STRUCTURAL ANALYSIS AND OPTIMIZATION OF SUN TRACKING SOLAR SYSTEM

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Abstract - *Solar trackers move the payload towards the sun throughout the day. In this paper different types of tracking systems are reviewed, and their pros and cons are discussed in detail. The results presented in this review confirm that structural strength of axis tracking system is more efficient compared to other tracking systems. However, in cost and flexibility point of view single axis tracking system is more feasible than dual axis tracking system. This project employs a solar panel mounted to a time-programmed stepper motor to track the sun so that maximum sun light is made incident upon the panel at any given time of the day. This is better compared to the light sensing method that may not be accurate always – for example, during cloudy days. With the impending scarcity of non-renewable resources, people are considering to use alternate sources of energy. The usage of solar panel to convert Sun energy into electrical energy is very popular, but due to the transition of sun from east to west, the fixed solar panel may not be able to generate optimum energy. The proposed system solves this problem by an arrangement for the solar panel to track the Sun, biggest challenge for such system is to handle the air velocity and pressure created on Structure due to the different angle creates resistance to air so we the current project will analyze this tracking movement to achieve the structural stability and optimization size.*

Key Words: Optimum energy, Air velocity, Structural stability, Optimization, Pressure, Solar panel.

1. INTRODUCTION

The usage of solar panel to convert Sun energy into electrical energy is very popular, but due to the transition of sun from east to west, the fixed solar panel may not be able to generate optimum energy. The proposed system solves this problem by an arrangement for the solar panel to track the Sun. This tracking movement is achieved by coupling a stepper motor to the solar panel such that the panel maintains its face always perpendicular to the sun to generate maximum energy. This is achieved by using a programmed microcontroller to deliver stepped pulses in periodical time intervals for 12 hours for the stepper motor to rotate the mounted panel in one direction and then return to the start point for next day light as desired. Furthermore, it can be enhanced by using an RTC (Real Time Clock) to follow the sun. This helps in maintaining the required position of the panel even if the power is interrupted for some time. Modern systems are increasingly becoming more and more complex. A large number of mechanical components, controls, computers and communication subsystems are found interconnected in a complex system this system will provide the sufficient tracking of sun, bur air resistance and various climate change condition creates large amount of air resistance so strength of mechanical structure is an extremely important for continuous operation and safety of surrounding as well as economical loss due to breakage of panel.

1.1 Structural Analysis

Structural analysis is the process of calculating and determining the effects of loads, pressure, and internal forces on a structure, building or object. Structural Analysis is particularly important for structural engineers to ensure they completely understand the load paths and the impacts the loads have on their engineering design. It allows engineers or designers to ensure a piece of equipment or structure is safe for use under the estimated loads it is expected to withstand. Structural Analysis can either be performed during design, testing or post-construction and will generally account for the materials used, geometry of the structure and applied loads.

1.2 Design Optimization

The area of design optimization is where the performance of a design can be made drastically better than an initial naive implementation. Before discussing details of how to make the designs optimal design - determining design parameters that lead to the best "performance" of a mechanical structure, device, or system. Planning - production planning - minimizing manufacturing costs. Control and manufacturing - identifying the optimal control parameters for the best performance (machining, trajectory, etc.) Mathematical modelling - curve and surface fitting of given data with minimum error hand calculations.

Here we are evaluating the structure for air resistance and determining the strength.

