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Influence of Vortex Generator on Flow Behavior of Air Stream

*Chakkapong Supasri [1)],Tanongkiat Kiatsiriroat [2)] and
Atipoang Nuntaphan[3)]

[1) ,2)]*Department of Mechanical Engineering, Faculty of Engineering*
Chiang Mai University, Thailand 50200
[3)]*Thermal Technology Research Laboratory, Mae Moh Training Center,*
Electricity Generating Authority of Thailand, Thailand 52220
Chakkapong.s@egat.co.th

ABSTRACT

This research studied the influence of delta wing and delta winglet vortex generators on air flow characteristic. Normally, the vortex generator has been used for enhancing the heat transfer performance by promote the helical flow of air stream. The vortex generator was setup in the wind tunnel and the flow pattern of air stream passing the vortex generator was observed by using smoke generator. The Reynolds number of air stream was between 30,000 and 80,000. It is found that the delta winglet having 20 mm fin height and 30 degree of air stream contact angle generates the maximum helical flow of air stream.

1. INTRODUCTION

Particulate matter is the byproduct of coal-fired power plant and it needs to eliminate from the flue gas before leaving the stack. In case of 300 MW coal-fired power plant, the electro-static precipitator (ESP) is normally used for collecting the fly ash from the flue gas. Although, the efficiency of this equipment is higher than 99.0%, however, the small size of fly ash, especially less than 2.0 micron, always escapes from the ESP. This fly ash normally accumulates on the tube bundle of heat exchanger and the heat transfer degradation is obtained.

Recently, the non-thermal plasma technology is adapted for dust collecting purposed. Under the electric field of this method, the smaller than 1.0 micron particulate matter can be merged together to become the bigger size particle and then collected by the conventional dust removal system (Thonglek). However, this new technology needs the low frontal velocity particle. Therefore, the vortex generator is selected as a velocity retardant apparatus for slowing down the particle velocity.

Actually, there are many research works reports the performance of vortex generator. For example, Gentry (1997) reported the heat transfer enhancement of flat plat attached with the delta wing vortex generator and they found the increasing of heat transfer around 50-60% in case of the contact angle and the aspect ratio of vortex generator were 40 degree and 1.0 respectively. Sherbini (2000) found the enhancement of heat transfer around 30% when setting the delta winglet vortex generator with the fin and tube heat exchanger. Chomdee (2006) used the delta winglet vortex generator to promote the turbulence of air flow for the electronic cooling application. Joardar (2008) showed the heat transfer enhancement of heat exchanger promoted by the delta winglet for refrigeration proposed. The effect of vortex generator row was observed in this work. They found 16.5-44% heat transfer enhancement for single row of delta winglet and 30-68.8% for 3 rows. Zeng (2010) used the numerical method for analyzing the parameter affecting the heat transfer enhancement and pressure drop of heat exchanger attached with the vortex generator. They found the increasing of contact angle, length and height of vortex promote the enhancement of heat transfer and increasing the pressure drop at the same time.

From above literatures, it can be seen that the application of vortex generator is mainly to promote the heat transfer of heat exchanger by generate the helical flow and also the turbulent of air stream passing its body. However, the application for the retardation of particulate velocity is very rare but applicable. Thus, the objective of this research work is to find out the suitable shape of vortex generator that generates the maximum helical flow of air stream by using the visualization technique. In this work, the delta wing and the delta winglet with 20-40 inclination degree from stream line are selected as vortex generators. The result of this investigation aims to serve the application for the non-thermal plasma technology.

2. EXPERIMENTAL SET-UP

In this work, two kinds of vortex generator which are the delta wing and the delta winglet were tested in the wind tunnel shown in Fig.1. The frontal velocity of air in the wind tunnel was 2-4 m/s generated by the induce draft air blower with the frequency inverter for controlling its speed. The flow phenomena of air stream passing the vortex generator was observed by using the smoke generator and recorded by the high speed digital camera. The dimension of vortex generator is shown in Fig. 2 (a) and (b). The contact angle (α) of both the delta wing and the delta winglet was varied at 20°, 30° and 40°.

