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A 3D-Based Modeling and Analysis of an Artificial Palm Tree for Video Surveillance Activities

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Abstract:- A study on the 3-D modeling and analysis of an artificial palm tree structure capable of housing a camera was made. The proposed system's design, simulation, and virtual testing were done using SolidWorks software. This work's primary objective was an aesthetically pleasing and functional solution that integrates with the urban landscape while providing an enhanced concealed security system. The natural form of a palm tree was incorporated into the artificial palm tree structure. The hidden camera ensures optimal coverage without compromising the overall appearance and presence of the device. This is so because, in the Nigerian situation, Miscreants will pull down the structure if they know of its presence. A detailed analysis of the system's structural integrity and stability was achieved using a 3D model of the artificial palm tree structure. Factors such as wind load, weight distribution, and material strength are considered to ensure the design can cope with environmental conditions. Virtual simulations allow for the maximization of the structure, ensuring it complies with safety standards, and the results of VonMise's stress show that the materials selected for the design are suitable for the work.

Keywords:- *Surveillance Camera, Artificial Palm Tree, Solidworks, 3D Modelling, Static and Wind Load Analysis.*

I. INTRODUCTION

Recently, security issues have become more complex. Terrorist attacks on critical national assets and infrastructure and Kidnapping are rampant. Nations are adopting strict measures to secure critical infrastructures by applying modern technologies to build a smart surveillance system. Intrusion detection detects a person or vehicle attempting to gain unauthorized entry into a protected area (Alcaraz & Zeadally, 2015). The surveillance system is the first level of protection and an early warning facility used extensively in recent times. Its installation aims to detect unauthorized access to assets within a sensitive area against theft, vandalism, diversion, sabotage, and other criminal acts(Jenn, 2002).

In recent years, integrating cameras on the street has gained much attention. This innovative study explores the seamless integration of technology and nature to address the modern-day need for discreet surveillance solutions. We use a powerful tool known for its design and engineering capabilities to create an artificial palm tree that goes beyond its aesthetic appeal. The palm tree is an attractive host for strategically placed cameras, enhancing security systems in a visually appealing manner(Sánchez & Lama, 2011).

This paper brings to the fore the use of advanced features of SolidWorks to model real-world scenarios, evaluate the feasibility of our design, and fine-tune it to meet the desired performance criteria. Hence, the ultimate goal is to create a solution that blends in with the surroundings and provides enhanced security coverage. This paper explores the intersection of design, engineering, and technology to show how innovation can be woven into our environment.

In the past, a 3D reconstruction of a tree using a Phyllotaxis was carried out from a single image. Since a typical palm tree has a simple, repetitive model, a 3D reconstruction was achieved from its single 2D image. An algorithm was developed that acquired the image and locate the Trunk and the prominent leaves. The tree model parameters were calculated, and the final reconstruction was achieved(Dror & Shimshoni, 2008). Meanwhile, Anca et al. (2011) performed the simulation of fusion welding by the Finite Element Method, which involves an implemented model of a moving heat source, temperature dependence of thermophysical properties, elasto-plasticity, non-steady state heat transfer, and mechanical analysis. The thermal problem was assumed to be uncoupled from the mechanical one, so the thermal analysis was performed separately and before the mechanical analysis at each time step. A special treatment was also performed on mechanical elements during the liquid/solid and solid/liquid phase changes to account for stress states. The result shows a three-dimensional stress state of a butt-welded joint.To carry out wind load analysis Prabhu et al., (2020) conducted a flow simulation of a sedan car's rear spoilers with Solidworks. The effort aimed to reduce the aerodynamic drag force experienced by the vehicle in motion. The drag and lift forces at various velocities on different spoiler designs were simulated. A numerical model based on computational fluid dynamics (CFD) was proposed, and different flow structure around the car's rear end was simulated. Močilan et al. (2017) presented an approach that involved CAD simplification, geometry meshing, CFD simulation, and analysis of the hydraulic tank partially filled with oil using the Volume of Fluid (VOF) multiphase model. The Simulations compared the amplitude of sloshing in the tank. Their result revealed that performing only static analysis without Fluid-Structure Interaction (FSI) analysis on such a tank will only lead to wastefulness due to oversizing the tank.

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Considering all the work, the research gap remains in a 3D modeling of the palm tree, structure by structure, with SolidWorks software and its static and wind load simulation to observe its real-life response to environmental factors of the area of installation.

II. MATERIALS AND METHOD

➢ *The Work was Carried Out with Solidworks CAD/CAM Software and is Divided into Three Parts. they Are:*

- Parts modeling and assembling;
- Static analysis and
- Wind load analysis (Computational Fluid Dynamics).