Fig 1: Panel Structure Single Panel Set

2. LITERATURE REVIEW

Following this trend, the implementation of large area solar arrays is considered to be a essential. Many design approaches of the supporting structures have been presented in order to achieve the maximum efficiency. They are loaded mainly by aerodynamic pressures. Optimization plays very key role in product design and prevent un-necessary inventory satisfying the functional needs. But optimization with apt design helps to built efficient products in the everyday competing market. Stress analysis plays important role in optimizing the design. In the current work, a solar panel aiding structure is designed to take rotational loads for safe operation. So the design should consider the loads coming on the structure for rotation along with inertia effect of the rotating members. The mechanism should withstand the aerodynamic loads, inertia loads and rotation loads along with frictional loads. The results summary is as follows:- Initial wind load calculations are carried out based on the given wind speed. Initial calculations are carried out to find critical position of loading. Calculations are based on projected area of the problem. A weight reduction of 13.9% can be observed in the problem. This reduction is also significant as the Production costs, manufacturing costs and maintenance costs will reduce with less requirement of the material. Also, dynamic effects in the structure also will reduce. The graphs are represented showing variation of weight, stress and deflection with iterations. Weight reduction with iterations can be observed along with increase in stress and deflection with reduction in thickness[1]. However in cost and flexibility point of view single axis tracking system is more feasible than dual axis. In future the present paper details will be useful in selecting an accurate and particular tracker with respect to region, available space and estimated cost. The present work may be useful to improve the design characteristics of different types of solar tracking systems to improve performance[2]. Design optimization is carried out using ANSYS optimizer tool for better stress distribution and reduction in weight. Initial analysis results shows stress and deflections are well below the allowable deflection (6mm) and stress (140Mpa) of the structure. So the structure is based on selecting suitable design parameters and state variables. Weight is considered as the objective function of the problem. Total of 6 design variables and 2 state variables are selected based on the stress and deflections on the structure based on the initial analysis. Total of 11 feasible sets are obtained using design optimization tool. Final weight of the structure is reduced from initial 4508kgs to 3880.9kg. So a reduction of 13.9% is obtained using the design tool [3]. Experimental research concerning the steady wind action on solar collectors, carried out in the boundary layer wind tunnel is based on a pneumatic mediation technique for each of the exposed surfaces. The purpose is to evaluate the lifting forces transmitted to the structures supporting solar collectors placed in solid rows on the flat roofs of multilevel buildings. Preliminary tests proved the satisfactory precision of the mediation procedure. Other tests established important shelter effects due to marginal attics [7].

3. METHODOLOGY

Methodology used in this paper is as follow,

- Started the work of this project with literature survey. I gathered many research papers which are relevant to this topic.
- After that the components which are required for our project are decided.
- After deciding the components, the 3D Model will be done with the help of SOLIDWORKS software.
- The Analysis of the components will be done with the help of SOLIDWORKS Simulation using FEA.
- The Experimental Testing will be carried out.
- Comparative analysis between the experimental & analysis result & then the result & conclusion will be drawn.

4. EXPERIMENTAL PROCEDURE

In mathematical terms, Finite Element Analysis (FEA), also known as the Finite Element Method (FEM), is a numerical technique for describing physical phenomena in terms of partial differential equations. Finite element analysis is widely used in many engineering disciplines for solving structural mechanics, vibration, heat transfer, and other problems. WE use the FEM to predict the behavior of mechanical and thermal systems under their operating conditions, to reduce the design cycle time, and to improve overall system performance. Geometric representation creates the geometric features of the system to be analyzed stored in a CAD database. Element formulation develops the equations that describe the behavior of each element. Material properties for each element are considered in the formulation of the governing Element formulation equations. This involves choosing a displacement function within each element. Assembly obtains the set of global equations for the entire model from the equations of individual elements. The loads and support (boundary) conditions are applied to the appropriate nodes of the finite element mesh. Solution of equations provides the solution for the unknown nodal degrees of freedom (or generalized displacements). A FEA model is composed of several different components that together describe the physical problem to be analyzed and the results to be obtained. At a minimum the analysis model consists of the following information: discretized geometry, element properties, material data, loads and boundary conditions, analysis type, and output requests.

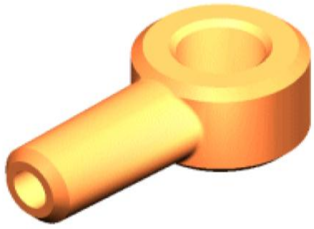

Fig 1: CAD Model Part

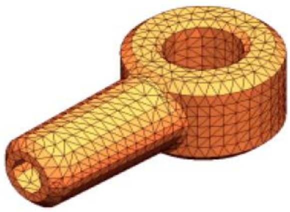

Fig 2: CAD Model divided in Small Pieces (Elements)

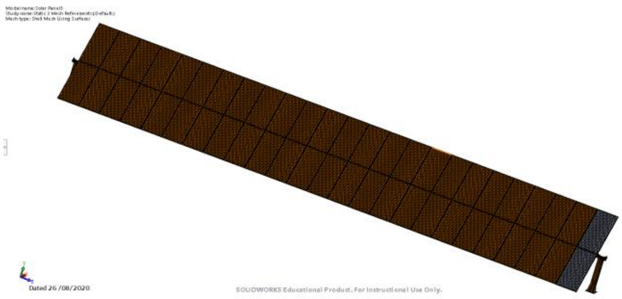

Fig 3: CAD Model Geometry Details

In a static analysis the long-term response of the structure to the applied loads (which are applied gradually and slowly until they reach their full magnitude) is obtained.

