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Solar Energy in Architecture: the Case of Facade Collectors

Ilija Nasov
MIT University,
Faculty of Management of Ecological Resources,
Skopje Camel Solar, Kosturski Heroi 66/9,
1000 Skopje, R. Macedonia

***Abstract* - The use of solar energy in architecture becomes more and more attractive nowadays. It offers great benefits such as: fossil fuel reduction, less CO_2 emission that labels the architectural goods as sustainable and eco-objects. Particularly, the usage of solar thermal systems in buildings has a big potential. Façade solar thermal collectors show double benefits in new architectural goods: integrated functional elements that fit the architectural appearance very well and at the same time those elements use a high fraction of solar energy for thermal energy needs of the building.**

In this work, the new model of a façade windows-like collectors is described. Namely, it is an ideal module that could fit or build-it in the south façade of the building. It could be used for residential, manufacturing or office building. With facade types of collectors, the architectural appearance of the buildings is not destroyed and at the same time the build-in elements are functional: they participate to a great portion of total energy needs of the building.

Keywords - facade solar thermal collectors, energy-efficiency, building integration, long term stability.

I. INTRODUCTION

Nowadays, it is very important the architects and civil engineers accept a new way of thinking for buildings where beside the architectural appearance, the energy efficiency of building will be also an important and valuable part of their decision. They usually are focused on a good appearance of the building; they are less interested in use of free renewable energy options.

Architectural goods that are declared as eco-friendly objects cover the energy needs from renewable energy source (RES). Concept of energy efficient buildings does not only mean the usage of insulating materials as building elements, but also use of RES in their concept. The most ecological and sustainable energy source in the architecture is the usage of solar energy for water and space heating. Tjose type of architectural goods are so-called *eco-friendly buildings.*

For this purpose usually, solar thermal systems (particularly, collectors) were installed on roofs initially, but not on facades; that philosophy is changed in the last decade or so. The ratio of available roof space and the required solar collector area is usually too small, and consequently it is difficult to supply enough energy from the *,,roof,, collectors* to the total energy needs of the building. In order to overcome this issue, it could be used the space of the facades especially if there is enough space on the south facade wall of the building. It is an ideal place to install solar collectors [1-4]. Even more, the south facade of the building could be more attractive or better place to accommodate the ,,functional,, building elements like *windows solar thermal modules*. Another benefit for *solar facade collectors* is the fact that their appearance could be very similar to the windows (glass) surfaces. They could be mounted in the same windows frames as the regular window glasses.

A. Facade solar thermal collectors

Due to the fact that facade collectors will be mounted under angle of 90^0 on the façade wall that means collectors' efficiency will be decreased annually (particularly, more in summer time than in winter) due to the fact that Sun has lower position in winter period (Figure 1). One way to compensate this decrease in collector's efficiency could be the use of collectors with very high efficiency.

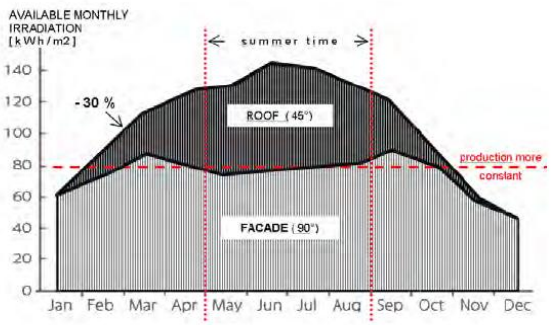


Figure 1. Roof versus facade collector annual yield pattern [3].

Although, vertical placement of collectors on a building will not maximise the peak yield possible during summer, it makes it easier to scale up a system for specific average requirements. As can be seen in Figure 1- the yield is much more constant in case of façade placement. Hence, overheating or overproduction can be minimized. In addition, with the right design the shortcomings due to the façade placement can be compensated by reduced thermal losses. In this context, the use of appropriate insulators and designs of the facade collectors could help in decrease of thermal losses.

