Super Slim: the Thinnest Solar Thermal Panel Ever

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ABSTRACT

Solar panels have become a common way to produce thermal energy from a free renewable energy source such as the sun. Together with their increasing diffusion, it has also increased the need to satisfy aesthetic requirements, imposed by architectural and landscape constraints. In order to satisfy this demand, the design of the panel has been optimized taking into account the fundamental heat transfer equations related to the panel operation. By a careful modeling and a subsequent realization of a physical model, it has been possible to realize an extremely thin thermal panel, only 43 mm thick, while maintaining high efficiency.

Keywords: solar panel, nanotechnology, modular panel, integration.

1 INTRODUCTION

Solar panels are nowadays a common system to produce thermal energy by means of a free and widely available energetic source, such as the sun. This makes them attractive for a huge set of application, such as domestic hot water production, pools heating, indoor heating, industrial heat generation and likewise, where the cost savings related to the use of a renewable energy source instead of a fossil one, such as oil, gas or electricity, are sound.

While increasing their diffusion and application, solar panels have to satisfy not only the energetic demand, but also and very often they have to integrate on the building where they are installed, lowering as much as possible the aesthetic impact of their presence on the building roof, both to satisfy purely architectonic aspects and landscape constrains imposed to the buildings. Moreover, the parallel diffusion of photovoltaic solar panels gives often the necessity to install on the same building both the thermal and the solar panels, which should then be as much modular as possible, in order to minimize the aesthetic impact. These lead to the necessity of producing the thinnest solar collector. In this paper we present the realization of such a panel.

2 THEORICAL CONSIDERATION

A solar panel is basically made of a collecting surface, adequately insulated against thermal losses to outer environment, which transfers the thermal energy delivered from the solar radiation to a suitable heat carrier fluid. Thermal insulation from the outer environment can be provided in two different ways: the first requires the use of vacuum, which is made into a pipe containing the collecting surface, the second requires the use of materials with low thermal conductivity, in order to prevent energetic losses to the outer of the panel body.

While the first approach, namely the vacuum pipe, doesn't allow for much an optimization, as decreasing the pipe diameter can't go beyond a certain extent, usually 50÷60 mm, without hampering the panel efficiency or increasing the panel cost, the second approach, namely the flat collector, offers the possibility to effectively reduce the panel thickness without dramatically affecting its cost and efficiency.

Thermal losses in a flat solar panel occur mainly in two directions: the first is the backside of the panel, the second is the front side, usually covered with a transparent material such as glass in order to allow solar light to reach the absorption plate. Thermal insulation on the back side is usually provided by low thermal conductivity material, such as rock wool, glass wool, polyurethane or, on most innovative solutions, nanotechnology materials, and the thermal losses can be calculated according to the equation [1]

$$Q = k\frac{\Delta T}{L} \tag{1}$$

where Q is the thermal flow, k the thermal conductivity of the insulating material, ΔT is the temperature difference between the two faces of the insulating layer and L is its thickness.

Insulation on the front side, because of the transparency need, is provided by a combination of the insulating capacity of air and glass, and thus the thermal losses in the gap between glass and plate can be calculated according to the equation [1]

$$Q = h\Delta T + k_{air}\frac{\Delta T}{L_{air}} = U\Delta T \tag{2}$$

where h is the convection heat transfer coefficient, and U is the global heat transfer coefficient.

While it is rather easy, according to the equation (1), to reduce the thickness of the back insulating layer by employing a material with a lower thermal conductivity, it is not as easy to do the same on the front layer.

The coefficient U, in fact, takes into account both convection and conduction heat transfer mechanism, and both vary with the distance L_{air}.

Radiative thermal losses can be neglected at this stage, as they are with good approximation constant within the distances L involved in this discussion.

In a very simple and intuitive model, we can look at the heat transfer phenomenon in this way: when the absorption plate is kept very close, eventually in touch with the glass, the heat transfer is purely conductive. Then, slightly increasing the gap between the plate and the glass, air starts to give a better insulation, thus U decreases, until the air layer is kept thin enough to prevent convective flow to develop.

