

Innovative Thermophotovoltaic Hybrid Resin Tile

Matteo Greppi¹, Giampietro Fabbri²

¹(CIRI EDILIZIA E COSTRUZIONI, Università degli Studi di Bologna,
Via Lazzaretto 15/5, 40136, Bologna, Italy)

²(D.I.N., Università degli Studi di Bologna, Viale Risorgimento 2, 40136, Bologna, Italy)

ABSTRACT : *The product developed and here presented is the result of a widespread research project related to hybrid thermophotovoltaic panels. Starting from the numerical analysis, experimental testing and relative optimization of different hybrid solutions, we moved on final prototyping of an innovative thermophotovoltaic bi-resin walkable tile suitable for covering different kinds of surfaces subjected to solar radiation. The tile is made up of a layer of photovoltaic cells placed in contact, by means of a thermoconductive paste, with an aluminum alloy heat sink which transfers the heat from the cells to the water flow. The bottom of the heat sink and the hydraulic and electrical connectors are encapsulated in an opaque insulated resin. The top and the cells are covered with a transparent resin. This solution is suitable for any flat surface exposed to solar irradiance (often not usable and / or unused from an energy point of view) allowing a double energy output (thermal and electric) and a guaranteed walkability 365 days a year.*

KEYWORDS – *integration; hybrid; thermophotovoltaic; walkability; energy efficiency.*

I. INTRODUCTION

In most commercially available solar panels, a large amount of incident solar energy is still wasted due to the low efficiency of converting solar energy into electrical energy. The conversion efficiency for commercial silicon cells is generally between 20% and 25% (Green [1], Polman [2]). Higher efficiency values of the photovoltaic cell can be obtained by applying a cooling system to the rear of the modules that allows the cells to operate at lower temperatures. Thermophotovoltaic solar collectors are devices that allow the direct transformation of surface incident solar radiation into electrical and thermal energy. These panels permit not only to exploit the amount of solar energy converted into heat when it hits the photovoltaic cells, but the cells are kept at a lower temperature, thus increasing their efficiency [3,4]. Recently, different prototypes of walkable hybrid panels have been developed by our research group, initially designed for nautical and camping sector (small sailboats up to 10 m and campers) (Fig.1). In 2016, a new prototype of hybrid solar panel was created, which can be used as a tile to pave private streets, public areas and terraces or to cover roofs thanks to its strength and compactness. This panel is covered with two different resins that protect it from atmospheric agents and provide good thermal insulation. A compact heat exchanger transfers the heat captured by the photovoltaic cells to the water flow. The main features, which characterize the patented resin hybrid tile, are its walkability, the simple installation procedure and the easy maintenance. The preliminary analysis on the efficiency of these systems was conducted at the Hangar laboratories of the University of Bologna located in Forlì.



Figure 1. Boat Prototype

II. THE PROTOTYPE

The designed prototype of the hybrid tile is composed of a layer of high-efficiency monocrystalline photovoltaic cells, placed on an aluminum heat sink (Fig. 2). The cells are welded together and then mechanically connected to the heat sink through a heat conductive paste, which ensures satisfactory thermal contact.

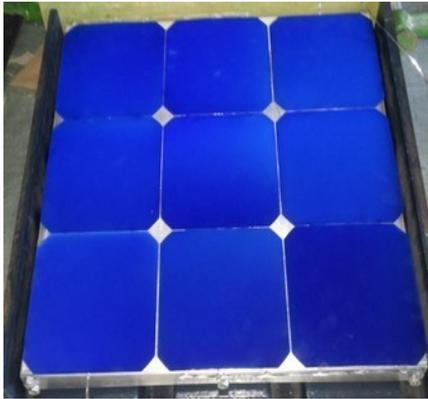


Figure 2. Front PV cells layer

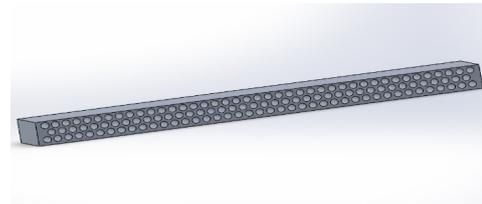


Figure 3. Heat sink cross section

One of the chosen and preferable solutions for the heat sink (especially aimed towards a large series production by extrusion) consists of an aluminum alloy block with internal parallel channels arranged in staggered rows as shown in Fig.3. In the aluminum modular block an inlet and outlet channel for the heat transfer fluid were also created. The photovoltaic cells and the heat sink are all enclosed in an epoxy or polyurethane resin case obtained by cold polymerization. The upper cover, created with a transparent high transmittance resin, allows the solar radiation to reach the cells, while the lower cover, made of an opaque insulated resin, limits outside heat losses (Fig.4). Both resins guarantee good mechanical resistance and airtightness to the entire hybrid panel. The insulated opaque resin was also used to make some feet that allow pipes and cables to pass under the tile within the floor distribution system. The inlet and outlet of the heat sink are joined to quick connectors that ensure a fast connection to the pipes' system downstream. The hydraulic and electrical connectors are integrated into the lower resin cover (Fig.5).



