Raa Tech

Automated Non-Destructive Cleaning of Solar Panels

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Team 303

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Customer Needs

To establish a baseline of what our device will accomplish, interviews were conducted with the sponsor and company employees who clean panels using the conventional method. It was established that the current method of maintaining panels is too bulky and labor intensive. Our goal at Raa Tech is to design and create an automated non-destructive cleaning device that will restore the panel to optimal energy production that is easy to install, operate, and safely remove from a roof or ground array, all while being simple, robust, and able to operate autonomously or by an individual with average capabilities.

Interpreted Needs: As current panel cleaning methods are large and labor intensive, residential system owners do not typically possess their own cleaning equipment. It is more common for the company to send out a team to service your panels when they notice energy production declining. This is an exhaustive task even for them, despite these employees being accustomed to labor intensive activities. Not to mention, the employees sent to clean the systems spend about the same amount of time cleaning as they would on a job site, where they could install a system itself. From a business standpoint, these companies would benefit from their employees spending less time managing systems, and more time installing new ones. Some key points we've narrowed down to include the following:

- Perform cleaning duties without requiring a human operator for the duration, allowing company employees to continue day-to-day operations elsewhere; although this system may require periodic monitoring.
- A lighter, easier to operate, mostly self-driven device that avoids damage to the roof or pre-existing solar structure

- Traverses array with the aid of sensors
- Capable of cleaning various levels of material buildup on panels
- Reduce weight by requiring less water which may be done by spraying a long narrow focused jet of solution on the panel directly in front of the brushes.

Table 1 Customer Needs

No.	Rating	Need/Statement	Interpretation	Source
1	3	Lightweight	Light enough to sit on panels, and relatively easy installation	Customer/ Current User
2	2	Autonomous	Cleans by itself using microcontroller	Customer
3	4	Power Requirement	How will the robot receive power and voltage	Customer
4	1	Clean Panels	Properly Clean Solar Panels	Customer
5	6	Interchangeable Brushes	Provides multiple cleaning methods	Customer
6	5	Solution Tank	Reservoir to hold cleaning solution	Customer
7	7	Nema Rated	Will be water Resistant	Customer

Main Task: To be able to clean neglected panels, but also gentle enough to use for general maintenance while not overwhelming the user or consuming unreasonable amounts of time.

Methods and Cleaning Process: When discussing cleaning methods with the customer, we determined the need for controlling the intensity of the cycle itself. This led to us deciding to implement a system of interchangeable brushes. For lightweight cleans such as removing pollen, softer brushes will be attached and a lower power cycle selected; which may or may not require the use of a cleaning solution. The amount of cleaning cycles and brush heads is yet to be determined.

Cleaning Solution Tank Location: A major design concern at this point is cleaning solution delivery. When this topic was presented to the customer, we received the response"For this to be an autonomous device, the design will contain or be equipped with the means to provide to itself whatever is necessary to perform the task at hand". Since the robot uses water *and* solution to clean the solar panels, a tank will be accounted for along with a constant water delivery method. We have discussed many options as to how we intend to tackle this challenge including but not limited to: a reservoir on the roof, ground or contained on the device itself. Each of these approaches will lead to more considerations, such as increased weight or extra system components that could potentially damage pre-existing structures. .

Weight and Size: Our constraints in the weight department are determined by ease of user use and avoidance of damage to the pre-existing structure. Since the weight of the robot is a major topic when dealing with glass, the team asked the customer what the maximum weight a solar panel could hold. With each panel having a different thickness of glass, the customer did not provide specific margins limiting weight and size, but did reply by saying "the lighter the better". By not having a specific weight limitation, the team of engineers will take in account weight distribution by utilizing the chart shown in Figure 1 below. Once the team creates the initial test design it will then be tested on an array of panels that are not in operation.

Fig1-Thickness, Weight, and Size Tolerances of various Glass Types

Type of glass	Nominal thickness t of glass (mm)	X, the maximum evenly distributed safe load per unit area in kg/m² supported by the following lengths L of glass (in mm)															
		300	400	500	600	650	700	750	800	850	900	1000	1100	1200	1300	1400	1500
Annealed	4	153	86	55	38	33	28	24	21	19	17	14	11	10	8	7	6
	5	244	137	88	61	52	45	39	34	30	27	22	18	15	13	11	10
	6	356	200	128	89	76	65	57	50	44	40	32	26	22	19	16	14
	8	627	353	226	157	134	115	100	88	78	70	56	47	39	33	29	25
	10	995	559	358	249	212	183	159	140	124	111	90	74	62	53	46	40
	12	1447	814	521	362	308	266	232	203	180	161	130	108	90	77	66	58
Laminated	4	69	39	25	17	15	13	11	10	9	8	6	5	4	4	3	3
	6	166	93	60	41	35	30	27	23	21	18	15	12	10	9	8	7
	8	305	172	110	76	65	56	49	43	38	34	27	23	19	16	14	12
	10	487	274	175	122	104	89	78	69	61	54	44	36	30	26	22	19
	12	711	400	256	178	152	131	114	100	89	79	64	53	44	38	33	28
Toughened	4	988	417	213	123	97	78	63	52	43	37	27	20	15	12	10	8
	5	1991	840	430	249	196	157	127	105	88	74	54	40	31	24	20	16
	6	2997	1482	759	439	345	276	225	185	154	130	95	71	55	43	35	28
	8	5283	2972	1775	1027	808	647	526	433	361	304	222	167	128	101	81	66
	10	8383	4716	3018	2054	1615	1293	1051	866	722	608	444	333	257	22	162	131
	12	12197	6861	4391	3049	2598	2240	1845	1520	1268	1068	778	585	450	354	284	231
Cast	4	129	73	47	32	28	24	21	18	16	14	12	10	8	7	6	5
	6	320	180	115	80	68	59	51	45	40	36	29	24	20	17	15	13
	10	895	503	322	224	191	164	143	126	111	99	81	67	56	48	41	36

Power: Providing the system with power has also proven to be a vital design consideration that will require either the use of long power cables or otherwise a heavy battery on the device itself. We have participated in multiple discussions where we considered tapping into the solar system generated power supply itself, but depending on the system being cleaned, the available power supply will likely vary. The customer mentioned that a 120V AC source may be present; but an AC compact generator will be required otherwise. Input and output voltages will also determine the interface we use to communicate with the device, which will depend on motor characteristics.

Array Size Limitations: When the team asked the customer what size array to base the initial design on, the response was “I would like to make a version of this device to incorporate the residential market as well, we are currently focused on marketing towards solar installation companies that regularly service their residential customer’s panels”. This being said, residential systems can at times be nearly as large as small commercial jobs. The team will assume the robot will be cleaning an array with at most one hundred panels, arranged in a single rectangular formation. At our current stage in the design process we are concerned more so with the mechanics of the system itself rather than the autonomy of the machine. After a design is chosen, sensors and controls will be incorporated to add convenience for the user. An example of this may include the cleaning device mapping edges of the array and planning its path, or the user manually entering the number of panels, rows, and columns along with panel type and whether they are horizontally or vertically arranged. Each of these features must be kept in mind throughout the design process, as they will add weight to the system.

NEMA Rating: The system's Nema rating will be considered during the duration of the design process for the device. The customer prompted the team to steer away from creating the type of device that would have to comply with NEMA ratings and have determined we can do so unless this system were to be permanently installed on the roof. Since the robot will not need to be inspected initially, the waterproof rating of the system will depend on the motor and controls and how the components are enclosed from the factory, especially since water is a vital system component.

References:

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