Experimental Investigation of Pressure Losses and Flow Characteristics in Bend-Diffusers by means of Installing Turning Baffles

Normayati Nordin[1], Safiah Othman[2], Vijay R.Raghavan[3], Mohd Faizal Mohideen Batcha[4], Siti Mariam Idris[5]

[1,2,4,5] Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia (UTHM)
Parit Raja, Batu Pahat, 86400 Johor
Malaysia

[3]Department of Mechanical Engineering
Universiti Teknologi Petronas (UTP)
Tronoh, Perak

[1]mayati@uthm.edu.my

Abstract:

A combined bend-diffuser is often used either as an ejector or an adapter in a duct line. Flow within a bend-diffuser is complex to be judged, thus susceptible to losses. In this study, turning baffles were used particularly to improve the overall performance of system in terms of pressure losses reduction and flow uniformity. The mechanisms of pressure losses and flow characteristics in a bend-diffuser with and without turning baffles were experimentally investigated. Bend-diffusers with and without baffles of 90^o bend angle and area ratio (AR) of 7.2 were considered. Static pressure and air velocity were measured using pitot static probe and digital manometer with accuracy of 0.1Pa by traversing. Three stations, *i.e.*, before bend (S1), before diffuser (S2), and after diffuser (S3) with two planes each were considered for measurement. Pressure losses coefficients obtained for a bend-diffuser without baffle were $K_{bend(w/o)}$, 1.249 and 1.145 for (a) and (b) planes respectively, $K_{diffuser(w/o)}$, 1.290 and 0.578 for (a) and (b) planes respectively and $K_{system(w/o)}$, 1.306 and 1.746 for (a) and (b) planes respectively. For a bend-diffuser with baffle, $K_{bend(with)}$, 0.227 and – 0.351 for (a) and (b) planes respectively, $K_{diffuser(with)}$, 2.899 and 1.275 for (a) and (b) planes respectively and $K_{system(with)}$, 0.573 and -0.134 for (a) and (b) planes respectively. The baffles installed in a bend-diffuser is proven to improve the overall system performance in terms of pressure losses reduction, however, further efforts should be taken to impro vve flow uniformity.

1. Introduction

A diffuser forms an important component of many fluid machines that is generally used to join conduits of different cross-section or to freely dicharge and distribute the air-flow. In the circulating fluidised bed (CFB) system, a diffuser is installed to assemble the lower and upper part of riser which are at different cross-section [1],[2]. In the air conditioning system, diffuser with free discharge is used as an outlet, discharging the conditioned air to the atmosphere [3],[4]. While, in the air craft application, diffusers are installed to convert kinetic energy into pressure energy [5],[6].

There are various types of diffusers which are at common dictacted by their geometries. However, this study is only focusing on a combined bend-diffuser configuration that is particularly used to freely discharge and distribute the air-flow. Generally, the flow within a combined bend-diffuser is not uniform and often susceptible to pressure losses.

The total pressure losses in a bend-diffuser basically depend on the inlet condition of the flow as well as the geometrical parameters of bend-diffuser [7]. If the area ratio (AR) is too large, *i.e.*, more than 7 [3], and the spacer length is sufficient less [4], flow separation at the wall will occur.

Turning baffles are proven capable to assist the airflow in making a smoother and more gradual change in direction. According to Mullinaxsol [8], the bend with turning baffles is 80% more efficient than the same bend without turning baffles. As to improve the overall performance of a bend-diffuser, turning baffles were used in this study. The invention and arrangement of turning baffles by Macbain [9] was applied.

2. Methodology

The mechanisms of pressure losses and flow characteristics in a bend-diffuser with and without turning baffles were experimentally investigated. The experiments were conducted in the Aerodynamic Laboratory, Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia. Figure 1 shows a simple schematic view of the experimental set up.

The maximum delivering pressure of compressor is 0.6 MPa. This compressor is capable for delivering up to 6.72e-03 m^3/s compressed air to a main duct of rectangular cross-section 14 cm wide and 6 cm high when a valve is fully opened.

