



University of Wales Trinity Saint David
School of Engineering

Assignment Title: Failure Mode and Effective Analysis – Technical
Report

Engineering Applications & Study Skills

ACMA4007

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Failure Mode and Effective Analysis: Technical Report

Introduction

This technical report aims to investigate and explain the importance of Risk Management within the manufacturing sector. Legal considerations will be discussed and considered. This report will

Literature Review

Definitions & Overview

In the 1950s, the concept of 'Risk Management' was introduced (Crawford, 1994), it can be defined as 'the identification, analysis, and prioritisation of risks followed by coordinated and economical application of resources to reduce, monitor, and control the probability and/or impact of unfortunate events' (Hubbard, 2020). The main objective of Risk Management is to ensure that risk is kept at an acceptable level, this is done by maintaining tolerable risks and developing plans to manage and minimise 'unacceptable risks to an acceptable level' (Labodová, 2004). Risk Management generates successful outcomes by controlling key risk variables, which if poorly managed could have adverse effects for the business (Oduoza, 2020), these effects could include 'a major product recall' and 'workplace accidents resulting in injuries' (Hubbard, 2020). It is paramount that, both businesses and individual employees throughout the manufacturing sector, are continually practising risk management, to ensure safety in the workplace, prevention and minimisation of losses and effective resolution strategies after an incident has occurred.

Legislation & Codes of Conduct

The Institution of Mechanical Engineers (IMechE) is a professional body, which has a set of by-laws and a code of conduct which members are expected to follow. The code of conduct has four principles (Institution of Mechanical Engineers, 2023). Risk management is an integral part of adhering to all four of these principles, as explained below;

Principle 1) Practise competently and maintain up-to-date knowledge and skills - this principle states that engineers should take the appropriate measures to assess, balance and limit risk in their work.

Principle 2) Act with integrity and respect for others - this principle states that engineers should identify and quantify any risks and hazards related to their work and manage them within the engineering and environmental guidelines, without compromising anyone's welfare or any health and safety criteria.

Principle 3) Promote sustainability - this principle states that it is unacceptable for engineers to minimise or justify any adverse effects and must never knowingly or deliberately cause damage to the environment.

Principle 4) Exercise engineering leadership - this principle states that whenever an engineer encounters and identifies an unmanaged risk they must take positive action.

(Institution of Mechanical Engineers, Revised, 2021)

All members of The Institution of Mechanical Engineers are obliged to follow these ethical standards, which promotes risk management. This is in order to prevent any harm to, and protect both IMechE members and members of the public, and also uphold reputations of the engineering profession and the professional institutions.

Failure Modes & Effects Analysis

One tool that can be used to assess risk and prevent any risk factors from reoccurring is a Failure Mode and Effects Analysis (FMEA), which was developed in the 1960s by the aerospace industry (Boweles & Peláez, 1995). The aim of an FMEA is 'is to identify potential failure modes, evaluate the causes and effects of different component failure modes and determine what could eliminate or reduce the chance of failure' (Liu et al., 2013). The prioritisation of corrective actions for the failure modes is determined by a risk priority number (RPN) which is obtained by multiplying the occurrence, severity and detection scores. A literature review by Liu et al., (2013) highlighted a number of shortcomings of the FMEA; difficulty precisely measuring the three risk factors, the relative importance between O, S & D being ignored and the RPN formula being questionable and debateable. Despite this, FMEAs are used in a wide range of industries including the manufacturing sector and can be a useful tool in identifying potential failures and prioritising corrective measures. The following section will discuss an FMEA carried out on teeming ladles at TATA Steel.

Results of Failure Mode and Effects Analysis

This Failure Mode and Effects Analysis (FMEA) (Item B & C in appendix) was carried out in TATA Steel, Port Talbot. It assessed the potential risk of numerous components of the Teeming Ladles that are used for carrying and transporting molten liquid steel around the BOS Plant. The FMEA produced a number of findings for each Potential Failure Mode (PFM) which will now be discussed.

Worn Down Refractories

This PFM had the highest amount of identified potential causes of failure. This was expected due to refractories being the largest component of the teeming ladles. It also produced the highest severity score; 10, as worn-down refractories can cause loss of containment of liquid steel. Resulting, in serious injuries, loss of production, and damage to the environment, the equipment and the plant infrastructure.

