

TRACKING SYSTEM FOR SOLAR THERMAL COLLECTOR

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Abstract: This paper presents in a concrete manner the purpose of a solar thermal collector and, in order to maximize its efficiency, proposes a tracking system mechanism type linkages. Different constructive variants are presented for this mechanism, used for different solar thermal collectors, as well as the structural synthesis, main kinematics parameters synthesis and the modeling of the kinematical-dynamic behavior, using the multibody system method.

1. INTRODUCTION

Conversion of solar energy into thermal energy is performed by means of solar collectors. They intercept incoming insolation using absorbers and by convection, conduction and radiation turn it into thermal energy. Solar collectors are sorting function of working principle in plate and concentrator. Plate collectors use the global radiation while the concentrator collectors use only direct radiation. Most used plate collector are flat-plate (fig.1,a) and vacuum tube (fig.1,b); most known concentrator collectors are parabolic trough (fig.2,a), central receiver and parabolic dish (fig.2,b) [6,8]

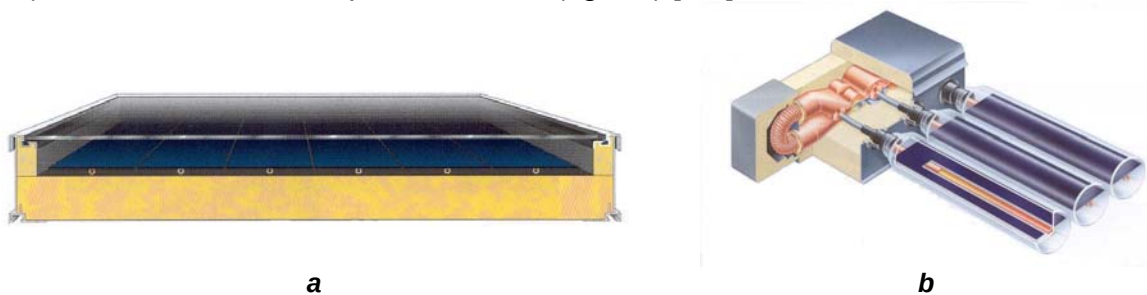


Fig. 1 Plate collectors

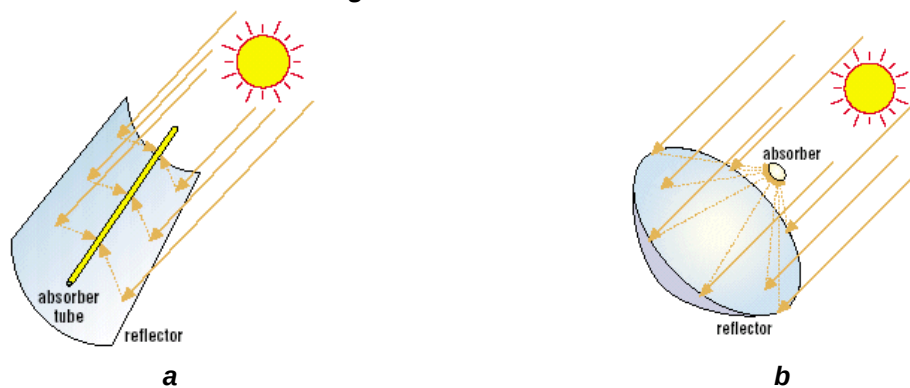


Fig. 2 Concentrator collector

Due to variation of the sun position on the sky, in order to obtain a better concentration of the radiations, these collectors are equipped with tracking systems.

Tracking systems are classified by their motions [1]. Rotation can be round a single axis (which could have any orientation but which in practice is usually horizontal east-west, horizontal north-south, vertical, or parallel to the earth axis) or can be round two axes. Due to the complexity and high price of the two axis tracking systems, in the paper is presented a single axis tracking system.

Most commonly tracking systems use a gear box and a belt [11,12], rope or chain transmission. Collectors tracking also use actuators or systems based on “hydro-mechanic” [10] or gravitation principle [13].

Belt and rope transmission tracking systems require accurate maintenance and could generate errors; chain transmission cannot be used for large dimension collectors; systems based on “hydro-mechanic” principle have large dimension and those based on gravitation principle require a daily human intervention and depend on environment temperature.