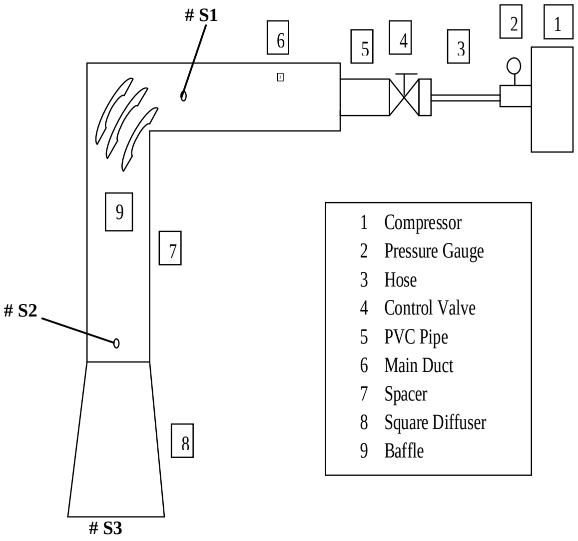


Figure 1: Schematic diagram of the experimental setup

The test section basically consists of 180 cm long upstream main duct before the bend to ensure a fully developed flow at the entrance. This main duct is connected to a diffuser preceded with a 90° bend and a spacer of 45 cm long. The tested diffuser, as shown in Figure 2, has an area ratio (AR) of 7.2 with a square inlet of 13 cm × 13 cm and axial length of 49 cm.

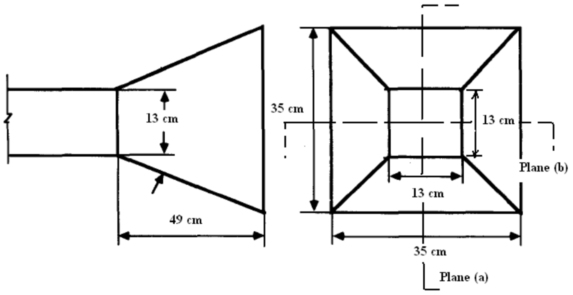


Figure 2: Schematic of the diffuser

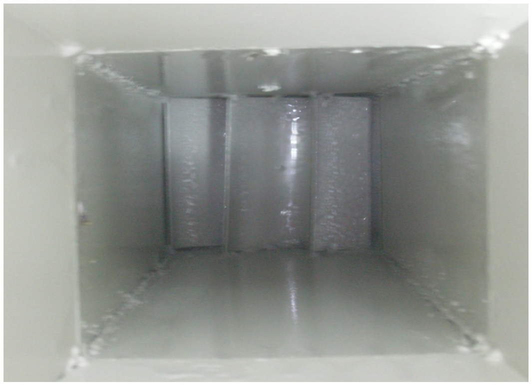


Figure 3: Turning baffles configuration

System without baffles was fabricated from acrylic, whereas system with baffles from smooth-steel plates of thickness 3 mm and supported by holders fixed on the ground. Although, the material used was different the findings obtained could still be justified.

Static pressure and air velocity were measured using pitot static probe and digital manometer with accuracy of 0.1Pa by traversing. Three stations, *i.e.*, before bend (S1), before diffuser (S2), and after diffuser (S3), with two symmetrical cross-section planes each, *i.e.*, section (a) and (b), were considered for measurement.

The overall loss coefficient (K_{system}) due to configuration bend-diffuser is determined by:

$$K_{system} = 1 - Cp_{system}$$

Cp_{system} is pressure recovery coefficient that is given by:

$$Cp_{system} = \frac{2(P_{st(S3)} - P_{st(S1)})}{\rho V_{(s1)}{}^{2}}$$

where,

$P_{st(S3)}$ = static pressure at station 3
$P_{st(S1)}$ = static pressure at station 1
ρ = density of air 1.172 kg/m^3
$V_{(S1)}$= air velocity at station 1

Flow profiles at diffuser outlet before and after installing baffles for 36 traverse points were plotted where the distance between each point is 7 cm. The air velocity at each traverse point (V_n) can be calculated by:

$$Vn = \sqrt{\frac{2(P_o - P_{st})}{\rho}}$$

where,

P_o-P_{st} = Stagnation pressure – static pressure, *i.e*, dynamic pressure.

