Improving the efficiency of the Lay-Up process in the manufacture of Solar Panels through time-study

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Abstract. Lay-Up is a manual process conducted during the manufacture of solar panels where the multiple layers are set together by hand. Since this process is done manually, there is no standard time period for it. Additionally, errors in process can increase production time needlessly. This research paper employs time-study to establish a standard operation time for Lay-Up aimed at singling out steps that cause loss of valuable time, efforts and resources. The time study is carried out by making a note of all the operations involved in Lay-Up and breaking them down into individual steps. The measurements are made using a digital stop watch and time sheet.

1. Introduction

Time study is a direct and continuous observation of a task, using a timekeeping device to record the time taken to accomplish a task. It is a core tool which is used by the managers in the industrial sector to enhance the performance or the operational efficiency. This is done by breaking down the work into simpler units and setting the execution benchmarks.

This research was carried out at the central factory of one of India’s leading manufacturer of solar panels. It was aimed at reducing production time and hence, increasing productivity in general. The timekeeping device used here is the digital stopwatch in mobile phones, while timesheet is used to record the data and maintain it.

2. Procedure for Manufacturing Solar Panels

The general flow of the manufacturing process for solar panels is provided below in Fig 1.

The first step is Tabbing and Stringing which takes cells and metal ribbons, and stacks them into strings (Fig 2). The strings are then laid onto EVA-covered tempered solar glass and layered with EVA (ethyl-vinyl acetate) sheets and a polymer backsheet as part of the Lay-up process. The appearance of the layers
in a panel are as shown in Fig 3. The research was particularly carried out to improve the efficiency of the Lay-Up process.

The steps following the Lay-Up process are multiple testing stages, lamination & trimming and the attachment of a junction box alongwith an aluminium frame.
Figure 1: Flowchart of manufacture of solar panels from stringing to testing.

Figure 2: Cells laid out in strings and connected via metal ribbons and bus-bars

Figure 3: Various layers of a solar panel

3. Time Study Procedure for Layup

- Observation of the Lay-up process until familiarity was felt with the process.
- The workers would load the EVA-covered glass onto the Lay-Up table; the strings were already arranged on it during the Tabbing & Stringing process. This was the first step of the Lay-Up process.
- The workers would tear up small pieces of adhesive tape and apply them on the cells to hold them in place. The time recording for this step was divided into two sub-steps – tearing of tape, and its deposition on the cells.
- Placements of a second layer of EVA sheet, polymer back-sheet and soldering strips were recorded in a similar way.
- The soldering operation of bus-bars with the string ribbons was recorded by breaking the operation into picking up the soldering iron, soldering, and placing the iron back.
- Finally, allowances of 10 seconds and 5 seconds were given for the top-edge and bottom-edge operations respectively.
4. Data Recording
Two workers are required in the lay-up process- one works at the top-edge while the other work at the bottom edge. The entire activity is recorded by the time study method in the table below.

| Activity                  | Observation | I  (s) | II (s) | III (s) | IV (s) | Average Time Taken (s) |
|---------------------------|-------------|--------|--------|---------|--------|------------------------|
| Top Edge                  |             |        |        |         |        |                        |
| Collection of cells-glass arrangement | 1.55  | 3.00  | 1.89  | 2.00   | 2.11   |
| Tape                      | Collection  | 2.19  | 6.38  | 9.27   | 4.39   | 5.55                   |
|                           | Deposition  | 10.10 | 7.13  | 9.94   | 8.42   | 8.89                   |
| Back-sheet                | Collection  | 3.05  | 3.37  | 4.12   | 4.39   | 3.73                   |
|                           | Deposition  | 3.24  | 3.24  | 2.73   | 2.10   | 2.82                   |
| Bus Bars                  | Collection  | 3.31  | 4.79  | 3.18   | 3.38   | 3.66                   |
|                           | Deposition  | 5.07  | 7.13  | 6.10   | 5.56   | 5.96                   |
| Soldering-1               | Pick Up     | 1.30  | 1.51  | 2.00   | 1.45   | 1.56                   |
|                           | Application | 15.27 | 10.47 | 10.33  | 16.65  | 13.18                  |
|                           | Put Down    | 2.24  | 3.60  | 3.00   | 1.96   | 2.7                    |
| Probes 1&2                | Collection  | 1.8   | 2.14  | 2.01   | 2.21   | 2.04                   |
|                           | Deposition  | 2.81  | 1.92  | 2.02   | 3.21   | 2.49                   |
| EVA strip                 | Collection  | 1.5   | 1.20  | 1.71   | 1.53   | 1.48                   |
|                           | Deposition  | 3.35  | 2.33  | 3.71   | 4.00   | 3.35                   |
| Back-sheet strip          | Collection  | 1.72  | 1.73  | 1.14   | 1.57   | 1.54                   |
|                           | Deposition  | 3.97  | 4.61  | 4.54   | 3.88   | 4.25                   |
| Soldering-2               | Pick Up     | 1.42  | 2.36  | 2.78   | 2.64   | 2.3                    |
|                           | Application | 7.32  | 10.40 | 8.72   | 10.08  | 9.13                   |
|                           | Put Down    | 1.94  | 2.64  | 1.32   | 1.16   | 1.76                   |
| Probes 3&4                | Collection  | 1.57  | 2.55  | 1.27   | 2.21   | 1.9                    |
|                           | Deposition  | 2.65  | 2.36  | 2.89   | 2.71   | 2.63                   |
| EVA                       | Collection  | 2.65  | 2.68  | 2.21   | 2.92   | 2.61                   |
|                           | Deposition  | 2.72  | 2.68  | 3.82   | 3.31   | 3.13                   |
| Back-sheet                | Collection  | 1.11  | 1.10  | 1.89   | 1.00   | 3.05                   |
|                           | Deposition  | 1.70  | 1.09  | 2.65   | 2.16   | 1.9                    |
| Tape                      | Collection  | 3.68  | 3.47  | 2.48   | 3.43   | 3.26                   |
|                           | Deposition  | 4.42  | 3.44  | 3.11   | 2.64   | 3.40                   |
| Allowance                 |             | 10    | 10    | 10     | 10     | 10                     |
| Aggregate Top Edge Production | 100.1 | 109.32 | 110.83 | 110.96 | 109.38 |
Since no manual process can be performed identically every time, an allowance is made to account for discrepancies that might creep in. Allowances in time sheets are provided according to scope of work and the steps involved.

