Air Flow Analysis and Effect of Angle on Rotation Vane Blade Trough 90° Pipe Bend

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Air Flow Analysis and Effect of Angle on Rotation Vane Blade Trough 90º Pipe Bend

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Abstract. The usual problem occurs when fluid flow pass through elbow or 90º pipe bend is that secondary flow will exist which then lead to high pressure drop. The high pressure drop happen will affect the elbow which is erosion will appear. To overcome this problem, a rotation vane blade with different angles are installed at the pipe. The rotation vane blade will reduce the pressure drop that happened. In this paper, analysis of air flow through 90 pipe bend and the effect of angle rotation vane blade toward it is investigated. The process of the investigation is made through experiment. The inlet velocity used in this experiment are 1.20, 1.30, 1.40, 1.45 and 1.50 m/s. Furthermore, all the inlet velocity produced turbulence flow. Then, rotation vane blade of angle 18º and 33º are installed between the pipes by turn before the 90º pipe bend. U-tube manometer are attached at two places which is Section A-A (before elbow) and Section B-B (after elbow). From this experiment, elevation heights that measured by u-tube manometer of the two sections which are located before and after the 90 pipe bend are recorded. Next, the elevation heights will be used in the Bernoulli equation in order to calculate the velocity distribution at all sections, pressure distribution at all sections and pressure drop between both sections. The result of this experiment show that the rotation vane blade produced slower velocity at section B-B and higher pressure at section B-B. Pressure drop between both sections A-A and B-B is lower when using larger angle of rotation vane blade (33º).

1. Introduction

Most of the industries in this world used any fluids as the main or subcomponent their working system like the oil and gas industry, automotive industry and city management industry. There are many problems can occur towards the piping system but one of the most common problems that can happen in just a few years of installation is corrosion. There are many factors that can lead to corrosion in the piping system. Some of them are pH of the fluid, oxygen in the water, the chemical contained in the fluid, fluid temperature and fluid velocity [1].

When comes to pipe or conduit, usually turbulent flow of fluid will happen at the bends or junction of the pipe. Parchen et al [2] stated that a serious flow disturbances are generated by bends, valves, junctions and other special sections within the pipe line. At the bend area, fluid will possess a secondary flow which happen due to the reaction of the different value of velocities from each streamlines toward the centrifugal force.

The investigation by Binnie [3] was one of the first research done to study the swirling flow in 90 pipe bend, by using the visualization flow in water. However, the investigations were limited to the movement of particles close to the wall, the finding shows flow pattern that existence of an air core, changing its position through the bend. Ogunsesan et al., [4] stated in her research that pipe bends are the most affected parts by erosion in a pipe system. This is due to the changed of the flow direction in the bend. Instead of following the conduit, the fluid tends to hit the bend. Figure 1 illustrate the gas flow in a 90º pipe bend.

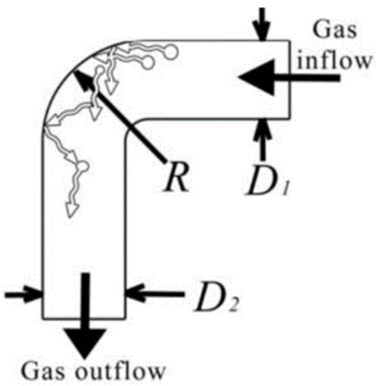


Figure 1: Schematic of gas particle flow transport through the bend

This phenomenon not only generating erosion at the 90 pipe bend, but also changing the pressure of the flow. In previous research of erosion in oil and gas industry made by Horikoshi et al., [5], at regular bend, the value of pressure on the outer side of bend is higher than that of inlet pressure and because of the sudden change in bend direction, pressure value of the inner side of bend becomes fewer. This pressure is negative and causes the gas flow leads to this region. But pressure distribution in outer side of the bend covers around all bend surface area. The loss of momentum in the gas flow causes the pressure rising in the outer side of bend.

