Analysis with the Finite Elements Method of Solar Collector's Tracking Systems

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Abstract: The tracking systems of the solar collectors are used to orient the solar collector normal to the solar radiation, in the way to catch the maximum amount of light from the sun. The paper presents the finite elements analysis of three main solar collector tracking systems: for plate, for dish and for trough solar collectors; the aim is to find out the critical position of the tracking systems, when the equivalent stresses and the displacements have a maximum value.

Key-Words: Solar collector, Tracking system, Diurnal motion, FEM, Stresses, Displacements.

1 Introduction

The solar collectors are used to transform the energy from the sun in heat used for domestic heat water or for buildings heating [3, 7].

The maximum amount of energy is collected from the sun when the solar collector's surface has a position normal to the solar radiation. During the day-light time, as inverse relative motion, the sun has a diurnal motion from east to west. During one year the sun has a smaller seasonal motion from north to south. Due to these considerations, it is necessary to find solution on the way to orient the solar collectors surface normal to the solar radiation during a day light period and during one year, also. The solution is given by the tracking systems [3, 7].

2 Problem Formulation

There are two types of tracking systems, mainly: tracking systems with one independent motion (according to the diurnal motion) and tracking systems with two independent motions (according to the diurnal and seasonal motions). Figure 1 … 3 show the finite element models of three main solar collector tracking systems with one independent motion: for plate, for dish and for trough solar collectors.

In the design process of the tracking system is important to find out the critical position of this, in order to identify the position when the equivalent stresses and the displacements values are maximum. The stresses and displacements fields are identified by using the finite elements method [1, 2, 5].

The materials characteristics, for each component of the tracking system, are defined as following [4, 10]:

- for the collector (made by glass): the *Young's* modulus *E*= $6.5\cdot10^{10}$ N/m^2, the *Poisson's* coefficient ν=0.161, the density ρ=2190 kg/m^3;
- for the collector's frame (made by aluminum): the *Young's* modulus *E*= $7\cdot10^{10}$ N/m^2, the *Poisson's* coefficient ν=0.346, the density ρ=2710 kg/m^3;

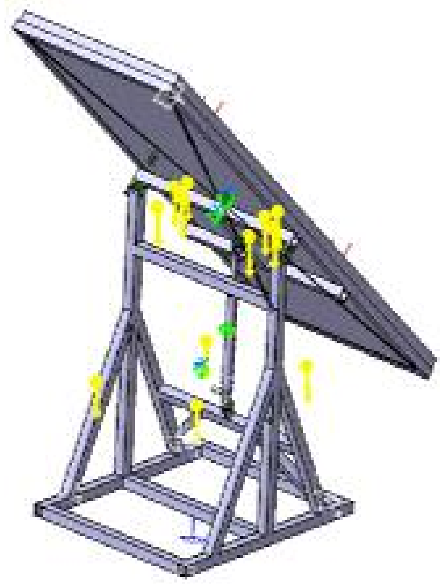

Fig.1

- for the tracing's components and the linear actuator (made by steel): the *Young's* modulus *E*= $2\cdot10^{11}$ N/m^2, the *Poisson's* coefficient ν=0.266, the density ρ=7860 kg/m^3.

