Study on the thermal performance of a solar chimney

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ABSTRACT

It has been investigated the effect of different construction parameters to the thermal performance of a solar chimney. These parameters are the thermal resistance of the walls, the glazing type and the solar chimney's thickness. The thermal performance of the solar chimney has been studied using up to date thermal dynamic simulation tools.

1. INTRODUCTION

The use of solar chimneys to provide ventilation in building has been studied intensively in the past but there is still lack of information concerning the optimum construction characteristics.

Generally, the following information is known and it is accepted that following affect positively the efficiency of a solar chimney:

- The flow in the solar chimney should not be laminar.
- The optimum orientation for a solar chimney is west for locations in the south of the north hemisphere.
- The absorption surface (collector) should have absorptance to emittance ratio as higher as possible. In any case the ratio should be higher than 1.
- The thickness – the distance of the absorptance surface and the glazing – should be between 0.1 and 0.25m in case of a single pane glazing.
- The thermal losses through construction elements of the solar chimney should as lower as possible.
- The higher the incident solar radiation, the higher the energy performance of the solar chimney.

VThe discharge coefficient of solar chimney's openings should be as lower as possible.

In order to investigate the effect of different construction parameters to the efficiency of a solar chimney the following general assumption have been done:

- The flow inside the chimney is laminar.
- Only steady – state conditions have been calculated.
- The air is incompressible.
- The chimney is simulated as a zone with one vertical external opening and one vertical internal opening.
- The room that the chimney is connected has only one opening that is open.

All calculations have been done using TRNSYS 15.1 software and a relative natural ventilation routine.

2. IN PUT DATA

2.1 Geometry

The solar chimney is facing southwest (225 degrees clockwise from north) while it has a width of 1.20m, height 6.00m and internal thickness 0.10m. On the upper side of the southwest façade it has an opening with an inclined window. The dimensions of the openings are 1.10m (width) and 0.60m height. The internal opening of the solar chimney is 0.40 by 0.60m.

The solar chimney is attached to a room which has a long axis along to northeast – southwest direction. Its long axis is 8.00m and the short is 4.00m. The 20% of the "big" facades have openings, while only the 10% of the smaller ones.

For the calculation has been assumed that only the 5% of the southwest façade is opened. All other openings have been assumed as closed.

2.2 Thermal properties of construction elements

The thermal resistance of the building skin elements has been assumed as following:

- Roof, approximately 2.17m² ºK/Watt
- Vertical opaque elements, approximately 1.67m² ºK/Watt
- Floor attached to the ground, approximately 0.63m² ºK/Watt

The vertical opaque elements consist of double brick wall with insulation and concrete beams with sufficient insulation. The floor construction has been assumed as to be made form reinforced concrete, lightweight concrete and ceramic tiles while the roof from reinforced concrete, lightweight concrete and sufficient thermal insulation. The fenestration covers the 15% of the openings and it is aluminium without thermal bridge. All openings have a double, clear glazing.

The construction elements of the solar chimney has been assumed that they are made from 10cm PU panel which thermal resistance is approximately 3.33m² ºK/Watt.

2.3 Meteorological data

The building is located in the area of Athens, Greece in an unobstructed site and 300m above the sea level. The meteorological data that have been used are hourly values of the following parameters:

- Total horizontal solar radiation
- Diffuse horizontal solar radiation
- Ambient temperature

- Relative humidity
- Wind speed
- Wind direction

Wind speed and wind direction will be used to calculate the pressure coefficient for external openings.

3. OPTIMIZATION OF THE SOLAR CHIMNEY

In order to optimize the solar chimney construction the following parameters have been taken into account:

- The thickness - distance of the absorptance surface and the glazing – of the solar chimney
- The thermal resistance of solar chimneys construction elements
- The glazing type of solar chimneys façade

Table 1 contains the values of the above parameters that have been used for calculating.

Table 1. Values of the optimization parameters

Parameter		
Thickness (m)	Thermal resistance (m^2°K/Watt)	Glazing type
0.10	3.33	Single
0.15	4.00	Double clear
0.20	4.50	Double clear, low emissivity
0.25	5.00	

4. CALCULATION RESULTS

The calculation results are given in the form of monthly average values of ventilation rate in m^3/h. The results are given in Appendix A.

The year average values of ventilation rate in m^3/h are given in Tables 2, 3 and 4.

Table 2. Yearly average values of ventilation rate

Thickness (m)	Ventilation rate in m^3/h	Relative difference from original design
0.10	904	
0.15	903	-0.2%
0.20	901	-0.3%
0.25	900	-0.5%

Table 3. Yearly average values of ventilation rate

Thermal resistance (m^2°K/Watt)	Ventilation rate in m^3/h	Relative difference from original design
3.33	904	
4.00	905	0.0%
4.50	903	-0.1%
5.00	901	-0.4%

Table 4. Yearly average values of ventilation rate

Glazing type	Ventilation rate in m^3/h	Relative difference from original design
Single	799	-11.6%
Double clear	904	
Double clear, low emissivity	940	3.9%

5. CONCLUSIONS

Firstly, they have to be mentioned the following:

- The whole study has been done for state – steady conditions and laminar flow.
- All openings have been assumed as vertical.
- All calculations have been done simulating not only the solar chimney but also the connected zone and taking into account the possible flow due to dynamic reasons (wind speed).
- The ventilation rate for the original design has been calculated equal to 904m^3/h or approximately 126m^3/h per square meter of collectors area which in accordance with other studies and experiments results.

According to calculation results the outcomes are:

- The ventilation rate is slightly affected by the solar chimney thickness in case that it is in the bibliography proposed range (0.10 – 0.25m).
- Over insulating the construction elements of the solar chimney does not affect the efficiency of the solar chimney. A very small reduction of the ventilation rate while increasing the thermal resistance of the elements may be credit to the thermal interaction of the solar chimney and the room.
- The use of single glazing reduces significant the efficiency of the solar chimney, while the use of low emissivity glazing increases by almost 4% the yearly average ventilation rate.

Also it has been noticed that the diurnal fluctuation in warm period has two peak values. The first is after noon and this is supposed because of the incident solar radiation and the temperature difference between the room and solar chimney. The second occurs some hours after sunset, while the temperature difference between the two zones is also high. After sunset the solar chimney is cooling faster as it has a light thermal mass construction in the contrary to room's heavy thermal mass construction.

APPENDIX A. MONTHLY AVERAGE VALUES OF VENTILATION RATE

Month	Thickness (m)				Thermal resistance (m^2°K/Watt)			Glazing type	
	0.10	0.15	0.20	0.25	4.00	4.50	5.00	Single	Double clear, Low - E
January	841	840	840	839	839	838	834	787	854
February	876	875	873	872	877	876	873	792	901
March	868	867	866	865	868	867	864	778	895
April	968	966	964	963	966	963	958	847	1004
May	867	865	863	861	865	862	857	740	911
June	875	874	872	871	875	872	867	756	919
July	1063	1061	1060	1058	1065	1064	1062	938	1112
August	1093	1091	1090	1088	1094	1094	1091	964	1143
September	922	920	919	917	924	923	922	798	968
October	918	916	914	913	920	920	919	813	953
November	759	758	756	755	763	762	760	666	790
December	797	796	795	793	797	795	793	708	820
Annual average	904	902	901	900	905	903	901	799	940

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