UPRM's CHRES Summer Research Program 2023

PROGRESS REPORT PRESENTATION

DE-NA0003982

Presentation

Hi, I’m Ian G. Padín Aponte, I’m an undergraduate student from the Mechanical Engineering Department of the University of Puerto Rico at Mayagüez and currently going to my six year on august. I’m passionate on topics such as mechanical designs, simulations and the process of manufacturing. My skills reside on designing, 3D printing and mechanical simulations. Some applications or software's that I use are Fusion 360, AutoCAD and Ansys. In addition, I like to participate on special projects or other activities that could increase my knowledge.

Work Description

- Across this summer internship under CHRES I have been working on designing and analyzing a solar panel mount. This mount must be resistant to the climate change present in Puerto Rico taking into consideration the natural disasters such as hurricanes. Other aspects to take into consideration for this project is the accessibility of the materials used in the design and economical aspect of the completed mount.

Initial Consideration and Decision

Solar Panel Description

- Monocrystalline solar, with a capacity of generating 370 Watts and has dimensions of [1755 x 1038 x 35][mm] with 45.2 [lb] of weight per panel.

Quantity of panels based on selection

- For the analysis made it was arrived that it was needed 7 panels. This was obtained using the values of the house I currently live. The process consisted of taking the energy statement of the house and used the highest consumption number across the year and dividing it by the bill cycle obtaining 10 Kw/h. Next, assuming 4 hours of peak sun it was divided the daily consumption with the hours obtaining 2.5 kW and finally the obtained value was divided by the capacity of the panel (370 W) obtaining a value of 6.76 panel giving a total of 7 panels for the analysis.

Equation: $\frac{Daily\ Consumtion}{Peak\ Sun\ Hours} = \frac{Watts}{Production\ Watts} = Numbers\ of\ Panels$

Design Process

Solar Panel Angle

- The solar panel mount was decided to be in an 18 degrees angle considering the latitude at which Puerto Rico is located. Having this angle enables for the solar panel to take advantage in the generation of energy at which the sun is perpendicular to the angle of the panel. Although the optimal angle change in winter and summer being in winter 33 degrees and in summer 3 degrees.

Mount Designs

- Taking into consideration the angles mention. First it was designed a fix structure at 18 degrees looking at the South. After finishing the design there was some flaws to be fix or change and it was created a second design in which the angle could be change from 18 degrees to 0 degrees in case of emergencies.

Materials and Structure of Designs

Design 1: (Static Design) [SD]

- The first design is composed of 5 triangular structures made of squared tubes of ¼ of thickness. On the diagonal square tube are 4 T-Slotted framing rails that are bolted to the structure using bolts of ½ of diameter. On top of the rails are the solar panels that are fixed to the frame using clamps.

Design 2: (Dynamic Design) [DD]

- This design consist of the same idea of the first but using 90 degrees angle L's instead of square tubes. These change enables the mount to change the angle making it safer in emergencies such as storms. Giving more protection to the integrity of the structure, but it has also to be considered that the change in materials reduces the strength or resistance to wind.

* Angles and distances were obtained using the Law of Sine

Pictures Of The Design Components: (SD)

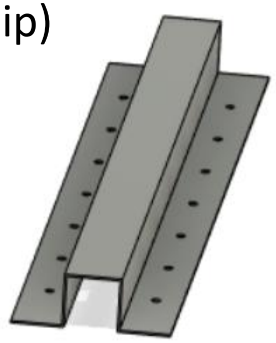
Triangle structure

T-Slotted Frame Rail

End Clamp

Concrete Bolt

Ground Supporter (Clip)



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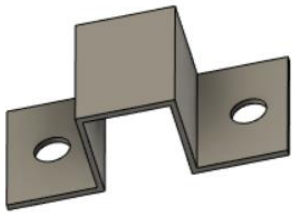

Heavy Hex Bolt

T-Bolt

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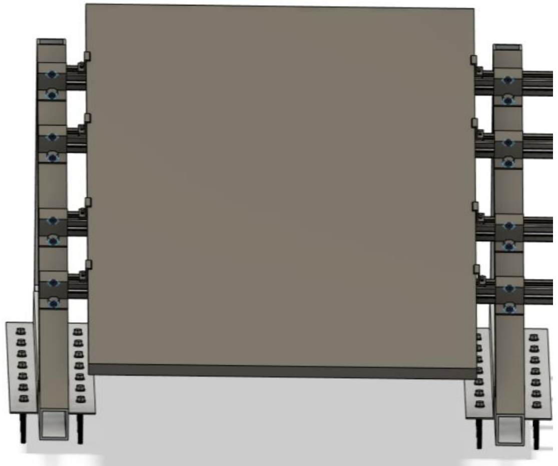
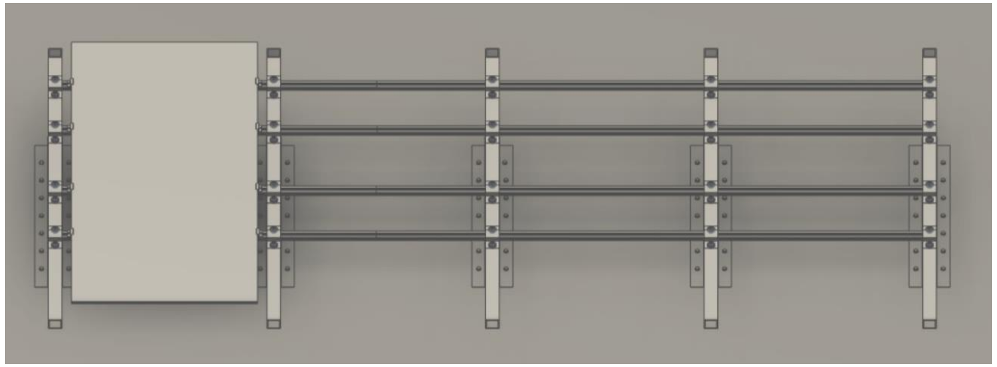
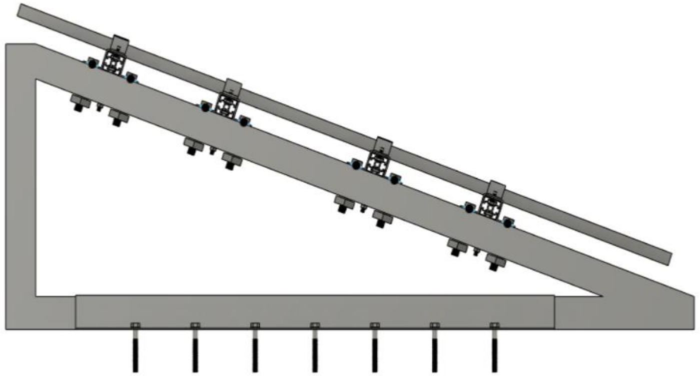
Assembly Pictures: (Static Design)

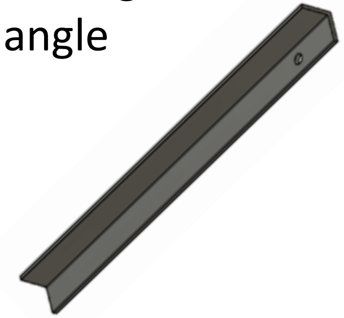




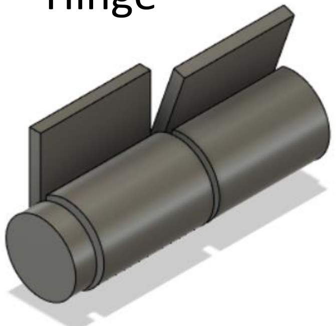


Pictures Of The Design Components: (DD)

