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Risk Assessment Technical Report

Workshop and Practice (ACHA4011)

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1. Introduction

Before a new product is launched on the market, manufacturing companies are likely to face several issues in the stages of design, development and manufacturing. In times of increasing global competition, it is more important than ever that risk management is flawless as unaddressed risks can result to missed production targets, safety incidents and vehicle recalls. (Smentowski, 2017)

The main aim of this investigation is to understand the importance of risk management in automotive manufacturing companies. In today's market, it is important to control future outcomes proactively as much as possible. Effective risk management therefore offers the potential to reduce the possibility of a risk occurring and the potential impact on both the company and the consumer.

The objective of this investigation is to assess the current assembly line of a vehicle manufacturer and to detect potential areas of failure in the installation process of braking components. One of the most effective and endorsed methods of risk management is Failure Mode and Effect Analysis (FMEA). This method determines the potential failure modes of manufacturing and assembly processes and aims to eliminate the failures as early on as possible. (Belu , et al., 2013)

2. Research

Failure Mode and Effects Analysis (FMEA) is an analytical methodology widely used to manage risks in the automotive industry because it aims to prevent failures that may occur at all levels from initial product design to product development and manufacturing. (AIAG & VDA FMEA, 2020) Some failures are easier to detect and some have a more severe impact on the company and the customer if not intercepted in time. Failure modes can emerge from the deviation from standards in the condition of machines, methods, work force and many more. (Baynal, et al., 2018)

They can affect the assembly line processes or the quality of the final product, which could lead to not only monetary losses and reputational risk but could also be breaching health and safety regulations. (Segismundo & Miguel, 2008)

Executed accordingly, an FMEA quantifies design or process failure modes so high-risks can be easily identified. Once completed, the results usually identify some high-risk characteristics that would have otherwise been missed or overlooked. Using the information attained from an FMEA, vehicle manufacturers should take corrective and preventive measures to avoid the potential failures. (Reid, 2005)

Vehicle manufacturers that are members of the Institution of Mechanical Engineers (IMechE) are expected to refer to their Code of Conduct which covers the fundamental behaviours all members are expected to abide by (IMechE, 2018) when conducting risks assessments. One of their Code of Conduct states that “Members shall act with care and competence and take all appropriate measures to assess and limit risk in all aspects of their work” (IMechE, 2018). This effectively means that members have an ethical responsibility to search for potential areas of weakness and take corrective measures when needed at all times

FMEA is an efficient and effective tool to stabilise production and enhance market competition however the use of RPN has been heavily criticised for the following shortcomings: assumption of equal importance of severity, failure to consider the direct and indirect relationship between the modes and causes of failure. (Baynal, et al., 2018)

In the late 1970s FMEA was used by Ford Motor Company in automotive production processes. Because these applications resulted in satisfactory improvements within Ford, the method has since been widely used in automotive industry as a risk assessment tool. (Baynal, et al., 2018) In present-day, large vehicle manufacturers such as Daimler AG use FMEA as part of their quality assurance

system (Mercedes-Benz, 2014) which impacts all suppliers working with them as they must meet quality standards in accordance to the updated AIAG/VDA FMEA regulations. (Daimler, 2020).

2.1 FMEA Procedure

In order to successfully implement the FMEA procedure the following steps are used:

a) Detecting a failure mode

Failure mode is defined as the way in which a product or process could fail to meet design intent or process requirements.

b) Severity Number (S)

Severity assesses the impact of the failure mode using a ranking scale from 1-10, 10 being the most severe.

c) Probability of Occurrence (O)

Occurrence assesses the chance of the failure occurring using a ranking scale from 1-10, 10 being most likely to occur.

d) Likelihood of Detection (D)

Detection assesses the chance of the failure being detected using a ranking scale from 1-10, 10 being least detectable

e) Risk Priority Number (RPN)

RPN is a function of the three parameters mentioned above, the severity number, probability of occurrence and likelihood of detection. It is calculated by multiplying the values of each of the parameters as per the formula below,

$$SPN = S \times P \times O \quad (1)$$

(Kiran, 2017)

3. Initial FMEA

Table 1 shows the initial FMEA carried out on the assembly line during the installation process of braking components. Four potential failure modes have been identified and ranked and the overall risk priority number (RPN) calculated. Then appropriate mitigation actions were recommended in order to lower the RPN value.

