MODELLING THE EFFECT OF VENTILATED AIR CAVITIES IN THE SOLVENT PROTOTYPE: A REVERSIBLE SOLAR SCREEN GLAZING SYSTEM. PRELIMINAR RESULTS

J.L. Molina[1], I.R. Maestre[2],
M. Sandberg[3], E. Maldonado[4], V. Leal[4], E. Erell[5], Y. Etzion[5], O. Gutschker[6]

[1] Department of Thermal Energy Engineering. University of Seville, Spain
[2] Department of Thermal Energy Engineering. University of Cádiz, Spain
[3] Department of Fluid Mechanics, University of Gävle, Sweden
[4] Instituto de Engenharia Mecanica, University of Porto, Portugal
[5] Ben-Gurion University of the Negev, Sde-Boqer Campus, Israel
[6] Brandeburgische Technische Universitaet Cottbus, Germany

ABSTRACT

To evaluate the impact of the natural ventilation of the air cavity in the prototype of the glazing system being studied in the frame of the project SOLVENT, funded in part by the Commission of the European Union, a prototype of a reversible naturally ventilated glazing system. The system consists of a double (clear and tinted) glazing. In the summer position the tinted glazing is in the outer position and the cavity is open to the outside air at both top and bottom extremes. The heat gains are reduced by the fact that the air flowing cools the inner glazing and the reduced transmissivity of the tinted glass. In the winter position the system is reversed making the tinted glass in the inner position. So when the radiation impinges the glazing it heats the tinted pane which is now open to the inside air making the air movement to increase the heat gains of the system.

KEYWORDS

Advanced Glazing, Ventilated Glazing, Solar Control, Daylighting

INTRODUCTION

To evaluate the impact of the natural ventilation of the air cavity in the prototype of the glazing system being studied in the frame of the project SOLVENT, funded in part by the Commission of the European Union, a prototype of a reversible naturally ventilated glazing system. The system consists of a double (clear and tinted) glazing, as sketched in figure 1. In the summer position the tinted glazing is in the outer position and the cavity is open to the outside air at both top and bottom extremes. The heat gains are reduced by the fact that the air flowing cools the inner glazing and the reduced transmissivity of the tinted glass. In the winter position the system is reversed making the tinted glass in the inner position. So when the radiation impinges the glazing it heats the tinted pane which is now open to the inside air making the air movement to increase the heat gains of the system.

A detailed model of the thermal and optical behaviour of complex glazing systems, which was developed in the frame of three previous European Projects (WIS, SOLCON, REVIS) has been improved including the model of the naturally ventilated air cavity. The model is iterative, doing two steps in the calculations: the first, assuming known temperatures in the glazing the air flow is calculated by a simple correlation based on theoretical analysis of the problem. In the second step the film coefficients are calculated which allows to calculate the new temperatures of the panes.

