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Automation of the Manufacturing Process of Voltage Regulators

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Abstract—*Quality and quantity of production are the two factors that the manufacturers strive to attain in order to have its mark in the market and it becomes even more arduous if it comes to an electronic manufacturing industry as micro level sized components has be handled with high level of accuracy. Hybrid micro circuits are one such device where the former mentioned factors are to be met to bring out a quality product which goes into the voltage regulators. Solder paste printing, component placement and reflow soldering are the important processes focused involved in voltage regulator manufacturing. The main aim of this paper is to reduce the rework, material movement and inventories which are the biggest factors of the 7 wastes called MUDA which were noticed in the current process layout that were collected by walk through the work floor as a part of time and motion study analysis. The time spent on rework process consumes a fair production rate. For this, Design of Experiments (DoE) has been performed on solder paste printing machines as 50-70 percent of the defects only takes place at this stage, which turns out to be the cause for dry solder and component shift and the material movement also has an impact reducing the efficiency of man which also feeds on time and a new layout has been suggested which cut downs the man power by two, reducing costs & production lead time by 26.19 percent and thereby increase the productivity. Both the models have been simulated using ARENA simulation software which also gives the utilization of the resources.*

1. INTRODUCTION

Automation is done to increase the throughput, quality and robustness of the procedures of a product. Through automation productivity can be increased with reduction in the direct human labour involvement and costs that adds to it. The cycle time can be reduced and work holding time can be substantiated through automation the labour can take up other operations too which increases the utilization of the resources.

Arena simulation is software used to model and simulate the line of work. The software is advantageous in analyzing the manufacturing processes, material handling involved.it vests with analyzing the transportation, supply chain management. It predicts the cycle time involved, throughput when the necessary data is given and key out the bottlenecks and the queue (inventory) where the processing time is higher.

2. LITERATURE SURVEY

[1]Al-Hawari, Aqlan, Al-Araidah, Using ARENA Simulation for pull type kanban system they obtained a correct measure of productivity and work in process.

[2]Alexandre Magno Castañon Guimarães & Madiagne Diallo through simulation could sort out the line imbalances and name out bottlenecks. The proper allocation of the resources is possible from former help in making a lean manufacturing line.

[3]Annamalai Pandian, Ahad Ali analyzed through ARENA simulation that how failures in the machines changes the throughput and for a complex floor plan how important is the connectivity between the maintenance and production departments for a interrupted material movement.

[7]F.K.H. Lau, V.W.S Yeung gave a power structure of all materials and their design in SPP and Reflow Soldering process for better quality product.

[8]K Hemanand et al. have put their efforts in reducing the wastes (motion) using a gravity feeder and also made changes in the layout through which they could increase the productivity.

[11]Mannan et al. studies gave the information that the volume of the paste deposited depends upon the squeegee speed.

[13]N. V. Ruikar, M. T. Telsang followed just-in-time method which reduces the waste and increases the productivity and simulated a model in WITNESS for different replications and

with MINITAB they concluded that one of the replications bring down the setup time and increase the productivity.

[14]Owczarek and Howland accounted that a firm association lies between the snap off height and the thickness of the paste deposited.

[16]Pan et al. gave his report saying the solder thickness vests with the stencil thickness and aperture design and print speed and viscosity of the paste together effect the thickness deposited.

[17]Praveen saraswat et al. used Value Stream Mapping (VSM) through which they could establish a relationship between productivity and wastes (WIP) and reduced the cycle time

