

University of Wales Trinity Saint David
School of Engineering

Failure Mode & Effects Analysis – Technical
Report

Engineering Applications & Study Skills
ACMA4007

Philip Craig Bartle

1808882

12/02/2024

Contents

1	Introduction.....	iii
1.1	Aims	iii
1.2	Objectives	iii
2	Literature Review	iv
3	Methodology	Error! Bookmark not defined.
4	Discussion	Error! Bookmark not defined.
5	Conclusions	xi
6	References.....	Error! Bookmark not defined.

1 Introduction

Manufacturing is a complex environment in which various processes, technologies, and human influences come together. In such a dynamic and fluid workplace, understanding and controlling risks are an integral factor when ensuring safety, reliability, and improving the efficiency of a process. Engineers play a significant role in this process, and this report outlines the importance of understanding some risk management techniques available. The primary focus of this report is to complete an FMEA for a band saw and consider the effectiveness of an FMEA in this scenario.

1.1 Aims

This report will discuss the relevancy of risk management within a manufacturing capacity, with a specific focus on Failure Modes & Effects Analysis (FMEA) as a critical tool and will look at Process Failure Modes & Effects Analysis (PFMEA) of a cutting process using a Kasto band saw.

1.2 Objectives

The primary objectives include assessing the usefulness of an FMEA in the workplace, in mitigating potential failures and understanding the legal considerations governing sound engineering practices set out by the HSE and IMechE respectively.

2 Literature Review

Failure Modes Effects and Analysis emerged from the US military in the 1940's and was used as a tool to analyze the root cause of failure through a structured and systematic approach. When utilized correctly, FMEA not only helps understand potential failure routes of a product. It also allows engineers to estimate the severity or impact of any failures along with offering a means to calculate the effectiveness of prevention strategies implemented because of carrying out an FMEA.

(University of Cambridge, n.d.)

FMEA can be applied at both the design stage (DFMEA) or during the process stage (PFMEA). FMEA is a mitigation tool that is employed during the analyze phase of the wider set of management techniques known collectively as Six Sigma DMAIC cycle. (JM, 2015). It assists us practice competently and maintain up-to-date knowledge and skills.

The application of DFMEA (design) initiates by assembling a multi disciplined team consisting of individuals with expertise across a variety of roles, promoting sustainability and acting with integrity and respect. This team can have expertise in fields including (but not limited to) design, manufacturing, quality and marketing. This multi disciplined team will systematically exercise leadership in examining the design component by component, identifying any potential failure modes that may impact safety, profitability, customer satisfaction and reputation. Each identified failure mode is rated based on severity, occurrence, and detectability. These factors are used to

calculate the risk priority number (RPN). The RPN is used to highlight and prioritize the most critical failure modes for further analysis and mitigation. FMEA carried out at the design stage can be extremely useful at preventing failure of an item during normal operating parameters. Once failure modes are identified, the team can develop a plan to address them. These changes can include alternative material selection, part or whole new design changes and additional testing to ensure conformity in line with existing HSE guidelines.

PFMEA (Process) is focused on the manufacturing process itself, identifying and preventing potential failure modes that could detrimentally impact safety, quality and reputation. PFMA follows a similar approach to DMFEA. A multidisciplined team will examine the manufacturing process in detail. The PFMEA can be carried out at any stage from the raw material receipt to the final product inspection. Any potential failure modes identified will be scored by multiplying the severity by occurrence and the detectability of failures with total given the RPN score calculated. The RPN is used to highlight and prioritize the most critical failure modes for further analysis and mitigation. Remedial steps are put in place to lower the RPN. These may include equipment and technology upgrades, process modifications, changes to testing and quality inspections or additional/more advanced training for technicians.

