Concept Development, Risk evaluation and Hazard Analysis of Process Safety Management (PSM) applied in Steel Plant

Ravindra[1] Nisha Kushwaha[2] Pravin Tathod[3]
PG Scholar[1] Department Head[2] Assistant Professor[3]
[1,2]Shiv Kumar Singh Institute of Technology and Science, Indore, India [3]IPS Academy, Indore

Abstract— For any industry to be successful it is to identify the Hazards to assess the associated risks and to bring the risks to tolerable level. Activities performed in plants because of the nature of operation, complexity of the systems, procedures and methods always involves some amount of hazards. Hazard analysis is carried for identification of undesirable events that can leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. It is widely accepted within industry in general that the various techniques of risk evaluation contribute greatly toward improvements in the safety of complex operations and equipment. Hazard analysis as in Process Safety Management (PSM) system involves identification of undesirable events that leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. The high risks activities will be marked in Red colour are un-acceptance and must be reduced. The risks which will be marked in yellow colour are tolerable but efforts must be made to reduce risk without expenditure that is grossly disproportionate to the benefit gained. The risks which will be marked in green have the risk level so low that it is not required for taking actions to reduce its magnitude any further. Later on the overall analysis will be verified and will be used for necessary modification.

Keywords: TATA-Steel Plant, Process Safety Management, Hazard Identification, Risk Assessment, Matrix Methodology

I. INTRODUCTION

Steel is a product of large and technologically complex industry having strong forward and backward linkages in terms of material flows and income generation. It is also one of the most important products of the modern world and of strategic importance to any industrial nation. From construction, industrial machinery to consumer products, steel finds its way into a wide variety of applications. It is also an industry with diverse technologies based on the nature and extent of raw materials used. In India, steel has an output multiplier effect of nearly 1.4X on GDP and employment multiplier factor of 6.8X [1].

The Indian steel industry has entered into a new development stage from 2007-08 [2], riding high on the increasing after a period of little activity, economy and rising demand for steel. The rapid rise in production has resulted in India becoming the 3rd largest producer of crude steel in 2015 and the country continues to be the largest producer of sponge iron in the world [3]. As per the report of the Working Group on Steel for the 12th Five Year Plan, there exist many factors which carry the potential of raising the per capita steel consumption in the country [4]. These include, an estimated infrastructure investment of nearly a trillion dollars, a projected growth of manufacturing from current 8% to 11-12%, increase in urban population to 600 million by 2030 from the current level of 400 million [5].

At the time of independence in 1947, India had only three steel plants – the Tata Iron & Steel Company, the Indian Iron and Steel Company and Visveswaraya Iron & Steel Ltd and a few electric arc furnace based plants. The period till 1947 thus witnessed a small but viable steel industry in the country, which operated with a capacity of about 1 million tonne and was completely in the private sector. From the fledgling one million tonne capacity status at the time of independence, India has now risen to be the 2nd largest crude steel producer in the world and the largest producer of sponge iron. As per official estimates [6], the Iron and Steel Industry contributes around 2 per cent of the Gross Domestic Product (GDP) and employs about 25 lakh people directly or indirectly [7]. From a negligible global presence, the Indian steel industry is now globally acknowledged for its product quality. As it traversed its long history since independence, the Indian steel industry has responded to the challenges of the highs and lows of business cycles [8].

A. Process Safety

"Process safety is a blend of Engineering (Design & Maintenance), operations and management skills focused on preventing catastrophic accidents, particularly structural collapse, explosions, fires and toxic releases associated with loss of containment of energy or dangerous substances such as toxic gases, molten metal, chemicals and petroleum products. Process Safety Incidents can [11]:

- Kill and injure many people
- Cause massive and long lasting pollution
- Cause major economic disruption
- Severely damage a company's reputation
- Cause companies to become "paralyzed" in the aftermath
- Lead to companies and individuals being prosecuted

Fig. 1: Process Disasters at Indian Steel Industry [12]

The most important 3 characteristics of safety management system are effort, time and money. In order to achieve a zero accident rate an organization needs to provide these 3 basics. The very next principle of the safety management system is the involvement and commitment towards the assigned work. Since without involvement a work cannot be completed and without commitment the goals and objectives set cannot sustain.

