Improving the Measurement Method of pocket dimension of chip carrier tape
-- A Gage R&R/ MSA Study

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Abstract

The chip pocket size of the paper carrier tape is one of the most important quality characteristics. The size of the chip pocket may greatly affect the pick & place performance in the SMT process. If the pocket size is too big, the residing chip may flip to the corner, meanwhile if the pocket size is too small, the residing chip may get stuck. Both scenarios are proven to be problematic for the pick & place vacuum suction nozzle. The quality check of the chip pocket size becomes a crucial inspection item to ensure that the width and length of the pockets are conforming to the specified specifications. However, not all inspection methods are equal as we shall see from this technical report.

A new approach to measure the pocket size of the paper carrier tape is examined. The new approach involves the light source coming from the top with bottom-up placement of the tape sample. The old method involves the light source originates from the bottom with bottom-down placement of the tape sample. After analyzing the physical characteristics of the tape samples and the measurement principle of the precision light projection measurement apparatus, we can see that in theory the new method enables the inspector to make more precise observations. The Gage R&R analysis of the new method versus the old method also confirms that the new method yield less variations from the inspectors and more variations from part-to-part, meaning that the new measurement system is able to detect differences among the measurement samples much better than the old method.

Keywords: Paper Carrier Tape; Chip Pocket Size; Gage R&R
1.0 Introduction

Before a product is being put to the market, it goes through a series of complex designing and testing process, and then the final product is promoted to markets. New innovations are stimulated by the customers, competitors, suppliers, etc., but not all of them will be immediately adopted by end users. After carefully considering which innovations will set future trend, the designers can focus on those particular ones are feasible. Then after the designing phase is completed, going through further testing and evaluations, and then mass production, finally the product can be introduced to the market.

The MLCC/MLCI chip pocket size of the paper carrier tape is one of the most import quality characteristics. The size of the chip pocket may greatly affect the pick & place performance in the SMT process of assembly line industries. If the pocket size is too big, the residing chip may flip to the corner, meanwhile if the pocket size is too small, the residing chip may get stuck. Both scenarios are proven to be problematic for the pick & place vacuum suction nozzle. The quality check of the chip pocket size becomes a crucial inspection item to ensure that the width and length of the pockets are conforming to the specified specifications. However, not all inspection methods are equal as we shall see from this technical report.

The MLCC/MLCI chip pocket size measurement has been a subject of great controversy due to lack of uniformed measurement method and judgment standard. The newly proposed method using the top light projection and inverted sample placement appears to be more precise and creates less measurement error than the existing bottom light projection method, as the measurement data and Gage R&R analysis would show.

2.0 Sample Description

The pocket size of the Paper Punch Tape is one of the most critical quality characteristics. Ideally, during the punching process the punch die would create a pocket edge that is perfectly smooth and straight, however, that is rarely the case due to poor process control and wear and tear of the punch die. Therefore in actual situation, the pocket edge would exhibit some degree of paper residue and/or lint around the actual pocket edge. The picture below shows the distinction between the actual edge and the paper residue:
The paper residue is a thin membrane lies on the bottom side of the paper tape. Furthermore, due to wear and tear of the punch die, worn out punching die would create uneven or curved pocket edges, as the below pictures show:

![Curved Inward](image1)
![Curved Outward](image2)
![Saw-shaped Edges](image3)

Another point that was observed is that the bottom part of the edge is most likely narrower than the upper part of the edge. The below picture describes the observed phenomenon:

![Tape Cross-Section](image4)

All three points mentioned above can create potential problems such as chip-stuck and chip-flip which would eventually cause SMT pick and place error. It is considered that the actual edges from the bottom side are the most critical in affecting chip-stuck and chip-flip problems.
3.0 Measurement Principle

The paper tape pocket size is measured with a light projection with a movable platform to track the X and Y distances. The following is a brief explanation of the Existing Method versus the newly proposed method.
When using the bottom light projection, the actual edge is difficult to determine because the lights are blocked off by any solid object in its path. In this case, the actual edge image is obscured by the paper residue and lint. Therefore when the inspector is aiming for the actual edge, his/her judgment is subjective.

Existing Method

Light Projection: Bottom
Sample Placement: Bottom Down
View Focus: From Top

New Method

Light Projection: Top
Sample Placement: Bottom Up
View Focus: From Top

When using the top light projection, 2 different shades of images would appear around the pocket edge. When the light comes from the top, it bounces and reflects back to the top when it hits an object surface. But when the object surface has a different thickness, light would travel through the thinner part and thus cause less reflection in that thinner part. This principle is observed when the thinner paper residue and/or lint would have a different shade of image.
compared with the actual solid edge. This would allow the inspectors to clearly distinguish where the actual edges begin. The following photos demonstrate the differences between the Existing Method and the New Method:

**Existing Method**

![Existing Method Image]

It is hard to determine where the actual edge begins. The judgment criteria for the inspector is hard to determine.

