Journal of Engineering Research and Reports

20(3): 123-140, 2021; Article no.JERR.65679
ISSN: 2582-2926

Increasing Singulation Machine UPH through Characterization and Standardization of Saw and Handler Parameters through DMAIC Methodology

Lloyd L. Rolluqui[1*], Patricio A. Cabading Jr[1] and Jimmy P. Domingo[1]

[1]Process and Equipment Engineering, ST Microelectronics, Inc. Calamba City, Laguna, Philippines 4027, Philippines.

Authors' contributions

This work was carried out in collaboration among all authors. Author LLR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author PACJ managed the analyses of the study. Author JPD managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i317289
Editor(s):
(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.
Reviewers:
(1) Ahmed M. Asfahani, University of Business and Technology, Saudi Arabia.
(2) Raveen Rathilall, Durban University of Technology, South Africa.
(3) Daniel A. Lowy, Hungary.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65679

Original Research Article

Received 19 December 2020
Accepted 23 February 2021
Published 17 March 2021

ABSTRACT

This study aims to address the problem of machine saturation and low capacity at package singulation, caused by increasing product loading and new devices that requires frequent machine setups and conversions.

With this evaluation, the process and equipment engineering group collaborated to improve the machine unit per hour (UPH) of package singulation machines at the manufacturing assembly. Target improvements were divided into three phases, so that the team could focus more on each phase and was able to define robust parameters without compromising the product quality. DMAIC methodology was used to improve the productivity of package singulation machines. With the help of our methodology, we identified the root cause and contributing factors to the problem.

UPH improvements per machine were validated and assessed in terms of machine efficiency and product quality, because of characterization and standardization of every parameter in each phase of the project. The achieved total improvement was of 17.64%.

**Corresponding author: Email: lloyd.rolluqui@st.com;*

Keywords: UPH (unit per hour); DMAIC (define measure analyze improve and control); package singulation.

1. INTRODUCTION (1-6)

Semiconductor industry represents the group of companies involved in the design and assembly of semiconductors. Over the years, it has become a viable business and has turned the driving force behind the wider electronics industry with billion-dollar annual sales revenue.

Therefore, semiconductor industry is widely recognized as a key driver and technology enabler for the whole electronics value chain. The global semiconductor industry is dominated by different countries all over the world in various sectors, like microprocessors, logic, memory, power semiconductors, transceivers, network processors, sensors, etc.

STMicroelectronics, Inc. is headquartered in the city of Calamba province of Laguna and is one of the 158 companies of STMicroelectronics, Inc. corporate family worldwide.

There are many processes in assembly of semiconductor devices, one important step being the Package Singulation. It is the cutting process of dividing a molded lead frame or substrate into an individual packaged semiconductor device by a dicer engine, as shown in Fig 1. Then, they are picked-up individually by a handler system and stored in a tray.

Machine UPH is the number of units produced within one hour by any equipment in a production area in a specified machine setting and parameters, when operated by trained personnel. One of the best singulation machine platforms in terms of output and quality that was equipped with an integrated handler and vision system. This machine was known to be more productive and efficient in terms of cutting and cleaning of sawn units. It also has the vision system, capable to detect common top and bottom defects. Singulation machines nowadays have a built-in vision system on their handler, as shown in Fig 2.

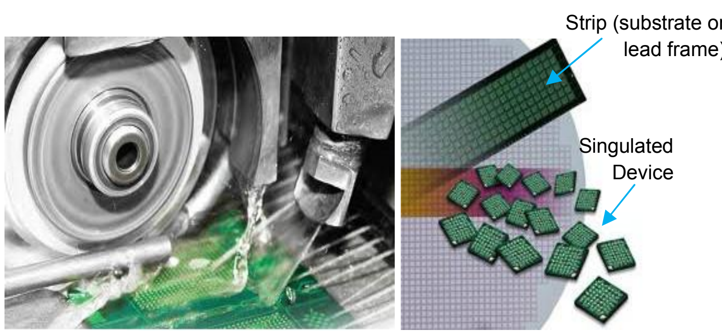


Fig. 1. Package singulation process

Fig. 2. Package singulation machine with integrated handler and vision system

Driven to support the business opportunity on top of the current package loadings at the manufacturing assembly, the management team decided to liberate capacity by UPH improvement to support future growth and cost competitive edge. Productivity and cost improvement can be accomplished by maximizing UPH by 10 to 20%. This increase is based on current IE (Industrial Engineering) standards by considering equipment capability and package complexity. One of the major assembly processes, which can increase the UPH, is package singulation.

There are currently 18x Package Singulation machines which are fully utilized by production group processing packages, like LGA-MEMS, QFN/BGA and QFN-mr packages, as listed in Table 1.

Nevertheless, even with allocated singulation machines, device loadings continue to increase and there have also been incoming new devices, which requires frequent machine setups and conversions. Currently installed equipment was already saturated based on IE calculation.

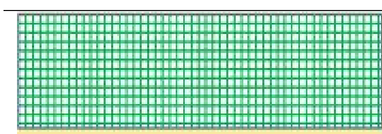
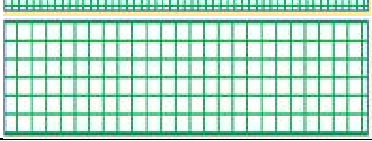
Previous improvement actions were initiated by the equipment engineering group to speed-up the machine and increase its capacity to sustain production to meet daily delivery requirements. These initiatives included the reduction of pick and place z-picker vacuum on/off delay from 100 ms to 10 ms. Despite these actions for packages with high strip density, the bottleneck remained the handler's pick and place, as shown in Fig. 3 and Table 2.

