Introduction to the New AIAG/VDA DFMEA

Matthew Barsalou

D 35 – May 23, 2021
Learning Objectives

• In this session you will:
  – Learn about changes implemented in the new FMEA Handbook
  – Be able to list the steps for creating a DFMEA
  – Evaluate risks based on Action Priority
Introduction to DFMEAs

- According to a poem by Lowe (1980), a kingdom fell due to a lack of a nail

- Sometimes it’s the simple details that matter

- Design Failure Modes & Effects Analysis (DFMEA) helps identify & link “simple” details
Evolution

- Failure Modes & Effects Analysis (FMEA)
  - 1949: Introduced in military standard MIL-P-1629
  - 1960s: Used for NASA’s Apollo program
  - 1970s: Used by Ford Motor Company
  - 1980s: Spread across industries
Types of FMEAs

• Design-Failure Modes & Effects Analysis (DFMEA) – for design concepts

• Process-Failure Modes & Effects (PFMEA) – for assembly processes
DFMEAs

• Performed as early as possible in the design process
  – Identifies risks of failure
  – Prioritizes risks
  – Develops & implements improvement actions

But we can’t think of every risk!
# DFMEA Documentation

## Design Failure Modes and Effects Analysis

<table>
<thead>
<tr>
<th>Function</th>
<th>Requirement</th>
<th>Failure Mode</th>
<th>Failure Effect</th>
<th>Severity</th>
<th>Failure Cause</th>
<th>Prevention Actions</th>
<th>Occurrence</th>
<th>Detection Actions</th>
<th>Detection RPN</th>
<th>Improvement Actions</th>
<th>Severity</th>
<th>Prevention</th>
<th>Detection RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Company Name**

**Part:**

**FMEA Type:**

**Customer:**

**Part Number:**

**DFMEA Team:**

**FMEA Nr.:**

**Version Date:**
DFMEA Documentation

- **Function**: What the component must do
- **Failure mode**: The failure
- **Failure effect**: Effect of the failure
- **Severity**: Consequences of failure (1-10 scale)
- **Failure cause**: Caused the failure

**Risk Priority Number** (RPN) = Severity x Occurrence x Detection

Prevention controls: Actions to prevent failure from occurring

Occurrence: How likely the failure is (1-10 scale)

Detection controls: Actions taken to detect failure if it occurs

Detection: How well failure can be detected if it occurs (1-10 scale)
<table>
<thead>
<tr>
<th>Rating</th>
<th>Severity</th>
<th>Criteria</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not noticeable to customer.</td>
<td>Highly unlikely: &lt;1 in 1.5 million opportunities</td>
<td>Almost certain to detect failure.</td>
</tr>
<tr>
<td>2</td>
<td>Some customers will notice. Very minor effect on product or system.</td>
<td>Extremely rare: 1 in 150,000 opportunities.</td>
<td>Excellent chance of detecting failure: 99.99%</td>
</tr>
<tr>
<td>3</td>
<td>Most customers notice. Minor effect on product or system.</td>
<td>Rare: 1 in 15,000 opportunities.</td>
<td>High chance of detecting failure: 99.9%</td>
</tr>
<tr>
<td>4</td>
<td>Customer slightly annoyed. Product or system slightly impaired.</td>
<td>Few: 1 out of 2,000 opportunities.</td>
<td>Good chance of detecting failure: 95%</td>
</tr>
<tr>
<td>5</td>
<td>Customer annoyed. Noncritical aspects of product or system impaired.</td>
<td>Occasional: 1 out of 500 opportunities.</td>
<td>Fair chance of detecting failure: 80%</td>
</tr>
<tr>
<td>6</td>
<td>Customer experiences discomfort or inconvenience. Noncritical elements of product or system impaired.</td>
<td>Often: 1 out of 100 opportunities.</td>
<td>Might detect failure: 50%</td>
</tr>
<tr>
<td>7</td>
<td>Customer very dissatisfied. Partial failure of critical system elements of product or system. Other.</td>
<td>Frequent: 1 out of 20 opportunities.</td>
<td>Unlikely to detect failure: 20%</td>
</tr>
<tr>
<td>8</td>
<td>Customer highly dissatisfied. Product or system inoperable, but safe.</td>
<td>Repeated: 1 out of 10 opportunities.</td>
<td>Very unlikely to detect failure: 10%</td>
</tr>
<tr>
<td>9</td>
<td>Customer safety or regulatory compliance endangered, with warning.</td>
<td>Common: 1 out of 3 opportunities.</td>
<td>Highly unlikely to detect failure: 5%</td>
</tr>
<tr>
<td>10</td>
<td>Catastrophic. Customer safety or regulatory compliance endangered, without warning.</td>
<td>Almost certain: &gt;1 out of 2 opportunities.</td>
<td>Nearly certain not to detect failure, or no controls in place.</td>
</tr>
</tbody>
</table>

