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Design and Analysis of Solar Operated Solar Panel Laminating Machine

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ABSTRACT
This research paper demonstrates the design and analysis of solar operated solar panel laminating machine. Lamination is one of the most critical processes in solar panel manufacturing, it ensures the quality and durability of photovoltaic modules. For lamination of these solar panels certain machines are available in the market, but they can only be operated using AC power and are very costly. In this article the design calculation of solar operated solar panel laminating machines are carried out which is less costly and can be operated by using both AC power as well solar power and can be used to laminate solar panels of power up to 100W. Compact size panel laminating machine which is used for lamination of solar panels of power rating up to 100W in 15 min with 5600W of electric heaters and 50m3/hr, flow rate of vacuum pump. From design calculation a maximum load of 476 Kg is to be applied for adhesion of solar modules with laminating material. The 3D model is created on a 3D experience platform software. According to the results obtained by Python programming analysis Aluminium alloy HE 30 is the best suitable material for heating plates. From the ANSYS thermal simulation the temperature difference of 0.34°C has been found out between the top and bottom surface of the heating plate which validates the design results done using Fourier's law of conduction. By using solar systems of 1500W and battery storage systems of 600Ah capacity the machine is operated in a cost-effective way to laminate the solar panels with the use of solar system.
Keywords - Solar panel, Laminating machine, AC power, Python programming, 3D experience platform.

1. INTRODUCTION

Lamination is one of the most critical processes in the solar panel manufacturing line; it ensures the quality and durability of photovoltaic modules. Lamination is a process of encapsulation of a solar module between two layers of laminating material. The most used laminating materials are EVA, TPO, and PVB. Existing solar panel laminating machines are meant for lamination of larger size solar panels which are heavier, costly

A new design has been devised to laminate the solar panels in a cost and energy efficient way by using AC power as well as solar power stored in batteries. In a solar operated solar panel laminating machine a solar module is laminated by sandwiching it between two layers of laminating materials such as EVA(Ethylene Vinyl Acetate), TPO, or PVB. The process of laminating starts with removing the air from the heating chamber so that no air bubble should be formed in the laminated panel and then heating the layup up to the temperature 135-140°C and pressing the layup together for a period of 15 minutes. Solar system is designed according to the load of the laminating machine so the machine can be operated by using the energy stored in the battery, reducing operating cost and being energy efficient. Schulze. et al. [1] have worked on the influence of the vacuum lamination process on laminate properties. This paper describes the various techniques which are identified to optimize the vacuum lamination process according to simulation results obtained by carrying tests. Hurter. et al. [2] have simplified encapsulation of solar cells using glass fibre reinforced polymers. This paper describes the various processes used to encapsulate solar cells and from the test results vacuum bagging is the best suited process for lamination of solar panels. Schulze. et al. [3] have worked on mechanical behaviour and lamination issues of solar modules containing elastomeric and amorphous encapsulates. This paper describes the mechanical behaviour and different properties of laminating material. Wiesmeier. et al. [4] have done an overview of PV module encapsulation materials**.** This paper describes the different types of encapsulating materials and to ensure the reliability EVA is best suited under different conditions.

Cattaneo. et al. [5] have studied the lamination process and encapsulation materials for glass–glass PV module design. photovoltaics international**.** This paper describes the typical lamination process for solar PV modules. Shi Lei. et al. [6] have invented a new hybrid heating system for solar cell module laminators. In this paper the researchers have developed a new hybrid heating system i.e. the gasoline-electric heating system to increase the thermal efficiency of the lamination machine. Bing-Mau chen. et al. [7] have done optimization of solar module encapsulant lamination by optical constant determination of Ethylene-Vinyl Acetate. Depending upon the physical properties of encapsulant materials and solar cells and operating temperature the properties of encapsulants can be optimized M.A.M Sobri. et al. [8] have studied Effect of different lamination temperatures on the quality of solar modules. From the mentioned paper we got the temperature of 133℃ for the suitable and perfect lamination of solar cells using EVA. Hiroshi Nagate. et al. [9] have worked on substrate type solar lamination. The laminated material includes support, and roller attached to the laminating material and photosensitive transfer layer overlayed on support Tingqiao Ye. et al.[10] have invented a high performance insulating hybrid photovoltaic thermal solar panel core and manufacturing method. It allows aluminum base polymer integrated to plate to have a better transmission of light.Anthony J. Armini. et al. [11] have worked on a multilayer laminate assembly which includes a processing chamber to receive the laminating assembly. The processing chamber is provided with independent control of temperature and vacuum pressure for effective optimum processing conditions.Prem Nath. et al. [12] have worked on solar cell lamination apparatus for simultaneous lamination of thin polymeric sheets onto at least one surface of plurality of spacedly disposed substrate such as photovoltaic modules.