To improve the machine UPH and increase its capacity, identification of bottleneck process at package singulation is important prior to proceeding with improvement actions. The latter are baselining of machine's actual performance, characterization, and standardization of parameters.

Table 1. Package singulation matrix

ESP machine	Package	ESP machine	Package
ESP073	MEMS	ESP058	QFN-MR
ESP051	MEMS	ESP055	QFN-MR
ESP070	MEMS	ESP052	QFN-MR
ESP061	MEMS	ESP076	QFN-MR
ESP043	MEMS	ESP060	QFN-MR/BGA117
ESP050	MEMS	ESP059	QFN-MR/ QFN
ESP049	MEMS	ESP056	QFN-MR/ QFN
ESP066	MEMS	ESP071	QFN-MR/ QFN
ESP064	MEMS	ESP072	QFN

Table 2. Package singulation bottleneck process

Strip illustration	Strip density	Bottleneck	
		Saw	Handler
	2800 units per strip	No	Yes
	600 units per strip	Yes	No

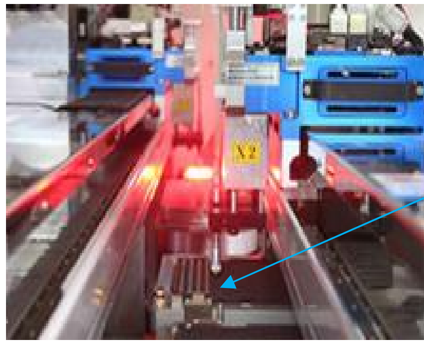


Fig. 3. Handler's pick and place process

Our proposed solution is different from previous improvement actions, in that no additional costs should be involved and cost avoidance of purchasing new package singulation equipment can be realized.

2. REVIEW OF RELATED LITERATURE (7-10)

DMAIC is a data driven improvement cycle designed to be applied to business processes to find flaws or inefficiencies particularly resulting to output defects and to prevent them. This methodology is not meant to be a quick fix approach, the logical use of the tools over time will save resources and maximize production. DMAIC methodology is to:

1. Define some very critical questions, like the errors in the production process and how they affect the production operations.
2. Measure their current production systems. When everything is evaluated, an organization can know what the root cause of their production problem is and start looking for ways to solve it. Having a data collection plan is very useful, when conducting this phase.
3. Analyze data gathered during the measurement phase about their production process. After analyzing available data, the organization can narrow down the cause of their production problems and figure out ways to maximize the production efficiency.
4. Improvement phase is the stage, where an organization tests, assesses, and implements all their ideas in terms of improving production.
5. Control phase is meant to secure that all improvement actions are maintained. The last stage of the continuous improvement process and it is all about strategies to maintain high level of production.

Overall, the process of DMAIC is all about improving the process with least variations.

A study conducted in steel industry on low productivity rate as compared to the target output, addressed the use of Six Sigma DMAIC approach to define problems, opportunities, and requirements, measure process performance, analyze the root cause, and propose improvements. With the help of this methodology, the root cause of the bottleneck in the production process was identified along with factors that contribute to this problem.

An action plan was put together to address all these factors, through rearrangement of process and fabrication of stopper to yield higher productivity rate. Improvement was sustained through monitoring and changing the work instructions for the targeted process.

3. METHODOLOGY

In this study, DMAIC methodology was used to achieve the objective of increasing the overall UPH of package singulation machines by at least 13% from an average UPH of 7707 to 8652 by the end of Q3'19, which covers all QFN, QFN-mr, and LGA packages.

3.1 Define Phase

Fig. 4 displays the current assembly monthly loading, LGA tops with 48mpcs followed by QFN at 16mpcs and QFN-mr at 13mpcs. 50% of the total package singulation machines were allocated to LGA, while 22% to QFN and QFN-mr, respectively.

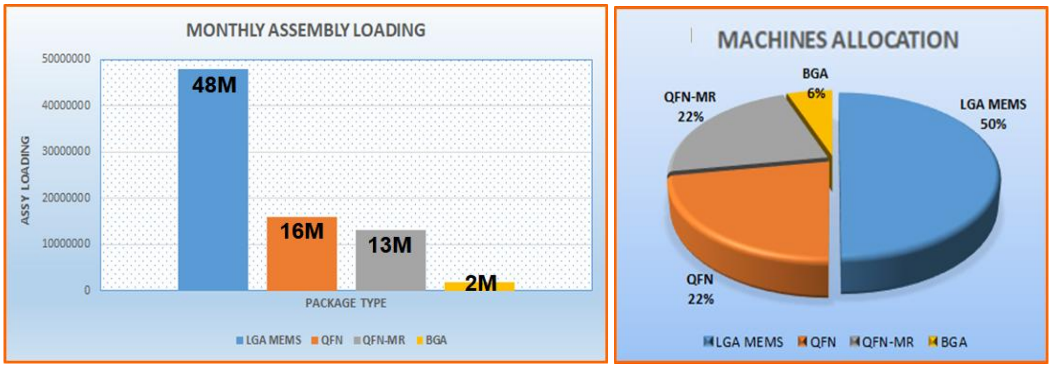


Fig. 4. Monthly loading and package allocation

3.2 Measure Phase (11-13)

Critical processes at package singulation identified in the framework of this project were the saw and handler cleaning and drying steps, along with handler motor speed and sawing processes, as displayed in Fig. 5.