**New Method**

![New Method Image]

Unit Burn-out Mark
Actual Edge
Paper Residue

Two shades of images are clearly shown to distinguish the actual edge and the paper residue.

### 4.0 Measurement Data

Three inspectors were assigned to measure 15 designated pockets of a paper punch tape sample, each pockets are repeatedly measured 3 times. In the New Method, the pocket widths are measured as the distance between the actual edges at the lower side of the pocket. The collected data are analyzed by Gage R&R ANOVA method using the Minitab.
### Gauge R & R Data Sheet

| Appraiser | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | Average Value |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------------|
| A         | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 |
| B         | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 |
| C         | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 |
| D         | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0250 |
| Average   | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 | 0.0425 |
| Range     | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 | 0.0500 |

**Between/Appraiser**

<table>
<thead>
<tr>
<th>Appraiser</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>Average Value</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0400</td>
<td>0.0400</td>
<td>0.0400</td>
<td>0.0400</td>
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<td>0.0400</td>
<td>0.0400</td>
<td>0.0400</td>
<td>0.0400</td>
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<tr>
<td>B</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0350</td>
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<td>0.0350</td>
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<td>0.0350</td>
</tr>
<tr>
<td>C</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0350</td>
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<td>0.0350</td>
<td>0.0350</td>
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</tr>
<tr>
<td>D</td>
<td>0.0350</td>
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<tr>
<td>Average</td>
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<td>0.0600</td>
<td>0.0600</td>
<td>0.0600</td>
<td>0.0600</td>
</tr>
</tbody>
</table>

**Average**

### Calculations

\[
\text{R}^2 = \frac{\sum \text{average range}}{\sum \text{sum of appraisers}} - \text{Average}^2
\]

\[
\text{UCL}_R = 2.58 \times \text{UCL}_{\text{LCL}}
\]

\[
\text{LCL}_R = 0.0000
\]

Note: **D4=3.27** for 2 trials and 2.58 for 3 trials; **D3=0** for up to 7 trials. UCL represents the limit of individual R's. Circle those that are beyond this limit. Identify the cause and correct. Repeat these readings using the same appraiser and unit as originally used or discard values and reaverage and recompute R and the limiting value from the remaining observations.
5.0 Data Analysis

The Gage R&R results are compared for the Existing Method and the New Method measurement data.

5.1 Analysis of Variance (ANOVA)

Existing Method

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part No.</td>
<td>14</td>
<td>0.0049525</td>
<td>0.0003545</td>
<td>3.1127</td>
<td>0.005</td>
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<tr>
<td>Inspector</td>
<td>2</td>
<td>0.0076221</td>
<td>0.0038111</td>
<td>33.4663</td>
<td>0</td>
</tr>
<tr>
<td>Part No. * Inspector</td>
<td>28</td>
<td>0.0031886</td>
<td>0.0001139</td>
<td>7.5956</td>
<td>0</td>
</tr>
<tr>
<td>Repeatability</td>
<td>90</td>
<td>0.0013493</td>
<td>0.000015</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>134</td>
<td>0.0171225</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ANOVA shows that from the measurement data obtained from the Existing Method, most of the variations come from the Inspector. The variations from the Part No. are insignificant.
The ANOVA shows that from the measurement data obtained from the New Method, most of the variations come from the Part No. The variations from the Inspectors are insignificant.

5.2 Gage R&R

The Gage R&R consists of 2 components, Repeatability and Reproducibility. The Repeatability, or Equipments Variability (EV) represents the variability of repeated measurements by the same inspector using the same designated equipment. The Reproducibility, or Appraisers’ Variability (AV) represents the variability of the measurements of the same designated samples using the same designated equipment performed by different inspectors. In a good measurement system, the Repeatability and Reproducibility should be as small as possible. Another important element of the Gage R&R analysis is the Part-to-Part variability, which represents the variability in measurements across different parts. In a good measurement system, the Part-to-Part variation should be as large as possible, meaning that the measurement system can effective distinguish differences between parts. Below is a comparison of the Gage R&R analysis result between the Existing Method and the New Method.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Formula of Variance</th>
<th>Relative Variance</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>( EV = \sqrt{MS_{EV}} )</td>
<td>( EV \times 100 )</td>
<td></td>
</tr>
<tr>
<td>AppV</td>
<td>( AppV = \sqrt{\frac{MS_{App} - MS_{AppPart}}{nr}} )</td>
<td>( AppV \times 100 )</td>
<td>( n: \text{parts, } r: \text{repeated, } k: \text{appraisers} )</td>
</tr>
<tr>
<td>IV</td>
<td>( IV = \sqrt{\frac{MS_{AppPart} - MS_{EV}}{r}} )</td>
<td>( IV \times 100 )</td>
<td></td>
</tr>
<tr>
<td>AV</td>
<td>( AV = \sqrt{AppV^2 + IV^2} )</td>
<td>( AV \times 100 )</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1: Resource Formula of Variance

