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Performance Investigation of Hybrid Flow Control Method in Curve Diffuser: Guide Vanes and Mesh Screen

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Abstract: This research investigates a hybrid flow control method that combines mesh screens and guide vanes in curve diffusers, addressing the challenges posed by diffusers with a 90-degree angle bend. The severe curvature in such diffusers often leads to flow separation, reduced flow homogeneity, and increased potential flow loading. By utilizing Computational Fluid Dynamics (CFD) software for numerical analysis, the study evaluates the effectiveness of the hybrid flow control method in improving curve diffuser performance and proposes an optimum device configuration. The research focuses on assessing the impact of guide vanes and mesh screens on flow separation and pressure loss, aiming to provide insights into system efficiency. The findings not only contribute to future research on curved diffusers but also support environmentally sustainable practices. By highlighting the potential of the hybrid flow treatment method in reducing flow separation, improving static pressure, and enhancing the overall performance of curve diffusers, this study offers valuable information for designing more efficient engineering systems.

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Keywords: Diffusers, curve diffusers, hybrid flow control method, mesh screens, guide vanes, Computational Fluid Dynamics (CFD), flow separation, pressure loss, operational performance, energy saving.

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1. Introduction

Diffusers are widely used in engineering systems to increase fluid pressure by slowing down the flow over a larger area, achieving a decrease in velocity and an increase in pressure. They come in various types, such as curved, straight, pyramidal, annular, and S-shaped, finding applications in wind tunnels, HVAC systems, gas turbines, and aviation engines. The goal is to optimize performance while balancing flow uniformity and pressure recovery. The efficient design of diffusers, especially at a 90-degree bend, has been extensively studied, emphasizing the importance of properly setting geometric and operational parameters, such as area ratio, curvature length, turn angle, turbulent intensity, and inflow Reynolds number. Neglecting these parameters can significantly impact performance, particularly with high-area ratio diffusers and steep 90-degree curves, leading to undesired flow separation and homogeneity issues. Bernoulli's principle, applied to ducts with low-velocity fluid flow, reveals that mass flow remains constant with constant air density, even when the tube diameter decreases and fluid velocity increases, resulting in pressure reduction. Diffusers effectively decrease fluid velocity while increasing static pressure, and maintaining air duct velocity within defined limits reduces noise and friction loss. Additional components can be integrated to decrease turbulent flow occurrence and enhance overall efficiency. [1]

1.1 Problem Statement

Excessive loss of velocity in a bending pipe can lead to flow division and drag, causing a decrease in system pressure. To counteract this, a centripetal force is required to provide inward acceleration for fluid flow in a curved diffuser. However, rapid flow deflection towards the outer wall can result in abnormal flow separation and inadequate flow homogeneity. Therefore, this research aims to investigate the effectiveness of the Hybrid Flow Control Method, which utilizes a mesh screen and guide vane in the curve diffuser. Previous studies have explored the performance of curve diffusers and examined the installation of flow control devices to improve flow behavior. Issues such as the static pressure recovery coefficient and flow uniformity index are interconnected. To address these challenges, researchers have proposed modifications to diffuser design and the incorporation of additional devices such as honeycombs, guide vanes, and vortex generators.

1.2 Objectives

1. To investigate the potential performance of the hybrid flow control method applied in the curve diffuser.
2. To propose the optimum configuration of hybrid flow control devices.

1.3 Scope of study

1. The Hybrid flow control method is considered an integration of guide vanes and mesh screens.
2. Investigate how devices installed in curve diffusers can reduce the flow separation and make the system in curve diffusers better.
3. Use mainly Computational Fluid Dynamics (CFD) software to analyze fluid flows using numerical solution methods. Using CFD is also to analyze complex problems involving fluid-to-fluid interaction.
4. Variable for this research is the velocity inlet which is 10.208 m/s, 10.945 m/s, 16.287 m/s, 22.249 m/s, and 29.067 m/s. Reynold's number is between 130000 to 40000.

2. Methodology

This study utilizes Solidworks 2021 and Ansys Fluent software to investigate the performance of a 90° curve diffuser with various inlet velocities. The design of mesh screens and guide vanes is incorporated to enhance the diffuser's performance. The simulation is conducted in Ansys Fluent to collect data on the diffuser's behavior, including pressure coefficients and flow characteristics. The collected data is then analyzed and interpreted using computational methods. The aim is to optimize the diffuser's performance by analyzing the impact of different configurations and inlet velocities.