An allowance represents time lost due to personal factors, shift adjustments, improper equipment and fatigue.

It includes:

- **Transfer Time**: Lay-up occurs on three in-line tables and when the next in line finishes up their module, the one on the previous table is transferred onto their table, so that no table stands idle.
- **Fatigue**: Since the work is manual, the workers are bound to get tired and get hampers the production time.
- **Inefficiency**: Due to sloppy work, slipping of equipments or materials, time is lost which is allowed for here.
- **Ineffective activities**: Some steps in an operation can be performed more efficiently but non-willingness to change methods, increases productive times.

5. Observations & Calculations

1. The lay-up procedure involves the operator to make a slit in the final EVA sheet for the probes to pass through.
2. The back-sheet that’s placed on it has a slit made already during its cutting.
3. Between the picking up of the cutter, slitting and putting it down, roughly 1.5 seconds pass.

Going by the popular adage, “Time is Money”, saving time saves money. Reduced production time means time saved which leads to more production in the saved time and hence, less wastage of money and generation of revenue.
As observed during the lay-up, placement of EVA sheet takes up around 1.5 seconds from the picking up of the cutter to putting it back down. This happens for every single module that is manufactured in either of the plants.

Presented here is a rough account of how by saving a mere 1.5 seconds of a process saves the company so much in the longer run. While other processes too contribute to wasted time, this process makes the maximum contribution.

If the slit on EVA is made prior to production in the same way as the back-sheet, a lot of effort can be saved in total. It can be explained according to the following calculation:

1) Total time lost per module: 1.5 seconds
2) Total time taken for Lay-Up of 1 module: 109.38 seconds (=110 seconds)
3) Total number of production hours in a day: 24 (Source: Production Dept.)
4) Modules manufactured in a day = 1200 (Source: Production Dept.)
5) Average Time taken to manufacture one module = (24 x 60) / 1200 = 1.2 minutes = 72 seconds
6) Total time lost every day = 1200 x 1.5 = 1800 seconds = 30 minutes
7) Total additional modules that can be manufactured in lost time = 1800 / 72 = 25
8) Increased growth = 25/1200 = 2% (approx.)
9) While 2% growth appears less, the total income is remarkable.
10) Approximately selling price of one module = ₹12000
11) At the same rate, total additional revenue generated in year = ₹ 12000x25x365 = ₹ 10, 95, 00, 000

Hence, by just saving 1.5 seconds in a single process, the effort, time and revenue that can be saved = ₹ 10, 95, 00, 000

6. Conclusion
By using Time Study Technique, 1.5 seconds saved in a single process, one can save Rs. 10, 95, 00,000 annually. The following are some recommendations that can lead to increased productivity and human efficiency:

- Ear-muffs for workers.
- Vibration padding to reduce noise pollution due to resonance as well as frictional wearing.
- Switching the glass loading and un-loading outlets in Stringer to reduce transportation time.
- Placement of stools with adjustable height at lay-up station to reduce fatigue in employees.
- Since the position of back-sheet strips and bus-bars is the same irrespective of position of strings, placing them during glass loading before Lay-up saves much time and reduces effort.
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