Abstract

In this paper, Thinking 6 Sigma and Lean problem solving techniques are adopted for the solution development to improve operator efficiency on Mal DS TSxP Taping Process. The conventional Six Sigma tools are replaced with lean tools to enhance the effectiveness of the design, methodology, and approach for value and waste analysis. This newly developed approach has systematically identified insufficient and poorly defined operator job contents that are the root cause for low personnel efficiency. The successful implementation of this technique has resulted in ~RM200k annual saving without any unwanted implications on overall machine performance, OEE and product quality.

This newly developed value and waste analysis approach has proven to be effective for personnel efficiency improvement at TSxP taping process. Also, it has opened up many other opportunities at back-end manufacturing environment to further strengthen its competitiveness.

Introduction

Six Sigma today, is a set of problem solving tools that systematically applied five phases of activities, namely Define, Measure, Analyze, Improve & Control (DMAIC) [1]. The problem solving approach make known to the world in 1988 after Motorola winning the Baldrige National Quality Award [3].

Lean Manufacturing System, also known as Toyota Production System (TPS) that focus on customer value through continuous elimination of waste (Muda) throughout the whole supply chain. Lean's primary focus is on the customer, to address added and non-value added activities in the process. The ultimate objective of creating flow in lean manufacturing system is to deliver products and service just-in-time (JIT), in the right amounts, and the right quality levels at the right place. A Six Sigma process is necessary to enable the fulfillment of Lean manufacturing concept. Value Stream Mapping (VSM), Standard Work, 5S, Single Minute Exchange of Die (SMED), Visual Management, Jidoka are the common tools applies to streamline the flow of Lean Manufacturing System. [4] [5]

In the competitive semiconductor business environment, only company deliver highest quality product and fast enough to adapt change will survive. Integration of Six Sigma & Lean tools in problem solving become new approach in the industries, whereby the classical Six Sigma problem solving tools were use to improve process quality by reduction of process variation, and LEAN tools were use to focus on process efficiency improvement. Overall, the systematic DMAIC approach remains the key step in the process of problem solving.
**Definition**

Thinking Six Sigma + Lean (T6s+Lean) is an integration of Six Sigma, Lean and 8D problem solving approach developed by Infineon. DMAIC remain the problem solving systematic in T6s+Lean. However, the application of problem analysis tools may be varies depend on the case under investigation.

Personnel Efficiency (PE) as per equation below:

\[ PE = \frac{Monthly\_working\_hours + OT\_hours}{Monthly\_output} \]

Where the PE value is lower, the better of personnel efficiency is optimized

**Project Objective**

Main objective of this project is to study the factors that causing low personnel efficiency at TSxP taping line of MAL DS and develop an improve solution through Infineon Thinking 6 Sigma + Lean DMAIC problem solving approach.

**Methodology**

Thinking Six Sigma + Lean (T6s+Lean) is an integration of Six Sigma, 8D and Lean problem solving approach. DMAIC remain as the foundation of the problem solving systematic in T6s+Lean. However, the application of problem analysis tools may be varies depend on the case under investigation as showed in Figure 1.

The Define phase is to ensure a clear, aligned understanding of the project topics and on the expected outcome of the project. The Measure phase helps the team to identify potential sources for the nonconformity in the process. In the Analyze phase, the hypotheses are verified to confirm that the real causes for problem. Also, to identify respectively suitable levers to improve the process performance. Purpose of phase Improve is to develop and to tests solutions to achieve the targeted process performance. Finally, in Control phase, the process change is to be rolled out on a broader scale and to assess the performance in a long term.

**DEFINE PHASE**

Objective of this phase is to describe the problem based on customers’ requirements and needs and to define the project scope and plan.

In this case, the object is Taping machine named THA and the non-conformity is unoptimized headcount efficiency where the man to machine ration is 1:2. A final problem statement is clearly defined by only facts: TSxP package run on THA Taping machine with final Personnel Efficiency of 2.54 which is above TCR target 2.30 and current actual headcount is not optimized where the man machine ration is only 1:2 (Figure 2).