A properly conducted FMEA helps engineers understand the consequences of potential failures. FMEA enables proactive risk mitigation and contributes to increasing the reliability of a given manufacturing process. Within the manufacturing industry, reducing risks is essential due to the intricacies of moving parts within the manufacturing process such as human factors, machinery and external influences. The Institute of Mechanical Engineers (IMechE) emphasizes the responsibility of engineers to prioritize safety, quality and ethical considerations in line with upholding the four main principles of their code of conduct. This ensures members of the public and IMechE members are protected along with the reputation of the organization and the engineering sector.

Adherence to legal frameworks is fundamental in good engineering practice. Compliance with H&S legislation in line with the Health and Safety at Work act 1974 (HASWA) ensures that manufacturing operations prioritize the well-being of employees and adhere to industry safety standards. Engineers need to integrate legal considerations into their risk management strategies to avoid legal repercussions and uphold professional integrity. When completing my PFMA for sectioning using a Kasto band saw, I first consulted the HSE website to ensure the equipment met the guidelines set by the HASWA 1974 (HSE, 2021) and Provision and Use of Work Equipment Regulations 1998 (PUWER) (HSE, 2023) as seen in figure 1 below (ToolSense, n.d.). Some simple but essential safety features required include an emergency stop button and guards.

PUWER Key Requirements



Figure 1. PUWER 1998 key requirements (ToolSense, n.d.)

3 FMEA

The PFMEA shown below (see figure 2.) focused on the sectioning process within R-Tech Materials, analysing potential failure modes whilst operating the Kasto band saw. The team consulted the HSE website and PUWER regulations, identifying four potential failure modes attributed to the cutting process. The team assessed their severity, occurrence and detectability and scored each out of 10 accordingly. The Risk Priority Number (RPN) was calculated for each failure mode observed.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
2	Item:	Kasto Band saw				Responsibility:				Workshop Manager				FMEA number: WS001			
3	Model:	600 / 360				Prepared by:				Craig Bartle				Page : 1			
4	Core Team:	R-Tech (STEEL)												FMEA Date (Orig): 31/01/2024 Rev: 0			
5																	
6	Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Occurrence	Current Controls	Detect	RPN	Recommended Action(s)	Responsibility and Target Completion Date	Action Results					
7												Actions Taken	Severity	Occurrence	Detect	RPN	
8	Cutting area of interest from as received sample	Sample incorrectly gripped	Damage to area of interest, hindering failure investigation - Unhappy customer	10	Sample incorrectly aligned in saw. Incorrectly packed grips.	4	Visual inspection	4	160	Physically check sample is secure prior to cutting. Ensure correct packing by checking both front and back of grips are square and parallel using a square.	Workshop Manager 31/01/2024	Procedure amended to include a new step on checking sample is correctly secured. Square purchased for checking sample correctly gripped.	10	2	1	20	
9	Cutting area of interest from as received sample	Material being ejected ie, springs	Serious injuries and damage to other equipment - company needs to repair/replace damaged asset	8	Dynamic risk assesment not carried out to ascertain direction of cut through various parts under stress.	3	None	8	192	Liaise with customer and as for a drawing to check internals of part. Place physical guard around saw when cutting.	Workshop Manager 31/01/2024	Customer contacted when unsure of internal make up of sample. Guard fitted around saw	3	1	1	3	
10	Cutting area of interest from as received sample	Band saw blade failing	Blade being ejected causing injury to personnel - lost working hours affecting productivity and delivery times.	5	Incorect blade used for material type/hardness.	3	None	3	45	Check material of sample with PMI gun and portable hardness prior to cutting	Workshop Manager 31/01/2024	Procedure ammentted to include PMI and hardness testing of material when spec not know by client.	5	1	1	5	
11	Cutting area of interest from as received sample	Coolant spillage	Slips, trip and falls - lost working hours affecting productivity and delivery times.	5	coolant flow too high slashing of sample being cut.	5	None	2	50	Vually check flow to ensure no splashing.	Workshop Manager 31/01/2024	Exlusion zone painted around saw to restrict access. Spill kit purched for saw.	5	1	1	5	
12																	

Figure 2. PFMEA of a Kasto band saw.

