Original Research Article

# Increasing Singulation Machine UPH Through Characterization and Standardization of Saw and Handler Parameters


## ABSTRACT

This study aims to address the problem on machine saturation and low capacity at package singulation due to increasing product loadings and new devices that requires frequent machine setups and conversions.

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

UPH improvement per machine were validated and assessed in terms of machine efficiency and quality of products as a result of each characterization and standardization of parameters in every phase of the project with a total improvement of 17.64%.


*Keywords: UPH (unit per hour), DMAIC, Package Singulation*



## 1. INTRODUCTION

The semiconductor industry is the group of companies involved in the design and assembly of semiconductors. Over the years, it became a viable business and turns the driving force behind the wider electronics industry with billion-dollar annual sales revenue.

This 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 different sectors like microprocessors, logic, memory, power semiconductors, transceivers, network processors, sensors, etc.

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There are many processes in assembly of semiconductor device and one of them is 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 on Fig 1. then individually picked-up by a handler system and store in a tray.

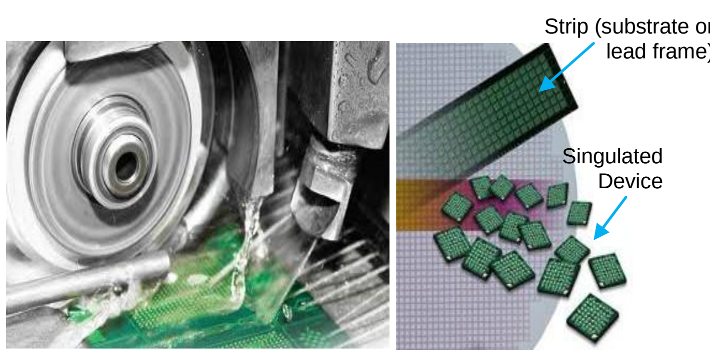


**Fig. 1. Package Singulation Process**

Machine UPH is the number of units produced within an hour by any equipment in a production area through a specified machine settings and parameters operated by trained personnel.
Among the best singulation machine platforms in terms of output and quality was a package singulation machine 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 that is capable to detect common top and bottom defects. Singulation machines nowadays has a built-in vision system on its handler itself as shown on Fig 2.
.


**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 manufacturing assembly, the management team decided to free-up capacity by UPH improvement to support future growth and cost competitive edge. Productivity and cost improvement by maximizing UPH and achieve 10% to 20% improvement based on current IE standards in reference to equipment capability and package complexity and one of the major assembly processes that has the opportunity to increase the UPH was the package singulation.

There are currently 18x Package Singulation machines which is fully utilized by production group processing packages like LGA-MEMS, QFN/BGA and QFN-mr packages as shown on Table 1.0.



**Table 1.0 Package Singulation Matrix**

| ESP M/C | PACKAGE | ESP M/C | 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 |

However, even there were allocated singulation machines, device loadings continue to increase and there were also incoming new devices which requires frequent machine setups and conversions.  The currently installed equipments were already saturated based on IE calculation.
There were also previous improvement actions from the equipment engineering group to speed-up the machine and increase its capacity to help achieve production daily delivery requirements like the reduction of pick and place z-picker vacuum on/off delay from 100 msec to 10 msec. But still, with this action for most of the packages with high strip density the bottleneck is still on the handler's pick and place as shown on Fig 3 and Table 2.0.

**Table 2.0 Package Singulation Bottleneck Pr**

| Strip Illustration | Strip Density | BOTTLENECK | |
|---|---|---|---|
| | | SAW | HANDLER |
| | 2800 units per strip | NO | YES |
| | 600 units per strip | YES | NO |

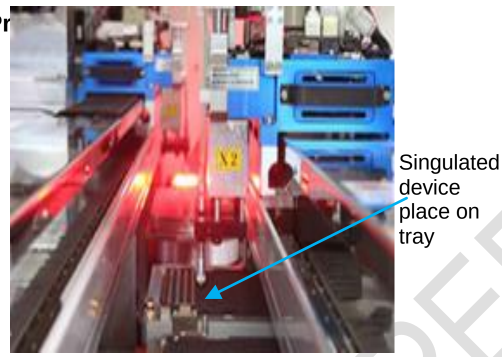



**Fig. 3 Handler's Pick and Place Process**

To improve the machine UPH and increase its capacity, identification of bottleneck process at package singulation is important before proceeding with improvement actions. These improvement actions are baselining of machine's actual performance, characterization, and standardization of parameters.
The proposed solution is different from previous improvement actions wherein no cost will be involved and cost avoidance of purchasing new package singulation equipment will be realized.