In identifying the process input variables, the team used the Input and Output Worksheet (I/O worksheet) to account for all variables in each process step that may potentially affect the machine UPH. 52 KPIV's (Key Process Input Variable) were found as potential X's (see Table 3)

All input variables listed in the I/O worksheet were filtered through the Cause-and-Effect Matrix (C&E Matrix as shown on Table 4), and the effects of each variable were scored with respect to the output response. By using the scoring matrix, we have identified the critical X's that impact the low machine UPH.

Reported below is the statistical validation of potential cause of the productivity problems, based on identified critical X's from the KPIV's that affect the low machine UPH.

A quick win was easily executed through machine baselining of saw and handler wash/dry parameters from the best performing machine (in terms of output). Fig. 6 shows the 4 process steps to which wash and dry parameters were baselined fast, from the identified best machine by package type. A 10.95% UPH increase was attained after implementation of the quick win, considered as Phase 1 of the project. Each improved machine executes a 5x lots visual validation with respect to UPH increase, without any detectable quality issues.

Fig. 5. Package singulation: A detailed process flow

Table 3. Input and Output Worksheet

		Characteristics of Process Outputs (KPOVs)				
Key Output	**Characteristic of Output**	**Specification**	**MSA**	**Z-Score (Short Term)**		
Low UPH	Machine Capacity					
			c = what you are controlling today			
Notes:			controllable noise = noise but w/in control			
1) Ensure the following items are captured as KPIVs: Operator, Shift, Month, Seasonal, Equipment, Hour				not controllable noise = mandatory (can control but not being control today)		
		Process Inputs (KPIVs)				
Process step	**SOP**	**Type of input**	**Input**	**Characteristic of input (KPIV / X)**	**C/N**	**Specification**
Material Preparation	DMS No. 8296346	Raw Material / Information	Input Material	Strips	Controllable	No of strips loaded, correct engrave
		Raw Material / Information	Input Material	Input Magazine	Controllable	Correctness of magazine no.
Saw/Handler Program Loading	DMS No. 8296346	SOP / WI / Checklist	Setup	Saw Program / Handler Program	Controllable	Correct program vs actual lot
Magazine Loading	DMS No. 8296346	Raw Material / Information	Input Material	Magazine Condition	Controllable	No deformation
		Equipment / Infrastructure	Setup	Magazine Up/Down Speed	Controllable	Optimum setting without vibration
Strip Placement on Chuck table	DMS No. 8296346	Equipment / Infrastructure	Setup	Strip alignment	Controllable	Correct alignment without error
		Equipment / Infrastructure	Setup	Strip placement speed	Controllable	Optimum setting without error
Cutting of strip at chuck table	DMS No. 8296346	Equipment / Infrastructure	Setup	Cutting Speed	Controllable	Not exceeding speed limit
		Equipment / Infrastructure	Setup	Cutting Mode (Dual/Single Spindle)	Controllable	Appropriate cutting mode per package
Pick-up of sawn units from chuck table	DMS No. 8296346	Equipment / Infrastructure	Setup	Unit picker alignment	Controllable	Correct alignment without vacuum error

Table 4. Cause and effect matrix

			Specification Limits (for Y)	**Machine Capability**		**Cause and Effect Matrix**			
			Customer priority	**10**					
S.No	**Process Step**	**Input**	**Characteristic of Input (KPIV / X)**	**Scoring**	**Total**	**Is X Continuous / Discrete?**	**Count 3's**	**Count 9's**	**X Selected / Discarded?**
16	Cutting of strip at chuck table	Setup	Cutting Speed	9	90	Discrete	0	1	Select the X
17		Setup	Cutting Sequence	9	90	Discrete	0	1	Select the X
18		Setup	Cutting Mode (Dual/Single Spindle)	9	90	Discrete	0	1	Select the X
19		Setup	Chuck table return speed (air curtain)	9	90	Discrete	0	1	Select the X
20		Setup	Cutting clearances	3	30	Discrete	1	0	Select the X
21		Setup	Jig/Cut wash settings	9	90	Continuous	0	1	Select the X
23	Pick-up of sawn units from chuck table	Setup	Unit picker alignment	1	10	Continuous	0	0	Discard the X
24		Setup	Unit picker pick-up speed	3	30	Discrete	1	0	Select the X
28	Cleaning /Brushing of sawn units	Tool	Brush Condition	0	0	Discrete	0	0	Discard the X
31		Setup	Brush count	9	90	Continuous	0	1	Select the X
32		Setup	Brush cleaning speed	9	90	Discrete	0	1	Select the X
33	Water/Air Rinsing	Setup	Water/Air rinsing count	9	90	Continuous	0	1	Select the X
34		Setup	Water/Air supply on clean box	0	0	Discrete	0	0	Discard the X

			Specification Limits (for Y)	**Machine Capability**					
					Cause and Effect Matrix				
			Customer priority	**10**					
S.No	**Process Step**	**Input**	**Characteristic of Input (KPIV / X)**	**Scoring**	**Total**	**Is X Continuous / Discrete?**	**Count 3's**	**Count 9's**	**X Selected / Discarded?**
36	Drying of Units	Setup	Dry block air blow count	9	90	Discrete	0	1	Select the X
37		Setup	Dry block air blow speed	9	90	Discrete	0	1	Select the X
43	Picking of units from turn table	Setup	PnP rubber pick heads	1	10	Discrete	0	0	Discard the X
45		Setup	Pick-up speed	9	90	Discrete	0	1	Select the X
49	Placement of units on tray	Setup	PnP rubber pick heads	1	10	Discrete	0	0	Discard the X
50		Input Material	Output trays	0	0	Discrete	0	0	Discard the X
51		Setup	Placement speed	9	90	Discrete	0	1	Select the X

