MECHTEST –DEVELOPING A METHODOLOGY FOR TESTING THE MEACHANICAL SNOW AND WIND LOAD ON SOLAR THERMAL COLLECTORS

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Synopsis

Within a growing market, quality assurance gains an increasing importance. The most important norm in the field of solar thermal collector testing is the EN 12975.

The methods used in the EN 12975 are nowadays in some cases inappropriate, because they can be applied only to a limited extent due to innovative collector concepts and designs. Further research is needed to develop new concepts for mechanical load tests in order to meet the actual quality requirements and to cover a wide range/variety of applications. Innovative products such as PVT and façade collectors need to be integrated in these testing methods.

Due to an increasing number of extreme weather events the mechanical load test needs to provide sufficient assurance that a collector can master these challenges. Therefore the forces, different collector designs have to withstand, have been analyzed in order to simulate them as representative as possible.

This paper provides a new concept of a mechanical load test, based on more realistic testing conditions to reduce the barrier for new collector concepts on entering the market, keeping the quality level high at the same time.

1 Introduction

The European Solar Keymark, based on the norm EN 12975 for solar collectors and the EN 12976 for solar thermal systems, is the worldwide best developed quality label. It is not only in Germany (for the Renewable Heat Act and the Market Stimulation Program) required to get subsidies. The norm includes a definition for performance tests as well as for mechanical load tests to check the reliability of solar thermal collectors.

Flat Plate Collector ETC with CPC-reflectors Compact solar system

Figure 2: Examples of different collector shapes, to illustrate the different conditions for wind and snow load

To satisfy the upcoming challenges new collector designs and modern installation systems imply for mechanical load tests, the testing facility and methods that are used need to be adapted.

The methods actually used in the norm are not applicable e.g. to vacuum tube collectors, so that the Solar Keymark Network decided to leave these collectors out which is noted in the corresponding certificates.

This led to the situation that the testing laboratories have been requested, both from assurance companies and collector manufacturers, to develop adequate testing procedures to deliver reliable and realistic data on the resilience of solar thermal collectors. The mechanical load test for the collectors needs to be adopted in order to meet quality assurance goals and secure further market entrance for innovative products.

2 Analysis of methods recently used by European accredited testing laboratories

The mechanical load test is one of the requested reliability test according to EN 12975. It is defined to be performed on a collector, orientated horizontal. Forces which have to be applied according to EN 12975 are minimum 1000 Pa or a higher value, when agreed with the manufacturer. By request the test is eventually performed until a visible damage occurs. The forces have to be applied in positive (F_{perm+}) and in negative (F_{perm-}) direction. Although recently not requested in the standard the table as well provides information, if angular orientated forces can be applied. At the moment there are different methods used to apply the representative mechanical load. Throughout the different institutes and test centres the methodology to apply these forces varies quite considerably. The following table gives an overview on the different methodologies. It shows as well to what kind of product forces can be applied by the respective method.

But none of the procedures is sufficient in respect to sliding snow loads. The odds are that Method A, E, F, G represent non equal forces on the aperture area of the collector. This will appear, when snow starts melting and freezing during a sunny winter day as shown in figure 1. The currently used methods are not applicable at all different collector geometries.

Table 1: Different testing methodologies and the respective applicability

	Description	FPC			ETC			ETC + reflector			Compact solar system		
		F_{perm} +	F_{perm} -	F_{slope}	F_{perm} +	F_{perm} -	F_{slope}	F_{perm} +	F_{perm} -	F_{slope}	F_{perm} +	F_{perm} -	F_{slope}
A	Sand bag	✓	0	✓	0	0	0	✓	0	✓	✓	0	✓
B	Water in tarpaulin	✓	0	0	✓	0	0	✓	0	0	0	0	0
C	Air pressure	✓	✓	0	0	0	0	0	0	0	0	0	0
D	Evacuated bag	✓	0	0	✓	0	0	✓	0	0	0	0	0
E	pulley and sling	0	0	0	✓	0	0	✓	0		✓	0	0
F	Suction cups (disc)	✓	✓	✓	0	0	0	0	0	0	0	0	0
G	Suction cups (oval) + vacuum cushions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Description of the methods:

A This method can only simulate positive forces and to a limited extend slope forces, exspecially in the beginning of the procedure the forces are not applied equally. The weight can only be escalated and therefore the expenditure of human labour is relatively high.