➢ *Parts Modeling and Assembling:*

The tree was designed using digital process design with Computer Aided Design and Manufacturing (CAD/CAM) Software called Solidworks. A natural Palm tree was obtained, and its shape and dimension were measured and documented for onward implementation on the CAD/CAM software. The design and assembling of the artificial tree were carried out in the sequence presented below:

➢ *Pro-Log Program for Modeling of the Palm Tree*

Below is the step-by-step procedure for modeling the Artificial palm tree using Solid Works 2021 Edition.

➢ *Palm Tree Leaves and Branch Modeling*

- *Phase I*

✓ Launch SolidWorks 2021 Edition;
✓ Select a new project;
✓ On the display window, select the front plane and click OK;
✓ From the origin, draw a center line and click OK;
✓
✓ From the end of the center line, draw a curve using a 3-point arc sketch tool;
✓ From the Menu Bar, select "Smart Dimension" and define the length of the center line, radius, and size of the curve (100mm, 2500mm, and 1500mm), respectively;
✓ At the end of the arc, select a plane and draw a circle;
✓ Convert the circle and the arc to a solid curved rod of 50mm diameter by applying the 'swept boss' feature menu;

- *Phase II*

✓ On the surface of the rod, select the top plane and make it normal to the plane;
✓ Draw a center line at the middle of the rod and another vertical at an angle of 30 degrees to the midline;
✓ Apply smart dimension to both center lines;
✓ On the vertical line, use "spline sketch tool" to draw the geometry of the leave;
✓ Apply dimension to the leave geometry;
✓ Using the Surface menu, filled the leaves geometry and apply thickness (0.7mm);

- *Phase III*

✓ At normal to the front plane of the rod, sketch a 3-point arc and make it construction geometry;
✓ Apply a curve-driven pattern of the leaves attached to the construction geometry line to form many designed leaves along the curve;
✓ Along the same plane, mirror all the developed leaves at the other end of the rod, forming well-designed leaves attached to a stem (Rod);
✓ Right-click on the material tab, select 'edit materials," and choose Carbon Steel Sheet. Name the project and save it in the desired folder. The detailed Drawing is shown below:

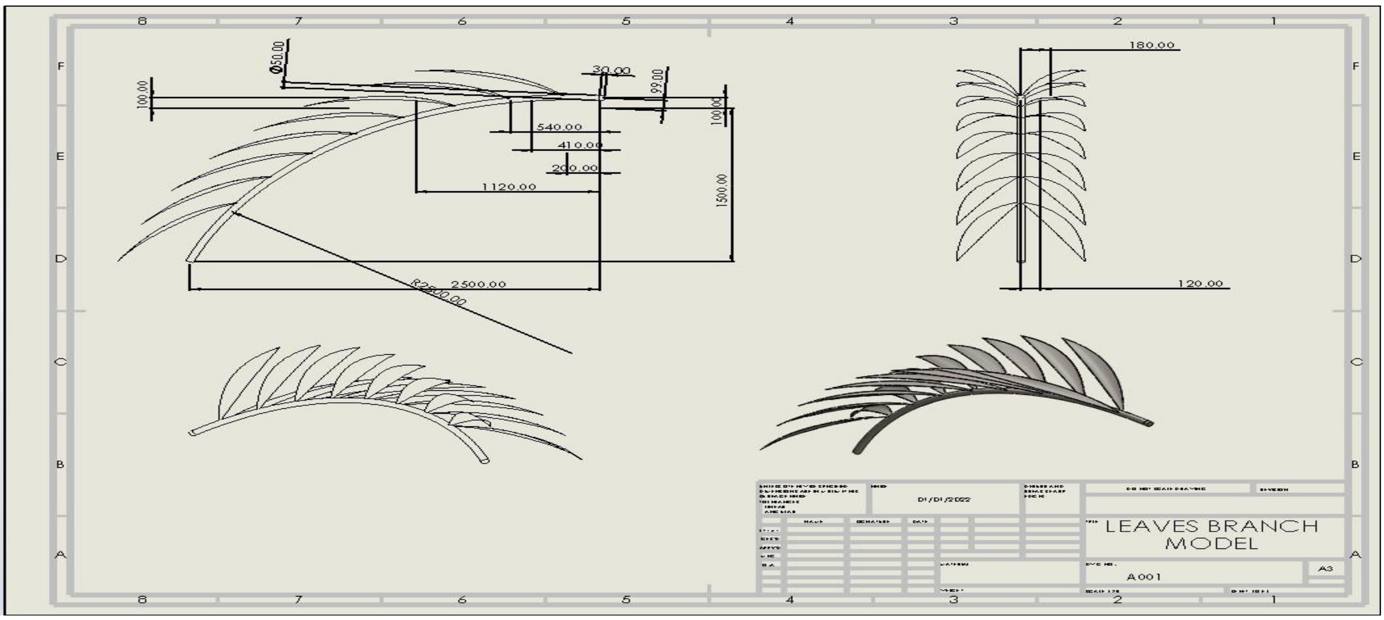

Fig 1: Model Drawing of Palm Tree Branch and Leaves

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➢ *Palm Tree Trunk Modeling*