3. METHODOLOGY

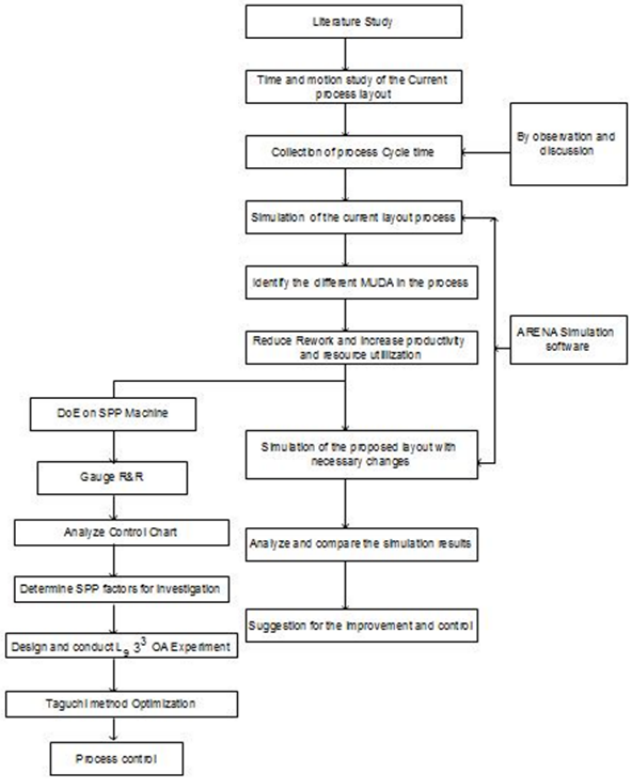


Fig. 1: Methodology followed in the project

4. TIME STUDY

The time and motion studies for the current assembly manufacturing has been carried out and the TAKT time, cycle time for each process involved are as follows

4.1 CURRENT LAYOUT STUDIES:

4.1.1 PROCESS FLOW DIAGRAM: The process flow and the sequence of the manufacturing process from the unprocessed matter (stocks) to the final packing of the product.

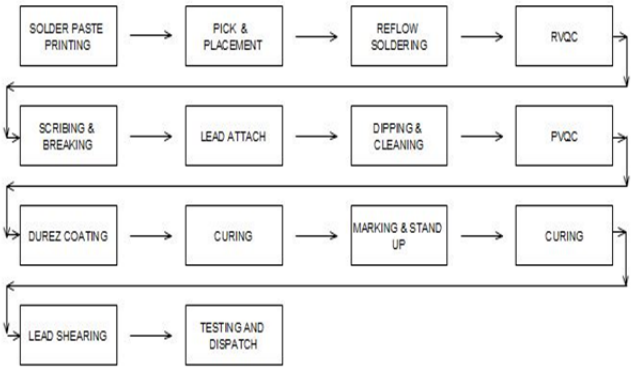


Fig. 2: Sequence of the manufacturing process

4.1.2 TIME STUDY

The TAKT time and the cycle time for the complete HMC Assembly process has being calculated.

TAKT Time is a calculated value that describes the theoretical demand rate of the customer. In other words, It is the rate at which a company needs to produce in order to meet the demand. It is calculated as follows

Table 1: TAKT Time calculation

Total available time	1 shift/day/25days
Customer demand/day	6285 circuits=157 substrates
Working time /shift	7 hours=25200sec
Break time (lunch, tea break and miscellaneous)	1.5 hour
TAKT Time	Working time per shift/ customer demand per day
	25200/157 = 160.5 sec

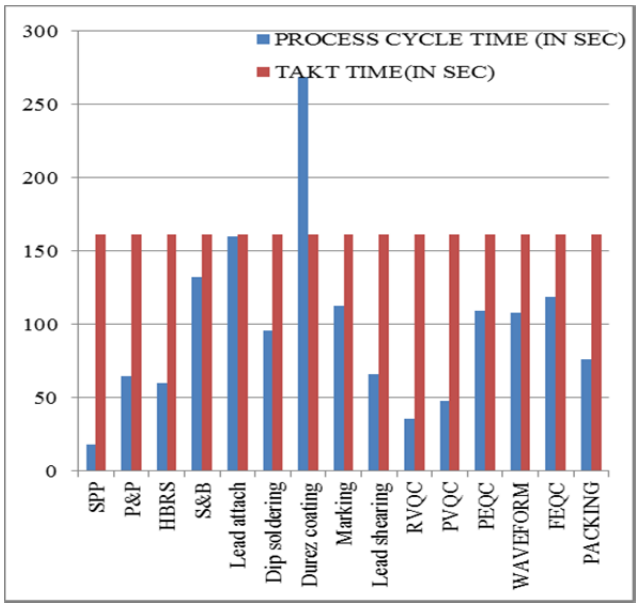


Fig. 3: TAKT Time

4.1.3 ARENA SIMUALION FOR THE CURRENT LAYOUT PROCESS

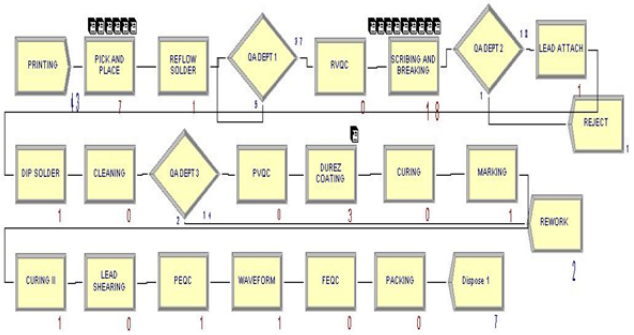


Fig. 4: ARENA Simulation for the current layout

Table 2: Idle time of the operator in a day

S. No	Operation	Man idle time	O/P	Idle time in a day in seconds	Idle time in a day in hours
1	Pick and placement operator	45	175	7875	2.1875
2	Durez operator	134.4	125	16800	4.6667