The potential failure modes were identified and numbered as follows:

- 1) Sample incorrectly gripped.
- 2) Material being ejected during cutting operation.
- 3) Band saw blade catastrophically failing (snapping).
- 4) Coolant spillage.

The failure modes were given initial scores based on severity, occurrence and detectability which were multiplied giving an initial RPN (in the column indicated in orange). The justifications for these rankings were decided by considering historical data and expert opinions within the team. A failure

mode with a high severity ranking may result in a safety hazard, whilst a high occurrence ranking signifies a frequently occurring issue. The RPN numbers first calculated (orange) were surprisingly high and it was immediately obvious remedial actions were required.

Remedial steps were proposed and applied based on the FMEA results. These actions included putting systematic checks in place, improving preventive maintenance schedules, and enhancing training for operators, as well as spill kits at the work location. Each proposed action aimed to reduce the severity, occurrence or detectability of potential failures.

The RPN was recalculated in line with the newly implemented control measures (indicated by the green column). All four processes observed a dramatic decrease in RPN score. This reduction in RPN not only improved the safety of the process, but also helped to improve the finished product by ensuring the samples were not damaged whilst carrying out the sectioning. Graphical representation of the reduction in RPN can be seen in figure 3. below.

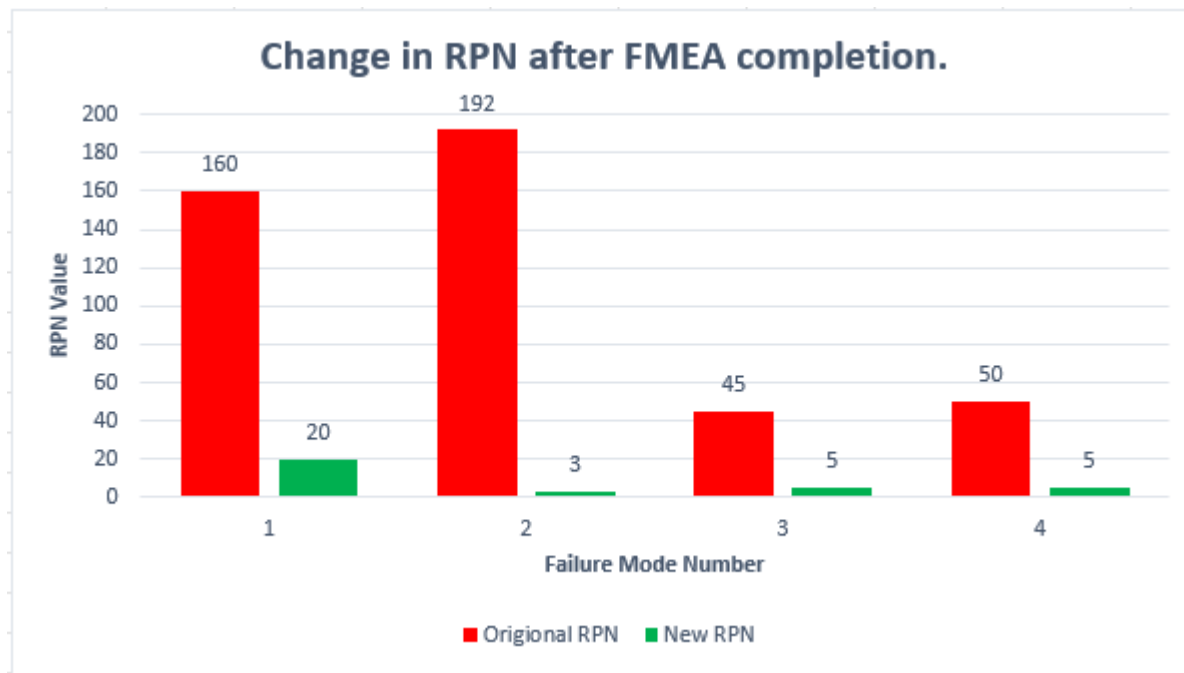


Figure 3. Graphical evidence of reduction of RPN score after remedial steps implemented.

