THE EFFECT OF DIRECTION OF LOW SPEED WINDS ON THE PERFORMANCE OF A SPLIT CHIMNEY

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Summary High concentrations of toxic gases discharged from chimneys are a health hazard. Previous study shows that a split chimney is capable of lowering the concentration of the smoke and harmful gases within the configuration before ejection to the environment but there might be leakages from its sides. The effect of low-speed wind at different directions on a split chimney with an arbitrary geometry is modeled. The results show that the leak can be eliminated by proper positioning of the configuration.

INTRODUCTION

A high concentration of smoke and toxic gases ejected from chimneys presents a health hazard. The concentration has to be lowered before reaching the ground. An effective solution is to use tall chimneys. The wind lowers the concentration before it reaches the surface. However, heavier-than-air toxic gases flow downward before dilution. This is particularly problematic in the case of low wind speed in high-density populated areas.

A simple configuration consisting of two identical half cylinders and placed off-centre is currently used to induce fire whirls. The experiments indicate that the entrained air swirls around the central vertical axis of the chamber and generates a whirling fire. The swirling flow also elongates the fire whirl [1] and increases the burning rate [1, 2]. The required extra oxygen is obtained by the entrained air from the side openings which are formed between two half cylinders. A recent research shows that the fuel located at the base of the configuration can be replaced by an inlet of the hot air inlet [3]. The results demonstrate that this change does not reduce the discharge of the configuration in comparison with an equivalent chimney. The research also indicates that the configuration is able to lower the concentrations of the exhaust toxic gases**.** In another research, the effects of wind speed on the performance of the split chimney were assessed. The results show under all wind speeds the configuration is able to dilute the exhaust gases and it does not have an adverse effect on the chimney discharge [4]. However, the results also show that the chamber ejects smoke and toxic gases from the side openings at speeds as low as 2 m/s. This is the main drawback of the design but it should be noted that the leakage at higher wind speeds is less harmful as the wind is expected to lower the smoke concentration in the vicinity of the chimney.

A dominant local wind direction can be identified for most places. The previous works did not consider the effects of wind direction on the performance of the split chimney except at $\theta = 0^o$ (see Fig. 1a). This work follows a computational approach to identify the best direction of the installation of the split chimneys in terms of the lowest side leakage.

MODELLING

A configuration similar to that used in previous study [4] is modeled. The configuration includes two hollow half-cylinders with a height of 2m, an external diameter of 1m and a wall thickness of 0.01m. The two half-cylinders are placed 0.071m off-centre (0.05m in both x and z directions, see Figs. 1a &1b). The smoke inlet has a circular shape and is located at the centre of the base (see Figs.1a & 1b).The domain is a box having a height of 20m, a width of 10m and a length of 25m. The chamber is located at the bottom of the domain, 5m away from the left side and 5m away from the front side (Fig, 1c). The number of tetrahedrons elements varies from 293606 to 304906. The wind blows from the left side of the domain with uniform speed of 2m/s. The chamber was modeled from zero degree to 165^o with an increment of 15^o (see Fig. 1a). The air was assumed to be an ideal gas and its properties varied with temperature. The thermal radiation was not modeled. The domain and the wind temperature were assumed to be 25^oC and hydrostatic pressure gradient was applied. The inlet had the properties of the air and its temperature and relative total pressure were assumed to be 100^oC and zero Pascal, respectively. The chimney and the bottom of the domain were assumed to be no slip, adiabatic and smooth walls. All sides (except the left side) and the top side were assumed to be opening. The solver (ANSYS-CFX) treats the specified pressure and temperature as total values for inflows. The initial temperature and the reference pressure at the bottom of the domain were assumed to be 25^oC and 101325 Pa, respectively. The governing equations were the continuity, Navier-Stokes equations and thermal energy equation. The Boussinesq approximation was not used. The convergence criterion was set on 1×10^{-5} of

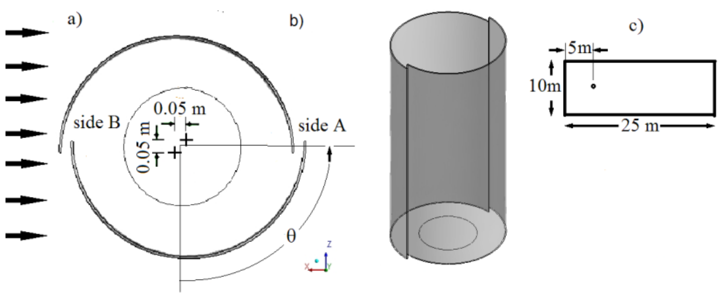

Figure 1: Modeling details a) top view of the split chimney, b) side view of the chimney, and c) top view of the domain

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the RMS residual for all variables. The RNG k-ε turbulent model was used. Previous work [3] indicated that the results of this technique are in good agreement with those from experiments.

