FEM ANALYSIS OF THE BEVEL GEAR HOUSING OF AN AZIMUTHAL TRACKED PV PLATFORM

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Abstract: The overall cost and reliability of the tracking system are influenced by the dimensioning results of the mechanical transmission and of the mechanical structure itself. The dimensions of the tracking system structure are directly depending on the loads of the PV platform. Subjecting a particularly azimuthal photovoltaic platform to various wind loads, the mechanical transmission housing of the altitudinal axis was analyzed using FEM.

1. INTRODUCTION

Of all renewable energy resources (solar, wind, hydro and biomass), solar energy can provide twice as much the amount of energy obtained from fossil fuels [3], therefore solar energy conversion systems are used in a wide range of domestic and industrial applications.

When climatological conditions are propitious, the theoretical potential of solar energy is significant, but only a small fraction of this quantity is accessible from technical point of view. PV panels' conversion rate does not exceed 19% of solar energy theoretical potential, so the aim is to optimize the electric conversion process of solar energy.

Maximizing the quantity of solar radiation received by the conversion systems using tracking systems, represents an economic and technological method accessible in order to optimize the photovoltaic conversion process.

The energetic performance of dual axis tracking systems is significant compared to the energetic performance of single axis tracking systems [4], thus leading to an increase interest in researching and innovating [1, 7], and further on their implementation [2, 8].

Being the most known tracking systems, their constructive solutions are varied. Their specific movements are performed using various mechanical transmissions, having as components linear actuators of screw-nut type, rotational actuators of worm gear type, chain drive systems or various combinations of these.

The accuracy of the tracking and the efficiency of the transmission of an azimuthal tracking system can be improved using straight bevel gears. Therefore these types of gears are increasingly used in the transmissions of the azimuthal tracking systems.

Dimensioning of the consisting mechanical transmissions and of the mechanical structure itself is an important stage in the embodiment design of a tracking system for PV platforms. The dimensioning results influence the reliability but also the costs of the tracking system.

The dimensions of structure and transmission of the tracking system are directly depending on the loads of the PV platform. From all the loads coming from weight, wind etc. the main one is the wind load [6].

Subjecting a particularly azimuthal photovoltaic platform to various wind loads, the mechanical transmission housing of the straight bevel gear used to perform the altitudinal movement was analyzed by using the finite element method.

2. AZIMUTHAL TRACKING SYSTEM DESCRIPTION

The tracking system analyzed in this paper is included in the azimuthal tracking systems category. These types of tracking systems are biaxial systems that set the PV platforms after two axes (z and x). By combining the altitudinal motion α, performed around horizontal axis and the azimuthal motion, performed around the vertical axis z, any position of the sun on sky can be determined (fig.1).