## 2.0 REVIEW OF RELATED LITERATURE

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 it affects the production operations.

2. Measure their current production systems. When everything is measured up, 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 the data, the organization can narrow down the cause of their production problems and figure out ways to maximize things.
4. Improvement phase is the stage where an organization tests, assess and implements all their ideas in terms of improving production.
5. Control phase is to make sure that they maintain all the improvement actions. 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 with less variations of the process.
There is a study in a steel industry regarding low productivity rate compared to target output that were addressed using 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 was identified as well as the factors that contribute to this problem.
An action plan was made 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 instruction of the process targeted.

## 3.0 METHODOLOGY

In this study, DMAIC methodology was used to achieve the objective of increasing the overall UPH of package singulation machines by 13.09% 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 are allocated to LGA while 22% for QFN and QFN-mr respectively.

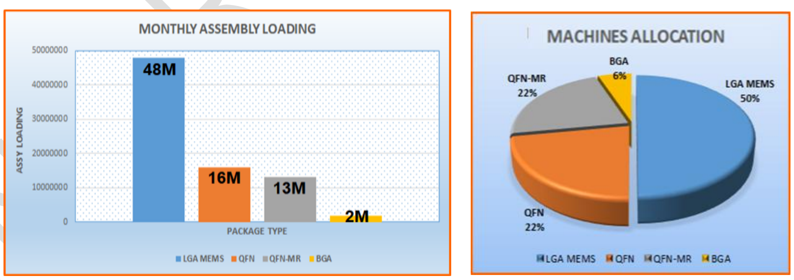



**Fig. 4 Monthly Loading and Package Allocation**

### *3.2 Measure Phase*

The critical processes at package singulation identified on this project was the saw and handler cleaning and drying process steps, handler motor speed and sawing process as shown on Fig.5.

**Fig. 5 Package Singulation Detailed Process Flow**

In identifying the process input variables, the team used the Input and Output Worksheet (I/O worksheet) to input all the variables in each process step that may potentially affect the machine UPH. There were 52 KPIV's (Key Process Input Variable) identified as potential X's as shown on Table 3.0.

All the input variables identified in the I/O worksheet were filtered thru the use of Cause-and-Effect Matrix (C&E Matrix as shown on Table 4.0) by scoring the effects of each variable with respect to the output response. With the use of this scoring matrix, we have identified the critical X's that affects the low machine UPH.

**Table 3.0 Input and Output Worksheet**

Input - Output Worksheet — Key Output Process Variables

| Characteristics of Process Outputs (KPOVs) | | | | |
|---|---|---|---|---|
| Key Output | Characteristic of Output (KPOV / Y / Mini Y) | 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, Seasona not controllable noise = mandatory (can control but not being contro

| | | Process Inputs (KPIVs) | | | |
|---|---|---|---|---|---|
| Process Step | SOP | Type of Input | Input | Characteristic of Input (KPIV / X) | C/N |
| **Material Preparation** | DMS No. 8296346 | Raw Material / Information | Input Material | Strips | Controllable |
| | | Raw Material / Information | Input Material | Input Magazine | Controllable |
| **Saw/Handler Program Loading** | DMS No. 8296346 | SOP / WI / Checklist | Setup | Saw Program / Handler Program | Controllable |
| **Magazine Loading** | DMS No. 8296346 | Raw Material / Information | Input Material | Magazine Condition | Controllable |
| | | Equipment / Infrastructure | Setup | Magazine Up/Down Speed | Controllable |
| **Strip Placement on Chuck table** | DMS No. 8296346 | Equipment / Infrastructure | Setup | Strip alignment | Controllable |
| | | Equipment / Infrastructure | Setup | Strip placement speed | Controllable |
| **Cutting of strip at chuck table** | DMS No. 8296346 | Equipment / Infrastructure | Setup | Cutting Speed | Controllable |
| | | Equipment / Infrastructure | Setup | Cutting Mode (Dual/Single Spindle) | Controllable |
| **Pick-up of sawn units from chuck table** | DMS No. 8296346 | Equipment / Infrastructure | Setup | Unit picker alignment | Controllable |