Analysis of the system is carried out using python programming language, a general code is written which by performing operations on input values provided such as heating plate material, vacuum pump capacity, size of solar panel gives output as time required for lamination of respective solar panel[13]. Various graphs have been plotted by using Python matplotlib library to demonstrate the results such as time required for lamination using different heating plate material, capacity of heater required according to the size of solar panel to be laminated. Steady state thermal analysis is done on the heating plate to determine the temperature that heater needs to provide at the bottom side of the heating plate which validates the theoretical results.

2. DESIGN OF SOLAR PANEL LAMINATING MACHINE

Design considerations for laminating machine

The following considerations are very important in the design of laminating machine,

A. Temperature - The optimal temperature required for lamination of a solar module is 135℃ and the room temperature is considered 30℃.
B. The heating plate material is an Aluminium Alloy
C. For uniform heating of plate thin film heaters are considered.
D. The maximum dimensions of length and width are considered amongst the different dimensions of a 100W solar panel of monocrystalline, polycrystalline or thin film panel.

Components for laminating machine

The following components are required for the construction of a laminating machine.

A. Vacuum pump- for creating vacuum and removing air from the heating chamber
B. Film heaters - required for uniform heating of heating plate upto required temperature.
C. Heating plate - used as a base plate for heating of module layup.
D. Pressure gauge - for measuring pressure inside the system.
E. Temperature sensor - for measuring the temperature of a heating plate.
F. Temperature controller - used to control the heaters and achieve the temperature .
G. Mild steel sheet metal for body work

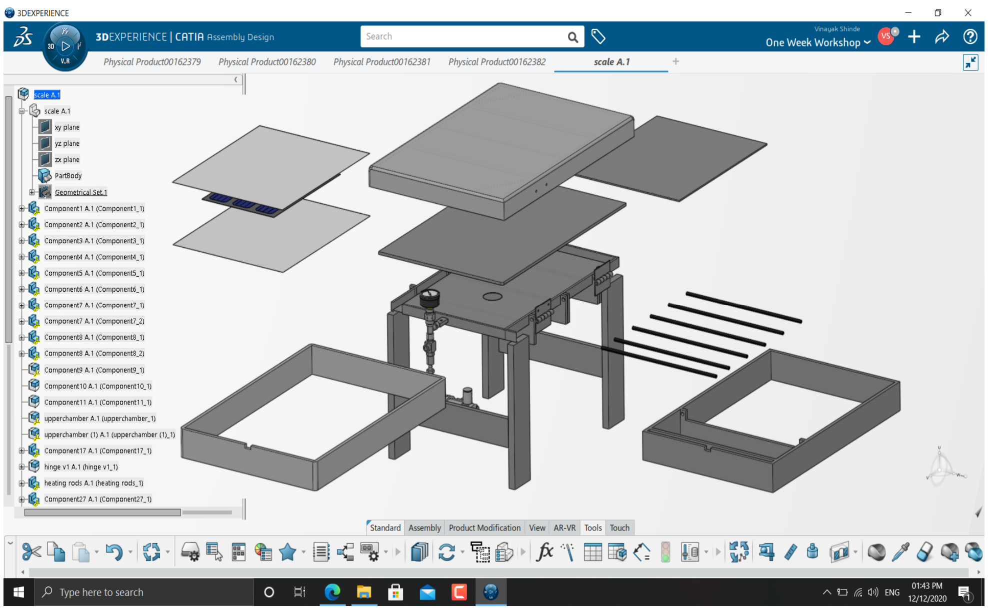

Figure 1. Solar panel laminating machine

2.1 Design calculations

Size of 100W solar panel = $L \times W$

Size of heating plate = $1.3701 \times L \times W$

Selecting heater of a specific capacity,

$q = Q/A$ ……………………… …….(1)

Temperature required at the bottom side of heating plate using Fourier's law of conduction

