.