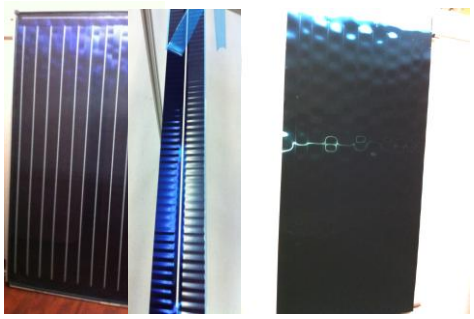
II. CHARACTERISTICS OF FACADE COLLECTORS

A. New thermal collectors

After production, flat plate collectors posses:

- a good heat transfer on all metallic surfaces;
- Al or Cu sheets (absorber) with selective coatings have also good heat transfer from the selective coating towards Cu tubes;
- selective coatings have an excellent and undisturbed optical characteristics.

Flat plate collectors have a relatively high coefficient of efficiency after their production. Those characteristics start to decrease over a period of time due to the humidity attack, corrosion issues, thermal dilatation during the day or in different time seasons, etc.



a) b)

Figure 2. Standard types of absorber welding: a) ultrasonic; b) laser. [Contact points and lines are initiators for corrosion.].

B. Solar thermal collectors during the exploatation period

In general, expected service life of the collectors is ~ 20-25 years, but decreasing of efficiency and esthetical appearance usually starts immediately after their installation. Namely, it is shown through the following observations:

- Decrease of optical properties;
- Decrease of heat transfer from the selective coating to the fluid;
- Temperature shocks of collector's results in different thermal expansions of Al sheets and Cu pipes that causes tension (stresses) in their contacts, weakens their function over a time and even splits up sometimes;
- Air and humidity between glass and absorber enable corrosion of the absorber;
- Destruction of selective coating as a result of classical ways of welding:

a) Standard ultrasonic welding due to the fact of removing the part of selective coating is a critical ,,corrosive,, point (Fig. 2a), or

b) laser welding that makes a point melting of Al and Cu that destroys selective coating on those spots (Fig. 2b);

- Destroyed sections of the selective coating allow penetration of corrosive agents like, water, salts, dust, and their migration underneath the coating (because of missing protective layer that could stop their penetration), etc...

As results of the above mentioned issues, the selective coating could be destroyed and consequently the optical characteristics of the absorber (collector) decreased.

III. NOVEL FACADE COLLECTORS

The facade window module consists of: two glasses between which is the absorber. Behind the absorber is material that absorbs the humidity in the inner space that could happen during the assembling of the collector (Fig. 3) [5, 6].

One of the most important characteristic of these modules / collectors is the fact that water vapour condensation is overcome, otherwise it can destruct the facade appearance and architectural design will be unacceptable. Since that there is no humidity issues in the inner area of the collector, it means that no oxidation or corrosion reactions of the absorber and Cu tubes could happen.

a) b)

Figure 3. Window facade collectors: a) window module, b) different coloured windows modules.

The absorber (Fig. 4a) in the novel windows-like thermal collector is welded in an unique and specific way by use of an automatic welding machine (Fig. 4b).

The main advantages of novel type of window facade collector (module) or CS-type of collector are summarised as:

- a good appearance of modules on the buildings (Fig. 3). The CS facade/window collector could be produced in different colours as shown in Fig.3b). The window module could be assembled in window facade frames as well;
- the surface area of contact between Cu tubes of the absorber and flat plate (that is Al or Cu material) is bigger than that one of the standard collector; it means better heat transfer between absorber towards absorber's fluid;
- the contact between Cu tubes and absorber's plate is stable and not changes during aging period of collectors;
- there is no any damage on selective coating of the absorber; no melting on the selective coating in spots as it happens in other ways of welding like, laser or ultrasound welding (Fig. 2);
- there are no wavy appearance on Al or Cu absorber plate due to the novelty in absorber's welding (novel CS type of welding).

a) b)

Figure 4. Novel Camel Solar (CS) type of absorber: a) front side, b) back side with three welding lines.

IV. Results and Discussion

Novel windows-like solar thermal collectors/modules offer great opportunities to be build-in elements in different types of facades. They offer an opportunity not just to replace solid walls of the facade, but also to have window-like appearance of the window- facade / building. At the same time, they are functional elements that cover a part of the total energy needs of the building.

