BIONICOL - DEVELOPMENT OF A BIONIC SOLAR COLLECTOR WITH ALUMINIUM ROLL-BOND ABSORBER

Project status after third year

Project aim

The aim of the project is to develop solar collectors with absorbers which feature bionic channel structures ("FracTherm®" structures), which are multiply branched in a fractal way in order to obtain a uniform flow distribution, a low pressure drop as well as a high thermal efficiency. The absorbers will be built of aluminium using the so-called roll-bond process. Small solar absorbers have already successfully been built in a previous research work. It is now necessary to develop collectors with typical dimensions needed for the market up to a prototype stage and demonstrate their efficiency and functionality as a basis for a following series production. It is expected that high-efficiency collectors at low costs can be obtained as a result of the project. The collectors are to be investigated for a wide temperature range in order to cover various applications. To reach the mentioned aims, the FracTherm® algorithm is to be developed further and the obtained designs have to be produced, evaluated and optimized. Moreover, the possibilities and constraints of the roll-bond production process have to be investigated in order to find out the best possibilities to produce a solar absorber with maximum efficiency and minimum costs. One of the very important tasks of the project will be the coating of the absorber after its channels are produced. Finally, the absorber has to be mounted into a collector casing and thus also has to fulfill a number of requirements. The target of a prototype and small-series production is to demonstrate the possibilities of manufacturing FracTherm® solar collectors with variations of the absorber. In order to prevent corrosion, it is necessary to work on appropriate heat transfer fluids. It is intended to build demonstration systems in various sites in Europe which are operated for more than one year within the project. The final objective is to evaluate the competitiveness of the developed solar collectors with state-of-the-art products.

Work done so far

During the project both theoretical and experimental fundamental research on FracTherm® structures have been carried out and the algorithm for the hydraulic adjustment of the channels has been improved.

A new fluid dynamics test facility has been developed and taken into operation at Fraunhofer ISE. The test facility allows experiments on direct flow visualization by hydrogen bubbles and indirect visualization by thermal imaging (Figure 1). Furthermore precise pressure drop measurements of both complete absorbers and single roll-bond channels can be done.

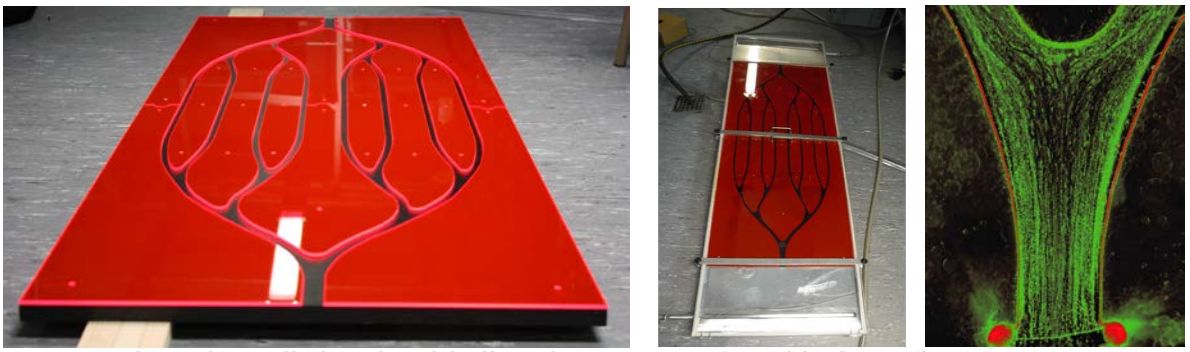

Figure 1: Specimen ("Small absorber") built as layer system from black PP, fluorescent PMMA and transparent PMMA cover (left), specimen inserted in custom-built sump attached to the hydraulic system (middle) and streamlines made visible by hydrogen bubbles (right)