Additionally, it produced the highest risk priority number (RPN); 560, the potential cause of failure is due to the high corrosive grade of liquid steel, which can damage the refractories. An occurrence score of 7 was given due to the refractories regularly needing to be wrecked and rebuilt every 140 lives, on average every 2-3 weeks. The current control measure of this risk consistent inspections being carried out after 20 lives to ensure that the refractory lining is still suitable for production. Due to regular checks, the detection score was 8. The recommended action is to shotcrete and bag the refractory lining when it is worn down, in order to create a protective coating to the refractories. With this recommended action being taken, the RPN was reduced to 320 due to the occurrence score being 4, as this would increase lives and protect the refractory lining. Therefore, reduce the frequency the teeming ladle would need to go out of service, which reduces the overall risk. This would also improve production and be financially beneficial in the long term.

The other potential causes of failure had RPNs which ranged from 120-280. A number of recommended actions were suggested; improved ladle-management-system, brick-inspection following transportation and build observations. This reduced the RPNs to 70-160.

Faulty Gearbox

Loss of power to the ladle gate was identified as the potential effect of failure for this PFM, the severity of this was an 8, as if the gate cannot open then the molten steel inside, will harden. This will cause financial, production loss and have negative effects on the environment. Three potential causes were identified; the current control measures were deemed necessary for both leaking fluid and worn gears. Recommended actions were identified for overheating; to improve the thermal resistivity and heat dissipation of the gearbox protective case and improving the airflow. The RPN was reduced from 168 to 112 as the likelihood of occurrence decreases.

Faulty Motor

Similarly, to above, loss of power to the ladle gate was identified as the potential effect of failure for this PFM. The potential causes identified were electrical overload; the current controls of inspections, overheating and sensors were deemed satisfactory. This factor had the same recommended actions as above, which reduced the RPN from 160 to 112.

Ladle Gate Failure

The potential effects of failure of this PFM is possible loss of containment and the flow of liquid steel rate, the severity was rated a 8. This severity was rated lower than 'loss of containment' in the Worn-down Refractories PFM, due to the location. Ladle Gate Failures tend to occur in the casters where it would be more contained due to there being a ladle blank for this exact scenario. One potential cause is a worn A&B holes, the recommended actions was to change this process by going from; A,A,B,B to A,B,A,B, this is to reduce the time on each hole and improve the tapping flow. This reduced the RPN from 448, to 182 as the occurrence decreased from 7 to 3. Additionally, it was recommended that the ceratex seal should be stored in a cold environment, in order so it does not melt and de-shape, which reduced the RPN from 144 to 48, as the occurrence of failure decreased.

Tipping Gear Failure

The potential effect of this failure is the lifting chain becoming stretched and therefore not allowing the ladle to operate correctly. The potential causes of this are stretched, snapped and frayed cables. The RPNs were relatively low and ranged between 28-72. The current controls of regular inspections and replacements were deemed effective enough to manage this potential failure mode and therefore it was not deemed necessary to take any further action. The main risk of this failure, is a loss of production due to there being one less teeming ladle in service, which has a negative financial impact on the company.

Ladle Shell Failure

The ladle shells having a campaign life of 40+ years, was identified as a potential effect failure, this is due to the likelihood of them warping and cracking increasing after this time, overall the severity was rated a 9. The first potential cause of failure was identified was; temperatures of 300°C on the shell. If this happens it can cause a 'hotspot' whereby, the molten steel can break through the refractory lining; if it is worn down enough. This could result in injury, loss of production, and major financial loss. The current controls identified were; temperature reading being taken. However, this reading will not always capture an accurate reading due to it only recording that specific part of the

ladle shell. The action that was recommended was a thermal camera being mounted, in order to take compartmentalised temperature readings. When this action was taken the RPN was reduced from 252 to 81, as it would produce more accurate readings and identify when the shell is getting too hot. The other potential cause of failure was cracking to the shell, however the RPN was already low; 36, with the control measures; cameras and inspections, that it was decided no further preventative actions could be taken.

Conclusion

To conclude, Risk Management is an integral part of the manufacturing industry in order to mitigate negative impacts and harm to both the company and employees. Despite some criticism of FMEAs, it proved a usual tool in identifying failure modes and prioritising corrective measures. It served as a useful analysis as part of a wider risk-management plan that would need to be completed of the teeming ladles.