B A frame applied with a synthetic blanket is placed above the collector in such a way, that it can be flooded by water, the height of the water correlates with the force on the collector. The big advantage of this approach is the equal spread of weight on the collector. But still this technique is only suitable for positive forces. It is not sufficient for compact systems, because the collector has to be horizontal.

C The collector is replacing one wall of a pressure chamber, which can be charged with either positive or negative pressure. Unfortunately it is difficult to seal the collector. Due to this reason this method is not appropriate for ETC's, where it is not possible to seal the collector in a sufficient way. It is not applicable to test slope forces.

D This testing facility consists of an oversize stuff bag in which the collector is inserted. Afterwards the bag is sealed completely and the air is evacuated. The atmospheric pressure takes an effect on the collector. This procedure is not sufficient on compact solar system and is only able to simulate positive forces.

E This procedure can only be performed with ETCs, where slings are fixed around the evacuated glass tubes. Load is impinged on the slings by using a pulley block, until the requested maximum load is reached. This technique can not apply negative forces and it is quite extensive to prepare.

F Pneumatic cylinders are operating to simulate both, positive and negative forces. When the cylinder is actually pulling, the suction cups are still connecting the cylinder with the collector. The standard test rig is only suitable for FPCs. Slope forces are performed well. Automation of the cycle and tests for several hours is possible.

G The new concept of the mechanical load test is based on the principle of pneumatic cylinders like they are used in method F, because the exact forces can be applied and measured. But instead of using standard suction cups the set-up is equipped with special devices. Now it is possible to adhere on convex surfaces, as well as providing enough contact area to spread the forces evenly. In addition vacuum cushion can be installed, to test reflectors, e.g. CPC reflectors. The testing pressure should be applied very homogeneous to simulate the real conditions. Therefore the method G is using special suction cups which apply the pressure on a maximum area.

3 Resulting forces from Wind- and Snow load

The lack of information resulting from the limited testing possibilities needs to be closed urgently. Especially for the concentrating technologies an exact knowledge on the loads and the resilience of the collector and its devices is necessary. As it is shown in Figure 1, snow does not only cover evenly the surface of a collector but also accumulates above the top and on the bottom of the collector. It causes shear forces and uneven distribution of the resulting pressure, which are not tested according to scheme in EN 12975.

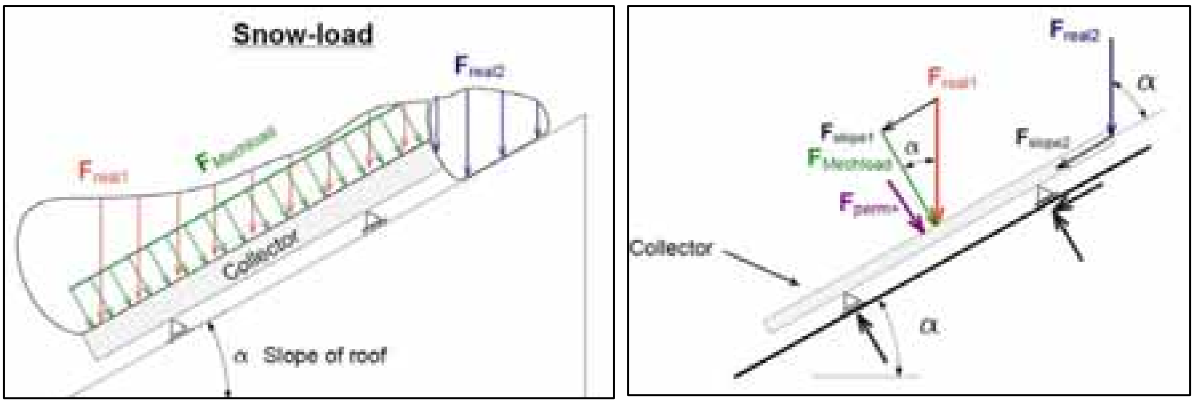

Fig.1: Snow load and its effects on a flat plate collector

At the moment the FPC and ETC are tested according to EN 12975,1-2:2006 in horizontal orientation. The pressure is raised in steps of 250 Pa, as well in positive as well as in negative direction until at least1000 Pa have been applied or the collector shows permanent deformation. ETCs are only tested applying positive pressure recently. As figure 1 shows the area load on the collector F_{real1} resulting from the weight of snow is split into the cosine and sinus ratio resulting from the angle of the slope. In addition the shear force of the snow (F_{slope2}) which is accumulated above the top of the collector will add an extra load which is not represented in the Norm.

The wind loads on a collector or a collector array are even more complex. Influencing factors are,

- the orientation
- the height of mounting
- the wind speed
- the geometry.

