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DESIGN AND MANUFACTURING OF A DUAL-AXIS SOLAR TRACKER STRUCTURE

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Abstract. *The aim of this study is to design and manufacture a dual-axis solar tracker structure with low costs and a simple structure; furthermore, this study focuses on the safety of the proposed structure when hit with a typhoon with a magnitude of 17 or an earthquake with a magnitude of 5. First, we use Solidworks to confirm the structure's operation interference; next, we use MSC-Marc finite element analysis software to perform static structure analysis; finally, we manufacture and assemble the proposed structure. The proposed structure is processed and manufactured according to the currently available and most frequently used specifications, which can reduce the cost for customizing special components, thus achieving cost control. The proposed structure is designed to be easily assembled/disassembled, and its total height is about 1.6 m. The result of the finite element analysis shows that the maximum stress will occur at the hole farthest from the rotation center of the proposed structure; the maximum stress is 27 MPa, which is lower than the yield stress, 245 MPa, of the steel material. The function test proves that the proposed structure can be loaded with up to 80 kg of solar panels.*
Keywords: Dual-axis, Solar tracker structure, Finite element analysis, Stress

1. **Introduction.** The governments of many countries have enacted relevant renewable energy regulations to encourage the development and use of green energy. The disadvantage of solar energy for power generation is that solar power generation needs the photovoltaic effect provided by the semiconductor material of solar batteries in order to generate power, so the area receiving sunshine should be large, which requires a lot of land; however, Taiwan has a large population, but not much land. Therefore, if we want to increase a solar panel's power generation, we can use the solar tracker structure. Solar tracker systems can be classified into active-type, passive-type, and mixed-type according to the system control type. The active-type control needs an additional sensing structure, and the system tracking precision depends on the sensitivity of the light sensing devices. The operation method of the passive-type system involves calculating the trace. We can calculate the tracking mode that can save the most power according to the latitude and the longitude of the installation location without being influenced by climate. Furthermore, the control system has no feedback signals for it to detect the operation status of the structure; accordingly, the precision requirement of the structure is higher.

This study adopts the elevation angle and azimuth angle to track the sun, so the rotation axis is designed to make one axis horizontal to the ground and the other axis vertical to the ground. Since we take the space limit problem into consideration, we designed the structure to be under the solar panels and then rotated the circular support holder and the circular rail according to the direction of the azimuth angle. The rotation axis at the direction of the elevation angle is also designed to be under the solar panels.

In 2005, Rosell et al. [1] used the PLC control to implement a dual-axis solar tracker system via a springs and linkage structure. Karimov et al. [2] used four solar energy batteries to implement a dual-axis solar tracker system, where one axis was controlled by the motor and the other one was manually adjusted. Tomson [3] claimed that the method can increase efficiency by 10-20% when compared to a structure that always faces south. In 2009, Barsoum [4] used belts to recommend using a tracker system to make the solar panel and the sunshine always be orthogonal to each other. The dual-axis solar tracker system can increase output efficiency by 40% when compared to a fixation-type system. Mousazadeh et al. [5] performed the efficiency arrangement for many different fixation-type, dual-axis and single-axis solar tracker systems. In 2010, Argeseanu et al. [6] considered production and maintenance costs to successfully design a new sensor structure for a dual-axis solar tracker structure. Lu and Shih [7] used the fuzzy controller to control the rotation angle of the system, which used four light sensors to track the position of the sun according to the position of the maximum power point of the solar panel, and then applied it to an active-type dual-axis solar tracker system. The result proved that the solar tracker system can be rotated to the proper angle by two fuzzy controllers in order to increase the collection amount of the sun's radiation.

Recently, Ray et al. [8] used an ADC microcontroller to track the two angles of the sun. The experiment's result proved that the tracker-type system can increase efficiency by 37% when compared with a fixation-type system. Rahmana et al. [9] designed a 7 W dual-axis solar tracker system and found that the system can increase the gain by 52% when compared with a fixation-type system.

The aims of this study are to reduce manufacturing cost and increase solar power generation. We provide a simple structure implementation method and ensure that the safety and stability of the structure are high; through a simple and strong functional design, we can provide a straightforward solar tracker structure.

