TECHNICAL SCIENCES

A NEW DIRECTION OF SOLAR TRACKERS AND PERSPECTIVES OF IMPLEMENTING THEM TO INCREASE EFFICIENCY

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ABSTRACT
The article assesses the efficiency of using alternative energy sources, in particular - solar batteries. The work on the tracker design was executed. In the design process, modern graphic and computational complexes were used for successful mathematical modeling of the designed object which was developed on the parameters of a specific climatic zone.

Keywords: Solar energy, dual axis tracker, static and dynamic strength, resource.

1. Target Setting

Alternative energy sources, such as wind energy and solar energy, are very relevant today. Solar energy is notable for the availability of applications to provide population with electricity while solving economic issues.

The use of solar energy is provided by solar panels. Modern technologies make it possible to improve them in order to ensure greater efficiency of the power generating device. The efficiency of solar panels is determined by the amount of perceived energy of the sun, and is provided by the location of the working surfaces of the panels perpendicular to the direction of solar radiation.

Considering the peculiarities of the trajectory of the daily sun path, the optimal location of the fixed solar panel is having an azimuth angle of 150°. Practice shows that the solar module fixed in this position loses 75% of the production of the maximum possible amount of electricity in the evening and in the morning. The sun has an additional seasonal path between the North and the South – it is about 46° for a year. When orienting the panel to the midpoint of the average annual trajectory of the sun path in the North-South direction, the output loss will be 8.3-9% from the maximum possible amount. [1]

2. Problem Setting

Mobile devices that provide tracking the position of the sun from sunrise to sunset become an alternative to fixed solar panels. Trackers are devices for positioning the working structure for electric panels to take full advantage of the solar energy. Tracking systems that convert solar energy into electricity are 30% more efficient than fixed solar panels.

Figure 1 visualizes the daily change of electricity generation on fixed structures with fixed solar panel mounting and during the transition to the mounting of working panels on mobile tracking systems. [2]

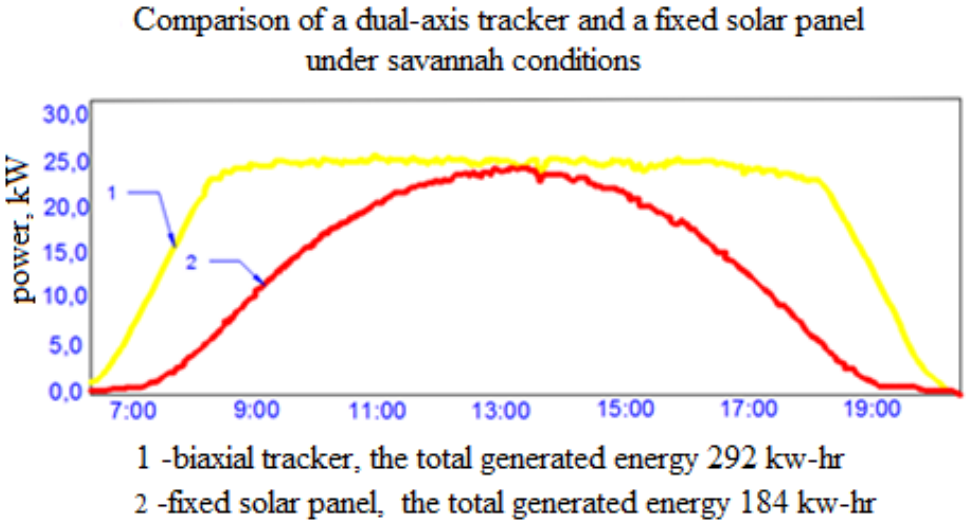

Figure 1 - The Graph of daily power generation of fixed and mobile tracking devices

To track the position of the sun the mechanism of two-plane rotation of the working panel is used.

3. Purpose of the Research

The object of the design research and calculated analysis presented in this paper is a dual-axis tracker.

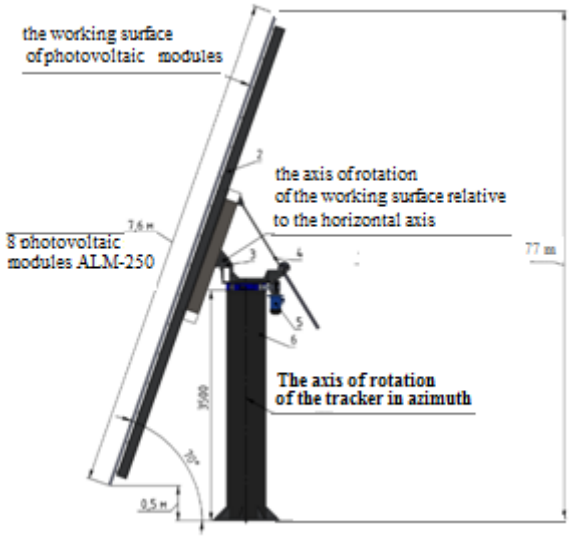

Figure 2 - Side view of the tracker

The tracker is performed on a biaxial scheme. Photovoltaic modules are located on the bearing frame.

The main components of the tracker are: - a bearing frame; - an intermediate frame; - a linear screw drive; - a rotary mechanism (RM); - a stand.

The tracker load analysis is performed with the wind speed being 20 m/s.

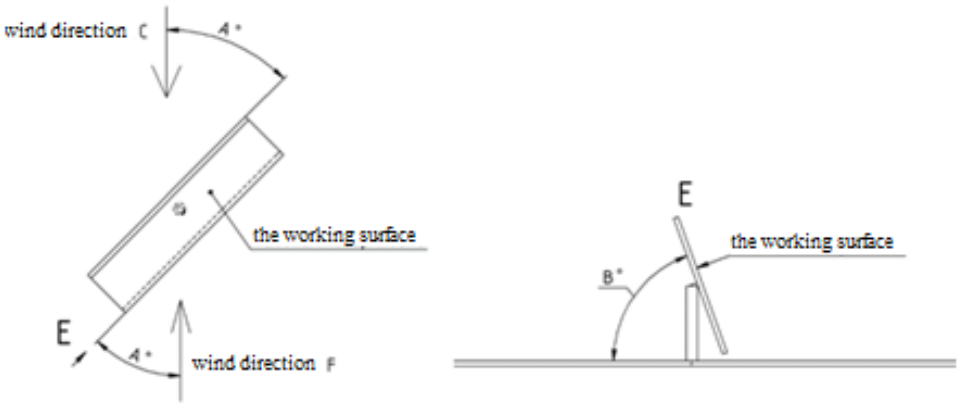

Figure 3 – The scheme of the analytic model

4. Progress and Results of the Research

While designing, the distributed pressure on the solar panel of the tracker from the wind load (according to the selected climatic zone) was calculated.

Figure 4 shows the result of this calculation.

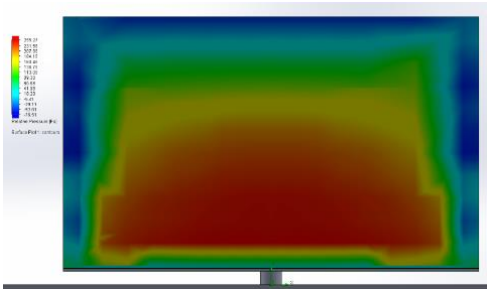

Figure 4 - The pressure distribution over the working surface

As a result of the tracker load calculation with the wind of 20 m/s, the maximum values are given in table 1.

Table 1

Maximum values of tracker loads.

F	M_t	M_v
24,043 N	17,489 N·m	24,108 N·m

Mt is the torque relative to the horizontal rotation axis of the tracker bearing structure (N·m).

Mv is the torque relative to the vertical rotation axis of the tracker bearing structure (N·m).

F is the force exerted upon the tracker (N).

The developed design of the tracker is subjected to numerical analysis to determine the stress-strain state affected by the calculated loads. [3], [4].

When calculating the static strength the loads exerted on the part are quasi-fixed. The static strength includes the determination of reserves as for long-term and low-cycle fatigue.

It should be noted that the software package based on ANSYS, a universal software system of finite element analysis (FEM), requires adaptation to specific tasks and identification with calculation conditions and experimental results. It is important to identify it with experiment for problems in which friction and nonlinear effects are present.

Solid 3-D models with fixed materials used in the tracker design were imported into ANSYS design complex. The panel itself, consisting of standard blocks, is presented in the model by a virtual material satisfying the condition of preserving the mass of blocks fixed to the structure.

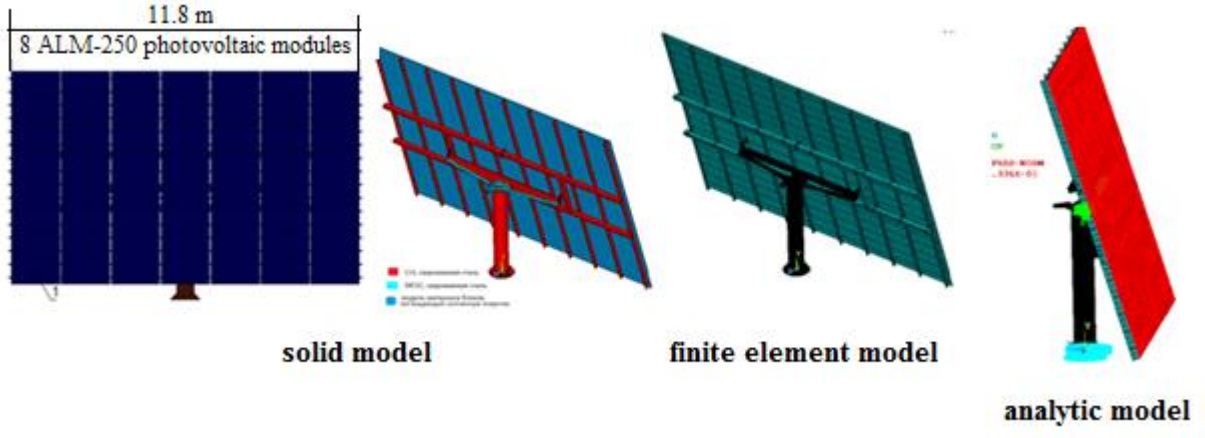

Figure 5 - Stepwise models of mathematical modeling

The main task of designing and ensuring reliable operation of the structure (Tracker) is to accurately determine the strain stress state of the main constituent parts.

The results of calculations for determining the strain stress state depend on the quality of the finite element grid, on the size of the element in the critical zone.

A finite element model of the Tracker has been created (Fig.6). A series of calculations has been made to determine the size of the elements for a stable result.

It has been accepted as the boundary conditions to fix the stand on the platform along all directions, modeling the fixing of the stand with elements of the fastener to the platform (Fig.6). The maximum pressure σ_{max} = 3.36e7 MPa is put to the load applied on the panel surface.

As a result of the calculation of the strain stress state indicators of the tracker structure have been obtained.

The value of displacing structural elements exerted by the applied maximum pressure from the influence of the wind on the working panel is shown in Fig. 6.

The upper part of the panel is moved to the greatest possible extent. The maximum displacement is 16.6 mm.

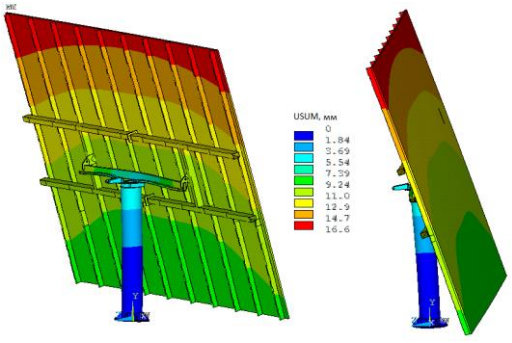

Figure 6–Distribution of total displacements of the Tracker structure

3-D strain stress state, the components of which are determined by calculations, is realized in zones of stress concentration. [5]

Huber Mises condition (1) can be taken as a criterion of structural strength in places of stress concentration:

$$\sigma_{экв} = \left\{ \frac{1}{2}\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6\left(\sigma_{xy}^2 + \sigma_{yz}^2 + \sigma_{xz}^2\right)\right]\right\}^{\frac{1}{2}}, \quad (1)$$

where σ_x, σ_y, σ_z are components of the stress state along the axes of a 3-D system.

$\boldsymbol{\sigma_{экв}}$ – equivalent stresses in the considered zone.

The maximum equivalent stresses on the components of the structure are shown in Fig.7.

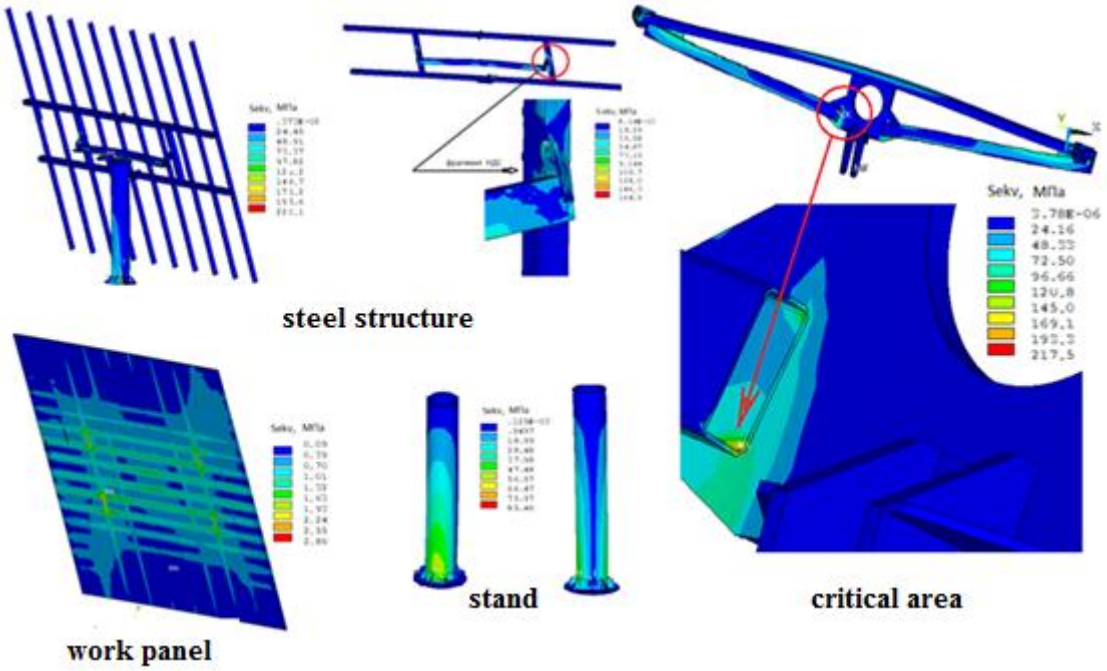

Figure 7 –Distribution of Equivalent stresses in structural elements

The maximum stresses in the structural panel have low values and are located at the mounting points of the panel on the frame.

The stress level in the bearing welded frame is 164.5 MPa, which is sufficient to provide the claimed structural life.

The critical zone is the zone that determines the structural life. The maximum stresses of 217.5 MPa are in the inner radius of the structure in the zone welded to the plane of the rotary mechanism.

The structure is in an elastic stress-strain state, residual deformations are excluded because $\sigma_{max} < \sigma_T =$ 345 MPa.

Low-cycle fatigue reserves are determined for parts where equivalent stresses exceed the fatigue limit.

For 09G2S steel σ_{-1}= 235 MPa> 217.5 MPa. It appears from this that the margin of safety for low-cycle fatigue is large enough.

Dynamic strength includes the calculation of natural frequencies and vibration forms.

The modal analysis of the Tracker structure has been performed. The first five forms of free vibrations and their frequencies have been determined. Figure 8 presents the results of the modal analysis.

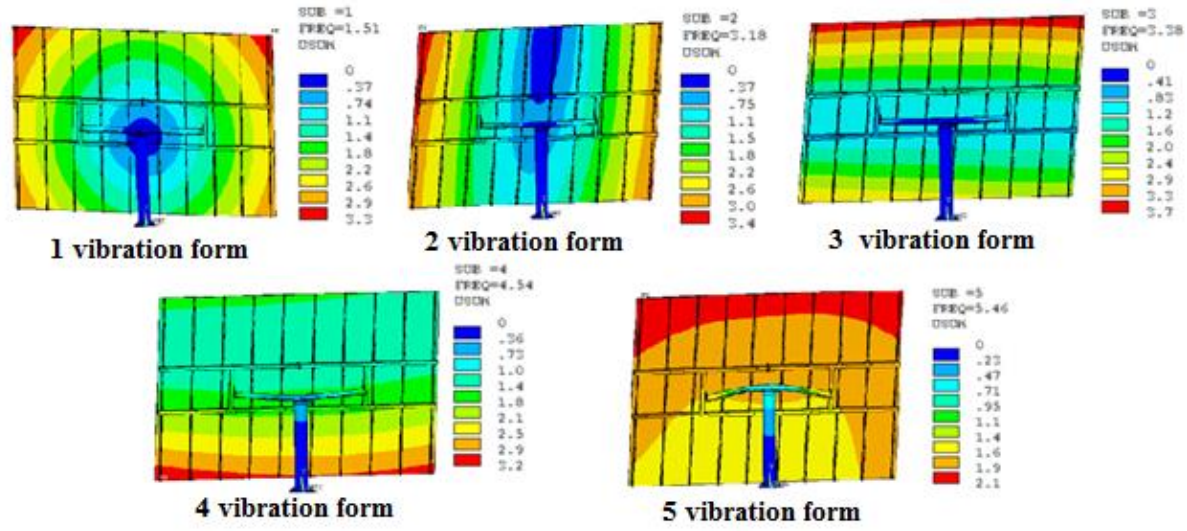

Figure 8 – Five forms of free vibrations of the structure

The results of the modal analysis show that the first five forms of free vibrations have a low frequency, namely:

f1= 1.51 Hz; f2= 3.18 Hz; f3= 3.38 Hz; f4= 4.54 Hz; f5= 5.46 Hz.

Natural frequencies are calculated to subsequently determine resonances when the natural frequency coincides with the forced frequency.

In our case, forced fluctuations can be provoked by natural phenomena, gusts of wind. But the level of free vibration frequencies is very low, and, therefore, in case of the resonance one should not expect high alternating stresses.

When completing numerical researches, mathematical modeling of the tracker structure tests, we moved on to the next stage of creating a thorough technique. We are at the stage of creatively developing a full-scale model for a series of tests. It is planned to prepare an article for publication according to the results of the planned activities.

5. Conclusions

The analysis of the conducted research shows:

- The developed design of the Tracker has sufficient reserves of long-term strength and margin of low-cycle fatigue.

- The modal analysis has showed low frequencies of the first five forms of free vibrations, which denies the presence of dangerous values of alternating stresses at resonance.

Since the ecological cleanness of the Earth is very relevant, solar energy is an alternative to energy from non-renewable fuel resources and a decisive factor in protecting the climate from global warming.

Maintenance of power supply devices based on solar energy is quite low-cost and includes periodic cleaning of solar cells [7].

For the population, the transition to solar panels as a source of energy is considerably cost-effective for the household.

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