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A Simulation on the Performance of Durability in a Polymer Solar Glazing Design

Sukmaji Indro Cahyono*, Han-Saem Eom*, Nam-Jin Ryu**, Kwang-Hwan Choi***

* Dept. of Refrigeration and Air-conditioning system, Graduated school, Pukyong National University
*Institute of Research and Development, KangNam Cooperation, Changwon City
***Dept. of Refrigeration and Air-conditioning Engineering, Pukyong National University

(E-mail: choikh@pknu.ac.kr)

Abstract

Nowaday the conventional solar collector material prices are rising up because of pricy metal material over the world. The solar collector is too expensive to recycle to save the earth. Advanced polymer research is founded a high thermal resistant polymer and also it has high sun energy transmission. It also has cheaper material and easy manufacturing process, compare with conventional solar collector material. This paper is focussing on glazing simulation of polymer solar collector against wind pressure. The modeling geometry of polymer solar glazing are purposed by single layer, double layer hollow, zig-zag and tower.

A simulation by using the Finite Volume was conducted to get Factor of Safety (FoS). The purpose of this paper is to find the best polymer glazing design, which can be as reference for the solar collector company to build Polymer. Hope fully new model of polymer solar collector has cheap, light, high sun energy transmitter, easy to be made and strong against wind force characteristics.

Key words: Polymer solar ollector, PPS, Simulation, Glazing

Nomenclature

V	: Wind speed in (m/s)
K_d	: Wind directionality factor
K_z	:Velocity pressure exposure coefficient
K_{zt}	: Topographic factor
q_z	: Velocity pressure
S_1, S_2, S_3	: Principle stress
S_V	: Von Mises Stress
FoS	: Factor of Safety
S_{Yield}	: Material Yield Strength
Pw	: Pressure every unit area solar glazing is faced by wind load

1. Introduction

In the conventional solar collector, such as copper tube, aluminum and glass are base material to be built. The average life time of a solar collector is around 10 years. After more than 10 years, the solar collector is likely to be inefficient and it recycle price is high [1].

Glazing as shown in figure 1 is one part of the solar collector, See Figure 1. the solar collector glazing material is made of high tampered glazing. it price is rise-up and expensive to recycle[1][2].

In order to minimize the production cost of current solar collectors, new materials which are lower cost and preferably more environmental friendly must substituted. Hopefully its efficiency is not decrease.

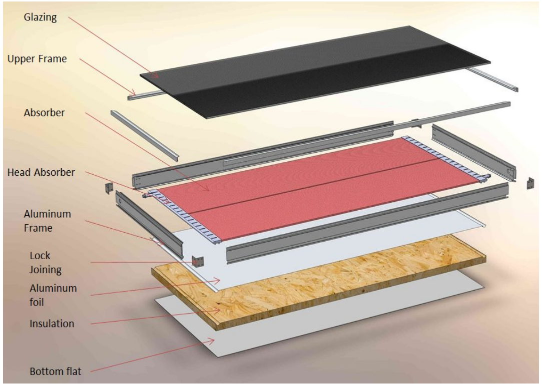

Figure 1. Structure of polymer solar collector

In recent years, high temperature resistant polymer (*Polycarbonate/PC*) from *Sabic* company, *Lexan 1412* is suitable as substitute glazing of material in the current solar collector, as show in fig.2.

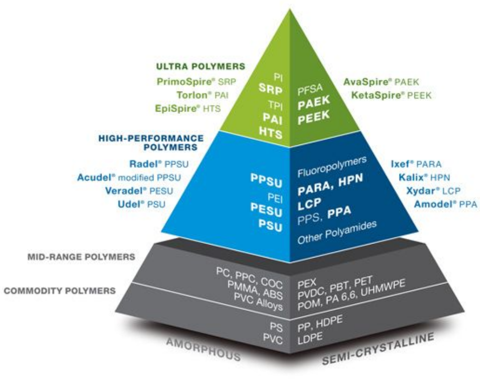

Figure 2. Classification of polymer

In this paper a novel polymer solar collector models are presented. Solidworks structural simulation is used in an effort to investigate its behavior. The performance of the glazing structure against wind load was obtained by Solidworks simulation.