2. Design of the Solar Tracker Structure.

A complete solar powered sunlight tracking system firstly requires a solar powered photovoltaic energy conversion and storage system which includes a receptor, light converging device and electrical facilities capable of converting solar energy into electricity. Furthermore, the system requires a sunlight tracking mechanism, enabling solar panels to trace along the trail of the sun to amass more sunlight. Moreover, a sensor is also required to accurately track the position of the sun and finally, a control system to fully utilize the cultivated electrical energy. In this study the maximum power of the solar panel selected is 250 W. Therefore, the proposed structure needs to mount four solar panels, which weigh a total of about 80 kg and proposed structure is installed on the fifth floor of a building. As there is no elevator to transport the proposed structure, the proposed structure should be designed to be easily assembled/disassembled in consideration of transportation convenience. The installation position limits the rotatable range of the proposed structure to a 4-m diameter.

The currently available solar electro-optical systems can be classified into three types: fixation-type solar tracker system, single-axis solar tracker system, and dual-axis solar tracker system. The dual-axis solar tracker system can absorb the most sunshine, followed by the single-axis solar tracker system and then the fixation-type system. Therefore, this study adopts the dual-axis solar tracker system.

As the initial design is the holder structure type, the horizontal level is difficult to calibrate during the assembly process. Since we considered that the proposed structure needed to be conveniently assembled/disassembled, we used aluminum extrusion for the

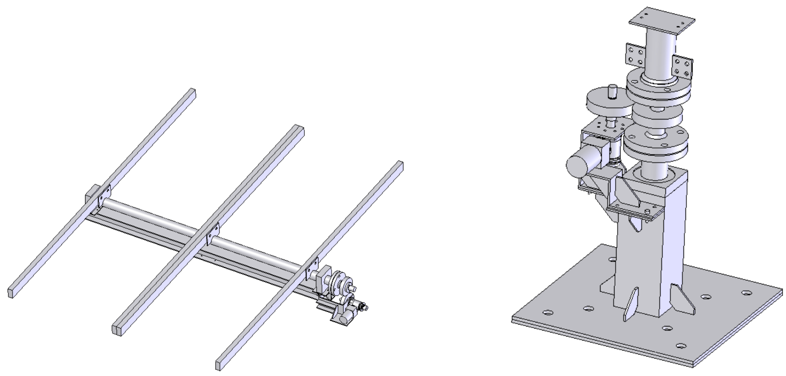

Figure 1. The assembled diagram of the elevation angle and azimuth angle rotation structures

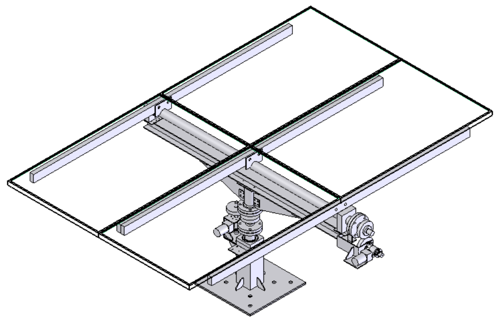

Figure 2. Assembled structure diagram of the completed design

entire structure. On the contrary, the space for installing the electrical control system does not need to be very large; thus, we directly connect the azimuth angle rotation structure to the elevation angle structure (as Figure 1), and the final design version is shown in Figure 2.

3. **Result and Discussion.** We use the post-processing function of MSC-Marc to discuss the calculation results of both the stress field and the displacement field. The boundary conditions of this research are being established based on the absence of both vertical movement of the mechanism's chassis that is being secured to the ground and lateral movement of the bolt hole on the mechanism's chassis as shown in Figures 3 and 4. As for the configuration of the structure's weight, every element on the Z axis of the structure is being subjected to gravitational acceleration of -9.8 m/s^2. Considering the gravitational acceleration generated during earthquakes, we are able to obtain vertical design spectra's acceleration coefficient of 0.175 through performing conversion in accordance to Construction and Planning Agency Ministry of the Interior's design guideline of earthquake resistance. According to the conversion by the standards of Central Weather Bureau, the structure must be capable of resisting magnitude 5 earthquake, thus requiring every element on the Z axis to be configured to generating gravitational acceleration of -4.5 m/s^2. Furthermore, wind direction will also affect the mechanism. As solar panel follows the movement of the sun, the size of its windward side will also change accordingly, this research will only focus on analyzing the angle which produces the largest windward side. The solar panel will stay level to the ground when typhoon occurs, the configuration of wind pressure is as shown in Figure 5, where dark green portion of the figure indicates area being subjected to wind pressure of 500 N/m^2, conversion according to Central Weather Bureau's typhoon standard progression yielded typhoon's wind pressure of magnitude 17. The body material is set as shown in Figure 6.

