Assuring the reliability of production processes using FMEA method
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Abstract
Today, the economic success of industrial companies is defined by low production costs, short delivery times and reliable product quality. These three factors are included in the integral quality assurance system which primarily takes into account the needs and the requirements of customers, and consequently enables the company to participate efficiently on the competitive market. To this end, preventive quality assurance methods should be used in companies. They serve to anticipate potential failures in time and to prevent their occurrence. This is possible with the known FMEA method (Failure Modes and Effects Analysis).

Some requirements of the TQM (Total Quality Management) system are given as well as our computerised solution, i.e. a software package developed at the Faculty of Technical Sciences - Department of Mechanical Engineering, Laboratory for Production Systems Planning.

The methods presented in this contribution assure the determination of potential risks, and the analysis and the prevention of failure effects or their moderation. The reliability analysis leads to a wide spectrum of technical safety requirements which are used to precisely assess the reliability of production systems.

Reliability of production processes and the philosophy of TQM

To be successful in present concurrent markets, industrial companies must assure short delivery times, low production costs and adequate
quality of products. Therefore it is of great importance to introduce and apply preventive methods of quality assurance so that potential failures could be predicted in time and their occurrence prevented.

The level of safety and reliability of production systems is determined by laws, technical rules and standards. Reliability and consequently the quality of production processes are comprehensive terms which exceed the limits of legal, economic and technical regulations, and increasingly reflect the policy, philosophy and culture of a nation.

The goal of Total Quality Management system (TQM) is the overall economic success of the company which depends not only on time and cost factors but also strongly on the reliability of production processes. Figure 1 shows that reliability, which is actually quality in certain time, is twofold: external and internal reliability.

**Figure 1: Role of reliability in quality management system**

The notion of reliability is not narrowed only to technical development but is broadened to human relations which bring about steady improvements of working efficiency of individuals and working teams. This is precisely the goal of the Total Quality Management system. Man remains the basic creator of quality and directly influences all planned and systems measures for winning customers' confidence and satisfying
quality requirements. Investigations in our companies have shown that the majority of failure causes are provoked by man, which inevitably leads to defective products.

FAILURE MODES AND EFFECTS ANALYSIS

The introduction of the TQMS is a process which needs an active support of all the employees. It covers, by different methods, all phases from the conception of the product to its sale. One of its efficient methods frequently used in practice is Failure Modes and Effects Analysis (FMEA) [2,3].

In the Laboratory for Production Systems Planning at the Faculty of Technical Sciences in Maribor, the FMEA method was completed by a computer program which allows a quick and efficient analysis performance and concurrent updating of data and results as well as their transfer to other departments in a company.

The FMEA method allows to determine potential risks, to analyse them and to prepare measures to prevent or attenuate the effects of failures on final products. To improve quality by preventing failures is an adequate way to achieve quality goals of a system and to solve the problems arising from the quality-costs-productivity circle. Costs for the achievement of adequate quality are the lowest if analyses and measures are performed in the development phase, but increase rapidly if failures are detected and repaired when the product should be put into use. It goes without saying that in the latter case also the image of the company is ruined.

The FMEA can be performed during the starting phase of product development or during the product manufacture itself. According to this we distinguish constructional and process or technological FMEA which complement each other.

Every Failure Modes and Effect Analysis demands thorough preparatory work which should include bellow stated data for a product or process [1]:

1. Product function including:
   - design plan, assembly plan
   - functional descriptions
452 Software Quality Management

- systems specifications
- working plan
- data on known failures (statistical quality control)

2. Safety regulations

3. Documented experience
   - testing reports

4. Manufacturing process
   - plan of the process cycle
   - plan of the product control
   - plan of the production facilities control

5. List of possible problems in introducing
   - new products
   - new materials and processes
   - new technologies

6. Catalogues
   - of potential failure types, causes and effects
   - of possible control measures
   - of estimation criteria for the failure occurrence and failure effects, and detection of their causes

7. Updating and transferring information to other company departments.

DESCRIPTION OF THE COMPUTER PROGRAM

The computer program developed in our laboratory allows to perform analyses with the help of catalogues of potential failures, effects, causes, measures, and assessment criteria which can be completed in each case by the user himself (Figure 2).