References

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Appendices

Item A. Personal Development Plan

Personal Development Plan

Name – Luke Read-Jenkins

Degree – Advanced Manufacturing Engineering

Previous Qualifications – Subsidiary Diploma In Mechanical and Manufacturing Engineering

Previous Experience – Worked as a Mechanical and Machine Maintenance Engineer

Goal	Objective	Resources Required	Measurement	Target Date
Complete my Personal Development Plan	To create a realistic plan to help me meet deadlines and organise work for this assignment	- PDP document - Calander	Complete PDP	25/01/2024
Background reading of an appropriate number of papers / books in order to complete literature review	To further my knowledge before completing assignment Gather papers and references for the literature review	- Google scholar - University library	Have a spreadsheet of different references I can use for my literature review	28/01/2024
Reading work records and speaking to my work mentors such as technical, RED Team Leaders and ladle men	To gain an understanding of the potential failure modes of the teeming ladles	- Work records - Dedicated time with colleagues	List of potential failures and corrective measures	31/01/2024
Produce my FMEA and RPNS	To find out what the most severe potential failures, the effects, current controls and recommendations	- FMEA document - Notes acquired - FMEA evaluation criteria	Progress on FMEA report	04/02/2024
Write my introduction and literature review	To complete these sections of my technical report	- Reference list	Completed sections of technical report	04/02/2024

Write FMEA section of my report	To analyse the finding from my FMEA and to justify my decisions	- Complete FMEA - Notes acquired - FMEA evaluation criteria	Completed sections on my technical report	07/02/2024
Create technical poster	To present the findings of my report and FMEA into a technical poster	-FMEA -Technical report -Poster template	Completed poster	09/02/2024
Check and compile work	Last read through to ensure I'm happy with the report and poster. To make sure its in the correct format	- FMEA - Technical report - Poster	Finalised version of my work	11/02/2024

Item B. Failure Mode and Effective Analysis Part 1

Item:

Teeming Ladles

Model:

Core Team:

Refractory Engineering Department

Responsibility:

Luke Read-Jenkins

Prepared by:

Luke Read-Jenkins

FMEA number:

1

Page :

1

FMEA Date (Orig):

01/02/2024

Rev:

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l a s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c	Current Controls	D e t	R P N	Recommended Action(s)	Responsibility and Target Completion Date	Action Results				
												Actions Taken	S e v	O c c	D e t	R P N
	Worn down Refractories	Loss of containment of molten liquid steel	10	A	Refractories installed incorrectly	3	RED Inspection and build report, scans and thermal scans	5	150	Team Leader to observe the build process for a longer time period or installation of camera	RED Team Leader / 12/01/2024	Actions Taken	10	1	7	70
					High corrosive grade steel that damages the refractories	7	Ladle men and RED Inspection after 20 amount of campaign lives	8	500	Shotcrete and bagging the refractory lining to provide a protective coating	Minteq 06/02/2024	Actions Taken	10	4	8	320
					Installed defected bricks	2	RED Inspection, Monolithic refractories inspecting bricks	6	120	A inspection of bricks after transport to RED	Monolithics to inspect refractories after transport to RED / 06/02/2024	Actions Taken	10	1	8	80
					Exceeding expected campaign life due to poor tracking	4	Ladle management system tracking campaigns	7	280	Get a more improved LMS that detects ladle campaign history	Ladle Technical / 01/05/2023	Actions Taken	10	2	8	160
	Faulty Gearbox	Loss of movement to ladle gate	8	B	Overheating	3	Sensors, Mechanical Inspection, Set campaign life for replacement	7	168	Improved thermal resistivity and heat dissipation to the gearbox's protective case. Increased air flow and sensors to flag up when reaching a high temperature	Mechanical / 05/09/2023	Actions Taken	8	2	7	112
					Leaking fluid	1	Mechanical Inspection, sensors	6	48	N/A						
					Gears grinding resulting in worn gears	2	Mechanical Inspection, sensors	5	80	N/A						

