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Risk Analysis of Potential Hazards by FMEA & Boston Rectangular Matrix in FF-Steel Mills

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***Abstract*—** Risks are any deviations of processes from their normal behavior that can cause economic, physical or emotional harm. Based on the nature of its job, the steel mills are the industries that are prone to a high number of risks. Also, the high number of applications of its product makes it a must to maintain a healthy working environment. However, it is quite difficult to neutralize those risks while keeping the cost constant. This research addresses those risks by applying scientific methods and providing a systematic way of prioritizing and analyzing the failure risks. It consists of two risk analysis methods. First is the Failure mode and effect analysis (FMEA). It helps identify the risks, shows the cause of each failure and shows the impact of each failure on the production system of the steel mill. The second method is the Boston Rectangular matrix, it helps prioritize the risks to be addressed. These are the most recommended methods to ensure a good production system. These methods use the statistics of Risk priority number (RPN) to prioritize the problems. They identify, evaluate, monitor and handle those risks in the best possible way. The data collected in this research is from the activities performed on the production side of a local Steel industry in Pakistan. This research shows the combined application of the FMEA and Boston matrix and proves that a high number of hazards can be identified and neutralized by properly implementing them more than any other method.

Keywords: FMEA, Boston Rectangular Matrix, Risk Priority Number.

I. Introduction (Backgroud)

The growing economic crisis and the competitive market environment give the ideal environment for innovation. Additional tariffs and rising prices of the products make the market less attractive day by day for the customers. Leading to discouraging the new as well as existing industrialist to abandon or shift their business in a direction where they are surer of the positive results. In such scenarios where the government is unable to add benefits for the markets, the only way to cope is to find and avoid failures that add up to the increasing cost of the product. For this purpose, a method of risk analysis, that is Failure Mode and Effect Analysis (FMEA) and Boston Matrix, was introduced which could analyze the drawbacks of the existing system and prioritize the issues that could be more fearsome. They highlight the issues for the industrialist to direct their resources in a direction where they can be more productive.

Some of the major contributors to the high cost of the products, other than the above mentioned, are the high maintenance costs, high labor costs for more hazardous jobs, and misuse or overuse of resources. FMEA and Boston Matrix use the Risk Priority Number (RPN) to give statistical value to the existing threats. RPN is the product of three factors in the FMEA i.e., severity (which shows the impact of the threat on the production), occurrence (shows the probability of the occurrence) and detection (whether the failure will be detected before happening). Whereas, in Boston Matrix RPN is the product of two factors, which are probability and impact. Once the threats are prioritized in terms of their seriousness, the available resources can be allotted to them most efficiently. Thus, keeping the cost of the product to the possible minimum.

II. Problem (Overview)

The industrial world revolves around profit. The cheaper the product, the more it will be market competitive and the more brand exposure can be observed in the market. This also leads to the addition of the customer's loyalty to the brand. The major contributors to the price of steel bars, other than the raw material and the labor, are the additional charges of unpredicted failures, faulty finished products, overuse of resources and the health hazards of the laborers.

III. Aim and Objectives

The aims and objectives of the research are mentioned below:

- It is to improve the cost efficiency of the existing steel mills, by pointing out the drawbacks of the traditional way of running the industry.
- Pointing out and prioritizing the risks that are of more serious concern to the production.
- It will also reduce the frequency of the failures.
- Provide prompts (standard/defined steps) for employees to follow when facing a potential failure mode.

- Reducing the lost time in production processes due to different failures.

IV. Literature Review

This section discusses the efforts made by many researchers to advance and apply FMEA and Boston Rectangular matrix in a variety of fields. Diverse techniques were put forth by researchers in the area of risk analysis of a production system. The following is a discussion of the outstanding studies carried out by various researchers on this topic.

Bouti and Kadi in 1994 implemented failure modes, and pointed out their causes and also their effects on a system service. They then appropriated a defined detection process and suggested correction measures. The researchers evaluated their work by further documenting the single failures of a system by FMEA. It was then referred to as Failure Mode Effects and Criticality Analysis (FMECA) when it was expanded by the Criticality Analysis Process (CA) for the classification of failure modes.