Priority number of risks (PNR) is calculated by multiplying assessment points obtained for the probability of failure occurrence (O), failure effects (E), and the probability of failure detection (D). The obtained number shows the priority for preparing measures for eliminating different failure causes. The causes showing the highest PNR, i.e. the highest probability of failure occurrence, should be treated first.
Determination of PNR for improved state

Failure Effect (E)
- No failure
- Failure of medium effect

Probability of Failure Occurrence (O)
- Improbable: 1
- Very low: 2-3
- Low: 4-6

PNR = O*E*D

Development Team

FMEA System

CATALOGUE OF POTENTIAL FAILURES
- Drill is excentral
- Drill is outside permissible limits
- Oval drill
- Surface quality

CATALOGUE OF EFFECTS

CATALOGUE OF MEASURES
- Automatic inspection
- Improving preparation
- Replacing material

Process FMEA

Operation
- Drilling φ 20 H7

Potential Failures
- Oval drill
- Early wear

Effects

Catalogue of failures, effects and causes

Catalogue of assessment criteria

PNR = O*E*D

Determination of PNR for the existing state

Failure Effect (E)
- High
- Moderate
- Low

Probability of Failure Detection (D)

Probability of Failure Occurrence (O)
The obtained value of the priority number of risks (PNR) should be taken into account when applying correctional measures:

1 ≤ PNR ≤ 125: no risk, correction is not necessary

125 < PNR < 200: medium risk value, risk is usually accepted, correction with simple measures

200 < PNR ≤ 1000: correctional measures are indispensable

In developing a new product, the FMEA first processes the product design or development, and determines the values of PNR. Engineering data with determined PNR values are then transferred to product technology where the PNR values are determined for individual operations, production resources and tools, and control means [4].

**Figure 3: Product planning with inclusion of FMEA**
The FMEA system allows the transfer of the PNR values into the technological data bank which provides information for other company departments and gives important orientation in business decisions. The PNR determines, in a way, the quality level of products, intermediate products and working process, and points to the necessity of introducing new processes, technologies and utilities in production.

![Diagram](image)

Figure 4: Presence of PNR in the documentation of some company departments

Quality assurance is a complex system of activities which are indispensable in the complete production cycle. Figure 4 shows that the FMEA method interconnects the majority of company business functions which are included in the production process and assure the reliable production [1].
IMPLEMENTATION OF THE FMEA

In the continuation, an example of the FMEA method implemented in a company producing parts for the automobile industry is presented.

The object of our observation was the operation of a lock assembly where we anticipated such potential failures as the lock getting stuck, malfunction, etc., and such potential failure effects as non-functional locks, dissatisfaction of buyers, etc. All these failures may result from different potential causes. We proceeded by recording the existing state and evaluated it by applying the PNR. For causes with higher PNR, we determined priority measures for preventing failures, assigned responsibilities to the staff to carry out these measures, and then evaluated the state for the second time using the PNR. It is considered a success if lower PNR values are obtained which correspond to the target quality policy of a company.
**TECHNOLOGY ANALYSIS OF POSSIBLE FAILURES AND THEIR EFFECTS**

Company: Faculty of Technical Sciences Maribor  
Department: Assembly  
Product: Car door lock