After this then comes the actual responsibility of the organization. It is because an organization needs to set goals, objectives and motivate employees to work for safety. For this management needs to appoint safety officers, provide trainings to the worker class people and try to change their mindset and made them work with all safety measures. Also communication is the most important aspect for safety management system. And for effective communication the employees at high position needs to interact with the worker class on a regular interval so that the worker class can put up their views for improving safety standards [16].

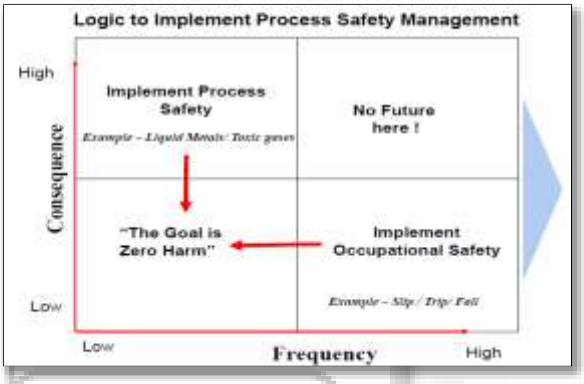

Fig. 2: How process safety is different from occupational safety [24]

II. LITERATURE REVIEW

D V R Seshadri et.al [28] the case on Tata Steel captures the success story of Tata Steel very effectively as to how a giant corporation, led by a world-class management team, reinvents itself and sets out on a growth path when faced with dramatic challenges from the environment. This analysis is aimed at summarizing some of the issues and the challenges Tata Steel is likely to face in the years ahead.

Firdos Ali et.al [29] Evolution of industries/companies started in the start of 19th century. Some small and major industries/company established in this century and these company/industries increases day by day throughout the world. Due to this evolution in industries small machinery is replaced with big or powerful machinery, power capacity also increases and system made more complex. Due to this or along with this risk and hazard also increases.

Somnath Kumar et.al [30] Steel manufacturing is an industry where safe working procedures are important, as workers face many risks due to the nature of the job. The work environment is often hot and noisy, and work tasks regularly heavy and demanding on the body, and there is an always present risk for crushing injuries and burns. Steel companies have significantly improved their safety performance over the last 10 years, but many have reached a plateau where further progress is more difficult to achieve.

Modi A et.al [31] Energy is needed in the wire rod plant processes for any value addition activity to develop the finished product. The increased energy costs and an uncertain steel markets have created the demand for a system in the steel plant, to utilizes the rolling process waste heat, or improve rolling process so that next further processing may be avoided for rolled product.. The process energy optimization is a tool to improve profitability, environment and productivity of an organization.

Devdatt P Purohit et.al [32] in industrial arena, if any industry to be successful, it has to be safe, reliable, and sustainable in its operations. The industry has to identify the hazards and assess the associated risks and to bring the risks to tolerable level. Hazard Identification and Risk Assessment (HIRA) is carried for identification of undesirable events that can lead to a hazard, the analysis of hazard of this undesirable event, that could occur and usually the estimation of its extent, magnitude and likelihood of harmful effects.

III. COMPANY DOMAIN

Tata Steel's management approach to sustainability is to integrate consideration of the 'triple bottom line' - economic, environmental and social performance - into Company thinking and business practice. At Tata Steel, the purpose of the organization is to go 'beyond business', to invest and develop for the benefit of society. This is achieved through the principles of Corporate Citizenship and Inclusive Growth. Acting with integrity and responsibility, and seeking to extend and share the benefits of its activities, has helped the Company to secure an excellent reputation and to enhance the trust of all stakeholders. This, in turn, has helped the business to flourish and grow. The creation of Tata Steel Group was an essential part of Tata Steel's growth and globalization strategy, and the Group has now developed a Vision and set of core goals.