Table 1-Initial FMEA

Failure Mode & Effect Analysis (FMEA) - Braking Component Installation Process					
Potential Failure Mode	Likelihood of Occurrence	Severity	Likelihood of Detection	Risk Priority Number (RPN)	Mitigating Actions Recommended
Brake calliper mounting bolts not torqued to correct level	4	7	7	196	Error-proofing, using a digital torque wrench that a required torque can be set.
Incorrect brake disc size installed	3	8	3	72	Error-proofing. All parts to be placed in a kit designed to match the shape and number of parts needed for the assembly.
Brake pads installed in wrong orientation, with friction material not contacting disc surface	2	8	6	96	Error-proofing, have one side of the brake pad a different colour for easy identification.
Brake line fitting not fully tightened	3	9	7	189	Secondary point-check to test that all brake lines are fully tightened

3.1 Brake calliper mounting bolts not torqued to correct level.

The likelihood of not torqueing bolts to the correct level was ranked a 4 because torque wrenches have an accuracy of $\pm 5\%$ and need to be calibrated. Although, the likelihood of occurrence is moderate, the severity is much higher with a ranking of 7 since it can lead to failure on the road.

Incorrectly torqued bolts are not visible unless completely loose which is why the likelihood of detection has been ranked a 7. They can only be detected if they are manually inspected.

The RPN was calculated to be 196 which would mean that it is a high-priority risk and needs to be amended before the low-priority risks.

The mitigating action recommended is to have use a digital torque wrench that a required torque can be set and automatically be fastened. This would not only decrease the likelihood of occurrence but it would also eliminate the need to have a secondary check and would make the process more ergonomic for the employees.

3.2 Incorrect brake disc size installed.

The likelihood of installing the incorrect brake disc size was ranked a 3 because it's visually detectable if a smaller or larger brake disc has been installed. However, if not detected, an incorrect brake disc size could lead to brake failure and would make the vehicle unsafe.

Since an incorrectly sized disc can be both visually detected and when the rest of the components are being installed, hence why the likelihood of detection was rated a 3.

The RPN was calculated to be 96 which is a medium-risk and the mitigating action recommended is to error-proof the process. If all the required parts were placed in a kit designed only for that assembly that needed to be scanned before assembly can begin, employees would know if they picked up the wrong kit. (Assembly, 2006)

3.3 Brake pads installed in the wrong orientation

The likelihood of installing brake pads in the wrong orientation was ranked a 3 because it's very unlikely to happen due to the fact that the employees installing it are trained and would be able to install them correctly, however it may still happen if the employees are fatigued and are careless, or they are working in a rush to meet a production deadline.

The severity was ranked an 8 due to the fact that if not detected then installing the brake pads incorrectly affects safe vehicle operation and could lead to brake failure on the road, which would endanger the customer.

Likelihood of detection was ranked a 6 because it would be difficult to detect if the brake pads are installed incorrectly if the callipers have already been installed since they would not be as visible.

The RPN was calculated to be 96 and the mitigating action recommended was to have one side of the brake pad a different colour for easy identification.

3.4 Brake line fitting not fully tightened

Likelihood of occurrence was ranked a 3 for not fully tightening a brake line fitting because it would only happen due to inattentiveness of operator fatigue. Not fully tightening a brake line fitting could lead to leakage of brake fluid. Brake fluid leakage could lead to loss of hydraulic pressure which would lead to a brake failure on the road thus endangering customers. Hence why the severity was ranked a 9.

The likelihood of detection was ranked a 7 because unless the brake line is leaking then it would not be blatantly obvious that the line fittings are not fully tightened.

For this reason, not fully tightening brake line fittings has a RPN of 189 and is a high-risk that needs to be amended promptly. The recommended mitigation action is to have a secondary point-check where all brake line fittings are checked to see if they are fully tightened and are operational.

4. Post-Mitigation FMEA

Table 2 shows the amended FMEA table that has been conducted with the recommended mitigation actions. New rankings have been given and a new RPN has been calculated.