<table>
<thead>
<tr>
<th>System Observation Point</th>
<th>Potential Failures</th>
<th>Potential Failures Effects</th>
<th>Potential Failures Causes</th>
<th>Existing State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riveting pins on tumbler and bolt</td>
<td>Lock gels stuck</td>
<td>Lock is non-functional</td>
<td>Broken pin</td>
<td>Visual inspection 2 9 6 108</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bias-riveted pins</td>
<td>Sample inspection 3 8 4 96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machine adjustment</td>
<td>Test cards 4 5 8 160</td>
</tr>
<tr>
<td>Riveting bushings on case, mounting bolt</td>
<td>Malfunction or break down</td>
<td>Non-functional lock, dissatisfied users</td>
<td>Deformed bushing</td>
<td>Sample inspection 5 8 4 160</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bias-riveted bushing</td>
<td>Visual inspection 3 8 6 144</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bolt without pins</td>
<td>Sample inspection 3 9 6 162</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machine adjustment</td>
<td>Test cards 4 7 8 224</td>
</tr>
<tr>
<td>Mounting lining</td>
<td>Failures in mounting</td>
<td>Poor aesthetic appearance</td>
<td>Carelessness of worker</td>
<td>Sample inspection 8 5 2 80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury with crack</td>
<td>Visual inspection 5 5 8 200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wrong machine adjustment</td>
<td>Technologist checks 2 5 4 40</td>
</tr>
<tr>
<td>Mounting springs and lever on cover</td>
<td>Malfunction</td>
<td>Dissatisfied users</td>
<td>Deformed lever</td>
<td>Visual inspection 6 5 7 210</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-lubricated lever</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td>No protection against damages and corrosion</td>
<td>Non-functional lock</td>
<td>Unsuitable packing</td>
<td>Incoming inspecting 7 5 2 70</td>
</tr>
</tbody>
</table>

**Preventing Failure Measures**

<table>
<thead>
<tr>
<th>Preparing Failure Measures</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic testing</td>
<td>Production, Control Technology</td>
</tr>
<tr>
<td>Correction of preparation</td>
<td>Automatic testing</td>
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<tr>
<td>Dynamic testing</td>
<td>Automatic testing</td>
</tr>
<tr>
<td></td>
<td>Dynamic testing</td>
</tr>
<tr>
<td>Automatic testing</td>
<td>Production Technology, Tool manuf.</td>
</tr>
<tr>
<td>Improvement of preparation</td>
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<td>Automatic testing</td>
<td>Production Technology, Tool manuf.</td>
</tr>
<tr>
<td>Training operators</td>
<td>Automatic testing</td>
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<td>Training operator</td>
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<tr>
<td>Routine inspection</td>
<td>Operator</td>
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<td>Supplier - AUDIT</td>
<td>Purchase</td>
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<tr>
<td></td>
<td>Operator</td>
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<td>Smaller quantity</td>
<td>Store</td>
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<tr>
<td>Automatic dosing</td>
<td>Technology, Tool manuf.</td>
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<td>Smaller box</td>
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<td>Lubricating equipment</td>
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<tr>
<td>Define packing</td>
<td>Technology</td>
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<td>New packing</td>
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**Carried-out Measures**

<table>
<thead>
<tr>
<th>Carried-out Measures</th>
<th>O</th>
<th>E</th>
<th>D</th>
<th>PNR</th>
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<td>5</td>
<td>2</td>
<td>10</td>
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</tbody>
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**Figure 6: Example of a process FMEA**
CONCLUSION

In industry there is an increasing tendency towards establishing manageable and efficient production processes. By constantly considering the FMEA strategy, the costs of failures and control no longer represent an outstanding financial item. Below are stated some of the most important criteria for a reliable production:

- build the TQM system
- assure cooperation with the research and development department
- determine reliability goals of production
- divide goals among different process elements
- introduce quality and reliability analyses (FMEA)
- assure the continuous evaluation of suppliers
- build a "zero defect" program
- introduce statistical process control and perform process reliability analyses
- regularly perform internal audits of the system and processes according to the quality assurance manual
- motivate workers
- improve CAQ
- support yearly improvement plans
- elaborate a quality assurance and reliability manual

In the system of Total Quality Management, the FMEA is considered to be one of rather important methods helping to build highly reliable production systems.

Reference: