Performance Study on The heat-transfer characteristic of a LVG in Different Sizes

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Abstract. In this paper, a new type of LVG were tested and the results show that it has good heat transfer function and pressure drop characteristic. In order to obtain the related functional influences of the newly LVG in different parameters, a three-dimensional numerical simulation was made. The result indicates that the perturbation effect of the same LVG at a lower current speed is better than the effect of a high speed. In order to avoid the breakdown of the vortex very quickly, the LVG sizes should be decreased appropriately when the current speed is high; to generate effective longitudinal vortex, the LVG must have large enough size and width, when the ratio of width to height is H=2, the effect is better than H=1; it is ideal for the attack angle of LVG in low speed zone to take Forty five degree angle.

1. Introduction
One of the most important elements of restricting the heat transfer efficiency in the heat interchanger is that heat resistance is so strong by the air side, therefore, reducing the air thermal resistance is the focus of the study. The LVG can generate vertical vortexes on the heat transfer wall, which can improve the effect of air-side convection heat transfer[1,2,3]. This is a passive heat transfer enhancement technology and it is usually used in engineering methods. Many academic and schoolmasters have studied the pressure characteristic of longitudinal vortex generator in rectangle windhole. They put forward various types of LVG and conducted research to them and achieved many results. On the basis of summing up our predecessors analysis, we studied semi-elliptic cylinder-shaped LVG and proved that it has good heat transfer function and smaller pressure loss through experiments. On the basis of this, we further studied the influence of heat transfer and pressure characteristic in different parameters through numerical simulation in order to provide guidance to more reasonable projects[4,5,6].

2. Newly LVG
The common types of LVG are delta-wing, rectangular wing, trapezoidal wing, half-cylinder and so on. On this basis, Zhou Guobing put forward a new kind of LVG ---inclined cutting semi-elliptical cylinder. In order to verify the good performance of the new LVG, we made a comparison experiment of heat transfer enhancement to the above-mentioned LVG as shown in Figure 1. In the Re range of about 4000—38000, we tested the delta wing within the right angle, rectangular wing, trapezoidal wing, inclined cutting semi-elliptical cylinder and so on and made a comparison between the non-
LVG rectangular air course in same boundary conditions. According to different working conditions, convection heat transfer coefficient and pressure loss performance were compared to verify the superior performance. In the experiment, all the generators are the height of 35mm and width of 70mm. The height width ratio is h/b=1/2 and the attack angle is 60 degree and the oblique cutting angle is a=20 degree. The front interval of vortex generator is 10mm and the water temperature is 1000C and the air temperature is the indoor temperature[7].

In the above devices, different LVG were tested respectively. Fig.1 and Fig.2 showed the variation conditions of the local convective heat transfer coefficient along the flow direction when the Reynolds numbers are 6000 and 38000 respectively. Compared with the direct current road, the effect of heat transfer improved significantly. When the effects of the selected various LVG were compared, the enhanced heat transfer effect of the inclined cutting semi-elliptical cylinder is best, followed by the rectangular wing. The average convective heat transfer coefficient and Reynolds number relationship also indicate that the heat transfer effects of the inclined cutting semi-elliptical cylinder and the rectangular wing are better. Fig.4 is the pressure drop efficiency comparison between the inclined cutting semi-elliptical cylinder LVG and other LVG. From the comparison figure we can see that the pressure drop efficiency of the inclined cutting semi-elliptical cylinder and the delta are better and the rectangular is worse. Taking various LVG’s local and overall convective heat transfer coefficient and pressure losses into consideration, we can know that the superiority of the inclined cutting semi-elliptical cylinder LVG. Therefore, we identified the superiority of the inclined cutting semi-elliptical cylinders.

3. Mechanism analysis of longitudinal vortex

All the principles of the LVG are the same, that is, when the flow is stagnated, the reverse, vertical and horizontal pressure gradient is formed at the generator’s meeting current wall. Under the function of this, the current entity will flow along the lower and external parts of the generator, which formed the series vortex at two sides. At the top generator, strong tip vortex is produced under the influence of the pressure and flow along the direction of the downstream in the form of
4. Mathematical and physical models

4.1. Physical models
Take the experimental flow channel as the calculation area. The channel is 1000mm long, 240mm wide and 80mm high. The top of the channel and two flanks are insulating materials with smooth surfaces. The underside is the heat transfer surface, which made of 1mm thick cooper and the temperature of the cooper should maintain at 1000°C. The air flows in the channel at different speeds. LVG is arranged in the heat transfer floor and the longitudinal vortex will destroy the thermal boundary. See the model shown in Fig.5.

4.2. The approach of the mathematical models
In view of the majority of the air cooler being in steady state, the basic equations do not include...
non-steady items and need not give the original condition. Considering the poor thermal conductivity of the air, the flow speed will not be so high. The property can be considered as constant approximately and handled according to incompressible fluid. The things we need to consider are the import and export boundary conditions, the wall conditions and the internal boundary conditions reflecting the LVG. For the heat transfer and flow problem of the turbulent flow through the built-in LVG, the most important thing is to introduce the energy dissipation equation of turbulent flow, that is the common used $\frac{k}{\varepsilon}$ equation. When the dissipative equation is introduced, the momentum equation correspondingly changes at the same time.