This Vision was developed and agreed in early 2008 by the management of Tata Steel Group. Two important ideas- Value Creation and Corporate Citizenship - make up the Vision for the Group. The Vision places equal emphasis on economic performance and Corporate Citizenship through social and environmental performance, thus truly integrating sustainability into the ethos and aims of the Tata Steel Group. Value Creation will help the Group to thrive commercially in a testing and competitive climate, enhance customer relations, and contribute to economic development in the areas of operation.

Fig. 3: TATA Steel Limited Pithampur [38]

In considering business strategy, the Company takes a holistic and long term view rather than seeking short term profits. Since 2005 Tata Steel has embarked on a journey to pursue growth and globalization through organic and inorganic strategies, to increase its capacity to more than 50mtpa by 2015.

In planning and undertaking this growth, the Company will seek to ensure that the benefits are shared by all its constituents and stakeholders. The Company has identified several strategic levers for growth and globalization, including building a stronger base in India, acquisitions in both growing and developed markets, strategic investments in raw material assets and focusing on the product offering.

IV. PROBLEM AND METHODOLOGY

Occupational Safety & Working Conditions is relatively neglected area by Indian industry and because of this while India has approximately 3% share of global manufacturing, India has almost 30% share of the industrial fatalities globally. Even Steel industry in India lags its global peers on this parameter and has patchy safety performance with many major incidents involving multiple fatalities. Most of the companies actually do not even have a proper safety management system comparable to global best practices. Though most of large ISPs are OHSAS- 18001 certified, never the less their contribution in workplace fatalities is not insignificant. Contractor workers which accounts for nearly half of the manpower deployed in steel industry are more susceptible to incidents as they are unskilled, not so educated and unaware of the hazardous work environment. However, in-spite of all efforts, their share in fatalities continues to be higher on year to year basis. Safety is still being managed in isolation and not as an essential / integral part of overall business decisions, culture & performance in most of the organizations [41]. Efforts for benchmarking by taking lessons from past failures & good practices from peer industry are limited to few organizations only.

S. No	Type of Hazard/Risk	Major areas where Hazard is faced
1	Toxic gases (rich in Carbon monoxide)	All over the plant
2	Explosive Gases (Rich in Hydrogen and Methane)	All over the plant
3	Harmful Chemicals	Coal Chemicals plant, CRM
4	Liquid metal/ slag (burn, explosions)	Blast Furnace, SMS, Continuous casting, Foundries
5	Extreme Temperature (-180^0 C to 1700^0 C)	Coke Ovens, Blast Furnace, SMS, Continuous casting, Foundries, Rolling Mills and Cryogenic Oxygen Plant
6	Fire	All over the plant
7	Electric Shock, Electrocution, Flash over	All over the plant and project sites
8	Rail/ Road Traffic Movement	All over the plant and project sites
9	Moving/ Rotating machines (Hit, Caught, pressed etc.)	All over the plant and project sites
10	Working at Height	All over the plant and project sites
11	Dust, noise, heat and Vibration	All over the plant
12	Material Handling	All over the plant and project sites
13	Confined Space (suffocation/ gas poisoning)	Furnaces, Tanks, Gas Pipelines, Gas holders, Sumps, Pits, Oil cellar, Conveyor/ cable galleries, Silos, etc.
14	High pressure Steam, Water & industrial gases	All over the plant

Table 1: Hazard in Steel Plant

As per ILO Code of practice on Safety & Health in the Steel Industry, 2005 Below are the most common causes of injury in the iron and steel industry:

1) Slips, trips and falls on the same level
2) Falls from height
3) Unguarded machinery
4) Falling objects
5) Engulfment
6) Working in confined spaces
7) Moving machinery, on-site transport, forklifts and cranes
8) Exposure to controlled and uncontrolled energy sources
9) Inhalable agents (gases, vapors, dusts and fumes)
10) Contact with hot metal, Reactive substances, hazardous chemicals
11) Fire and explosion
12) Extreme temperatures
13) Radiation (non-ionizing, ionizing)
14) Noise and vibration
15) Electrical burn, Electrical Flash and electric shock
16) Manual handling and repetitive work etc.

