Numerical Simulation of Aerodynamic Improve Schemes for Wind-Loading Solar Power Stent

Yung-Lan Yeh, Cheng-Lin Wu

***Abstract*—The aerodynamic improvements for solar-power stent under wind loading via CFD simulation are well studied in present paper. The stent is a new integrated design and much different from past design. Under wind loading, the stent will sustain direct wind pressure and strong torque. It will cause structural damage and then economic losses. Four kinds of aerodynamic improvements on the top are proposed to reduce vortical structure due to stent structure. Results reveal proper lead-angle will make velocity difference smoother and this phenomenon depends on wind speed strongly. Present results also provide good reference for following using.**

***Index Terms*—aerodynamic, solar-power stent, CFD, vortical structure**

I. Introduction

THE solar energy is widely used for the new way electric power in present day because of inexhaustible and Carbon free. There are more and more solar panel apparatus equipping on the roof in a place where with enough sunshine, especially in Southern of Taiwan. But the serious damage due to bad weather is worse because of Global warming. The structure of stent may not be strong enough to endure pull and stress producing by strong wind gust. In order to solve this problem, the wind loading situation under load is worth to be studied and further analyzed structure configuration of stent.

Therefore, the preliminary wind loading test is necessary to know the effect of wind loading under load. Beside difficult wind tunnel test, the CFD simulation is an excellent method to well analyze the velocity and pressure distribution of the stent under wind loading after suitable adjustment.

Present stent is designed by Green Point Company. It has one-piece shape and is much different in appearance from other commercial solar-power stent. As shown in Figure 1, the solar-power panel can be mounted directly on stent without any other fixed bracket. In order to have sufficient stength and prevent corrosion caused by the weather, the FRP material is adopted to make this type of stent.

Present study totally proposes four different kind of aerodynamic improvements to investigate the vortical structure development on the top and after the stent. Velocity and pressure distribution contours are used for following analysis primaryly. Results of this paper also provide a useful aerodynamic improvement proposal for power stent or any other structure which has similar top design.

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II. Methodology

The CFD simulation is the primary experimental method in this study to investigate the aerodynamic characteristics of solar panel stents under wind loading. The 2D simulation model is mainly constructed by ANSYS Gambit and Fluent is the adopted simulation program.

The turbulent $k-\varepsilon$ model is used and the residual is fix at 10^{-5} to reduce experimental error. In order to reach a convergence stable state, the literation number in this study is fix in 8,000 based on preliminary test. Figure 2 is a sample to reveal the number of literation which reach the stable state. Proper literation number can reduce computer time efficiently.

The wake flow is the main flow structure to be analyzed in this work and that is an obvious structure when flow passes a blunt body. The earliest researcher who indicated this vortical structure was the famous German Turbulence scholar von Kármán. So later known as this structure is the Kármán Vortex Street. The overall structure is also similar to the eyes of cat, so its nickname is “Cat’s Eye”. This interesting structure often appears in the surrounding of natural environment. When rich water vapor in the low altitude pass through an island in the ocean, the backside of island will appear such a strong flow structure just likes the Kármán Vortex Street and it will exist for a long time. When sunset, the clouds in the sky also appear such instability phenomenon because of velocity difference in the interface between upper and lower surface. This structure often appear in the interface with different velocity which is called shear layer typically. And the major mechanism is due to velocity gradient in transverse direction.

Based on basic physical theorem, present work well study the velocity and pressure distributions at various wind speed and also propose four practical improvements to reduce the structural stress due to the vortical development. Three velocity settings are based on the standard Beaufort wind force scale and the scale setting is mainly in accordance with the seasonal average wind speed in Taiwan. The settings of velocity are 4.4, 19.6 and 34.59 m/sec respectively.

III. Results And Discussion

According to previous study [6], it indicates that the influence is mainly caused by the shape of stent top. And the lower stent is mainly affected by direct wind pressure. Therefore, this work further study the modification of top

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shape and look for possible improvement way.

As shown in Figure 3, there are four different shapes to be following analysis. They are original shape (R1), no leading-angle, round angle (R2), wing-shape angle respectively. Simulation experiments are carried out in three different wind speed and compared these four different shape in detail.

Figure 4 to 5 are pressure and velocity distribution contours of different shape in wind speed of 4.4 m/sec. Due to the sharp edge of the top structure, vortical structure will be produced in back of stent and reveal a distinct vortex center. It makes complex flow condition without leading-angle. Beside intensity, the pressure distribution contours are similar under conditions of R1 (please see Figure 4) and R2 (please see Figure 5). But in the condition of wing-shape, low pressure region becomes small behind stent obviously. It indicates the strength of vortical structure is weaker consequently because of smaller velocity gradient and pressure variation due to streamline appearance.