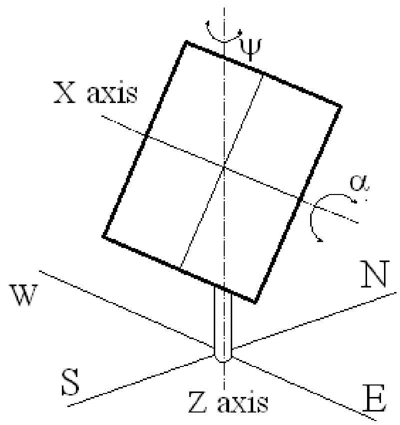
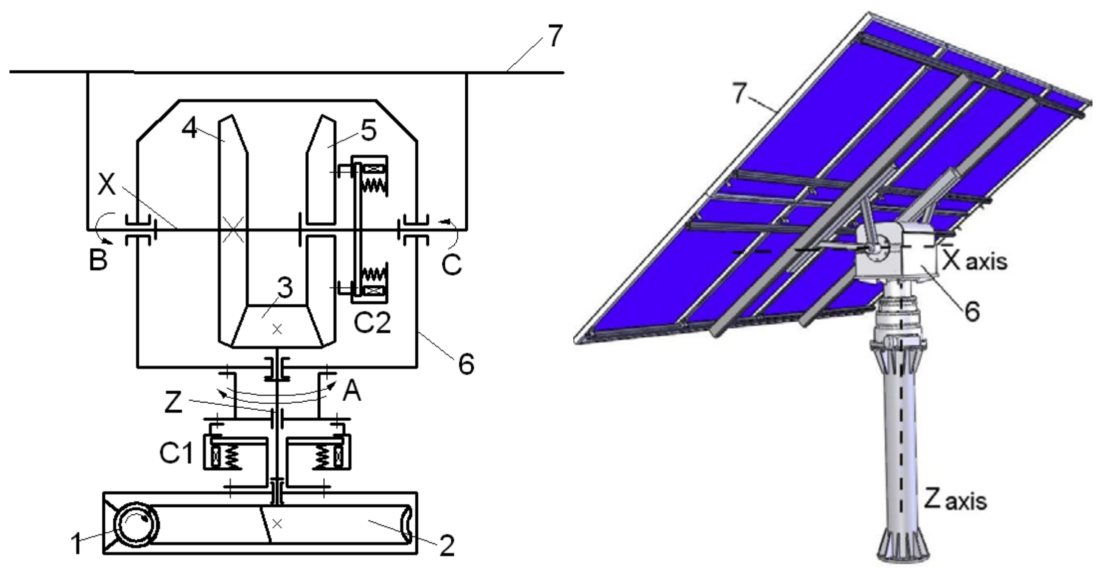


Fig.1. Rotation axes of the azimuthal tracking system



a ***b***

Fig.2. Azimuthal tracking system (a – structural scheme, b – assemble view)

The component parts of the tracking system presented in the structural scheme in figure 2 are: 1 – worm drive, 2 – worm wheel, 3 – bevel pinion, 4,5 – bevel wheels, C1, C2 – brakes, 6 – bevel gear housing and 7 – PV platform. The flow motion is transmitted from the motor shaft through the worm gear 1-2 to the bevel pinion 3 and following to the bevel wheel 5.

Engaging and disengaging C1 and C2 brakes allow the system to perform the altitudinal and azimuthal motion.

The platform orientation is achieved using two types of transmission gears. Azimuthal motion, performed around the vertical axis z using a slew drive, determines the platform to follow the East – West movement of the Sun.

The seasonally motion of the Sun is followed by the platform through the straight bevel gear transmission on the horizontal axes of the system, presented in Figure 3. Engaging C2 brake determines the subassembly consisted of elements 3, 4, 5, 6 and 7 to move together as one part in order to perform the azimuthal movement.

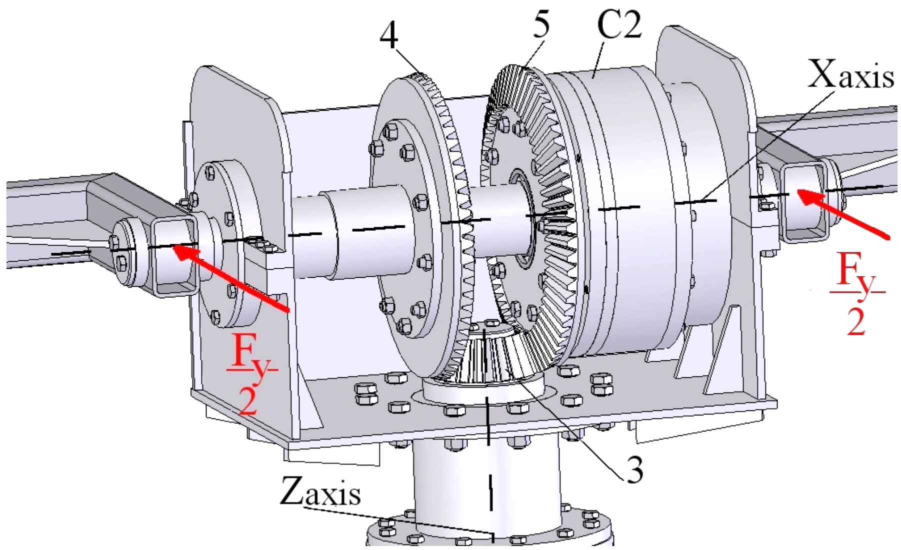


Fig.3. Altitudinal axis of the tracking system

3. WIND ACTION ON PV PLATFORM

Due to the constructive characteristics of the PV platforms, such as: large surfaces exposed to wind action, their height above the ground level and their orientation to the wind direction, they are subjected to high mechanical forces.