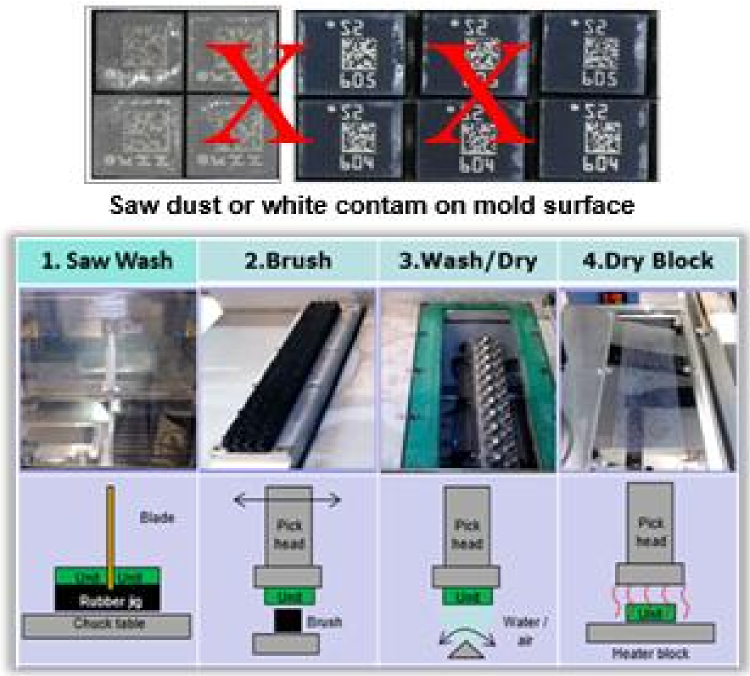


Fig. 6 Saw and Handler Wash/Dry Process Steps

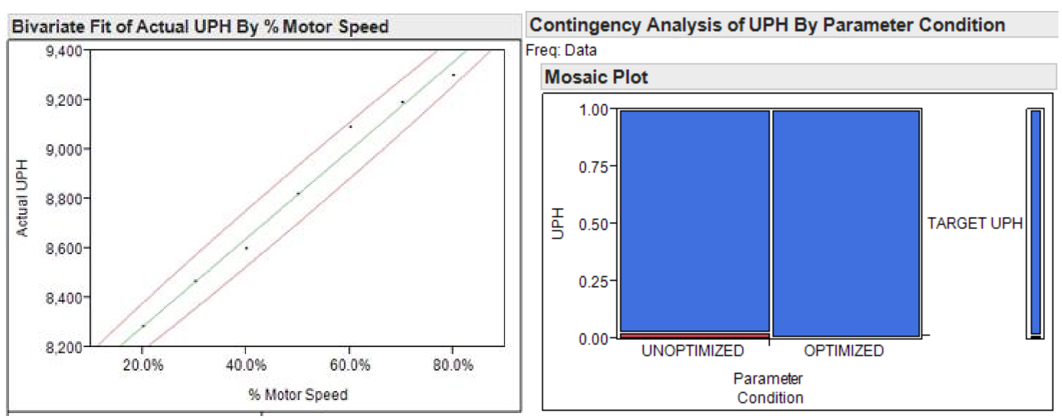


Fig. 7 2-Proportion and Regression Statistical Testing

3.3 Analyze Phase

A test plan was set to validate the existing wash and dry, handler speed and saw parameters that contribute to low machine UPH. Statistical testing using 2-proportion test and regression analysis were applied to validate potential causes.

Validation results based on statistical testing shows that the potential factors contribute to low machine UPH of package singulation machines.

3.4 Implementation Phase

Baselined wash and dry parameters were implemented during the analyze phase, as a quick win. Handler motor speed and saw parameter improvement (Fig. 8) was also executed and implemented across all applicable package singulation machines, after these parameters were validated as top contributors of the problem.

Potential problem analysis was also conducted, after implementation of corrective actions, to assess possible effect to product quality. This was done by performing visual inspection on lots processed from all the improved singulation machines.

3.5 Control Phase

After standardization of identified saw and handler parameters, the team has continued to