As for wind speed of 19.6 m/sec (as shown in Figure 6(a) to (d), it can be seen the same result of pressure distribution. The most interesting is that the trailing vortex will appear during higher wind speed when top appearance is wing-shape. It will continuously decrease pressure intensity in back of stent and further deteriorate deflection torque sustained by the structure. Consequently, it is not proper to change the top appearance to wing-shape angle.

The velocity distribution contours are shown in Figure 7(a) to (d). There is no obvious difference under different shape and vortical structure behinds stent is obvious. When wind speed reaches 34.59 m/sec (as shown in Figure 8 and 9), the velocity distribution has no change and there is significant appearance of wake flow behind stent in the contour. It also reveals that it is not proper to use wing-shape top appearance.

Concluding velocity and pressure results of various top shape, it can be seen that the top structure with leading-angle has a uniform flow structure at different wind speeds. Although the wing-shape structure can efficiently slow down the development of vortical structure at low wind speed, the wake flow appears at high wind speed. It will adversely affect the bearing and stress of the stent.

Present work also provides an useful improve suggestion for solar power stent design in different wind speeds. Including bearing stress and bending moment, the solution of aerodynamic problem is one of the essential for future design.

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Figures

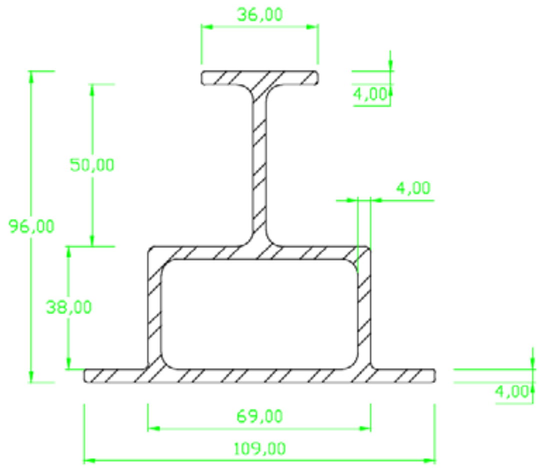


Fig. 1 Structural Design of Solar-power panel stent

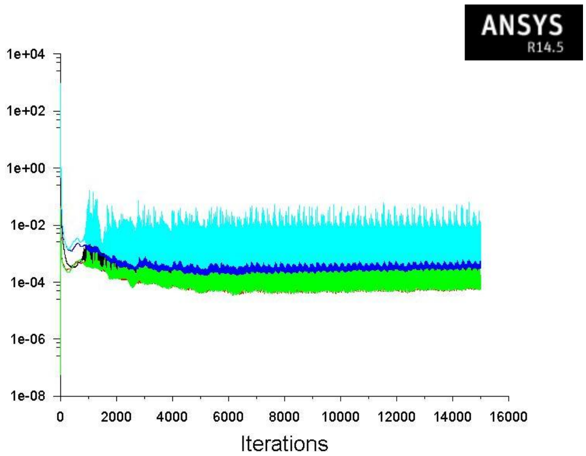


Fig. 2 Literation number at 4.4 m/sec

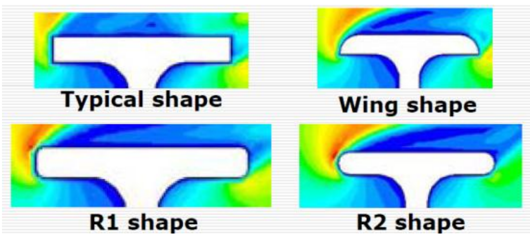
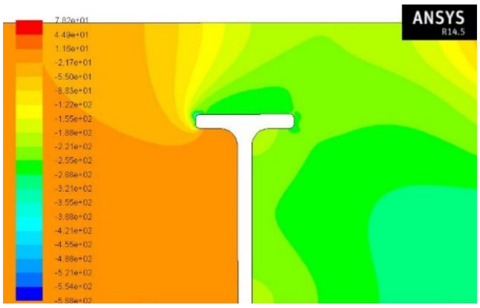
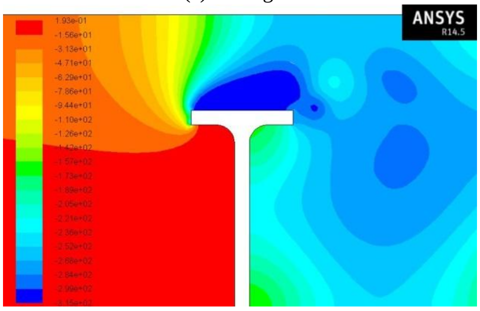


