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Analysis, Evaluation and Risk Management in One of the Pipe Industry by FMEA in Sistan and Baluchistan Province

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Abstract: At present, the advancement of science and industry has caused humans to be exposed to many dangers that never existed before. Increasing incidents and damages to industry in the world, especially Iran, confirms this claim. Today, several methods are used to identify and investigate hazards, and the existence of various analytical methods always forces the analyst to choose a method. The purpose of this study was to identify the hazards in a pipe-laying workshop in Sistan and Baluchestan province using the failure mode and effect analysis and finally provide a risk management solution. To accomplish this study and collect necessary data and complete the sheets for analyzing the failure mode and its effects, a team of experts was formed and using the process of observing the method and interviewing the relevant people and reviewing the technical and operational documents, risk assessment. Dangers were taken and necessary corrective actions were presented. In 15 units of the plant, the activities and sub-activities were assessed, 44.85% of the hazards, 49.17% of the average risks and 5.98% of the identified risks and a control solution was provided for each of them. By providing control solutions, you can reduce many incidents at the plant and improve the level of safety. If the risks at medium and low level ignore what might be the great risks and opinions on the major risks is also training staff as one important way to reduce risks because many employees do not know how to handle properly.

Key words: Risk identification, risk analysis, safety, failure mode and effect analysis, pipe manufacturing.

Introduction

With the progression of societies, the requirement for heavy work has been reduced to a great extent (Ghaljahi et al., 2015). Nevertheless, in many societies, there are still jobs in the scope of heavy work (Ghaljahi et al., 2017). According to the International Labour Organization (ILO), there are approximately 317 million annual work-related incidents, which imposes significant economic blows to societies (Kolahdouzi et al., 2017). The most important part of any health and safety programme is to identify and assess risks (Ghaljahi et al., 2018). Risk assessment is a logical method for assessing potential risks entailing the identification of hazards and relevant consequences for individuals, materials, equipment and the environment. Using risk assessment methods, valuable information is obtained which may be beneficial for decision making on risk reduction, improving hazardous environments, emergency planning, and the maintenance of facilities (Karegar et al., 2011).

There are numerous methods for risk assessment, but a simple applicable method is the FMEA (Failure Mode and Effect Analysis) method which analyzes failure factors and relevant consequences as well as determining points that require optimization in terms of health and safety whilst prioritizing hazards, thus, enabling the appropriate training for labourers (Risk Management Handbook, 2009). Since the FMEA method considers risk control possibilities, it is an effective method in risk assessment. In this method, the risk priority number is used which is the product of multiplying the three factors of occurrence possibility, severity of outcome and diagnostic capability (FMEA Handbook, 2004).

The FMEA method is a group risk assessment method and the views of each member are considered based on their type of expertise and skills in subjective and qualitative analysis. The goal of FMEA is to prevent incidents and by optimizing processes and products, it causes significant reduction in human injuries and relevant damages (Baydar et al., 2001). The FMEA is a qualitative and inductive method. Another of its goals is to increase the reliability of the process by preventing identified system defects (Xiao et al., 2011).

The FMEA is a relatively time-consuming method and requires detailed and precise information about the system under assessment (Zhou et al., 2004). The effectiveness of this method in analyzing hazards is significant enough to be implemented in high risk industries such as the aerospace industry and nuclear power plants to prevent accidents (Guimar Fes et al., 2007). The FMEA method has also been used in various industries such as electronics, automobile (Attar Jannesar Nobari et al., 2010), consumables, power generation plants, roads, buildings, telecommunications etc. (Duwe et al., 2005).

Lui Hu Chen et al. (2013) conducted a study reviewing the academic work done using this method and categorized these researches and approaches. One of the advantages of this method compared to other semi-quantitative risk assessment methods is its attention to error factors in addition to the effects and consequences of the errors.

Numerous hazards including environmental, physical, machine and equipment hazards as well as human hazards in pipe-laying workshops should be accurately identified and controlled (Varnere, 2007).

In regard to pipelines, risk determination and assessment is a prominent component of the risk management process. The factors which may cause risks in pipelines are categorized into two main groups: human error related factors and factors that are independent of human errors and are related to the work environment (Dziubin et al., 2006).