Technically the selective coating is totally undisturbed - there is no diffusion processes of oxygen, hydrogen, no corrosion could happen of the absorbers' plate during the long period of its lifetime. Comparison of efficiencies of the novel thermal collectors and other types of solar flat plate thermal collectors showed greater efficiency for the novel type of collector (Fig. 5). The reason is that there is no need of use of a portion of collector's energy to evaporate the humidity from the inner space of the collector (humidity doesn't exist at all).

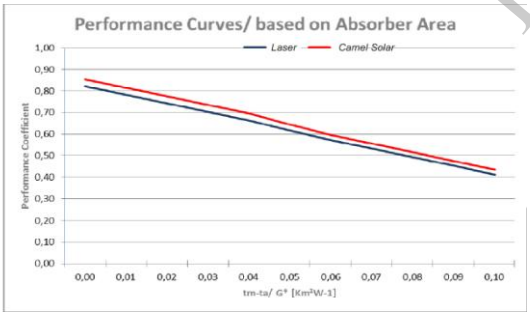


Figure 5. Comparison of efficiency curves of two types of absorbers: laser welded (blue line) and CS new type of absorber (red line).

With the *novel type of CS absorber* welded with three lines on the back side of absorber (Fig. 4b) most of the problems of collectors' aging mentioned in section 2 are overcome. Our observations showed the following preliminary results for this type of facade collectors:

- Optical characteristics measured in-house facility are nearly the same over a period of time of 2 years; visually it is not possible to see any destroying of the selective coating,
- During temperature shock tests (from -20 ^{0}C to +100 ^{0}C), it was showed that welding lines stay nearly the same on contact areas and consequently no changes on heat transfer.
- Due to the fact that there are no humidity issues between glass and absorber (Fig. 4) corrosion on the contacts between Al sheets and Cu tubes actually does not happen.
- No destruction of selective coating appeared on the protective layer of the coating after the stress tests; therefore the optical characteristics after aging of the absorbers/modules are nearly the same as initial characteristics.
- An independent R&D laboratory performed measurement of efficiency of collectors assembled with laser welded absorber (blue line, Fig. 5) and new type of CS-absorber (red line in Fig. 5). In temperature range from 0 to 100 ^{0}C, new type of CS-absorber has 7 to 8 % better efficiency compared to the efficiency of laser welded absorber.
- CS collector was subjected on humidity tests with other types of absorbers welded in different ways. The less corrosive attack on the selective coating is observed on the novel CS-type welded absorber compared to other types of standard welded absorbers. Also, on the back side on standard ways of absorbers' welding where is direct contact between laser welded spots and ultrasonic welded area was shown corrosion and forming of metal oxides from that process, but on the back side of CS absorber there are no any traces of corrosion [5-9].

Figure 6. Installed window modules in the existing window frames of CS building. Left and right windows columns of the building are existing standard glasses; the middle column of windows (circled in red) are CS-modules.

V. Conclusion

Novel type of windows facade collectors are functional elements in the new building concepts that beside their good architectural appearance they provide a big portion of the total energy needs of the building that comes from renewable solar source. The main characteristics of these collectors are summarised as:

1) The facade-window module's appearance is very attractive; it could be very similar to other windows glass surfaces on the facades. There is no additional cost for their installation since the facade collectors could be integrated in the existing windows frames; this is a big benefit of these type of collectors. Fig. 6 presents installation on the south façade on the production plant of CS building (Camel Solar, Skopje, R. Macedonia).

2) *A new type of CS-absorber* is assembled in the window / module collector. The absorbers are actually, free of welding lines, waves and folds and present good replace to classical windows. This is due to the fact that a new concept of absorbers' welding is conducted (Fig. 3,4).

3) *The long term stability* of these functional architectural elements is solved, no humidity issues exist; no water vapour condensation during the life time of the facade collectors happens.

4) Consequently, *collector's efficiency* is prolonged and is stable during their lifetime. Actually, this type of absorber shows better efficiency than other types that are welded in classical way (Fig. 5).

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