- Select a new project;
- On the display window, select the front plane and click OK;
- From the origin, draw a center line of 10m in length and click OK;
- At the left side of the center line, draw a rectangle of 10m in length and 5mm in width;
- Exit the Sketch and select the features menu;
- Revolve the Sketch at 360 degrees and click OK;
- Right-click on the material tab, select 'edit materials", and choose Galvanized Steel. Name the project and save it in the same folder. The detailed Drawing is shown below:

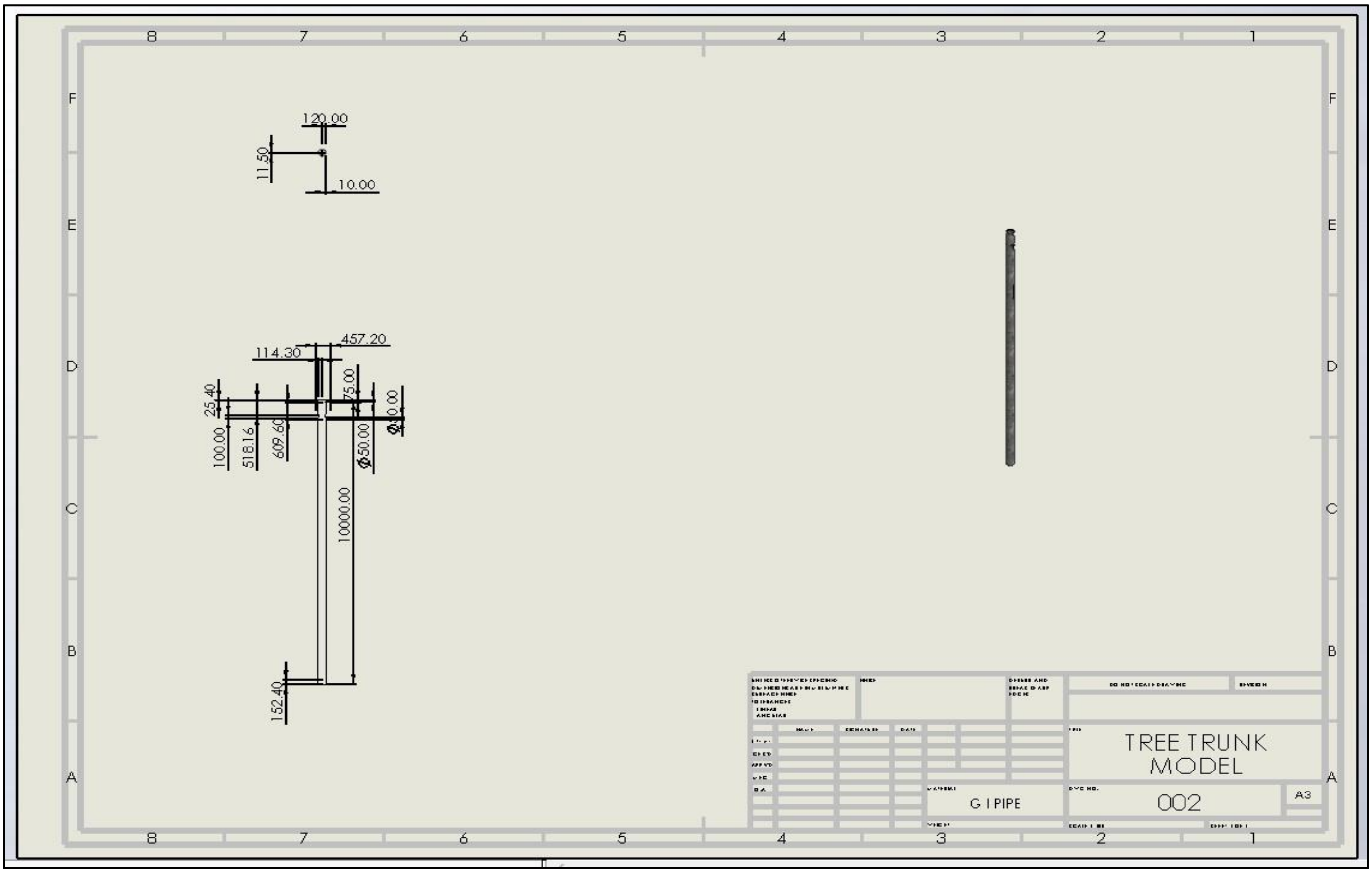

Fig 2: Model Drawing of Palm Tree Trunk

➢ *Palm Tree Base Modeling*

- *Phase I*

- Select a new project;
- On the display window, right-click on the top plane and select Sketch;
- On the sketch window, select "Center rectangle" and draw it from the origin
- Apply smart dimension to the rectangle and click OK;
- Go to the Feature tab and select extrude base;
- Apply the extruded size and click OK;