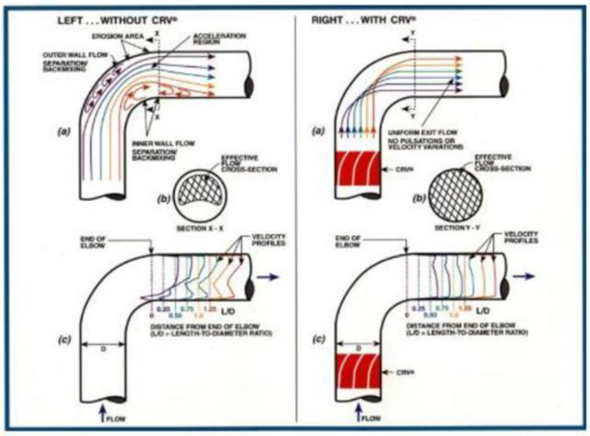


Figure 2: Fluid flows in an elbow with and without the rotation vane.

Wang et al., [6] had explained that installing the Cheng Rotation Vane (CRV) upstream of the elbow eliminates the flow separation. As a result, the effect of erosion towards the pipe elbow will be reduced due to the particulates and droplets are carried along with the flow much the same as in a straight pipe. In addition, the maximum fluid velocity reached is much lower and the entire cross-sectional area of the elbow is available for flow than in a plain elbow.
Zhao et al., [7] had carried out an experiment to measure the pipe flow effects produced by Cheng Rotation Vane installed in a single elbow. This flow conditioning installation are intended to improve pipe flow conditions so that the fluid meters installed downstream can measure satisfactorily. The

experiment were done at Reynolds number at 105 and 50 mm diameter pipe flowing. It had been found that as the angle has increased from zero degrees to the maximum angle, the pressure drop increase and the velocity profile become flatter. When the angle increases past maximum angle, the pressure drop continuous to increase. The purpose of this research is to study and analyze the velocity, pressure, and pressure drop of fluid flow in the result of using different angle blade of rotation vane through 90º elbow pipe fitting.

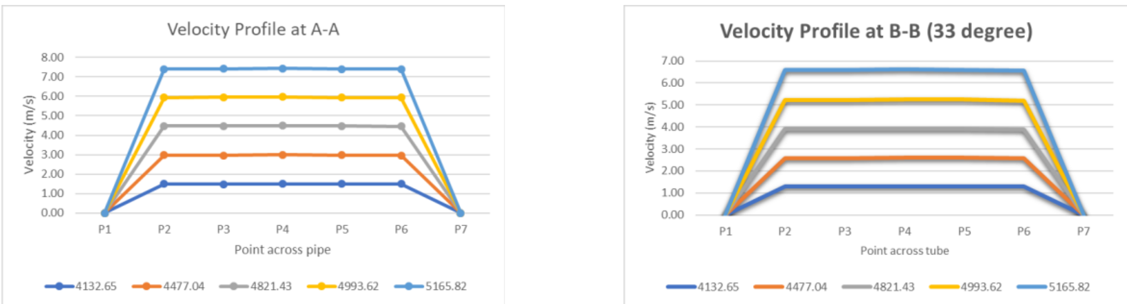
2. Results

The velocity and the pressure distribution can be interpret by plotting graphs from the data. Pressure drop between both sections can also be explained by plotting graphs which later can be used to determine which rotation angle blade that can give lowest pressure drop.

2.1. Velocity distribution

The fully developed turbulent flow must be reach before taken the data. These conditions must be observed for a more accurate analysis result. The minimum distance to fully developed turbulent flow in this experiment is 30.67D.