The advantage of the proposed tracking system consists in the simplicity and liability, which means a low price and allows them to be used for plane solar collectors and concentrator collectors as well.

2. TRACKING SYSTEMS DESCRIPTION

Solar energy has a reduced importance on the Romanian energy production at this moment. In the next years it is estimated a significant raise of the solar energy. Considering the solar energetic potential, Brasov is included in the 4th area, having a potential less than 950 kWh/m² along one year. In order to increase the amount of the collected solar energy, it is very important to use tracking systems.

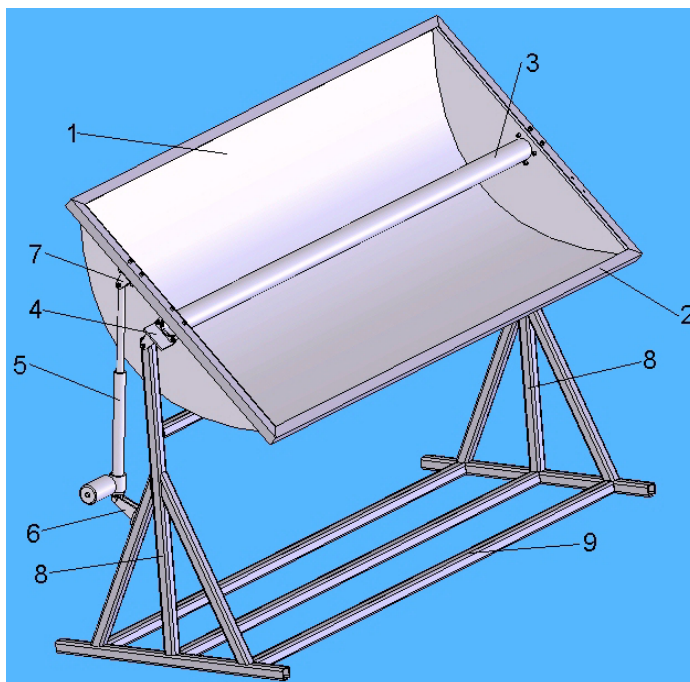


Fig. 3. Parabolic through collector

Three constructive variants are presented in this paper, based on a planar linkage mechanism.

Parabolic through collectors are most used, having the advantage of concentrating the sun radiation on the pipe where the heating fluid passes thru. Figure 3 presents solution for a tracking system used for this type of collector. The reflector 1 of the collector is assembled on the frame 2, fabricated by equal leg angles. At the collector ends, round the receiver 3 is mounted a flange, bolted both to reflector 1 and frame 2 (fig. 4). The flange

has a U shape with unequal legs. The bracket 10, welded to the long leg of the flange, generates a rotational joint with the leg 8 of the supporting frame. Both legs 8 and the reinforcing pipes 9 are made by square tube and making a supporting frame which is mounted on a building roof of Transilvania University of Brasov.. The fork piece 7 is also assembled to the frame 2 with screws and generates the joint between the mobile axial actuator part and the through collector (see fig. 3 and fig. 4).

The actuator cylinder 5 is jointed to the leg 8 of the supporting frame by means of a fork piece too (fig 5). Using this tracking system, the solar collector can rotate relative to its horizontal position in a range of $\pm 45^\circ$.