- *Phase II*

✓ Select the top plane and click normal;
✓ On the sketch window, select "Center rectangle" and draw it from the origin;
✓ Apply smart dimension to the rectangle and click OK;
✓ Right-click on it and convert it to construction geometry;
✓ Select the center circle and draw four circles at the edges of the rectangle;
✓ Apply smart dimension to the constructed circles and click OK;
✓ Go to the Feature tab, select extrude cut, and click OK. The detailed Drawing is shown below:

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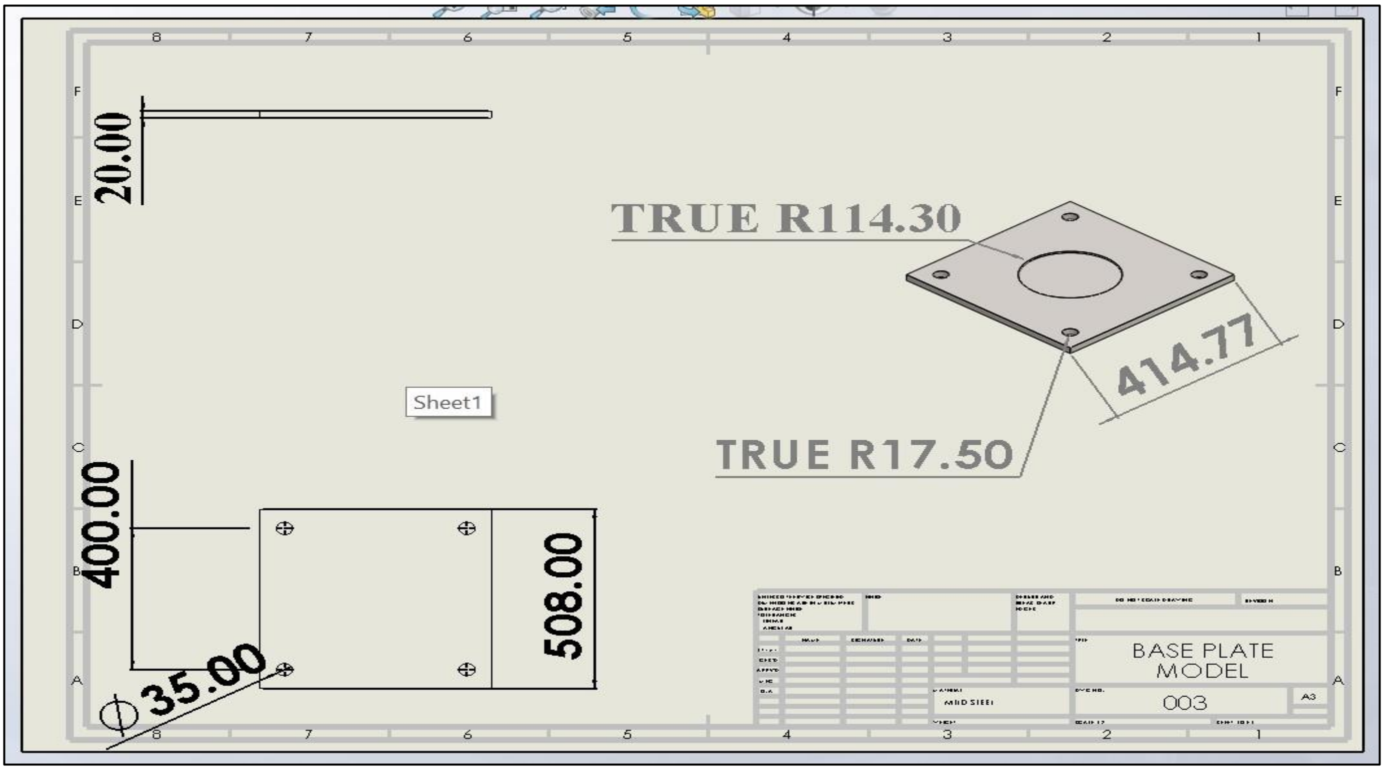

Fig 3: Model Drawing of Palm Tree Base Plate

➢ *Palm Tree Assembly*

- *Phase I*

✓ Select a new project;
✓ On the display window, select Assembly and click OK;
✓ On the Menu tab, select "Insert component" and browse to pick the Base plate from the saved folder;
✓ Drop the Base plate in the middle of the environment, Right click on it, and apply Float;
✓ Select the origin of the Base plate, mate it with that of the Assembly to have a common origin, and click OK.