Are more detailed analysis of these boundary conditions and their resulting forces will be published soon elsewhere.

In order to determine the exact size and directions of the forces and its mountings, collectors have to be equipped with force transducers and to be monitored at different climatic conditions (See 4.1). Initially snow and specially wind loads can be measured and used for a realistic mechanical load test.

A special situation is to keep in mind for "compact systems". Systems which are build with the tank on top and the collector area directly connected to the tank. To these "not separable" constructions typically the standard EN 12976-1, 2:2006 is applied. Referencing to test the complete system according to the reliability tests defined in EN 12975 (collectors). But without any adoption these tests are not applicable to these systems. This is especially true for the mechanical load test. In detail this becomes obvious when defining the boundary conditions for the test. Most of these systems are not constructed to be turned in a horizontal orientation for example. Often then the tank is not supported enough anymore. A lot of open questions arise as well:

- Is the tank to be filled with water during the test?
- Is the orientation to be chosen with the lowest incident angle?
- Is the load of 1000Pa to be calculated into the horizontal plane or has the force to be raised?
- When testing the mounting equipment in these cases as well, because the complete system is not to separate,
- Why testing only the collector when it comes to separable products?

Ongoing work at Fraunhofer ISE will contribute to answer these questions. Read as well a paper published at this EuroSun conference from my colleagues Peter Kovács, Pedro Dias, Stephan Fischer, Enric Mateu and Stefan Mehnert[i]: "Joint European efforts on solar thermal collector standardization and certification"

4 Conception of a mechanical load test

A wide range of collector technologies for different applications results in diverse collector designs. This again leads to different load situations. Figure 2 shows some typical different geometry of standard collectors, which can be tested by the new developed testing rig. Surplus to these, effort is put on preparing to test as well PVT and façade collectors.

The mechanical load test rig is adjustable in its length and width as well as the angle of the plane the forces can be applied, which allows a great degree of freedom for different testing conditions. The highly adjustable test rig makes it possible to simulate slipping snow, causing shear force parallel to the collectors' glass cover.