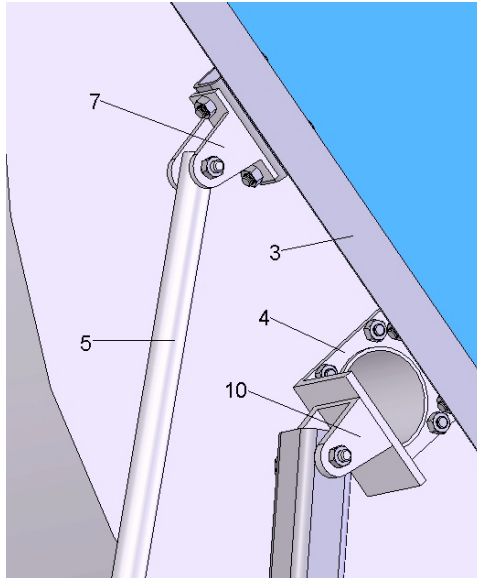


Fig.4. Joints of tracking system

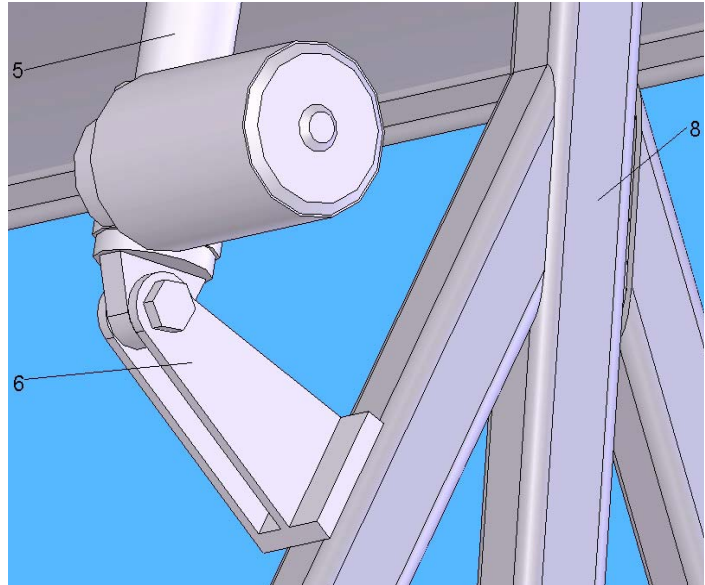


Fig.5. Actuator joint at the frame leg.

The dish concentrator collectors are used to obtain electrical power[9]. Figure 6 presents a constructive variant for a dish collector.