The air is moving around and on the surface of PV platforms produces two types of forces: pressure forces normal to the surface and friction forces along surface, resulted from air friction with the panel surface.

Wind generates high aerodynamic forces, influenced by the wind speed, gust effect, air density, platform orientation to the air flow direction, shape and size of the platform and the topographical characteristics of the implementation zone. Therefore, the problem occurred is to identify, design and optimize the constructive parameters of the PV platforms, in order to withstand to wind loads.

To analyze the bevel gear housing of the altitudinal axes, had been considered three load cases of the azimuthal tracking system, as presented in table 1.

Wind action on the PV platform was established by determining the force produced on the platform surface using pressure coefficients:

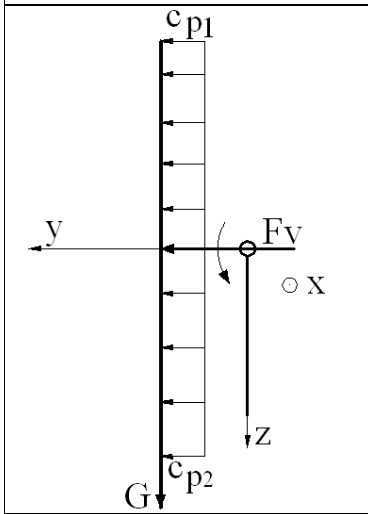
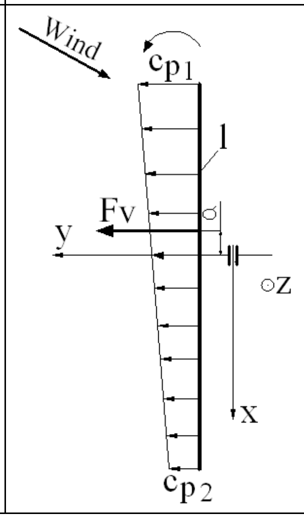
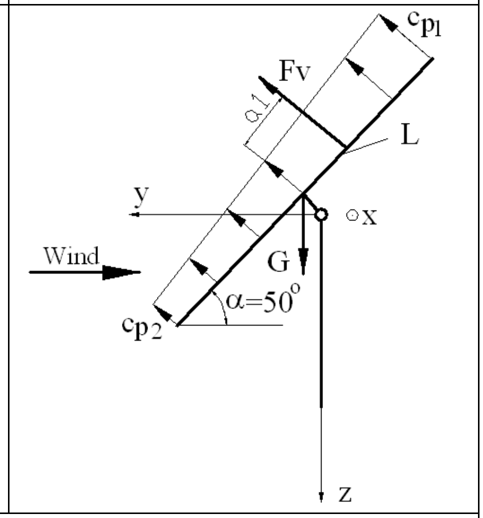
$$F_v = \frac{1}{2}\rho v^2 c_p S \qquad (1)$$

where ρ represents the air density; v – wind speed; c_p – pressure coefficient; S – surface area of wind action.