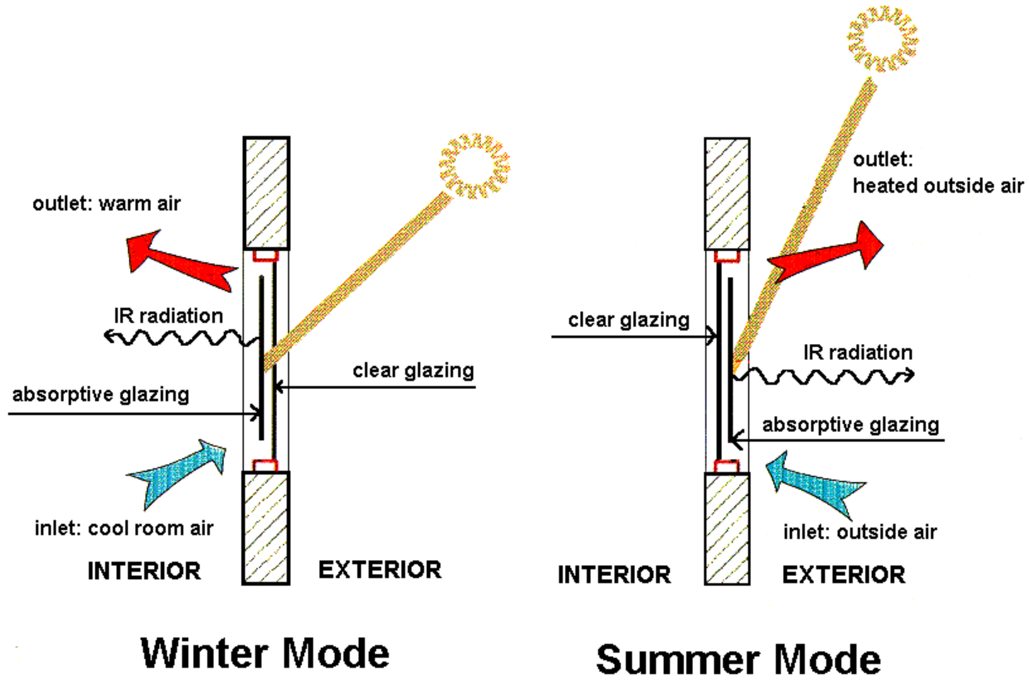

Figure 1 : The reversible glazing system in Winter and Summer positions

The model predictions have been checked agaist experimental results obtained at three PASSYS Test Cells located in Cottbus (Germany), Porto (Portugal) and Sde-Boqer (Israel).

THEORETICAL MODEL

Optical and Thermal Modelling

The details of the thermal and optical model have already been provided, see for example Molina (19XX). That model has been improved for taking into account the air movement inside the ventilated gap due to the stack effect produced by the difference of temperatures between the glazing and the outdoor air (summer position) or indoor air (winter position). Assuming uniform temperatures in the panes limiting the gap and constant, and known, film coefficients (in principle, different values for both sides) in the gap the equation obtained for the temperature evolution of the air in the gap is:

$$T(z) = HT_{12} + (T_i - HT_{12})\exp(-A \cdot z)$$

$$HT_{12} = \frac{h_1 T_1 + h_2 T_2}{h_1 + h_2} \qquad A = \frac{(h_1 + h_2)W}{\dot{m} c_p} = \frac{(h_1 + h_2)}{\rho\, c_p v e}$$

$$B = 1 - \exp(-A \cdot L) \qquad R = \frac{\dot{m} c_p}{S_{glazing}} = \frac{\rho\, c_p v e}{L}$$

More details can be seen in Molina (2002).

Aeraulic Modelling

Assuming an equilibrium among the bouyancy, inertia and friction forces it ispossible to oobtain a value for the average speed the air in the air gap:

$$U = \left(\frac{g \int_0^H \frac{(T(x) - T_i)}{T_i} dx}{\frac{1}{2}(1 + f\frac{H}{2d} + k_{in} + k_{out})} \right)^{1/2}$$

Where g is the gravity acceleration T_i is the inlet temperature, $T(x)$ is the average temperature of the glass panes at the x position, f is the friction factor, k_{in} and k_{out} are the coefficients of losess in the inlet and the outlet of the ventilated air gap, H is the height of the glazing and d is the tickness of the airgap.

Details of the deduction can be seen in Sandberg (2002).

METHODOLOGY

The methodology followed for comparing the model results with the experimental values has been the following :

1. Selection of a small but reasonable part of the experimental points.
2. Using the theoretical models, calculation of the film coefficients and air velocities that fit better the temperatures calculated to the experimental values.
   This step provide a simple correlation for the film coefficient and a correction factor for the theoretical air velocity, and an optimization method is used for minimizing the average error between calculated and experimental values. For the rest of the film coefficients, well known correlations are used, like those recomended in the European Standard EN-673 or taken from the literature.
3. Application of the correlation for film coefficient and correction factor for air velocity obtained in 2, for comparing all the data in the experimental recordset.

RESULTS AND DISCUSSION

A part of the results obtained are shown in figures 2 to 5. Figures 2 and 3 are obtained for Winter position. Figure 2 is the comparison for the points used in obtaining the correlations and figure 3 includes all the points in the recordset. The correlation obtained for this position is $h_{cam} = 4.69 \times \Delta T^{0.3433}$, and the correction factor for the air velocity is 0.88. The average deviation for temperatures is 1.4 degrees.

Figures 4 and 5 are the equivalent to 2 and 3 but for the summer position. The results are $h_{cam} = 0.838 \times \Delta T^{0.727}$, and the correction factor for the air velocity is 0.72. The average deviation for temperatures is also 1.4 degrees.