Table 2- Post-Mitigation FMEA

Failure Mode & Effect Analysis (FMEA) - Braking Component Installation Process					
Potential Failure Mode	Likelihood of Occurrence	Severity	Likelihood of Detection	Risk Priority Number (RPN)	Potential Risk Remaining
Brake calliper mounting bolts not torqued to correct level	2	7	7	98	Likelihood of detection is still high and if the failure mode does occur, it is very likely that it will be overlooked.
Incorrect brake disc size installed	1	8	1	8	The risk has been minimised as much as possible, the next step would be to eliminate the failure completely
Brake pads installed in wrong orientation, with friction material not contacting disc surface	1	8	4	32	The likelihood of detection could still be decreased in order to minimise the RPN and make it a low-risk
Brake line fitting not fully tightened	3	9	2	54	If overlooked even after a secondary point-check, it would endanger customers.

4.1 Brake calliper mounting bolts not torqued to correct level

The new RPN value is 98. The reason for that is that the implemented mitigation actions have lowered the likelihood of occurrence from a value of 4 to a value of 2. This is due to the fact that using a digital torque wrench allows the employee to see the amount of torque applied to the mounting bolt with an accuracy of $\pm 3\%$.

However, there are still potential risks remaining. The likelihood of the failure mode still has a high ranking and if the failure were to happen then it is very likely that it would be overlooked and not detected until after it has reached the customer.

The severity ranking cannot be changed as no matter how much the potential failure can be prevented, the severity of a potential failure will stay the same. If the mounting bolts are not torqued to the correct level, excessive torque could damage the bolts and insufficient torque could cause the mounting bolts to come off. Either scenario could lead to brake failure which could put the customer's life in danger.

4.2 Incorrect brake disc size installed

The new calculated RPN value is 8. The reason for that is that the enforced mitigation actions have lowered both the likelihood of occurrence and detection to a value of 1. By introducing a kit designed to hold all the part required for an assembly that has to be scanned before assembly can begin, the likelihood of occurrence decreases because even if the employee picked up the wrong kit, scanning it beforehand would inform them of it.

The potential risks remaining are that if somehow, the incorrect brake disk is still installed and not intercepted in time, it could to brake failure on the road. The severity ranking cannot be changed as no matter how much the potential failure can be prevented, the severity of a potential failure will stay the same. If a smaller brake disc was installed than the intended size, then it could create problems for the customer. A smaller brake disc would mean have less stopping power since it would cover a smaller surface area.

4.3 Brake pads installed in wrong orientation

The new RPN value is 32. The reason for that is that the implemented mitigation actions have lowered the likelihood of occurrence and improved the likelihood of detection. Any assembly process can be subjected to constraints such as fatigue, carelessness or just time-pressure. A simple method to correct that is error-proofing. Having one side of the brake pad be a different colour for easy identification is a classic example of poka-yoke.

However, there are still potential risks remaining. The likelihood of the failure mode still has a high ranking and if the failure were to happen then there is a high chance that it would be overlooked and not detected until after it has reached the customer due to the fact that installing brake pads in the wrong orientation would not offer enough friction for a car to stop effectively. Hence why the severity rank cannot be changed, brake pads installed incorrectly would not make the vehicle safe to drive.

4.4 Brake line fitting not fully tightened

The new RPN value is 54. A secondary point-check would increase the likelihood of detection because it would require the operators to check everything one more time and make sure everything is adequate and up to standard.

The only remaining potential risk is if the failure has been overlooked and neglected even after the secondary check, the severity of the failure would not change. The potential failure would make the vehicle inoperable and it would fail to meet health and safety regulations as well as endanger the customer.

5. Conclusion

FMEA is a valuable tool to the automotive industry as it is efficient and effective in decision-making and it controls the stability of the manufacturing processes and it improves product and system performance by decreasing failure rate. It is an integral part of risk management and the achieved results support that.

Although the traditional FMEA helps to stabilise production it does have its limitations. It fails to evaluate the relative relationship of each of the parameters. The greatest limitation is that it has a bias towards the severity rating. This can be seen in the conducted FMEAs, none of severity ranks were amended. Likelihood of occurrence and detection can always be reduced however only in rare cases can the severity rating be reduced as well.

It is important to know that while FMEA is successful it is only an assessment tool that identifies where and how a process might fail and it assesses the relative impact of a possible failure. However, FMEA does not remove the failure and it should be used in conjunction with other tools to ensure that risks are eliminated.

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