Process Evolution through Integration of Shainin and Taguchi - A Case Study in Alternator Manufacturing

by

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1.0 Overview of Lucas - TVS

1.1 Lucas–TVS Auto Electrical plants

- Established 1961, originally a joint venture between Lucas Plc UK and TVS, wholly owned since 2001
- Four decades of leadership on Indian Market
- 7 plants in India, main plant in Chennai with 2600 employees
- Product development capability: 80% of revenue from In-house developed products
- Technical Collaboration
  - Mitsubishi Electric: Geared Starters / Internal Fan Alternators
  - Denso: Ignition Systems, Two Wheeler Starters
  - YDK Japan: Blower Motors
1.1 Other Plants

- PLANT II: Rewari, Haryana
- PLANT III: Nettappakkam, Pondy
- PLANT IV: Chakan, Pune
- PLANT V: TV Koli, Pondy
- PLANT VI: Pant Nagar, Uttarakhand
- PLANT VII: Maraimalai Nagar (Near Chennai)

1.2 Product Range

<table>
<thead>
<tr>
<th>Products</th>
<th>Annual Units (In Lacs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternators</td>
<td>25.30</td>
</tr>
<tr>
<td>Starters</td>
<td>33.90</td>
</tr>
<tr>
<td>Two Wheeler Starters</td>
<td>38.00</td>
</tr>
<tr>
<td>Wipers</td>
<td>22.10</td>
</tr>
<tr>
<td>Compressor Motors</td>
<td>4.70</td>
</tr>
<tr>
<td>Ignition Coils</td>
<td>13.50</td>
</tr>
</tbody>
</table>
1.3 Blue Chip Customer Base

**PASSENGER CARS**
- **Commercial Vehicles**
  - Mercedes-Benz
  - Audi
  - Volkswagen
  - BMW
  - Honda
  - WABCO
  - GM
  - Fiat

**COMMERCIAL VEHICLES**
- **Tier 2**
  - Mack
  - Paccar
  - Volvo
  - John Deere
  - Mando
  - Peugeot
  - Hyundai
  - Fiat

**TRACTORS**
- **Construction**
  - Mahindra
  - Swaraj
  - John Deere
  - Same Deutz-Fahr

**PICK UPS & SUVs**
- **Buses & Coaches**
  - Tata
  - Ashok Leyland
  - Mahindra Navistar

**TWO-WHEELERS**
- **Engines**
  - Kohler
  - Volvo

**TRACTORS**
- **Construction**
  - Larse & Touberc
  - Komatsu
1.4 Recognitions & Awards

**TS 16949**

**OHSAS 18001**

**ISO 14001**

**Deming Award**

- JIT Innovation Award from JIT Management Lab, Tokyo
- JIT Grand Prix Award from JIT Management Lab, Tokyo (Thrice)
- Frost & Sullivan – Platinum Award for Manufacturing Excellence
- BIS – Rajiv Gandhi National Award
- Energy Conservation Award

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1.4 Recognitions & Customers Awards

**Quality**

- **Maruti Suzuki** Best Warranty Improvements 2009
- **Maruti Suzuki** - VA/VE Award, 2006
- **Maruti Suzuki** - Vendor Performance Award for Quality, 2004-05
- **Ford** - Q1 Award, August 2006
- **Hyundai Motor India** - Best Quality Performance Award, 2008-09
- **Hyundai Motor India** - 100 PPM Award, 2003
- **Mahindra** - Best Quality Performance Award (FES ), 2006-07