90-degree steel angle



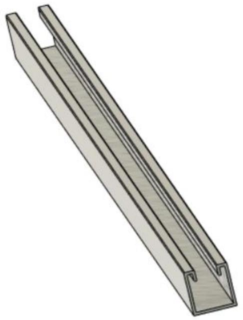
Hinge



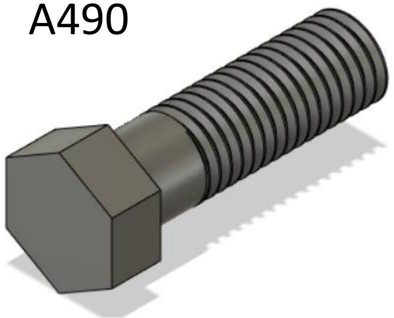
Wedge Anchor

End Clamp

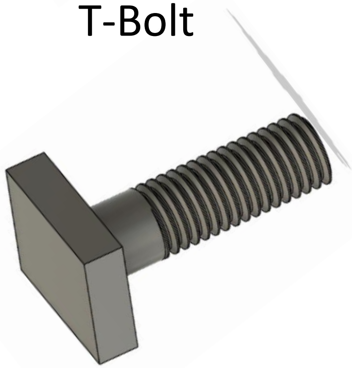
Strut Channel



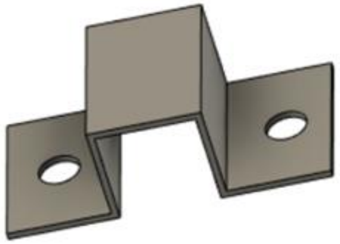
Heavy Hex Bolt A490



T-Bolt



Clip



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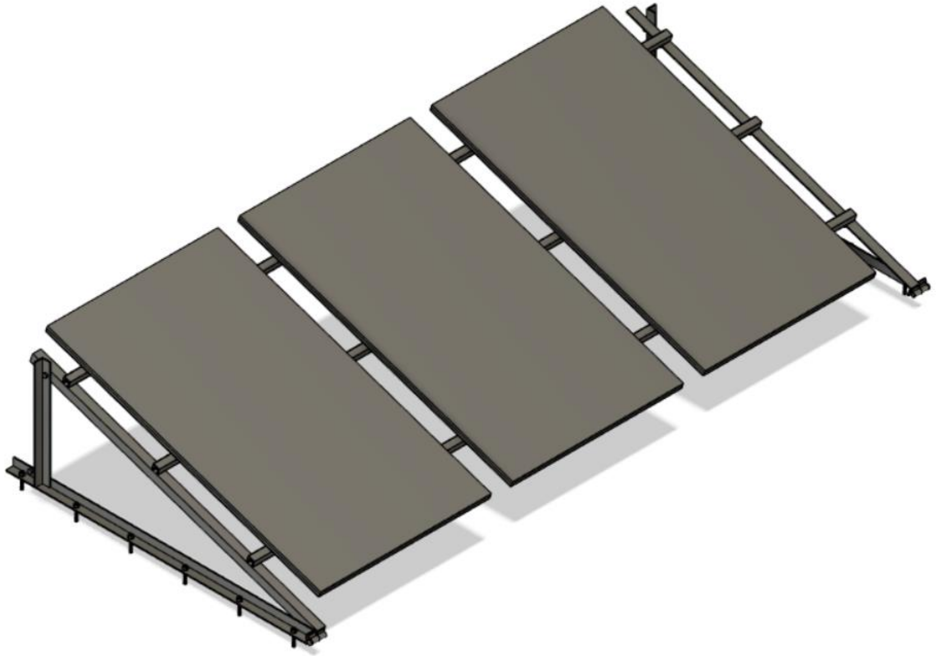
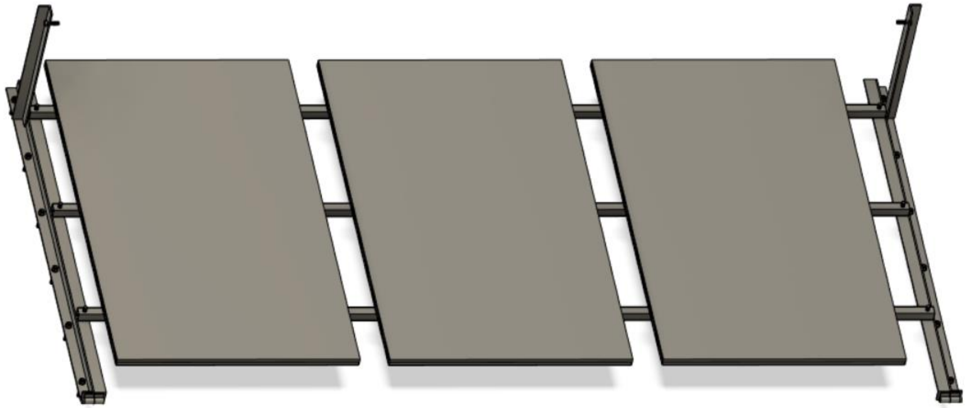
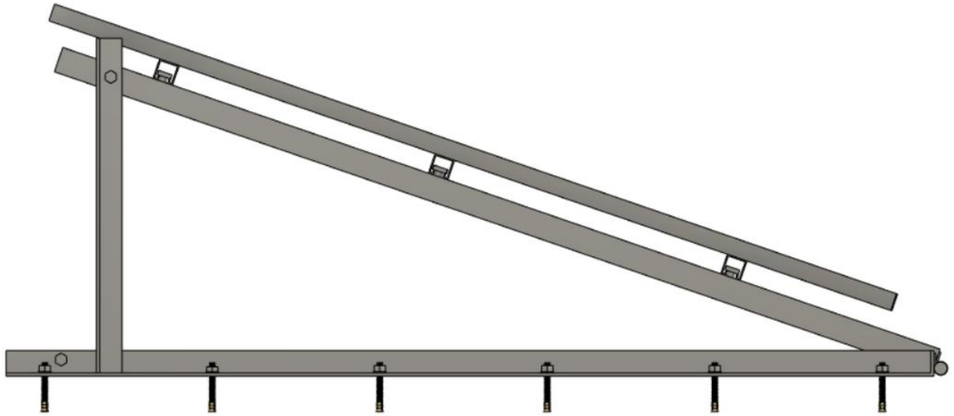
Assembly Pictures: (Dynamic Design)







Advantage and Disadvantage of Designs

Advantage

Static Design:

- Resistance to strong winds.
- More capacity for solar panels.
- Stronger components.

Advantage

Dynamic Design:

- Angle can be adapted depending the situation.
- Has less components in the structure.
- Its economically accessible.

Disadvantage

Static Design:

- Quantity of materials used.
- Expensive to construct.
- In case of storms, it cannot be adapted.

Disadvantage

Dynamic Design:

- Less resistant to winds.
- Less capacity for solar panels.
- Weaker components.