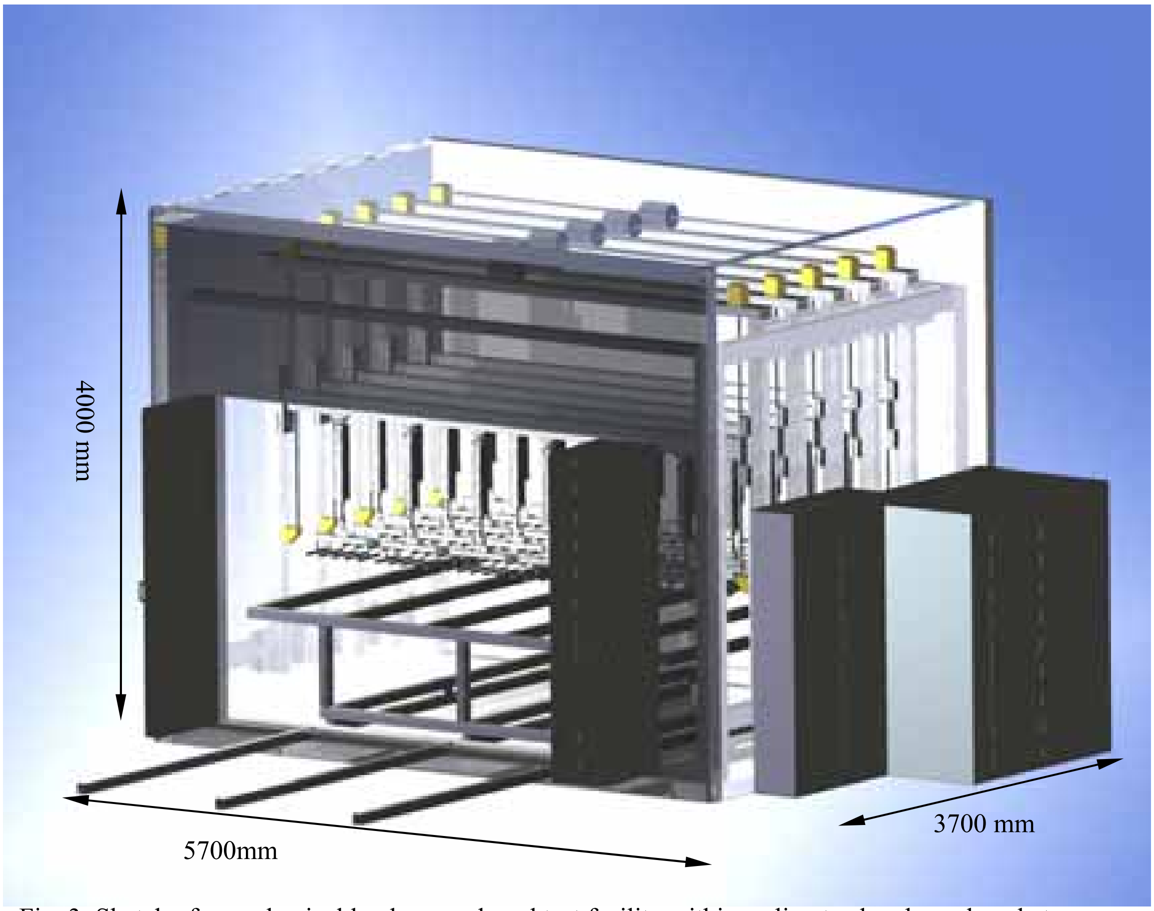

Fig. 3: Sketch of a mechanical load research and test facility within a climate chamber, planed at Fraunhofer TestLab Solar Thermal Systems

In addition, the chamber can be chilled and heated from –25° C till +60° C which will be used to test the collectors in preconditioned surroundings. Properties of materials used (silicones, glues, polymers, …) will be tested at different temperatures. Adhesives and seals which are used for the transparent cover tend to loose their consistency and maybe can not withstand the wind gust of a thunderstorm when already weakened by heat. New collector designs which use polymers could in the worst case get brittle and have problems to handle loads at low temperatures.

4.1 Exposition of Collectors

The work on mechanical wind and snow loads is going on at Fraunhofer ISE for the next years as well. So two different collector types (FPC and ETC) were exposed at three different locations (mountain - Zugspitze, coast – Gran Canaries, city - Freiburg) and will stay there for at least one year. The aim is to measure exact data for different wind and snow situations. With this information the new developed mechanical load test procedure will be double checked, to be as realistic as possible. Data of the depth of snow, wind strength and its directions will be correlated with measured temperatures and resulting forces. Forces on the collector will be measured including F_{slope} and F_{perm+} as well as F_{perm-}.

4.2 Simulation of forces on the collector

Besides the monitoring of collectors there parts of the forces can be modelled by a computer based simulation. In future, these parameters might be used to simulate new collector designs more easily.

4.3 Field analysis

Recently more and more insurance companies are worried about damages caused to collectors and roofs due to wind and snow loads. Working together quite closely with partners from the German collector manufacturing industry the situation will be analysed systematically.

5 Empiric Analysis

Using the research and test facility a lot of empirical studies can be performed under very reproducible conditions. A comparison of different collector types, and mounting equipments will be possible on basis of these experimental data... This information will help the manufacturer to build durable collectors and still improve the cost benefit ratio by saving or changing material.

During the procedure of the test the applied forces and the collectors´ deformation will be plotted at each pneumatic cylinder, so a force deformation diagram of the collector can be made. And reasons for possible breakage can be identified more easily.

6 Further use of the results

The idea is to have different "installation classes" for the collectors. So the installer or costumer can easily choose which class is the appropriate for his conditions and then easily check if the collector was approved for this class. This system of classes will be orientated towards the wind zone and snow zone classes already established in many countries.

The proposed approach is giving results in a more differentiated way then the test procedure does right now. The pass and fail criteria would therefore changed to a detailed table of installation and load requirements the collector was approved for (see Table 2). By doing this, not every product has to fulfil all the hardest boundary conditions, which makes the testing more flexible. For example a national regulation or subsidy scheme can refer the level which seems to be adequate. At the same time the clear documentation keeps the information level for the consumers high. It even offers to the manufacturer to adjust their products according to special market needs.

A credible, modern testing procedure, covering new collector designs and installation concepts can be established. This would lead to a higher planning security in terms of entering new market segments as facades, lightweight designed roofs but also single family houses (roof-replacing collectors). This finally leads to a cost reduction by optimized dimensioning and can help inducing more standardised mounting equipments.

Fig. 5: Table of possible criteria for a classification

Description	Class 1	Class 2	Class 3	Class 4
Wind	*km/h	*km/h	*km/h	*km/h
Snow	* kN/m^2	* kN/m^2	* kN/m^2	* kN/m^2
Building height	* m	* m	* m	* m
Altitude above Sea level	* m	* m	* m	* m
*				

*= to be defined

7 Literature

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