The mesh numbers are increased until the results changed less than 8% for validation of simulation and the wind pressure distributions over its area are calculated by manual calculation data.

The validation of the simulation model, the mesh number are increased until the result change less than 8% and for wind load validation of simulation, the wind pressure distributions over its area were compared to manual calculation data.

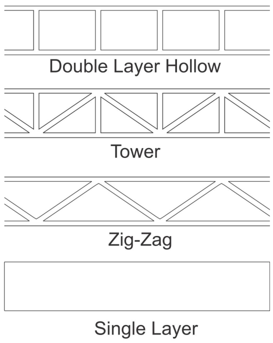

Figure 3. Model of polymer solar glazing

2. Wind Load Calculation Standard

One parameter of performance of glazing structure in solar collector is resistance against wind load. *ASCE 7-05 (American Society of Civil Engineers)* wind pressure standard calculation for application on the roof of the building is used [3].

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.613 K_z K_{zt} K_d V^2 \quad , \quad (N/m^2) \qquad (1)$$

q_z is the velocity pressure calculated by Eq.(1) within the mean roof height z.

Wind speed-up effect shall be included in the calculation of design wind loads by using the factor, K_{zt}. If the site conditions and location of structure do not meet the conditions, such as upper hill, ridge or escarpment, and then K_{zt} = 1.

Velocity Pressure Exposure Coefficient, K_z: base on the exposure category, a velocity pressure exposure coefficient shall be determine from the table.

Also, wind Directional Factor, K_d shall be determine from the table. This factor shall be applied when used in conjunction with load combination.

3. Factor of Safety (FoS)

Factor of safety (also called Safety Factor and abbreviated FoS) is a term describing the structural capacity of a system beyond the applied loads or actual loads.

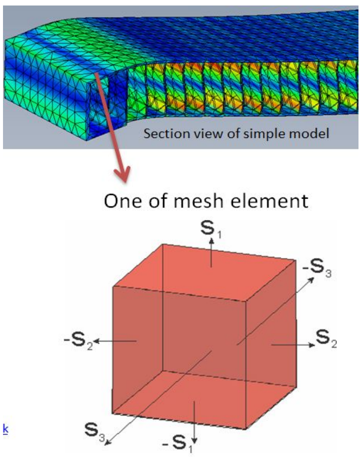

Figure 4. Solidworks structural simulation base on Finite Volume

The term means the fraction of total structural capability over that required [5].

Structural simulation with Solidworks is a base on *Finite volume* and it use *Von Mises stress*, S_V also known as the shear-energy theory equation as governing equation.

In terms of the principal stresses, s_1, s_2, and s_3, the maximum Von Mises stress is expressed as:

$$S_V = \left[\frac{(s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_1 - s_3)^2]}{2}\right]^{\left(-\frac{1}{2}\right)} \quad (3)$$

The ultimate (ultimate strength) calculation will determine the safety factor until failure. The yield stress calculation will determine the safety factor until the part starts to plastically deform.

FoS shall be calculate by following equation:

$$(\mathrm{FoS}) = \frac{S_{Yield}}{S_{VonMises}} = \frac{Material\,Strength}{Deasign\,Load} \quad (4)$$

Minimum FoS is depend on government policy, but 2,5 was used as minimum factor of safety.

A package of polymer solar collector consists of several parts and different materials. To increase accuracy of structural simulation, the simple models are introduced. The assumption is decided to decrease computational loads and they are:

- The length of the model becomes 50 mm, even tough real length is 1,854mm.
- Wind speed is 30m/s.
- Fix geometry area is described as the area in the model supported by a case of the solar collector.

- The property of polymer material was the following specified by Polymer Sabic company Lexan SLX1412.

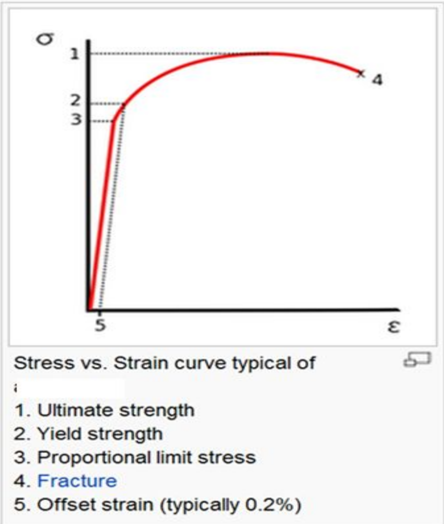

Figure 5. Stress-Strain curve

Considered with heat resistant specification of polymer material (Lexan SLX). The heat factor is regardless in this simulation.