Group	Item	Nature of Hazard	Hazard Potential	Remarks
Raw materials Management	Coal for coking	Fire	Moderate	Fire hazard
	Water treatment chemicals like acids/alkalis	Toxic	Major	Bio-corrosive
		Fire	Moderate	Flammable
Production units				
Coke Plant	Dusts and fumes	Asphyxiation	Moderate	Air pollution
	VOC emissions from battery	Toxic	Moderate	Health hazard

	Coke oven gas	Fire & Toxic	Major	Fire and CO hazard
	Tar	Fire & Toxic	Moderate	Flammable
Agglomeration	Dusts	Respiratory	Moderate	Air pollution
Iron making in BF	Release of untreated wastewater	Toxic	Major	Severe pollution of surface water
	BFG handling	Fire	Major	Fire hazard
	Hot metal & slag Handling	Heath	Major	Fire hazard
Steel making in LD shops	Release of untreated wastewater	Toxic	Major	Severe pollution of surface water
	LD gas handling	Fire	Major	Fire and CO hazard
	Hot liquid steel & slag handling	Heath	Major	Fire hazard
Rolling Mills	Gas firing	Fire	Major	Fire hazard
	R e lease of untreated Waste water	Toxic	Major	Severe pollution of surface water
Captive Power Plant		Fire	Major	Fire hazard
Utilities				
Fuel gas	Gas leaks	Fire & Toxic	Major	Fire and CO hazard
Electric Power supply	Short circuit	Fire	Major	Fire hazard
Liquid fuel	Fuel handling & storage area	Fire & Toxic	Major	Fire & CO hazard
Hydraulic oil and lubricants	Accidental discharge of hydraulic oil under pressure	Fire & Toxic	Moderate	Fire & personal injury

Table 2: Identification of Hazards

V. Calculation and Results

Hazard Identification and it dealing in steel plants with the identification and quantification of risks that are exposed to, due to accidents resulting from the hazards present or handling of hazardous substances in the workplace. This involves Hazard analysis which essentially is identification and quantification of the various hazards that are likely to occur in the industry as well as quantification of the consequences due to a particular hazard. The risk analysis estimates the probability as well as severity of a particular hazard over an exposed group of people, plant equipment or both.

Model assists in identifying the most likely hazards which can have significant impact on workplace safety in an industry. It helps in devising effective management measures as well as engineering measures for both preventive as well as post-disaster management.

The scope of this report includes the study of proposed operations, storage and handling of hazardous materials with respect to Hazard Identification, Risk Assessment and updating of existing Disaster Management plan (DMP). Based on the Hazard Identification and analysis, the major disaster scenarios would be worked out to estimate the consequence of failure. Pithampur based TATA Steel plant already has a comprehensive Disaster Management plan (DMP) and the same would be evolved to also meet the emergency situations due to the proposed expansion-cum-modernization project.

The present report includes hazard identification and consequence analysis for the new projects included in the proposed expansion-cum-modernization of TATA Steel plant as well as ongoing for existing critical units of TATA Steel Plant. The primary potential hazards due to the proposed units are identified based on a detailed Primary Hazard analysis (PHA) along with consequence analysis for the risk assessment. Proposed Expansion-cum-modernization projects

1) Modernized BOF gas holder in modernized SMS-I
2) New BOF gas holder in SMS-II
3) Revamped propane storages within modernized SMS complex

The process is an ongoing and continual process for existing units and is undertaken on periodical basis for ensuring good workplace safety at TATA Steel plant. It also involves a periodic review of the same as well as dissemination of information to various employees through instruction and along with adequate documentation and record-keeping.

1) Hazard identification
2) Assessment of risks associated with the identified hazards
3) Control measures to manage the exposure to the risks
4) Monitoring and review of the effectiveness of the controls.

Existing Facilities of TATA Steel plant are

1) Energy Management Department (Fuel gases etc.)
2) Blast Furnace
3) Coke Oven and By-product plant
4) Steel making Shop
5) Cold Rolling mill
6) Sinter Plant
7) Raw Material handling plant

A. *Gas Mixing Stations*

A maximum total of 75,000 m^3/hr of mixed gas is proposed to be handled by a new Gas mixing station envisaged at TSL's Coke Oven complex, wherein BF Gas and Coke Oven gas will be tapped from existing as well as future producing units and will be mixed in suitable proportions to produce Mixed gas of desired calorific value for use at the existing and new coke oven batteries. The results of MCA analysis indicates a maximum fire hazard distance for causing significant damage (@37.5 Kw/m^2 thermal radiations) extending up to 38 m in the case of complete failure of the holder and catastrophic release of BOF gas, subsequently being ignited during worst meteorological conditions resulting in a fireball.

