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To cite this article: Tianyu Zhang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 022121

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Study of Unequal Speed Leveling Of Pulverized Coal Piping in Cold State

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Abstract. The equality of flow of coal powder and wind in each pulverized coal piping makes great differences on the heat flux uniformity in combustion chamber. Thus, a common way to ensure the equality is to change the opening degree of the adjusting holes on the piping to get equivalent wind flow in cold state. However, the operating condition of the piping is in hot state with coal powder, which changes the resistance characterizes in each piping. Present paper casts light on the calculation method of unequal speed leveling in cold state, in order to get equivalent wind speed in hot state with powder.

1. Introduction

The uniform aero-dynamical field is critical to the safe operation of unit, and the equality wind and powder distribution in pulverized coal piping is important to the heat flux in furnace.

In order to get equal distribution of powder and wind in each piping, engineers conduct an experiment in cold state to balance the wind distribution in each piping, and according to relevant guidance [1], the goal can be reached. However, due to the different resistance characteristic in hot state with powder, the equal cold setup may not meet the demands in actual hot working condition.

In present study, a calculation method is studied based on a 350MW unit. The pressure drops distribution of vertical section, horizontal section, piping elbow and burner is investigated. The predicted wind flow distribution (unequal) is also in the scope of present investigation.

2. Model and governing equations

The concern in present study is the layout of the piping of each mill. Due to the similarity of layouts, only the piping of the lowest and highest mill is studied. The parameters of the layouts is listed in Table 1&2.

Table 1. Piping layout of A mill (lowest level)

Item	Vertical Section/m	Horizontal section/m	Elbow	remark
A1	5.89	14.16	3×90(1.2) +90(1)	-
A2	6.09	29.95	2×90(1.2)+2×90(1) + 2×41(1.2)	-
A3	6.09	51.37	3×90(1.2) +2×90(1) +65(1.2) +45(1.2)	-
A4	5.89	26.32	3×90(1.2) +90(1) +52(1.2) +49(1.2)	-

Note:

1. Column of Elbow, the number in the bracket is the radius of elbow(m), number outside is the elbow angle

2. The thermal expansion of piping is neglected.

Based on the parameter above, the pressure drop can be divided into vertical and horizontal section, elbow, orifice and burner.

3. Vertical and Horizontal section

The additional pressure drops caused by powder in the wind is mixed with pressure drop of pure wind, and is calculated as:

$$\Delta P_{H\mu} = \lambda_{\mu} \frac{L}{D} \frac{\rho w^2}{2} \quad (2-1)$$

$$\lambda_{\mu} = (1 + k\mu) \lambda_0$$

where λ_{μ} - Friction loss factor of mixture of wind and coal powder;
 λ_0 - Friction loss factor of mixture of pure wind;
 μ - Powder concentration, kg/kg.
 L - Piping length, m;
 D - Equivalent diameter, m;
 w - Wind velocity, m/s.

The correction parameter k is different in various literatures [2-4], and listed in Table 2.

Table 2. Value of k

Application	Standard of Soviet Union (1958)	Standard of Soviet Union (1974)	TPRI	Zhejiang University
Vertical	$1 + \mu$	$1 + 2.5\mu$	$1 + \mu$ ($\mu < 0.5$) $1.5(\mu \geq 0.5)$	$1 + 1.18\mu$
Horizontal	$1 + \mu$	$1 + 2.5\mu$	$1 + 0.65\mu$	$1 + 0.86^{1,12}$
Elbow	$1 + 2.5\mu$	$1 + 0.75\mu$	$1 + 5.5\mu$	$1 + 3.3\mu$

3.1. Elbow

The local resistance can be calculated as:

$$\Delta P_{local} = \varepsilon \frac{\rho w^2}{2}$$

$$\varepsilon = \varepsilon_{\theta} (1 + k\mu)$$

$$\varepsilon_{\theta} = \varepsilon_{90} \left(-0.0216 + 1.6398 \frac{\theta}{90} - 0.7826 \left(\frac{\theta}{90} \right)^2 + 0.1585 \left(\frac{\theta}{90} \right)^3 \right) \quad (2-2)$$

$$\varepsilon_{90} = 0.1099 + 0.4752 e^{-\frac{x-0.4997}{0.2853}} + 0.1555 e^{-\frac{x-0.4997}{1.3708}}, \quad x = \frac{R}{D}$$

where ε - Local resistance coefficient, subscript is the elbow angle, °;
 R - Turning radius, m.