- **Maruti Suzuki** Vendor Upgradation Award, 2011
- **Maruti Suzuki** Best Vendor Upgradation Award, 2010
- **Maruti Suzuki** Best Vendor Upgradation Award, 2009
- **Maruti Suzuki** Best Supplier Support Award, 2008
- **Maruti Suzuki** - Best Supplier Support Award, 2007-08
- **Maruti Suzuki** - Best Vendor Award, 2006
- **Maruti Suzuki** - Superior Kaizen Performance Award, 2004
- **Mahindra & Mahindra** – Annual Commodity Award, 2011
- **Ashok Leyland** - Outstanding Performance in Management, 2007-08
- **Cummins India** - Excellent Performance Award, 2007+2008
- **Cummins India** - Best Performer Award, 2003
- **Honda Motorcycles and Scooter India** - Achievement Award 2008-09
- **Honda Motorcycles and Scooter India** - Best Supplier Award, 2005
- **Hyundai Motor India** - Overall Best Performance, 2004
- **Tata Motors** - Enduring Relations Excelling Together Award, 2008

**Performance**

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Case Study -

2.0 Introduction about Alternator
3.0 Problem Definition

3.1 Case Study – Problem Definition

**Problem Statement**

- Poor First Pass Yield during Pilot Production Trial Run of a New Product Introduced

<table>
<thead>
<tr>
<th>Expected Yield</th>
<th>Actual Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 95 %</td>
<td>&lt; 85 %</td>
</tr>
</tbody>
</table>

**Pilot run rejection data**

- Qty Produced = 200
- Qty Rejected = 32

88% of rejection due to Initial Cut in Failure
3.2 Case Study – Problem Definition

**What is Initial Cut In Failure?**

- When alternator is generating sufficient Threshold Current - the warning lamp on the Dash Board is OFF - indicating to the driver proper functioning of alternator. The failure to produce this current is called Initial cut in failure - **Warning Lamp Not OFF**

![Typical Alternator Circuit Diagram]

4.0 Diagnostic Approach – Shainin Method
4.1 Case Study – Cause Analysis

**Cause & Effect Diagram:**

**Stator**
- Id oversize
- Resistance imbalance

**Assembly Process**
- Rotor rubbing
- Slip ring tag broken
- Insul bush damaged
- Carbon brush broken
- Positive diode shorting
- Regulator A terminal damaged

**Warning lamp NOT OFF**
- Rpm Meter not working
- Stator phase nut not tighten
- Improper soldering on stator leads
- Excess basket OD
- Ineffective soldering of stator leads

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4.2 Case Study – Cause Analysis

**Diagnostic Approach:**

**Conventional Approach**
- Check Conformance to Standards & Specifications
- Identify the cause by conducting Fresh experiments
- Fresh Experiments conducted with pre determined levels for Specified factors - to avoid failure phenomenon
- The factors and their levels are chosen based on Experience & Knowledge

**Shainin Clue Generating Approach**
- Identify the Cause from the existing Good & Bad
- Select BOB - Best of Best & WOW - Worst of Worst from the existing lot
- Conduct Designed Experiments using these BOB & WOW to Identify the Culprit cause.

**Since Pilot Run - all the parts have been checked for conformance prior to assembly.**

**Hence, to cut short time & effort Shainin Approach is Preferred**

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4.3 Case Study – Shainin Approach

**Shainin Component Search:**

This is a diagnostic study by Elimination

- **A pair of BOB & WOW Selected**
- **First phase of Elimination – Identify which is contributing**
  Using D/d Ratio by disassembling & reassembling Twice - BOB / WOW
  
  - **Assembly Process**
  - **Constituent Parts**

  - **If D/d Ratio < 1.25**

  - **If D/d Ratio > 1.25**

- **Second phase of Elimination – Identify which part is contributing by Swapping parts by pre determined Priority between BOB & WOW.**

- **Capping Run – confirming the Finding**

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4.4 Case Study – Shainin Approach