B. BOG Gas Holder

There are two (2) BOF gas holders, i.e. a replaced BOF gas holder of SMS-1 of 50,000 m^3 capacities and a new gas holder of 80,000 m^3 capacities, both located within the SMS complex of TSL's TATA Steel Plant.

The results of MCA analysis indicates a maximum fire hazard distance for causing significant damage (@37.5 Kw/m^2 thermal radiations) extending up to 84 m in the case of complete failure of the holder and catastrophic release of BOF gas, subsequently being ignited during worst meteorological conditions resulting in a fireball.

C. Mounded Propane Bullet

TSL has envisaged two (2) propane bullets, each of 100Tonne capacity, located within the TSL's TATA Steel Plant for heating and cutting purposes. The results of MCA analysis indicates a maximum fire hazard distance for causing significant damage (@12.5 Kw/m^2 thermal radiation) extending up to 45 m in the case of complete failure of the pipeline connections on the bullets and release of propane, subsequently being ignited during worst meteorological conditions resulting in a jet fire. Explosion effects having significant potential for damage (@0.21 bar (g) overpressure) is also observed to be up to a distance of 45 m.

D. Risk Analysis for Proposed Products

The hazardous event scenarios likely to make the significant contribution to the risk of potential fatalities are enlisted in Table 3. The risks to people at plant site are categorized as "On-site" risks while the risks to communities outside the plant premises is categorized as "Off-site" risks.

S. No	Hazardous event	Consequence of significant damage	(A) Consequence severity* (1=least severe; 5=most severe)	(B) Likelihood* (1=least likely; 5=most likely)	(C) RISK RANK
1	Onsite vehicle impact on personnel	Potential for single fatalities, onsite impact only	3	3	9
2	Entrapment/struck by Machinery	Potential for single fatalities, onsite impact only	3	2	6
3	Fall from heights	Potential for single fatalities, onsite impact only	1	3	3
4	Electrocution	Potential for single fatalities, onsite impact only	2	3	6
5	Gas Mixing Station fire & explosion as well as toxic dispersion	Potential for multiple fatalities, onsite impact only	4	1	4
6	BOF gas holder failure and fire & explosion as well as toxic dispersion	Potential for multiple fatalities, onsite impact only	5	1	5
7	Propane Bullet's fire & explosion	Potential for multiple fatalities, onsite impact only	3	1	3
Based on Survey and Analysis					

Table 3: Hazardous Events Contributing to Risk and their Risk Ranking

The above risk analysis indicates that although the most severe consequences will be due to rupture of BOF Gas holders followed by Gas Mixing station and Mounded propane bullets, their chances of occurrences are low due to implementation of better safety features in the installations and constant monitoring of vessel / pipe work integrity for regular repair and maintenance, and hence these facilities have low levels of risk in the facility.

VI. CONCLUSION

The risk assessment and analysis for TSL's steel plant for most severe hazardous events is broadly summarized below:

The nearest habitations in the vicinity of the TSL Plant are Pithampur village at distance >4000min NW, Mhow village at distance >3000m in SW, in SE at distance >2500m at distance >2300m in the NE, which are far away from the hazard distances observed for thermal effects (maximum at 127m) as well as toxic effects (maximum at 50m) due to failure of above identified hazardous facilities of TSL. Also, these facilities are located in the central part of the TATA steel plant away from each other to prevent multiple hazards, initiated due to fire in one facility and leading to a hazard in another facility, also known as domino effect. So, there will be no significant impact on the local community or damage to property / environment.

The most severe damage effects due to the identified hazardous facilities will be limited to the plant premises and adequate safety controls as well as implementation of recommended control strategies in the design as well as operation stage will ensure effective management of the associated risks.

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