The formula is defined by the method of polynomial regression and the value of k can be set as shown in Table 2.

3.2. Orifice

The pressure drops caused by orifice (adjusting hole) can be calculated as a circular orifice plate (however, other shape of orifice has more application in actual use):

$$\Delta P_{orifice} = 158.89 - 161.36 \left(\frac{d}{D}\right)^3 + 481.13 \left(\frac{d}{D}\right)^2 - 478.66 \left(\frac{d}{D}\right) + 24.21\mu + 22.49 \left(\frac{d}{D}\right)^2 \mu - 46.68 \left(\frac{d}{D}\right) \mu \quad (2-3)$$

where d - Orifice diameter, m;

Equation (2-3) has high-level accuracy when μ is between 0 and 0.6.

3.3. Burner

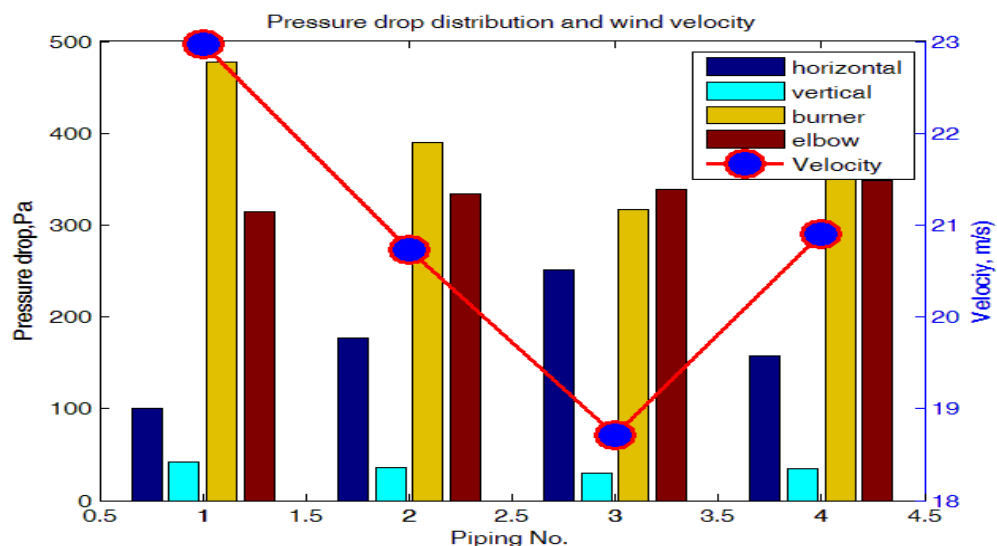
Other pressure drop in piping also concludes lifting head loss, acceleration pressure drops and burner, and the former two is relatively small in value and hence neglected. The pressure drops caused by burner is calculated as (tangential burner):

$$\Delta P_{burner} = 1.5(1 + 0.8\mu) \frac{\rho w^2}{2} \quad (2-4)$$

Therefore, the total pressure drop is the sum of the pressure drop above.

4. Results and Conclusion

In this section, the pressure drop of horizontal and vertical section, burner, orifice and elbow in cold and hot state is studied. In the case of cold state, the calculation parameters are set as: temperature 20°C, total wind flow 83t/h, and according hot state parameters setup are set as: temperature 70°C, total wind flow 83t/h, and coal feed flow 56t/h. Based on the formula and above, the pressure drop can be calculated as shown (cold and hot state with adjusting holes full opened).