- *Phase II*

✓ On the Menu tab, select Insert Component again and pick Tree Trunk;
✓ Drop the Trunk to be in contact with the Base plate in such a way that it is perpendicular to each other;
✓ Select the origin of the truck and MATE it with the origin of the Assembly;
✓ Apply weld beads at their point of intersection and click OK;

- *Phase III*

✓ On the Menu tab, select Insert Component again and pick Brazing plate;
✓ Drop the brazing plate to be in contact with the Tree trunk and the Base plate in such a way that it is perpendicular to the two components;
✓ Apply weldment at the point of their intersection;
✓ Go to the menu tab and select "Circular Component Pattern" to pattern the brazing plate;
✓ Select the number of patterns to be six (6) in a clockwise direction;
✓ Click Ok.

- *Phase IV*

✓ On the Menu tab, select Insert Component again and pick Leaves and Branch;
✓ Drop the selected leaves and branch in the environment close to the point of intersection between the branch and the Trunk;
✓ On the Menu bar, choose MATE, then click on the head of the branch and the mark point of the Trunk and apply "Concentric," then click OK;
✓ Apply weld beads at the intersecting point of the two components;
✓ Repeat Step i to iv to the second mark point of the Trunk, which is 610mm between them;
✓ Apply Six (6) "Circular Component Patterns" each to both of the branches produced;
✓ Click OK to View a fully assembled Palm Tree, as shown in the figure below:

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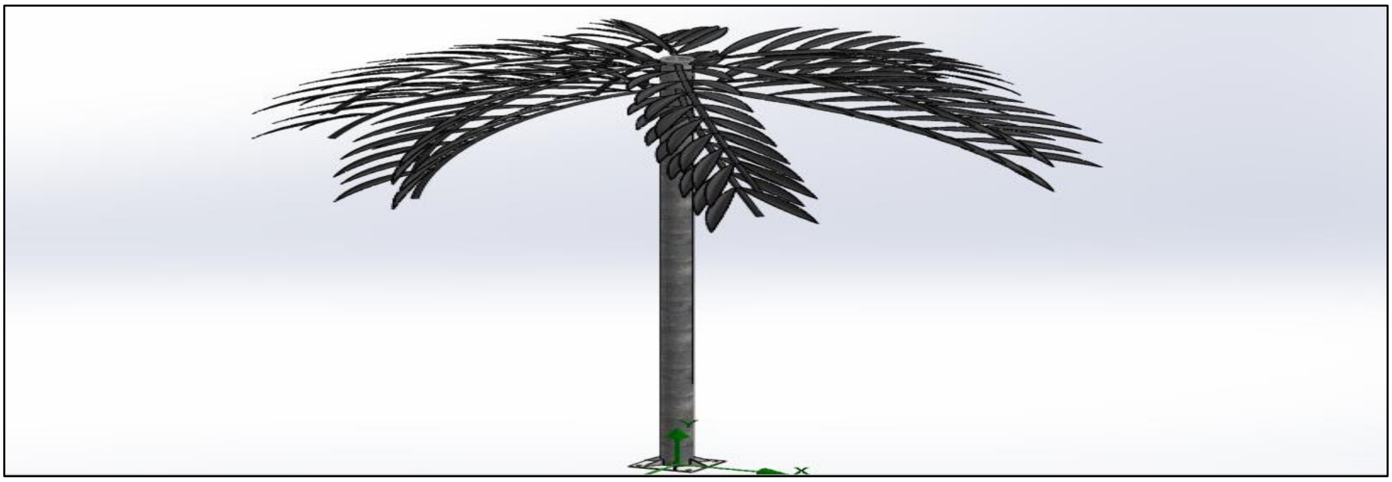

Fig 4: 3D Assembly Model of an Artificial Palm Tree

➢ *Data for Simulation of the Tree*

- Maximum wind speed for Afaka General Area in the last ten years (m/s) =12
- Adopted wind speed (m/s) = 25
- Length of Tree (m) = 10
- Inner radius of tree trunk (m) = 0.1083m
- The external radius of tree trunk (m)= 0.1143m
- Branch length (m) = 2 each
- Branch weight (kg) = 6.5 each
- Camera weight (kg) = 7.5
- Palm nut weight (kg) = 5 each

The above data was used for the simulation of the Model. Accordingly, meshing, the shear stresses, and possible deflection to be exerted on the tree, as well as the Von misses stress due to the wind loading, were obtained and presented under the results below:

III. RESULTS AND DISCUSSION

A. Results

The Tree branches, Trunk, and base holding the tree are the most essential parts of the artificial Palm tree. In designing the leaves and stems, For the structural property, each of the leaves/branches is assumed to be a cantilever beam fixed at one end and subjected to shear stress occasioned by the wind loads/pressure of the area(Shahbazi et al., 2015). This product was designed for installation at the Nigerian Defence Academy (NDA) Permanent Site, Kaduna, Nigeria. Thus, the loads were evaluated considering the maximum wind speed recorded in a few years at Afaka General Area, where NDA is situated. Table 4.1 shows the materials selected based on data collected for maximum wind speed for two years. The data was obtained from the Nigerian Metrological Agency (NiMET), Kaduna.