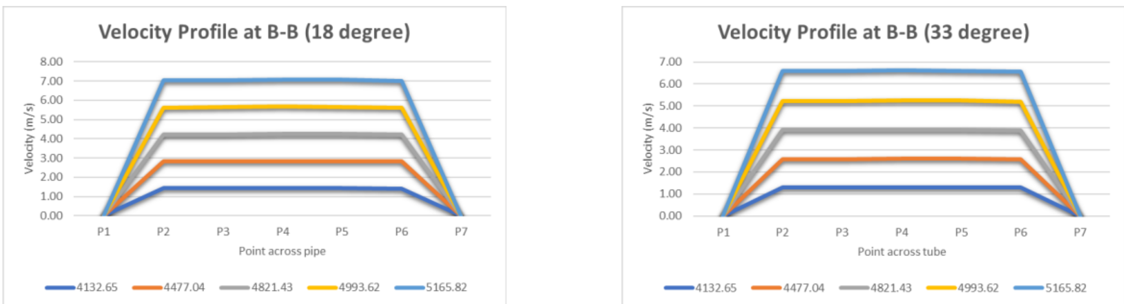
Figure 3 and 4 show the velocity distributions at both section A-A and BB respectively. The horizontal axis indicates the point across the pipe section. Meanwhile the vertical axis represents the velocity distribution and Reynolds number can be identify by the different colour of the line. Both figures indicate that when Reynolds number increase, the velocity distribution also increase. The velocity at the wall of the pipe—P1 and P7 are the lowest.



(a) (b)

Figure 3: Velocity Profile at section A-A (a) 18º (b) 33º

The velocity keeps increasing until point 4 and start decreasing from point 5 until point 7. This is because the velocity of the flow of air is maximum at the center of the pipe cross section. The maximum velocity is at Reynolds number of 5165.82. Due to the slow inlet speed of flow of air which is overall inlet velocity is under 1.50 m/s, the elevation height given by the u-tube manometer only has slight differences among the Reynolds number.



(a) (b)

Figure 4: Velocity Distribution at section B-B (a) 18º (b) 33º

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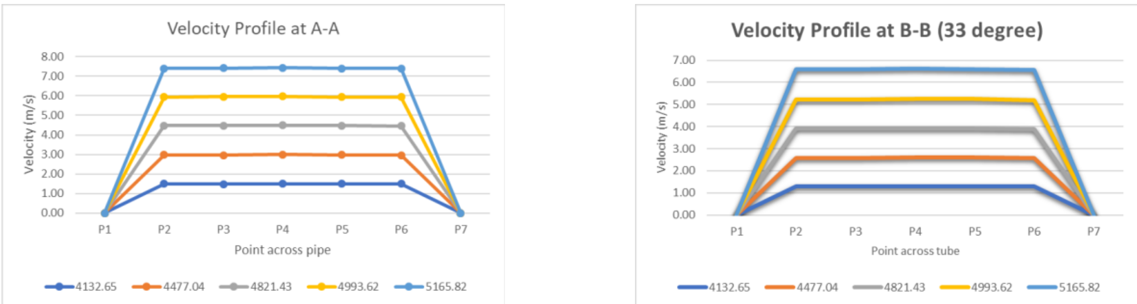
Table 1 shows the maximum and minimum value of the velocity for each Reynolds number for section A-A and B-B. The velocity at B-B should be higher than A-A because of the flow of air had pass through the 90º pipe bend. However, the result shown above display the opposite. This is because of the diameter of pipe at section A-A and B-B are different. Inner diameter of pipe at section B-B is larger than A-A, hence with the constant slow of speed of air, the velocity of air in larger diameter tend to be slower than in the smaller diameter.

Table 1: Maximum and minimum velocity at section A-A and B-B (18º rotation vane blade).

Velocity Inlet (m/s)	Reynolds number	Velocity at A-A (m/s)		Velocity at B-B (m/s)	
		Maximum	Minimum	Maximum	Minimum
1.20	4132.65	1.51	0.00	1.43	0.00
1.30	4477.04	1.48	0.00	1.41	0.00
1.40	4821.43	1.51	0.00	1.41	0.00
1.45	4993.62	1.47	0.00	1.41	0.00
1.50	5165.82	1.47	0.00	1.40	0.00

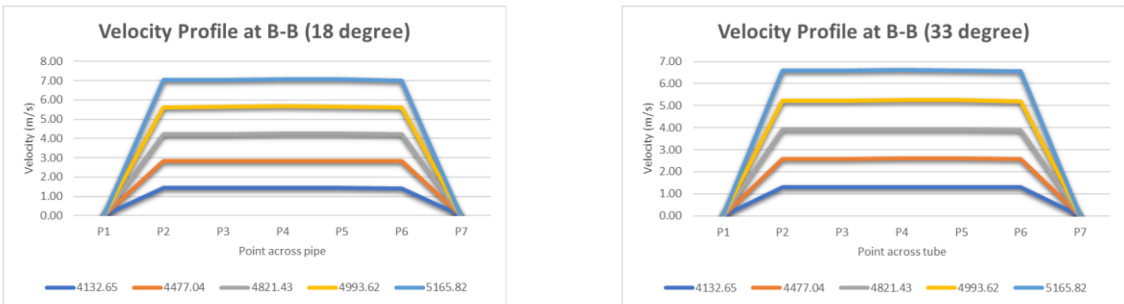
2.2. Pressure distribution

Figure 5 and 6 shows the pressure distribution across the cross section of the pipe at both section A-A and B-B respectively. The graph illustrate that the higher the Reynolds number, the lower the pressure across the cross section of the pipe.



(a) (b)

Figure 5: Pressure distribution at section A-A (a) 18º (b) 33º



(a) (b)

Figure 6: Pressure distribution at B-B (a) 18º (b) 33º

The area under the graph is in negative value because the value of the pressure is inversely proportional with the velocity. Hence, it is normal if the pressure graph has negative area under the graph compare to the velocity of the point across the cross section of the pipe. This consist of potential energy, kinetic energy, and pressure. The potential energy is constant in a horizontal pipe. When the velocity increases, pressure reduced correspondingly in order to keep constant.

From the Figure 6, it can be seen that the pressure at section A-A is smaller than B-B. This situation occurred because of the flow of air is changing direction from straight line to 90º angle. The changing of direction has made the pressure to increase. Other than that, the different in the inner diameter of pipes where sections AA and B-B located can also be the reason why the pressure at section A-A is lower than pressure at section B-B. This is because the velocity is slower at section B-B compared to section A-A because of inner diameter of B-B is larger than A-A, hence pressure will be increase. The maximum pressure occur at the wall of the pipe (P1 and P7), while the minimum value of pressure occur at the center of the pipe. This is due to the nonexistence of shear stress at the centreline of the pipe and there is friction between the fluid and the pipe wall which later generate the shear stress

2.3. Pressure Drop

Figure 7 shows that the highest pressure drop occur at Reynold number of 4821.43. The value of pressure drop at P1 and P7—wall of the pipe is approximate to zero because the shear stress at that point is maximum. Pressure drop keep increasing from point 1 to point 4, while start to decline from point 5 onwards. The maximum pressure drop occurred at the center of the pipe—P4 is because it has the minimum shear stress. However, there are several Reynold's number that show unstable pressure drop which are Reynolds number of 4123.65, 4477.04 and 4993.62. This situation happened might be because of parallax error or the condition of the blower is not stable enough during the experiment.

(a) (b)

Figure 7: Pressure drop between section A-A and B-B (a) 18º (b) 33º.

3. Conclusion

In conclusion, there are relation between velocity distribution, pressure distribution and pressure drop with the Reynolds number. Overall, when Reynolds number increase, the velocity also increases this relation can be prove by the equation 1 (Reynold number), which is:

$$Re = \frac{\rho V D_H}{\mu} = \frac{V D_H}{v} \quad (1)$$

From this equation, the value of velocity is directly proportional with Reynolds number. Next, the value of pressure decreases when velocity increase. When the air flow horizontally, the potential energy is constant, hence the pressure is inversely proportional with the velocity. This is due to shear stress which occur between air and pipe wall. Because of that, maximum velocity happened at the center of the pipe but there is minimum pressure at the same point. Other than that, flat velocity profile has been achieved when 18 and 33 rotation vane blade is used. Then, the pressure drop is corresponded with the Reynold number.

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