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ON SOLAR PANEL ORIENTATION

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Abstract: *In the field of solar energy, the majority of researches are focused on the precision of solar panels and mirrors orientation. But, the good working of solar systems is disturbed by the devastating effect of the wind and the dusting of optical surfaces. It should be profitable, in order to increase the efficiency of solar energy capture, to minimize the effect of the two phenomena mentioned below. The wind forces applied to solar panels and their tracking mechanisms are in direct relation with the wind velocity and the continuous surface of the panel. The wind velocity and direction are random facts, but the shape and the continuous surface of the mirrors and panels emerge from human decisions.Therefore to minimize the wind effect it should split the continuous mirror surface into mini-mirrors able to orientate alone. A large continuous mirror could become an area of micro-mirrors with an equivalent energy efficiency but more insensitive to the wind effect.*

Key words: *solar energy, micro-mirror, tracking mechanism, wind effect.*

1. Introduction

Solar panels and solar mirror designed to work in atmosphere, on the ground or on building roof, need to be able to support the dynamic pressure of the wind. This pressure is in relation with the air velocity. During the storm period the wind velocity increase dramatically and cause important damages to solar systems (Fig.1).

Fig.1. *Important solar panel damages caused by wind*

Therefore it is important to protect the solar panels and mirrors against the wind effect. There are two ways of safety:

1. To rotate the panels in a parking angle, that means in horizontal position;
2. To design the panels with discontinuous surfaces in order to decrease the dynamic forces of the wind.

The first construction involves a good meteorological surviving and an automatic system control, able to change at once the panelsô orientation to protect them against the wind. There are a lot of

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causes, such as the terrain configuration and the presence of the gaps between the panelsô rows that modulate the wind forces.

The inclination of the panels and the reverse air current influenced the entire amount of wind forces.

The idea of panel shape redesign could be unacceptable because of the attempt requested. So, it could be used a set of individual cells fixed on a cluster as a wire net on a frame.

The orientation function could be performed by the global rotation of the entire frame (Fig. 2) like a solid state panel. Another option is to fix the frame and to rotate each cell or micro-mirror individually (Fig. 3).

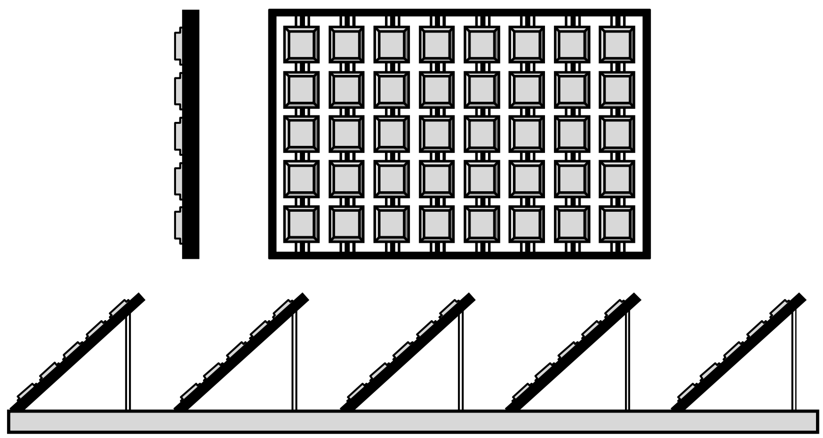

Fig.2. *Solar system with entire panel orientation*

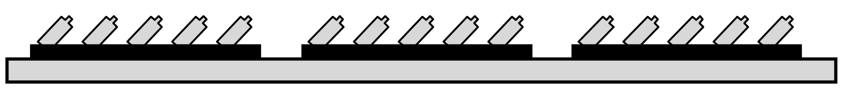

Fig.3. *Solar system with individual cell (mirror) orientation*

The individual cell (mirror) orientation becomes possible if every cell will be suspended on a tracking mechanism and there is one actuator for entire panel, or there develop an individual actuator for each cell. This last case requires a very chip and simple actuator.

2. Micro-mirrors actuators types

A consistent set of acting solutions for micro-mirrors has been develop in the last decade and many of these solutions could be take into account.