**Table 4.0 Cause and Effect Matrix**

Cause and Effect Matrix

| | | | Specification Limits (for Y) | Machine Capabi | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 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 |
| 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 pickheads | 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 (PnP) | Setup | PnP rubber pickheads | 1 | 10 | Discrete | 0 | 0 | Discard the X |
| 51 | | Setup | Placement speed | 9 | 90 | Discrete | 0 | 1 | Select the X |

Potential causes of the problem based on identified critical X's from the identified KPIV's that affects the low machine UPH will now proceed to statistical validation.

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

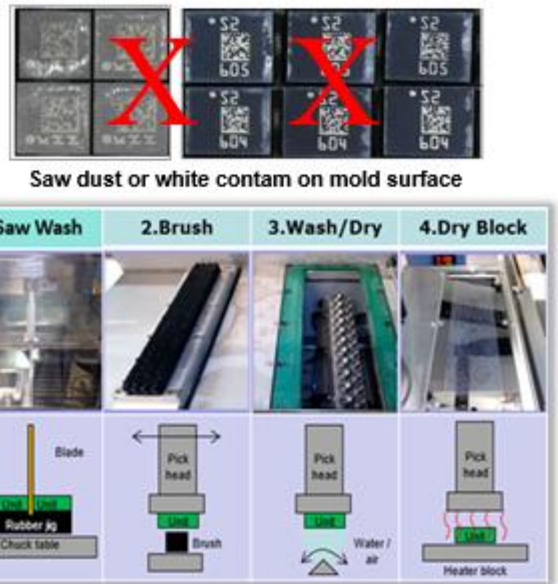



**Fig. 6 Saw and Handler Wash/Dry Process Steps**

### *3.3 Analyze Phase*

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

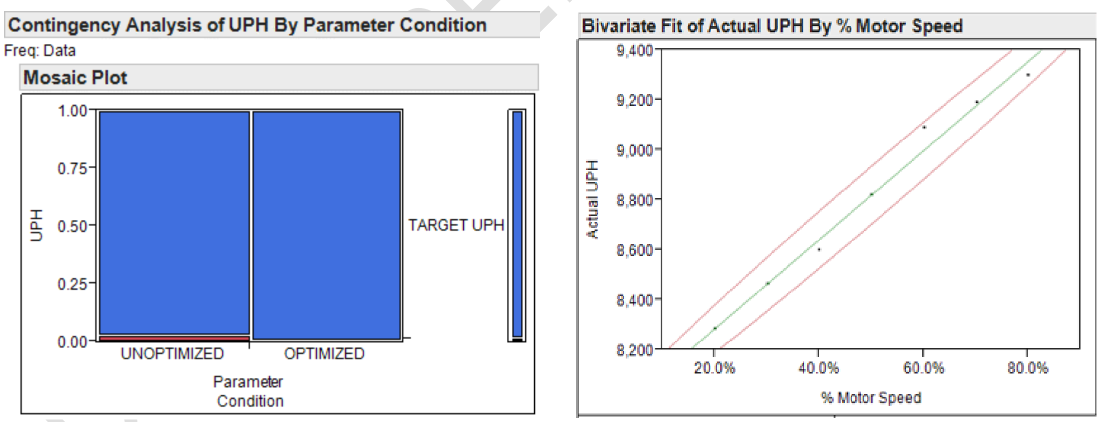



**Fig. 7 2-Proportion and Regression Statistical Testing**

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

### *3.4 Implementation Phase*

Implementation of baselined wash and dry parameters were executed 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 validating 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 is done by performing visual inspection on lots processed from all the improved singulation machines.