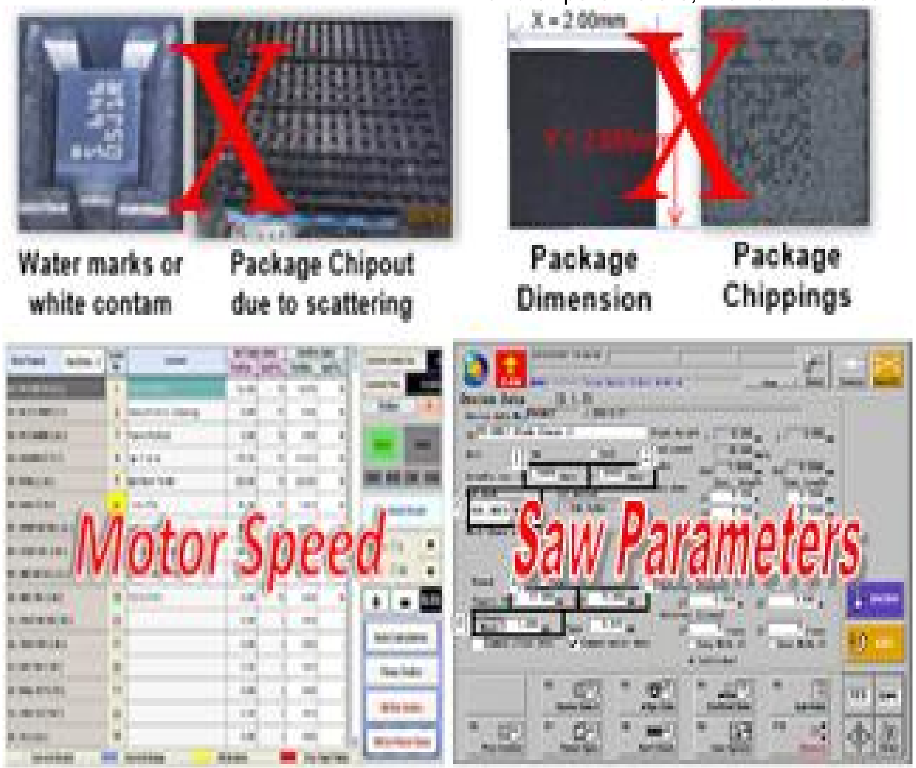


Fig. 8. Handler motor speed and saw parameters

Table 5. Post visual inspection validation

Machine I.D.	Package Size	UPH improvement			Summary
		Phase 1	Phase 2	Phase 3	
ESP049	2.5x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP050	2.5x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP051	2.5x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP073	2.5x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP061	2.0x2.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP043	2.0x2.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP070	2.3x2.3	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP066	3.0x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP052	7.0x7.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP055	7.0x7.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP056	7.0x7.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP058	7.0x7.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP059	3.0x3.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP060	9.0x9.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP071	5.0x5.0	5x lots validation	5x lots validation	5x lots validation	PASSED
ESP072	5.0x5.1	5x lots validation	5x lots validation	5x lots validation	PASSED

monitor results of improvements via visual inspection at post process, with passing result as shown on Table 5. All improvement actions and standardization of parameters were documented and deployed to all shop floor personnel handling these package singulation machines. Continuous UPH improvement is being done to fan-out these improvements on the other machine platforms.

4. RESULTS AND DISCUSSION

4.1 Phase 1: Wash and Dry Parameter Validation

This phase of the work was done after machine baselining of saw and handler wash and dry parameters from the best performing machine (see Table 6). Validation of machine UPH was acknowledged by IE, after standardization of parameters. 5x lot validation was performed through visual inspection, without quality issues. UPH improved from 7700 units to 8463 units or a total of 10.95% improvement.

4.2 Phase 2: Handler Motor Speed Validation

This validation was done after machine standardization of handler speed parameters baselined from the best performer machine (Table 7). Validation of machine UPH was verified by IE. 5x lot validation through visual inspection was performed without detectable quality issue. UPH improved from 8463 units to 8818 units or a total of 4.72% improvement.

4.3 Phase 3: Saw Parameter Validation

After the standardization of saw parameters baselined from the best performer machine per package type (shown in Table 8), validation of machine UPH was acknowledged by IE. 5x lot validation through visual inspection was performed with no quality issues. UPH increased from 8818 to 8975 units, which corresponds to a total of 1.98% improvement.

4.4 Summary of UPH Improvements

After completing all 3 phases of improvements, a total of 17.64% UPH improvement was achieved versus the project target of 13%. These improvements yielded the production of a total of 461K units per day, manufactured as additional machine capacity (Table 9).

Figs. 9 and 10 shows how machine UPH increases in every phase of the project.

4.5 Process or Quality Control Results

This phase was based on the actual data, gathered from the process control group regarding defects trapped during quality control gating. Fig. 11 shows results of the only few occurrences of white contam and package chipout at PC gate, but the cause is not machine related.

4.6 Validated Cost Savings

More than one thousand USD cost savings were achieved, which is equivalent to 2 quarters of Preventive Maintenance consumable parts replacement.