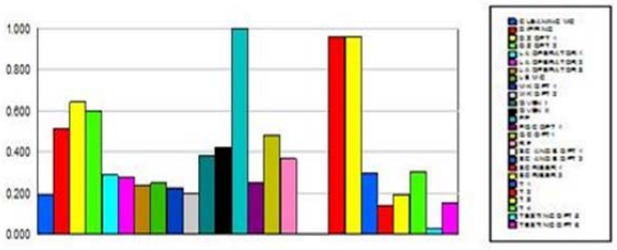
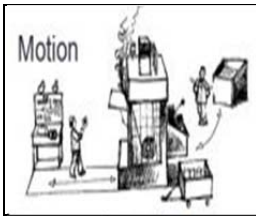
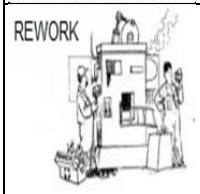


Fig. 5: Current utilization of resources

4.1.4 PROBLEMS IDENTIFIED IN THE CURRENT LAYOUT

	In the current process a motion and transportation distance of 149.77 meters was observed
	Due to the different cycle times a much of inventory was observed at pick and placement and scribing and breaking processes
	The next process after the scribing and breaking has to wait till the circuits are disposed.
	At the durez coating stage and pick and placement the operator idle time is vey high that can be conferred form the table.
	Dry solder was observed which was due to the improper solder paste printing so, DoE has been performed to get optimal printing parameters for the SPP machine so that rework can be reduced Dry solder was observed which was due to the improper solder paste printing so, DoE has been performed to get optimal printing parameters for

In this regard DoE (Design of Experiments) has been performed on the solder paste printing machine. For a circuit to have a good soldered joint, it is very much important to maintain the volume of the solder paste deposited i.e., (180-220µm) thickness failing of which forms a dry solder as the components will not adhere to the pad surface area.

Taguchi Design :Taguchi Orthogonal Array Design $L_9 3^3$

Table 3: The parameters, levels considered and their description

Solder paste printing parameters	Level I	Level II	Level III	Description
1 Snap off height (mm)	0.254	0.508	0.762	Distance b/w stencil and HMC
2 squeegee speed (mm/s)	37.77	42.5	48.57	Squeegee travel speed
3 Squeegee pressure (bar)	0.037	0.048	0.048	Air pressure applied on the squeegee