Figure 2: Object and Nonconformity are identified with a final problem statement

A problem clarification consisting of 10 elements is needed to provide sufficient
information and solid state to identify the root cause and to define suitable solution, e.g., The nonconformity was first noticed since September 2011, with the potential saving RM78,000 (Figure 3)

Figure 3: A problem clarification of 10 elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimension 1</th>
<th>Dimension 2</th>
<th>Dimension 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td>2</td>
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<td>9</td>
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<tr>
<td>10</td>
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</tr>
</tbody>
</table>

SIPOC tool is used to provide a high level process map to identify the business process that needs to be improved. The five high level process are: tested unit supply and obtain F1 material; prepare lot traveler; setup equipment and PC buyoff; machine running and output send to incoming 100% VI rack.

Next, Voice of Customer (VoC) is undertaken to lead the team step by step to a good understanding of what the customer wants and needs and to identify the Critical to Quality (CtQ) characteristics, which a key attribute of products must be met to satisfy the customer needs. As showed in Figure 4, customer is DS Management and the requirement is to improve the man to machine ratio from 1:2 to 1:3 so that the personnel efficiency target could be achieved.

Figure 4: Voice of Customer (VoC)

<table>
<thead>
<tr>
<th>Customer</th>
<th>Stakeholders</th>
<th>Need</th>
<th>Driver</th>
<th>C/D/P</th>
<th>Metric</th>
<th>Target</th>
<th>Requirements</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS</td>
<td>Management</td>
<td></td>
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</tbody>
</table>

The team concluded that there is no containment action requires in this case as the visual data analysis show the THA Taping process is in control and show no special cause in I-Chart as illustrated in Figure 5.

Figure 5: Visual Data Analysis shows the process is in control and no containment action required

In the last step of the Define phase, the team completed a project charter which gives the Project Leader, project customers a clear agreement on the project scope, project schedule, and other relevant elements. With the completion of the goals, project can be continued to Measure phase.

MEASURE PHASE

Objective of this phase is to measure the actual process capability at the potential sources of the nonconformity.

At Measure Phase, process mapping is employed to identify the potential source of the low personnel efficiency at TSXP production. The sequence of the single activities performed in THA taping process is recorded.

Figure 6: The result for the taping process mapping
In this case, VA/NVA & 7 Waste Analysis is used to identify and eliminate waste at the taping process as showed in Figure 7.

Figure 7 details the VA/NVA analysis for the TSXP taping.

<table>
<thead>
<tr>
<th>VA</th>
<th>NVA</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>39</td>
<td>Walk and Print protocol result</td>
</tr>
<tr>
<td>38</td>
<td>37</td>
<td>Setup parameter</td>
</tr>
<tr>
<td>35</td>
<td>34</td>
<td>Clean sealing</td>
</tr>
<tr>
<td>32</td>
<td>31</td>
<td>Clean chuck table</td>
</tr>
<tr>
<td>30</td>
<td>29</td>
<td>Perform JHAM activities</td>
</tr>
<tr>
<td>28</td>
<td>27</td>
<td>Perform manual inspection under microscope</td>
</tr>
<tr>
<td>26</td>
<td>25</td>
<td>Equipment PC buyoff</td>
</tr>
<tr>
<td>24</td>
<td>23</td>
<td>Material Preparation</td>
</tr>
<tr>
<td>22</td>
<td>21</td>
<td>Workstation Check</td>
</tr>
<tr>
<td>20</td>
<td>19</td>
<td>Lot Preparation</td>
</tr>
<tr>
<td>18</td>
<td>17</td>
<td>Travel to wafer rack to get the sawn frame</td>
</tr>
<tr>
<td>16</td>
<td>15</td>
<td>Insert Paper Tape (Bottom)</td>
</tr>
<tr>
<td>14</td>
<td>13</td>
<td>Insert carrier tape</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>Insert cover tape</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>Fold pizza boxes</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>Insert Paper Tape (Top)</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Print material protocol</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Print material protocol result</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Manual inspection</td>
</tr>
</tbody>
</table>

