RISK ASSESSMENT FOR BLAST FURNACE USING FMEA

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Abstract

Blast furnace is a tall reactor to process iron ore into pig iron, modern day blast furnace size range varies from 70 to 120 feet. Blast furnace iron making process is a complex task it has potential hazards like fire and explosion, co poisoning, hot metal sparks, heat stress, emission of air contaminants like particulate matter, sulphur dioxide and nitrogen oxides etc. Organization need to take necessary steps to manage the hazards and its consequences to perform work safely. Various reliability engineering and risk assessment techniques are applied to improve the blast furnace safety to prevent the blast furnace workers from accidents. This paper aims to provide the necessity of risk assessment techniques for implementing safety in an integrated steel plant. Risk assessment using failure mode effect analysis was carried in an existing steel plant blast furnace capacity of 0.6MTPA(Metric Ton Per Annum) which produce around 1000 ton of hot metal called pig iron daily. Failure mode effect analysis one of the systematic risk assessment technique is applied to the each activity of the blast furnace operation to find out the potential failure modes and its effects with detection. Risk priority number, severity, detection, occurrence are the factors determined in this work are used to suggest the safety precautions. Risk priority number helps to find out the highest hazardous activities which need more attention than the other activities. Safety precautions suggested in this paper can prevent the occurrence of failures and protect the blast furnace workers from fatal accidents and injuries.

Keywords: *Blast furnace, Failure mode effect analysis, Risk priority number, and Safety.*

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1. INTRODUCTION

Blast furnace plays a vital role in an integrated steel plant for producing pig iron which is then converted into various grades of steel in an electric arc furnace. Raw materials like iron ore, coke, limestone are charged at the top of the blast furnace through skip car system. Coke is almost pure carbon act as a fuel as well as reduces the iron ore into pig iron. Hot air from stove is blasted in to the furnace making the coke burn much faster than the normal and temperature rises to 1200 degree Celsius. Pulverized coal is injected through tuyeres at the velocity of 160 to 240 m/s to furnace to reduce the fuel consumption. Due to temperature rise various chemical reactions take place inside the blast furnace carbon monoxide reacts with unburned coke to form carbon dioxide that reduces the iron oxides in ore. The molten iron is very dense so its runs to the bottom of the furnace. Impurities are removed by the lime stone used as the one of the raw material .slag is an impurity which is lighter stays above the molten metal used for various purposes outside the plant. Blast furnace gas produced from the process is cleaned in gas cleaning plant and used as a fuel in captive power plants, Vacuum decomposing boiler. Excess blast furnace gas is burn using flaring system. Molten iron and slag is removed from different tap holes at regular intervals. Operation in blast furnace exposes workers to wide range of hazards that would cause fatal accidents. In past blast furnace explosion has shown many tragic and fatal accidents, so controlling the blast furnace operation is a complex task for the blast furnace workers and safety professionals. To prevent the accidents and unnecessary failures an effective risk assessment is important.

2. LITERATURE REVIEW

From the literature survey it is clear that some researches on FMEA have been carried out by previous researchers on the other hand still a lot of applied research in the above field is required as to explore the fruitful application of the FMEA technique in the area of blast furnace process. Some of the past research work are discussed as under. Arun chauan et al. (2011) conduct a case study and implement failure mode effect analysis in a casting industry to identify the potential failure modes and its effects along with the prevention measures. Prevention suggested in this paper decrease the loss of cost and time. Hoseynabodi et al. (2010) applies failure mode effect analysis method to wind turbine systems with aid of reliability analysis tool software and compare the result between FMEA and reliability field data. These results are useful for future wind turbine systems design to prevent failures at the design stage. Narayanagounder et al. (2009) addressed the limitation in traditional FMEA and proposed a new approach to overcome these limitations. The risk priority code was used to rank failure modes, when two or more failure modes have the same RPN. They proposed a new method to rank failure modes. An analysis of variance was used to compare the means of two risks priority number values when there is a disagreement in ranking scale of severity, occurrence and detection. H.shiroyehzad et al. (2010) applied FUZZY-FMEA preventive technique to decrease the failure rate in ERP implementation with the failure cause and effect by implementing fuzzy number. Burlikowskwa et al. (2011) describes about a new approach about production development and cost reduction using failure mode effect analysis. Popovic et al. (2010) describes about the implementation of risk analysis parameter into the FMEA method and inconsistencies of the traditional method. Huges et al. (1999) stated that the traditional qualitative methods for modeling mechanical system are in appropriate for automated mechanical production.