4 Discussion

Although the overall RPN number reduced, the severity of the failure remained constant throughout the FMEA.

Despite the changes, some risks remained due to inherent limitations and dangers of using machinery. It's essential to document these residual risks, acknowledge their existence, and continuously monitor and update risk management strategies accordingly.

The advantages of FMEA within the workplace are clear. However, it must be noted that there are also some disadvantages to the process. FMEAs usually show a biasness towards high severity ratings regardless of the associated chances of occurrence and detection. An example would be, the

severity of an exploding gas pipe could be ranked at severity 10, even though both the chance of this happening and the likelihood of detection are rated at the lowest score of 1. As a result of the high severity rating, no improvement in RPN is possible as severity ratings are inherently difficult to reduce (ChatSmith, 2024). FMEA only provides a theoretical assessment and relies heavily on the experience of the team completing the FMEA. It does not eliminate the problems it uncovers and there is still a requirement to solve any problems and put any controls in place. These controls can be both costly and time consuming.

5 Conclusions

The end user of any given product expects said product to be safe and fully operational. FMEA can help meet these demands by improving both the design and processes, in turn, delivering superior quality products and services. FMEA can be used proactively and adapted to many industries or applications, from petrochemical to retail and medical to education. FMEA can improve product design to deliver safer, improved quality and increased reliability, along with reducing the costs for design, development and production. It can provide information to highlight products meet the highest quality and safety standards like Six Sigma and ISO 9001. Whilst continuing to adhere to health and safety laws and good practices set out under HSE and IMechE. These benefits mean FMEA has become an integral tool in industry that is here to stay.

6 References

ChatSmith, 2024. *ChatSmith A.I.* [Online]

Available at: <https://docs.smith.ai/category/rnvhemh4fk-chat>

[Accessed 07 02 2024]. Used as a template fir this report.

HSE, 2021. *HSE Introduction to wood cutting.* [Online]

Available at: <https://www.hse.gov.uk/woodworking/bandsaw.htm>

[Accessed 05 02 2024].

HSE, 2023. *Equipment and Machinery.* [Online]

Available at: <https://www.hse.gov.uk/work-equipment-machinery/puwer.htm>

[Accessed 07 02 2024].

JM, 2015. *Six Sigma Daily.* [Online]

Available at: <https://www.sixsigmadaily.com/failure-modes-and-effects-analysis-fmea-and-six-sigma/>

[Accessed 05 02 2024].

ToolSense, n.d. *toolsense puwer-regulations.* [Online]

Available at: <https://toolsense.io/glossary/puwer-regulations/>

[Accessed 07 02 2024].

University of Cambridge, n.d. *IFM Management Technology.* [Online]

Available at: <https://www.ifm.eng.cam.ac.uk/research/dmg/tools-and-techniques/fmea-failure-modes-and-effects-analysis/>

[Accessed 02 02 2024].

7 Appendices

Personal Development Plan

Name – Philip Craig Bartle

Degree – DA6MTS Material Science

Previous Qualifications – GCSE

Previous Experience – Inspection Engineering petrochemical, Marine, Aerospace and Medical

Goal	Objective	Resources Required	Measurement	Target Date
To gain a degree in Material Science.	To put aside enough time weekly to complete all tasks to the best of my ability.	Access to literature and material made available by university. Internet.	Measuring progress through assignment and examination results.	2027
To become a welding engineer.	Complete my degree so I meet the requirements to progress to welding engineer	UWTSD and TWI as well as recommended literature.	To successfully complete all modules of my degree.	2028
Achieving chartership.	To complete my degree and achieve my welding engineer qualification (TWI)	Access to institute of mechanical engineers (IMechE).	Achieving degree and becoming a member of IMechE.	2030
Achieving a Doctorate.	Completing a degree and masters in material science	Resources supplied by UWTSD	Gaining both degree and masters in Material Science.	2032
Becoming a director.	Become a manager before becoming a director within R-Tech.	Access to courses	Gain promotion to consultancy manager.	2032

Understanding Failure Modes Effects Analysis

CRAIG BARTLE 1808882

School of Engineering

BEng (Hons) Material Science

What is Process Failure Modes Effects Analysis (PFMEA)?