Materials and Bill list

Material list and bill for the solar panel mount Square tubes structure				
List of Materials				
List #	Name of Product	Quantity needed	Price	Total Price
1	Solar Panel of [1755 x 1038 x 35][mm]	4	$300.00	$ 1,200.00
2	Galvanized Steel Squared Tube [3 x 3 x 0.25][in] of 20 ft long	4	$262.06	$ 1,048.24
3	Black Steel A36 Smooth Plate [4' x 8' x (1/8")]	3	$175.00	$ 525.00
4	Aluminum T-Slotted Framing of 10'	4	$75.56	$ 302.24
5	Aluminum T-Slotted Framing of 8'	4	$61.85	$ 247.40
6	Black-Oxide Steel Machined Neck T-Slot Bolt: [M10 x 1.5 mm Thread, 60 mm Thread Length, 10 mm Wide Slot]	20	$18.27	$ 365.40
7	Flat Washer M10	20	$0.14	$ 2.80
8	Hex Nuts M12-1.50	20	$0.72	$ 14.40
9	Heavy Hex Bolt A490 [3/4 x 4-1/2]	40	$4.00	$ 160.00
10	Stainless Steel 316 Hex Nut 3/4-10	40	$3.18	$ 127.20
11	Flat Washer F436 Heavy 3/4	40	$4.63	$ 185.20
12	Tapcon 1/2 in. x 3 in. Hex-Washer-Head Large Diameter Concrete Anchors	70	$35.00	$ 245.00
13	End Clamps for Solar Panels	32	$59.99	$ 59.99
			Total Material Price	$ 3,282.87

Material list and bill for the solar panel mount L' structure				
List of materials				
List #	Name of Product	Quantity needed	Price	Total Price
1	Black Steel Angle1/4" Thick, 2" x 2" x 20',Black Steel A36 / A529-50	2	52.95	105.9
2	10 ft. 12-Gauge Half Slotted Metal Framing Strut Channel in Silver Galvanized	4	35.57	142.28
3	2 ft. 12-Gauge Half Slotted Metal Framing Strut Channel - Silver Galvanized	0	15.73	0
4	1/2 in. x 3-3/4 in. Wedge Anchor (25-Pack)	1	27.77	27.77
5	Steel Machined Neck T-Slot Bolt: 5/8"-11 Thread Size, 2" Long	6	4.81	28.86
6	5/8 in. Zinc-Plated Create-a-Bolt with Nuts, Washers & Lock Washers (4 of Each Piece)	2	5.72	11.44
7	Heavy Hex Bolt A490 5/8 x 2	4	1.63	6.52
8	Flat Washer Stainless Steel 316 5/8	4	0.52	2.08
9	Heavy Hex Nut A193 2H 5/8	4	0.9	3.6
10	4 Pcs 3⅜ x 1⅝ inch Weldable Lift Off Hinges, Heavy Duty Metal Door Hinges Steel Gate Flag Hinges with Removable Pin	1	21.99	21.99
11	End Clamp Solar Panel Mounting	18	37.99	37.99
			Total Price	388.43

Simulation Process

Process:

- For the simulation process it was first obtain the force of drag that felt the structure on the different components at different velocities. Then this information was brinded to Ansys to perform and obtain the deflection and stress that the component in analysis has.

Equation used:

- $Fd = Cd * A * \frac{\rho * V^2}{2}$

Legend:

Fd = Drag Force	A = Area	V = Velocity
Cd = Coefficient of Drag	ρ = Density	∴ Density is assumed at 1 atm and 25 Celsius

Wind Velocities and Descriptions

Beaufort number	Description	Speed	Visual Clues and Damage Effects
0	Calm	Calm	Calm wind. Smoke rises vertically with little if any drift.
1	Light Air	1 to 3 mph	Direction of wind shown by smoke drift, not by wind vanes. Little if any movement with flags. Wind barely moves tree leaves.
2	Light Breeze	4 to 7 mph	Wind felt on face. Leaves rustle and small twigs move. Ordinary wind vanes move.
3	Gentle Breeze	8 to 12 mph	Leaves and small twigs in constant motion. Wind blows up dry leaves from the ground. Flags are extended out.
4	Moderate Breeze	13 to 18 mph	Wind moves small branches. Wind raises dust and loose paper from the ground and drives them along.
5	Fresh Breeze	19 to 24 mph	Large branches and small trees in leaf begin to sway. Crested wavelets form on inland lakes and large rivers.
6	Strong Breeze	25 to 31 mph	Large branches in continuous motion. Whistling sounds heard in overhead or nearby power and telephone lines. Umbrellas used with difficulty.
7	Near Gale	32 to 38 mph	Whole trees in motion. Inconvenience felt when walking against the wind.
8	Gale	39 to 46 mph	Wind breaks twigs and small branches. Wind generally impedes walking.
9	Strong Gale	47 to 54 mph	Structural damage occurs, such as chimney covers, roofing tiles blown off, and television antennas damaged. Ground is littered with many small twigs and broken branches.
10	Whole Gale	55 to 63 mph	Considerable structural damage occurs, especially on roofs. Small trees may be blown over and uprooted.
11	Storm Force	64 to 75 mph	Widespread damage occurs. Larger trees blown over and uprooted.
12	Hurricane Force	over 75 mph	Severe and extensive damage. Roofs can be peeled off. Windows broken. Trees uprooted. RVs and small mobile homes overturned. Moving automobiles can be pushed off the roadways.

Link of Source:

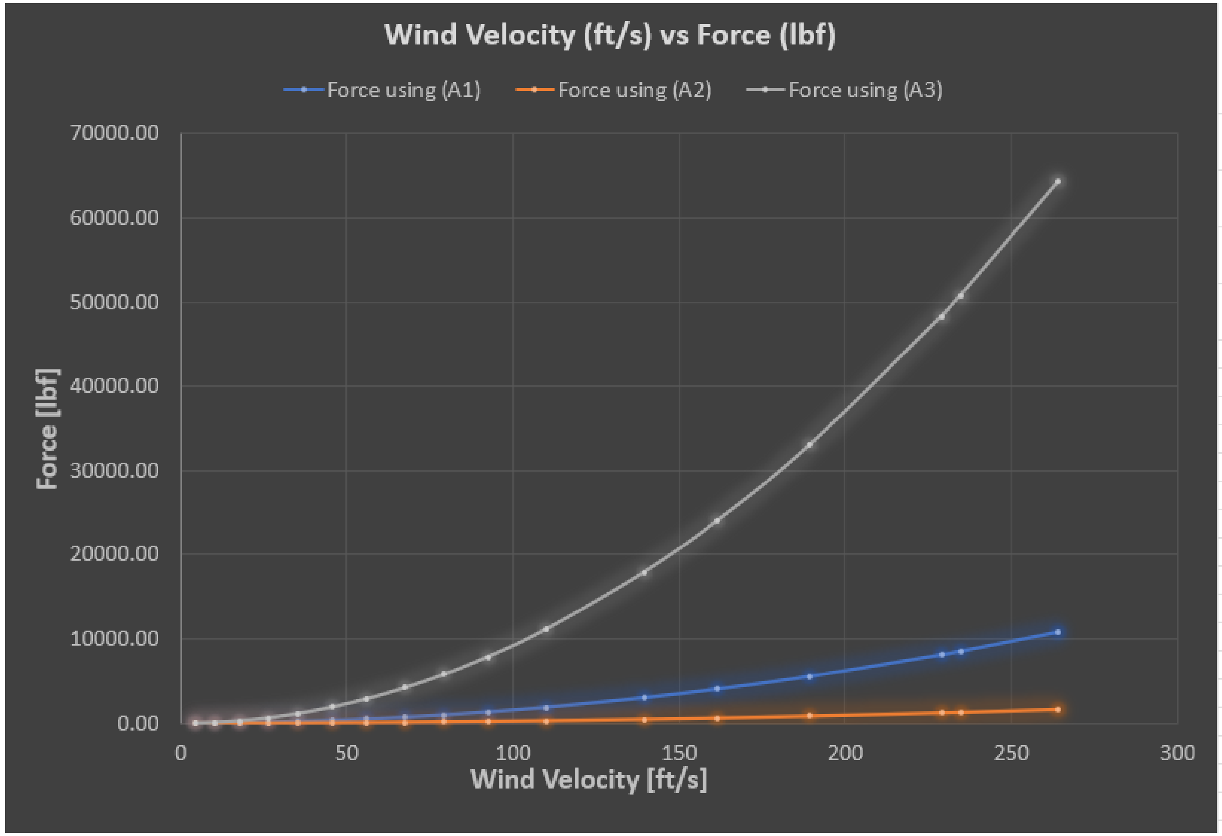
https://www.weather.gov/pqr/wind

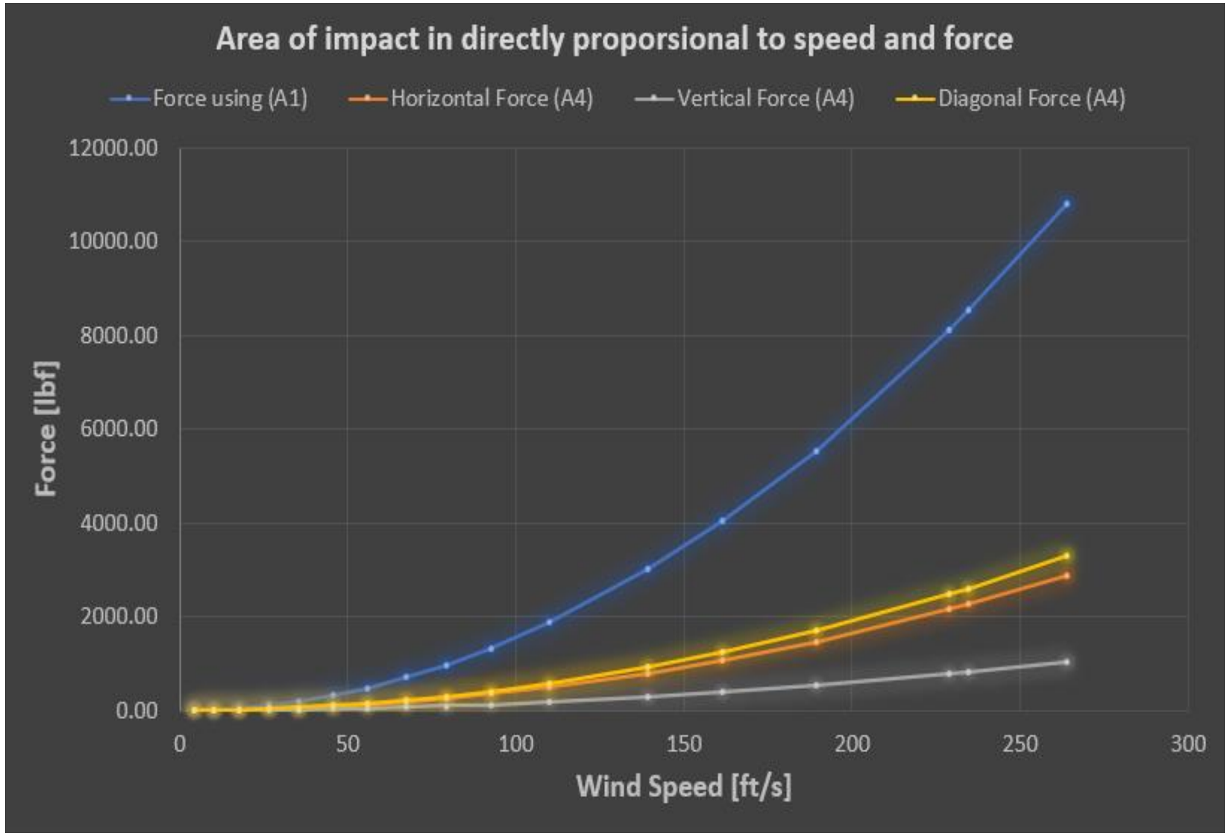
Force Calculations and Assumptions

Force Calculations in the system due to wind force (Drag)

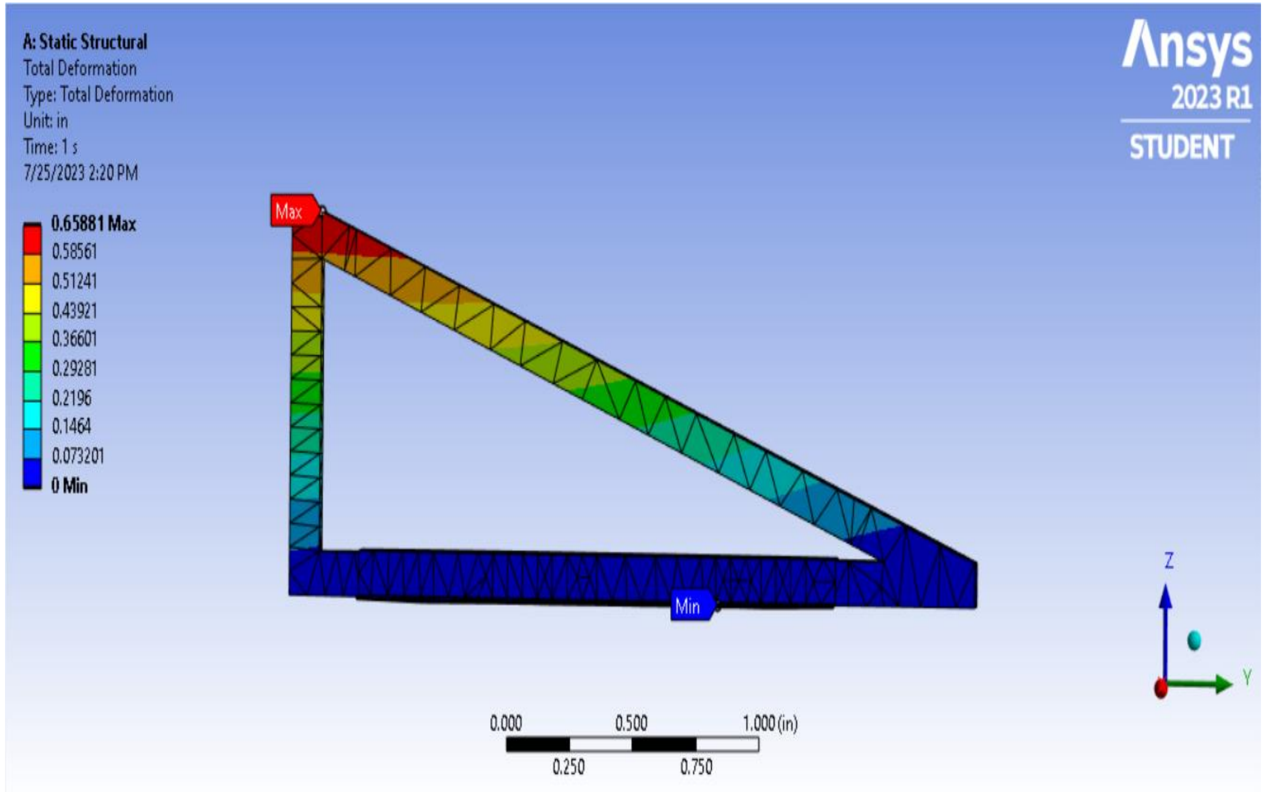
Wind Speed (mph)	Wind Speed (ft/s)	Area of the system			Density of air in (lbm/ft^3) (assuming 1 atm and a constant temperature of 25 Celcius) (77 Fahrenheit)	Coefficient of Drag		Force (Fd) [lbf]					
		Area sides for analysis	Area (in^2)	Area (ft^2)	0.0739	Coefficient of drag for a rectagular	1.28	Force using (A1)	Force using (A2)	Force using (A3)	Horizontal Force (A4)	Vertical Force (A4)	Diagonal Force (A4)
3	4.401	Side Area of triangle structure (A1)	471.197	3.272				3.00	0.46	17.85	0.80	0.29	0.91
7	10.269	Back side of triangle structure (A2)	71.750	0.498				16.32	2.49	97.20	4.34	1.57	4.98
12	17.604	Back side of solar panel structure (A3)	2806.333	19.488				47.96	7.30	285.64	12.75	4.60	14.63
18	26.406							107.91	16.43	642.70	28.69	10.36	32.91
24	35.208	Second Design						191.84	29.21	1142.57	51.01	18.41	58.51
31	45.477	Triangular Structure (A4)						320.07	48.74	1906.27	85.10	30.71	97.62
38	55.746	Horizontal	125.28	0.87				480.94	73.23	2864.37	127.87	46.15	146.68
46	67.482	Vertical	45.216	0.314				704.76	107.31	4197.37	187.38	67.63	214.95
54	79.218	Diagonal	143.712	0.998				971.21	147.89	5784.27	258.22	93.20	296.21
63	92.421							1321.92	201.29	7873.04	351.47	126.85	403.18
75	110.025							1873.47	285.28	11157.94	498.11	179.78	571.40
95	139.365							3005.88	457.71	17902.29	799.19	288.44	916.77
110	161.37							4030.05	613.66	24001.96	1071.49	386.72	1229.14
129	189.243							5542.48	843.96	33009.64	1473.61	531.86	1690.42
156	228.852							8105.39	1234.22	48273.70	2155.03	777.79	2472.09
160	234.72							8526.38	1298.33	50781.01	2266.96	818.19	2600.49
180	264.06							10791.20	1643.19	64269.71	2869.12	1035.52	3291.24