Figure 4. Hybrid Tile

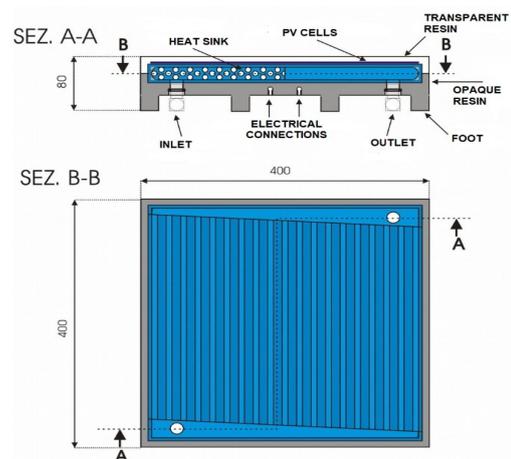


Figure 5. Tile Sections

III. RESULTS

The prototype of the hybrid tile was inserted in an experimental apparatus, previously described by Fabbri [5,6], consisting of a water circulator (adjustable with three variable speeds), Rilsan pipes, a thermostatic bath, pressure sensors and meters to detect the flow rate. Type T thermocouples provide temperature values and a pyranometer measures the global incident radiation. The heated fluid leaving the panels is cooled in the thermostatic bath and returned by pumping to the inlet of the heat sink, at a fixed temperature. The values analyzed for the fluid flow rate are 1.8×10^{-5} , 3×10^{-5} , 4.25×10^{-5} m³/s. Type T thermocouples are connected with a digital interface for data acquisition, which also measures the frequency signal of a flow meter to determine the mass flow in the circuit. A dedicated LabView interface collects and processes the measured data. The global radiation incident on the inclined surface (33°) was compared with the data collected by the "Ridolfi" airport meteorological station located in Forli next to the university laboratory. The experimental setup used is shown in Fig.6.

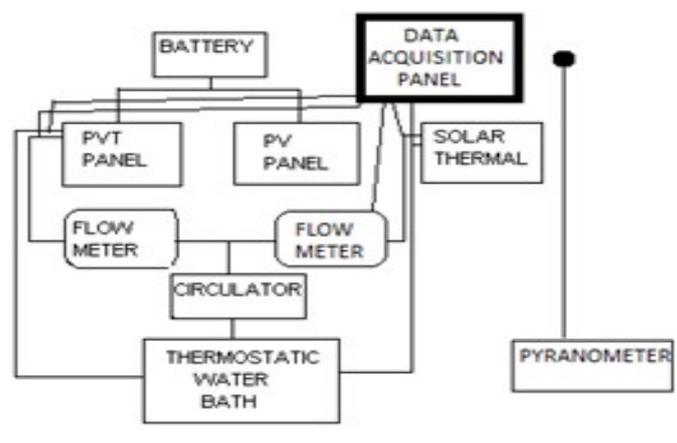


Figure 6. Experimental Setup

Under shown some preliminary results regarding thermal and electrical efficiency of the patented thermophotovoltaic tile are described. These results have been simultaneously compared with the same size PV panel. The tile thermal efficiency (η_t) has been calculated by measuring inlet and outlet water temperatures, fluid flow rate and output thermal power Q_t while the comparative PVT-PV electrical efficiency has been tested by measuring the PV cell open circuit voltage [V].