The analysis indicated that some tasks involved transportation and motion waste. Operation Value Add (OVA) and Non Value Add (NVA) contributed more than 70%. These revealed that there are some improvement opportunities at the taping process. Operation Value Add (OVA) is the activity that is not a value add to customer’s point of view but necessary for operation to complete the process, example: Visual Inspection, Statistical Process Control (SPC)

As a result, activities such as scheduled JHAM, reels and pizza box transportation, manual pizza box folding, over-processing on lot traveler checking, manual lot traveler recording, equipment set-up, transportation on peel off force measurement, transportation on test strip to quality check, visual inspection, motion on reel changed and wafer change assist, machine assist, transportation and motion on print material protocol and transportation on good material submitted for next process were categorized as non value add activities.

After VA & NVA and seven waste analyses, the team used Cause and Effect Matrix as showed in Figure 8 to help to find the relationship between process elements and the non-conformity by giving a grade from 1 to 10 on the relationship between non value add process elements and the non-conformity in taping process. The top three non-conformities identified are job balancing for operator is not optimized, inconsistent of process method, and abnormal process issues.

Pareto Analysis to identify and confirm the top three possible causes for the nonconformity by 80/20 Rule. With brainstorming ideas from the team, a Fishbone Diagram in Figure 9 is to identify the potential root cause that contributes to the high OVA & NVA contribution.

Figure 9: Fishbone Diagram
ANALYZE PHASE

Objective of this phase is to test the hypothesis of the nonconformity by data and facts.

At Analyze Phase, the three hypotheses were evaluated based on the non-conformities identified at the previous stage. Figure 8 shows the three hypotheses developed and the summary of findings.

Hypothesis 1: High percentage of NVA activities in Taping operation causing low personnel efficiency.

\[ H_0: \text{NVA activities cause no significant impact to low personnel efficiency} \]

\[ H_1: \text{NVA activities cause significant impact to low personnel efficiency} \]

Propositional test method used to determine the \( p \) value. If \( p \) value smaller than 0.05, this revealed that there is a significant difference and the hypothesis accepted. Based on the proportion test carried out, \( p \) value obtained for high percentage of NVA activities in taping operation which cause low personnel efficiency was 0.025 and smaller than 0.05, this two proportion test indicate NVA contribution is significantly higher than the VA activity and therefore the NVA operator activities needed to be reduced. Therefore, \( H_1 \) is accepted.

Hypothesis 2: Operator to operator manual activities processing time is not consistent resulting low personnel efficiency

\[ H_0: \text{No significant difference between operator manual activities processing time} \]

\[ H_1: \text{Significant difference between operator manual activities processing time} \]

Data collection method is 2 data sample point for each operator for each manual activities processing time:

1. Do the manual inspection and send to Q buy off
2. Perform peel force test
3. Paste two units and used cotton stick onto the recording book
4. Pack processed spool
5. Equipment Setup – Key in info manually on computer display
6. Obtain F1 material from F1 material room

Based on Normality Test and I control Chart, each manual activities processing time show normal and stable in the process and can be further proceed with one variable test against IE MOST STD Time. Based on one variable test, \( p \) value obtained for operator to operator manual processing time is not consistent resulting low personnel efficiency was bigger than 0.05. Therefore, \( H_0 \) is accepted.

Hypothesis 3: High frequency of Visual Inspection Processing Time causing low personnel efficiency

\[ H_0: \text{High frequency of visual inspection Processing Time cause no significant impact to low personnel efficiency} \]

\[ H_1: \text{High frequency of visual inspection Processing Time cause significant impact to low personnel efficiency} \]

The frequency of visual inspection process between SOP (Standard of Procedure) and current is the same. Therefore, it was concluded that high personnel of visual inspection processing time causing low efficiency is not valid.