Micro-mirrors work at high frequency has a lot of consecrated applications such as:

- laser beam steering;
- optical interferometer;
- optical display;
- biomedical imaging;
- real-time image recognition;
- spectroscopy;
- and so on;

But the acting solutions can be emulated. In spite of the wide variety of applications of micro-mirrors in other fields, they could be used even in the field of solar energy.

Micro-mirrors are acted by several type of micro actuators. The actuators are categorized by driving mechanisms in four ways:

- Thermal (expansion) actuators;

- Piezoelectric actuators;
- Electrostatic actuators;
- Electromagnetic actuators.

2.1. Thermal actuators

Thermal actuators use the Joule heating and they can provide large forces and displacements.

Thermal actuators can work at voltages lower than other micro-actuation mechanisms [1].

2.2. Piezoelectric actuators

The advantages of piezoelectric actuator include a low-voltage high response frequency and great output power [2].

Piezoelectric actuated micro-electro-mechanical systems (MEMS) mirror scanners present low driving voltage, with highly repeatable and reliable results for MEMS applications. Piezoelectric material has the highest energy density as compared to other silicon based actuators, primarily due to their large dielectric strengths [3].

2.3. Electrostatic actuators

Another actuator is scratch-drive actuator. This is a kind of stepping electrostatic actuator with compliant hinges made from poly-dimethyl-siloxane [4].

A self-aligned angular vertical comb-drive (AVC) actuators on-chip assembly using in-plane electro thermal actuators and latching mechanisms is shown in [5].

Electrostatic actuation is often used in many optical MEMS devices, including micro-mirrors and sensors. Electrostatic actuation is considered the most popular actuation method. An electrostatic actuator is preferred, especially for highly integrated mirror arrays, because it consumes low power. Devices can be fabricated within a chip, thereby making integration easy.

The energy density of electrostatic actuators is lower than of piezoelectric, magneto-striction, and electro-thermal actuators [6].

2.4. Electromagnetic actuators

Magnetic sensors have been used for non-destructive evaluation (NDE) of engineering structures. Therefore non-destructive evaluation methods need high sensitive sensors and in the same time small enough to resolve the details of magnetic field distribution [7].

The flexible fluidic actuators contain an elastic deformable element and are driven by a fluid.

A particular design will direct its volumetric expansion in such a way that the overall elastic deformation of the actuator describes a desired motion. These deformations are similar to the deformations that are produced by loading an elastic material at one end and fixing it at the other one [8].

3. Panel solutions to avoid overshadowing

The tracking function of solar panel changes its axial position and shadows other panels. If some panels are put together it is necessary to prevent the overshadowing of the neighbours.

A configure draft of panels (with symmetrical position of panel axis) is shown in Fig.4 and another one (with asymmetrical position of panel axis) in Fig.5.

Both of them are consist of three panels able to be rotated by a linkage mechanism.

The difference between them resides

from the axis position of the each panel.

The maximum rotation angle ű$_0$, can be calculated from triangle ABC from (Fig.4) and it is shown in Equation (1).

$$\varphi_0 \le \arccos \frac{b}{b+c} \qquad (1)$$

If it is introduced a position factor $k = \frac{c}{b}$ and $k \in [0 \div 0.5]$ the maximum value of angle ű$_0$ from Equation (1) becomes Equation (2).

$$\varphi_0 \le \arccos \frac{1}{1+k} \qquad (2)$$

The maximum rotation angle ű$_1$, can be calculated in a similar method from the same triangle ABC from (Fig.5) and it is shown in Equation (3).

$$\varphi_1 \le \arccos \frac{b}{b+2c} \qquad (3)$$

If it is introduced the same position factor $k = \frac{c}{b}$ and $k \in [0 \div 0.5]$ the maximum value of angle ű$_1$ comes from Equation (4).

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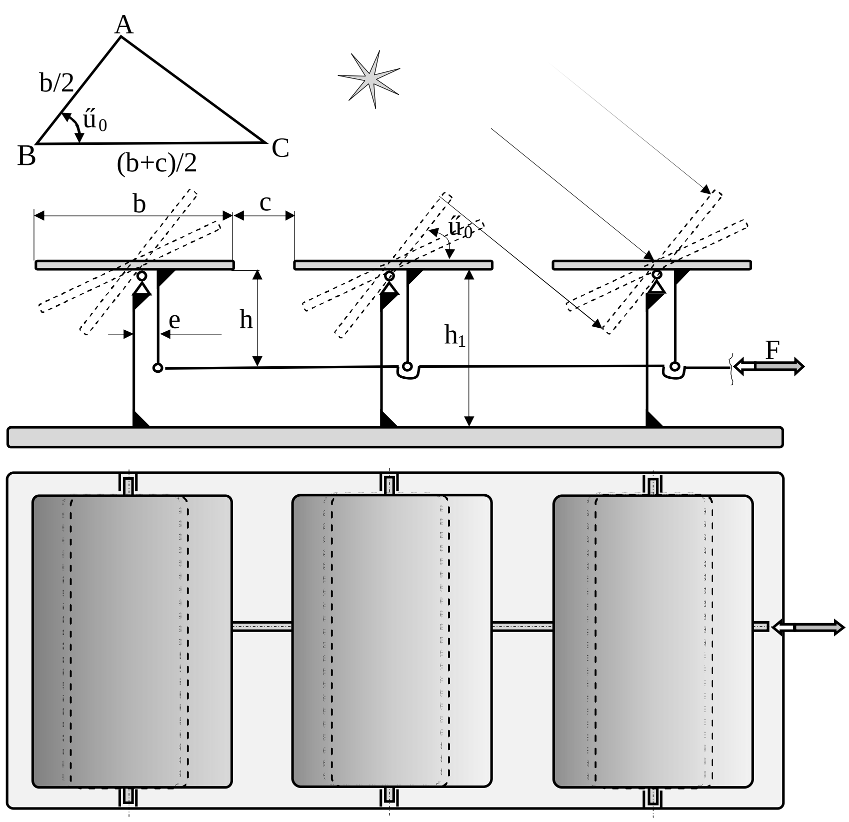

Fig.4. *Frame with three symmetrical panel axes*

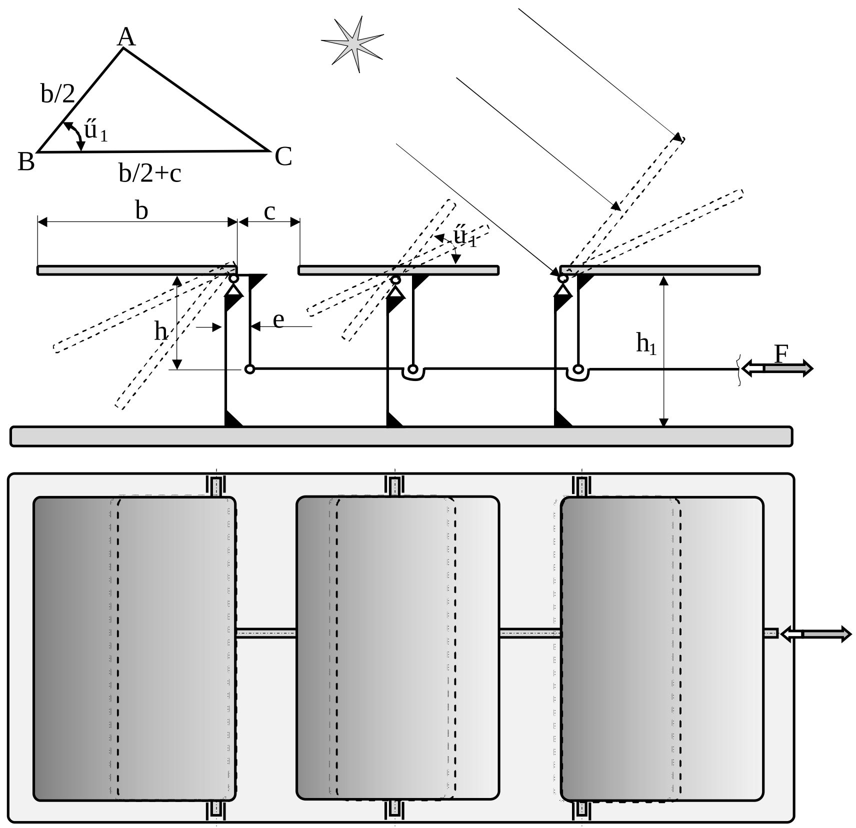

Fig.5. *Frame with three asymmetrical panel axes*

$$\varphi_0 \le \arccos\frac{1}{1+2k} \qquad (4)$$

The maximum rotation angles limit by the overshadowing phenomenon is shown in Fig.6.

It is observed that the frame with symmetrical panel axis (Fig.4) performs a rotation angle $ű_0$ lower then frame with asymmetrical panel axis $ű_1$ (Fig.5). When the position factor rises it causes the increase of the rotation angle $ű_1$, respectively $ű_1$.

But the angle $ű_1$ increases faster than angle $ű_0$. Therefore the frame in Fig.5 is better than the similar in Fig.4.

In order to do another evaluation of the two frames the diagram in Fig.7 shows the time gain in minutes by the cumulated two increasing periods, in the morning and in the evening. It observes that position factor $k \in [0.2 \div 0.25]$ causes the highest gain of time, about 86 ï 90 min/day.

So the full lighting period of solar panels is given by Equation (5).

$$T = \frac{2\varphi_{\max}}{15^{\circ}}[h] \qquad (5)$$

The optimum position factor could be, $k = 0.25$ and for this value the period of full solar lighting becomes:

T_0=4h54min ï symmetrical panel axis;

T_1=6h25min ï asymmetrical panel axis.

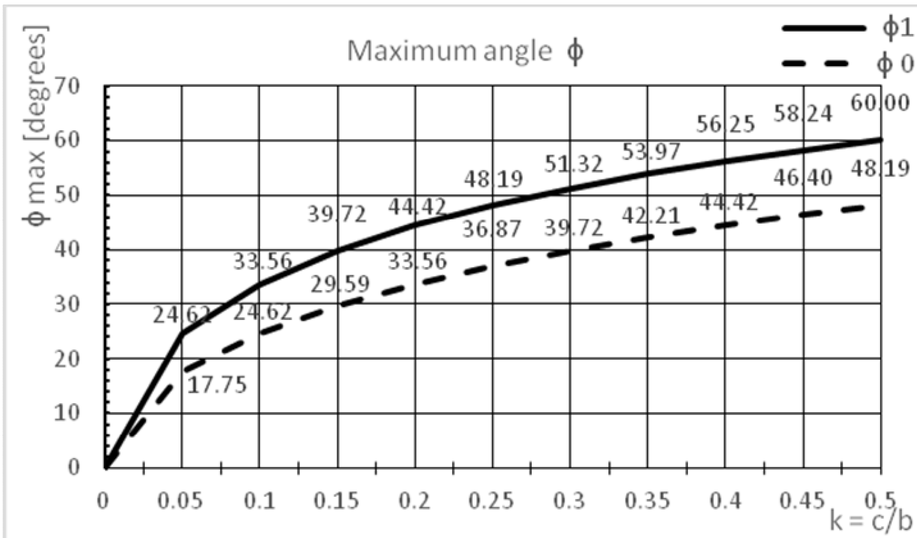

Fig.6. *Rotation angles φ_0 and φ_1*

The meaning of *full lighting period*, in this paper, is the time period, in a sunny day, when the sunlight strikes the panels surfaces perpendicularly and the panels do not shading each other. Obviously the panels work the entire day, but the efficiency decreases in the morning and in the evening periods, when the shading appears.

The values of the full time periods, for the two cases described above, are shown in Table 1.

The value of *k* factor should not overhead the value 0.3 because the time gain gradient decrease dramatically, below 2.26 min, as it is shown in Fig.7. In the same time, the increase of *k* factor causes the extension of the assembly dimensions.

The length of bar h should be larger than the value calculated with Eq. (6).

$$h \geq (b - e)\,tg\varphi \qquad (6)$$

Table 1 *Values of time period gain and full lighting period*

k	φ_0 [º]	φ_1[º]	Angular gain $2(\varphi_1-\varphi_0)$	Time gain [min]	Full lighting period T_0 [h/day]	Full lighting period T_1 [h/day]
0	0	0	0	0	0	0
0.05	17.75	24.62	13.73	54.94	2.37	3.28
0.1	24.62	33.56	17.87	71.50	3.28	4.47
0.15	29.59	39.72	20.25	80.99	3.95	5.30
0.2	33.56	44.42	21.72	86.86	4.47	5.92
0.25	36.87	48.19	22.64	90.56	4.92	6.43
0.3	39.72	51.32	23.21	92.82	5.30	6.84
0.35	42.21	53.97	23.53	94.10	5.63	7.20
0.4	44.42	56.25	23.67	94.69	5.92	7.50
0.45	46.40	58.24	23.69	94.77	6.19	7.77
0.5	48.19	60.00	23.62	94.48	6.43	8.00