The researched pipe production plant includes a production hall, office buildings, warehouses, service department (carpentry, welding, and painting workshop), engine room, electricity section, maintenance and repair, quality control, construction workshop, garden and green space. The production of composite pipes (GRP) with a daily production capacity of 60 pipes with various internal diameters for producing pipes required for plumbing and irrigation projects takes place by 350 directly employed and 1,200 indirectly employed employees. The production line includes resin and styrene tanks, a printing and rowing chamber, waste pans, chamfering machine, hydro-test device and bogie (transfer roller).

In regard to the mentioned issues and the importance of identifying and assessing risks to improve conditions and reduce risks in the work environment, research on risk assessments in this industry in Iran is scarce. This study aims to assess and present control measures to reduce risks in the pipe manufacturing industry.

Materials and Methods

The current study is descriptive-analytic-cross sectional approved and implemented by the Ethics Committee of Zabol University of Medical Sciences and Health Services. This study was conducted in 2017 to assess the risks of hazards in various sections of a pipe manufacturing plant in the Sistan region. The following procedure was conducted.

In order to identify and analyze the risks, a team of experts consisting of two professional health experts and two safety officers was formed who initially studied all the duties of employees, inventories and guidelines. In the second stage, an accurate inspection of all the stages of employee duties, machinery and equipment of the work place was systematically conducted. In the final stage, all the steps were evaluated using the FMEA technique. The following steps were taken to implement this technique (Habibi et al., 2006):

Stage One: Risk Severity Determination

The assessment team evaluated the risks and effects based on individuals' awareness according to Table 1.

Stage Two: Determination of the Probability of Occurrence for Each Hazard

Table 2 was used to determine the degree of occurrence, and in most cases, in-person interviews with technicians and labourers were used to improve evaluations.

Table 1: Risk rating based on outcome severity

Rating	*Effect severity*	*Characteristic*
10	Dangerous, without warning	The severity of the outcome is disastrous such as a danger of death, complete destruction by earthquake etc.
9	Dangerous, with warning	The outcome severity is disastrous and entails a warning.
8	Very severe	The outcome severity is irreparable. Inability to conduct main duty. The loss of a body part.
7	Severe	The outcome is severe such as the equipment catching fire or severe burning.
6	Moderate	Severity is a high but compensable, such as local burns, sectional injuries.
5	Minor	The outcome is not severe such as laceration and mild intestinal toxicity.
4	Very minor	The outcome severity is very low but is experienced by the majority of individuals such as gas leaks.
3	Minor effects	Minor effects such as hand scratches whilst lathing.
2	Very minor	Very minor effects
1	None	No effects

Table 2: Risk rating based on the occurrence probability

Rating	*Possible risk rates*	*Occurrence probability*
10	1 in 2 or higher	Extremely high, risk is almost inevitable.
9	1 in 3	
8	1 in 8	High, repetitive risks
7	1 in 20	
6	1 in 80	Moderate, case risks
5	1 in 400	
4	1 in 2000	
3	1 in 15000	Low, relatively rare risks
2	1 in 150000	
1	Less than 1 in 15000000	Unlikely, risk is unlikely

Table 3: Risk rating based on risk discovery probability (traceability)

Rating	*Discovery probability*	*Risk discovery probability criteria*
10	No probability	There is no control and if there is, risks cannot be discovered.
9	Almost none	There is very insignificant probability of detecting or trace risks with current control methods.
8	Insignificant	There is insignificant probability to determine and trace risks using current control methods.
7	Very insignificant	There is very insignificant probability to determine and trace risks using current control methods.
6	Insignificant	There is low probability to determine and trace risks using current control methods.
5	Moderate	In half of the cases there is a probability to determine or trace risks using current control methods.
4	Relatively high	There is relatively high probability to determine and trace risks using current control methods.
3	High	There is high probability to determine and trace risks using current control methods.
2	Very high	There is high probability to determine and trace risks using current control methods.
1	Almost certain	The risks are almost certainly determined and traced using current control methods.

Table 4: Number of activities and sub-activities of each pipe manufacturing plant unit

Unit name	*Number of activities*	*Number of sub-activities*
Production hall	7	25
Hydro-test unit	5	13
Parts warehouse	4	4
Materials warehouse	1	6
Services and support	3	10
Engine room	1	1
Electricity	1	1
Repair and maintenance/ preparation	2	3
Quality control	3	5
Products warehouse	2	2
Installation projects	1	1
Building activities	1	5
Green space	2	3
Health and safety	2	2
Welfare building	3	3

Stage Three: Assignment of the Degree of Discovery to Any Risk and Its Effect

The discovery probability is a type of system ability determination in identifying a cause or mechanism of hazard occurrence. The risk discovery probability is determined based on Table 3.