<table>
<thead>
<tr>
<th>Resource</th>
<th>Formula of Variance</th>
<th>Relative Variance</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRR</td>
<td>$GRR = \sqrt{EV^2 + AV^2 + IV^2}$</td>
<td>$GRR \times TV \times 100$</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>$PV = \sqrt{\frac{MS_{Part} - MS_{ApprPart}}{rk}}$</td>
<td>$PV \times TV \times 100$</td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>$TV = \sqrt{GRR^2 + PV^2}$</td>
<td>$1.41 \times \frac{PV}{GRR}$</td>
<td>Nd = the number of distinct categories</td>
</tr>
</tbody>
</table>

### Existing Method

<table>
<thead>
<tr>
<th>Source</th>
<th>VarComp</th>
<th>%Contribution (of VarComp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gage R&amp;R</td>
<td>0.0001301</td>
<td>82.96</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>0.000015</td>
<td>9.56</td>
</tr>
<tr>
<td>Inspector</td>
<td>0.0000822</td>
<td>52.38</td>
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<tr>
<td>Inspector*Part No.</td>
<td>0.000033</td>
<td>21.02</td>
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<tr>
<td>Part-To-Part</td>
<td>0.0000287</td>
<td>17.04</td>
</tr>
<tr>
<td>Total Variation</td>
<td>0.0001568</td>
<td>100</td>
</tr>
</tbody>
</table>

### New Method

<table>
<thead>
<tr>
<th>Source</th>
<th>VarComp</th>
<th>%Contribution (of VarComp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gage R&amp;R</td>
<td>0.0000213</td>
<td>90.79</td>
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<tr>
<td>Reproducibility</td>
<td>0.0000128</td>
<td>18.45</td>
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<tr>
<td>Inspector</td>
<td>0.0000085</td>
<td>12.34</td>
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<tr>
<td>Inspector*Part No.</td>
<td>0.0000071</td>
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<tr>
<td>Part-To-Part</td>
<td>0.0000479</td>
<td>69.21</td>
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<tr>
<td>Total Variation</td>
<td>0.0000692</td>
<td>100</td>
</tr>
</tbody>
</table>

The comparison shows that the total Gage R&R of the New Method is significantly smaller than the Existing Method. In particular, the Reproducibility from the New Method is significantly reduced, which suggests that the New Method yields less measurement variations contributed by different inspectors. This make sense since in the New Method the inspectors have a clear judgment rule in determining where to aim for the actual pocket edge, while as in the Existing Method the inspectors have to “guess” were to aim.

The Part-to-Part variation statistics shows that in the New Method, 69.21% of the variation is contributed by the parts (different pockets), while the Existing Method only yield 17.04%. This suggest that the New Method is more effective in detecting differences between the parts (pockets).

The graphical charts of the measurement variation analysis also confirm that the New Method gives more stable measurement results among different inspector, and it is better in detecting part-to-part variations.

### 6.0 Conclusion / Discussion

From the measurement principle, we can see that the New Method allows the inspector to better distinguish where the actual edge of the pocket lies, while in the Existing Method the
inspectors’ judgment of the actual edge can be subjective. The measurement data analysis shows that the New Method yields less variability contributed by different inspectors, because the judgment criteria can be clearly defined, thus it is much easier to standardize the measurement method among different inspectors. The data analysis result also reveals that the New Method is better in detecting part-to-part variations.

The Gage R&R of the New Method can be further improved by accurate training of a standardized inspection procedure and judgment criterion; this will further reduce the Reproducibility (Appraisers’ Variation). In addition, over-hauling and calibration of the measuring equipment will reduce Repeatability (Equipment Variation).

So in conclusion, all evidences suggest that the New Method is a better choice in measuring paper punch tape’s pocket size.

**New Method**

**Gage R&R (ANOVA) for Measure**

<table>
<thead>
<tr>
<th>Gage name</th>
<th>Pocket Width Measurement - New Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data of study</td>
<td>22.11.2006</td>
</tr>
</tbody>
</table>

**Components of Variation**

- **Gage R&R**
- **Repeat**
- **Reprod**
- **Part-to-Part**

**Measure by Part No.**

- **Parts**
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12
  - 13
  - 14
  - 15

**Measure by Inspector**

- **Inspectors**
  - A
  - B
  - C

**X-bar Chart by Inspector**

- **Sample Mean**
  - UCL = 0.69419
  - LCL = 0.58499

**R Chart by Inspector**

- **Sample Range**
  - UCL = 0.01356
  - LCL = 0.00000

**Part-to-part variation accounts for the most of the overall variation**

**X-Chart shows flat trend among different inspectors**

**Straight line shows stable measurement results among different inspectors**
References