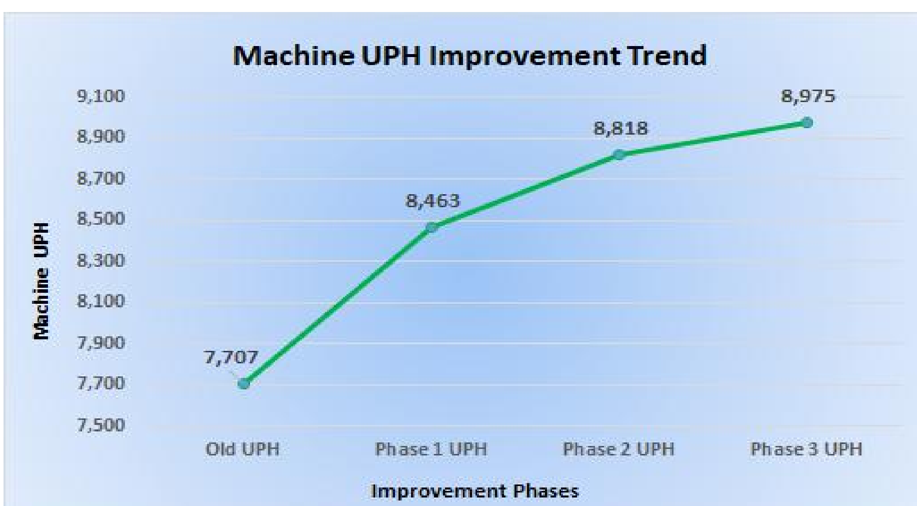


Fig. 9. Machine UPH improvement trend by phase

Table 6. Saw and handler wash and dry parameters

Machine I.D.	Package Size	Saw				Handler									
		Wash on Saw				Wash on Brush/Clean box/Dry Block						Pick and Place			
		Jig wash count (CH1/CH2)		Work wash count (CH1/CH2)		Brush Clean count		Clean Box count		Dry Air blow count		X1 assy (%)		X2 assy (%)	
		From	To	From	To	From	To	From	To	From	To	From	To	From	To
ESP049	2.5x3.0	6/6	5/5	6/6	5/5	10	10	20	20	40	20	100	100	100	100
ESP050	2.5x3.0	6/6	5/5	6/6	5/5	10	10	20	20	20	20	100	100	100	100
ESP051	2.5x3.0	6/6	5/5	6/6	5/5	10	10	20	20	20	20	100	100	100	100
ESP073	2.5x3.0	6/6	5/5	6/6	5/5	15	10	40	20	25	20	100	100	100	100
ESP061	2.0x2.0	6/6	5/5	6/6	5/5	50	20	40	30	20	20	100	100	100	100
ESP043	2.0x2.0	6/6	5/5	6/6	5/5	30	20	50	30	20	20	100	100	100	100
ESP070	2.3x2.3	6/6	5/5	6/6	5/5	25	20	20	20	30	20	100	100	100	100
ESP066	3.0x3.0	6/6	5/5	6/6	5/5	15	10	25	20	25	20	100	100	100	100
ESP052	7.0x7.0	1/1	1/1	1/1	1/1	8	8	10	10	8	8	100	100	100	100
ESP055	7.0x7.0	1/1	1/1	1/1	1/1	8	8	10	10	8	8	100	100	100	100
ESP056	7.0x7.0	1/1	1/1	1/1	1/1	8	8	10	10	8	8	100	100	100	100
ESP058	7.0x7.0	1/1	1/1	1/1	1/1	8	8	10	10	8	8	100	100	100	100
ESP059	3.0x3.0	6/6	5/5	6/6	5/5	25	10	15	15	25	15	100	100	100	100
ESP060	9.0x9.0	1/1	1/1	1/1	1/1	20	8	15	10	20	8	50	100	50	100
ESP071	5.0x5.0	2/1	1/1	2/1	1/1	15	10	10	10	15	15	90	100	90	100
ESP072	5.0x5.1	2/1	1/1	2/1	1/1	10	10	10	10	20	15	100	100	100	100

.

Table 7. Handler motor speed parameters

Packages	QFN-MR 7X7		VIKINGS		QFN3X3		UM16		MEMS 3X3		MEMS 2X2		NEWTON		MEMS 2.5X3	
Machines	**ESP052**		**ESP060**		**ESP059**		**ESP071**		**ESP066**		**ESP043**		**ESP070**		**ESP050**	
Improvement	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**
MZ UP/DN	60%	80%	70%	80%	60%	80%	30%	80%	60%	80%	50%	80%	20%	80%	5%	80%
Rail Slow Down	10%	10%	5%	10%	5%	10%	2%	10%	1%	10%	5%	10%	5%	10%	10%	10%
Rail Slow Up	5%	5%	5%	5%	5%	5%	5%	5%	2%	5%	1%	5%	5%	5%	5%	5%
CT Slow Down (SP)	10%	50%	20%	50%	5%	50%	2%	50%	20%	50%	5%	50%	20%	50%	20%	50%

Packages	**QFN-MR 7X7**		**VIKINGS**		**QFN3X3**		**UM16**		**MEMS 3X3**		**MEMS 2X2**		**NEWTON**		**MEMS 2.5X3**	
Machines	**ESP052**		**ESP060**		**ESP059**		**ESP071**		**ESP066**		**ESP043**		**ESP070**		**ESP050**	
Improvement	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**	**To**
CT Slow Up (SP)	5%	10%	10%	10%	10%	10%	1%	10%	20%	10%	5%	10%	5%	10%	10%	10%
CT Slow Down (UP)	10%	20%	30%	20%	10%	20%	10%	20%	8%	20%	5%	20%	10%	20%	5%	10%
CT Slow Up (UP)	5%	5%	3%	5%	5%	5%	5%	5%	2%	5%	3%	5%	5%	5%	5%	5%
Brush Left	20%	50%	50%	50%	20%	50%	20%	50%	20%	50%	10%	50%	15%	50%	15%	50%
Brush Right	20%	50%	50%	50%	20%	50%	20%	50%	20%	50%	10%	50%	15%	50%	15%	50%
Package Loading	80%	80%	50%	80%	80%	80%	60%	80%	20%	80%	80%	80%	20%	80%	60%	80%
Package Unloading	80%	80%	20%	80%	80%	80%	60%	80%	20%	80%	80%	80%	20%	80%	60%	80%
Water Remove Left	30%	50%	50%	50%	20%	50%	50%	50%	20%	50%	10%	50%	40%	50%	50%	50%
Water Remove Right	5%	10%	5%	10%	10%	10%	10%	10%	15%	10%	5%	10%	5%	10%	20%	10%
Dry Block Slow Down	5%	10%	50%	10%	2%	10%	5%	10%	10%	10%	10%	10%	30%	10%	5%	10%
Dry Block Slow Up	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	10%	10%	10%	10%	10%	10%
Turn Table Down	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	50%	80%	50%	80%	50%	80%
Turn Table Slow Up	3%	10%	5%	10%	10%	10%	5%	10%	5%	10%	5%	10%	2%	10%	10%	10%