**Fig. 8 Handler Motor Speed and Saw Parameters**

### *3.5 Control Phase*

After standardization of identified saw and handler parameters, the team continue to monitor the results of improvements through method of visual inspection at post process with passing result as shown on Table 5.0.

All the 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.

**Table 5.0 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 |

## 4.0 RESULTS AND DISCUSSION

### *4.1 Phase 1:  Wash and Dry Parameter Validation*

After machine baselining of saw and handler wash and dry parameters from the best performer machine as shown on Table 6.0. Validation of machine UPH were acknowledged by IE after standardization of parameters. 5x lots validation thru visual inspection were performed without quality issue. UPH improved from 7700 units to 8463 units or a total of 10.95% improvement.

**Table 6.0 Saw and Handler Wash and Dry Parameters**

| Machine I.D. | Package Size | Saw | | | | Handler | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wash on Saw | | | | Wash on Brush/Cleanbox/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 |

**NOTE: All parameters are within specification**

### *4.2 Phase 2: Handler Motor Speed Validation*

After machine standardization of handler speed parameters baselined from the best performer machine as shown on Table 7.0. Validation of machine UPH were acknowledged by IE. 5x lots validation thru visual inspection were performed without quality issue. UPH improved from 8463 units to 8818 units or a total of 4.72% improvement.

**Table 7.0 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% |
| Chuck Table Slow Down (SP) | 10% | 50% | 20% | 50% | 5% | 50% | 2% | 50% | 20% | 50% | 5% | 50% | 20% | 50% | 20% | 50% |
| Chuck Table Slow Up (SP) | 5% | 10% | 10% | 10% | 10% | 10% | 1% | 10% | 20% | 10% | 5% | 10% | 5% | 10% | 10% | 10% |
| Chuck Table Slow Down (UP) | 10% | 20% | 30% | 20% | 10% | 20% | 10% | 20% | 8% | 20% | 5% | 20% | 10% | 20% | 5% | 10% |
| Chuck Table 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**

### *4.3 Pha*

After standardization of saw parameters baselined from the best performer machine per package type as shown on Table 8.0, validation of machine UPH were acknowledged by IE.

5x lots validation thru visual inspection were performed without quality issue. UPH improved from 8818 units to 8975 units or a total of 1.98% improvement.

**Table 8.0 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 |

### *4.4 Summary of UPH Improvement*

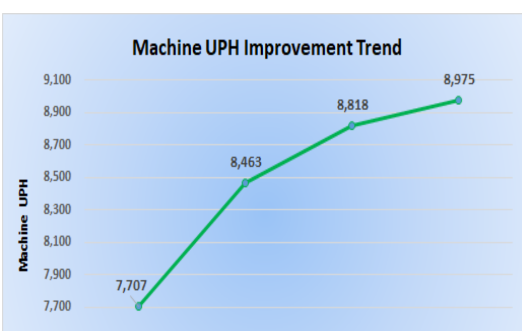
After completing all 3 phases of improvements, a total of 17.64% UPH improvement was achieved versus the project target of 13.09%. These improvements gave production a total of 461 units per hour produced as additional machine capacity as shown on Table 9.0.