In cases where the loads are changing with time or frequency, a dynamic analysis is required. For example, you perform a dynamic analysis to simulate the effect of an impact load on a component or the response of a building during an earthquake. A nonlinear structural problem is one in which the structure's stiffness changes as it deforms. All physical structures exhibit nonlinear behavior. Linear analysis is a convenient approximation that is often adequate for design purposes. It is obviously inadequate for many structural simulations including manufacturing processes, Such as forging or stamping; crash analyses; and analyses of rubber components, such as tires or engine mounts. Dassault Systems SOLIDWORKS Corp. offers complete 3D software tools that let you create, simulate, publish, and manage your data. SOLIDWORKS products are easy to learn and use and work together to help you design products better, faster, and more cost-effectively As shown in Fig 1. The SOLIDWORKS focus on ease-of-use allows more engineers, designers and other technology professionals than ever before to take advantage of 3D in bringing their designs to life. SOLIDWORKS Simulation Standard is an intuitive virtual testing environment for static linear, time-based motion, and high-cycle fatigue simulation. It delivers a concurrent engineering approach, helping you know if your product will perform properly and how long it will last-lasting the design phase, SOLIDWORKS Simulation Professional enables you to Optimize your design, as shown in fig 2 determine product mechanical resistance, product durability, topology, natural frequencies, and test heat transfer and buckling instabilities, It can also perform sequential multi-physics simulations.

Table -1: Material Properties

Properties	Material 1	Material 2
Name	Plain Carbon Steel	PE High Density
Model type	Linear Elastic Isotropic	Linear Elastic Isotropic
Default failure criterion	Max von Misses Stress	Unknown
Yield strength	2.20594e+08 N/m^2	5.5e+07 N/m^2
Tensile strength:	3.99826e+08 N/m^2	2.21e+07 N/m^2
Elastic modulus:	2.1e+11 N/m^2	1.07e+09 N/m^2
Poisson's ratio:	0.28 kg/m^3	0.4101
Mass density:	7,800 kg/m^3	952 kg/m^3
Shear modulus:	7.9e+10 N/m^2	3.772e+08 N/m^2
Thermal expansion coefficient:	1.3e-05 /Kelvin	-

In that given table we mesh both material and take best result Bonded: - With this option two parts behave as if they were welded. So, in fact two parts will act as one welded structure for all frame and structural profile. No Penetration:-This contact type prevents interference between two parts, but allows gaps to form. Note that this is the most time-consuming option to solve.

Table -2: Mesh information

Mesh Type	Shell Mesh Using Surfaces
Mesher Used	Curvature-Based Mesh
Jacobian Check For Shell	On
Maximum Element Size	77.1631 Mm
Minimum Element Size	59.1578 Mm
Mesh Quality Plot	High

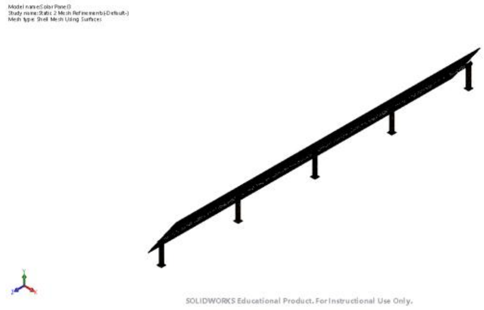

Fig 4: Mesh Geometry

4.1 Study Results

Table -3: Solar Panel3-Static [Angle 80]-Stress details

Name	Stress1
Type	Von: Von Mises Stress
Minimum	0.000 N/Mm^2 (Mpa) Node: 929
Maximum	479.816 N/Mm^2 (Mpa) (Singularity) 159.99 N/Mm2 At Cantilever Sections And 79 N/Mm2 At Over All Structure Node: 17485

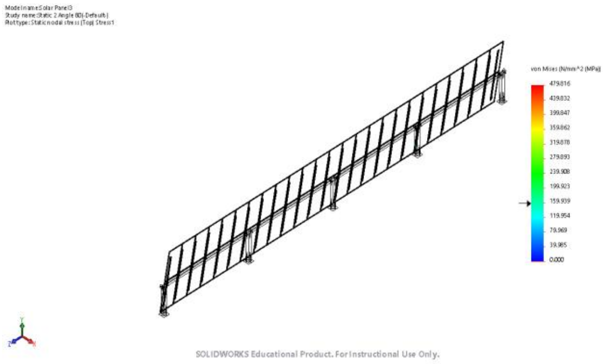

Fig -5: Solar Panel3-Static [Angle 80]-Stress

Table -4: Solar Panel3 Static [Angle 80]-Displacement details

Name	Displacement1{1}
Type	Ures: Resultant Displacement
Minimum	0.000e+00 Mm Node: 929
Maximum	1.657e+02 Mm Over Cantilever Portions 47 Mm On Structure Node: 138431