CGA strongly improved the roll-bond process (e. g. new ink formulation, modified silk screen, modified inflation press) in order to cope with the special challenges of producing large panels with FracTherm® structures to be used as solar absorbers. An important aspect with respect to the operation of aluminium absorbers is corrosion prevention. Within the project it could be shown that the commercially available solar fluid TYFOCOR® L allows an appropriate corrosion protection even under extreme stagnation conditions. In contrast to state-of-the-art absorbers, roll-bond absorbers cannot use pre-coated sheet metal. They have to be coated after the absorber production. Since it would have been too expensive to adapt an existing coating plant for glass as originally intended, the prototype absorbers for the demonstration plants have been coated with the coating plant of Fraunhofer ISE. The absorptance was less and the emittance higher than that of state-of-the-art absorbers, however these values strongly depend on the surface quality which is again influenced by the pre-treatment (e. g. polishing). A first generation of BIONICOL prototype collectors (without header channels) has been built and tested. The performance was rather promising; however a direct comparison with an existing, commercial collector was not yet possible.

For the second generation of BIONICOL prototype collectors it was therefore decided to develop absorbers having the same dimensions as the commercial TiSUN collector FM-S 2.00. Moreover, the new FracTherm® channel design should ensure a good emptying behavior under stagnation conditions both in horizontal and vertical installation. In order to be able to connect several collectors in parallel, different header concepts have been investigated both theoretically and practically. Finally, a header concept based on hydroformed tubes (Figure 2) has been developed and produced in small-scale series production at the Fraunhofer Institute for Machine Tools and Forming Technology IWU.

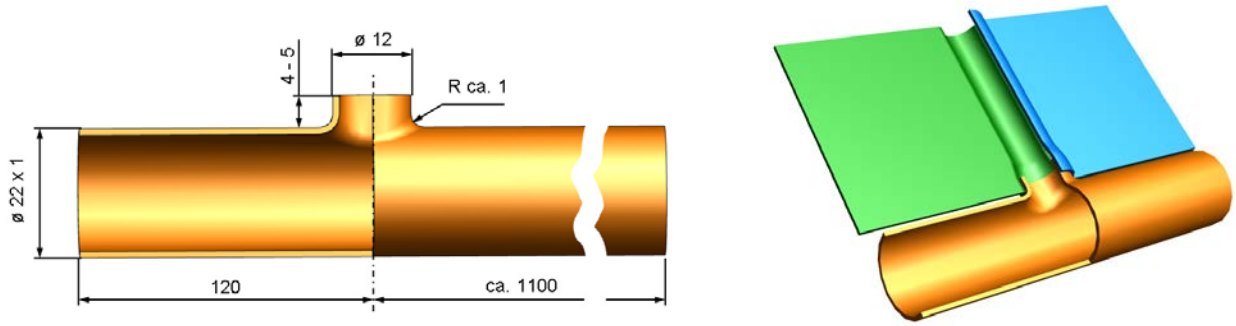

Figure 2: Header tube with collar produced by hydroforming (left) and basic connection concept with roll-bond absorber (right); source: Fraunhofer IWU

Since there was still a lot of manual work necessary, the scrap rate (untight absorbers) was still rather high. Nevertheless, it was finally possible to install two demonstration plants in Austria (22 m² and 16 m²). Since roll-bond absorbers are not as flexible as state-of-the-art absorbers, mounting the absorbers in the collectors was a special challenge. TiSUN found solutions both for the prototype collectors and for a potential future series production. Moreover, TiSUN has developed new full-aluminium connectors (Figure 3) in order to connect several collectors in parallel. They were used in the demonstration plants.

Figure 3: BIONICOL header tube end-forming for the connector part (left) and aluminium connectors used in the field test systems (right)

Originally it was planned to include a demonstration phase of one year within the project. However, this could not be reached due to many delays caused by several reasons. The demonstration plants were installed at the end of the project (Figure 4).

So far they work properly without any problems, even under stagnation conditions (induced deliberately). It is intended to continue the operation and monitoring of the plants also after the official end of the project. A further demonstration plant is planned to be installed in spring 2012.