Another method for decision-making method of failure mode, effects, and criticality analysis (FMECA) failure prioritization was given by Braglia et al. (2003). The method is founded on a fuzzier version of the TOPSIS-recommended technique for order. By sidestepping the inherent difficulties in determining "crisp" values for the three FMECA factors, namely the occurrence of failures, chances of detection, and severity of different failures. A special strategy for classification is offered to address the fundamental ranking issue of the final fuzzy criticality value, allowing for quick and efficient conclusion sorting. The characteristics are illustrated through an application to a significant Italian household appliance company and a comparison with traditional FMECA.

Another research of FMEA technique monitoring of production processing in a metalworking company is by M. DUDEK-BURLIKOWSKA. It accomplishes the following goals: determining how errors affect the product and risk reduction strategies; verifying or finishing the process's requirement specification; and saving time and money by using the FMEA method to identify possible hazards in a metallurgical industry.

The Yazd Steel Complex research on Failure Mode and Effect Analysis (FMEA) Method Assessment and Risk Management of Potential Hazards, whereby the use of FMEA a large number of hazards were identified. The before and after of the implication shows that a crucial tool for locating hazards is the FMEA.

FMEA is implemented on blast furnaces by R. Suresh, M. Sathyanathan, K. Visagavel AND M. Rajesh Kumar in Risk Assessment for Blast Furnace using FMEA to reduce potential hazards. Examples include fire and explosion, co-poisoning, hot metal sparks, heat exhaustion, and the release of air pollutants such as particulate matter, sulfur dioxide, and nitrogen oxides.

The research of Improving Decision-Making Grid based on interdependence among failures by Shahin, A., Labib, Emami, and Karbasian with a case implements FMEA in a steel industry and keeps their focus more on customer requisites. Thus, it as "House of Reliability", which enhances standard analysis and introduces the most significant relations between failure modes.

The research of Risk project management analysis by U D Widianti, T Harihayati and Sufaatin uses the probability impact matrix to find out the unidentified risks in a local industry. The impacts associated with the risks show serious concerns about the cost and time of the project. It has played a vital role in overcoming those risks by going through some case studies and implementing the Boston matrix.

The application of the predictive impact matrix in the construction sector is described in the study Project Risk Management Issues in the Nigerian Construction Sector by Ubani, Emmanuel Chinenye, Amade, Benedict, Okorocha, Kevin Aku, and Agwu, Franklin Okogbuo. The research's conclusions showed that the construction industry has a low degree of awareness and use of risk management procedures. The achievement of project schedule, cost, quality, and scope objectives would not be possible if difficulties with risk management were not managed.

Arvanitoyannis and Varzakas (2007) used the FMEA methodology to evaluate manufacturing risk. FMEA in Manufacturing and Assembly Processes (PFMEA) is a vital preventative strategy for quality control and every likely manufacturing process failure mode that Mikosa and Ferreira (2007) presented. Based on the impact levels, as well as the likelihood of occurrence and detection of the failure kinds, they reached their decision. They talked about developing and utilizing a formal ontology for knowledge representation in the field of PFMEA based on description logic (DL). This was done largely to help organizational knowledge operations in manufacturing environments with scattered resources by enabling computational inference and ontology-based information retrieval

V. Methodology

The research data collection is majorly based on the observations made and interviews conducted in the steel industry. In this research, different risks were evaluated in the industry using FMEA and Boston matrix methods. To give a proper analysis of the research due consideration was given to the maintenance procedures, labor health and safety, production processes and general procedures. The following step-wise procedure will be followed to achieve the objective of the research.