$Q/A = q = K \times (T_1 - T_2)/\Delta x$ ……………………………..(2)

Calculating mass of heating plate,

$m=\rho\times V$ …………………………………...(3)

Calculating energy required for heating the plate,

$E = mC_p\Delta T$ …………………………….(4)

Calculating time required for heating of layup,

$t = E/Q$ ……………………………..(5)

Calculating time required for vacuum creation,

$t_v = (V_t \times In\ (P\,a/Pe) \times 2.3)/V_p$ ……………………………..(6)

Calculation of solar system required,

Battery capacity = Total load/ DOD × battery voltage ……………………………..(7)

Solar panels required,

Wattage = total load/sun hours × solar derating factor …………………………....(8)

Inverter selection,

KVA = Total solar panel wattage/ Efficiency …………………………....(9)

Charge controller selection,

Amp = Solar panel wattage/panel voltage ……………………….....(10)

3. RESULT & DISCUSSION

Table 1. Lamination time for different size solar panels

Sr.no	Size of solar panel in (W)	Input (Size of solar panel in cm)	Output (Lamination time in min.)
1	10	33 * 23	4
2	25	51 * 34	5
3	50	61 * 50	**7**
4	100	122 * 67	15
5	120	113 * 68	15

Table 1.the output from the python program is plotted in the form of a table containing the time required for the lamination of solar panels depending upon the various inputs given to the python programming language such as size of the panel, capacity of heater, flow rate of pump. According to the size of solar panels the lamination time required increases for a particular vacuum pump flow rate and the heater capacity. In the above table the lamination time for the solar panels of power rating 10, 25, 50, 100 and 120W is found out using the python code and is stated which is the output of the python code.

From design calculations of solar panel laminating machine, it is possible to laminate solar panels of wattage rating upto 100W within 15 minutes by heating the layup at temperature of 135℃ and achieving the vacuum upto 0.5mbar. The amount of energy required to heat the heating plate is 4083151.8 J and the capacity of heater used is 5600W, to operate the system on solar photovoltaic a system of 1350W is required and to store the energy from solar panels Lead-acid batteries of 450Ah capacity are used.

The following figure shows the graph plotted using Python programming language and using matplotlib library, figure 2 shows the time required for lamination of different size solar panels and the time generally depends on the size of solar panel, figure 3 shows the time required for lamination of 100w solar panel by using different materials for heating plate, figure 4 shows the capacity of heaters required which depends on the size of solar panel dimension and figure 5 shows the temperature distribution along the cross-section of heating plate which is performed in Ansys Mechanical simulation.

In Ansys simulation the heating plate is provided with boundary conditions such as temperature at the top face of the heating plate, heat flux or input capacity of the heater. The material for the heating plate used is Aluminum alloy and the properties such as thermal conductivity, specific heat, mass of the plate, and density are taken into consideration for the setup of steady-state thermal analysis