Figure 3 shows the configuration of baffles applied in this study which was suggested by MacBain [9]. This arrangement is expected to reduce losses approximately to 0.15.

3. Results and Discussion

The mechanisms of pressure losses reduction and flow characteristic of bend-diffuser with and without turning baffles are discussed. The initial idea of introducing baffles is to primarily guide the air-flow, thus avoiding separation to occur. However, this may result an excessive pressure loss due to skin friction.

There should be a trade-off between the flow uniformity and pressure losses when to have baffles in the system. A cautious approach should be taken particularly in choosing baffles configuration.

Figure 4 compares the average static pressure of system with and without baffles for each station. The pressure of system without baffles at S1 (a) and (b) is higher

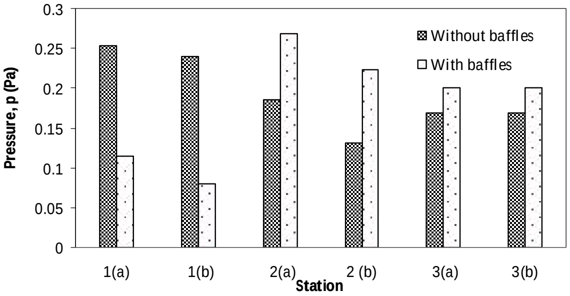


Figure 4: Average static pressure of bend-diffuser with and without turning baffles

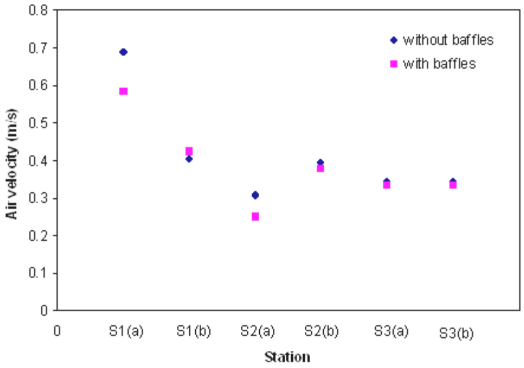
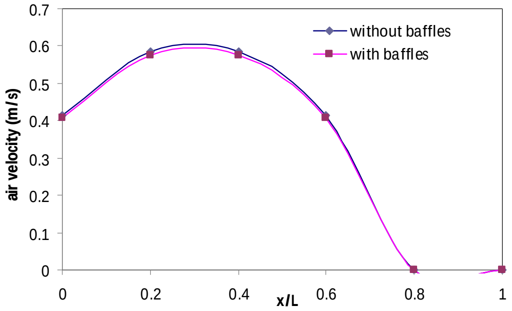


Figure 5: Air velocity distribution of bend diffuser with and without turning baffles

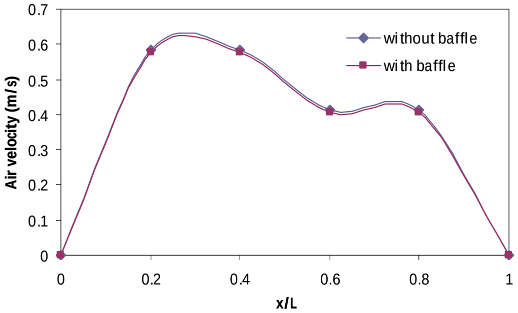
than a system with baffles. This is because of material used, acrylic, that having less friction effect than steel.

Having said that, bend-diffuser without baffles still exposed to huge losses of approximately 33% as a result of separation which occured even before air entering the diffuser. Turning baffles was installed primarily to treat the air-flow, thus, could recover a pressure up to 50%.