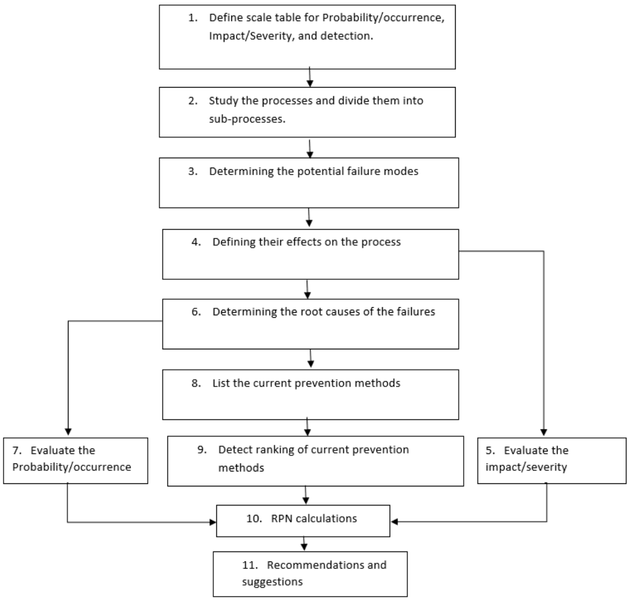

Figure 1. Methodology

A. *RPN methodology*

RPN stands for "Risk Priority Number". Decisions in this study will be made by the RPN scoring and crisis level. RPN is a mathematical model that is obtained by the product of detection, severity and occurrence. These numbers are used to identify the most severe, intermediate and low-risk failure modes. Risk criteria are set up for separate rankings. Failures with high RPN ratings are considered unacceptable risks and failures with low RPN ratings are considered acceptable risks. These failures are dealt with through different strategies accordingly such as allocation of resources aimed at improvement, more focus of maintenance teams towards areas of high RPN and so on.

$$RPN = Severity * Occurrence * Detection$$

$$RPN = S*O*D$$

1) *Severity/impact*

Severity suggests the seriousness of the impact of a hazardous situation. By seriousness, it suggests the quantity of damage it may cause, whether it is recoverable damage or not. Can it be covered instantaneously by doing some minor maintenance work or does it require shutting down the production process? The following table suggests the ranking of severity for the RPN calculations.

TABLE I. EFFECTS GUIDELINES

Effect	Rank	Criteria (production based)
No	1	No effect
Very slight	2	Can be covered in maintenance
Slight	3	Requires maintenance
Minor	4	Available alternate route as option
Moderate	5	Requires alternate path activation
Significant	6	Leads to machine failure
Major	7	Instant machine failure
Extreme	8	Quickly replaceable
Serious	9	Time consuming & costly procedure
Hazardous	10	Production failure/hazardous effect

2) *Occurrence/frequency*

Occurrence shows the frequency of the failures that can happen in the design life of an equipment or a part. It is the percentage of how often a failure might happen. The greater the occurrence rate, the greater the risk of stopping the production process of the industry. The under-mentioned table suggests occurrence rate criteria

TABLE II. OCCURRENCE GUIDELINES

Occurrence	Rank	Criteria
Almost never	1	Failure unlikely, history shows no failure
Remote	2	Rare number of failures likely
Very slight	3	Very few failures likely
Slight	4	Few failures likely
Low	5	Occasional number of failures likely
Medium	6	Medium number of failures likely
Moderately high	7	Moderately high number of failures likely
High	8	High number of failures likely
Very high	9	Very high number of failures likely
Almost certain	10	Failure almost certain

3) *Detection possibility*

Detection is the assessment of the possibility of detecting the cause of failure before it has occurred. The detection possibility is rating to find the efficiency of the current control measures used to cope with the failure modes before the product is released. The under showed table shows the detection possibility rating criteria

TABLE III. DETECTION GUIDELINES

Detection	Rank	Criteria
Almost certain	1	Proven detection methods available in concept stage
Very high	2	Proven computer analysis available in early design stage
High	3	Simulation and/or modeling in early stage
Moderately high	4	Tests on early prototype system elements

Medium	5	Test on preproduction system components
low	6	Tests on similar system components
Slight	7	Tests on product with prototypes and system components installed
Very slight	8	Proving durability tests on products with system components installed
Remote	9	Only unproven or unreliable techniques available
Almost impossible	10	No known techniques available

B. *FMEA analysis*

Prioritizing a risk depends upon the risk priority number. The higher the RPN, the higher the risk and thus greater efforts are to be inclined. There is quite a possibility that RPN for a failure is low but in one of its factors, it has a high value. Therefore, both risks associated with high RPN and low RPN were considered in this investigation. For this, a crisis level was used to define a criterion. Normal, semi-critical, and critical levels make up crisis levels. They are mentioned under;

- **Level 1 (Normal level)**

Level 1 is the normal level of risks where the risk value of all three factors (that is severity, occurrence and detection) individually is below 5. According to the concerned engineers these risks do not require as such immediate actions or maintenance. However, due consideration can be given to the failures with RPN greater than 70.

