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RISK ASSESSMENT TECHNICAL REPORT:

An analysis and evaluation of assembly line processes from the viewpoint of a
process engineer

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ABSTRACT

In this report failure mode and effect analysis (FMEA) is utilized to identify weaknesses and reduce the risks of potential failures that occur in the brake component installation process. Potential failures are ranked by severity, occurrence, and detection to calculate a risk priority number (RPN). The methodology for conducting FMEA is explained; followed by a subjective study discussing the mitigating actions implemented to lower the original RPN Values. A justification of the corrective actions taken is included as well as a second FMEA providing new rankings for comparison and to determine if the actions taken were successful in reducing the risk priority numbers.

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1 INTRODUCTION

Human safety is an important parameter in the manufacturing process of a vehicle; it is vital to identify and minimize any issues before a product reaches the customer. The objective of this report is to assess a company's current brake component installation process, using failure mode and effective analysis with the intention of minimizing the risk priority number of each potential failure mode. Originally developed in the 1940s FMEA is a systematic engineering technique used to define, identify, prioritize, and reduce potential modes of failure with components. Being an effective, well-structured method FMEA testing has been successfully implemented in various industry's including but not limited to, aerospace^{[7][8]}, biomedical^[1] and automotive^[9].

Failure is a big cause for concern in any business therefore identifying and managing the risk before a product is distributed is crucial. It is important for engineers to understand risk management as techniques like FMEA improve the quality, reliability, and safety of the production process. From an economical point of view the development time and cost are reduced when risk management procedures are implemented which in turn increases company profits. Risk management also helps to increase the customers safety and satisfaction with the product which should be a top priority for any engineer.

2 LITERATURE REVIEW

Failure Mode and Effect Analysis is utilized to manage risk in a variety of industries. In the manufacturing industry FMEA methodology is used to improve the quality and reliability of components, but can also reduce the development time and subsequently the cost by identifying areas of concern and rectifying issues before production ^[19]. There are lots of studies about FMEA in different fields, Baynal used FMEA as a decision-making tool improving the performance of a product by decreasing failure rate; corrective activities resulted in 96 % improvement in door seal cuts problem caused by the doorstep assembly. Door seal cuts problem caused by instrument panel assembly and the noisy door window problem were solved completely ^[3]. Gundewar concluded that electrical faults have higher Risk Priority Number when compared with mechanical faults after conducting a FMEA analysis of electromechanical induction motor ^[17]. Kim and Zuo concluded that when comparing the severity values for all failure modes, one can identify failure modes that are more serious if a preselected level is reached ^[14]. They developed a model that indicated a functional relationship between severity, occurrence, and detectability.

In the automotive industry FMEA has been applied to a brake by wire system. The report showed vast improvement due to FMEA being implemented ^[16]. Banduka et al integrated lean approach into PFMEA in the automotive industry to successfully improved the process and product quality minimizing the risk of failure. The lean approach became popular worldwide after leading Toyota to first place in world's car manufacturers ^[21].

The IMECHE code of conduct protects members of the public as well as IMECHE members. Put in place to uphold the reputation of the engineering profession the IMECHE code of conduct states that “Members shall act with care and competence... taking all appropriate measures to assess and limit risk in all aspects of their work for others to whom they owe a duty of care.”^[12]. Conducting FMEA analysis on components in an assembly line shows that the engineer and company are limiting risks to the best of their ability’s.

The engineering industry has specific health and safety legislation to prevent or manage risks looking into the legislation revealed that approximately 14 people every year suffered accidents due to a slippery floor; many of these cases caused by company machines leaking oil. This incident lead to an ‘Oil leak plan’ being implemented which reduced slip rates by two thirds a preventative measure taken included vacuuming oil collecting in the bunding and then reusing it^[10].

3 INITIAL FMEA

Failure mode and effect analysis allows companies to assure the quality of their products, this often vastly improves sales and adds to the brands value. It is essential for the quality of the product being delivered to be monitored this prevents defects from emerging. The FMEA technique begins by identifying areas that could fail and then calculating the priority number of each risk in relation to the total system as shown in figure 1. FMEA assesses the possibility of failure and the risk level based on likelihood of occurrence, severity of the issue and ease of detection. These three terms are then multiplied to obtain the Risk Priority Number (RPN).