Failure Modes Effects and Analysis emerged from the US military in the 1940's and was used as a tool to analyze the root cause of failure through a structured and systematic approach. When utilized correctly, FMEA not only helps understand potential failure routes of a product. It also allows engineers to estimate the severity or impact of any failures along with offering a means to calculate the effectiveness of prevention strategies implemented after carrying out an FMEA. (University of Cambridge, n.d.)

What is Process Failure Modes Effects Analysis (PFMEA)?

Failure Modes Effects and Analysis emerged from the US military in the 1940's and was used as a tool to analyze the root cause of failure and improve quality through a structured and systematic approach. When utilized correctly, FMEA not only helps understand potential failure routes of a product. It also allows engineers to estimate the severity or impact of any failures along with offering a means to calculate the effectiveness of prevention strategies implemented after carrying out an FMEA. (University of Cambridge, n.d.)

How we carried a PFMA of Kasto Saw to improve sectioning.

- Team assembled.
- HSE, PUWER and IMechE codes consulted.
- Failure modes identified.
- Initial scores allocated and RPN calculated.
- Controls put in place.
- New scores allocated with controls measures.
- Training given and systems continually monitored.



The image below is a successful completion of FMEA (Photo courtesy of (Median.com, n.d.))



The above image shows the Kasto saw prior to the findings of the PFMEA being carried out. The saw was photographed at R-Tech Materials workshop (R-Tech Materials, 2024).

The PFMEA (table 1) below illustrates four failure modes detected. Note the initial high RPN scores that were dramatically reduced directly as a result of carrying out the PFMEA on the Kasto saw and implementing the recommendations.

Failure Mode	Original RPN	Reduced RPN	RPN Decrease (%)
1	100	30	87.5
2	100	5	95
3	45	5	88.9
4	50	5	90



Graphical representation to illustrate successful use of PFMEA of a cutting process within R-Tech Materials.

Table 2 highlights the positive effect carrying out an PFMEA on the Kasto saw has had on the sectioning process within R-Tech. The RPN score has dropped significantly. This reduction in RPN has made R-Tech a safer place and improved the quality of our service to our customers.

Table 2 below highlights the change in RPN values.

Failure Mode	Original RPN	Reduced RPN	RPN Decrease (%)
1	100	30	87.5
2	100	5	95
3	45	5	88.9
4	50	5	90

Summary of Key Findings

A team carried out a PFMEA of the Kasto saw with the aim of improving safety and quality. Four main failure modes were identified and a RPN score was calculated. Steps were put in place to lower the RPN score with the ultimate goal of improving safety and quality of service. The RPN values were recalculated with the new steps and showed a large reduction in RPN of 87% plus!

The FMEA has proved a highly successful tool in risk mitigation. |

See your line manager if you would like to carry out an FMEA in your department.



(Barton Staffing Solutions Inc, 2017)

References

- Barton Staffing Solutions Inc, 2017. Barton Staffing Solutions.com. [Online]
Available at: <https://www.bartonstaffing.com/2017/08/23/safety-is-the-property-quality-is-the-standard/>
[Accessed 07/02/2024].
Median.com, n.d. Median.com. [Online]
Available at: <https://www.median.com.au/what-is-failure-modes-and-effects-analysis-fmea/>
[Accessed 07/02/2024].
R-Tech Materials, 2024. R-Tech Kasto saw in workshop. n.d. n.s.
University of Cambridge, n.d. IFM Management Technology. [Online]
Available at: <https://www.ifm.com.au/what-is-failure-modes-and-effects-analysis-fmea/>
[Accessed 02/02/2024].