RPN<70 (normal level)

- **Level 2 (Semi critical)**

Level 2 of the FMEA analysis shows the risks of semi-critical level. In this level, at least one factor of the three (especially severity and occurrence) will have a risk value greater than 5. However, their relative value is low in terms of RPN. In such scenarios, preventive or corrective actions are required to prevent a major loss in the future. Typically, RPN values greater than 70 and smaller than 140 falls within this criterion.

70<RPN>140 (semi-critical level)

- **Level 3 (Critical level)**

The level 3 is the critical level of the FMEA analysis. At this level, at least two factors will have higher risk values individually and their combined RPN ranges from 140 to above. Since these RPN numbers are considered for most immediate maintenance and preventive actions and they are prioritized above all other risks.

RPN>140 (critical level)

VI. INTRODUCTION TO INDUSTRIAL PROCESS

A common type of steel industry process consists of four steps, these are;

A. Scrap collection
B. Melting process
C. Milling process
D. Cooling process

A. *Scrap collection*

Scrap collection is one of the vital and key steps towards an efficient production system. The location where the raw material for the furnaces is placed is known as a scrap yard. Where overhead cranes are used to shift the scrap to the furnace. Here four types of scraps are used

1) *Shredded scrap:*

They include the uniform, magnetically separated iron and steel scrap that comes from automobiles. They are used in the first and last heat of the lining, as they cause less damage compared to others. One of the other purposes of its use is to lower the carbon content in the furnace.

Figure 2. Shredded scrap

2) *Bundles scrap:*

Old black, hydraulically compressed to box size, and weighing no less than 75 pounds per cubic foot, bundles are a high quality of scrap. Tin or lead-coated material may not be present in this grade of scrap.

Figure 3. Bundles scrap

3) HMS (Heavy Melting Scrap):

Steel and wrought iron scrap that has undergone heavy melting is referred to as this. It is divided into HMS 1 and HMS 2, with HMS 2 containing galvanized and blackened steel whereas HMS 1 does not.

4) Head and tails:

Head and tails are the scrap pieces from the CCS where irregular heads and tails are trimmed from the product so that the products do not damage the property of the industry ahead. These scraps are reused in the furnaces.

Figure 4. Head and tail scrap

B. Melting process

Following are different stages of melting process

1) Scrap Vibro-Feeder

A vibratory feeder is a device used to "feed" material into the furnace. Gravity and vibration are both used by vibratory feeders to move material. Vibration is then employed to move the material after gravity determines the direction—either down or down and to the side

2) Induction Furnace

Induction furnaces are one of the well-controllable melting processes in which heat can be adjusted according to the requirement. They stop the loss of numerous priceless alloying components. By electromagnetic induction, the magnetic field causes circular electric currents called eddy currents inside the metal. In actuality the eddy current increases the molecular kinetic energy of the metal which is converted into heat energy, thus causing melting.

3) Ladle

The ladle is a vessel used to transfer molten metal from one location to another.. Ladle is placed at the top of CCM for the flow of molten metal through gravitational flow into the tundish.

Figure 5. Ladle

C. Continuous casting machine

A continuous casting machine is a platform where a ladle is placed above the tundish, which provides continuous feed and the desired shape is formed at a constant rate towards the end of the machine. CCM has the under-mentioned parts;

1) Tundish

An open, big container with two holes in the bottom is called a tundish. To prevent splashing and provide a smoother flow, it is used to feed molten metal into an ingot mold. There is a separate lining for tundish. Below tundish oscillators are placed which continuously give to and fro motion to the mold bodies so that the molten metal flows continuously through mold bodies.