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## DFMEA Documentation

### Design Failure Modes and Effects Analysis

<table>
<thead>
<tr>
<th>Part:</th>
<th>FMEA Type:</th>
<th>Customer:</th>
<th>Part Number:</th>
<th>DFMEA Team:</th>
<th>FMEA Nr.:</th>
<th>Version Date:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Requirement</th>
<th>Failure Mode</th>
<th>Failure Effect</th>
<th>Severity</th>
<th>Failure Cause</th>
<th>Prevention Actions</th>
<th>Occurrence</th>
<th>Detection Actions</th>
<th>Detection</th>
<th>Improvement Actions</th>
<th>Severity</th>
<th>Prevention</th>
<th>Detection</th>
<th>RPN</th>
</tr>
</thead>
</table>

- **Recommended actions:**
  Actions to improve prevention and/or detection
- **Responsible & target date:**
  Who will perform the actions & when they will be completed
- **Actions taken & completion date:**
  What was done & when finished
- **Re-evaluate Severity, Occurrence & Detection**
- **Re-calculate Risk Priority Number**
  \[ \text{RPN} = \text{Severity} \times \text{Occurrence} \times \text{Detection} \]
### DFMEA Example – Retaining Clip

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retaining clip spring must have sufficient tension to hold clip to assembly</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Failure Effect</th>
<th>S</th>
<th>Failure Cause</th>
<th>Prevention Controls</th>
<th>O</th>
<th>Detection Controls</th>
<th>D</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintended release of spring</td>
<td>Retaining clip falls off</td>
<td>8</td>
<td>Incorrect tension specified on drawing</td>
<td>Use of carryover design</td>
<td>5</td>
<td>Test in spring tension tester</td>
<td>6</td>
<td>240</td>
</tr>
</tbody>
</table>

- **Severity:** 8 due to total product failure
- **Occurrence:** 5 due to previous use of similar design
- **Detection:** 6 due to use of a proven test method with test to failure

S – Severity; O – Occurrence; D – Detection; RPN – Risk Priority Number = S x O x D
## DFMEA Example – Retaining Clip

### Function
Retaining clip spring must have sufficient tension to hold clip to assembly

### Failure Mode
- Unintended release of spring

### Failure Effect
Retaining clip falls off

### Failure Cause
- Incorrect tension specified on drawing
- Use of carryover design

### Prevention Controls
- Test in spring tension tester

### Detection Controls
- Use of carryover design

<table>
<thead>
<tr>
<th>Function</th>
<th>Failure Mode</th>
<th>Failure Effect</th>
<th>S</th>
<th>Failure Cause</th>
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<th>Detection Controls</th>
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</thead>
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<td>6</td>
<td>240</td>
</tr>
</tbody>
</table>

- **Recommended actions:** Implement degradation testing (detection)
- **Responsible & target date:** Jane S. / 22 July
- **Actions taken & completion date:**Degradation testing performed on 22 July
- **Re-evaluate detection:** Degradation testing implemented so rating is now 5
- **Re-calculate RPN:** $8 \times 5 \times 5 = 200$ (additional actions?)

