# The Effects of Flow Straightener

*by* Dewi Puspitasari

# The Effects of Flow Straightener Inclination on Distribution of Flue Gas Flow

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**Abstract.** Emission from industrial sector must be controlled to maintain its effects on the environment. The measurement of emission quality has been regulated by the government, which have function to monitor the concentration of hazardous compounds. In order to obtain measurement accuracy, the velocity of flue gas in the sampling point should be uniform and has low helicity as well as it should has low head loss to keep the performance of the equipment. In this work, flow straightener inclination under variation : without flow straightener, 0°, 45° upward and 45° downward were installed on the chimney. The objective of this research is to keep streamline condition in measurement area and minimize helicity effect. This research has done by computation fluid dynamic to investigate the effects of flow straightener inclination on velocity distribution, reducing the streamline inclination and helicity. The best condition under achieve by inclination 45°, whereas there are improvement on quality of velocity distribution with pressure drop still be tolerated and flue gas which was first concentrated in the pipe wall has been shifted to the center of the chimney.

**Keywords:** Flow Straightener, Velocity Distribution, Streamline Inclination

## INTRODUCTION

Emissions from industry is related to changes in air quality. The large energy consumption is the reason why the emission has given a significant effect on the environment. According to data of energy consumption, industry sector is the largest energy consumer in Indonesia [1]. Related to energy consumption, some researches also reveal for some parameter the emission from industry is also became the highest contribution [2],[3].

In order to control the emission effect, Indonesian government through Environmental ministry and local government ask the companies to do Environmental Management Planning and Environmental Monitoring Planning. for air pollution control, the companies should do a monitoring activity to control the emission quality. The monitoring activity is purposed to review the obedience level of companies in maintaining their equipment, so that the emission quality generated by each equipment is fulfilled the environmental threshold. In order to obtain an accurate emission measurement, the installation of chimney should be regulated. An accurate emission measurement is an important factor to obtain a correct data which is used to manage the emission load.

According to U.S. EPA Method 1, 1996, flue gas velocity should be measured in a sampling plane with specified distance from inlet and discharge outlet [4]. For better measurement result, the streamline in sampling plane should be uniform, vertical, has low inclination degree and free from cyclonic flow. These streamline properties are needed to obtain an accurate flow velocity. This accuracy is determined by the existence of flow regime [5]. Whereas a uniform velocity is the main factor which affects the velocity measurement [6]. There are many solutions to eliminate cyclonic flow, one of them by installing flow straightener [7].

## BASIC OF THEORY

### Variation Coefficient

To know the change of uniformity of velocity in the reference plane, the method used is to calculate the Average Deviation (MD) by the equation (1) :

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$$AD = \frac{\sum_{i=1}^{n} |v_i - \bar{v}|}{n} \quad (1)$$

where: $v$ : Actual velocity of flue gas

$\bar{v}$ : Average velocity of flue gas

## Pressure Drop

The pressure drop is expressed as the pressure drop coefficient (K) as described in the following equation :

$$K = \frac{\Delta P_T}{0.5\, \rho_{ch}\, V_{ch}^2} \quad (2)$$

# RESEARCH METHODS

## Creating chimney Geometry

In order to analyze the performance of flow straightener and generate a swirling flow, an installation of chimney is created. Dimension of chimney is created based on the information provided by the previous study. In briefly the height of chimney is 4 times its diameter and the height of inlet is 1.15 time to its diameter [8]. Having created chimney geometry, it continues with numerical simulation to justify that the properties of flue gas streamline is close to the previous study. The figure 1 describes the redesign dimension of the chimney. When it has determined the final chimney dimension, it continues with installing the previous flow straightener and flow straighteners which have been modified as described in figure 1.