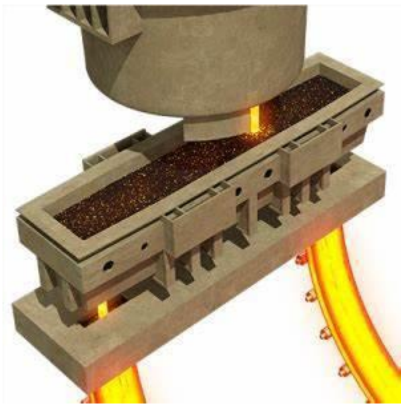

Figure 6. Tundish

2) Mold bodies

Mold bodies are square shaped structures, which is the first step in shaping the steel bar. The casing for the molten metal is made of copper. Whereas the mold body also has a water jacket installed in it for the continuous cooling of molten lava. Water flows through it with the pressure of 6 bars and the water which flows through is distilled water.

3) Rollers and shears

In the middle of the path of flow, we have multiple idle rollers, whose only purpose is to guide the billet in a proper direction. And onwards we have withdrawal and straightener motors to make the billet a straight product. For have a standard size of a billet dividing shear is installed which is operated hydraulically. It continuously cuts the billet at a constant rate and constant distances.

D. Milling process

The Mill shop is the region where the billet is passed through several processes to achieve a 60-grade iron bar. By following the under-mentioned sequence, we can understand the mill shop in a better way.

1) OHCT (overhead cross transfer)

OHCT is used to transfer billets to the turntable. They have three teeth which are moveable towards one side and fixed towards the other side.. To limit their movement limit switches are attached on each end, when the frame of teeth hits the limit switch the motor starts rotation in the opposite direction. The limit switch is attached at the start and end to keep the frame at the required root.

2) Roughing Mill (RM)

Roughing mill reduces the size of the billet and increases their lengths after passing them again and again through the rollers. RM has three rollers placed one over another. So that the size of the steel bar decreases. The areas of billet after respective passes are given and the length after each pass is calculated through the continuity equation;

$$A1L1 = A2L2$$

3) Main line

In main line after the CCS we have the following machines;

a) Pinch roller

It is the cantilever structure that is horizontal. To manage the roll up and down synchronous clamp, it has a double roll device and one air cylinder. The drive speed is increased by a two-stage cylindrical gear using a pinch roll DC motor. Up and down rolls are fitted at two swing arms, respectively. They are simply used for pushing the material forward with the desired linear velocity.

Figure 7. Pinch roller

b) Snap shear

These have cylinders and solenoid valves and are used to cut the material while it is being transferred to another roll or rolled over in an intermediate mill. Whenever the industry comes up with some issue in the line snap shears will turn the long iron rods into small pieces continuously of the same lengths. They are installed one on the main line and one on the alternate line.

Figure 8. Snap shear

E. Walking beam cooling bed

To safely move and cool the hot steel following the rolling process, cooling beds are essential to the production of steel. Any mechanical issues or failures with the cooling bed will have severe repercussions for the mill because it is an essential component of the manufacturing process in a steel mill. Therefore, before installation, the cooling bed and its components must be made using the best materials and undergo extensive testing. Following are the parts of the cooling bed;

1) Twin channel

After being sheared by the Flying Shear into two strands, the TMT bars exit the Quenching boxes and are collected by the twin channel. The C-type channel is operated through a cam and follower mechanism which is powered by a hydraulic power pack system..

2) CI-Grid

CI-Grid is a cast iron grid that provides a bed for the falling of the bars.

3) Walking beam cooling bed

Long bars and other structural steel parts are transported across the bed by two sets of rakes, one moving and the other immovable.

4) Chain transfer mechanism

They are simply several chains operated by a single motor connected to a central shaft. The chains are connected through 4 spur gears each. From layer transfer the steel bars are handled by the layer transfer mechanism.

5) Layer transfer

They have a mechanism for transferring the product to the run-out conveyor. Vertical plates move in between the gaps of run out conveyor.