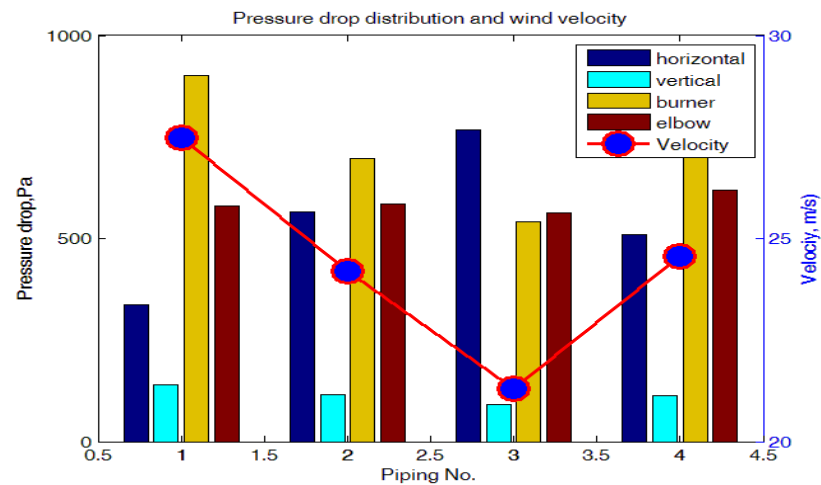
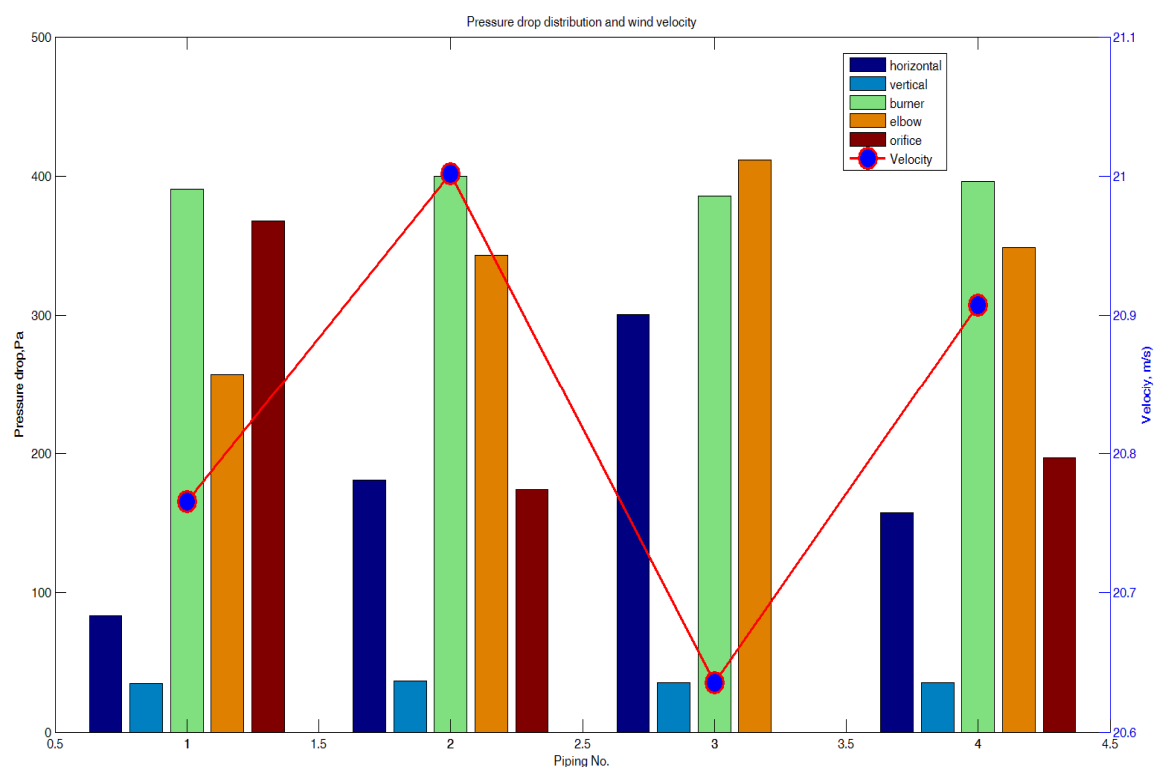


Fig 1. Pressure drop and velocity distribution in cold and hot state with orifice full open

As shown in Figure. 1, the original setup of piping may lead to great deviation in balance of wind flow, which need to be corrected by adjusting the orifice. Meanwhile, due to the temperature rise, the velocity in each piping accelerates, leading to more pressure drop compared with that in cold state. It can also be seen that; the pressure drops distribution changes. If the orifice is adjusted according to the equality in cold state, then the hot state result can also calculate.