Area, Speed and Force Relations



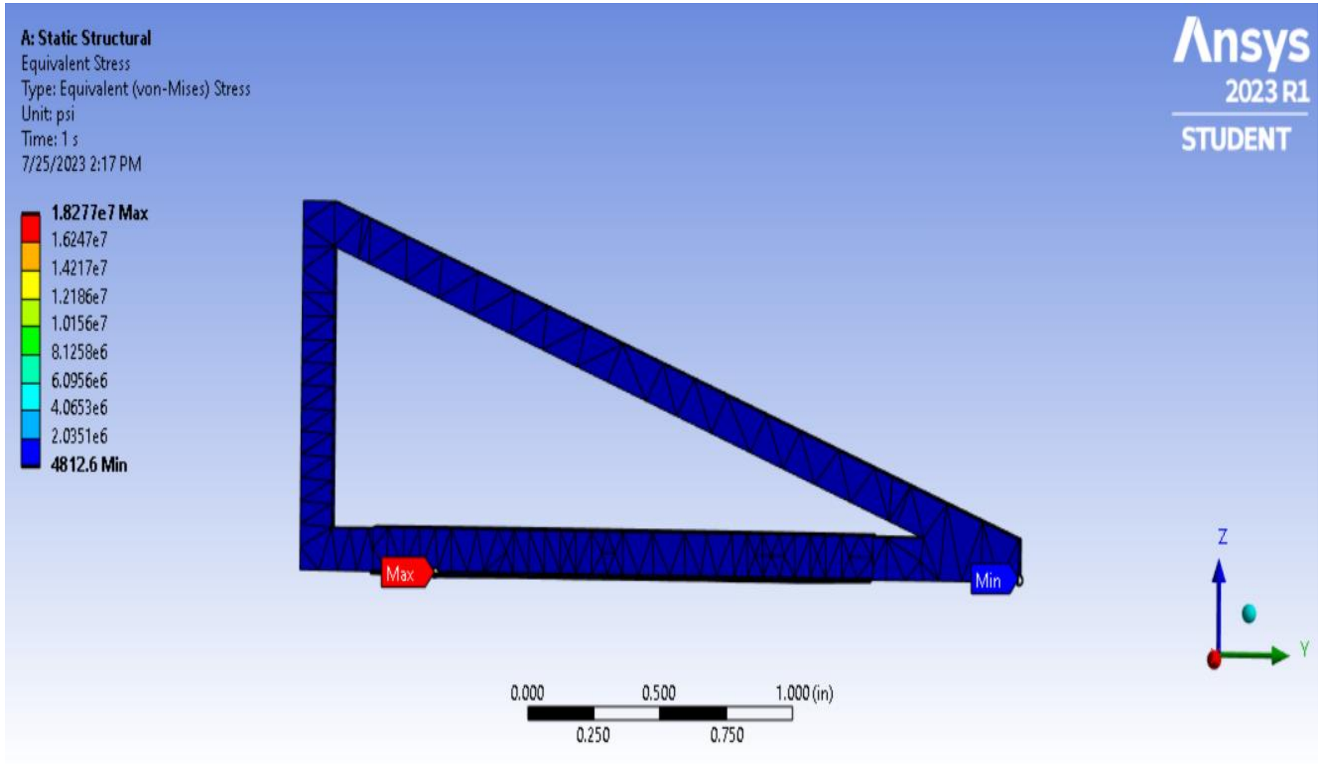


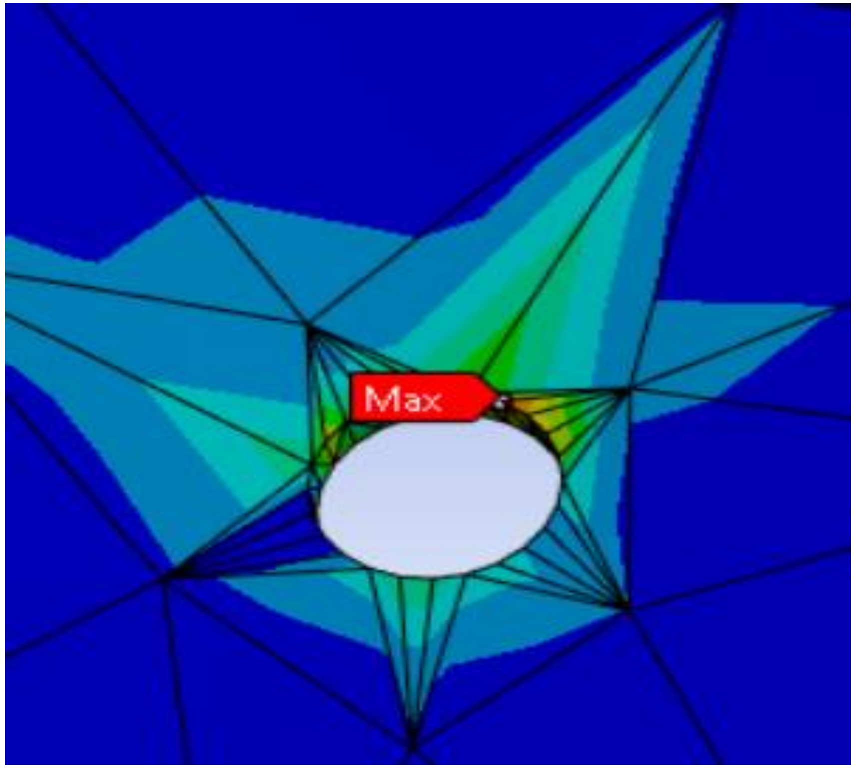
Results from Static Design



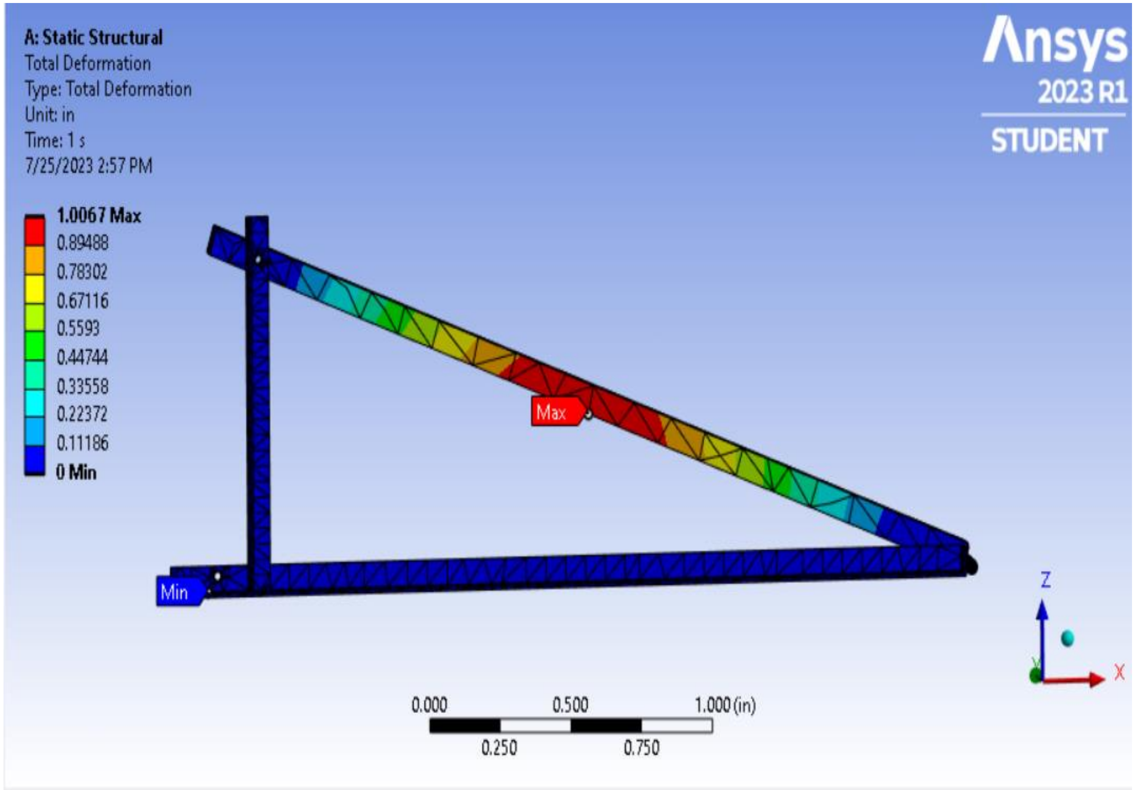
Deflection and Stress from Static Mount				
Velocity		Deflection on triangular section	Stress on triangular section	Force (lbf)
MPH	Ft/s	in	psi	
3	4.401	0.0080902	7.86E+05	2.997555
7	10.269	0.01163	9.87E+05	16.32002
12	17.604	0.032841	1.47E+06	47.96088
18	26.406	0.073417	2.37E+06	107.912
24	35.208	0.1303	3.64E+06	191.8435
31	45.477	0.21723	5.75E+06	320.0723
38	55.746	0.3263	8.85E+06	480.9411
46	67.482	0.47806	1.32E+07	704.7585
54	79.218	0.65881	1.83E+07	971.2079
63	92.421	0.89629	2.50E+07	1321.922
75	110.025	1.271	3.56E+07	1873.472
95	139.365	2.0387	5.74E+07	3005.882
110	161.37	2.7342	7.71E+07	4030.046
129	189.243	3.7603	1.06E+08	5542.479
156	228.852	5.4993	1.56E+08	8105.389
160	234.72	5.7849	1.64E+08	8526.379
180	264.06	7.3214	2.07E+08	10791.2