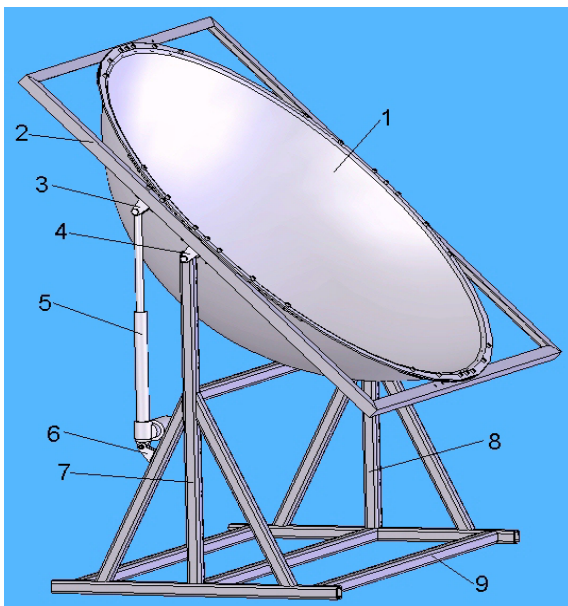


Fig. 6. Dish concentrator collector

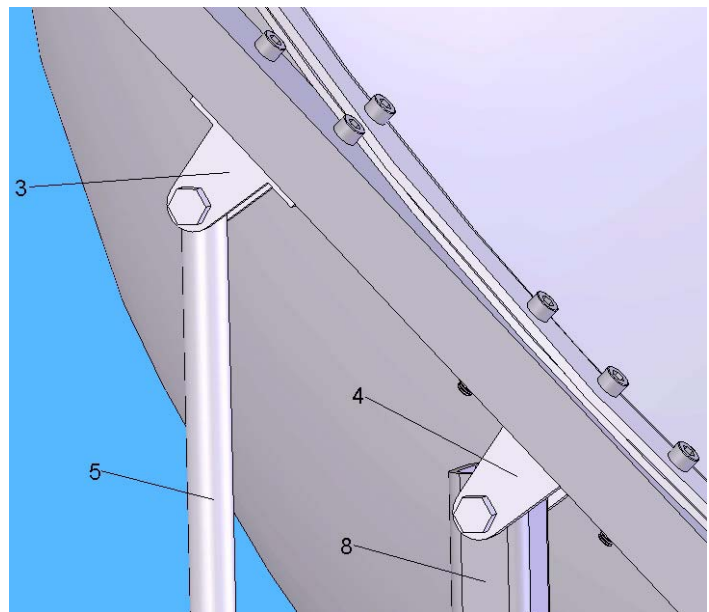


Fig. 7. Mechanism joints

This design is similar with the previous one, but the frame 2 has a square shape, the collector being connected on four areas by means of circular crown sectors assembled with cylindrical head screws (fig. 7). Thus, the entire assembly is rigid and voids the distortions which could cause the collector deterioration. The placement of joints 3 and 4 on the frame 2, made by equal legs angles, takes into account the possibility of tilting the collector in a range of $\pm 45^\circ$. The actuator is jointed to the frame leg 8 by means of piece 6.

Flat plate solar thermal collectors are most used for generating heating and domestic hot water in individual houses but they can also be used in hybrid systems along with conventional or no conventional systems. Figures 8 and 9 present a constructive variant of a flat plate solar thermal collector with a tracking system. In comparison with the

previous collectors the surface of the flat collector is wider but the concentrating phenomenon does not occur.

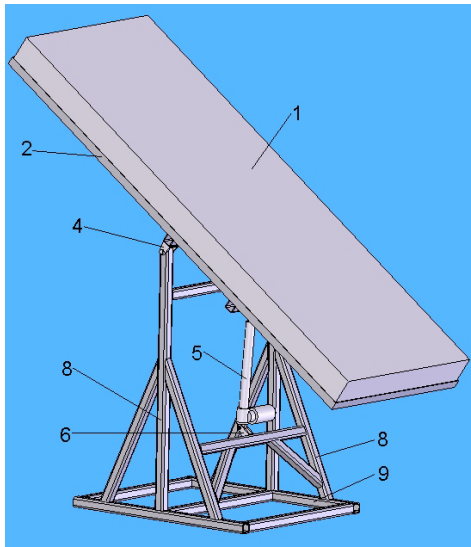


Fig. 8. Flat plate collector

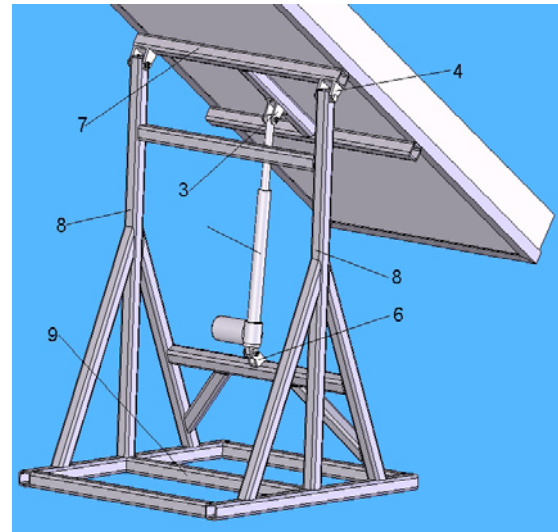


Fig. 9. Tracking system joints

The box of the solar collector 1 being rigid, the supporting frame is fixed on the assembly 7 which has a I shape. The actuator 5 is connected at the midpoint of assembly 7 by means of rotational joint 3 (see fig. 9). The joints 4 make the bound between the assembly 7 and the frame legs 8. The movement between the actuator 5 and the frame legs 8 is performed by means of joint 6. The entire system is mounted on the building roof using the supports 9.

3. KINEMATICAL AND DYNAMINC ANALYSIS OF THE TRACKING SYSTEM

In order to determine the kinematics conditions necessary for the tracking system, it is considered as a math example the month of March when the average day time is 12 hours. Thus, the reflector should rotate 180° during the 12 hours (12 hours $\times$ 60 minutes=720 minutes, maximum 15° /hour)

Figure 10 presents the tracking mechanism scheme for a parabolic trough collector. The mechanism driving is performed by means of a gear box equipped with an adequate control system.