**Shainin Component Search: **

**Elimination Phase 1**

<table>
<thead>
<tr>
<th></th>
<th>BOB WL Current O/P</th>
<th>WOW WL Current O/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial assembly</td>
<td>0.31</td>
<td>0.08</td>
</tr>
<tr>
<td>After 1st re-assembly</td>
<td>0.39</td>
<td>0.06</td>
</tr>
<tr>
<td>After 2nd re-assembly</td>
<td>0.28</td>
<td>0.05</td>
</tr>
<tr>
<td>Median</td>
<td>0.33</td>
<td>0.065</td>
</tr>
<tr>
<td>Range</td>
<td>0.11</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**Specification of WL current O/P**

- **> 0.12 amps**

**D / d Test:**

- Difference between the medians ($D$): $0.33 - 0.065 = 0.265$
- Average range ($d$): $(0.11 + 0.03) / 2 = 0.07$

- $D/d = 0.265 / 0.07 = 3.785 > 1.25$

**Inference:** 
Assembly Process is not Culprit

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4.4 Case Study – Shainin Approach

**Shainin Component Search:**

Elimination Phase 2

**Control limits for Swapping:** This is not same as Specification

Control limit BOB = Median of BOB +/- (2.776/1.81)d
BOB :- Min = 0.2227, Max = 0.4375;
Control limit WOW = Median of WOW +/- (2.776/1.81)d
WOW- Min = -0.0423, Max = 0.1723

**Priority for Swapping:** This is based on Knowledge & Experience

1. Rotor assembly
2. Regulator Rectifier Assembly
3. Stator Assembly

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**Shainin Component Search:**

Out put measured with parts interchanged

<table>
<thead>
<tr>
<th></th>
<th>First Reassembly</th>
<th>Second Reassembly</th>
<th>ROTOR INTERCHANGE</th>
<th>Bring back to original</th>
<th>RECTIFIER &amp; REGULATOR</th>
<th>Bring back to original</th>
<th>STATOR ASSY</th>
<th>Bring back to original</th>
<th>Capping Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.32</td>
<td>0.28</td>
<td>0.23</td>
<td>0.25</td>
<td>0.29</td>
<td>0.32</td>
<td>0.06</td>
<td>0.3</td>
<td>0.07</td>
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<td>2</td>
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</tr>
</tbody>
</table>

**Inference:**

Hence Stator is the Culprit

Total Reversal when Stator is Interchanged

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4.5 Case Study – Shainin Approach

**Shainin Paired Comparison**: To Identify the Product Feature Contributing to the Defect

- Six pairs of Bob & Wow Selected
- These pairs are compared in all aspects – whether specified in the design or not
- Significance of each feature compared is decided using “Tukey End Count Test”

The response of each feature compared is arranged in either ascending or descending order. The no. of continuous good or bad at either end is called the top & bottom end counts.

The Significance level of each feature is based on the total end count which is sum of top & bottom count:

<table>
<thead>
<tr>
<th>If the Total End count is</th>
<th>Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>90%</td>
</tr>
<tr>
<td>7</td>
<td>95%</td>
</tr>
<tr>
<td>10</td>
<td>99%</td>
</tr>
<tr>
<td>12</td>
<td>99.7%</td>
</tr>
</tbody>
</table>

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4.5 Case Study – Shainin Approach