Table 1: Material Selection

S/N	Tree Component	Proposed Materials	Selected Material	Reason Of Selection	Yield Strenght
1	Leaves	Mild steel Galvanize steel Stainless steel Fiber material	0.7mm Mild steel sheet	Ductility, availability, machinability, and cost(Engineering, n.d.)	250-350 MPa
2	Petiole (stem)	Y16 mild steel rod 16mm galvanized round pipe Stainless steel round pipe	Y16 mild steel rod	Versatility, weldability, availability, and cost(Sultana et al., 2020)	250-350 MPa
3	Trunk	Mild steel pipe Stainless steel pipe Galvanize iron pipe Wood Concrete	Galvanize iron pipe	Strength, corrosion resistance, and cost(Ghasemivinche & Hamadani, 2017)	200-400 MPa
4	Trunk bottom (Bucket-like)	Mild steel sheet Aluminum sheet Stainless steel sheet	Aluminum sheet	Heat resistance and corrosion resistance(RAMLI, 2010)	137-483Mpa
5	Trunk base (Base Plate)	Mild Steel Iron manganese alloy Galvanize steel plate	Iron manganese alloy	Strength, Toughness, corrosion resistance, and cost(Varadaraajan, 2015)	200- 500Mpa

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B. Meshing of the Palm Tree Model

A constrain was applied at the base of the palm tree, and the entire Model was meshed as shown below:

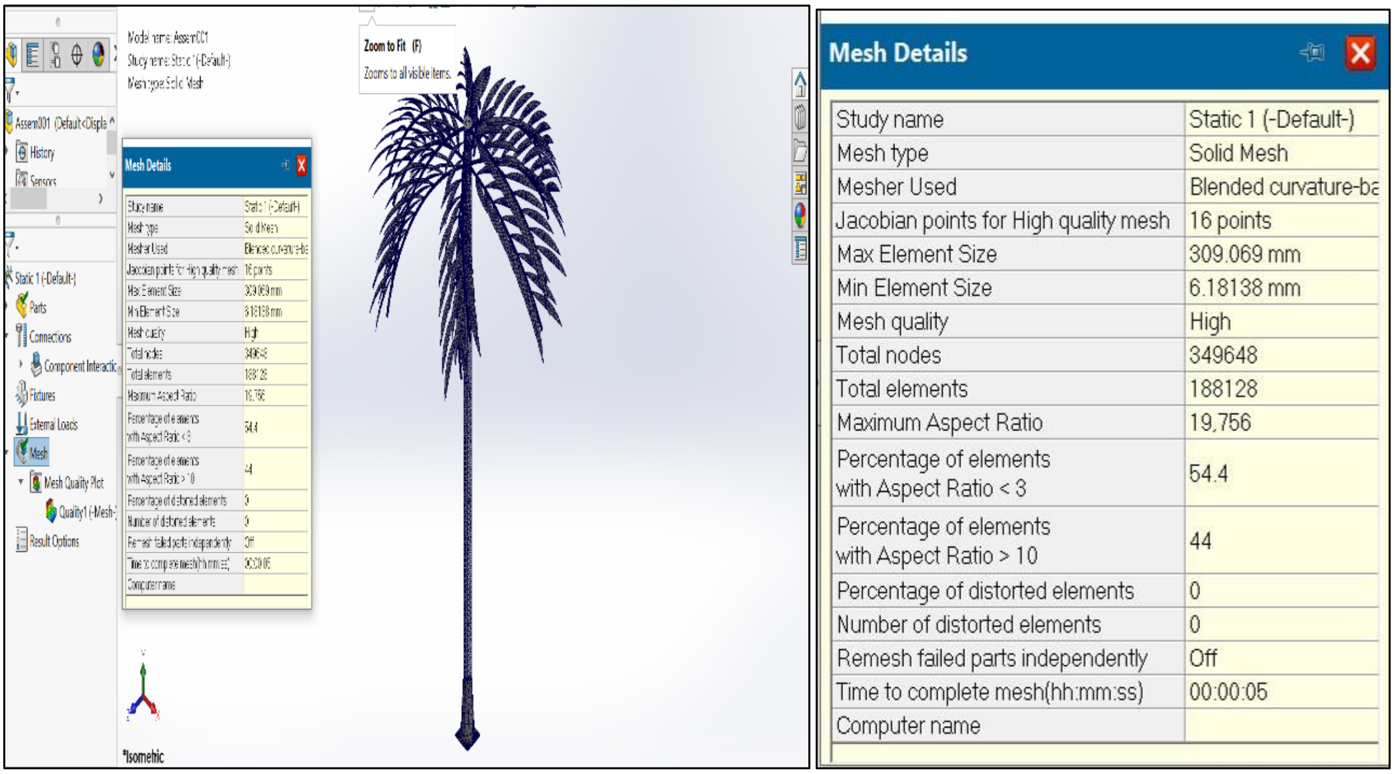

Fig 5a and 5b: Meshed Result of Palm Tree Model

From the above results, it can be observed that the Model is of high quality, with 188,128 total elements and 34,9648 total nodes. Accordingly, the result shows 16 Jacobian points with a 54.4% Aspect ratio of less than 3 and a 44% Aspect ratio of greater than 10. Hence, the finite element analysis is optimum since its maximum Aspect ratio is less than 20 (Javidinejad, 2012).

C. Wind Loading (Computational Fluid Analysis) of the Model

The tree's computational fluid analysis was carried out to obtain pressure and the shear stress exerted on the tree under the wind properties obtained from NiMet (Maximum wind speed adopted as 25m/s). The flow direction boundary condition was assigned in the Z-direction at ambient temperature and pressure for 205 complete iterations(Jonuskaite, 2017). The results obtained are as shown below:

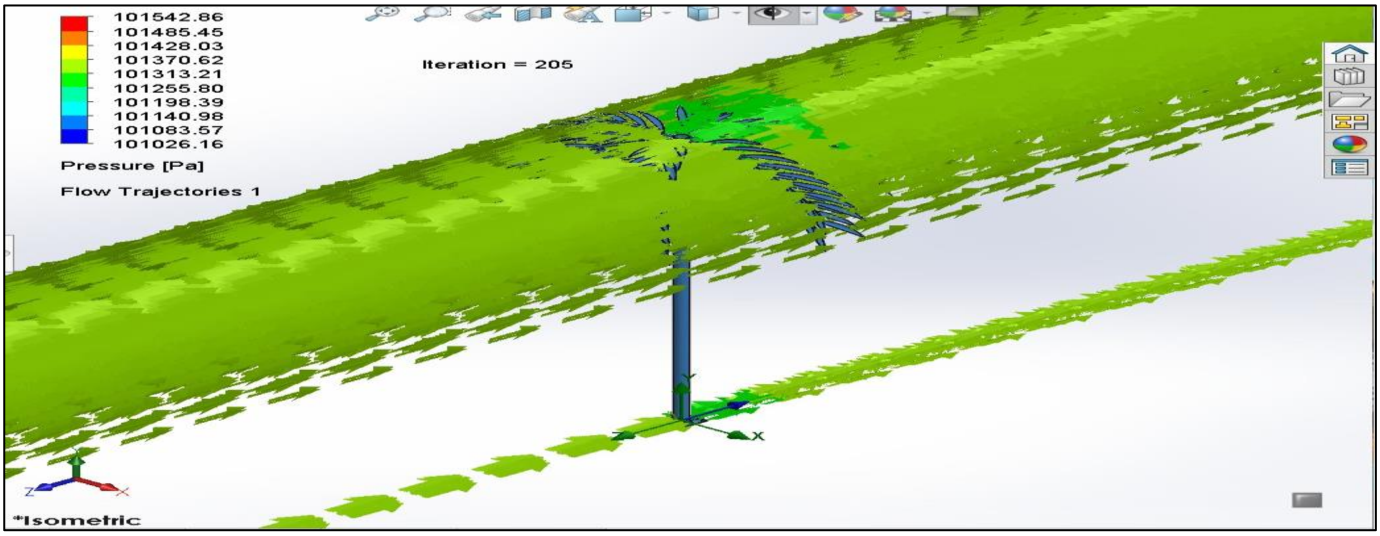

Fig 6: Wind Flow Analysis Result

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The resultant Fluid static pressure, as well as its Average shear stresses, were transferred as external load to the Static simulation environment for static analysis.

D. Static Analysis Based on the Obtained Wind Loading Result

The static analysis simulation carried out results in Von Mises stress deflection and the strain experienced by the Model. The results are as shown below:

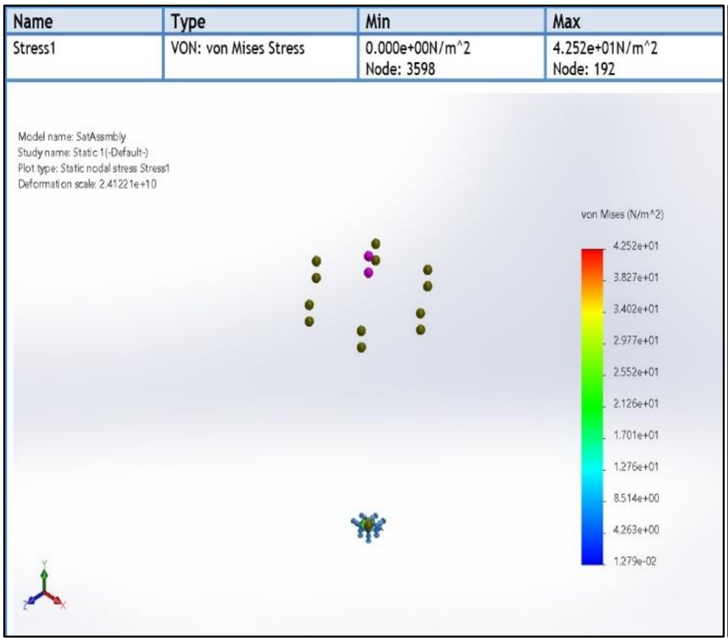

Fig 7: Von Mises Stress Result
(Max 4.252 x 10^1 N/m^{2}))

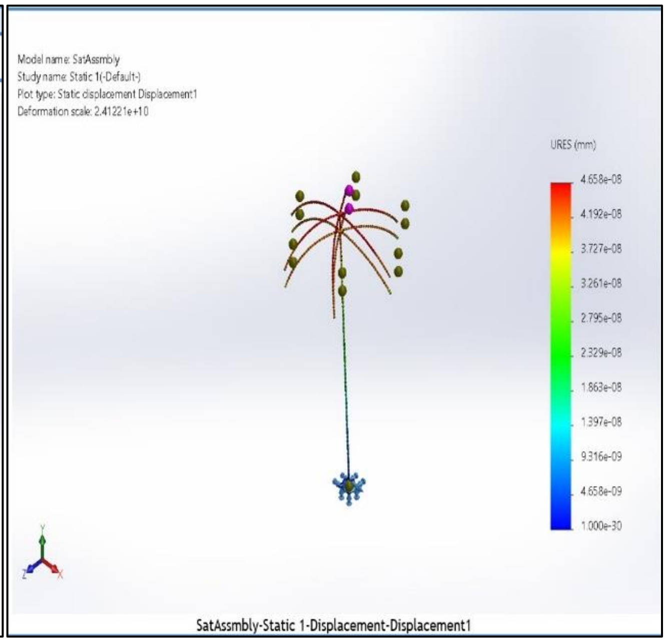

Fig 8: Displacement results
(Max 4.658 x 10^{-8} mm)

From the above results, considering the design theory presented earlier, it can be stated that the Von Mises stress is far less than the Ultimate tensile strength of the selected materials. Accordingly, the Deflection/ displacement of the tree as simulated is negligible and is far less than 1% of the design height of the tree, which is **10m** high. Hence, the design is optimum and conforms to all requirements.

IV. DISCUSSION

The simulated results shown above revealed an insignificant deflection (Max 4.658 x 10^{-8} mm), while the Von Mises stress was obtained as 4.252 x 10^{1} N/m2 equivalent to 4.252 x 10^{-5} Mpa (0.00004252 Mpa), which is significantly lower than the yield strength of the materials used (200 MPa and above). This suggests that the materials used in the simulation have a high margin of safety and are unlikely to experience any plastic deformation or failure under the applied loads.

The low Von Mises stress revealed that the structure or components being analyzed are operating well below its critical limit, indicating that the materials used in the design are suitable and have a high factor of safety, providing confidence in the structural integrity and reliability of the system.

It is also important to note that the Von Mises stress measures the combined effect of all the stresses in a material, considering both tensile and shear stresses. By comparing this value to the yield strength of the materials, we can assess their ability to withstand the applied load, indicating that the design is robust and capable of withstanding the applied forces or pressure without any concerns of failure.

Table 2: Comparison with the State of the Art

S/N	SOTA Dror & Shimshoni, 2008	CURRENT WORK	REMARKS
1	Performed based on 3D reconstruction of the whole tree.	3D modeling of individual parts.	Current work gave room for assigning material that guides in simulation.
2	There is no room for assembling parts.	Assembling of parts carried out.	
3	No meshing of the Model.	Meshing was carried out.	Meshing helps in proper analysis.
4	No analysis was carried out.	Wind load analysis carried out.	Current work shows the model behavior due to wind.
5	No static simulation	Static simulation carried out.	Current work shows the model behavior due to all the dead and live loads.

V. CONCLUSION

An artificial palm tree was successfully modeled using Solidworks software. Accordingly, the modeled tree was simulated for fluid dynamic and static analysis while applying all the possible loads and twice the maximum wind speed experienced by Afaka and Environs for two years, considering all the loads exerted by the tree. The virtual simulations allow for the maximization of the structure, ensuring it complies with safety standards, and the results of VonMise's stress show that the material selected for the design is suitable for the work. We can conclude that our main objective was achieved. Hence, the tree can be constructed to serve its purpose successfully.

- **Conflict of Interest:** There is no conflict of interest.

- Author Contribution Abubakar, Buhari: Conceptualization, Modeling and Simulation, Writing – original draft. Garba, Danladi King: Main supervisor, correction and editing. Imam, Abubakar Sadiq: Assistant Supervisor, input and editing. Yakubu, Shuaibu Ochetengu: Assistant Supervisor II, input and editing.

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