S – Severity; O – Occurrence; D – Detection; RPN – Risk Priority Number = S x O x D
AIAG/VDA FMEA Handbook

• Two FMEA standards are now combined
  – AIAG’s (Automotive Industry Action Group)
  – VDA’s (Verband der Automobilindustrie) – German Association of the Automotive Industry
AIAG/VDA FMEA Handbook

• Required use of the new standard:
  – Fiat Chrysler Automobiles (FCA)
    • Can be used immediately, but an agreement between supplier and FCA is required
  – Ford
    • Can be used immediately
  – General Motors
    • Implementation anticipated in 2023
  – Honda North America
    • Can be used immediately
    • Anticipated to be in use in 2022 for new parts
AIAG FMEA Handbook

- Required boundary diagrams to identify the limits & interfaces of the system
AIAG FMEA Handbook

• Required p-diagrams (parameter diagrams)

- Noise factors
  - Variation
  - System interactions
  - Over time
  - Customer
  - Environment

- Input factors
- Control factors
- Ideal function
- Error states

The system
VDA FMEA Handbook

- Required use of a structure tree
  - Software is used to create the structure tree

- DFMEAs can be difficult to create
AIAG/VDA FMEA Handbook

- Failures causes, failure modes, and failure effects are linked between system elements
  - A failure mode at one system element is an effect for a lower system element and the cause of failure for a higher system element
AIAG/VDA FMEA Handbook

- Failure effect, modes & causes are linked between system elements
  - A failure in one element is an effect for a lower element & the cause for a higher element

<table>
<thead>
<tr>
<th>System element 1</th>
<th>Failure effect</th>
<th>Failure</th>
<th>Failure cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>System element 2</td>
<td>Failure effect</td>
<td>Failure</td>
<td>Failure cause</td>
</tr>
<tr>
<td>System element 3</td>
<td>Failure effect</td>
<td>Failure</td>
<td>Failure cause</td>
</tr>
<tr>
<td>System element 4</td>
<td>Failure effect</td>
<td>Failure</td>
<td>Failure cause</td>
</tr>
</tbody>
</table>

Focus element
AIAG/VDA FMEA Handbook

• Replaces RPN by an Action Priority (AP)
  – Tables are used to identify the AP on a scale of High (H), Medium (M) & Low (L)
    • Emphasis is given to high severity ratings together with a high occurrence rating
    • Ex.: A severity of 9 and occurrence of 8 is always High regardless of detection
  – Tables are available in the handbook
### AIAG/VDA FMEA Handbook

- New DFMEA form lists the focus system element & the next higher & lower system element, as well as their functions.

<table>
<thead>
<tr>
<th>Higher level system element</th>
<th>System element in focus</th>
<th>Lower level system element</th>
<th>Higher level function and requirement</th>
<th>Function and requirement in focus</th>
<th>Lower level function and requirement</th>
<th>Potential failure effect(s)</th>
<th>Sev.</th>
<th>Potential failure mode(s)</th>
<th>Potential failure cause(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System element 1</td>
<td>System element 2</td>
<td>System element 3</td>
<td>SE 1’s function</td>
<td>SE 2’s function</td>
<td>SE 3’s function</td>
<td>Failure at SE 1 is the effect</td>
<td></td>
<td>Failure at SE 2 is the failure mode</td>
<td>Failure at SE 3 is the failure cause</td>
</tr>
</tbody>
</table>
AIAG/VDA FMEA Handbook

• Two possible approaches – component or function
  – Lowest level uses a function in place of a component when the focus is a component

<table>
<thead>
<tr>
<th>Assembly as Focus Element</th>
<th>Component as Focus Element</th>
</tr>
</thead>
</table>
| **System Element 1: Final product**  
Failure effect: Water leak in vehicle | **System Element 1: Final product**  
Failure effect: Water leak in vehicle |
| **System Element 2: Assembly**  
Failure mode: Water pump seal not tight | **System Element 2: Component**  
Failure mode: Coupling not tightly sealed |
| **System Element 3: Component**  
Failure cause: Coupling with wrong tolerance | **System Element 3: Component Function**  
Failure cause: Wrong tolerance |
AIAG/VDA FMEA Handbook

• Step 1: Planning & Preparation
• Step 2: Structure Analysis
• Step 3: Functional Analysis
• Step 4: Failure Analysis
• Step 5: Risk Analysis
• Step 6: Optimization
• Step 7: Results Documentation
Step 1: Planning & Preparation

- Form a DFMEA team (cross-functional)
- Review relevant documents
  - Drawings and specifications
  - Requirements (legal, customer, etc.)
  - Previous, comparable DFMEAs
  - Lessons learned
- Establish project plan & timing
  - Schedule reviews
  - Recommendation: Multiple 2-hour DFMEA sessions
**Step 1: Planning & Preparation**