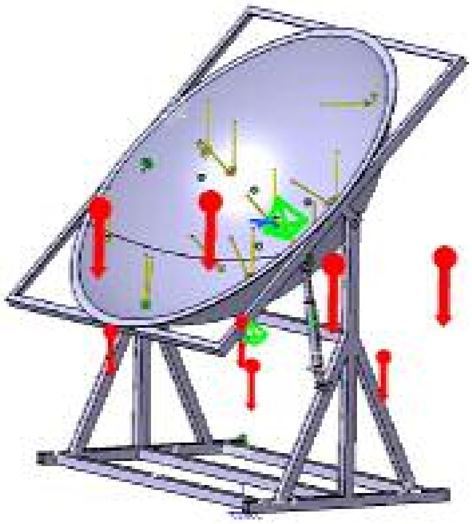

Fig.2

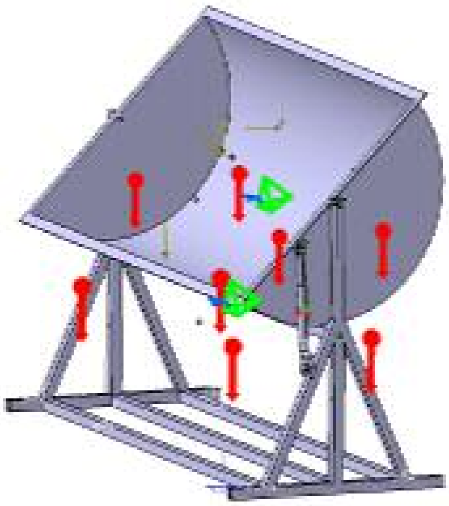

Fig.3

The external loads are materialized by forces and pressures which are produced by extreme meteorological situations; it is considered a 30 cm thick snow layer on the collector's surface an a 16 m/s wind speed is acting on the structure (for higher wind speeds the collector is oriented in a horizontal position – according to the standards) [4, 6, 8, 9].
According to the collector's dimensions, the snow is acting with a weight force equal with 660 N on the collector's surface. For the static friction coefficient of the materials snow/glass, the snow is staying on the collector's surface until an inclination angle (from the vertical plane) equal with 21.71^o.
The modeling of the geometrical domain consists in the modeling of the component elements (the tracking system, the frame, the collector, the linear actuator); the final model results by assembling the component elements.
The constraints are represented by the clamp applied to the seating surface of the base and by the links between the component elements [4, 6, 8, 9, 10].
The finite elements analysis is done by considering the orientation angle between [-45^0, 45^o].

3 Problem Solution

The following figures are presenting the stresses and displacements fields for plate, dish and trough type solar collectors, respectively.