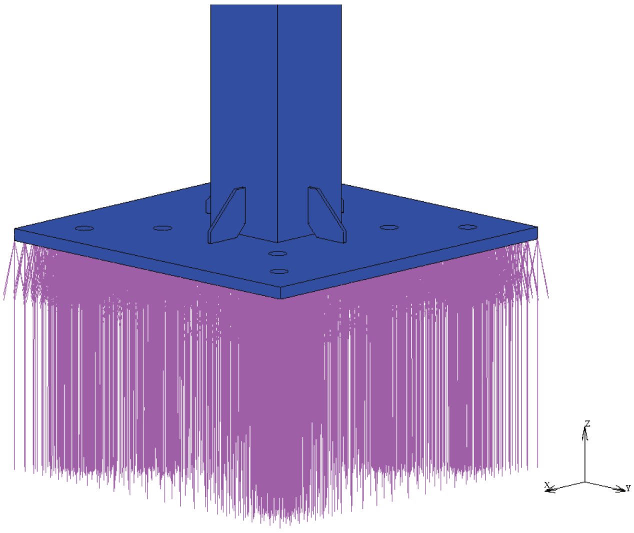

FIGURE 3. The boundary conditions 1

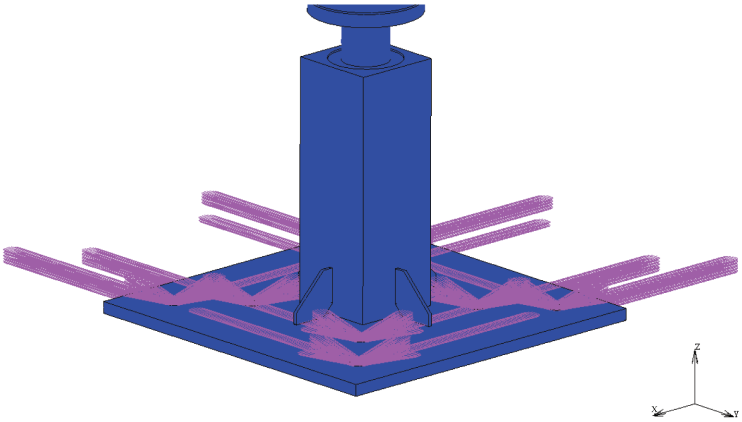

FIGURE 4. The boundary conditions 2

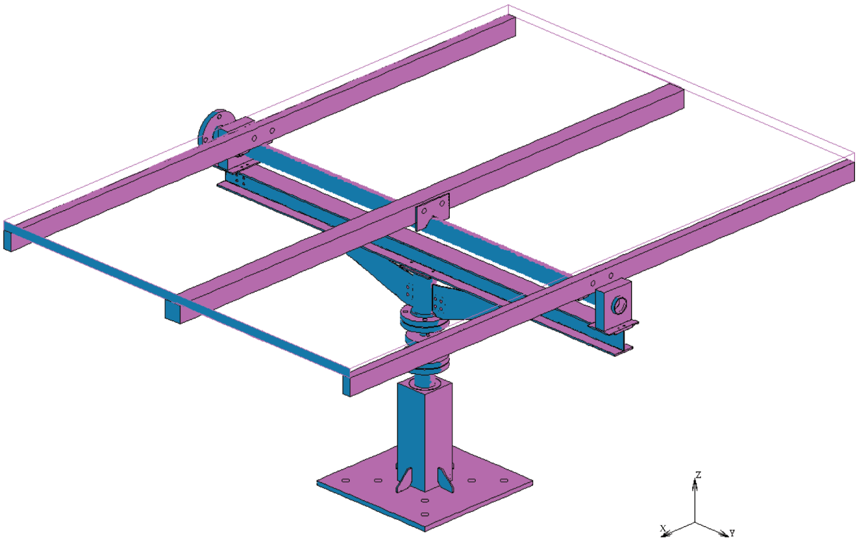

FIGURE 5. The wind pressure setting

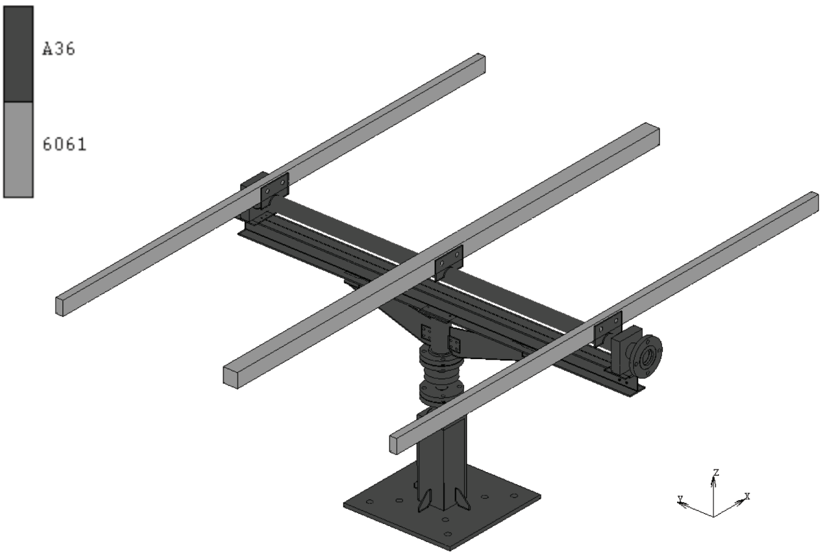

Figure 6. The structural materials setting

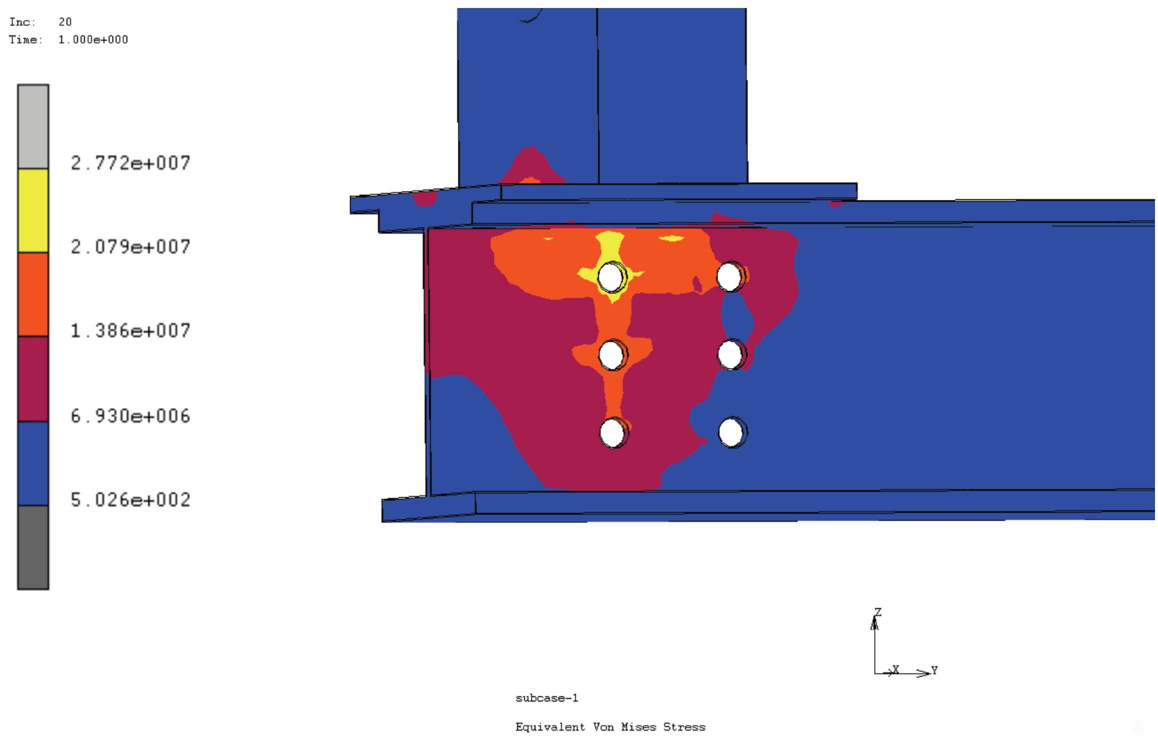

Figure 7. Stress distribution diagram of the partial enlargement

As shown in Figure 7, the stress field distribution diagram of the proposed structure, the blue area is the minimum stress distribution; the yellow area is the maximum stress distribution. In general, the proposed structure falls within the blue area; a portion of the stress is concentrated around the holes or joints where the material was soldered. Since the left side and the right side of the H-shaped steel beam have no support structure connecting to the ground and only the azimuth angle rotation structure supports the middle area, the bearing bases at both ends of the steel beam suffer from stress concentration phenomenon. The maximum stress point is at the hole furthest from the rotation center of the structure; the hole at the motor base is farther from the center when compared to the hole at the H-shaped steel beam. However, as the H-shaped steel beam should receive