Figure 4: The first installed and running BIONICOL field test system on the TiSUN flat roof

The efficiency curves of the second generation BIONICOL collector and TiSUN FM-S 2.00 as a reference have been measured at the "TestLab Solar Thermal Systems" of Fraunhofer ISE. A direct comparison of both collectors is possible because they feature the same dimensions, thermal insulation and glazing. A full efficiency curve has been measured in high-flow mode and in addition the conversion factor has been measured in low-flow mode. It can be seen from Figure 5 that the BIONICOL collector offers superior thermal efficiency in any mode of operation compared with the reference.

It must be stated as well that the BIONICOL collector was equipped with a selective coating with relatively poor optical properties compared with state-of-the-art (ε = 6.5 %, α = 93.3 %). By decreasing the surface roughness it is possible – proven by experiments at Fraunhofer ISE – to reduce the emittance to about 4 %. In that case the thermal efficiency especially at high operating temperatures can be increased significantly.

Concerning the development of a potential commercial product it can be stated that the thermal and hydraulic collector performance is superior to the existing FM-S 2.00, but the maximum pressure is reduced and the collector still needs further steps regarding a series production and cost reduction. Especially the high investment of a coating plant together with the number of absorbers to be coated annually will have an important impact on the commercial perspectives of a potential product.

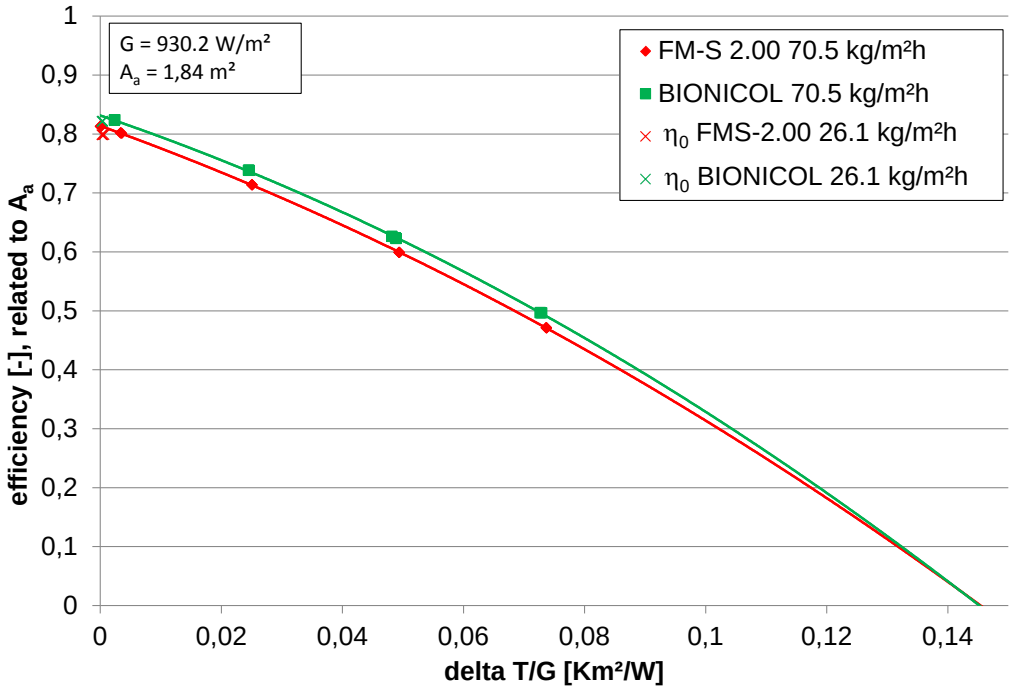

Figure 5: Efficiency curves of FM-S 2.00 and BIONICOL collector at standard flow rate as well as η_0 at low flow rate of 26.1 kg/m²h (with reference to the aperture area of the collector)

Project data

Project duration: 1.9.2008-31.8.2011

Project consortium:

Fraunhofer Institute for Solar Energy Systems, Germany **(coordinator)**

TiSUN GmbH, Austria

CGA Technologies S.p.A., Italy

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