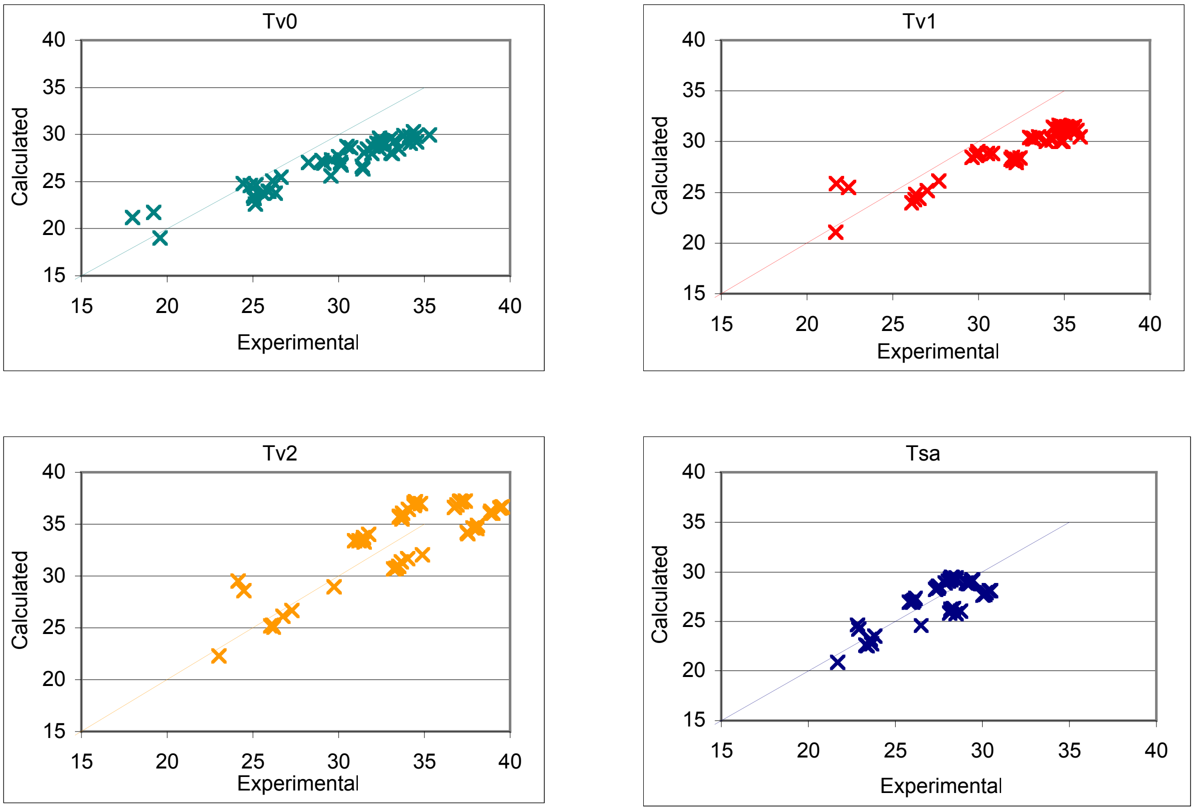

Figure 2: Comparison of calculated and measured temperatures. Porto. Winter Position. Only the points used in the correlation development