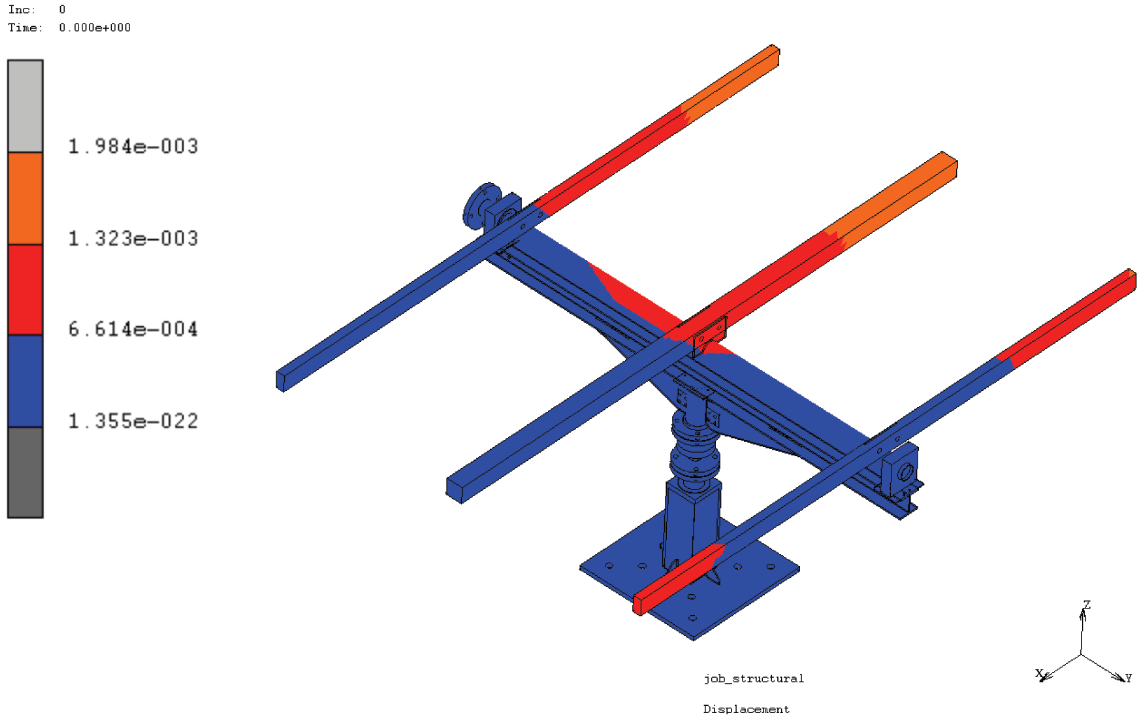

FIGURE 8. Displacement field distribution diagram

all the load above the structure, the maximum stress point should be located on the H-shaped steel beam. Its maximum stress is 27 MPa, which is lower than the yield stress of 245 Pa of the steel material. Therefore, the strength of the proposed structure is high enough to resist a typhoon with a magnitude of 17 or an earthquake with a magnitude of 5.

Figure 8 is the displacement field distribution diagram of the proposed structure, in which the deformation status of the structure can be seen. The blue area is the minimum displacement distribution; then, from the purple area and orange area to the yellow area, the yellow area is the maximum displacement. The deformation takes place at the extrusion, and the maximum deformation point is the end of the middle extrusion, where the deformation amount is 1.9 mm.

4. **Conclusion.**

The proposed dual-axis solar tracker system is a low-cost, simple structure that is convenient for transportation and can be quickly assembled. Via the computer-aided design, and analyses, the results prove that the proposed structure has higher safety and reliability. After the study of single-axis and dual-axis solar tracker systems, and after several initial designs and continuous 3D modeling improvements and discussions, we finally completed the design and manufacturing of the proposed dual-axis solar tracker system.

The study found that the proposed solar tracker system has several advantages, which are summarized below.

(1) Low cost and simple structure. The proposed system is manufactured by the currently available and most frequently used components in the market, which can reduce the cost of manufacturing customized components.

(2) Via the finite element analysis, the result shows that the proposed system can resist a typhoon of a magnitude of 17 and an earthquake of a magnitude of 5.

(3) The whole structure can be disassembled, making the system convenient for transportation.

Although the research had completed the dual axis sun light tracking system, the actual efficiency of conversion is yet to be tested, and we will perform time trial and simulation of conversion efficiency in future researches.

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