3. FAILURE MODE EFFECT ANALYSIS

Failure mode effect analysis was originally developed by NASA to improve and verify the reliability of space program hardware. FMEA is one of the most important and widely used tools for reliability analysis. It is intentional to be a proactive action process carried out in advance implementing new or changes in products or process ideally FMEA are conducted in the design or process development stages, although conducting it an existing products and processes may possibly have benefits in effective FMEA identifies corrective actions required to reduce failures to assure the highest possible yield safety and reliability. Failure mode effect analysis is four types system, design, process, service. System FMEA focus on systems and sub systems in early concept stage to demonstrate balancing among the operational components. Design FMEA minimizes the effect of failures in sub and main assemblies it maximizes the design quality and reduces cost. Process FMEA identifies the deviation in the process flow, materials, methods, people and environment. Service FMEA maximizes customer satisfaction through quality and reliability. Even though it is widely used reliability technique it has some limitation in prioritizing the failure modes and output may be large for even simple systems, may not easily deal with time sequence, environmental and maintenance aspects.

3.1 Risk Priority Number

Risk priority number methodology is a technique for analysing the risk associated with potential failures during a FMEA analyses. To calculate risk priority number severity, occurrence, and detection are the three factors need to determine.

RPN= Severity× Occurrence× Detection

3.2 Severity (S)

Severity is the seriousness of the effect of potential failure modes. Severity rating with the higher number represents the higher seriousness or risk which could cause death. An example rating for severity is given in the table 1.

Table -1 Example table of Severity

Ranking	Effect	Severity effect
10	Hazardous without warning	Very high severity without warning
9	Hazardous with warning	Very high severity with warning
8	Very high	Destructive failure without safety
7	High	System inoperable Equipment damage
6	Moderate	System inoperable with Minor damage
5	low	System inoperable without damage
4	Very low	Degradation of performance
3	Minor	System operable with Some degradation in performance
2	Very minor	System operable with minimal interference
1	None	No effect

The severity rating given in illustration is the representation of operability of a machine.

3.3 Occurrence (O)

Occurrence ratings for FMEA are based upon the likelihood that a cause may occur based upon past failures and performance of similar system in similar activity. Occurrence values should have data to provide justification. An example rating for occurrence is given in the table 2.

Table- 2 Example table of Occurrence

Rating	Classification	Example
10 9	Very high	Inevitable failures
8 7	High	Repeated failures
6 5	Moderate	Occasional failures
4 3	Low remote	Few failures
2 1	Remote	Failures unlikely

3.4 Detection (D)

Detection is an assessment of the likelihood that the current controls will detect the cause of failure mode. An example for detection rating is as shown in the table 3.

Table- 3 Example table of Detection

Rating	Detection	Detection by design control
10	Absolute uncertainty	Design control cannot detect failure mode
9	Very remote	Very remote chance the design control detect failure mode
8	Remote	Remote chance the design control detect failure mode
7	Very low	Very low chance the design control detect failure mode
6	low	Low chance the design control detect failure mode
5	Moderate	Moderate chance the design control detect failure mode
4	Moderately high	Moderately high chance the design control detect failure mode
3	High	High chance the design control detect failure mode
2	Very high	Very high chance the design control detect failure mode
1	Almost certain	Design will control detect failure mode

3.5 Steps in FMEA

To conduct FMEA there are some necessary steps as to follow.

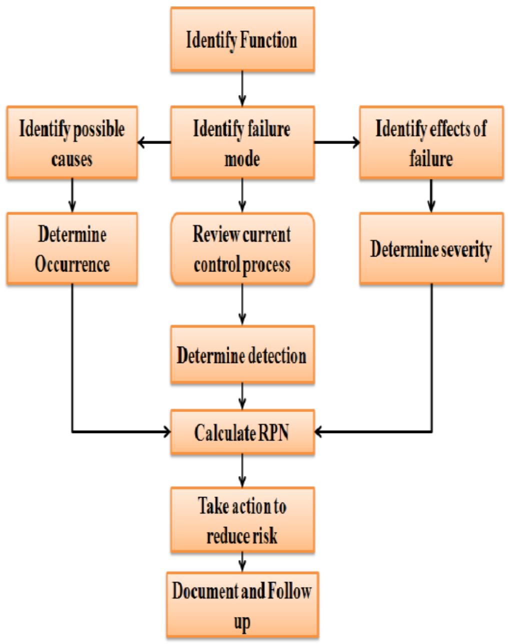

Fig 1 Step in FMEA

Figure 1 shows step by step process to conduct FMEA. Review team first collects all the component data with the help of process flow diagrams, P&ID. With that information review team finds the potential failure mode and its effects. Next step is to find the failure occurrence with its severity rating. List the current control methods to rate detection, with the help of severity, occurrence and detection rating calculate RPN. Give the control measures to prevent the occurrence of failure and finally document and follow up the FMEA report.

4. FMEA IMPLEMENTATION

Case study is conducted and FMEA technique is applied to the blast furnace in an integrated steel plant. Blast furnace is used for the production of pig iron for steel making in steel plant. Blast furnace is manufactured by CERIS technology china capacity of 0.6 MTPA. Failure mode effect analysis is executed by a multidisciplinary team of experts in blast furnace operation with the help of process flow chart the analysis team identifies the components in process. For the analysis break down details; accident reports for the past five years are taken. Criteria of ranking of severity, occurrence and detection are selected suitably by analyzing the past failure records of the furnace. Using values of severity, occurrence and detection number risk priority number is calculated.