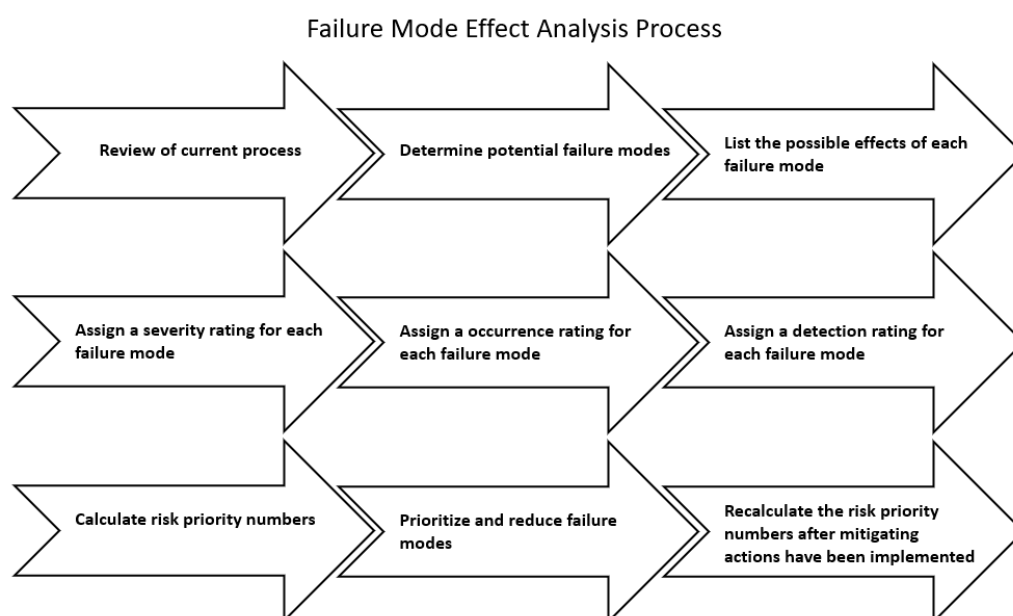


Figure 1 - FMEA Process Flow Diagram

Displayed above in figure 1 is the process carried out when conducting failure mode and effective analysis. To begin with the current process is reviewed and potential failures are noted then severity, occurrence and detection rating are given to each failure mode, these values are then used to determine a risk priority number. Finally mitigating actions are discussed and

implemented, a second FMEA can then be conducted showing how the mitigating actions effect each failure mode^[13].

Severity Ranking	
Ranking	Effect
10	Hazardous – No Warning
9	Hazardous – With Warning
8	Very High
7	High
6	Moderate
5	Low
4	Very Low
3	Minor
2	Very Minor
1	None

Table 1 - FMEA Severity Ranking

This report primarily focuses on issues in the production line however processes that lead to failure with a product also can occur when the user makes a mistake. Including those types of failure ensures that the product works correctly, regardless of how the user operates, it will move the product closer to 100 percent total customer satisfaction. The initial FMEA is show in table 2 as well as the mitigating actions implemented with the intention of lowering the RPN.

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 caliper mounting bolts not torqued to correct level	7	7	8	392	• On-torque method
Incorrect brake disc size installed	5	6	7	210	• Visually inspect the brake disc being installed and replace if nessasary
Brake pads installed in wrong orientation, with friction material not contacting disc surface	6	7	6	252	• Visually inspect the brake pads being installed and replace if nessasary
Brake line fitting not fully tightened	7	6	8	336	• On-torque method

Table 2 - Initial Failure Mode and Effect Analysis

3.1 Brake Caliper Mounting Bolt

In the United States 23% of all service problems were traced to lose fittings or fastenings, even in new cars 12% were found to have loose fastening^[5]. This indicated that the likelihood of occurrence for the brake caliper mounting bolts not being torqued correctly is high hence giving this a value of 7 for likelihood of occurrence. In the event that the brake caliper mounting bolts

torque is not correct the caliper maybe prevented from locking with the brake disc while braking or in an extreme case could fall off the vehicle. If the vehicle is unable to brake this is dangerous and if only one wheel is able to brake the vehicle would pull to one side which is why the severity is 7. Referring back to the previous point if 12% of new vehicles are found to have incorrectly fastened bolts this failure is clearly likely to go undiscovered therefore the likelihood of detection is 8.