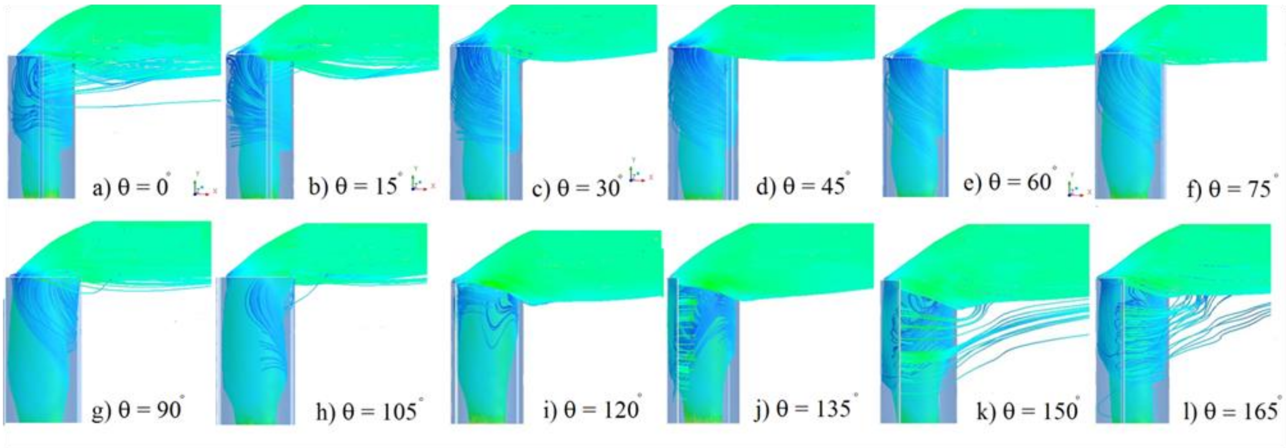

Figure 2: Leakage from the split chimney at different wind directions (see Fig. 1a) a) θ=0°, b) θ=15°, c) θ=30°, d) θ=45°, e) θ=60°, f) θ=75°, g) θ=90°, h) θ=105°, i) θ=120°, j) θ=135°, k) θ=150°, and l) θ=165°.

RESULTS

Figure 2 shows the results of the simulation. The chimney and the streamlines originated from the circular inlet are shown. Figure 2a shows the chamber does not leak at the heights less than 1.01m when θ=0°. At θ=15°, the minimum height that the leak can be identified increased to 1.63m. At angles of 30° and 45°, the minimum height increased to 1.74m and 1.80m, respectively. Table 1 shows the leak occurs only at side A. No leak was detected in the cases of θ from 60° to 105° (see Figs. 2d, 2e, 2f, 2g). At angle 120°, the leak reappears only from side B and occurs at the heights above 1.39m. At angle 135°, the leak exists at the heights of 0.31m above the bottom which is the lowest height observed in this work. Further increase of the angle raises the minimum height of the leak. At angles 150° and 165°, the leak appears at the minimum height of 0.57m and 0.68m respectively. No leaks were observed at angles 120°, 135 °, 150°, and 165° from side A.

Table 1: The minimum height of the leakage at different wind directions (see Fig. 1a)

Wind angle (degree)	H_{min} (m)	Side of leakage
0	1.01	A
15	1.63	A
30	1.74	A
45	1.80	A
60	N/A	N/A
75	N/A	N/A
90	N/A	N/A
105	N/A	N/A
120	1.39	B
135	0.31	B
150	0.57	B
165	0.68	B

DISCUSSION

The results show that the side leakage of a split chimney depends on the wind direction and can be eliminated if the line connecting two sides is parallel to the wind. In that case, the performance of the chimney remains stable if the wind direction changes less than 15° degrees in both directions (θ=90° -15°=75° to θ=90° +15° =105°). Further change of the wind direction (up to 15°) without an adverse effect is possible in only one direction (θ=70°-15°=60°). The worst direction of the low speed wind in terms of leakage occurs at θ=135°. In this angle, side A does not properly face the wind and side B faces away from the wind. It should be noted that the results of this work are valid only for the specified geometry and a wind speed less than 2 m/s.

CONCLUSION

A split chimney with an arbitrary geometry under different directions of the low speed wind was modeled. The results show that the performance of the split chimney in terms of the side leakages improves if it is set up in a way that the line connecting two side openings becomes parallel to the wind.

References

[1] Lei, J, Liu, N, Zhang, L, Chen, H, Shu, L, Chen, P, Deng, Z, Zhu, J, Satoh, K & de Ris, Jl 2011, 'Experimental research on combustion dynamics of medium-scale fire-whirl' Proceedings of the combustion Institute, vol. 33, no. 2, pp. 2407-15.

[2] Kuwana, K, Morishita, S, Dobashi, R, Chuah, KH & Saito, K 2011, 'The burning rate's effect on the flame length of weak fire whirls', *Proceedings of the Combustion Institute*, vol. 33, no. 2, pp. 2425-32.

[3] Al-Atresh, Sharfian,A. 2012, 'Using a split chimney to dilute exhaust pollution-a CFD approach', paper presented to 2012 International Conference on Fluid Dynamics and Thermodynamics technologies (FDTT 2012), Conference Proceedings, Mar. 17-18, Singapore.

[4] Sharfian,A. 2012, 'the effect of wind speed on the perfomance of a split chimney', paper presented to 2012 International Conference on Fluid Dynamics and Thermodynamics technologies (FDTT 2012), Conference Proceedings, Mar. 17-18, Singapore.