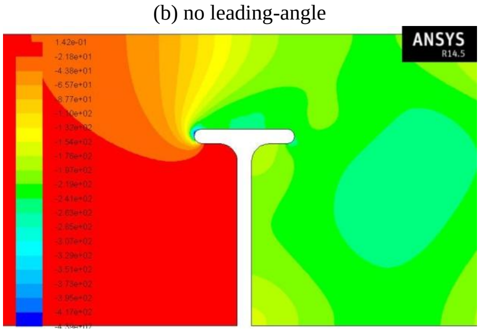
Fig. 3 Four different top shapes



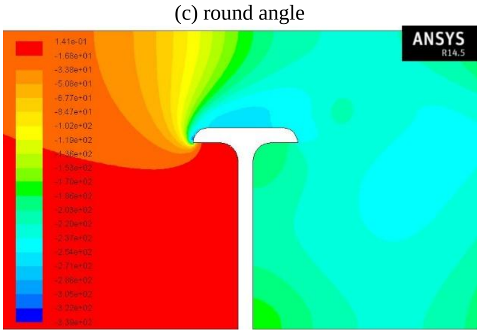
(a) R1 angle



(b) no leading-angle

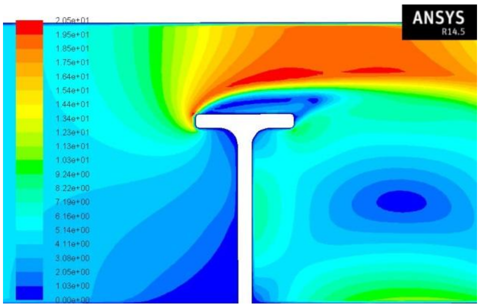


(c) round angle

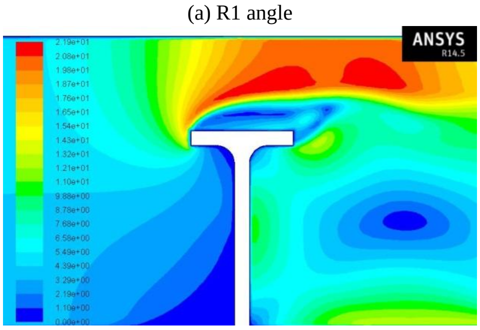


(d)wing-shape

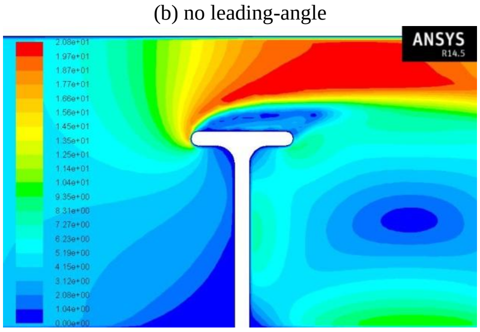
Fig. 4 Pressure distribution contour
(wind speed=4.4 m/sec)



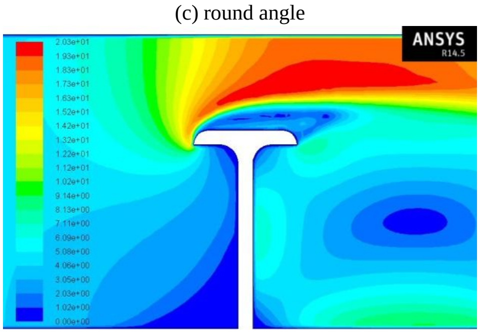
(a) R1 angle



(b) no leading-angle



(c) round angle



(d)wing-shape

Fig. 5 Velocity distribution contour at
(wind speed=4.4 m/sec)