2.1 Modelling

The research conducted by Muhammad Musleh Anuar (2021) serves as a reference for modeling the diffuser in this study. The same model is utilized for all scenarios, with the distinction lying in the installation of different devices within the curve diffuser. The aim is to investigate the impact of these devices on the diffuser's performance and analyze their effectiveness in improving flow characteristics and pressure recovery.

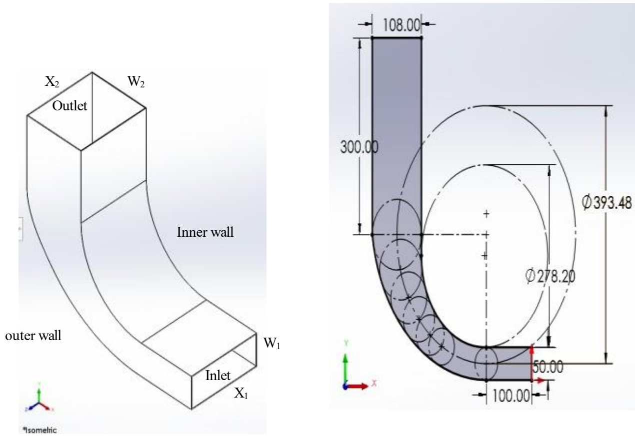

Fig. 2.1 - 90o curve diffuser model

Table 2.1 - Design dimension of curve diffuser

Angle (°)	W_1 (mm)	X_1 (mm)	W_2 (mm)	X_2 (mm)	r_{in} (mm)	L_{in} (mm)	r_m (mm)	L_m (mm)
90	50	130	108	130	196.74	222.14	139.1	309.04

After conducting extensive research on previous studies related to wire mesh screens, careful consideration was given to selecting the appropriate parameters for the woven wire mesh screen used in this study. Based on the research findings, it was decided to use a wire diameter of 1.2mm and a pitch of 6mm for the mesh screen configuration. The selection of the wire diameter and pitch for the mesh screen configuration was based on previous research that demonstrated their effectiveness in controlling flow separation.

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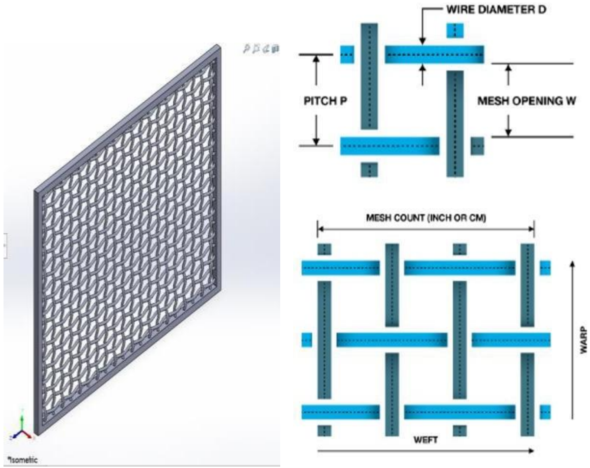

Fig. 2.2 - Mesh Screen model

The design and methodology for incorporating the guide vane in the study are based on previous research conducted by Juan Pablo (2021) and Nur Hazirah (2017). These studies provide valuable insights into the design and implementation of guide vanes for flow control in diffusers. By incorporating the findings from the studies, the guide vane design in this study is tailored to the specific diffuser geometry and aims to optimize flow control. This design will use 30 mm for both Rc and W. Additionally, the aerodynamic factor, Rc (curvature radius), is considered in the design of the guide vane. The value of Rc is chosen to optimize the aerodynamic performance of the system.

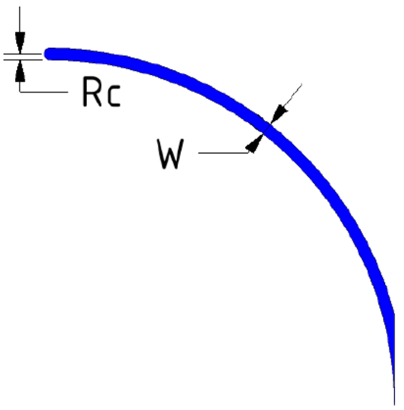

Fig. 2.3 - Dimension of the Guide Vane

Fig. 2.4 - Guide Vane model

2.2 Solver Setting

Analyzing the velocity data in conjunction with other parameters, such as pressure coefficient or Reynolds number, allows for a comprehensive understanding of the flow behavior and the performance of the hybrid flow control method in the curve diffuser. It helps in assessing the impact of different configurations and optimizing the design to achieve desired flow characteristics, such as reduced flow separation and enhanced static pressure recovery.