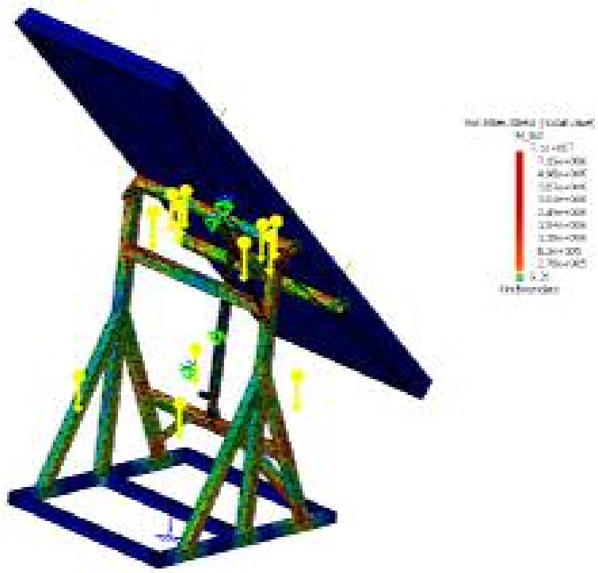

Fig.4

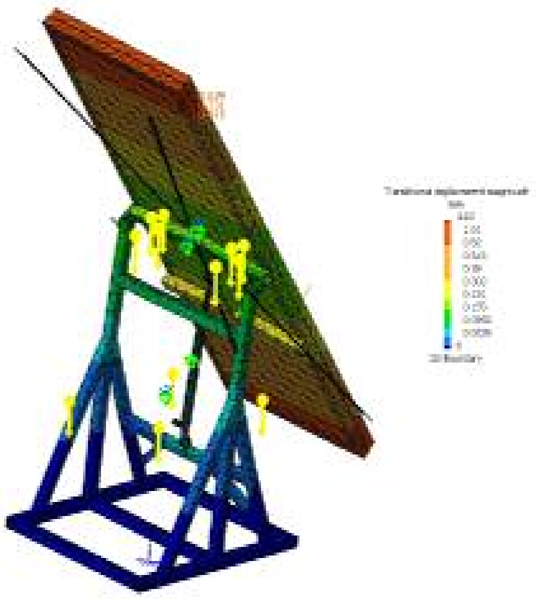

Fig.5

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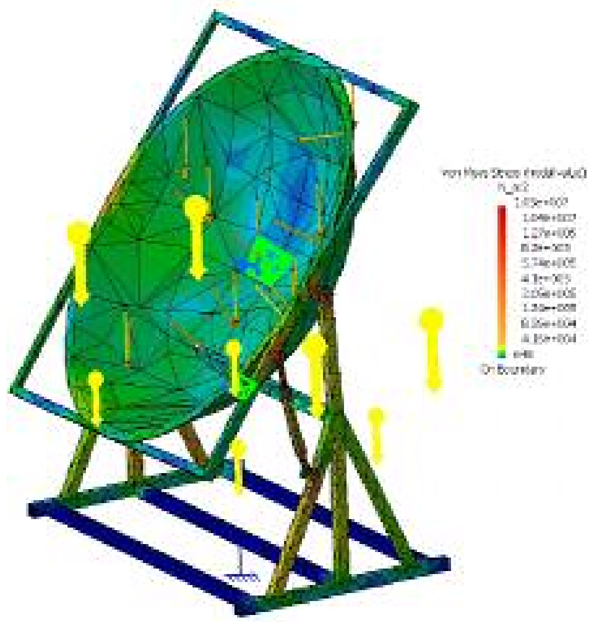

Fig.6

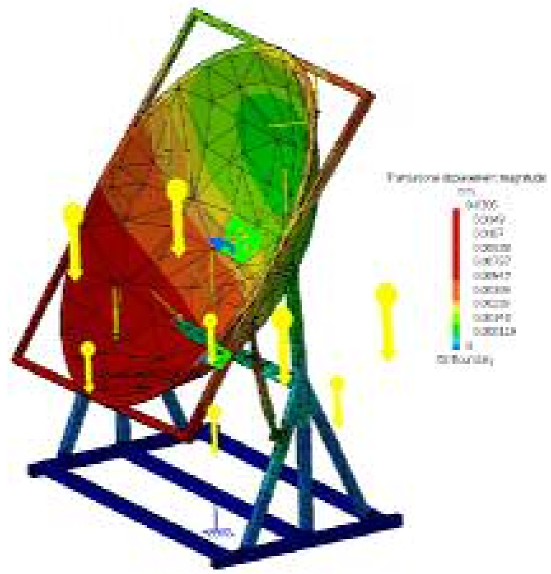

Fig.7

The stresses and displacements fields are shown for the orientation position of 45°. In this case the stroke of the linear actuator has a minimum value and the stresses and displacements maximum values are maximum.

On the presented figures it can be observed that the equivalent stresses are having maximum values in the rotational joints between the supporting frames, the basic structures and the linear actuators. The values of the maximum equivalent stresses are: 71 MPa for the plate solar collector; 10.5 MPa for the dish type solar collector; 34.4 MPa for the trough type solar collector. The displacements have small values (less than 1.02 mm).

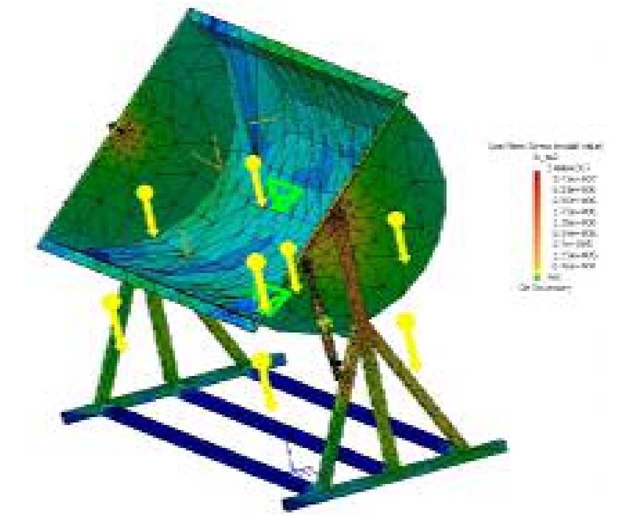

Fig.8

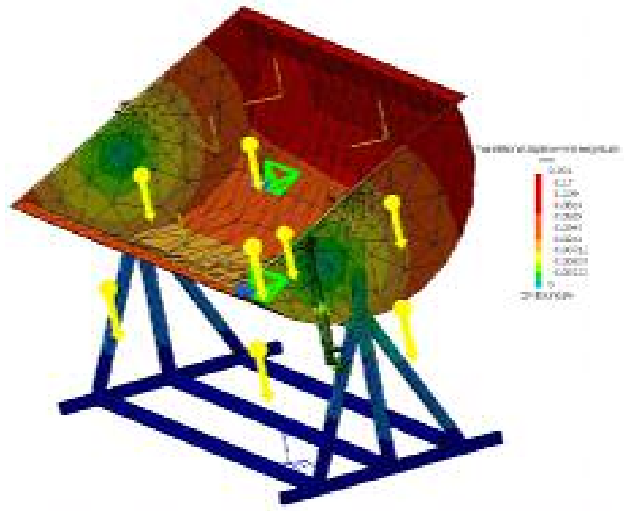

Fig.9

The variation of the maximum equivalent stresses and of the maximum displacements, for the plate, dish and trough type solar collectors with the orientation angle is presented in figures 10 … 15.