Note: All parameters are within specification

Table 8. Saw parameters

Machine	Package type	Channels	Feed/Cutting speed		Cut entry clearance (CH1/CH2)		Blade cutting mode (Spindle)		Air curtain sweep speed	
			From	To	From	To	From	To	From	To
ESP058	VQFN-mr 7x7	CH1	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
		CH2	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP055	VQFN-mr 7x7	CH1	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
		CH2	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP052	VQFN-mr 7x7	CH1	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
		CH2	150 mm/sec	150 mm/sec	2 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP056	QFN Repat 3x3	CH1	20 mm/sec	20 mm/sec	5 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
		CH2	20 mm/sec	20 mm/sec	5 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
ESP060	Vikings 9x9	CH1	120 mm/sec	130 mm/sec	5 mm	2 mm	Single	Single	150 mm/sec	150 mm/sec
		CH2	120 mm/sec	130 mm/sec	5 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP060	Yosemite 3.5x4.5	CH1	15 mm/sec	15 mm/sec	2 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
		CH2	15 mm/sec	15 mm/sec	2 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
ESP059	QFN Repat 3x3	CH1	20 mm/sec	20 mm/sec	2 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
		CH2	20 mm/sec	20 mm/sec	2 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
ESP071	VFQFPN28 (UM16)	CH1	25 mm/sec	25 mm/sec	5 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
		CH2	25 mm/sec	25 mm/sec	5 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP072	VFQFPN28 (UM16)	CH1	25 mm/sec	25 mm/sec	5 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
		CH2	25 mm/sec	25 mm/sec	10 mm	2 mm	Dual	Dual	150 mm/sec	150 mm/sec
ESP066	MEMS 3.0x3.0	CH1	30 mm/sec	30 mm/sec	5 mm	2 mm	Single	Single	60 mm/sec	150 mm/sec
		CH2	60 mm/sec	60 mm/sec	5 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec
ESP064	MEMS 3.0x3.0	CH1	70 mm/sec	70 mm/sec	2 mm	2 mm	Single	Single	60 mm/sec	150 mm/sec
		CH2	70 mm/sec	70 mm/sec	2 mm	2 mm	Dual	Dual	60 mm/sec	150 mm/sec

Note: All parameters are within specification

Table 9. Phase improvement summary

Rawline	Old UPH	Target UPH	Target % Improvement	Phase 1 New UPH	Phase 1 % Improvement	Phase 2 New UPH	Phase 2 % Improvement	Phase 3 New UPH	Phase 3 % Improvement
CCFZ*UAW1AC2	4,314	4,961	15%	5,026	16.49%	6,227	23.90%	6,374	2.36%
88X0*UP31BA5	7,690	8,843	15%	8,244	7.21%	8,268	0.29%	8,369	1.22%
EAZX*UM16BCS	4,192	4,820	15%	4,284	2.20%	4,303	0.44%	4,303	0.00%
EAZX*UM16BCS	6,143	7,065	15%	6,185	0.68%	6,223	0.61%	6,380	2.52%
G53N*MV36BFA	7,322	8,201	12%	10,140	38.48%	10,158	0.18%	10,164	0.06%
G53N*MV36BFA	12,207	3,671	12%	12,972	6.27%	12,999	0.21%	13,020	0.16%
77BA*MV3WBAA	10,150	1,164	10%	11,433	12.16%	13,514	18.20%	14,440	6.85%
77AA*MV4YABA	12,038	3,242	10%	12,197	1.32%	12,358	1.32%	12,431	0.59%
77NN*MV7UACC	12,476	3,724	10%	13,605	9.03%	13,660	0.40%	13,749	0.65%
CU)U*UAC7ABD	6,014	6,916	15%	6,313	5.58%	6,494	2.87%	6,494	0.00%
CCZH*UAQ3BEC	2,230	2,565	15%	2,699	21.03%	2,793	3.48%	2,997	7.30%
			13%	8,463	9.82%	8,818	4.19%	8,975	1.78%
				PHASE 1	9.82%	PHASE 2	14.00%	PHASE 3	15.78%
				PHASE 1	10.95%	PHASE 2	4.72%	PHASE 3	1.98%
					10.95%	(P1+P2)	15.67%	(P1+P2+ P3)	17.64%

Old DLC K/day	New DLC K/day	Addt'l Capacity K/day	Total per macro package	Macro package
80	119	38	51	QFN < 5x5
143	156	13		
75	77	2	6	QFN >= 5x5
105	109	4		
150	208	58	363	LGA - MEMS
250	267	17		
208	296	176		
247	255	8		
256	282	104		
112	121	27	41	QFN - MULTIROW
42	56	14		
	Total Capacity Added	**461**		