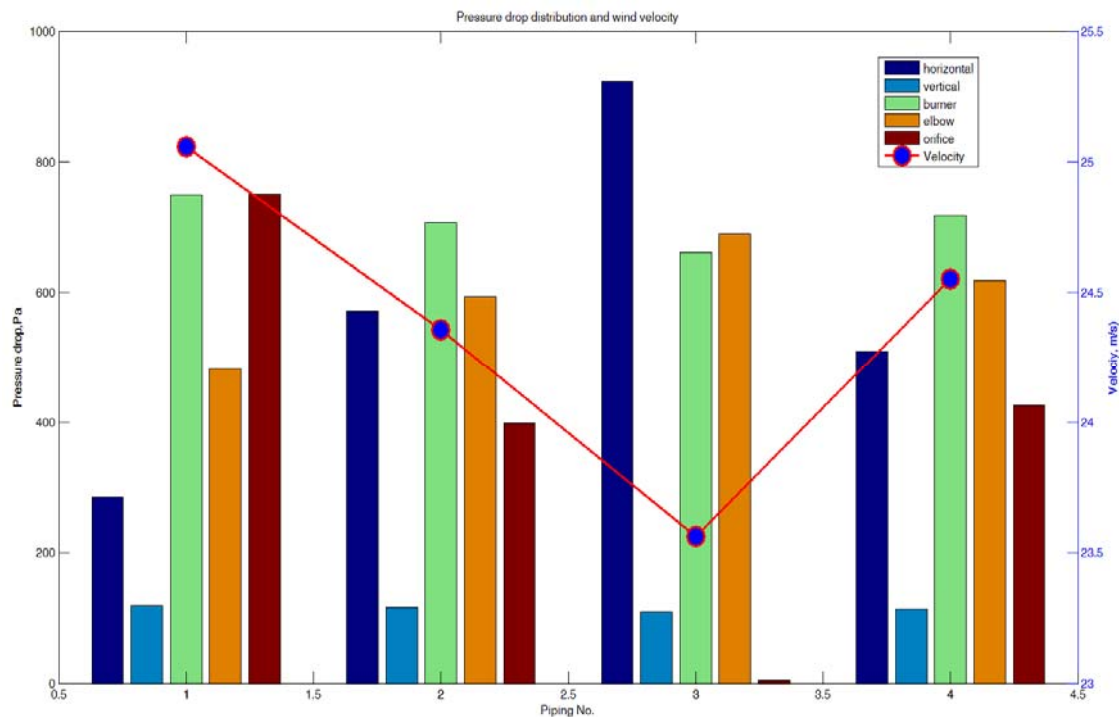
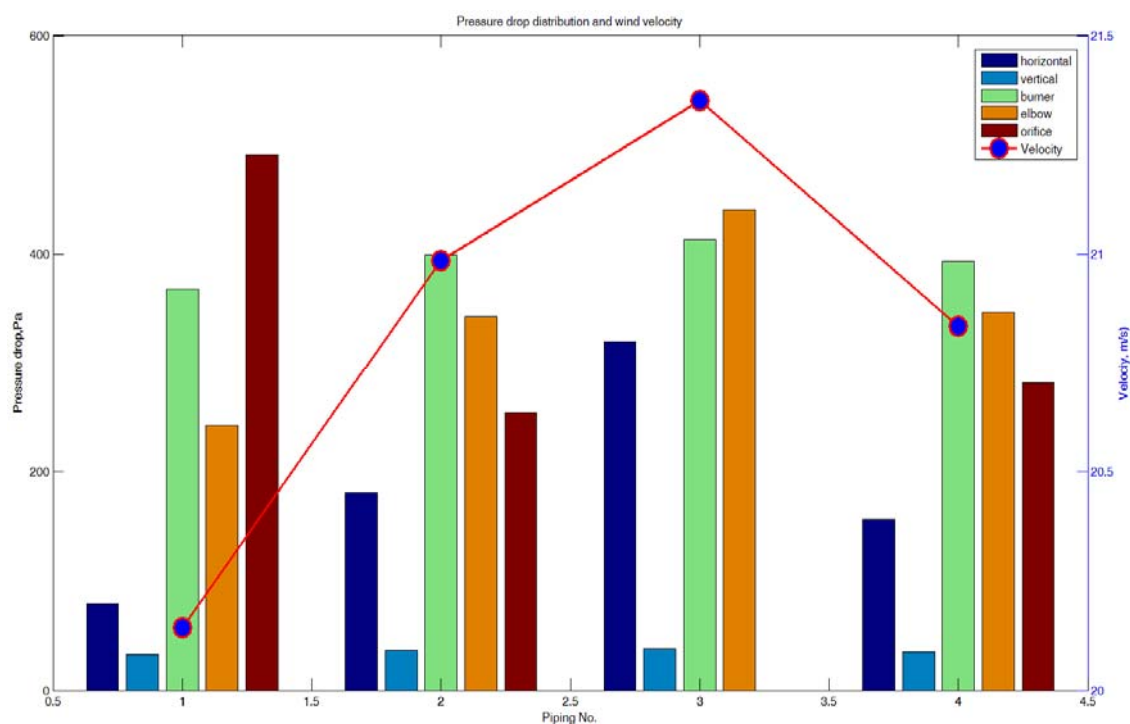