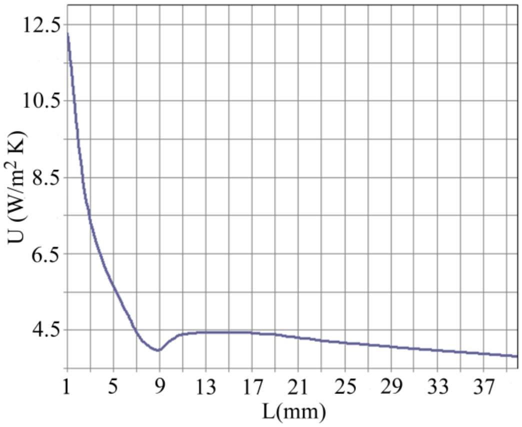

Figure 1: correlation between the global heat transfer coefficient U and the plate - glass gap L as obtained from the numerical model.

As soon as convective flow starts to develop, the value of U starts to increase with L, as convection is more efficient than conduction in transferring heat, then, for further increase in L, falls down again as the air insulation provided from a thicker air layer becomes predominant.

To validate this theory, a numerical model has been developed [2], which allowed to calculate the value of the convection heat transfer coefficient versus the plate – glass distance. The result of this simulation are reported in fig. 1.

It is clearly visible the presence of a local minimum in the value of U, around a L value of about 9 mm, while the value of U falls down for higher values of L according to the intuitive model explained before.

EXPERIMENTAL

In order to determine the effective distance where the local minimum of U is found, a set of physical models of the panel have been realized, with a different gap value each. All of them have been tested in order to evaluate their thermal production capability, and the presence of a minimum in the losses, and thus of a maximum in the produced thermal energy, according to the theoretical model, which has been then confirmed.

By combining an innovative nanotechnology material, having a very low thermal conductivity, and this last finding [3], it has been then possible to realize a solar panel with an extremely low thickness, only 43 mm. As a reference, conventional solar panels have a thickness of about 100 mm. This very low thickness, as compared with the commercially available photovoltaic solar panels, which is usually around 40÷45 mm, make this panel a very interesting candidate for a roof integration with photovoltaic modules, as it will make possible to realize a uniform surface despite the use of two different products. Moreover it is not a big issue to modify the width and length of the panel in order to fit those of photovoltaic module, allowing for a complete modularity of the two systems.

The panel is realized as follows:

- size (L x W x H): 1645 x 948 x 43 mm
- collector aperture: 1.4 sq. m.
- overall dimensions: 1.6 sq. m.
- covering: double extra clear tempered glass, 3.2 and 4 mm thick
- absorber: sputtering coated copper, absorbance 90%, emissivity 5%
- thermal insulation: nanotechnology material
- inset plate and structural support: zinc phosphate, galvanized plasma-coated inset plate
- weight: 41 kg

The panel has been certified from an independent institute, in order to evaluate its performances, obtaining the following results:

- η_0 : 0.769
- a_1 : 3.89
- a_2 : 0.011

The panel complies the European standard UNI EN 12975, and is current under certification to obtain the Solar Keymark, which is the main quality label for solar thermal products.

SUMMARY

An innovative solar panel, Super Slim, has been achieved by an R&D project aiming at obtaining a solar thermal panel as highly efficient as traditional collectors, even while relevantly reducing its thickness.

The panel features are:

- Better insulation: a thin layer of innovative nanotechnology material, offering a lower thermal conductivity than common rock wool, polyurethane or polystyrene.
- Half the common thickness: placed behind the copper absorber, this heat-insulating material reduces the solar panel thickness by half the traditional panels' overall dimension: it is the only enabling architectonical integration in buildings vertical walls or among pitched roofs tiles, even on balcony railings, with a significant reduction of environmental impact.
- Same dimensions as PV panels: moreover, the panel dimensions are the same as common photovoltaic panels; even the thickness of this revolutionary thermal solar panel is the same, thank to the above mentioned nanotechnology application. An array of SuperSlims and common photovoltaic modules, variously matched according to one's energy requirements, may be installed in a straight line on the same tray(s), with no gaps, interspaces or drops. Solar plants integrating both the thermal and photovoltaic solutions may be developed, though respecting environmental constraints and satisfying special planning controls. Efficient and harmonious structures can be made up, at last.
- Higher efficiency: the reduced distance between glass covering and copper absorber has not reduced the collector efficiency, as the problem has been brilliantly solved by double glazing the flat plate panel, what minimized the heat loss. The light transmission loss due to double glazing is recovered by the high transmittance of extra-clear glass layers with a thin film anti-reflection coating, which assures very high transmission rates (over 95%). The titanium oxide coating deposited by sputtering on the copper absorber assures high selectivity, that is high absorbance within the visible spectrum and low emissivity in the infrared region.

REFERENCES

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