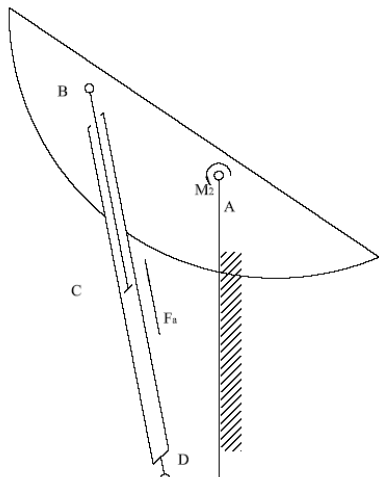


Fig.10 Structural scheme of a tracking system mechanism

a). structural model

- number of bodies $n_c=2$

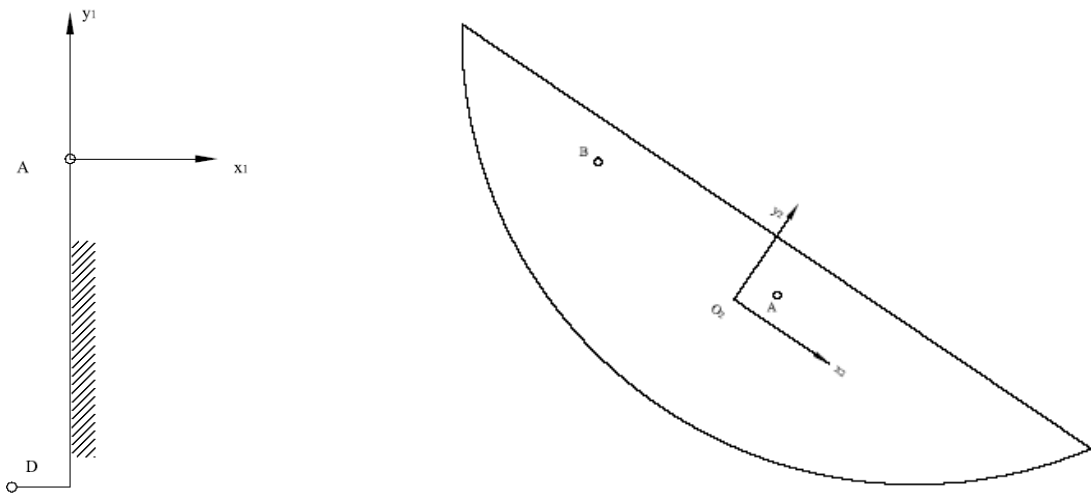
Body	Restriction	Place	r_g
1-2	R	A	2

Mechanism degrees freedom

$$M=3(n_c-1)-\sum r_g=3(2-1)-2=1$$

b). kinematical model

- bodies geometry



Body 1 : $x_{A1} = 0; y_{A1} = 0;$
 $x_{D1} = -176.5\text{mm}; y_{D1} = -535\text{mm};$

Body 2:- the reference system is placed on the mass

center $x_{A2}^{(2)} = 11.5\text{mm}; y_{A2}^{(2)} = 11.5\text{mm};$
 $x_{B2}^{(2)} = -151\text{mm}; y_{B2}^{(2)} = 237\text{mm};$

Geometrical and kinematical equations:

$$\begin{aligned} F_{1R} : x_{A1} &= x_{O2} + x_{A2}^{(2)} * \cos(\varphi_2) - y_{A2}^{(2)} * \sin(\varphi_2); \\ F_{2R} : y_{A1} &= y_{O2} + x_{A2}^{(2)} * \sin(\varphi_2) + y_{A2}^{(2)} * \cos(\varphi_2); \\ F_3 : \varphi_2 &= \frac{1}{2} \varepsilon_2 * \Delta t^2 \end{aligned} \quad (1)$$

The system of displacement functions is composed of 3 equations where F_{1R} and F_{2R} are geometrical constraints of type R for point A and F_3 is the driving constraint for the acceleration phase [3,4,5]. The collector should rotate 15° in 60 seconds. Thus the angular acceleration ε_2 is determined. The kinematical restriction for the deceleration phase is as follows:

$$F_3 : \varphi_2 = \varphi_0 + \omega_0 * \Delta t + \frac{\varepsilon_2 * \Delta t^2}{2}, \quad (2)$$

where φ_0, ω_0 –is the rotational angle and angular velocity corresponding to the acceleration phase.

Using the software Maple 5 for numerical solving of the equation systems (1), the following displacement, velocity and acceleration functions are obtained (fig 11).

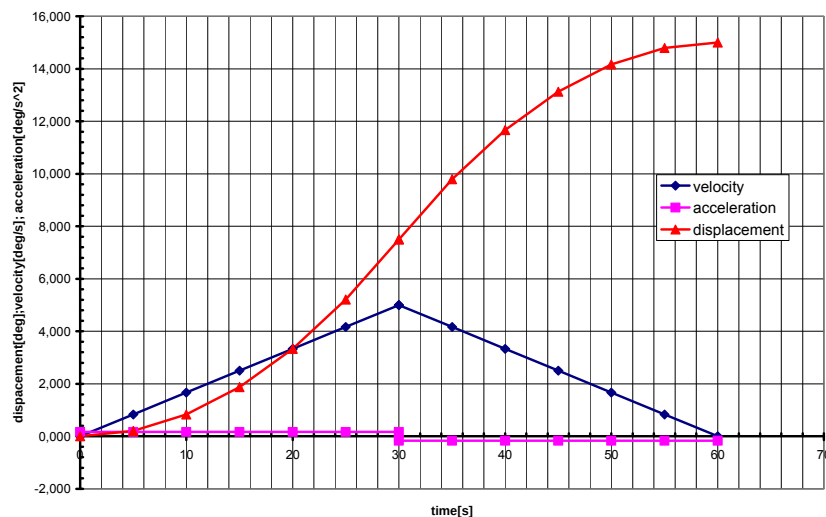


Fig. 11 Movement function of the parabolic through collector

Figure 12 presents the displacement curve obtained for the linear actuator, taking into consideration that it starts from the initial position shown on figure 3 (the most open position).

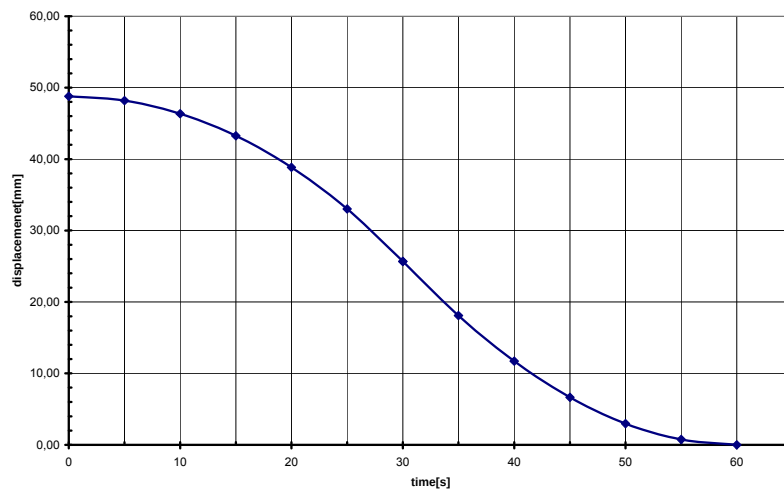


Fig.12. Displacement of a linear actuator for the parabolic through collector

c). Dynamic model

On the dynamic model of the system, only the inertial effect of the collector was taken into account and the wind speed was considered as acting uniformly on the collector surface.

$$E_c = \frac{1}{2} J \cdot \omega^2; E_p = m \cdot g [h_0 + e \cdot \sin(45 + \varphi_2)];$$

Where: m is the collector mass $m = 45$ kg, $e = 0.016$ m represents the distance between the mass center and the rotational axis of the collector, $h_0 = 1.067$ m – is the elevation of the rotational axis.

The movement equation is:

$$(J \cdot \omega - m \cdot g \cdot r \cdot \cos(45 + \varphi) \cdot \dot{\varphi}) - m \cdot g \cdot r \cdot \cos(45 + \varphi) = T \quad (3)$$

Based on the dynamic model, the torque required for the collector orientation is obtained (fig. 13).