4.1 Sample Calculation

Sample calculation for cold blast process in blast furnace is shown below. Cold blast in iron making refers to were the air from the environment is blown into the stoves for preheating at the pressure 100 to 280 kpa. In cold blast process the potential failure mode is increase or decrease in pressure if the pressure decrease it does not cause accident only effects the process but if the pressure increase the safe limit it leads to explosion in stove.

4.2 Steps to Calculate RPN

Step1. Potential failure mode of cold blast process found.
Step2. Potential effect of failure found with severity. Failure not only stops the process it also causes serious accident.
Step3. From the table values of severity, occurrence, detection values are calculated and tey were obtained as 4,1 and 8 respectively.
Step4. RPN value calculated as RPN = $S \times O \times D$
Considering S = 8, O= 1 and D= 2

$$RPN = 8 \times 1 \times 2 = 16$$

Table- 4 FMEA chart

Component/process	Failure mode	Failure effect	Failure cause	Existing control	S	O	D	RPN	Additional control
Bleeder valves	Failed to operate	Explosion	Corrosion	Reliable supplier	10	2	3	60	Periodic maintenance

Conveyor feed belt	Friction	Fire	Improper maintenance	Belt sway switch	8	2	2	32	Lubricate the rotating parts regularly
Skip car rope for charging	Rope breakage	injury	Overloading	Weighing	3	4	1	12	Calibrate load cells
Cold blast Blower	Flow pressure increase	Rupture in stove	Failure of valves	Flow meters	8	1	2	16	Interlock system
Hot blast blower	Stove shell crack	Fire & explosion	Excess temperature	Thermocouple	9	1	2	18	Periodic maintenance
Blast furnace gas injection	Pipeline rupture	Co Poisoning	Over pressure	Detectors	10	2	2	40	Provide detectors with alarm system
Oxygen injection	Pipeline rupture	Fire & explosion	Over pressure	Detectors	10	2	2	40	Provide detectors with alarm system
Cooling water supply pump	Pump failure	Explosion	No power supply	Redundant power supply	10	4	2	80	Check the fuel level of diesel generator
Tapping hose	Oxygen hose cut	Fire	Ageing	Reliable supplier	8	4	4	128	Change hose periodically
Hot metal lifting by crane	Rope breakage	Hot metal ladle falls down	Overloading	Safe working load are marked	9	3	2	54	Interlocks with alarm
Gas cleaning filter bags	Filter bags failure	Improper gas cleaning	Excess temperature	Monitoring system	4	3	3	36	Regular inspection
Lancing hose	Tuyere puncture	Burns	Ageing	Reliable supplier	5	4	4	80	Check defects before use
Water spraying Nozzle	Pin holes	Gas temperature increase	Spraying water excessively	Monitors	7	3	1	21	Check the water level for every 5 minutes
Butterfly valve to regulate flow	Valve partially closed	Co poisoning	Dust	Air line respirators	9	3	2	54	Periodic maintenance
Steam injection	Pipelines crack	Burns	Excess pressure	Line inspection	7	2	3	42	Display Cautionary notice

4.3 Risk Priority Graph

The following graph chart-1 shows the top five risk priority number values.

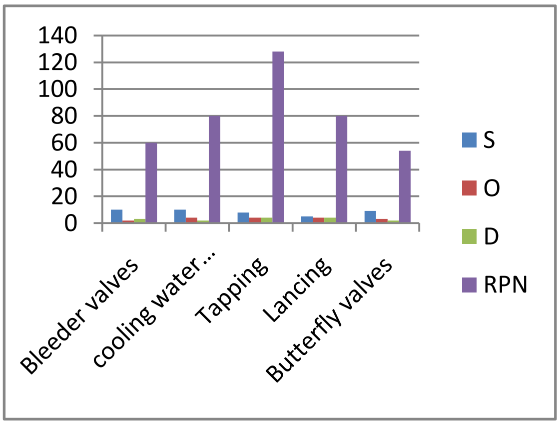

Chart-1.RPN graph

5. ANALYSIS OF THE RESULT

Higher value of risk priority number was obtained for tapping process. Detailed safety audit should be conducted on the cast house to reduce accident rates. Proper housekeeping, awareness should be given to the workers involving in cast house activities. Barriers, shields should be arranged to prevent cast house workers from molten metal sparks. Proper training should be given to all operators and workers; this will reduce risk priority number value.

6. CONCLUSIONS

The present work deals with the basic process of blast furnace. With the help of FMEA a risk assessment tool all possible failure modes are evaluated with their severity value and the causes are calculated with occurrence value. Finally, the RPN for each process was calculated and the preventive control measure were suggested for each and every process, the safety precaution suggested in this paper would help to reduce the down time failure and its effects.

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