4. Structured simulation by Solidworks

Simulation proses has started with drawing the model, then input the pressure load and fix geometry as boundary condition (free body diagram). Next step is meshing all volume of structure, and run simulation by iteration process. After finish, the results are checked and numbers of mesh (Adaption) are increased, and then iteration process was repeated. The higher number of mesh result is more accurate, but needs longer time to iterate and high computational load.

The results from the second step is compared with the first step if the difference is more than 8%. it needs the second step until the difference less is than 8%.

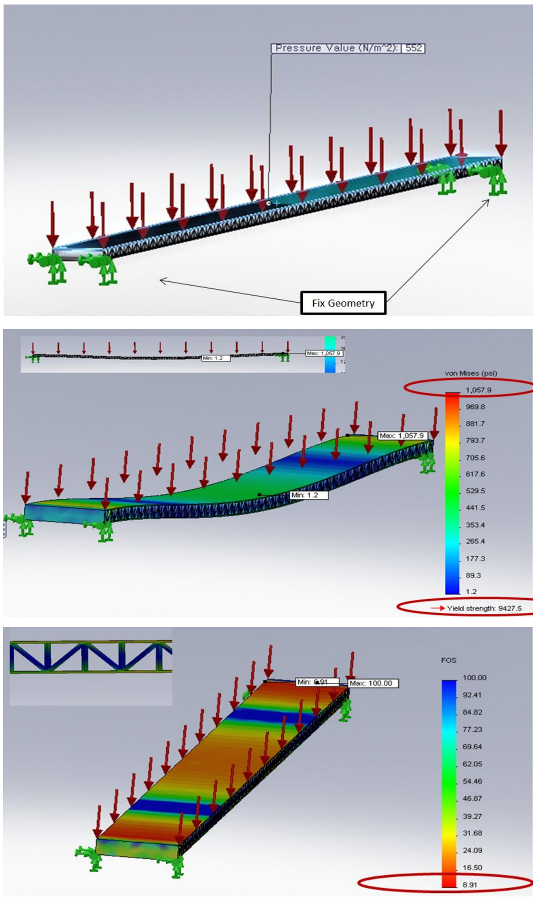

Figure 6. Free body diagram, Von mises stress distribution and FoS distribution diagram

The best model criterions are high FoS, minimum displacement, and low weight. All of the models thickness are 10mm.

5. Experiment results and discussions

The glazing thickness models are 10mm. The result of simulation is Von mises stress distribution. The lowest Von mises stress is used to find Factor of the safety and compare with other models.

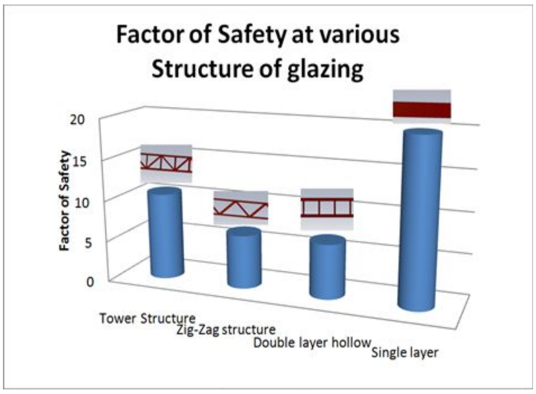

Figure 7. The Factor of the safety in the various models

FoS of single layer model is the highest compare with other models. It means the strongest structure in single layer but, its sun energy transmission will be low. The lowest model is the zig-zag structure and other models are middle. Consider with standard SRCC OG-100 Certified, Even though it has the lowest FoS, but it is two times more safer than standard FoS. So all of the model are good.