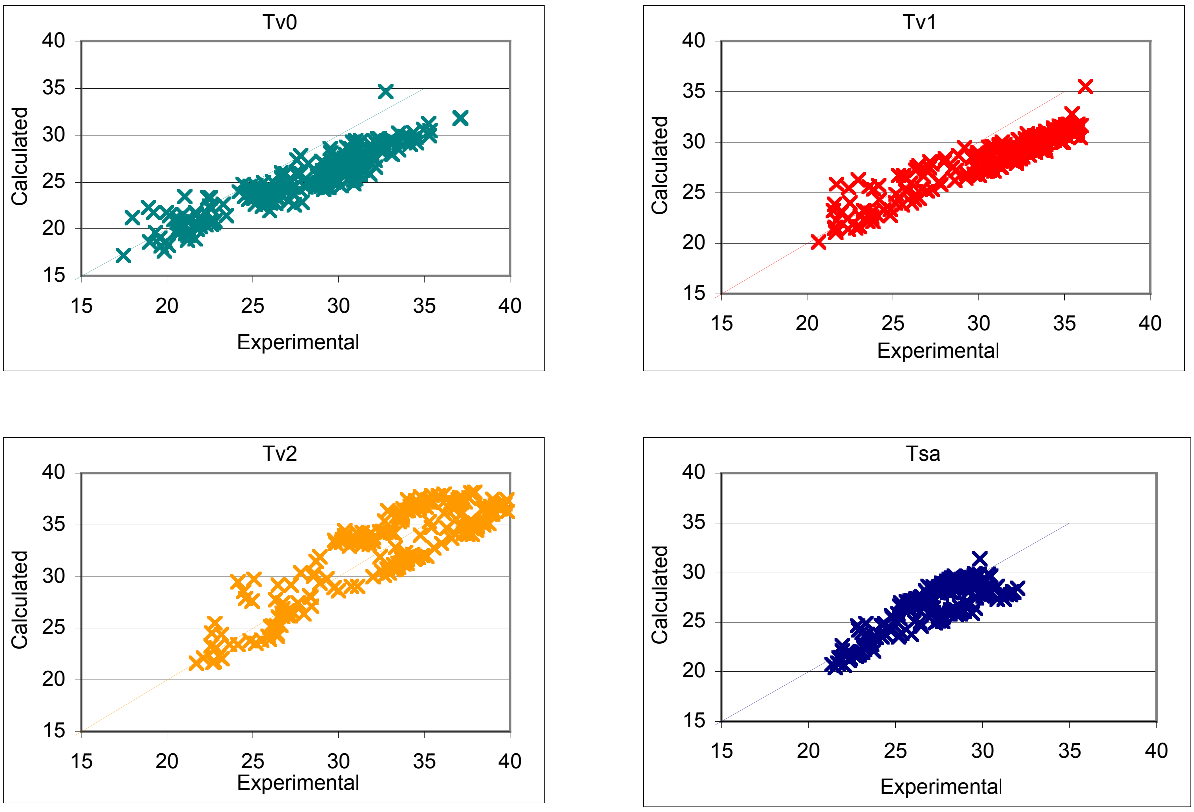

Figure 3: Comparison of calculated and measured temperatures. Porto. Winter Position. All the points in the recordset

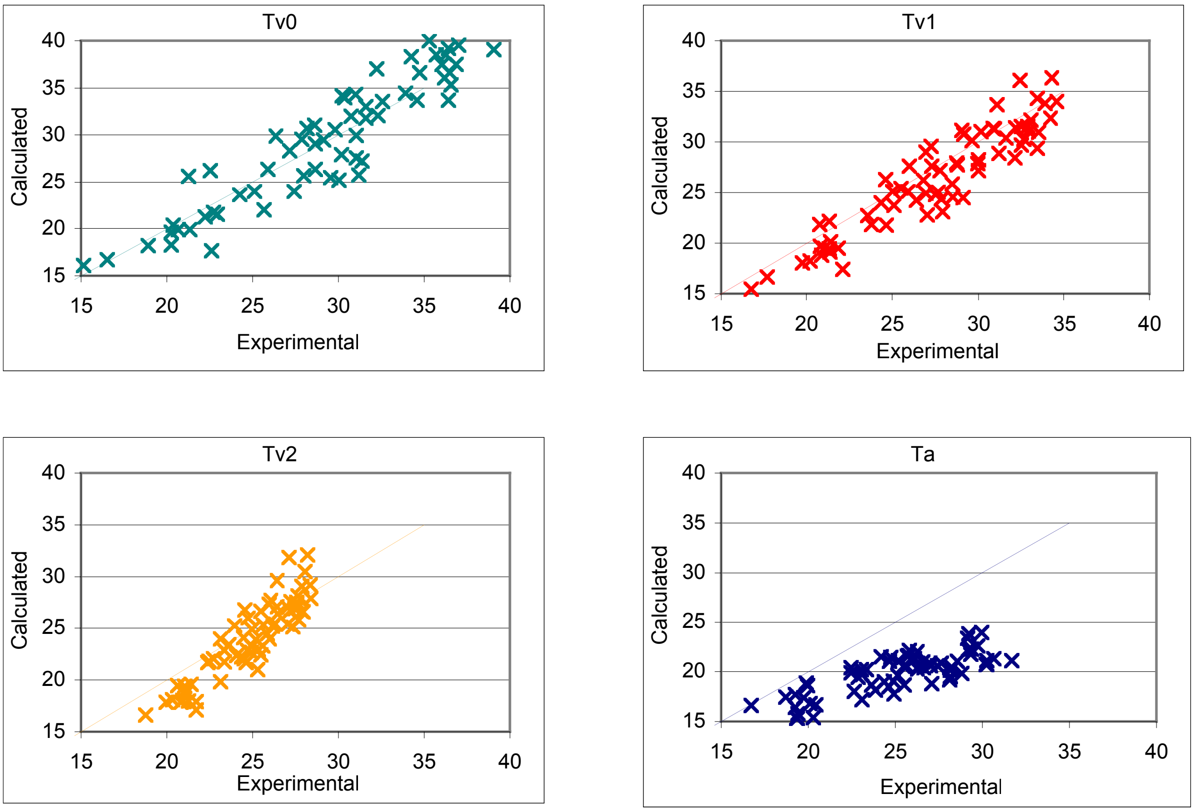

Figure 4: Comparison of calculated and measured temperatures. Porto. Summer Position. Only the points used in the correlation development