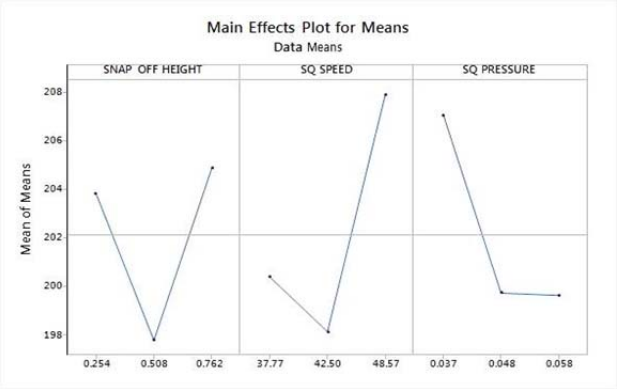


Fig. 6: Main effects plot for means

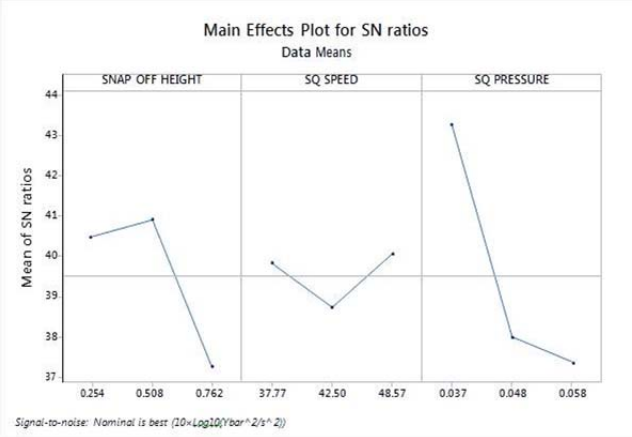


Fig. 7: Main effects plot for S/N ratios

Table 4: Experimental results

	Control factors			S/N ratio	Mean
	Snap off height	**Sq speed**	**Sq pressure**	**PSNRA1**	**PMEAN1**
1	0.254	37.77	0.037	44.463	207.033
2	0.254	42.5	0.048	38.1542	197.387
3	0.254	48.57	0.058	38.8609	207.08
4	0.508	37.77	0.048	39.6502	193.6
5	0.508	42.5	0.058	37.95591	191.233
6	0.508	48.57	0.037	45.1191	208.507
7	0.762	37.77	0.058	35.3627	200.587
8	0.762	42.5	0.037	40.1249	205.8
9	0.762	48.57	0.048	36.2172	208.213

Table 5: Analysis of Variance results

Source	DoF	Adj SS	Adj MS	F-value	SS'	P
Snap-off-height	2	24.280	12.140	8.178	21.312	23.92%
Squeegee pressure	2	61.848	30.924	20.831	58.879	66.08%
Error	2	0	0			
Pooled error	2	2.969	1.4845		8.907	10.00%

Note: Squeegee speed is pooled into error term

The pooled ANOVA has been done as the error term variation and variance values are zero. It is not possible to compute the F-value with the error variance V_e is in the denominator which is an indeterminate form, So, the signal factor, squeegee speed having the variation as 2.9690 which is an insignificant value and its F-value has a confidence interval of less than 95% is added into pooled term and then computed.

The percentage of significance effect of Snap-off-Height and squeegee pressure are 23.919% and 66.084% and as the squeegee speed is the only pooled error term the % value is 9.9968.

Even from the response table for S/N ratios we can observe the rank of the factors matching with the ANOVA result

Table 6: Response table for S/N ratios

Response Table for Signal to Noise Ratios

Nominal is best (10×Log10 (Ybar^2/s^2))

Level	SNAP OFF HEIGHT	SQ SPEED	SQ PRESSURE
1	40.49	39.83	43.24
2	40.91	38.75	38.01
3	37.23	40.07	37.39
Delta	3.67	1.32	5.84
Rank	2	3	1

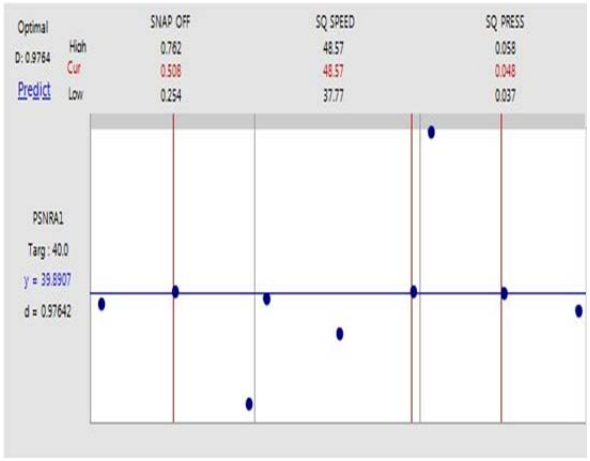


Fig. 8: Optimization plot for Taguchi design

The Taguchi method is employed so as to optimize the solder paste printing machine performance. The main effect from the ANOVA results is the Squeegee pressure so, it is to be set at either level2 as it maintain the pressure and also the solder paste will not stick to the stencil during the retract (back) motion of the squeegee. From the optimization plot $H_2S_3P_2$ level will give a better value 39.8907 and if used, gives the specified nominal thickness value can be achieved.

5. SUGGESTED LAYOUT

If the SMT line is conveyorized then the time and space can be well scheduled utilized and the operator can be reduced by one or utilized for the other processes where the inventory is building up.

5.1 SOLUTIONS FROM THE PROPOSED LAYOUT

From the suggested layout the time wasted in the material movement is reduced from 149.77meters to 51.96 meters and the flow of the work can be increased by using the operator where the cycle time is less can be used which reduces the

processing time at the stage with more processing time. This can be implemented at the durez coating and dip soldering stages. Time taken for the durez coating is 115 min on an average which involves two operations namely jig loading and coating where half the time is idle time. So, usage of two machines reduces the time to half i.e., 57.5min and after completing the process the one of the operators can be assigned to the dip soldering process so as PULL the material flow

A simulation with the proposed layout has been done and the analysis of the proposed layout results with the current layout will be discussed.