Item C. Failure Mode and Effective Analysis Part 2

Teeming Ladie / For transporting molten liquid steel	Faulty Motor	Loss of power to ladle gate	8	C	Electrical overload	2	Electrical Inspection, sensors	5	80	N/A						
					Overheating	4	Sensors, back up motor for quick turn around time, Mechanical Inspection	5	160	Improved thermal resistivity and heat dissipation to the motor's protective case. Increased air flow and sensors to flag up when reaching a high temperature	Mechanical / 15/09/2023	Actions Taken	8	2	7	112
	Ladle gate failure	Possible loss of containment and the flow of liquid steel rate	8	D	Thermal shock causing cracking	6	Replacement plates in stores, Lademen Inspection	2	96	N/A						
					Worn A hole and B hole	7	Replacement plates in stores, Lademen Inspection	8	448	Change the process of how they switch between the two pouring holes	Lademen 15/11/2023	Actions Taken	8	3	8	182
					Ceritex seal	3	Replacement seals in stores	6	144	The storage of the seal should be improved - Should be in a cold environment to achieve better results	Lademen 15/07/2023	Actions Taken	8	1	6	48
	Tipping gear failure	Lifting chains become stretched not allowing ladle to pour or be viewed in ladle pits	6	E	Stretched cables	2	Mechanical Inspection	6	28	N/A						
					Snapped cables	1	Cameras, Visual Inspection, Replacement set of cables in stores	8	48	N/A						
					Frayed cables	2	Replacement set of cables in stores, Mechanical Inspection	6	72	N/A						
	Ladle shell failure	Ladle shells have a campaign life of 40+ years causing warping and cracking	9	F	Temperatures of 300 degrees celcius on shell	4	Ladle man has to go out with a temperature reading gun and not getting an accurate full shell temp	7	252	Thermal mounted camera to get compartmented temperature readings	Ladle Technical /	Actions Taken	9	1	9	81
					Cracking to shell	1	Cameras, Mechanical Inspection	4	36	N/A						

Item D. Technical Poster of Risk Management & Failure Mode Effective Analysis on Teeming Ladles

Risk Management & Failure Mode Effective Analysis on Teeming Ladles.

Luke Read-Jenkins / 2318055

School of Engineering
Advanced Manufacturing Engineering

Introduction

The aim of this project was to explore the relevance of risk management in the manufacturing sector, alongside discussing the usefulness of Failure Mode and Effect Analysis (FMEA) as a tool to assess risk.

An FMEA conducted at TATA Steel, Port Talbot on the teeming ladles to explore different failure modes and examine which corrective measures should prioritized and could be put into place to reduce potential risk and failure.

Literature Review

Risk Management can be defined as 'the identification, analysis, and prioritisation of risks followed by coordinated and economical application of resources to reduce, monitor, and control the probability and/or impact of unfortunate events' (Hubbard, 2020).

Possible effects of poor Risk Management:

- Major product recall
- Workplace accidents
- Injuries
- Adverse Effects for the business (Hubbard, 2020; Oduoza, 2020)

Legislation & Codes of Conduct:

Risk Management is an integral part of the four IMechE Principles:

- 1) Practice Competently
- 2) Act with Integrity and Respect
- 3) Promote Sustainability
- 4) Exercise Engineering Leadership



Image 1. Teeming Ladle at TATA Steel, Port Talbot

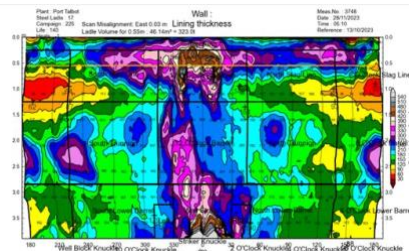


Image 2. Thermal Imaging Scan from Camera



Image 3. Bottom of Ladle / Tipping Gear

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Failure Modes and Effective Analysis: FMEAs

Aims

- Identify potential failure modes
- Evaluate the cause and effect of different components
- Determine what could reduce / eliminate the chance of failure

(Liu et al., 2013)

Advantages

- Can track product failure modes, effects and causes.
- Using severity, occurrence and detection gives you risk priority number which provides you with most crucial to non-crucial
- Failures can be eliminated or minimised

Disadvantages

- FMEA's can be time-consuming
- Can be inaccurate if some failure modes or effects are underestimated or overlooked
- Are not suitable for processes that have multiple failures

Results of Teeming Ladles FMEA

- Worn out Refractories had the most identified causes of failure and had the highest severity score.
- It also produced the highest risk priority number; 560 which was reduced to 320 after recommendation actions of creating a protective coating was considered
- Loss of power to ladle gate was an identified effect of failure for both a faulty gearbox and a faulty motor. Overheating was a cause of this so it was recommended that the airflow and thermal resistivity was improved
- Ladle shells can become too hot and may crack and warp, allowing steel to break through the lining. The recommended action for this a thermal camera (as shown in image 2) being mounted to take accurate temperature readings. This reduced the RPN from 252 to 81