- Fill out DFMEA header
  - Recommendation: Customize to the organization’s needs

<table>
<thead>
<tr>
<th>DFMEA</th>
<th>QMI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization:</strong> Quick Molding Inc.</td>
<td><strong>Location:</strong> Small Town</td>
</tr>
<tr>
<td><strong>Project:</strong> Deluxe heat transfer manifold</td>
<td><strong>Product:</strong> Heat transfer manifold pipe</td>
</tr>
<tr>
<td><strong>Project owner:</strong> Ware</td>
<td><strong>Project leader:</strong> Duran</td>
</tr>
<tr>
<td><strong>DFMEA number:</strong> 46484154581</td>
<td><strong>Revision date:</strong> 1 April 2021</td>
</tr>
<tr>
<td><strong>Product line:</strong> Manifolds</td>
<td><strong>System element:</strong> Pipe</td>
</tr>
<tr>
<td><strong>Team:</strong> Holland, Martinez, Spence</td>
<td><strong>Revision number:</strong> 4</td>
</tr>
</tbody>
</table>
Step 2: Structure Analysis

- Create a structure tree or equivalent (boundary diagram, model, parts)
  - Identify interfaces & interactions

Inlet

| Physical connection |

Pipe

| Physical connection |

Outlet

Control

Electrical signal
**Step 2: Structure Analysis**

- List the focus element & the next higher & lower elements

<table>
<thead>
<tr>
<th>Higher level system element</th>
<th>System element in focus</th>
<th>Lower level system element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manifold assembly</td>
<td>Pipe</td>
<td>Inlet</td>
</tr>
</tbody>
</table>
Step 3: Functional Analysis

- Use a function tree or function analysis in DFMEA form together with p-diagram
  - Identify requirements of each function

Noise factors
- Variation: Part to part
- System interactions: Interlinks of other systems
- Over time: Ice buildup
- Customer: Rough usage
- Environment: Cold environment

Input factors
- Hot air

Pipe

Cooling effect

Error states
- Heat build up
- Clogging
- Corrosion

Control factors
- Connectivity test
Step 3: Functional Analysis

- Identify the functions of the three system elements

<table>
<thead>
<tr>
<th>Higher level function and requirement</th>
<th>Function and requirement in focus</th>
<th>Lower level function and requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat removal</td>
<td>Hot air transfer</td>
<td>Solid seal</td>
</tr>
</tbody>
</table>
Step 3: Functional Analysis

- Alternatively, functions can be used if no system elements are available.

<table>
<thead>
<tr>
<th>Step 2: Structure analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Higher level system element</strong></td>
<td><strong>System element in focus</strong></td>
</tr>
<tr>
<td>Manifold assembly</td>
<td>Inlet</td>
</tr>
<tr>
<td>Producibility</td>
<td>Manifold assembly</td>
</tr>
</tbody>
</table>

Focus is on the inlet with no lower level system element.

No higher level system element so a function is used.

Function “smooth air flow” used as a lower level system element.

Lower level system element is used.
Step 4: Failure Analysis

- Identify failure effects, modes & causes
  - Effect relates to the system function
  - Mode pertains to hot air transfer
  - Cause relates to sealing

<table>
<thead>
<tr>
<th>Potential failure effect(s)</th>
<th>Sev.</th>
<th>Potential failure mode(s)</th>
<th>Potential failure cause(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat buildup -&gt; partial loss of functionality</td>
<td>7</td>
<td>Reduced heat transfer</td>
<td>Inlet diameter too small</td>
</tr>
</tbody>
</table>
Step 5: Risk Analysis

- Identify & evaluate current prevention & detection actions

<table>
<thead>
<tr>
<th>Step 5: Risk Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current prevention actions</strong></td>
</tr>
<tr>
<td>Use inlet diameter from previous design for new application</td>
</tr>
</tbody>
</table>
Step 6: Optimization