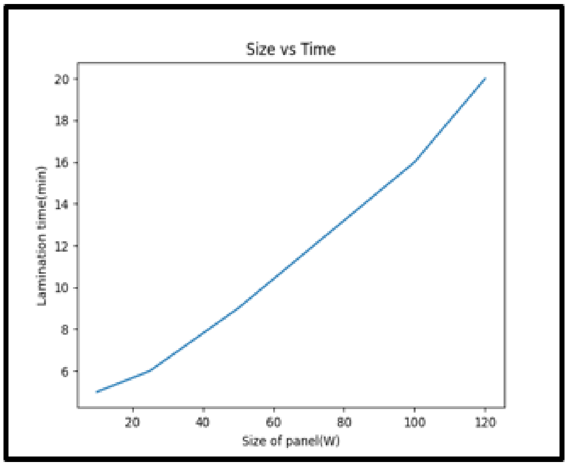

Figure 2. Panel size vs lamination time

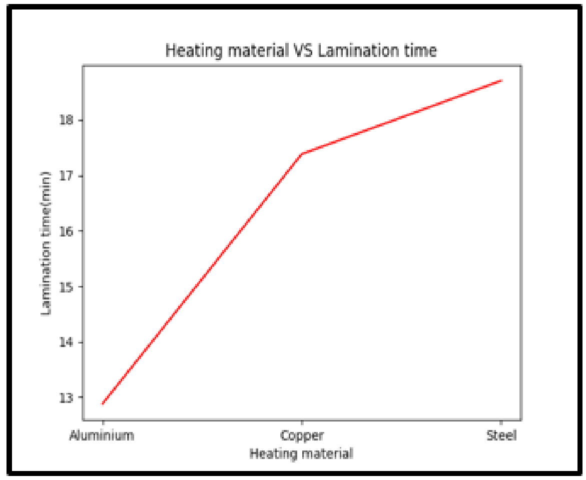

Figure. 3 Heating material vs lamination time

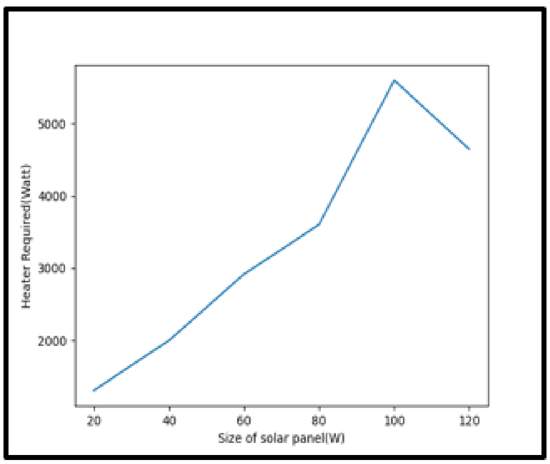

Figure 4. size of panel vs heater required

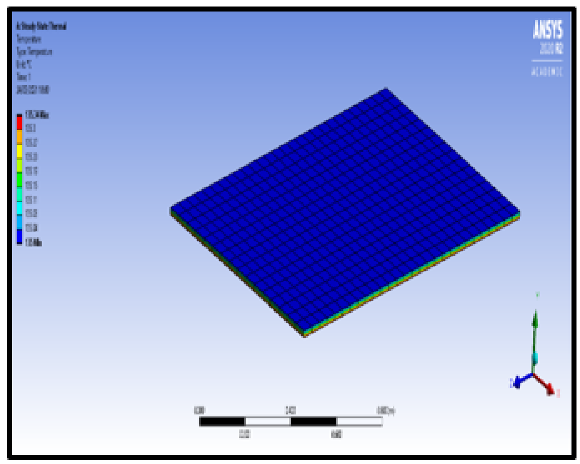

Figure 5. Analysis of heating plate

4. CONCLUSION

Designing the solar panel laminating machine, the design considerations, design calculations, selecting the materials these are very important parameters. By using the solar panels and batteries for operation of machines it becomes a very energy saving and cost-effective way to laminate the solar panels. From design calculations it is observed that Aluminium alloy is the best material for heating plates and it takes less for heating because its thermal properties like high thermal conductivity, high specific heat and less density which in terms contribute to less mass for heating. 1.The machine can laminate all types of solar panels of size up to 100W in 15 minutes.

With the development of this solar panel laminating machine, it is possible to laminate the small size solar panels of power rating up to 100W in 15 min by using 5600W of electric heaters and 50m3/hr. flow rate of vacuum pump.

2. The process of lamination is made energy efficient and cost-effective with the help of the solar system of 1.5 KW and battery capacity of 600Ah. The machine is operated on AC power as well.

3. From the analysis results obtained using python code it is concluded that Aluminium alloy HE-30 is best suited as a heating plate material because it takes least time for heating.

4.From python analysis done on design calculation it is concluded that the time required for lamination is directly proportional to the size of the solar panel.

5. From the ANSYS thermal simulation the temperature difference of 0.34℃ has been found out between the top and bottom surface of the heating plate which validated the design results done using Fourier’s law of conduction.

NOMENCLATURE

L	Length of solar panel	K	Thermal conductivity of heating plate
W	Width of solar panel	T_1	Temperature at bottom face of heating plate
q	Heat flux	T_2	Temperature at top face of heating plate
Q	Amount of heat transfer	Δx	Thickness of plate
A	Cross-section area	m	Mass of heating plate
ȝ	Density of heating plate material	V	Volume of heating plate
E	Energy required for heating the plate	C_p	Specific heat of plate material
ΔT	Temperature difference	t	Time required for heating
V_t	Total volume to be evacuated	P_a	Atmospheric pressure
P_e	Vacuum pressure	V_p	Flow rate of vacuum pump

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