**Shainin Paired Comparison:** Response Arranged in Descending order

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Stator Basket OD</th>
<th>Stator Basket ID</th>
<th>Stator Overhang</th>
<th>Stator ID</th>
<th>ID ovality</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2</td>
<td>119.2</td>
<td>G5</td>
<td>99.36</td>
<td>G5</td>
<td>15.65</td>
</tr>
<tr>
<td>G4</td>
<td>119.18</td>
<td>B4</td>
<td>99.32</td>
<td>B6</td>
<td>15.55</td>
</tr>
<tr>
<td>B5</td>
<td>119.17</td>
<td>B6</td>
<td>99.29</td>
<td>G4</td>
<td>15.49</td>
</tr>
<tr>
<td>G5</td>
<td>119.14</td>
<td>G6</td>
<td>99.24</td>
<td>G6</td>
<td>15.47</td>
</tr>
<tr>
<td>B4</td>
<td>119.13</td>
<td>B5</td>
<td>99.22</td>
<td>B1</td>
<td>15.45</td>
</tr>
<tr>
<td>G1</td>
<td>119.1</td>
<td>G4</td>
<td>99.21</td>
<td>G3</td>
<td>15.39</td>
</tr>
<tr>
<td>B3</td>
<td>119.1</td>
<td>G1</td>
<td>99.2</td>
<td>G2</td>
<td>15.35</td>
</tr>
<tr>
<td>B6</td>
<td>119.08</td>
<td>B2</td>
<td>99.2</td>
<td>B2</td>
<td>15.33</td>
</tr>
<tr>
<td>B2</td>
<td>118.99</td>
<td>B3</td>
<td>99.18</td>
<td>B4</td>
<td>15.31</td>
</tr>
<tr>
<td>G6</td>
<td>118.98</td>
<td>G3</td>
<td>99.17</td>
<td>B5</td>
<td>15.27</td>
</tr>
<tr>
<td>G3</td>
<td>118.95</td>
<td>G2</td>
<td>99.16</td>
<td>G1</td>
<td>15.24</td>
</tr>
<tr>
<td>B1</td>
<td>118.95</td>
<td>B1</td>
<td>99.14</td>
<td>B3</td>
<td>15.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Top end count</th>
<th>Bottom end count</th>
<th>Total end count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Inference:**

- Stator ID is the only feature contributing significant @ 99.7% confidence
- If the ID of the stator core is near to the top limit of the speciation – the defect occurs

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5.1 Case Study – Shainin Validation

**Shainin B vs C Test:** To validate the finding

- Six pairs of units build fresh to confirm the finding
  
  **Six presumed Bad units**
  
  Assembled
  
  With
  
  the significant part conforming to (WOW) Bad unit values & other parts random
  
  **Six presumed Good units**
  
  Assembled
  
  With
  
  the significant part conforming to (BOB) Good unit values & other parts random
  
  **Tukey test applied to the response of these pairs:**
  
  **Six presumed Bad units**
  
  If Results into
  
  Actual Bad units
  
  Validates the earlier Finding
  
  **Six presumed Good units**
  
  If Results into
  
  Actual Good units

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5.0 Root Cause - Validation

5.1 Case Study – Shainin Validation

**Shainin B vs C Test:**

Response from Suspected “C” and Better “B” Process

<table>
<thead>
<tr>
<th>6 nos with Current (C ) and 6 nos with claimed Better Process (B ) are tightened in random order</th>
<th>Tukey Test on Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>95.44</td>
</tr>
<tr>
<td>C5</td>
<td>95.44</td>
</tr>
<tr>
<td>C3</td>
<td>95.435</td>
</tr>
<tr>
<td>C6</td>
<td>95.435</td>
</tr>
<tr>
<td>C2</td>
<td>95.43</td>
</tr>
<tr>
<td>C4</td>
<td>95.43</td>
</tr>
<tr>
<td>B5</td>
<td>95.4</td>
</tr>
<tr>
<td>B2</td>
<td>95.39</td>
</tr>
<tr>
<td>B3</td>
<td>95.385</td>
</tr>
<tr>
<td>B1</td>
<td>95.38</td>
</tr>
<tr>
<td>B3</td>
<td>95.375</td>
</tr>
<tr>
<td>B6</td>
<td>95.37</td>
</tr>
</tbody>
</table>

**Inference:** If the ID of the stator core is near to the top limit of the speciation – the defect occurs – this is validated.