**Table 9.0 Phase Improvement Summary**

| Rawline | Old UPH | 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 | 5,026 | 16.49% | 6,227 | 23.90% | 6,374 | 2.36% |
| 88X0*UP31BA5 | 7,690 | 8,244 | 7.21% | 8,268 | 0.29% | 8,369 | 1.22% |
| EAZX*UM16BCS | 4,192 | 4,284 | 2.20% | 4,303 | 0.44% | 4,303 | 0.00% |
| EAZX*UM16BCS | 6,143 | 6,185 | 0.68% | 6,223 | 0.61% | 6,380 | 2.52% |
| G53N*MV36BFA | 7,322 | 10,140 | 38.48% | 10,158 | 0.18% | 10,164 | 0.06% |
| G53N*MV36BFA | 12,207 | 12,972 | 6.27% | 12,999 | 0.21% | 13,020 | 0.16% |
| 77BA*MV3WBAA | 10,150 | 11,433 | 12.16% | 13,514 | 18.20% | 14,440 | 6.85% |
| 77AA*MV4YABA | 12,038 | 12,197 | 1.32% | 12,358 | 1.32% | 12,431 | 0.59% |
| 77NN*MV7UACC | 12,476 | 13,605 | 9.03% | 13,660 | 0.40% | 13,749 | 0.65% |
| CU)U*UAC7ABD | 6,014 | 6,313 | 5.58% | 6,494 | 2.87% | 6,494 | 0.00% |
| CCZH*UAQ3BEC | 2,230 | 2,699 | 21.03% | 2,793 | 3.48% | 2,997 | 7.30% |
| | | PHASE 1 | 10.95% | PHASE 2 | 4.72% | PHASE 3 | 1.98% |
| | | | 10.95% | otal (P1+P2) | 15.67% | (P1+P2+P | 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 | | |

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



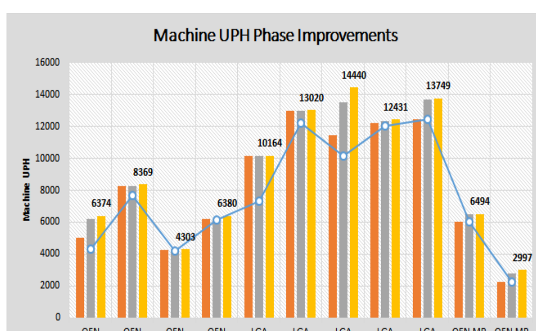



**Fig. 9 Machine UPH Improvement Trend by Phase Package**

**Fig. 10 Machine UPH Phase Improvement by Type**

### *4.5 Process or Quality Control Results*

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

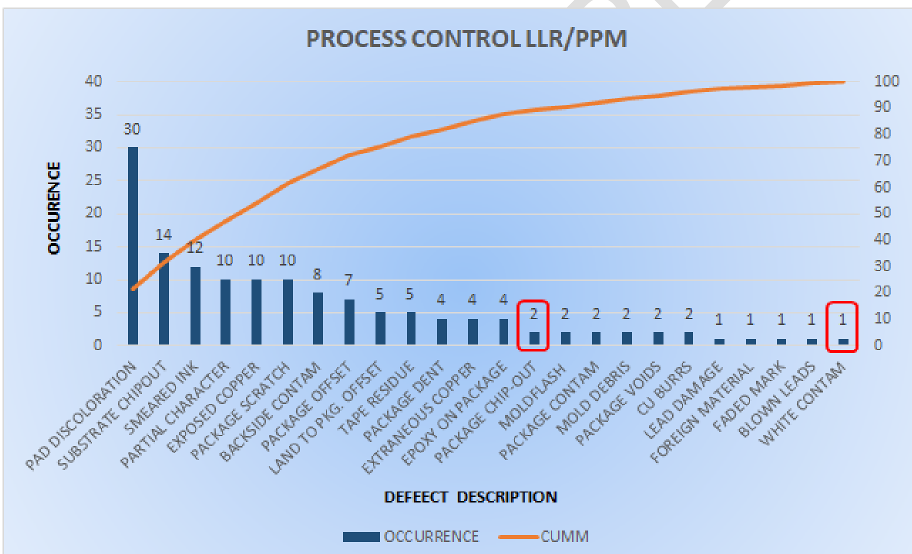



**Fig. 11 LRR/PPM Pareto Graph**

### *4.6 Validated Cost Savings*

More than a thousand USD cost savings which is equivalent to 2 quarters of Preventive Maintenance consumable parts replacement.

## 5.0 CONCLUSION

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

## 6.0 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 based on this study. Machine handler speed and saw parameters also contributes to the increase of UPH. DMAIC methodology is highly recommended to use in solving machine productivity.


## COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.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