6) Run out conveyor

Run-out conveyors are used for feeding the product to the cold shear. There are several run-out conveyor tables. Rollers are interconnected by the v-belts. Pulleys are four-groove pulleys.

VII. FMEA AND BOSTON MATRIX IMPLEMENTATION

The ultimate goal of a risk analysis tool is a reliable production system. An effective risk management system ensures such production. As per the methodology, after the analysis of the industrial processes and dividing them into sub-processes, the next step is to find the failures, their causes and the current remedial measures towards the risks. The tables below summarize the process.

A. FMEA Worksheet at Melt Shop

TABLE IV. FMEA WORKSHEET FOR MELT SHOP

FAILURE MODE AND EFFECT ANALYSIS WORKSHEET ITEM: Melt Shop							
Process function	**Potential Failure Mode**	**Potential effects of failure**	**S**	**O**	**D**	**RPN**	**Recommended actions**
OHC (Over Head Cross Transfer)	Jamming of jaws due to scrap	Inability to provide feed to vibro-feeder	3	4	6	72	Apply covering shield over the jaws
	Failure of hydraulic pumps	Unavailability of scrap to furnace	3	3	10	90	Avoid excessive loading
	Interrupted power supply to magnet	Wastage of shredded scrap	4	2	5	40	Installation of heavy generators
	Failure of motors	No movement of OHC	5	3	7	105	Insuring proper maintenance to moving parts
Vibro-feeder	Damaged motor shaft	Damaging the vibro-feeder	5	6	4	120	Proper lubrication, avoid overloading
	Not suitable for small feed	Burning of labor	9	7	9	567	Use of conveyors for small feed
Crucible	Damaged lining	Damaging furnace	5	6	5	150	Maintenance of lining after each heat
	Closed container shaped scrap	Blasts in furnace	7	5	2	70	Insuring proper scrutiny
Induction furnace	Disrupted power supply	Surplus cost addition	5	2	5	50	Installation of heavy generators
	Improper lining	Blasts in furnace	6	4	5	120	Maintenance of lining after each heat
	Damaged coils	Blasts in furnace	6	3	6	108	Insuring proper lining
Hydraulic power pack	Excessive loading	Damaged hydraulic system	8	2	3	48	Inspection by engineer before using HPP
	Damage from scrap	Cracks in hydraulic cylinders	4	4	7	112	Do not use vibro-feeder and HPP simultaneously
	Ill experienced operator	Leads to scraping of complete production	5	3	4	60	Proper training sessions for new employees
Ladle	Improper lining	Damaging of ladle	3	3	5	45	Training for operators and inspection by engineers
	Damaged slide gates	Death/waste of molten metal	10	6	3	180	Avoid overuse of slide gates

B. FMEA Worksheet at CCM

TABLE V. FMEA WORKSHEET FOR CONTINUOUS CASTING MACHINE

FAILURE MODE AND EFFECT ANALYSIS WORKSHEET ITEM: CCM (Continuous Casting Machine)							
Process function	**Potential Failure Mode**	**Potential effects of failure**	**S**	**O**	**D**	**RPN**	**Recommended actions**
Tundish	Improper lining	Damaged tundish	4	3	5	60	Proper training to workers
	Over loading	Damaged CCM	9	3	3	81	Inspection by engineers
Mold body	Vague shape/ structure	Compromised quality	2	7	3	42	Avoid overuse of a single mold body
Oscillator	Damaged motors	Waste of production	5	6	4	120	Proper maintenance, installation of heat insulators
Cooling Chamber	Disrupted distilled water supply	Compromised quality	3	5	4	60	Vigilant operator to check the gauges
	Leakage in closed loop supply	Physical damage to labor	2	7	6	84	Insuring proper maintenance of tubes

Dummy bars	Cracked bars	Stucked ballets	4	3	7	84	Avoid over-heating
	Excessive heating	Deformed shape	5	4	3	60	Training of workers
Dividing shear	Improper hydraulic system	Improper edges of ballet	7	5	9	315	Proper maintenance
	Damaged cutting tools	Improper edges	5	6	8	240	Changing of tools after a prescribed limit
	Non-stable base	Compromised quality	6	4	7	168	Proper installation

The same method is applied for the mill shop, mainline and walking beam cooling bed. Based on the data above, it can be observed that the sources of high risks are majorly from the worker's negligence and wrong drawing specifications. Sources of moderate risks vary from ill skill sets, unrealistic time schedules and inappropriate materials. A total of 63 readings were recorded; out of which **31 normal risks, 20 semi-critical risks and 12 critical risks** were detected.