Table 2.2 - Boundary condition

Parameters	Input
Time Viscous	Steady Realizable K-epsilon turbulence model
Wall treatment	Enhanced Wall Treatment (EWT) Air
Fluid Density	1.164 kg/m^3
Viscosity	1.872E-5 kg/ms^{-1}
Solid Density	Acrylic Plate 1180 kg/m^3
Velocity	10.208 m/s 10.945 m/s 16.287 m/s 22.249 m/s 29.067 m/s
Pressure outlet wall	0 gouge pressure No slip

Table 4.1 - Pressure Coefficient for Curved Diffuser with Different Models

	Without device			With guide vane		
Journal	**Journal data**	**Experiment data**	**Deviation %**	**Journal data**	**Experiment data**	**Deviation %**
(Muhammad Musleh Anuar, 2021)	0.190	0.69745705	72.8 %	0.25	0.68565193	63.5 %
(Nur Hazirah Nohseth, 2017)	0.210	0.69745705	69.9 %	1.62	0.68565193	60.2 %

Overall, the data demonstrate the positive impact of the guide vane and mesh screen on the performance of the curve diffuser in terms of pressure recovery. The results suggest that the hybrid flow control method involving these devices can effectively improve the pressure recovery capabilities of the system.

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3. Effect of Employing Device in Curve Diffuser

Based on the findings, flow separation occurs in the curved diffuser near the outlet wall, resulting in reduced velocity and disrupted flow patterns. Guide vanes are effective in mitigating flow separation, particularly at the corner of the outlet wall, by redirecting and controlling the flow. This improves performance by reducing flow separation and enhancing pressure recovery.

However, the addition of mesh screens introduces new flow dynamics. While guide vanes improve flow along the inner wall, mesh screens modify flow patterns and can lead to additional areas of flow separation. These findings highlight the complexity of flow separation and the impact of hybrid flow control methods. Careful design and optimization of hybrid configurations are necessary to achieve desired performance improvements while managing flow separation effects.

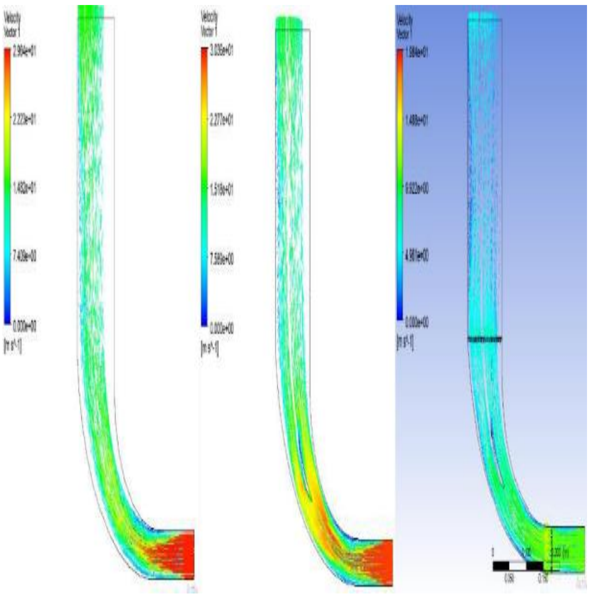

Fig. 3.1 - Some results for velocity streamline

3.1 Results and Discussion

The most significant improvement in performance is observed in the curve diffuser with one guide vane and two mesh screens. In this configuration, the pressure coefficients are significantly lower, ranging from 0.100 to 0.237. This indicates a substantial enhancement in static pressure recovery and a reduction in flow separation. This configuration proves to be highly effective in mitigating flow separation and promoting smoother flow patterns. The mesh screens play a crucial role in breaking up larger eddies and promoting smoother flow, resulting in improved pressure recovery. The velocity values and Reynold numbers are similar across all configurations, ensuring comparable flow conditions. Overall, the data highlights the potential of the hybrid flow control method, particularly the configuration with one guide vane and two mesh screens, in achieving better performance in terms of reducing flow separation and enhancing static pressure recovery in curve diffusers.