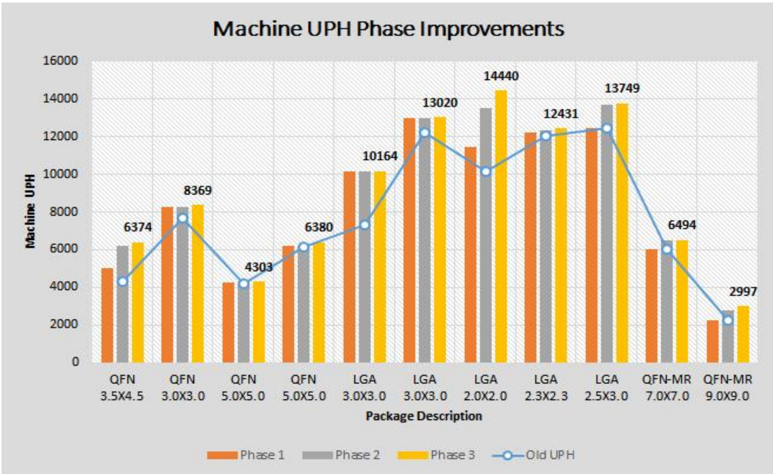


Fig. 10. Machine UPH phase improvement by package type

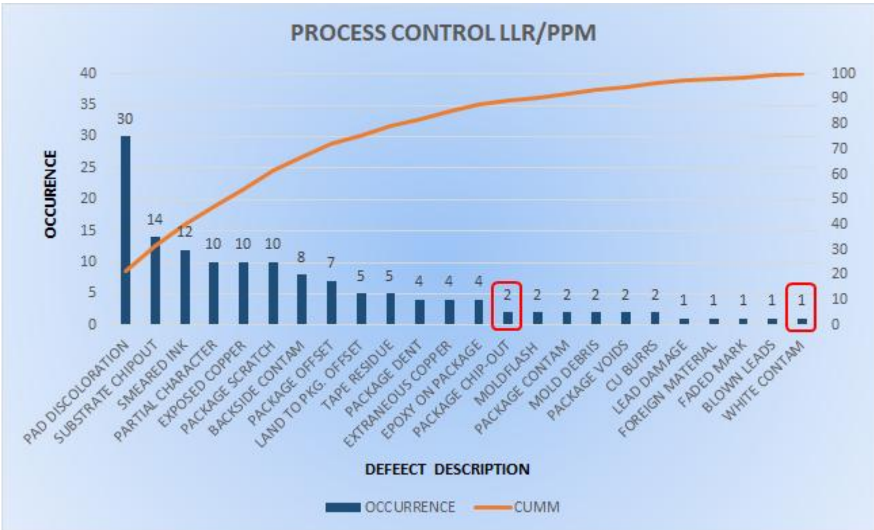


Fig. 11. LRR/PPM pareto graph

5. CONCLUSION

Increasing the UPH of package singulation machines using the DMAIC methodology is an effective and inexpensive solution to address low production capacity of machines. Measurement of current machine condition and validation of potential causes plays an important role in identifying the problem.

6. RECOMMENDATIONS

Machine baselining was initially executed to identify the best machine to be the model machine in standardization of machine parameters. It is recommended to check first the frequencies of cleaning and drying cycles, which was proven to be the top contributor of the problem addressed in this study. Machine handler speed and saw parameters also contribute to the increase of UPH. DMAIC methodology is highly recommended for being used in solving machine productivity.

ACKNOWLEDGEMENTS

The authors would like to thank STMicroelectronics Calamba Management for the support in this study. Thanks also to all the support groups who helped us during the execution of improvement actions especially the equipment engineering group.

DISCLAIMER

The products used for this research are commonly and predominantly utilized products in our area of research and country. There is no conflict of interest between the authors and product manufacturers because we do not intend to use these products as an avenue to any litigation, but strictly for advancing the knowledge. Also, the research was not funded by the producing company, but it was rather funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FL Amaya AMR, Aceituna, JAC. Soriano productivity improvement using lean six sigma DMAIC methodology in a steel manufacturing company, International Journal of Engineering Technology Research and Management. 2019 ;3(7).
2. Shmula Contributor. How to maximize production with the DMAIC process, Shmula.com; 2019.
3. Munro RA, Ramu G, Zrymiak DJ. The certified six sigma green belt, Handbook 2nd Ed, American Society for Quality; 2015.
4. Adam Henshall. DMAIC: The complete guide to lean six sigma in 5 key steps, Process.st, Article; 2017.
5. Nazrul Anuar, Amalina Taib. Saw singulation characterization on high profile multi chip module packages with thick leadframe, EPTC; 2004. IEEE Cat.No.04 EX971
6. Noorazam Bin Azman, Mohd Akif Emir A. Aziz challenges in singulation process of corner lead with wettable pocket on thin QFN packages. IEMT; 2018.
7. Hwa-Young Jeong, Jong-Hoon Kim, Kumhee Han. Development and implementation of an operation efficiency management system using the uph according to operation start time. IEEE; 2002. ICPADS.2001.934819
8. Samuel H Huang, John P Dismukes , Shi J, Su Qi, Mousalam A Razzak, Rohit Bodhale, Eugene Robinson D. Manufacturing productivity improvement using effectiveness metrics and simulation analysis. Int. J. Prod. Res. 2003;41(3)513-527.
9. Srinivas Rao D, Krishnaiah A, Krishna Y, Syed Adil. Optimization of cutting parameters for improved machining of Fe-Al alloy. IEEE; 2017, I2CT.2017.8226317.
10. Adar Kalir, Yair Nahum, Andy Sharon. The hidden productivity: How to get more out of your equipment; IEEE 2012, ASMC.2012.6212926.
11. Koh Wen Shi, Yow KY. The characteristics and factors of a wafer dicing blade and its optimized interactions required for singulating high metal stack lowk wafers, IEEE; 2013. EPTC 2013.
12. TK Wei, MN Mahmud. Optimization of semiconductor device packaging singulation process IOP conference series: Materials Science and Engineering. 2020. 2019;530 (1).

13. Wei-Sheng Lei, Ajay Kumar, Rao Yalamanchili. Die singulation technologies for advanced packaging: A critical review, 10.116/1.3700230 Journal of Vacuum Science and Technology. 2012;B30:040801.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65679