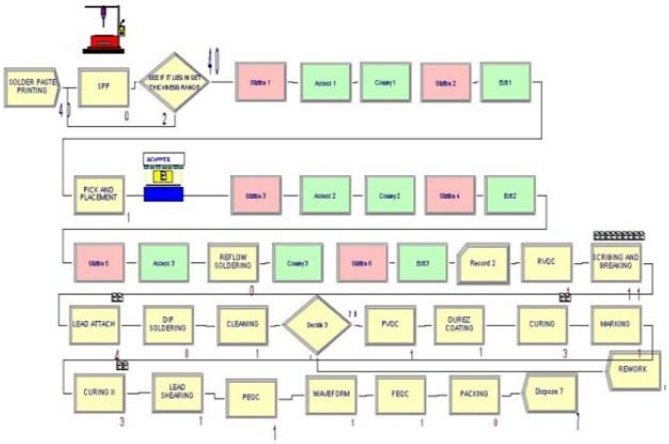


Fig. 9: ARENA simulation for the proposed layout

The total time taken to dispose 7000 circuits is 930 minutes whereas the current layout takes 1260minutes for the same number. The inventory or the WIP also got reduced at the scribing and breaking operation and pick and placement machine as well. As the solder paste printing, pick and placement and reflow soldering machine are automated one operator can be reduced or assigned at the other operation.

The solder paste printing can be scheduled printed and put on the conveyor the pick and placement can work on a single substrate at a time and can hold one more substrate the time the machine completes one substrate the conveyor starts and the feeds one substrate into the machine that is held, meanwhile the operator can knead the stencil as it is very important to maintain the thickness (volume deposition) of the solder paste and check the parameters too. By the time placement of the substrate gets completed it observed by the operator whether the solder quality is checked and the cycle is continued.

The substrates are to be pulled (PULL KANBAN) immediately without any delay from RVQC and random distribution of the substrates are to be taken without waiting for the next line to drop in, in order not to increases the inventory, it must be distributed not only in random fashion but by observing whether it is smaller number busy or the larger remaining capacity.

6. RESULTS AND DISCUSSION

From the current and the proposed layout simulation done on ARENA, the production lead time cycle time and the WIP at different stages of the production line for a batch of 7000# circuits to get disposed has been performed and are listed in the tables below.

Table 7: Comparison of the WIP in the current and proposed layout

Operation	WIP in the current layout	WIP in the proposed layout	%Reduction
Pick and place	2666.7	452.8	83.02
Scribing and breaking	6000	4977.37	17.04
Durez coating	1000	452.8	54.72

Table 8: The reduction in the production lead time and cycle time in the current and proposed layout

Time	Current layout	Proposed layout	% Reduction
Production lead time	1260 min	930min	26.19
cycle time	1756.6 Sec	1574.2sec	10.38

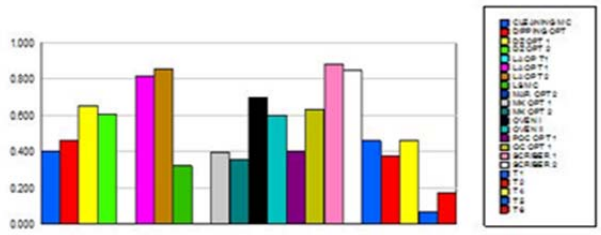


Fig. 10: Proposed utilization of resource

7. CONCLUSION

From the time and motion study analysis,

a) Rework can be reduced to some extent by maintaining the optimal level of the parameters result achieved and optimization taguchi plot values was snap off height at 0.508 mm, squeegee speed at 48.57mm/s and the squeegee pressure being 0.047 bar.

b) WIP built up and motion was reduced by utilizing two machines at the durez coating (which reduces the idle time of the operator), making the SMT a continuous automized line will help in rotation of the resources and by making changes in the current layout respectively.

c) With all this changes put together and simulated in ARENA Simulation software the process time and the production lead time has been significantly reduced by 330 minutes. By automating SMT line we can reduce one operator and the cost involved too. Which reduces the cost of the operator by Rs350/- per shift/day which saves an amount of 100000 per annum leaving the conveyor cost and then the WIP at the scribing and breaking stage is high as the human resource is utilized for reflow soldering also which is a cause for the increase in the WIP. Automating SMT also finds an answer for the reduced WIP at the scribing and breaking stage as the operator need not waste time doing reflow soldering too.

d) time and motion studies help a company in the continuous improvement of the process.

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