Thus the Root cause of the defect is Validated
5.2 Case Study – Root cause

**Stator ID Variation - Root cause:**

**Process Capability of Stator ID:**

\[ \text{C}_p = 1.44 \]
\[ \text{C}_pk = 1.25 \]

**Root Cause:**

- Stators having ID near to the design target are Good.
- Whereas ID near to the top limit but still within specification are leading to defect
- And Stator ID population spreads up to the top limit of the specification

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6.0 Improvement approach – Taguchi Method
6.1 Case Study – Improvement

**Stator ID Manufacturing Process:** It is a coining process done in 250 ton hydraulic press.

**Factors affecting variation / Consistency in Stator ID:**

1. Ram Pressure
2. Dwell time
3. Diecushion pressure
4. Initial pack thickness of stator before coining
5. Coil hardness of stator material

**Selecting Levels of Factors & Response:**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Ram Pressure)</td>
<td>100 bar</td>
<td>160 bar</td>
</tr>
<tr>
<td>B (Dwell Time)</td>
<td>3 Sec</td>
<td>5 Sec</td>
</tr>
<tr>
<td>C (Hardness)</td>
<td>112 Bhn</td>
<td>119 Bhn</td>
</tr>
<tr>
<td>D (Die Cushion ejection pressure)</td>
<td>5 Bar</td>
<td>20 bar</td>
</tr>
<tr>
<td>E (Pack Thickness)</td>
<td>0.78 mm * 30 layers</td>
<td>0.81 mm * 31 layers</td>
</tr>
</tbody>
</table>

**Interactions considered**

- AB: Ram pressure & Dwell time
- AC: Ram pressure & Hardness

It is decided to conduct experiment at different levels of these known factors to identify significance.

6.2 Case Study – Improvement

**Improving Stator ID:**

- Levels of factors and their interactions are selected based on domain knowledge and experience.
- It is decided to measure Stator ID and ID ovality as Response.
6.2 Case Study – Improvement

**Improving Stator ID**:

**Experiment Design**:
Taguchi L8 OA design is chosen – based on the no. of factors, their levels / interactions and Deg. Of freedom

<table>
<thead>
<tr>
<th>Factors</th>
<th>Ram Pr</th>
<th>Dwell time 1*2</th>
<th>Hardness 1*4</th>
<th>Die cushion</th>
<th>Initial pack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Exp 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Exp 2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exp 3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Exp 4</td>
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<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exp 5</td>
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<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Exp 6</td>
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<tr>
<td>Exp 7</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Exp 8</td>
<td>2</td>
<td>2</td>
<td>1</td>
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**Experiment Response Table**:

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram Pr</td>
<td>Stator ID (mm) 95.33 - 95.44</td>
</tr>
<tr>
<td>Dwell time 1*2</td>
<td>ID Ovality (mm) 0.1 Max</td>
</tr>
<tr>
<td>Hardness 1*4</td>
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</tr>
<tr>
<td>Die cushion</td>
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<tr>
<td>Initial pack</td>
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<table>
<thead>
<tr>
<th>Exp 1</th>
<th>Exp 2</th>
<th>Exp 3</th>
<th>Exp 4</th>
<th>Exp 5</th>
<th>Exp 6</th>
<th>Exp 7</th>
<th>Exp 8</th>
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</tr>
</tbody>
</table>

**Dr. N. Ravichandran**
6.3 Case Study – Improvement

Experiment ANOVA Table:

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DOF</th>
<th>Mean Square</th>
<th>F₀</th>
<th>Ftable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram pressure</td>
<td>0.0004</td>
<td>1.0000</td>
<td>0.0004</td>
<td>0.6677</td>
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<tr>
<td>Dwell time</td>
<td>0.0062</td>
<td>1.0000</td>
<td>0.0062</td>
<td>11.7774</td>
<td>5.3200</td>
</tr>
<tr>
<td>1 &amp; 2</td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0267</td>
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</tr>
<tr>
<td>Hardness</td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0030</td>
<td></td>
</tr>
<tr>
<td>1 &amp; 4</td>
<td>0.0015</td>
<td>1.0000</td>
<td>0.0015</td>
<td>2.8516</td>
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<tr>
<td>Die cushion</td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0742</td>
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</tr>
<tr>
<td>Initial Thickness</td>
<td>0.0003</td>
<td>1.0000</td>
<td>0.0003</td>
<td>0.5015</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>0.0042</td>
<td>8.0000</td>
<td>0.0005</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0126</td>
<td>15.0000</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Only Dwell time is Significant for Stator ID

ANOVA TABLE - ID Ovality

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DOF</th>
<th>Mean Square</th>
<th>F₀</th>
<th>Ftable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram pressure</td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0069</td>
<td></td>
</tr>
<tr>
<td>Dwell time</td>
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<td>1.0000</td>
<td>0.0005</td>
<td>1.9931</td>
<td>5.3200</td>
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<tr>
<td>1 &amp; 2</td>
<td>0.0001</td>
<td>1.0000</td>
<td>0.0001</td>
<td>0.3379</td>
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</tr>
<tr>
<td>Hardness</td>
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<td>1.0000</td>
<td>0.0001</td>
<td>0.5586</td>
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</tr>
<tr>
<td>1 &amp; 4</td>
<td>0.0001</td>
<td>1.0000</td>
<td>0.0001</td>
<td>0.3379</td>
<td></td>
</tr>
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<td>Die cushion</td>
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<tr>
<td>Initial Thickness</td>
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<tr>
<td>Error</td>
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<td>0.0002</td>
<td>1.0000</td>
<td></td>
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<tr>
<td>Total</td>
<td>0.0028</td>
<td>15.0000</td>
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</tr>
</tbody>
</table>

No factor is Significant for ID Ovality

6.4 Case Study – Improvement

Selecting Optimum Levels:

- From the Response graph the optimum level of the significant factor is chosen
- Dwell time of 5 Sec yields response closer to the design target
- The levels of other factors are chosen by studying the response table and based on Technical and economic feasibility etc..
- It is observed at Die cushion pressure of 20 bar - burr is noticed hence not chosen
- Further the hardness & initial pack are noise factors within the specified tolerance band and are not significant - hence the allowable tolerance band is chosen as optimum.

Recommended levels of factors:

Ram pressure = 160 bar
Dwell time = 5 sec
Die cushion pressure = 5 bar
7.0 Result Validation

7.1 Case Study – Result Validation

Confirmatory experiment at Optimum Levels (Stator manufacturing):

- An experiment run at optimum level & process capability observed

<table>
<thead>
<tr>
<th></th>
<th>Cp</th>
<th>Cpk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>1.44</td>
<td>1.25</td>
</tr>
<tr>
<td>After</td>
<td>2.02</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Inference:
The selected Optimum levels have yielded the desired reduction in variation
7.2 Case Study – Result Validation

**Confirmatory Second Production Trial Run (Alternator Assembly):**

- Alternators assembled with stators manufactured from new process –
  with some stators selected near to the top limit of the improved population

<table>
<thead>
<tr>
<th></th>
<th>Before Improvement</th>
<th>After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>First pass Yield</td>
<td>84 %</td>
<td>98 %</td>
</tr>
<tr>
<td>Qty Produced (Nos)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Qty Rejected (Nos)</td>
<td>32</td>
<td>4</td>
</tr>
</tbody>
</table>

**Failure Modes**

<table>
<thead>
<tr>
<th>Initial Cut in Failure - W lamp Not OFF (Nos)</th>
<th>Before Improvement</th>
<th>After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td></td>
<td>Zero</td>
</tr>
<tr>
<td>W lamp Not ON (Nos)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mild Glow (Nos)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bind (Nos)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pulley Damage (Nos)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Through bolt damage</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Brush Broken</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Improving Stator ID Process Capability has Eliminated top ranked defect and has improved First Pass Yield of the Assembly

8.0 Standardisation
## 8.1 Case Study – Standardizing Improvement

**Process Standards Updated:**

![Image of a table and chart]

Dr. N. Ravichandran

### 9.0 Conclusion

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9.1 Case Study – Conclusion

Summary:
- Initial Production trial run of a new product - yielded low first pass yield.
- Major contribution of defect being from Initial Cut in Failure - Warning Lamp Not Off
- Cause & effect diagram indicated contribution from both process as well as parts.
- Shainin Clue Generating Experiments conducted - to quickly funnel down to the culprit
- Variation from the design target of Stator ID is identified as the root cause
- Taguchi L8 OA conducted to optimize the factors affecting the Stator ID
- The optimum levels improved the process capability
- The improved process capability Eliminated the Defect
- Second production trial run confirmed the findings
  - Paved way for PPAP and Production Ramp up without delay

9.2 Case Study – Conclusion

Inference:
- A process standard acceptable to previous products - not acceptable to new product
- Shainin clue Generating tools - enhances the process of identifying the unknown cause
- Shainin Clue generating tools - questions the design specification also
- Shainin Tools generates clue from the available product & process
- Taguchi OA enhances the optimization process once the unknown cause is identified

Future Study:
- Taguchi Parameter designed experiment is to be conducted - to make the process more robust - irrespective of variation in noise factors.
- A study for integrating various problem solving tools are required.
10.0 Overview of Shainin Tools

10.1 Overview of Shainin Tools

**SHAININ PHILOSOPHY**

**DO NOT LET THE ENGINEERS DO THE "GUESSING"**
**LET THE PARTS "DO THE TALKING"**

**DETECTIVE APPROACH TO SOLUTION**

FACTS FROM PRODUCT / PROCESS → Combined with ENGINEERS’ KNOWLEDGE → Detect → SOLUTION
10.2 Overview of Shainin Tools

CLUE GENERATING TOOLS

- **MULTI - VARI**
  - TO FILTER CYCLICAL; POSITIONAL & TEMPORAL VARIATION

- **COMPONENT SEARCH**
  - TO FILTER PRODUCT PARAMETERS WHEN COMPONENTS ARE INTERCHANGEABLE

- **PAIRED COMPARISON**
  - TO FILTER PRODUCT PARAMETERS

- **CONCENTRATION CHART**
  - TO FILTER VARIATION WITHIN UNIT

- **PRODUCT PROCESS SEARCH**
  - TO FILTER PROCESS PARAMETERS

**TO FILTER OUT UNIMPORTANT VARIABLES**

WHEN VARIABLES ARE UNKNOWN & MANY

---

10.3 Overview of Shainin Tools

FORMAL DOE

- **VARIABLES SEARCH**
  - 5 TO 20 VARIABLES

- **FULL FACTORIAL**
  - 4 OR FEWER VARIABLES

- **B vs C TEST**
  - ONE VARIABLE

**TO HOME IN ON RED X - ROOT CAUSE**

WHEN VARIABLES ARE KNOWN

---

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10.4 Overview of Shainin Tools

VALIDATION TOOL

B vs C TEST

TO CHECK PERMANENCY OF IMPROVEMENT

TURNING THE PROBLEM ON & OFF
WHEN ROOT CAUSE IS KNOWN

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10.5 Overview of Shainin Tools

OPTIMISATION TOOLS

SCATTER PLOTS
WITH NO INTERACTION OF FACTORS

RSM RESPONSE SURFACE METHODOLOGY
WITH INTERACTION OF FACTORS

TO FIND REALISTIC SPECIFICATIONS & TOLERANCES

TIGHTEN THE TOLERANCES OF IMPORTANT VARIABLES
OPEN UP TOLERANCES OF UNIMPORTANT VARIABLES

Dr. N. Ravichandran
10.6 Overview of Shainin Tools

Salient Learning Points

- MOST UNSUSPECTED CAUSES ARE REVEALED USING CLUE GENERATING TOOLS.

- CONFORMANCE TO SPECIFICATION DOES NOT MEAN FREE OF DEFECT.

Thank You