- Identify improvements & assign responsibility for improvement actions

<table>
<thead>
<tr>
<th>Planned improvement actions</th>
<th>Responsible</th>
<th>Due date</th>
<th>Status</th>
<th>Implemented improvement actions</th>
<th>Completion date</th>
<th>Sev.</th>
<th>Occur.</th>
<th>Det.</th>
<th>AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>P: Check heat transfer rates per supplier’s documents</td>
<td>C. Spence</td>
<td>6 Jan. 20</td>
<td>Done</td>
<td>P: Supplier documents checked</td>
<td>5 Jan. 20</td>
<td>7</td>
<td>3</td>
<td>6</td>
<td>M</td>
</tr>
</tbody>
</table>
Step 7: Results Documentation

• A company specific document should be created to communicate risk:
  – Purpose & scope of the DFMEA
  – Timing & team members
  – An explanation of how functions were identified
  – A summary of high-risk failures together with actions taken to address them
  – Timing for continuing actions
  – Commitment to review & update the DFMEA during mass production & when failures occur
Example: New Tie Clip Design

- All three components of the assembly are shown in a boundary diagram.
Example: New Tie Clip Design

- p-diagram shows possible influences on tie clip

**Noise factors**
- Variation: Spring force, dimensions
- System interactions: Spring to top and bottom components
- Over time: Wear due to repeated usage
- Customer: Improper storage
- Environment: Use in hot and humid environments

**Input factors**
- Mechanical force

**Control factors**
- Holding force test
- Opening force test
- Surface requirements

**Ideal function**
- Holds tie to shirt

**Error states**
- Insufficient tension
- Too much tension
- Difficult to grip surface
Example: New Tie Clip Design

- Structure analysis:

<table>
<thead>
<tr>
<th>Step 2: Structure analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher level system element</td>
<td>System element in focus</td>
</tr>
<tr>
<td>Top component</td>
<td>Spring</td>
</tr>
</tbody>
</table>
Example: New Tie Clip Design

- Functional analysis:

<table>
<thead>
<tr>
<th>Step 3: Function analysis</th>
<th>Higher level function and requirement</th>
<th>Function and requirement in focus</th>
<th>Lower level function and requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grip tie</td>
<td>Hold tie to shirt</td>
<td>Grip shirt</td>
</tr>
</tbody>
</table>
Example: New Tie Clip Design

• Failure analysis:

<table>
<thead>
<tr>
<th>Potential failure effect(s)</th>
<th>Sev.</th>
<th>Potential failure mode(s)</th>
<th>Potential failure cause(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie falls off</td>
<td>8</td>
<td>Clip not tight enough</td>
<td>Insufficient spring tension</td>
</tr>
<tr>
<td>Difficult to remove</td>
<td>7</td>
<td>Clip too tight</td>
<td>Too much spring tension</td>
</tr>
<tr>
<td>Difficult to remove</td>
<td>7</td>
<td>Slippery surface</td>
<td>Insufficient surface roughness</td>
</tr>
</tbody>
</table>
Example: New Tie Clip Design

- Risk analysis:

<table>
<thead>
<tr>
<th>Current prevention actions</th>
<th>Ocur.</th>
<th>Current detection actions</th>
<th>Det.</th>
<th>AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use spring per company spring standard</td>
<td>4</td>
<td>Spring tension test</td>
<td>3</td>
<td>M</td>
</tr>
<tr>
<td>Use spring per company spring standard</td>
<td>4</td>
<td>Spring tension test</td>
<td>3</td>
<td>M</td>
</tr>
<tr>
<td>Use hammered surface</td>
<td>2</td>
<td>Operation trials</td>
<td>2</td>
<td>L</td>
</tr>
</tbody>
</table>
Key Take-aways

- New AIAG/VDA FMEA Handbook helps identify potential failures early in the design process
  - Boundary diagrams help identify system interactions with other components
  - P-diagrams help identify influences, functions & failures
  - Tree structure links causes, failures & effects though the assembly or system
Summary

• In this session you should have learned about:
  – Changes implemented in the new FMEA Handbook
  – How to list the steps for creating a DFMEA
  – How to evaluate risks based on Action Priority
References

• VDA. 2003. *Qualitätsmanagement in der Automobilindustrie: Sicherung der Qualität während der Produktrealisierung Methoden und Verfahren – System FMEA.*
Questions?