C. Prioritizing risks based on Boston Matrix

Boston Rectangular matrix is used to prioritize these risks. By observing the numbers and plotting them against the risk mapping table, risks can be prioritized. The failures that fall within the region of red colored are to be addressed before any other risks. The red region shows the critical risk level and thus has the potential to stop or cause hindrance in the production system. Similarly, the risks in the yellow region are to be placed following them. The yellow indicates the semi-critical level risks. Followed by the risks in the green region. They indicate the risks of the normal level. They are not considered an immediate serious threat to the production system but constant delay in maintenance might lead these risks to a critical level. So, they are placed at the bottom of the priority of maintenance list. Given figures below indicate Boston matrix plots for probability and impact, and probability and detectability.

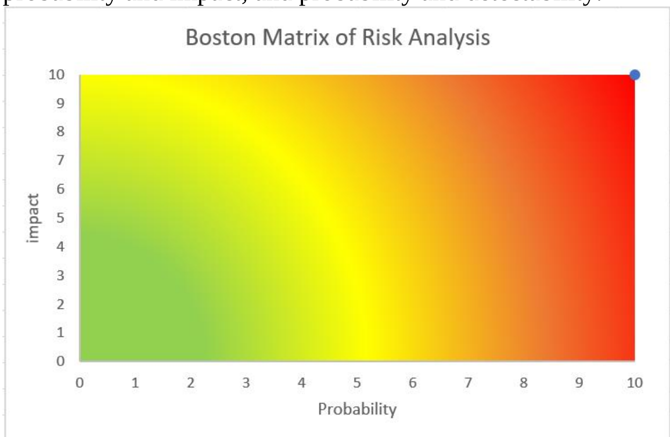

Figure 9. Risk Mapping of steel industry (probability vs impact)

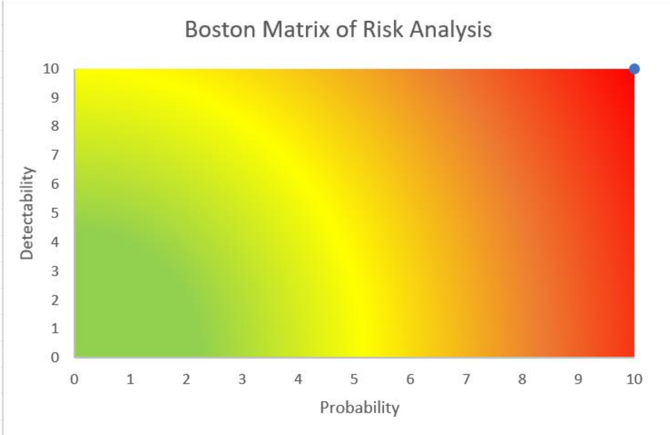

Figure 10. Risk Mapping of steel industry (probability vs detectability)

1) Risk mapping Worksheet at Melt Shop

TABLE VI. RISK MAPPING FOR MELT SHOP USING BOSTON MATRIX

RISK MAPPING OF STEEL INDUSTRY WORKSHEET ITEM: MELT SHOP						
Process function	**Potential Failure Mode**	**S**	**O**	**D**	**RPN**	**Risk status**
OHC (Over Head Cross Transfer)	Jamming of jaws due to scrap	3	4	6	72	Moderate
	Failure of hydraulic pumps	3	3	10	90	Moderate
	Interrupted power supply to magnet	4	2	5	40	low
	Failure of motors	5	3	7	105	Moderate
Vibro-feeder	Damaged motor shaft	5	6	4	120	Moderate
	Not suitable for small feed	9	7	9	567	High
Crucible	Damaged lining	5	6	5	150	Moderate
	Closed container shaped scrap	7	5	2	70	Moderate
Induction furnace	Disrupted power supply	5	2	5	50	Low
	Improper lining	6	4	5	120	Moderate
	Damaged coils	6	3	6	108	Moderate
Hydraulic power pack	Excessive loading	8	2	3	48	Low
	Damage from scrap	4	4	7	112	Moderate
	Ill experienced operator	5	3	4	60	Low