The highest RPN calculated was 392 for the brake caliper mounting bolt not being torqued to the correct level, as it was the highest RPM this means that it should be the top priority. While researching it was found that the 'on-torque method' is widely used in the automotive industry to ensure that bolts are correctly tighten which is why it is the chosen mitigating action for this failure mode^[4]. Before decided which mitigating actions to implement further research was conducted into the 'off-torque method' and the 'marked faster method' however they are less widely used in the automotive industry and have been proven less effective. The flaw with these methods is the coefficient of friction is assumed to not change when the bolt is being tightened however when applied to real life circumstances this is not the case^[18].

3.2 Incorrect Brake Disc Size

An incorrect brake disc being fitted is possible especially if visual checks are not being carried out on components, as seen in table 2 the likelihood is 5. If the wrong size brake disc was fitted this could cause brake judder due to the pads not being correctly positioned. If the disc fitted was smaller in size it is likely the car would not be able to slow down as fast as it normally would therefore this was given an 8 in severity. The likelihood of detection is a 7 as without any mitigating actions in place this could be missed.

The risk priority number for an incorrect size brake disk is the lowest at only 210 however to reduce this further it is recommended that a visual inspection is carried out. The disc that is fitted to the vehicle should have its size checked against the intended disc size to ensure that it is correct.

3.3 Wrong Orientation of brake Pads

Brake pads being installed in the wrong orientation will reduce the friction between the pad and disc this could prevent the disc from stopping and be fatal. Lack of friction on a brake pad due to it being installed incorrectly could cause the vehicle to one-sided brake which may result in the car jolting to one side, the likelihood of this occurring is noted as 6 ^[11]. The vehicle being up able to stop or jolting to one side is possible to cause an accident therefore the severity is a 7.

The risk priority number for the brake pads being installed the wrong way is 252 as seen in table 2. The recommended mitigating action for this potential failure mode is that a visual inspection is carried out to ensure that the pads are correctly installed.

3.4 Brake line fitting not tightened

As mentioned previously many cars from production have loose fittings hence the likelihood of occurrence for the brake line fitting not being correctly tightened is 7. This could be severe as if air enters the brake line it will compress and not transfer pressure to the caliper piston which could prevent the brake pads from locking with the disc however modern cars have warning lights

indicating a problem with the brakes [6]. As with the brake caliper bolt not being correctly torqued this is very unlikely to be detected and therefore is given a detection rating of 8.

Brake line fitting not tightened correctly has the second highest risk priority number out of all of the potential failure modes. As with the caliper mounting bolt extensive research was conducted into how this problem is overcome in the automotive industry and the most effective solution found was to use the 'on torque method'. This method includes measuring the torque needed to rotate the bolt, or in this case fitting, by an angle in the tightening direction this can be used to ensure all fittings are torqued to the correct specification as they have been turned through the same angle^[4].

4 POST-MITIGATION FMEA

After conducting the initial FMEA the mitigating actions discussed above were implemented with the intention of lowering the risk priority numbers for each failure mode. After conducting a second FMEA figure 2 was constructed which is a graph showing the drop in risk priority numbers from the initial FMEA compared with the risk Priority number once the mitigating actions had been put in place.

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	4	7	4	112	Vehicle pulls to one side while braking as brake caliper becomes misadjusted
Incorrect brake disc size installed	4	6	3	72	Brake slower or quicker than usual due to insufficient or excessive friction between pads and disc
Brake pads installed in wrong orientation, with friction material not contacting disc surface	3	7	3	63	Vehicle brakes slower or brakes stop working due to the the wrong orientation of pads
Brake line fitting not fully tightened	4	6	4	96	Spungy brake pedal due to air in the system may lead to brake failure

Table 3 - Post Mitigation Failure Mode and Effect Analysis

When comparing table 3 to table 2 it is made clear that the mitigating actions implemented significantly reduce the risk priority numbers across the board. The failure mode with the biggest difference from the first FMEA is the brake caliper mounting bolts not torqued to the correct level with a drop of 280. Realistically it is near impossible to completely remove any risk which is why each failure mode still has potential risks and high severity ratings. This is a disadvantage with using FMEA, the severity cannot be minimized by changing actions on the production line as regardless of what is changed to lower the RPN there is always a chance the component will fail.