Fig 2. Pressure drop and velocity distribution in cold and hot state with orifice adjusted according to cold state

As seen from Figure.2, adjustment of orifice introduces new pressure drop and changes the pressure drop distribution, in order to get the equality of wind flow in each piping. However, the equality setup (orifice opening degree) in cold state may not meet the demands in hot and working condition as shown in Fig.2(b). Therefore, it is suggested the adjusting work be done according to the hot state results.



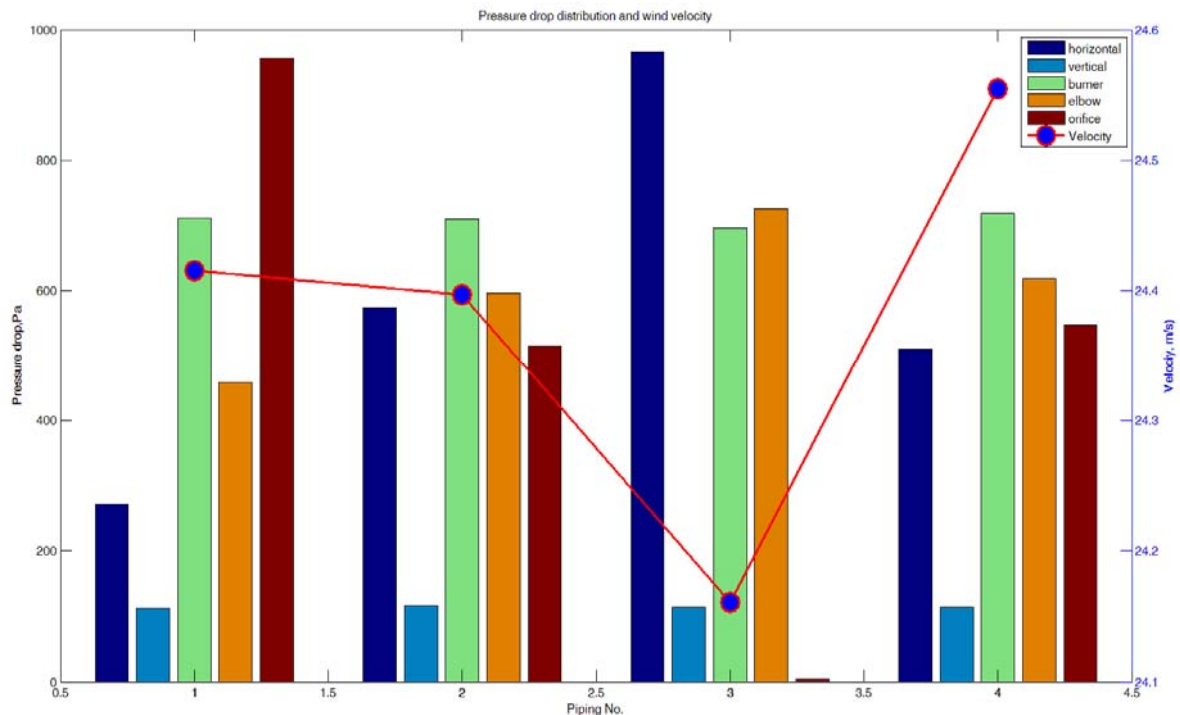


Fig 3. Pressure drop and velocity distribution in cold and hot state with orifice adjusted according to hot state

As shown in Fig. 3, the equality (velocity error is limited) in hot state is reached while the cold state is not, and the inequality in cold state is the goal to reach in cold-state leveling experiment. It can also demonstrate that the inequality adjusting method in cold state can get more equal velocity distribution in piping in working condition.

It can be seen from Fig 2 and 3, in the ideal condition of pulverized coal piping leveling, the adjustment in cold will result in around 3% error in hot working condition. Meanwhile, used the predicted orifice opening obtained from hot state leveling condition will also lead to around 3% error in cold condition, which indicate the direction of leveling experiment in cold state. However, it is worth mentioning that the uniform distribution of the mixture of powder and wind is influenced both by piping component setup and mill's separator and wing ring. Therefore, the performance of these apparatus will also determine the uniformity of the powder in each piping.

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