Ladle	Improper lining	3	3	5	45	Low
	Damaged slide gates	10	6	3	180	High

2) *Risk mapping Worksheet at Mill Shop*

TABLE VII. RISK MAPPING FOR MILL SHOP USING BOSTON MATRIX

RISK MAPPING OF STEEL INDUSTRY WORKSHEET ITEM: MILL SHOP						
Process function	**Potential Failure Mode**	**S**	**O**	**D**	**RPN**	**Risk status**
Turntable	Jamming of billets	5	4	7	140	Moderate
	Damaged motors of conveyors	4	5	3	60	Low
	Overheated stopper sensors	4	4	4	64	Low
RM	Irregular grooves	5	3	2	30	Low
	Positioning of grooves	6	2	3	36	Low
Autopass	Stucked ballets	3	9	7	189	High
	Varying feed rate from RM	5	3	4	60	Low
	Non-synchronized speed of motors on autopass	5	4	4	80	Moderate
Motor (for RM)	Miss alignment with the pinion	5	5	2	50	Low
	Irregular power supply	5	7	5	175	Moderate
	Non-Firm base	6	5	7	210	High
Speeder	Damaged blades	5	3	4	60	Low
	Improper ionization of water	3	6	4	72	Moderate
Lube cell	Damaged motors and pumps	3	7	3	63	Low

Similarly, it is implemented for main line and cooling bed in the industry.

VIII. RESULT AND DISCUSSIONS

1) *RESULT AND DISCUSSIONS*

The efficiency of any risk analysis method depends upon the participation of the organizational workforce in it. The greater their input, the more astonishing will be the outcomes. Though for better results long and consistent efforts are required to be implemented. Failure Mode and Effect Analysis gives an overall thorough perspective of looking at irregularities and ambiguities. It gives an ideal way of comparing and identifying techniques for hazard management. In this research around 12 critical risks and 20 semi-critical risks were identified, along with their consequences, severity and frequency estimation. A greater achievement of the research is that it gives a hybrid approach to risk management which combines the strengths of FMEA and Boston rectangular matrix. During the study following main causes of failure risks were observed:

a) Human Error

Human error refers to an error that is caused by an operator, worker, designer or engineer which may result in an accident. It can be initiated by miss communication between operators, or their negligence in their works.

b) Machine or Component failure

Another reason for failures in the steel industry is the unwanted incidents of failures in mechanical, structural or electrical performances. These failures are mainly due to the negligence of the operators, as they overdo a component or machine and leads them to their limits.

c) Installation errors

These errors are due to a slight or complete installation fault. That over time leads to a big disaster. For instance, the vibration of the motor base on the RM can lead to the loss of multiple lives.

d) ill maintenance

The error arises again from the negligence of the operator who does not keep a vigilant eye on the operating machine. Failures were observed because of ill lubrication, jamming of scraps and over usage.

e) External events

These errors consist of things that are outside human capabilities. Such as the aging process of machines or natural disasters

CONCLUSION

This research concludes that to prevent potential risks and failure processes, a systematic management system is essential. It avoids unwanted deviations and recommends actions that are most suitable to them. The most vital step in the management system is the implementation of a documentation system of data collection of different deficiencies and subsequent events that lead to a disaster. Also performing preventive actions reduces the possibility of a failure of the production. The findings also indicate that selecting a suitable method is essential for determining the risks.

The research has pointed to a more sensible way of prioritizing the risks for maintenance activities and also helped in the reduction of the frequency of failures. This research is useful for comparing and contrasting the proposed risk management strategies with the present risk management techniques. To increase productivity, it is necessary to reduce various manageable hazards to increase production.

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