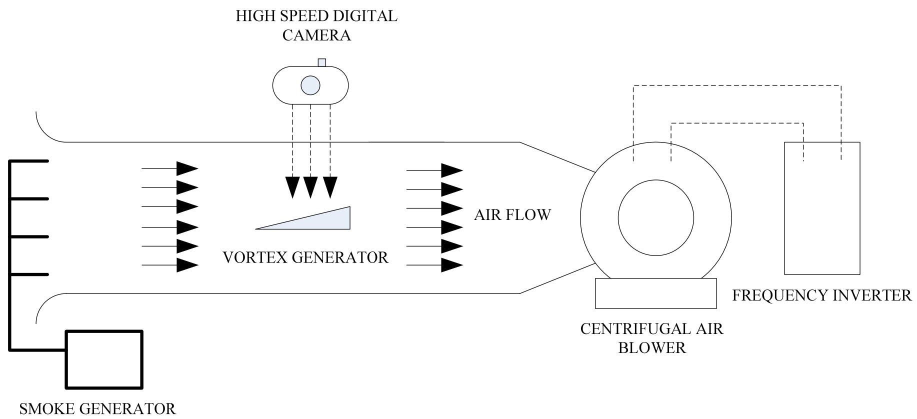


Fig. 1 Wind tunnel for observing the air flow phenomena passing the vortex generator.

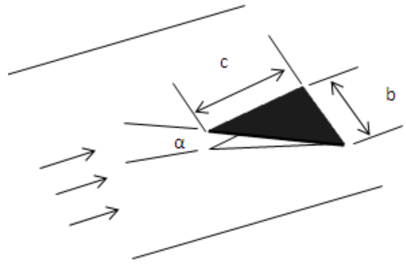
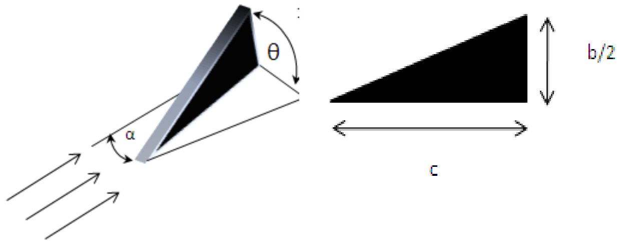
	
Delta wing b = 40 mm., c = 80 mm, α = 20°, 30° and 40°	Delta winglet b = 40 mm., c = 80 mm, α = 20°, 30° and 40°
(a)	(b)

Fig. 2 Vortex generator (a) delta wing and (b) delta winglet.

3. RESULTS AND DISCUSSION

Table 1 shows the visualization results in case of using delta wing as a vortex generator. Firstly, it is found that this kind of vortex generator produces two helical flow of air stream when passing its body. This helical stream line starts at the both sides of the wing edge. The prominent helical flow is observed at α = 30° when the air velocity is 2.0 m/s. But, in case of the frontal velocity is increased to 3.0 and 4.0 m/s, the stand out helical flow is observed at α = 20°. However, the negligible helical flow is found at α = 40°. From this observation, it should be notice that the helical flow generated by the delta wing depends on two dominant parameters which are the contact angle and the velocity of air stream. In case of low frontal velocity, the contact angle should be increased for producing the helical flow. However, if the frontal velocity of air is raised, the contact angle has to be reduced.

Table 1 Air flow phenomena in case of delta wing at various conditions.