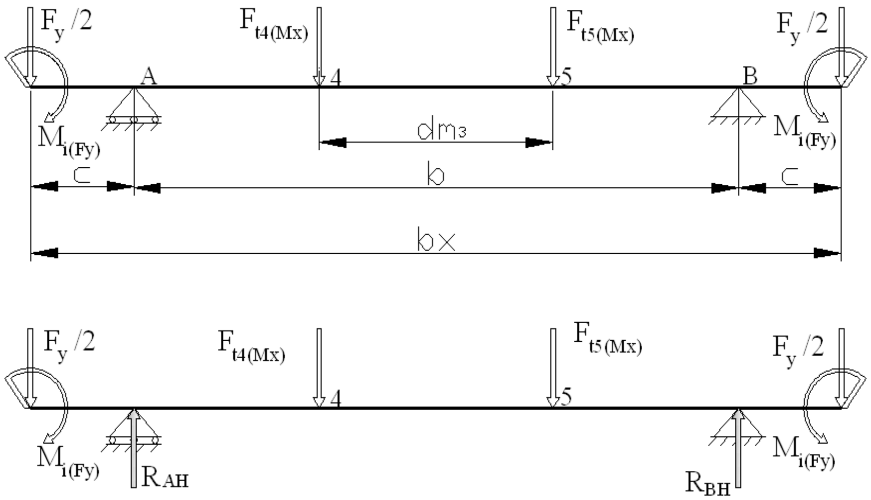
Turbulent air flow around and on PV panels surface determines the appearance of complex pressure distribution, which leads to aerodynamic forces non uniform in frequency and intensity. These forces can cause vibrations and high tensions to the mechanical structures.

For each case were determined the forces on each axes of the system (x, y and z) and according to the pressure distribution generated on the platform surface by wind action, the moments were determined.

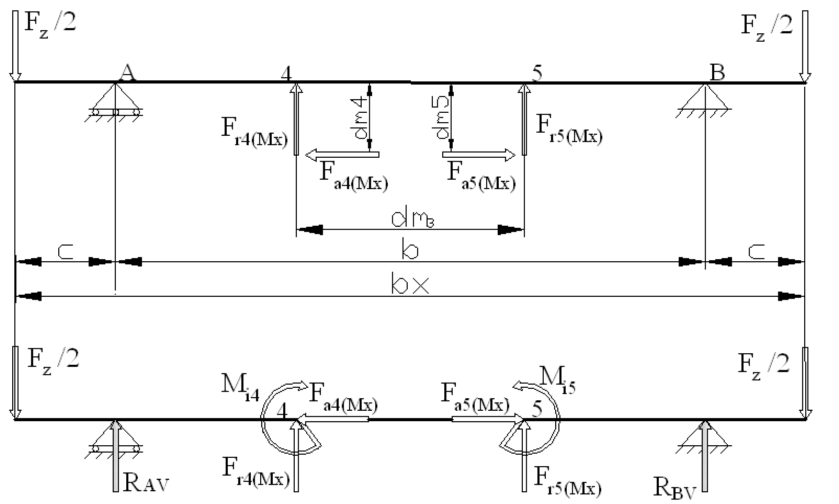
Table 1. Loads cases

Cases			
a		b	c
			
Input data			
L	3320	3320	3320
l	3840	3840	3840
c_{p1}	1.2	1.6	1.6
c_{p2}	1.2	0.8	0.8
a	–	l/18	–
a_1	–	–	L/18
F_v	2152	2152	2152
Forces [N]			
F_x	–	–	–
F_y	2152	2152	1383
F_z	4000	4000	2617
Moment [Nmm]			
M_x	1284000	1284000	1222146
M_y	–	–	–
M_z	–	458957	–

Altitudinal shaft was loaded both in horizontal and vertical planes, determining this way the two bearing reactions. As an example, in figure 4 is presented the altitudinal shaft loading in the first case, both in horizontal and vertical planes. In table 2 are presented the values of the bearing reactions obtained for each case in both planes.



a



b

Fig.4 Altitudinal shaft load in case a
a –horizontal plane; b – vertical plane

Table 2. Bearing reactions

Cases			
a		b	c
Plane [H]			
R_{AH}	8923	-7016	8160
R_{BH}	8923	-6526	8160
Plane [V]			
R_{AV}	1130	807	480
R_{BV}	1130	807	480
Total reactions			
R_A	8994	7062	8174
R_B	8994	6576	8174

4. THE ANALYSIS OF THE BEVEL GEAR HOUSING USING FEM

The finite element analyses of bevel gear housing aims to establish the equivalent stresses that arise in the walls of the housing. It was considered that the housing assembly is embedded on the bearing housing in the right of the clamping screws, where the restrictions were applied.