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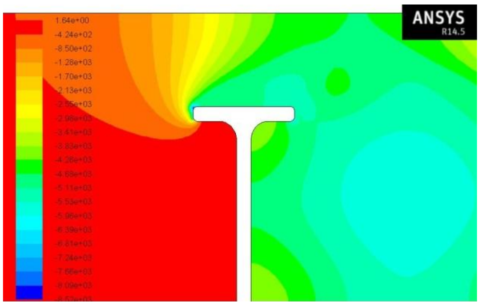
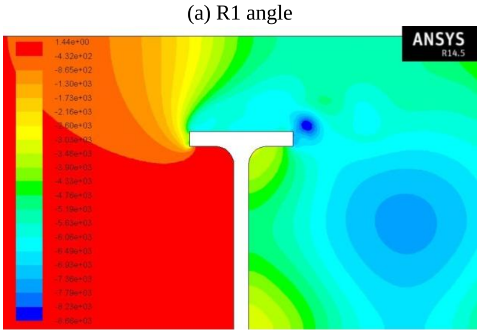


(a) R1 angle



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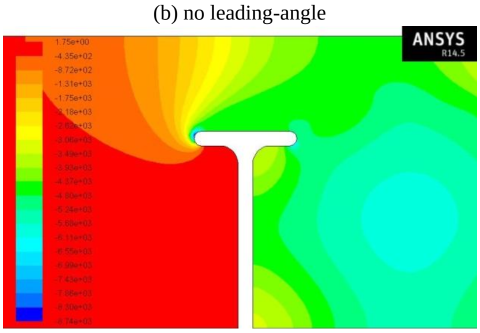
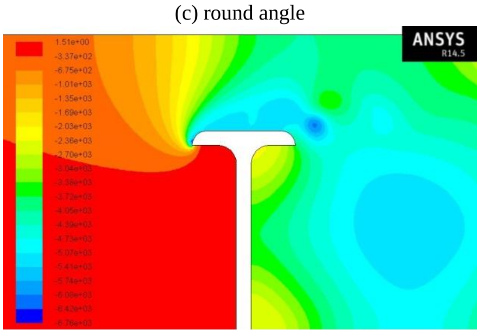
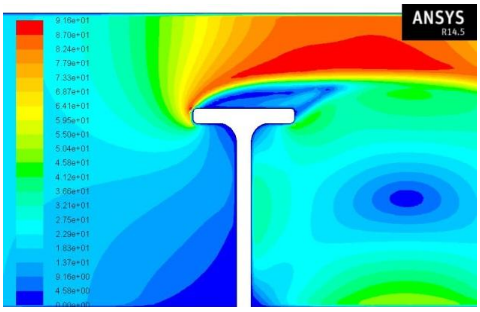


(c) round angle

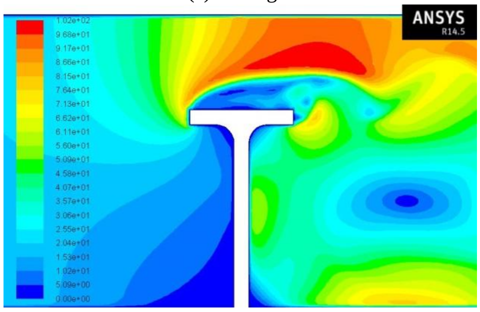


(d)wing-shape

Fig. 6 Pressure distribution contour
(wind speed=19.6 m/sec)



(a) R1 angle



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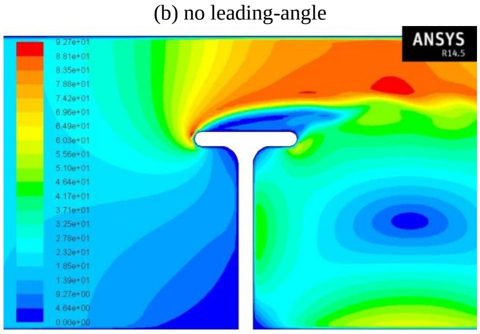
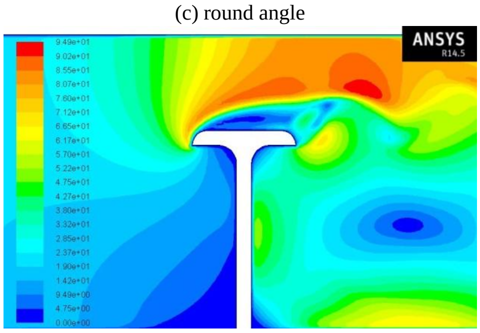


(c) round angle



(d)wing-shape

Fig. 7 Velocity distribution contour at
(wind speed=19.6 m/sec)