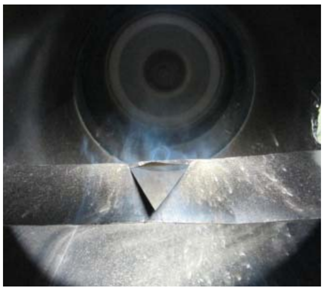
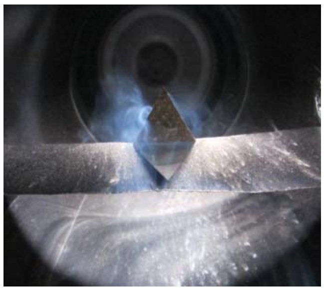
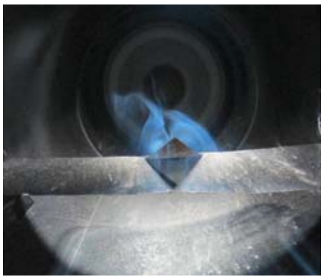
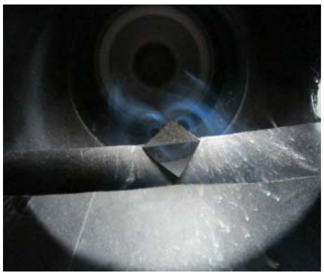
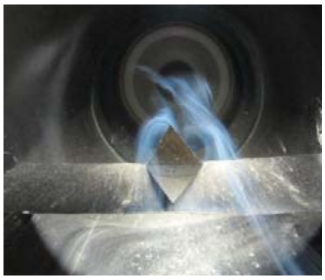
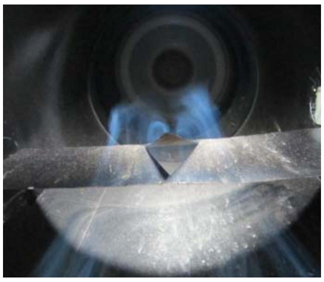
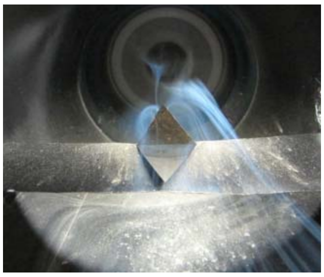
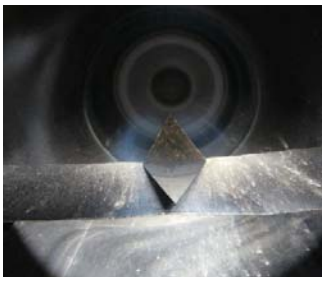
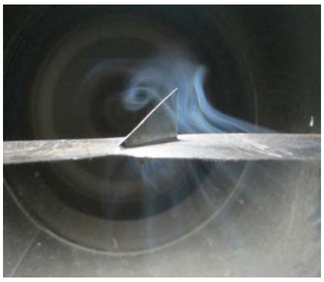
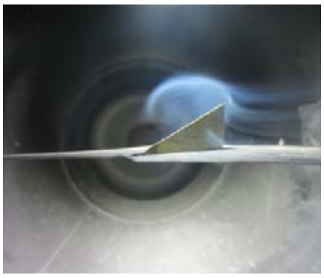
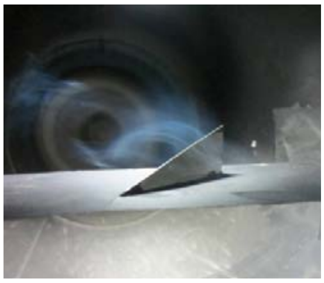
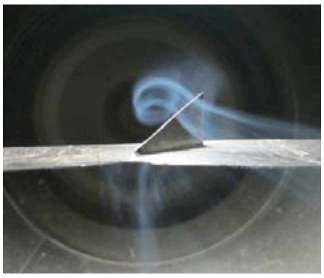
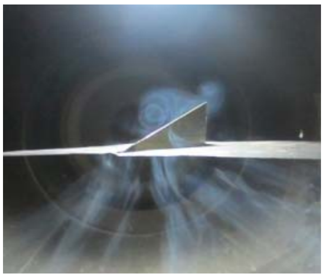
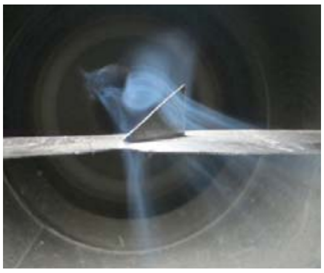
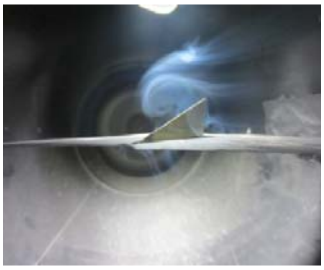
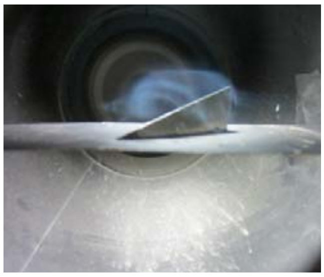
Air velocity (m/s)	α = 20°	α = 30°	α = 40°
2.0			
3.0			
4.0			

Table 2 Air flow phenomena in case of delta winglet at various conditions.

Air velocity (m/s)	α = 20°	α = 30°	α = 40°
2.0			
3.0			
4.0			

The visualization result in case of using delta winglet as a vortex generator is shown in table 2. It is found the helical flow generated by the upper triangular edge of the winglet for all cases. Differ from the previous case, this case generates only single helical flow but larger than the other. It should be noted that the prominent helical flow is found at α = 30° for the velocity equals to 2.0 m/s. When the air velocity is increased, it is found the obvious helical flow at α = 30°. This result agrees well with the previous result for the case of delta wing. It means that the effect of contact angle and air flow velocity is the same as case delta wing.

4. CONCLUSION

The conclusion of this study should be remarked as follow;

- The delta wing generates the double helical flow while the delta winglet generates the larger single helical flow of air stream passing its body.
- The helical flow generated by the delta wing and the delta winglet depends on two dominant parameters which are the contact angle and the velocity of air stream. In case of low frontal velocity, the contact angle should be increased for producing the helical flow. However, if the frontal velocity of air is raised, the contact angle has to be reduced.

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