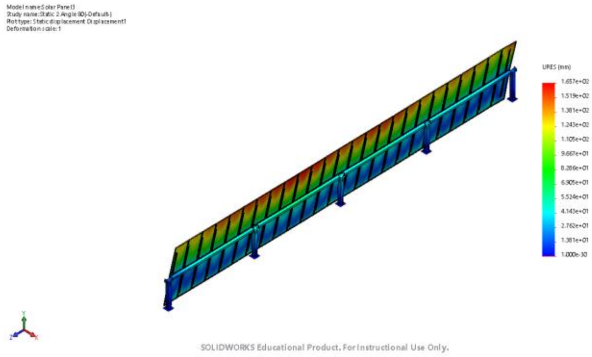

Fig -6: Solar Panel 3 Static [Angle 80]-Displacement1

Table -5: Solar Panel3 Static [Angle 80]-Strain details

Name	Strain1
Type	Estrn: Equivalent Strain
Minimum	0.000 Node: 382
Maximum	0.001 Node: 32779

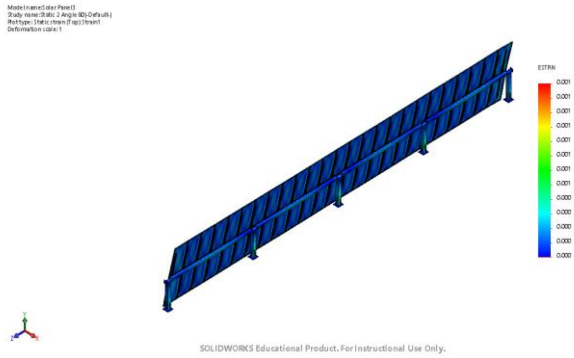

Fig -7: Solar Panel3-Static [Angle 80]-Strain

Table -6: Solar Panel3 [Angle 80] Displacement details

Name	Displacement1{2}
Type	Deformed Shape

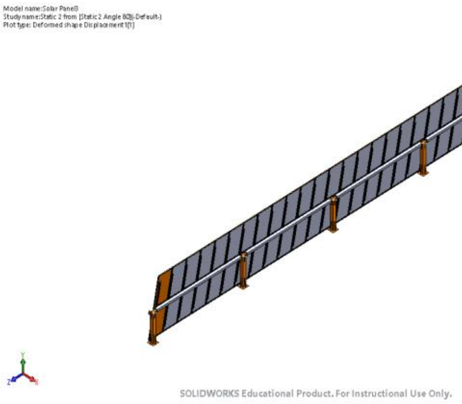

Fig 8: Solar Panel3-Static [Angle 80]-Displacement

4.2 Refinement Suggestions

This project work gives an idea about structural strength of sun tracking solar system, based on the above study, we observed there is refinement require in strength so we have change model for rib section also removed the sharp corner to avoid the singularity.

Modification dimension for rib is for thickness 10 mm to 12 mm and also change in geometry

Pin support and diameter change from 10 mm to 16 mm for more rigid support during movement of sun tracking.

5. CONCLUSIONS

This project work gives an idea about structural strength of sun tracking solar system, based on the above study, we observed

- Deflection: - 73 mm at cantilever side and 25mm is maximum for structure.
- Stress: - 159 N/mm2 is max Stresses at cantilever sections and 53 N/mm2 over structure
- FOS: - 1.3 at Cantilever section and 4 at all section

Kindly note,

- Singularity is observed on Roller Shaft connection, Rib Sharp Area, Hat Section End Profile
- Cantilever condition at both ends creates a maximum deflection at end but still this will not increase the stress value as structure is rigid and safe.
- We concluded as structure is safe and work in condition of air velocity in India West zone as per IS Building Code

6. FUTURE SCOPE

There future scope of research work may be as follows:

- Further we can analyses for linear dynamics to check the real world scenario
- Geographical changes in velocity should be considering for optimum structure design.

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