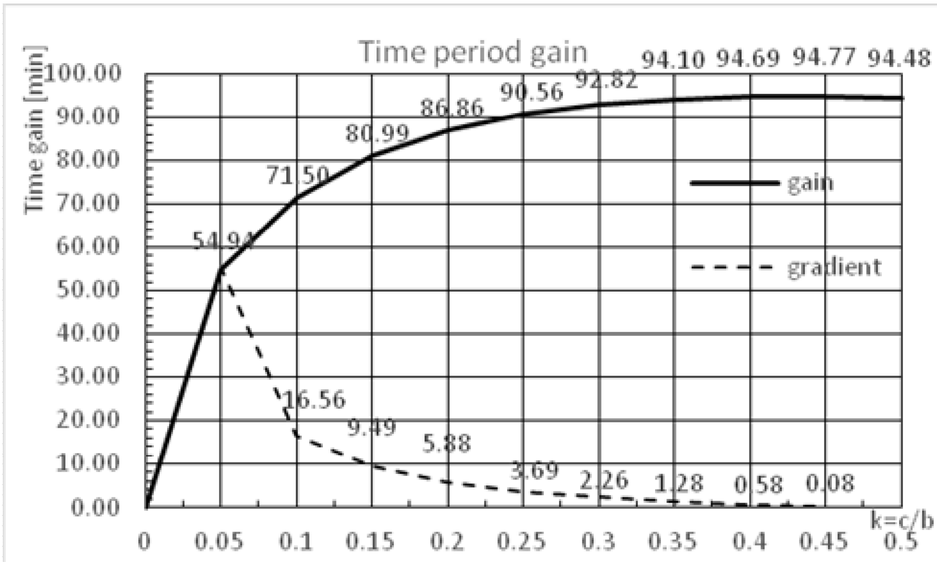

Fig.7. *Time period gain*

The panel orientation with four bar linkage (Fig.8) offer large movement amplitude but it is quit complicate and expansive.

The four bar linkages for the application of solar components tracking should perform extreme position that imply to cross through some dead points.

To act a mechanism with dead points becomes difficult and it is a solid argue to give up the solution.

In spite of this, the linkage with a flexible element (Fig.9) should be chipper and also attractive as financial point of view.

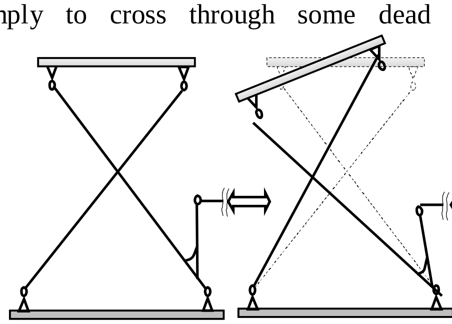

Fig.8. *Four bar linkage*

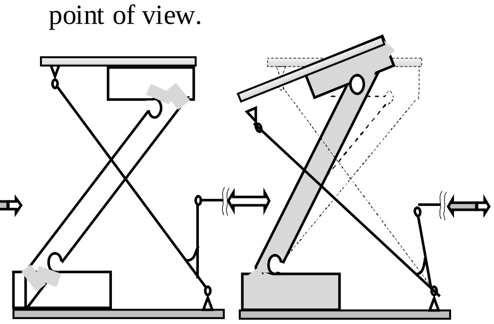

Fig.9. *Flexible element linkage*

4. Conclusions

In order to actuate these mechanisms it can be used electrostatic, electro-magnetic, piezoelectric, thermal and fluidic actuators. The electrostatic actuation can perform the lowest act force, but if the components are small enough to be used.

Two configure drafts of panels frames were studied, one of them with symme-trical position of panel axis and the other one with asymmetrical position of panel axis). Both of them are consist of three panels able to be rotated by a linkage mechanism. The difference between them has been evaluated and it has been revealed the best one. This analyze must be continued over the other mechanisms.

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