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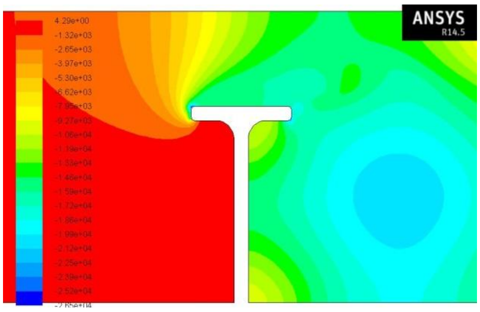
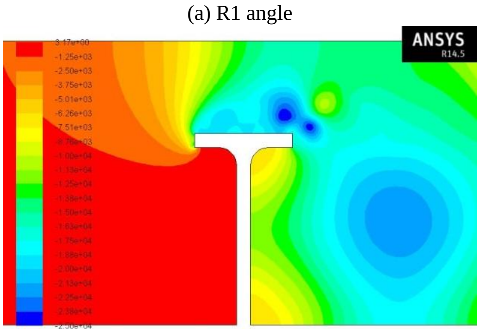
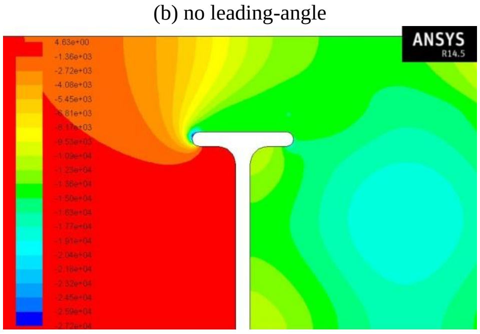


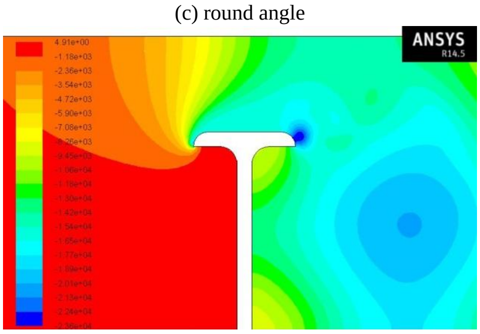
(a) R1 angle



(b) no leading-angle

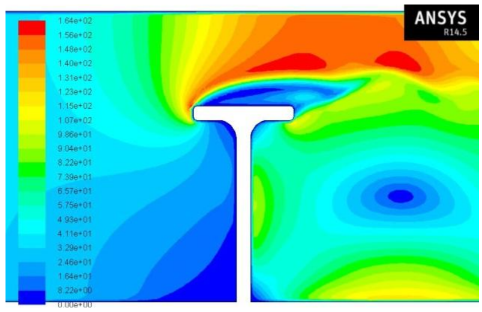


(c) round angle

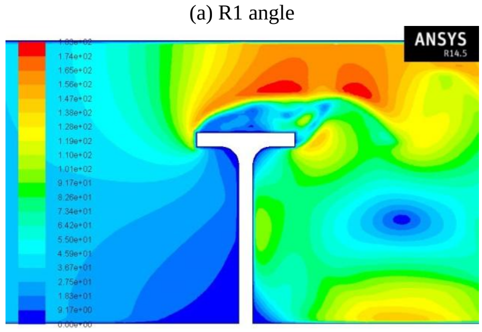


(d)wing-shape

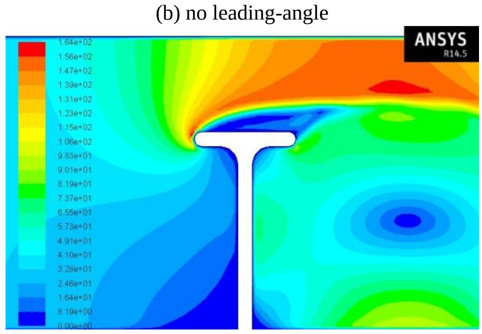
Fig. 8 Pressure distribution contour
(wind speed=34.59 m/sec)



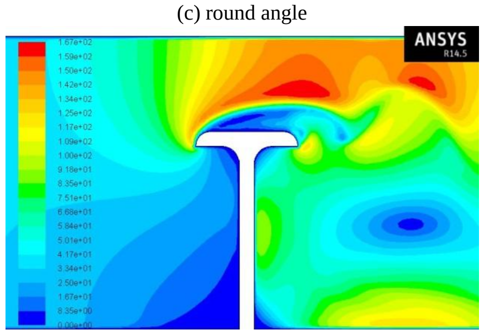
(a) R1 angle



(b) no leading-angle



(c) round angle



(d)wing-shape

Fig. 9 Velocity distribution contour at
(wind speed=34.59 m/sec)

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