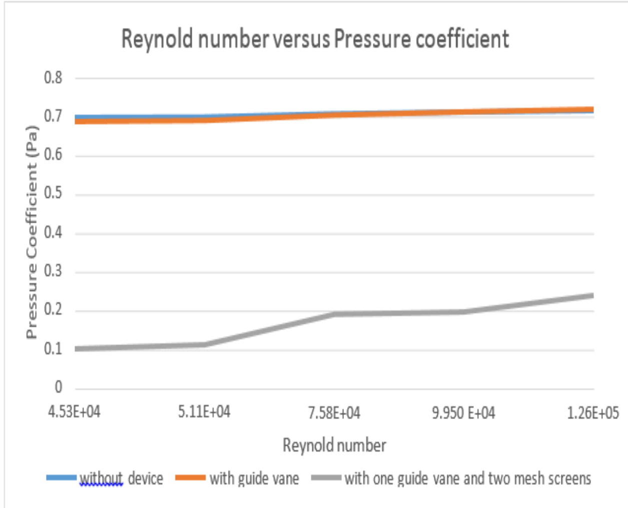

Fig. 4.1 - Graph Reynold number versus pressure coefficient

4. Conclusion

In conclusion, the study highlights the potential performance improvements of hybrid flow control methods in curved diffusers and proposes an optimum device configuration. The findings reveal that flow separation near the outlet wall adversely affects pressure recovery and overall performance. However, the incorporation of guide vanes and mesh screens shows promising improvements. Guide vanes redirect the flow, reducing flow separation and enhancing pressure recovery. Mesh screens act as flow straighteners and turbulence dampeners, further improving flow characteristics and pressure recovery. The analysis of pressure coefficient (Cp) values confirms the superior performance of hybrid flow control configurations. Significant percentage improvements in Cp values demonstrate the effectiveness of these configurations compared to previous studies. Recommendations include comprehensive performance analysis, optimization of mesh screen configuration, fine-tuning of the hybrid flow control configuration, consideration of real-world practical implications, and suggestions for future research directions. By implementing these recommendations, engineers can optimize pressure recovery, minimize pressure drag, and improve overall performance in curved diffusers.

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References

[1] N. N. B. M. Z. A. A. K. S. H. C. Y. M. Z. F. S. M. M. A. Teo Wen Yong, "Effect of Expansion Direction/Area Ratio on Loss Characteristics and Flow," Semarak Ilmu Publishing, pp. 52-53, 2021.
[2] S. Hassan, "Aerodynamics Simulation of vehicle Body by using CFD Technology,"ResearchGate, 2014.
[3] Normayati Nordin, "Performance Investigation of Turning Diffusers at Various Geometrical and Operating Parameters," ResearchGate, 2016.
[4] N. N. M. Z. F. S. A. H. S. M. R. H. C. Y. W. Y. Muhammad Musleh Anuar, "Effect of Employing Vortex Generator on Curve Diffuser Performance," JAMEA, 2021.
[5] L. M. J. A. A. S. Hudhaifa Hamzah, "Role of Honeycomb in Improving Subsonic Wind Tunnel Flow Quality: Numerical Study Based on Orthogonal Grid," ResearchGate, 2021.
[6] B. V. S. P. E. A. Juan Pablo Hurtado, "Optimization Study of Guide Vanes for the Intake Fan- Duct Connection Using CFD," MDPI, 2021.
[7] X. S. T. X. Lu Zhang, "Enhancing Flow Field Performance of a Small Circulating Water Channel Based on Porous Grid Plate," MDPI, 2020.
[8] Y. H. JinwenYang, "Flow separation control in a conical diffuser with a Karman-vortex generator," ScienceDirect, 2020.
[9] J. B. James Scheiman, "Comparison of Experimental and Theoretical Turbulence Reduction from Screens, Honeycomb, and Honeycomb-Screen Combinations," NASA Langley Research Center, Hampton, Va., 1981.
[10] A. V. J. Bjorn Lindgren, "Design and evaluation of a low-speed wind-tunnel with expanding corners," Royal Institute of Technology, 2002.
[11] B. L. Arne V. Johansson, "Design and Evaluation of a Low-Speed," Royal Institute of Technology, p. 8, 2002.
[12] G. H. Angel Huminic, "Aerodynamics of curved underbody diffusers using CFD,"ResearchGate, 2020.
[13] J. M. O. A. V. J. Bjorn Lindgren, "Measurement and calibration of guide-vane performance in expanding bends for wind-tunnels," ResearchGate, 1998.