The forces were applied, as a distributed load, in the right of ball bearings. The values of the forces are equal to the values of bearing reactions forces, corresponding to the load cases presented in Table 2. Were analyzed all three load cases, the situation shown in figure 5 and figure 6 being the most stressed cases.

Considering the thickness of the plates used in bevel gear housing construction, two situations were analyzed: in the first situation, presented in figure 5, the plates thickness was considered to be 8 mm and FEM analysis revealed a maximum stress of 165 MPa, higher than the allowable stress of 150 MPa; in the second situation the thickness of the plates was increased to 10 mm (see Figure 6), as such FEM analysis conducting to a maximum stress of 124 MPa, lower than the allowable stress.

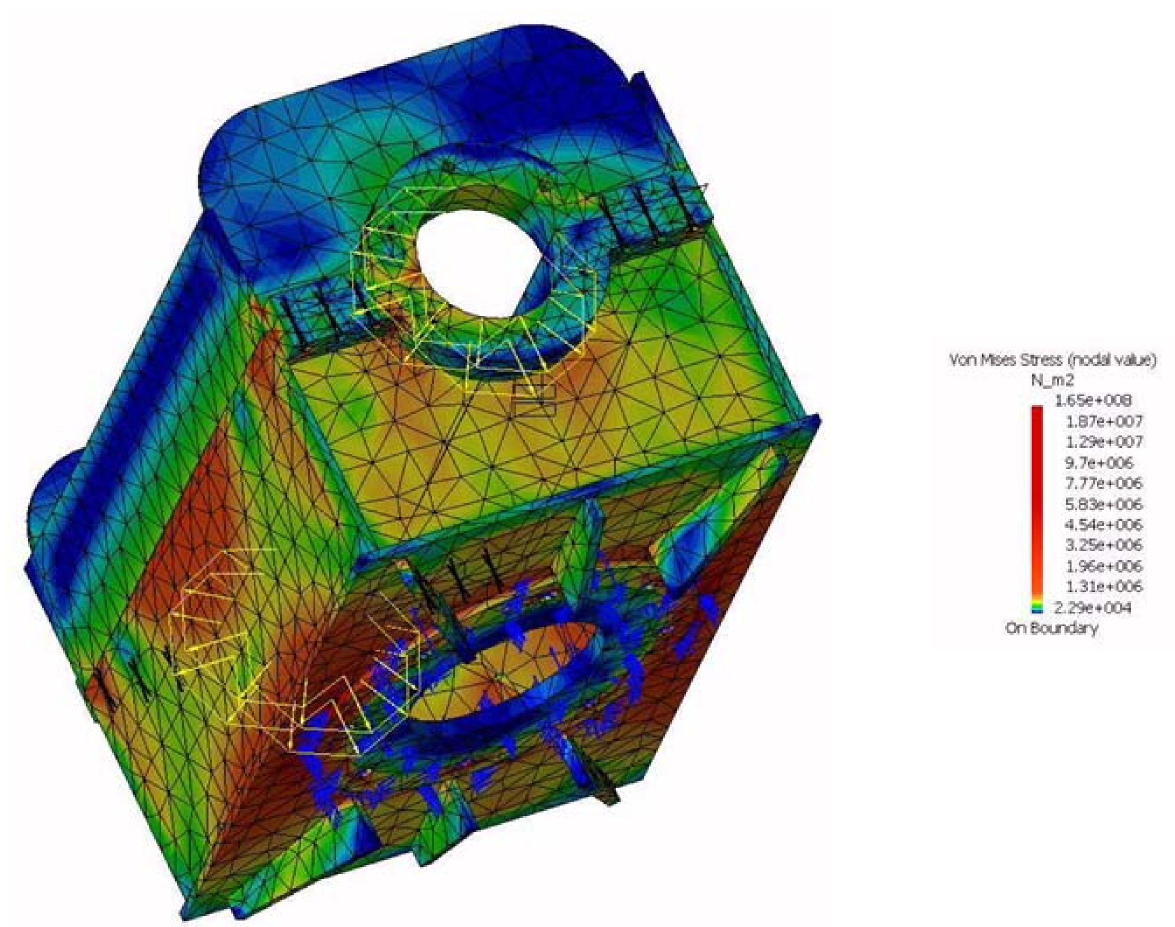


Fig. 5.Von Mises equivalent stresses, for base plate thickness of 8 mm

In figure 7 are presented the deformations obtained for load case a (see table 1 and 2). For a base plate thickness of 10 mm, the deformation obtained of 0.362 mm is situated within acceptable limits of such construction, compared to a deformation of 0.494 mm obtained for a base plate thickness of 8 mm. This deformation occurs at the middle of the housing length in the separation plane between housings.

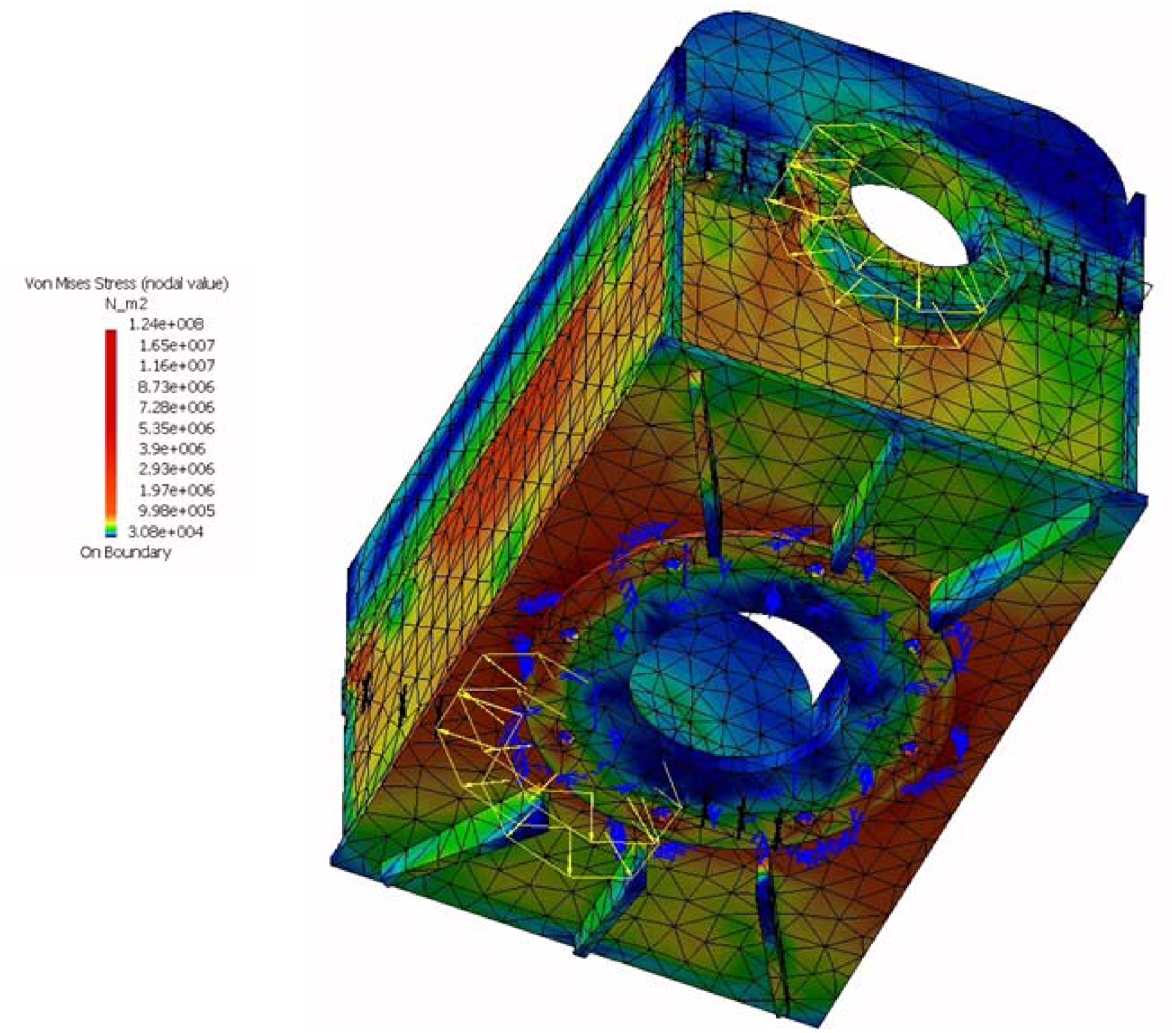


Fig.6. Von Mises equivalent stresses

5. CONCLUSIONS

The quantity of electric energy obtained by photovoltaic modules can be increased by increasing the conversion area, therefore by using biaxial azimuthal tracked platforms. An increased tracking accuracy and efficiency requires the use of high performance gears, such as cylindrical or bevel gears.

Therefore, the design and construction of the mechanical transmissions require special attention to wind loads that influence the size and durability of the tracking system.

Using finite element analyses on mechanical system of these types of structures allows a precise determination of equivalent stresses arising from wind loads, thereby determining the most sensitive points in terms of system resistance.

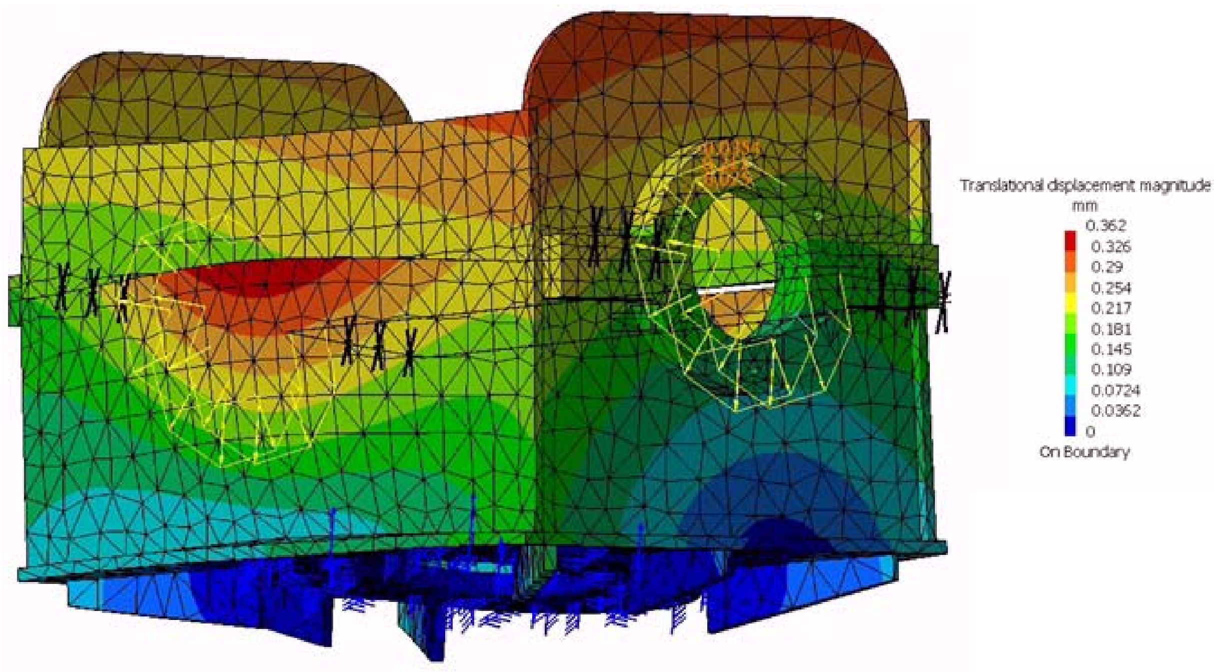


Fig. 6. Deformations

Constructive measures can be taken in order to avoid deterioration of the mechanical system of a PV platform, if the results of finite element analyses are considered.

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