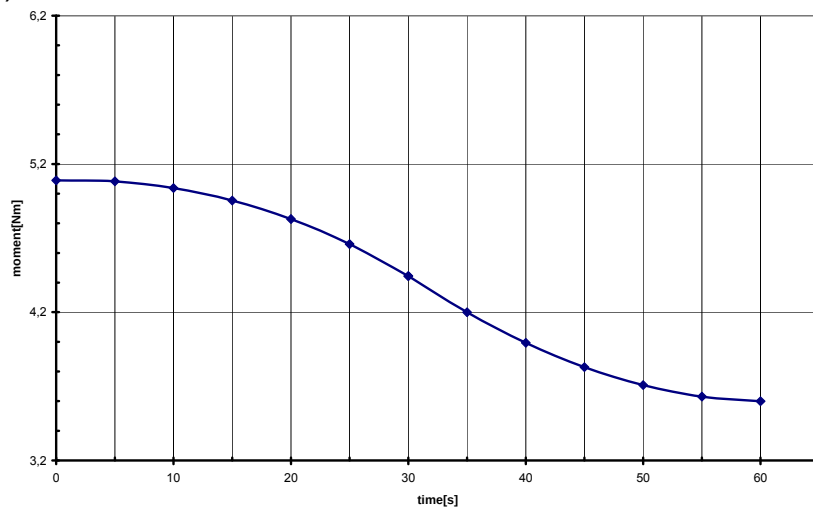


Fig. 13 Required torque for parabolic through collector orientation

The same algorithm is used in case of dish and flat plate collectors. Figure 14, a, b presents the movement function and the required torque for the dish collector and figure 15, a, b for the flat plate collector

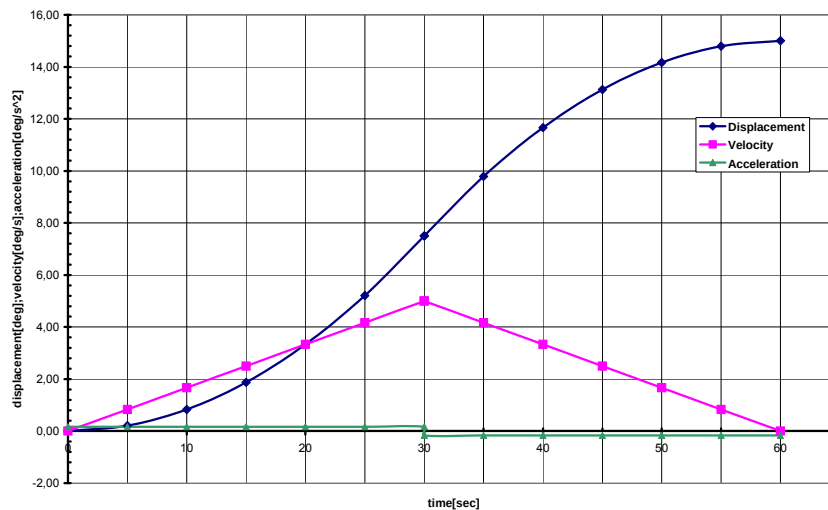


Fig. 14,a Movement function for the dish collector

4. Conclusions

By numerical solving of system (1) for the three collector types are obtained the displacement, velocity and acceleration functions as follows: figure 11 for parabolic through collector, figure 14, a, for dish collector and figure 15, a, for flat plate collector. Analyzing the diagrams, is noticed that the three collector types perform a $15^\circ/\text{hour}$ rotation which proves that the designed tracking system achieves the imposed movement functions and assures the desired placement of the collector along the operating cycle.

The following parameters are obtained from the dynamic analysis:

- For the parabolic through collector, the actuator displacement is 480 mm and the required torque is 5 Nm;
- For the dish collector, the actuator displacement is 535 mm and the required torque is 18,6 Nm;
- For the flat plate collector, the actuator displacement is 600 mm and the required torque is 42,5 Nm.