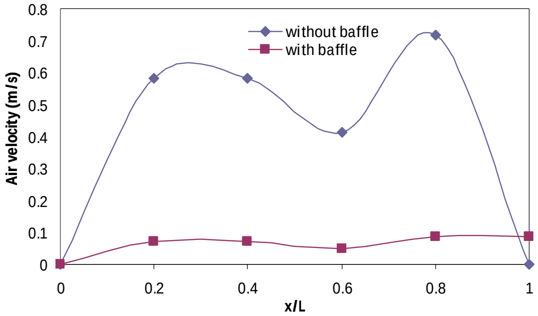
Figure 5 shows that there is no significant different in terms of air velocity distribution along the test section before and after having baffles. In fact, the air velocity at point reached diffuser outlet was almost the same 0.3 m/s. Further investigation was then carried out by taking into consideration several flow profiles at diffuser outlet.



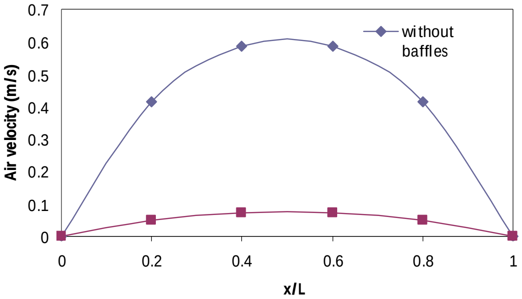
(a)



(b)



(c)



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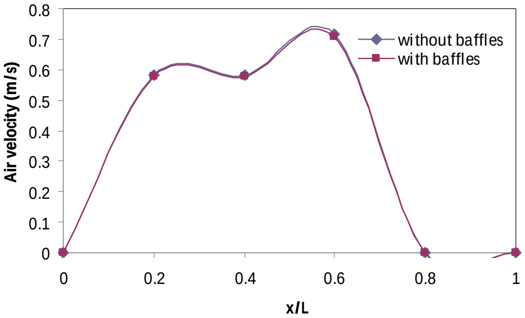
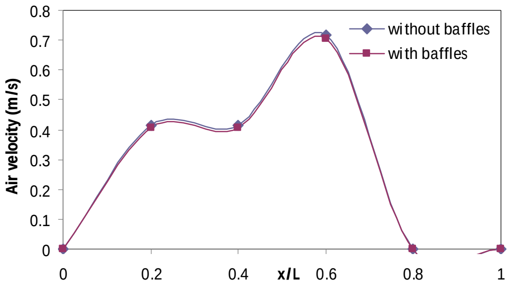


(e)



(f)

Figure 6: Flow profiles at plane (a) x=0 cm, (b) x=0.07 cm, (c) x=0.14 cm, (d) x=0.21 cm, (e) x=0.28 cm and (f) x=0.35 cm

There are at least six flow profiles that have been plotted in order to verify the flow uniformity of bend diffusers with and without baffles. Apparently, there is no considerable change in terms of flow uniformity while having baffles, apart from the plane x=0.14 cm. This might have something to do with baffles configuration. Furthermore, the tested diffuser has a large area ratio of 7.2, which apparently subjects to asymmetric flow separation. Numerical investigations with a number of proposed baffles configurations and diffuser geometries are recommended to be done in future.

Table 1 shows the result of losses coefficient for the bend, diffuser and overall system.

Table 1: Pressure loss coefficient (K) of bend, diffuser and overall system

Part	Loss Coefficient (K)	
	without baffles	with baffles
Bend(a)	1.249	0.227
Bend (b)	1.145	-0.351
Diffuser(a)	1.290	2.899
Diffuser(b)	0.578	1.275
System(a)	1.306	0.573
System (b)	1.746	-0.134

There is a significant drop in terms of losses while having baffles for the bend. On the other hand, the losses in the diffuser increase more than a half when baffles was introduced. This was mainly due to skin friction and excessive separation occurred in the diffuser. However, the overall system with baffles still shows a promising improvement in terms of pressure losses reduction.

4. Conclusion and recommendations

In the present work the performance of bend-diffusers with and without turning baffles in terms of pressure loss reduction and flow uniformity was experimentally investigated. Basically, there was a promising performance in terms of pressure losses reduction for the overall system while introducing baffles. However, further efforts should be taken in order to improve flow uniformity.

It is recommended to extend this work by implementing numerical solutions of selecting the optimum configuration of baffles to be installed in the system. Besides, there is still a gap of studying the diffuser geometries particularly when space provided is limited to install the whole system.

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