With three hypotheses tested, the team move forward to Improve phase.

IMPROVE PHASE

Objective of this phase is to develop and to test solutions to achieve the targeted process performance.

At Improve phase, suggestion of regrouping and re-consolidating the value added and non-value added of taping activities with the idea of removing the NVA task from the
operator was proposed to improve multi-machine operations. Compared to the current state, the future state of process introduced "machine operator and "butterfly operator" concept by re-designing job content of operator into two different groups of operators. “Machine operator” is responsible for value add tasks such as material preparation, e.g.: pizza box, reels, carrier tapes, attend machine stoppages whereas the 'butterfly operator' is responsible for non value add tasks such as transportation, quality check as illustrated in Figure 9

Figure 9: Consolidation of value add and non value add tasks

Based on the new future state of process steps, the workflow step for THA taping was divided into two separate parts. There are the "machine operator" activities and "butterfly operator" activities. The non value added activities of carried out by the machine operator was reduced by 31.5% and the walking distance of operator was reduced by 57%. By introducing butterfly operator, it shares some of these non value activities which original own by the machine operator. As a result, the machine operator was able to take-care additional equipment since the job load significant reduces compare to the initial state. The new task allocation of machine operator and butterfly operator are illustrated in Figure 10.

Figure 10: Improved process step by redesigning job content of operator and butterfly operator

The trial run lasted for two months to ensure that the changes of man to machine ratio from 1:2 to 1:4 and 1:16 brings no impact to Overall Equipment Effectiveness (OEE) and Mean Time To Repair (MTTR). With the total number of operators to run fourteen THA taping machines is optimized from seven to five, fourteen THA Tapers performance and operator availability to repair the machine process to be maintained in normal and stable state.

Statistically, two sample T-Test show no significant difference of before and after of MMO change, I control show the before and after of MMO change is stale. Lastly, the box plot also showed that there is no extreme compared before and after of MMO change. The result can be showed in Figure 11.

Figure 11: Solution is verified through several of statistic tools.

In conclusion, the result showed that change of MMO does not bring negative impact to OEE and MTTR. With the successful implementation at Improve phase, the team moves forward to Control phase.

CONTROL PHASE

The objective of this phase is to roll out the process improvement and assess the long term performance for sustainability.

The solution from Improve phase was successfully rolled out and gone live in taping production with some action item needed including formal shift briefing across all the shifts, documentation of change on IE MMO database. Besides this, long term
performance verification is monitored and the result showed there is a significant personnel efficiency improvement from 2.54 reduced to 1.94 which is achieving the TCR target of 2.30 as well (Figure 12).

**Figure 12: Long Term Performance Verification of Personnel Efficiency Tracking**

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**RESULT**

With the successful project completion, the team decided to review the business case. As showed in the table 1, the achievement of the project is showing double up of the project target from RM 78,000 to RM 174,000 with the man to machine ratio is improved from 1:2 to 1:4 and the headcount required is improved from twenty one to fifteen daily. Also, the solution deployment was successfully rolled out in Wuxi DS and other sites of IFX.

<table>
<thead>
<tr>
<th></th>
<th>Before Project</th>
<th>Project Target</th>
<th>After Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMO</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>H/C per day</td>
<td>21</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>-</td>
<td>RM 87K</td>
<td>RM174K</td>
</tr>
</tbody>
</table>

Table 1: Compare project achievement VS project target

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**CONCLUSION**

This study applies the Thinking 6 Sigma and Lean problem solving approach to low personnel efficiency in TSxP packages on THA taping process. Redesigning the job content of operator by using the VA & NVA analysis was able to improve headcount productivity without implications of machine performance and product quality. Headcount productivity is improved and operation cost is minimized. This systematic approach can be applied by other thinking 6 sigma and lean practitioners to conduct lean activities in other manufacturing sectors.

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**Reference**