Table I: Electric efficiency (PVT Vs PV)

Date	Hour	PVT [V]	PV [V]	Difference (%)
16/06/20	11:15	3,62	2,95	18,5
23/06/20	10:45	3,95	3,11	21,2
04/07/20	10:15	3,71	3,16	15,1
15/07/20	11:20	3,67	3,09	16,1
28/07/20	16:30	3,73	2,96	20,6
09/08/20	09:45	3,81	3,02	20,7

Innovative Thermophotovoltaic Hybrid Resin Tile

19/08/20	16:20	3,35	2,65	20,9
28/08/20	11:10	3,64	2,98	18,2
09/09/20	13:50	3,42	2,85	16,7
23/09/20	15:30	2,95	2,36	20,1

Table II: Experimental dataset (PVT tile)

Date	Irradiance [W/m ²]	Fluid flow [l/min]	Q _t (thermal power) [W]	η _t [%]
16/06/20	920	1,9	76,8	50,3
23/06/20	1060	1,9	83,1	49,1
04/07/20	985	1,9	67,8	43,1
15/07/20	978	1,9	76,2	51,2
28/07/20	1056	1,9	85,2	47,3
09/08/20	996	1,9	71,8	46,4
19/08/20	1021	1,9	81,3	44,5
28/08/20	988	1,9	75,6	48,1
09/09/20	922	1,9	67,2	45,5
23/09/20	950	1,9	69,1	45,4

Date	Irradiance [W/m ²]	Fluid flow [l/min]	Q (thermal power) [W]	η _t [%]
16/06/20	920	2,3	85,4	58,1
23/06/20	1060	2,3	100,1	59,7
04/07/20	985	2,3	81,9	52,2
15/07/20	978	2,3	87,6	56,2
28/07/20	1056	2,3	98,0	58,4
09/08/20	995	2,3	88,2	55,4
19/08/20	1021	2,3	93,4	57,2

Innovative Thermophotovoltaic Hybrid Resin Tile

28/08/20	988	2,3	86,9	55,2
09/09/20	922	2,3	77,3	52,4
23/09/20	950	2,3	79,5	52,3

Date	Irradiance [W/m ²]	Fluid flow [l/min]	Q (thermal power) [W]	η_t [%]
16/06/20	920	2,5	80,9	55,8
23/06/20	1060	2,5	95,0	56,9
04/07/20	985	2,5	69,4	46,6
15/07/20	978	2,5	84,1	49,2
28/07/20	1056	2,5	94,1	52,2
09/08/20	996	2,5	84,7	51,3
19/08/20	1021	2,5	89,7	49,1
28/08/20	988	2,5	83,5	53,0
09/09/20	922	2,5	74,2	50,3
23/09/20	950	2,5	76,3	50,2

V. CONCLUSION

The following work presents a patented walkable thermophotovoltaic tile, which can be used as a cover for floors, roofs and terraces, especially where surfaces are lacking. In order to evaluate the thermal and electrical efficiency of this prototype, a preliminary experimental analysis was carried out. The removed thermal power and the open circuit voltage of the photovoltaic cell layer were measured under different operating conditions. The dependence of the efficiency of the photovoltaic cells on the cooling conditions has been highlighted and shows a double energy advantage (thermal and electrical). The use of transparent epoxy resin guarantees good optical properties and produces other obvious advantages in addition to its walkability, such as ease of installation, easy cleaning and maintenance. Mechanical, thermal and electrical tests are underway on the prototype in order to acquire the product certifications necessary for future marketing. The research and development phases are now turning towards the analysis of new materials and solutions that can make our tile even more performing from an energetic and functional point of view (epoxy and polyurethane resins with particular functional characteristics, new heat sink geometries and plant solutions downstream of the system).

REFERENCES

- [1] MA. Green, O. Dupre, R. Vaillon, Physics of the temperature coefficients of solar cells, *Solar Energy Materials and Solar Cells* 140, 2015, 92-100.
- [2] Polman A, Harry A.A, Photonic design principles for ultrahigh-efficiency photovoltaics, *Nature Materials*, 11, 2012, 174-177.
- [3] H.A. Zondag, Flat-plate PV-Thermal collectors and systems: A review, *Renewable and Sustainable Energy Reviews*, 12, 2008, 891-959.
- [4] H. A. Zondag, D. W. De Vries, The yield of different combined PV-thermal collector designs, *Solar Energy* 74(3), 2003, 253-269.

Innovative Thermophotovoltaic Hybrid Resin Tile

- [5] G. Fabbri, M. Greppi, Experimental characterization of a new hybrid thermophotovoltaic industrial prototype, *Energy Procedia* 81, 2015, 117-121.
- [6] G. Fabbri, M. Greppi, Experimental analysis of PVT panels for industrial applications, *Energy Procedia* 45, 2014, 308-314
- [7] M. Greppi, G. Fabbri, Experimental characterization of a hybrid industrial solar tile, *Energy Procedia* 126C, 2017, 621-627.

Matteo Greppi, et. al. "Innovative Thermophotovoltaic Hybrid Resin Tile." *International Journal of Engineering Science Invention (IJESI)*, Vol. 09(11), 2020, PP 59-62. Journal DOI-10.35629/6734