4.3. Treatments of the boundary conditions

The flowing conditions this paper considered is the velocity field and temperature field of the entrance are uniform. The velocity perpendicular to the main direction is 0. From the experimental facility, the temperature conditions of the border are different, and the top and sides are considered to be insulators. The relevant boundary conditions are as follows: the velocity boundary is zero; the temperature boundary is zero except subface. Some experiments indicates that the effect of the built-in LVG as the rib is weak, so we only consider its disturbance effect to the flow and ignore its heat transfer influence. Therefore, the without-slippage-velocity boundary conditions are the same as mentioned above, and no temperature conditions are required.

5. Process design and result analysis

In fact, there are a number of elements that influence the longitudinal vortex’s formation and development, such as the airflow rate, the overall size of the LVG, the attackangle of the LVG, the width-height ratio, the inclined cutting angle $a$ and so on. Of these factors, the inclined cutting angle $a$ is normally 200. This value in the existing research is ideal, and we don’t consider any more. Then the elements needed to analyze are airflow speed, the overall size of LVG, attack angle, the width-height ratio and so on. so we designed different simulation contents according to different elements. The six main kinds simulation conditions are as follows:

Determine the attack angle, front interval and the width-height ratio, and change the air flow speed to investigate the influence of the air speed. Determine one air flow speed between 0.5m/s and 8m/s and change the overall size of LVG and do not change the width-height ratio to investigate the overall size influence of the at stable speed. Change the width-height ratio at certain flow speed. The original with-height ratio is 1/2 then changes to 1/1. Change the attack angle. The original attack angle is 450. Add two 300 and 600 angles as variables. Change the front interval of the LVG. The initial interval is 25mm and then changes to 15mm at certain flow speed. Put double rows of LVG along the flow direction at the heat transfer surface to investigate the effect of disturbing the heat transfer.

The width-height ratio of rows is H=2 as the initial value, the height is 35mm, the width is 70mm; when the variable is H=1, the height is 35mm and the width is 35mm. The initial interval takes $s=25mm$ as its initial value and then we can go on a series of calculation examples.

If the second part takes the overall sizes into consideration, the parameter should be set as follows: $\beta = 45^0$, $s = 25 mm$, $H = 2$, $u = 0.5 m/s$.

E3: $b=0.07$, $h=0.035$. E4: $b=0.05$, $h=0.025$. In order to observe the effect of different parameters, we take several section along the airflow direction to make a comparison between the different calculation simulation results. The temperature distribution shows clearly on the section, and thus displays the effect of perturbation intuitively.

Fig.6 Contrast fig of temperature filed $x=0.2m$
From the above comparison chart we can clearly see the difference of the effect. From the comparison of the temperature field, firstly, no matter the $x=0.20m$ or the $x=0.40m$, the disturbing flow effect of the larger size disturbing LVG is better. Because the larger size of LVG corresponds more high temperature zones, that is to say at this time the disturbing flow effect is better; second, from $x=0.20m$ to $x=0.40m$, the distances of the high temperature zones the larger size LVG correspond are obviously longer. That is to say, at the fixed parameters, the survival time of the longitudinal vortex the larger size LVG generated is longer, so the disturbing flow effect is more durable and the final enhanced heat transfer effect is better.

In order to investigate the attack angle, the parameters of the fourth part should be set as follows: $S=25mm, H=2, b=0.07, h=0.035, u=0.5m/s$.

As the same, we also take several section along the airflow direction to make a comparison between the different calculation simulation results.

From Fig.7 we can see clearly the difference of the disturbing flow effect: when $\beta=30^\circ$, the disturbance temperature field is relatively small, indicating the weak strength of the disturbing flow and the excessive attenuation. When $\beta=60^\circ$, the disturbing flow temperature field has the largest area, indicating the strong effect of the disturbing flow. But at the same time it decays very fast, indicating that the interference between the longitudinal vortexes is increased, that is to say the bottom vortex and other vortexes interfere with each other, which make the development of the mainstream vortex influenced and not have a lasting survival. We can see that when $\beta=45^\circ$, the intensity and the decay processes are relatively satisfactory. At this moment the disturbing flow effect is better and the heat transfer effect is the best. Other parts of the calculation examples can also be calculated and analyze as this and the principles of the related factors can also be got and the related conclusions can be got according to the results of the analyzing simulation. We will no longer state here one by one.

6. conclusion

Summing up the test and the numerical simulation results, we can get some laws about the enhanced heat transfer problems of the LVG in direct current road: The speed of this simulation process takes between $0.5m/s$ and $8m/s$. From the comparative results we can see that the to the same spoiler yuan the disturbing effect of the lower flow rate is better than the effect of the higher speed. Meanwhile, in order to avoid the vortex breaking down very quickly, the size of the LVG should be reduced properly at the high flow speed. Despite the larger the LVG the greater the pressure loss, the LVG must have large enough overall size to generate effective longitudinal vortex and have large enough width. When $H=2$, the effect is better than that of $H=1$. In the low speed area the attack angle of the LVG taking 45 degree angle is more ideal, the degree should be reduced in the high speed area, which can
extend the distance of the longitudinal vortex. The front interval of the LVG should be between 20cm to 30cm. If the distance is too long the influence area of the vortex will be small. If the distance is too short the interference between the vortexes will increase, leading to aggravated dissipation. According to the speed range of the experiments, the interval should be 30cm when double LVG are set.

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