This model allows the determination of the real behavior of the tracking system for the three collector types

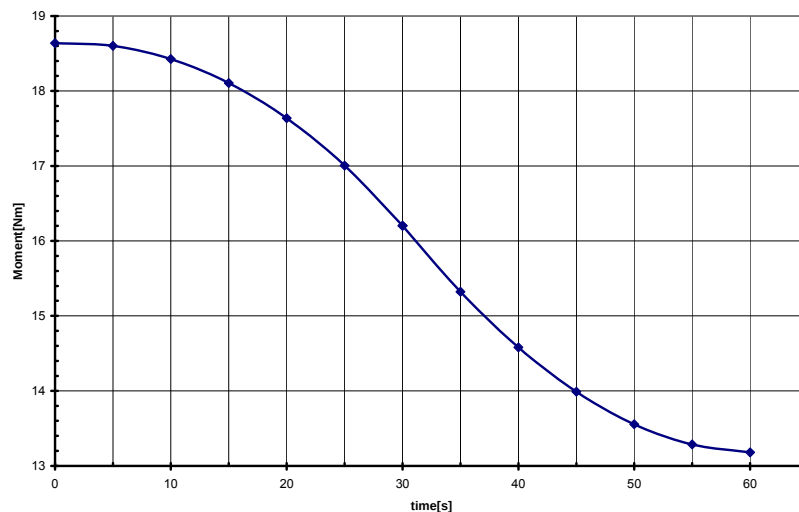


Fig 14,b Required torque for the dish collector

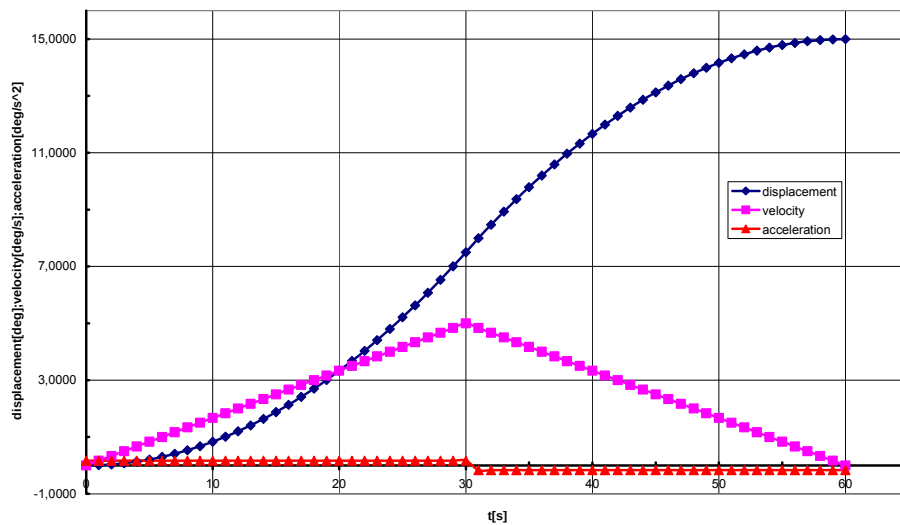


Fig. 15, a Movement function for the flat plate collector

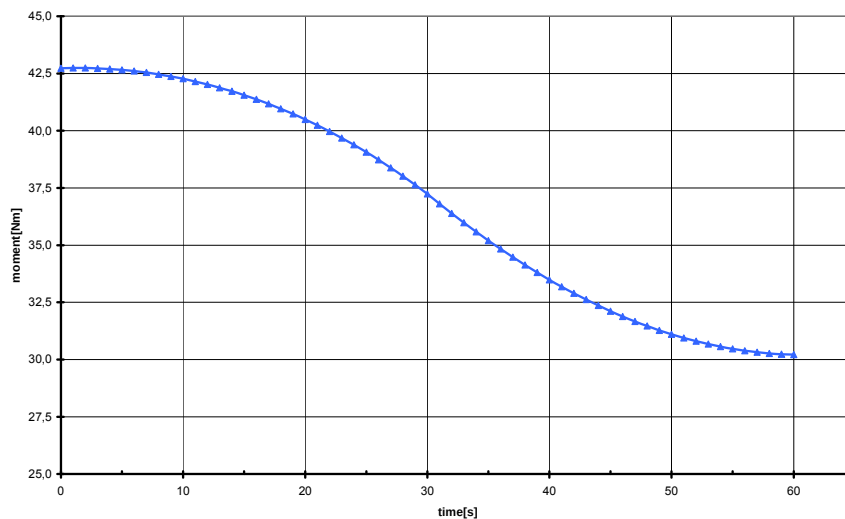


Fig.15, b Required torque for the flat plate collector

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