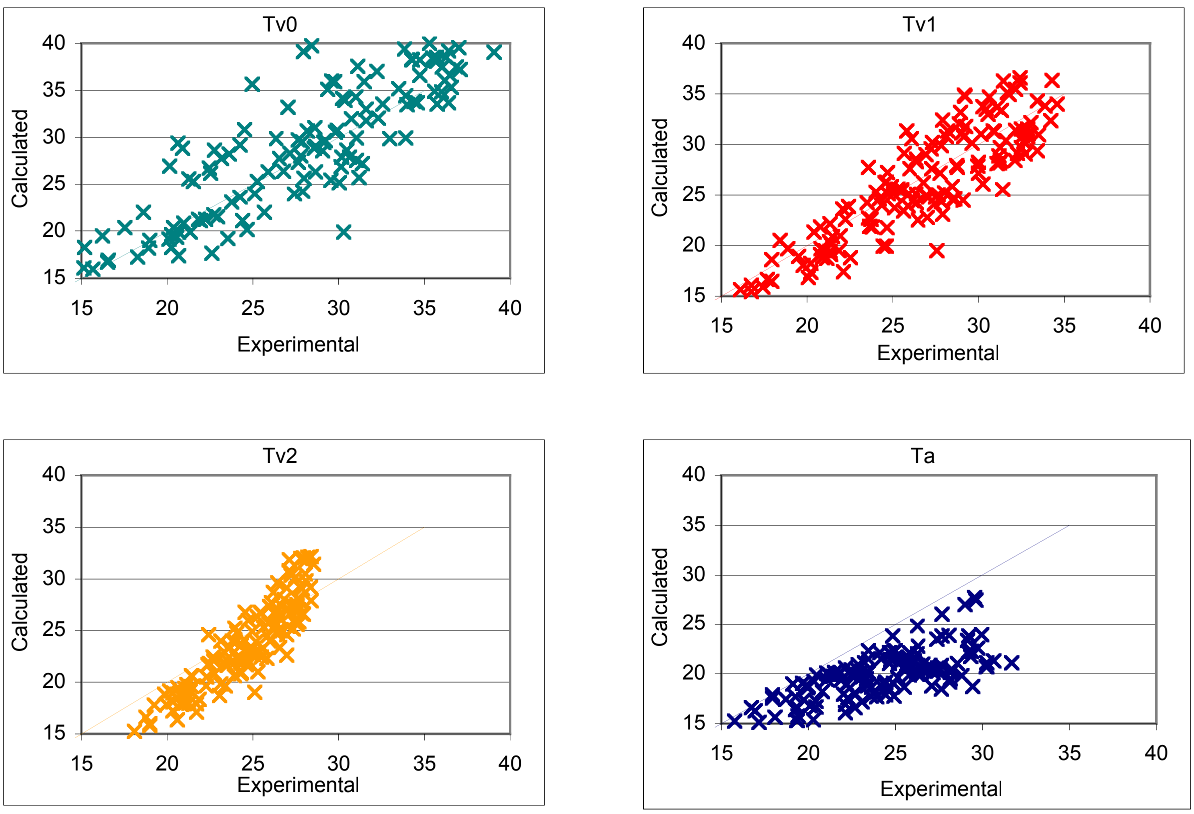

Figure 5: Comparison of calculated and measured temperatures. Porto. Summer Position. All the points in the recordset

In the figures Tv0 is the temperature at the outer glass, Tv1 is the second glass pane and Tv2 is the teperature in the inner glass pane; Tsa or Ta are the air temperature at the outlet of the air gap. In the optimisation procedure it is only paid attention to the deviation between the temperatures of the 'interesting' parts of the glazing for the heat gain calculation: In Summer, only the inner temperature is relevant, whereas in Winter both, the inner glass and outlet air temperature, must be taken into account.

The results obtained are significant only for the geometry and optical configuration of the glazing system used in the test being analised. Next steps in the research includes:

- comparison of the rest of the test cell results, with different geometries, glazing properties and meteorological conditions.
- Obtention of a generalized correlation for both film coefficient and air velocity for the ventilated gap

CONCLUSIONS

The optical and thermal model for complex glazing systems has been improved with the inclusion of a model for the air movement through the ventilated gap of the particular prototype being studied in the SOLVENT Project.

Of course, the model is perfectly valid for any other fixed ventilated configuration like those appearing in some double skin façade buildings.

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