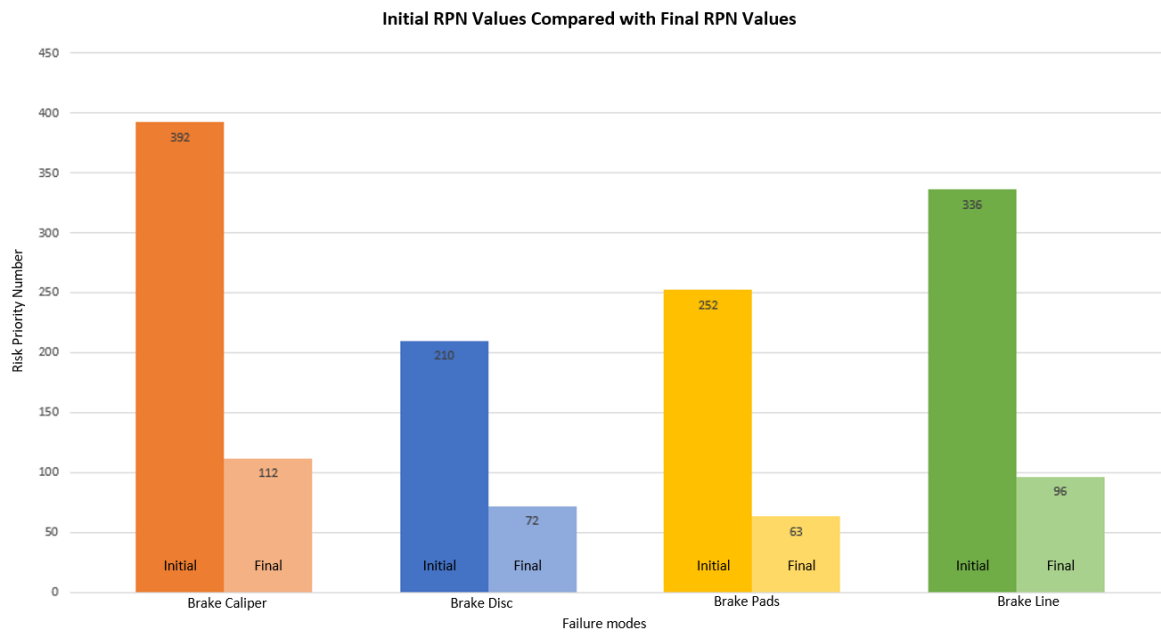


Figure 2 - RPN Comparison Graph

5 CONCLUSION

The brake system is crucial for the safety of customers in the vehicle; It is important to identify, control, and decrease potential failures in the design and manufacturing process. In this report FMEA was successfully implemented to improve the assembly line process and overall safety of named components. Figure 2 displays a visual representation of how mitigating actions successfully lowered the rpm of each category. Even after implementing mitigating actions the brake caliper still had the highest RPN followed by the brake line. This is due to research showing that one of the most significant problems the automotive industry currently faces is finding an efficient way to ensure torque values are met.

There have been numerous studies to investigate whether FMEA is an effective tool for mitigating risks. Fault tree analysis (FTA) was performed on a manufacturing system prior to conduction FMEA by Peeters et al this successfully lowered the risks^[15]. Taguchi loss was incorporated with FMEA by Sustrisno to evaluate the critical level of waste in operation of manufacturing process^[20]. To further improve the assembly line processes grey theory could be integrated with the FMEA technique as using FMEA alone has limitations such as failing to evaluate the relative relationship of each weight of the given parameters^[2]. Combining GRA and FMEA together would be beneficial as this provides the ability to assigning weight to each failure mode in FMEA. Combining the two techniques would provide more effective and consistent results for comparison.

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