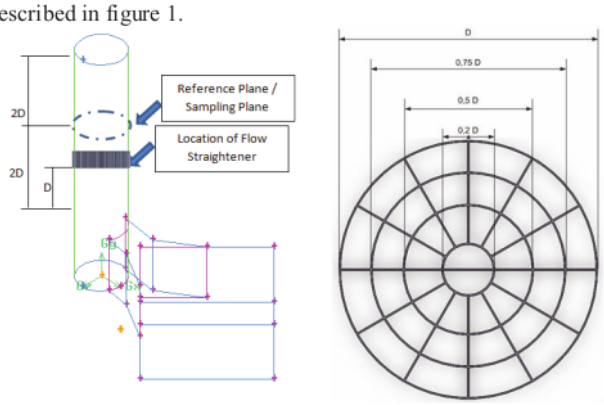



**FIGURE 1.** Geometry and dimension of chimney used to analyze the effect of flow straightener inclination.

## Boundary Condition

Each flow straightener installed on chimney is analyzed numerically by flowing flue gas from inlet to outlet. Velocity of flue gas in chimney is set to be 17.5 m/s with temperature of 190° C. Chimney is operated in standard environmental condition with atmospheric pressure of 1 atm. Since flue gas is consisting of many substances, it's assumed that the flue gas has composition as Table 1.

Table 1. Typical composition of flue gas Source: [11]

| Name of Substanace | Fraction of Volume (%) | Fraction of Mass (%) |
|---|---|---|
| Carbon Dioxide ($CO_2$) | 11 | 16.66 |
| Argon (Ar) | 1 | 1.32 |
| Water Vapor ($H_2O$) | 6 | 3.97 |
| Oxygen ($O_2$) | 6 | 6.57 |
| Nitrogen ($N_2$) | 76 | 72.81 |
| Other Substances | Close to zero | Close to zero |

## Computational Analysis

Flue gas is assumed as compressible gas and steady. Since temperature of inlet is almost equal to temperature of outlet, it is also assumed that the boundary condition is adiabatic. Numerical simulation is conducted with fluent 6.3 software. The solver of numerical simulation is based on density property of fluid. Realizable K-ε turbulence model is used with standard wall treatment. In order to mixing these 5 main substances of flue gas, "species transport" method is used. Density is computed as ideal gas while viscosity is computed by "mass-weighted mixing law".

## Result and Discussion

### Velocity Profile

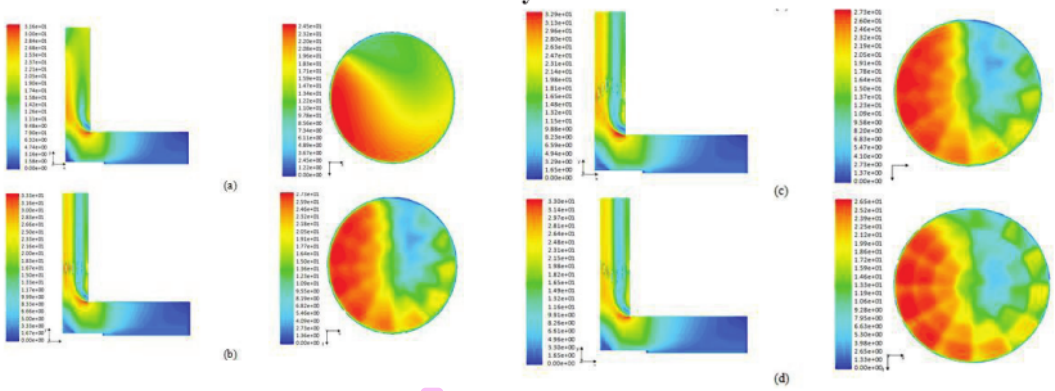
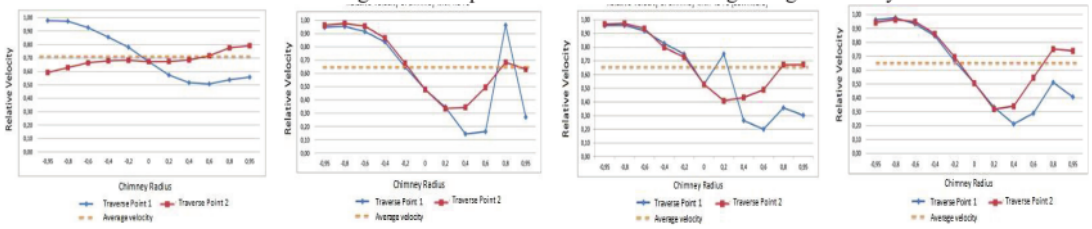



**FIGURE 2.** Profile of velocity magnitude from inlet to outlet. (a) without flow straightener, (b) with 0° flow straightener (c) with 45° flow straightener (upward) (d) with 45° flow straightener (downward)

Figure 2 describe the inclination of flow straightener is affecting the amount of fluid flow inside flow straightener. The upward inclination is able to direct flue gas which concentrate near the wall to the center of chimney. Meanwhile the downward inclination is able to direct flue gas to the right side of chimney as a result of rotational movement. The alteration of streamline is caused by the resistance generated by flow straightener. This resistance will generate the pressure at inlet of flow straightener, finally the flue gas will alter its direction to lower pressure location. Meanwhile flow straightener is used, the amount of flue gas is still concentrated near to the wall. The existence of inclination can cause flue gas is distributed to location which has lower pressure in chimney. Its mean that the inclination of flow straightener has positive effect in distributing flue gas velocity.




(a) (b) (c) (d)

**FIGURE 3.** Velocity of flue gas along to traverse point located in sampling point. (a) without flow straightener, (b), with 0° flow straightener (c) with 45° Flow Straightener (upward) (d) with 45° Flow Straightener (downward)

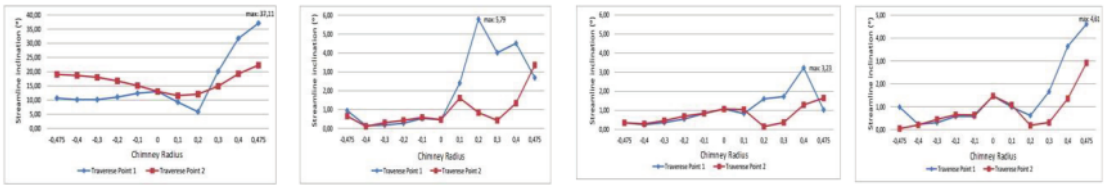
Figure 3. describes the average relative velocity and average deviation such as Table. 2. According to the data, modification of flow straightener inclination can improve the average deviation till 7.33 % (downward) and 11.70% (upward).

Table 2.The typical average velocity of flue gas

| Simulation Condition | Average of Relative Velocity | Average Deviation |
|---|---|---|
| With no Flow Straightener | 0.702 | 0.114 |
| With 0º Flow Straightener | 0.639 | 0.246 |
| With 45º Flow Straightener (upward) | 0.656 | 0.217 |
| With 45° Flow Straightener (downward) | 0.647 | 0.228 |

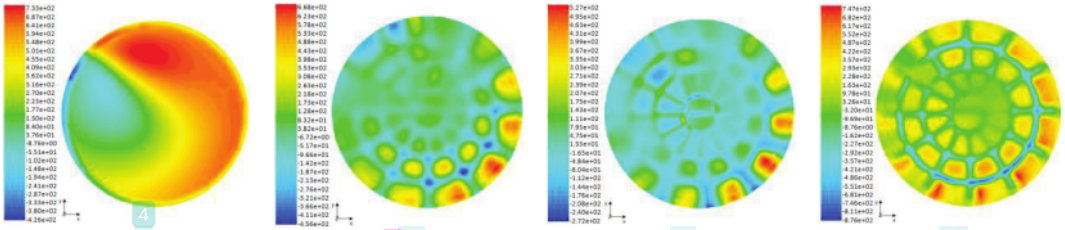
## Streamline Inclination and Helicity

The figures 4 describe streamline inclination of flue gas along the traverse points. Previously without installing flow straightener, the maximum inclination value is close to 37º. With installing various flow straighteners, the inclination is successfully reduced. The lowest value of streamline inclination is resulted by 45º flow straightener (upward) with maximum streamline inclination of 3,23º. It's followed by 45º flow straightener (downward) with maximum streamline inclination of 4.61º and 0° flow straightener with maximum streamline inclination of 5.79°.




(a) (b) (c) (d)

**FIGURE 4.** Inclination angle of flue gas along to traverse points. (a) Without flow straightener, (b) with 0º Flow straightener, (c) with 45º Flow Straightener (upward) (d) with 45º Flow Straightener (downward)



(a) (b) (c) (d)

**FIGURE 5.** Helicity of flue gas in reference plane (a) without flow straightener, (b) with 0º flow straightener (c) with 45º flow straightener (upward) (d) with 45º flow straightener (downward)

## Pressure Drop

The highest pressure drop coefficient is occurred in chimney with 0º Flow straightener with value of 2.206. Meanwhile 45º (downward) of flow straightener has the lowest coefficient of pressure drop with value of 1.023 and followed by 45° (upward) with value of 1.998. The high inclination angles apparently are effective to direct the flue gas without loosing high pressure (the degree of inclination of flow straightener is effective in directing the flow of exhaust gas without having to lose much pressure). The average pressure along chimney in three simulation condition is described in Fig. 6.

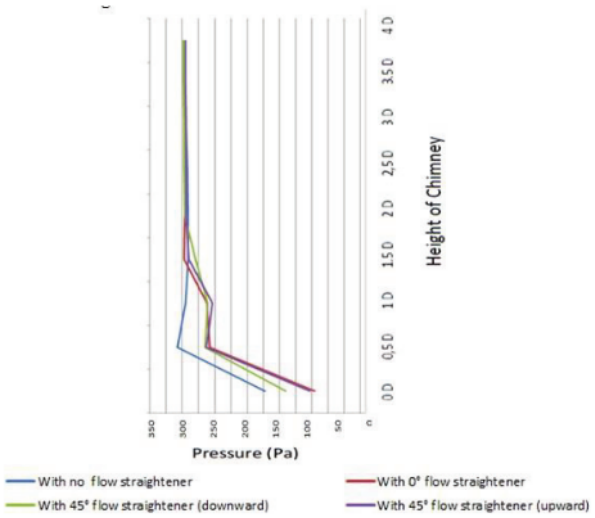



**FIGURE 6.** Average pressure along the chimney in three condition simulation

## CONCLUSION

The performance of flow straightener is related to its shape, one of the shape parameter is the inclination. In order to investigate the effect of flow straightener inclination, 3-D numerical simulations have been conducted. The investigation is focused for four parameters, the parameters are: velocity distribution, streamline inclination, helicity and pressure drop.The best velocity distribution is resulted by 45° flow straightener (upward); meanwhile the 45° flow straightener (downward) also can improve the velocity distribution of 0° flow straightener. For streamline inclination, both types of 45° flow straightener (upward dan downward) are able to reduce the inclination to lower than 5°, eventhough the 45° flow straightener generates the lowest streamline inclination. For helicity parameter, the lowest helicity is also generated by 45° flow straightener (upward) with maximum value of 527 $m/s^2$ and average value of 23 $m/s^2$. while the 0° flow straightener is also able to reduce helicity with maximum value of 667 $m/s^{2a}$ and average value of 31 $m/s^2$. Finally the highest helicity is resulted by 45° flow straightener (downward) with maximum value of 746 $m/s^2$ and average value of 61 $m/s^2$. The highest pressure drop is resulted by 0° flow straightener with value of 2.206, while 45° flow straightener (upward) and (downward) are having lower pressure drop coefficient. Considering the simulation result, both 45° flow straightener (upward) and (downward) re improving the quality of velocity distribution, streamline inclination, helicity and pressure drop effectively. In conclusion the modification of flow straightener inclination can be applied for generating better streamline pattern. For the next research is needed to improve the performance of this flow straightener.

## ACKNOWLEDGMENTS

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