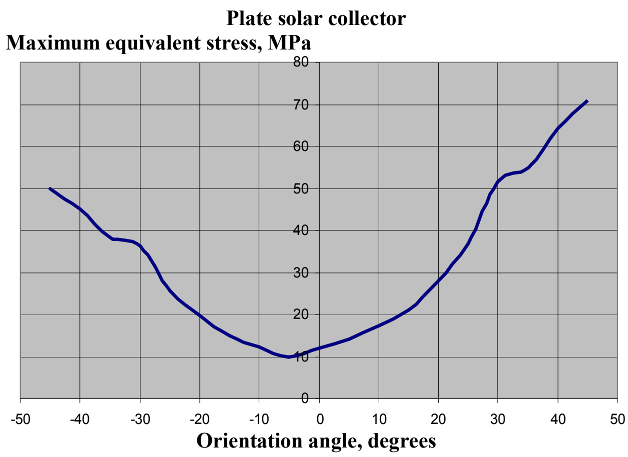

Fig.10

Plate solar collector

Maximum displacement, mm

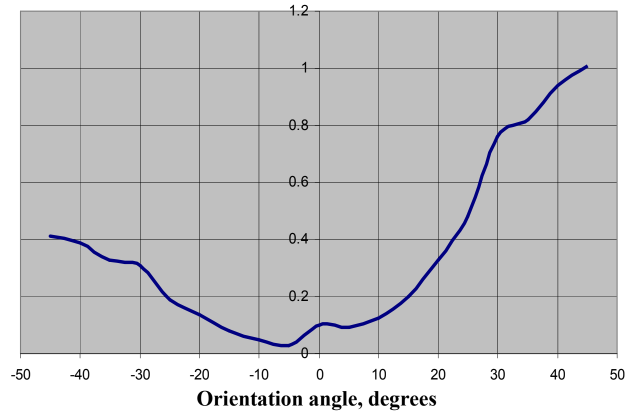

Fig.11

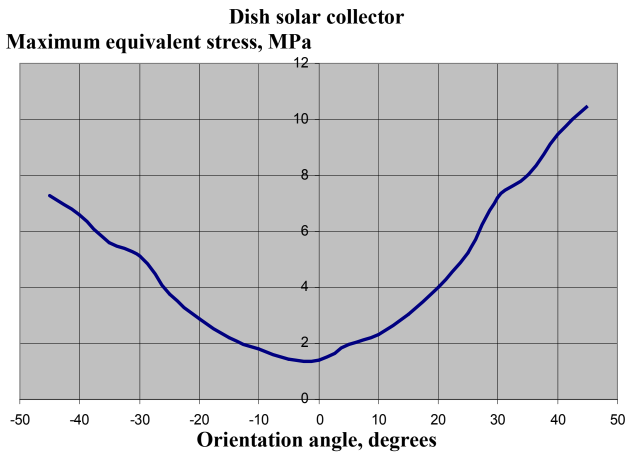

Fig.12

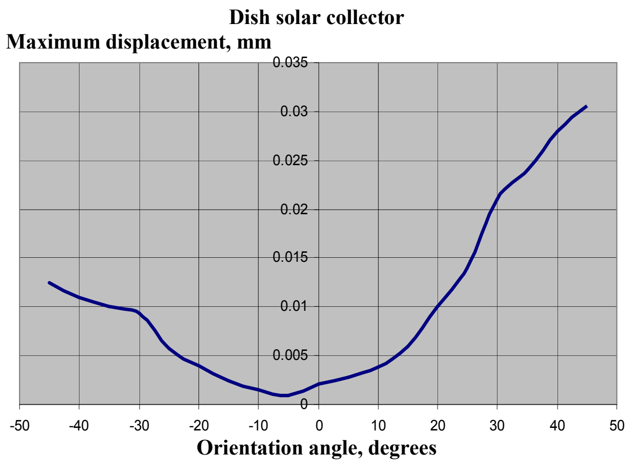

Fig.13

4 Conclusion

According to the results obtained form the finite elements analysis of the presented solar collectors tracking systems, some important conclusions can be issued:

- the maximum values of the equivalent stresses are obtained in the rotational joints of the structures (the joints between the frame, supporting structure and the linear actuator);

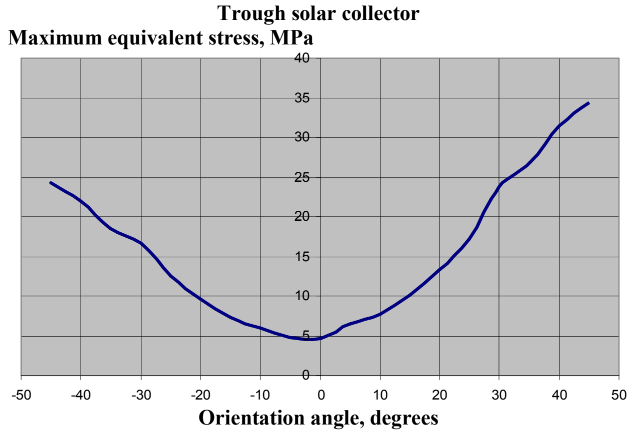

Fig.14

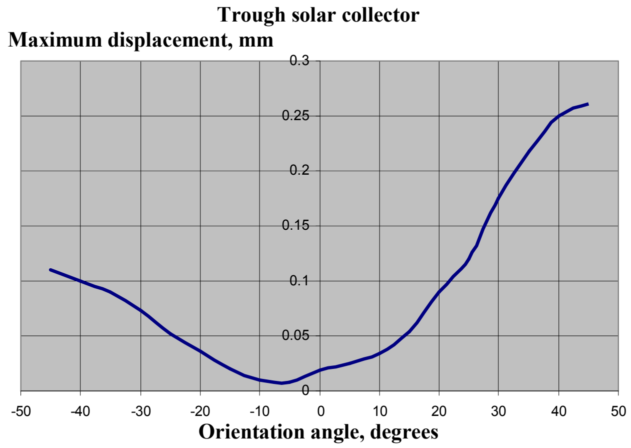

Fig.15

- the maximum values of the equivalents stresses are the following: 71 MPa for the plate type solar collector, 10.5 MPa for the dish type solar collector and 34.4 MPa for the trough type solar collector;
- to reduce the maximum stresses there are imposed new constructive solutions for the rotational joints (bigger bolts);
- the maximum values of the displacements are small (the maximum value of the displacement is obtained in the case of plate type solar collector – 1.02 mm) and the influence on functioning of the tracking system is insignificant;
- the maximum values of the equivalent stresses and displacements are obtained for big orientation angles (in this case the actuator stroke has a minimum stroke and it means that the structure is a stabile one).

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References:

[1] P. K. Barnerjee, *The Boundary Element Methods in Engineering*, Mc Graw-Hill Publishing House, Maidenhead, England, 1993.

[2] G. Bee, J. O. Watson, *Introduction to Finite and Boundary Element Methods for Engineers*, John Wiley & Sons Publishing House, Chichester, England, 1992.

[3] J. A. Duffie a. o., *Solar Engineering of Thermal Processes*, John Wiley & Sons Inc., USA, 1991.

[4] M. J. Fagan, *Finite Element Analysis. Theory and Practice*, Longman Group, England, 1992.

[5] M. Gerardin, A. Cardona, *A. Flexible Multibody Dynamics: A Finite Element Approach*, John Wiley & Sons Publishing House, Chichester, England, 2001.

[6] M. T. Lates, *Metoda Elementelor Finite în Inginerie. Aplicatii*, Editura Universitatii Transilvania din Brasov, Romania, 2008.

[7] R. Lates, I. Vişa, Solar Collectors – An Overview, *Proceedings of Conference of Sustainable Energy*, Brasov, Romania, 7-9 July 2005.

[8] G. L. Mogan, *Metoda Elementelor Finite in Inginerie. Bazele Teoretice*, Editura Lux Libris, Brasov, Romania, 1997.

[9] O. C. Zienkiewicz, R. L. Taylor, *The Finite Elements Method*, Vol. I. Mc Graw-Hill Publishing House, Maidenhead, England, 1988.

[10] O. C. Zienkiewicz, R. L. Taylor, *The Finite Elements Method*, Vol. II. Mc Graw-Hill Publishing House, Maidenhead, England, 1989.

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