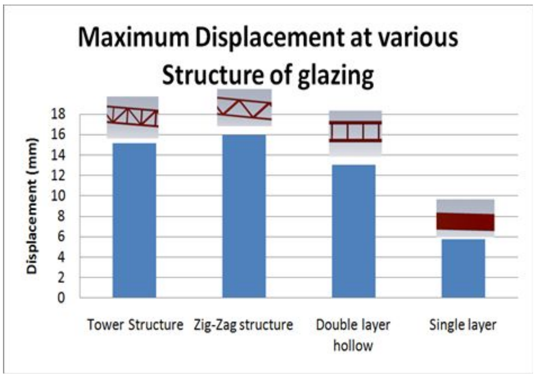

Figure 8. Maximum displacement of various models

The maximum displacement of zig-zag structure is the highest compare with other models. It means that this model has high risk to bend. Standard solar collector mechanical side glazing clam is 20-25mm each side. Solar collector will be damaged if the maximum displacement is 40mm. In Fig.8, all of model are safe and suitable.

Fig.9 has shown that a single layer is heaviest model. It means this model is the most expensive than other models.

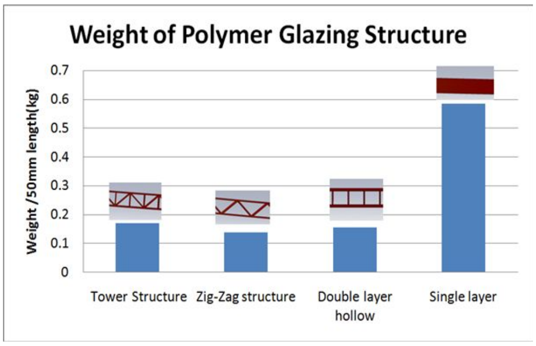

Figure 9. Weight of polymer Glazing of various models

Three glazing models are suitable as substitute of the solar glazing material. But considering with machining and making process the double layer hollow model is suitable. The structure is low weight. The sun energy transmission is better. Because the solar energy is through only 2 thin layer boundary to the absorber.

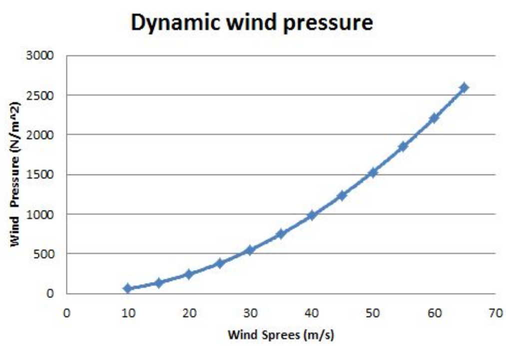

Figure 10. Dynamic wind pressure with wind sprees

In Fig.10, various wind speeds are calculated by using equation 1. The graph trend of the wind pressure is rise-up along with increasing the wind speed. Following with the graph of dynamic wind pressure, polynomial equation was built as:

Pw = 0.6143V2 - 0.1064V + 1.3794

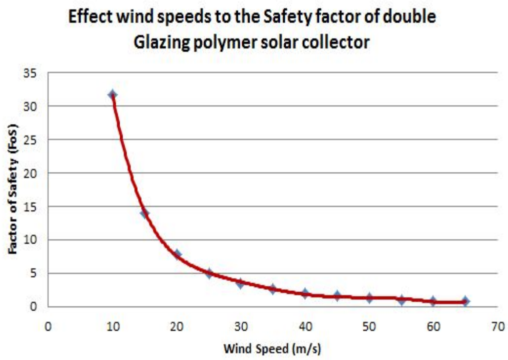

Figure 11. Factor of safety of double layer hollow in various wind speed

The structure is still safe until 36 m/s of wind speed. If the wind speed is more than 36m/s, the FoS is lower than 2.5 and it is lower than SRCC OG-100 Certified standard.

6. Conclusions

The best glazing model with 10mm of thickness is double layer hollow. FoS of double layer hollow model is 6.61, maximum displacement is 13.01mm.

To know the performance of double layer hollow glazing model, various of wind speed was simulated. According to the calculation result, the equation of dynamic wind pressure was built as following;

Pw = 0.6143V2 - 0.1064V + 1.3794

The maximum wind speed allowable to the standard FoS is 36m/s and the maximum wind speed is 38m/s.

The best design as good as reference to the solar collector company is double layer hollow model with 10mm thickness.

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