Deformation and Stress at 54mph



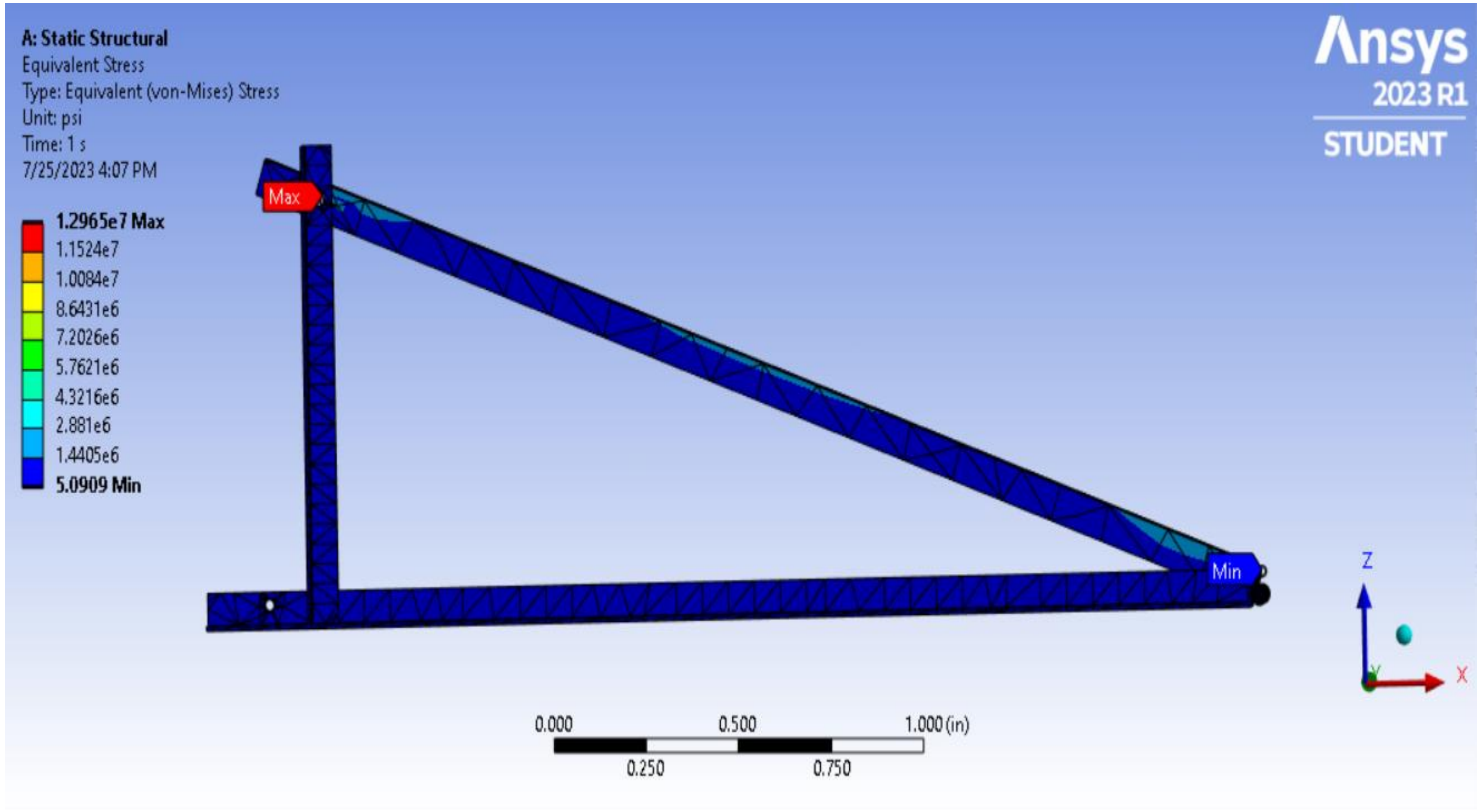


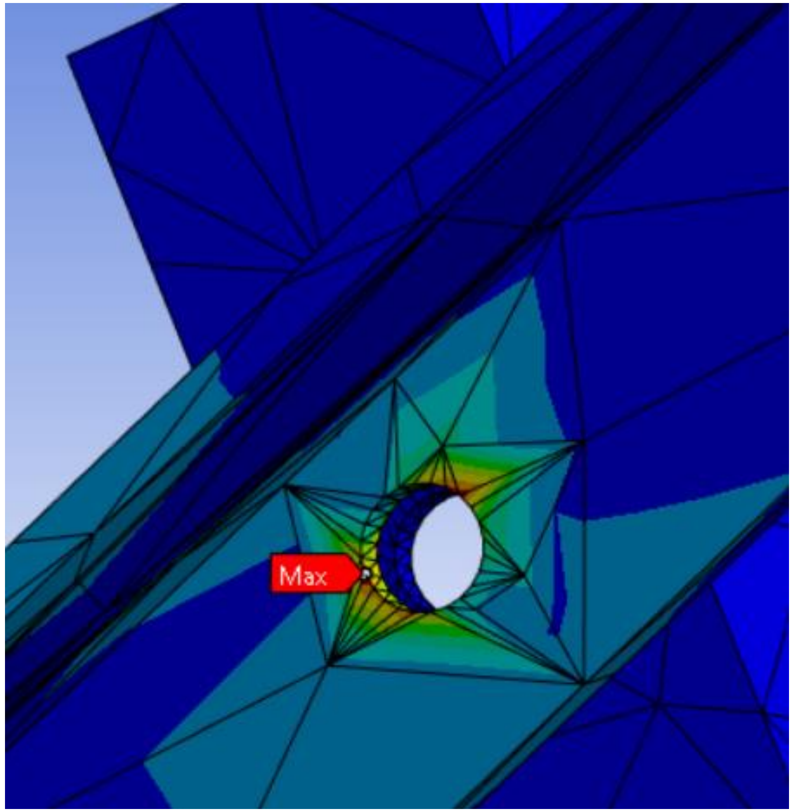
Results from Dynamic Design at 18 degrees



Dynamic Design at 18 degrees						
Velocity		Deflection on triangular section	Stress on triangular section	Force (lbf)		
MPH	Ft/s	in	psi	Horizontal	Vertical	Diagonal
3	4.401	0.1528	2.04E+06	0.796978	0.287645	0.914235
7	10.269	0.16201	2.03E+06	4.339103	1.566067	4.9775
12	17.604	0.18724	1.98E+06	12.75165	4.60232	14.62775
18	26.406	0.23969	2.69E+06	28.69121	10.35522	32.91245
24	35.208	0.31835	3.88E+06	51.0066	18.40928	58.51102
31	45.477	0.47143	5.76E+06	85.09955	30.71409	97.61995
38	55.746	0.66621	8.17E+06	127.8707	46.15104	146.6839
46	67.482	0.93867	1.15E+07	187.3784	67.62853	214.9467
54	79.218	1.2638	1.56E+07	258.2209	93.19697	296.212
63	92.421	1.6924	2.09E+07	351.4674	126.8514	403.1775
75	110.025	2.3668	2.93E+07	498.1113	179.7781	571.3967
95	139.365	3.7522	4.65E+07	799.192	288.444	916.7742
110	161.37	5.0054	6.21E+07	1071.493	386.7227	1229.138
129	189.243	6.8562	8.50E+07	1473.613	531.8556	1690.42
156	228.852	9.9926	1.24E+08	2155.029	777.792	2472.091
160	234.72	10.508	1.30E+08	2266.96	818.1902	2600.49
180	264.06	13.279	1.65E+08	2869.121	1035.522	3291.245

Deformation and Stress at 54mph





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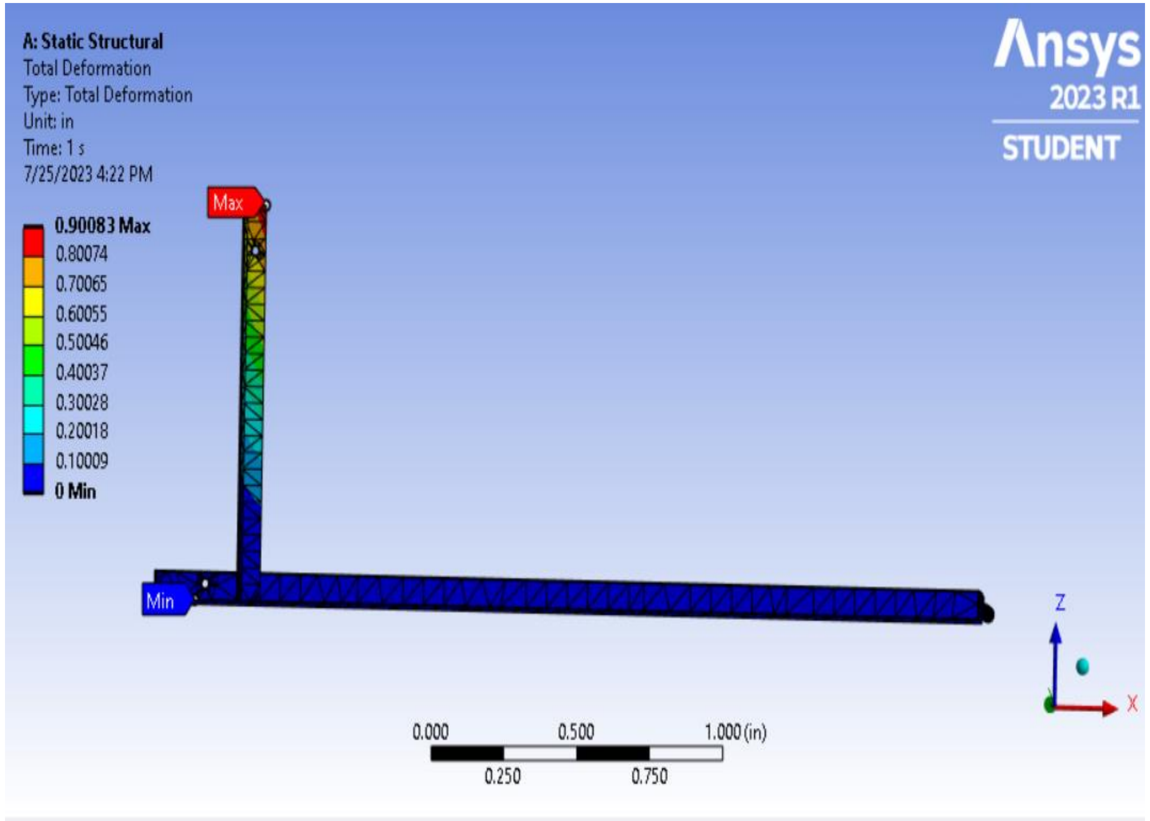
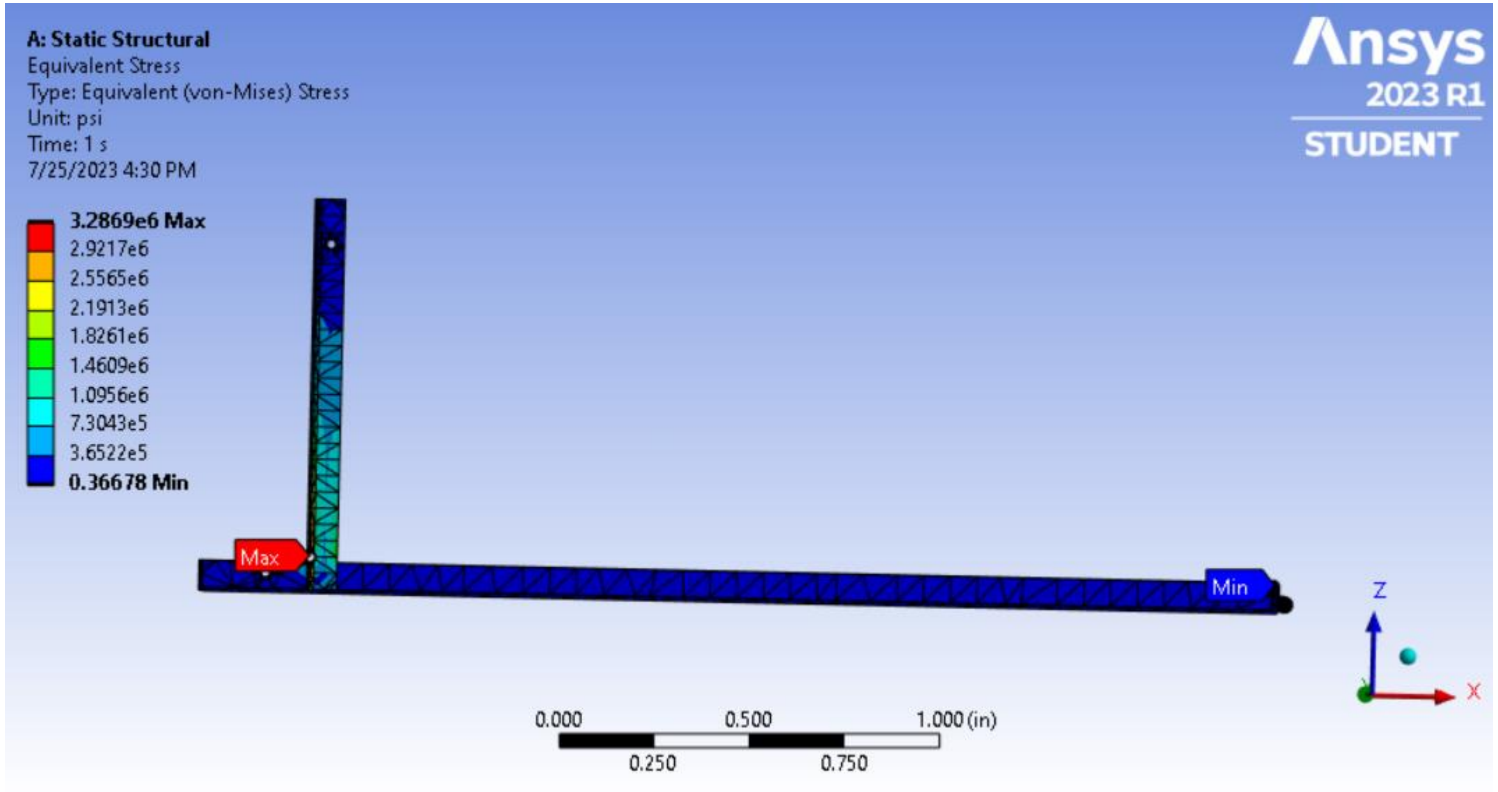
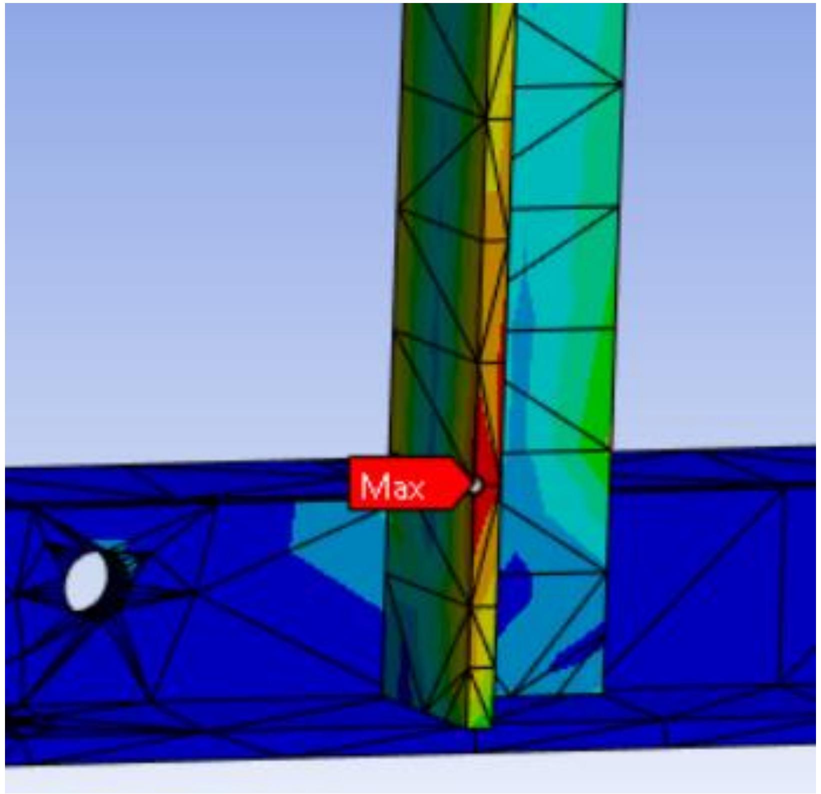
Results from Dynamic Design at 0 degrees



Dynamic Design at 0 degrees						
Velocity		Deflection on triangular section	Stress on triangular section	Force (lbf)		
MPH	Ft/s	in	psi	Horizontal	Vertical	Diagonal
3	4.401	0.0035637	5.99E+05	0.796978	0.287645	0.914235
7	10.269	0.015185	6.20E+05	4.339103	1.566067	4.9775
12	17.604	0.044054	6.70E+05	12.75165	4.60232	14.62775
18	26.406	0.098778	7.66E+05	28.69121	10.35522	32.91245
24	35.208	0.17539	9.00E+05	51.0066	18.40928	58.51102
31	45.477	0.29244	1.11E+06	85.09955	30.71409	97.61995
38	55.746	0.43928	1.60E+06	127.8707	46.15104	146.6839
46	67.482	0.64358	2.35E+06	187.3784	67.62853	214.9467
54	79.218	0.88679	3.24E+06	258.2209	93.19697	296.212
63	92.421	1.2069	4.41E+06	351.4674	126.8514	403.1775
75	110.025	1.7104	6.25E+06	498.1113	179.7781	571.3967
95	139.365	2.744	1.00E+07	799.192	288.444	916.7742
110	161.37	3.6789	1.34E+07	1071.493	386.7227	1229.138
129	189.243	5.0594	1.85E+07	1473.613	531.8556	1690.42
156	228.852	7.3988	2.70E+07	2155.029	777.792	2472.091
160	234.72	7.7831	2.84E+07	2266.96	818.1902	2600.49
180	264.06	9.8505	3.60E+07	2869.121	1035.522	3291.245

Deformation and Stress at 54mph





Conclusion

Based on the results provided by the simulations it can be concluded that between the two designs the more adequate would be the dynamic design. For the reason's that the cost of production is low in comparison to the static design and the angle of the mount can be modified. But it also must be considered that the (SD) is more resistance that the economic one in terms of wind resistance. For this reason, there must be some changes to the second design to increment the resistance to wind and at the same time maintain the mount at al low price.

Reference

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