Step Four: Assignment of Priority Scores for Each Risk

The risk priority number (RPN) in the FMEA method is obtained by multiplying the severity of the outcome probability by the risk factor discovery score. Each of these factors is a number between 1 and 10 and the RPN number can be between 1 and 1000. The higher this number, the damages are more severe and the consequences are dire. If one of the three factors have an RPN number of over 6, the implementation of prevention measures is necessary and if at least two of the three factors have an RPN number of over 6, such preventive measures should be implemented instantly.

Step Five: Provision of Corrective Measures to Eliminate or Reduce the Dangers of Risks

In this stage the FMEA team writes recommended measures on the FMEA worksheet to reduce or eliminate risks. These measures are based on the knowledge and experience of team experts and legal requirements. The FMEA team prioritizes risks, recommends corrective measures on the worksheet and presents them to the plant manager and workshop supervisors to eliminate equipment defects and to implement corrective measures to reduce RPN. This is a continuous process.

Result and Discussion

In the researched plant, 15 units were assessed in 38 activity and 78 sub-activity units which were identified based on Table 4.

Based on the above explanations and with the aid of Tables 1 to 3, the risk priority score is identified for various risks at the pipe manufacturing plant by the assessment team using the FMEA worksheet. An example of this worksheet is presented in Table 5 which presents control paths.

For each sub-activity, a description of a hazardous activity and its effects is presented on the FMEA worksheet, in which 301 hazardous activities were written for the plant and the risks were categorized into three groups: low, moderate and clear. Corrective measures were assigned for each risk (Table 6).

By using the FMEA technique, the errors related to various parts of the pipe manufacturing plant were identified. The relevant effects, causes and recommended measures were determined by team members. Faye et al. (2010) suggested that the advantage of implementing such techniques is that labourers are not viewed as transgressors and by rooting the causes of errors, a safe environment can be provided for all employees.

This method has been criticized due to its arduous nature in engaging members, difficulties in analyzing (Burgmeier, 2002), rating system issues (Wetterneck, 2004) and unreliability of its scoring system (Wetterneck, 2006). Lindsay (1992) utilized the FMEA method in his research and emphasized the flexibility of this method in risk assessment. He referred to the impact of various environmental factors on projects risk assessment and described an environmental conditions assessment as a measure in projects risk assessment which is in accordance with the current study. The application of decision making methods in risk assessment and management is of importance, which is also emphasized by Singh and Makeset (2009).

It is noteworthy that the majority of identified risks can be easily eliminated or controlled with minimal costs whereas incidents caused by these risks can inflict significant damages to the whole system. The failure

Table 5: Risk priority number for each risk at the pipe manufacturing plant (production hall)

Sub-activity	*Hazardous activity description*	*Hazard effect*	*A*	*B*	*Risk criteria*	*Risk type*	*Corrective measure*
			Activity—Using an angle grinder				
Using an angle grinder	The risk of electric shock caused by working with an angle grinder	Burns caused by electric shock/death	3	1	3	Moderate	Present a stone grinding training guide, delivery of relevant rules and regulations to each unit
	Risk of breaking the stone plate	Eye injuries	2	2	4	Moderate	Present a stone grinding training guide, delivery of relevant rules and regulations to each unit
	Small stones hitting the eyes due to grinding	Eye injuries	3	2	6	Clear	Present a stone grinding training guide, delivery of relevant rules and regulations to each unit
	Risk of cutting by the angle grinder	Severed body part	2	3	6	Clear	Present a stone grinding training guide, delivery of relevant rules and regulations to each unit
	Risks from angle grinder noise	Hearing problems	3	1	3	Moderate	An awards and punishment mechanism to use safety equipment and control by HSE colleagues
	Risk of fire due to friction	Burns	2	1	2	Low	Present a stone grinding training guide, delivery of relevant safety regulations to each unit
	Risk of cutting hands by sharp parts	Wounds	1	2	2	Low	Use of tarpaulin gloves
			Activity:—Left and lower roming operator activity				
Going up and down stairs	Risk of falling	Fracture	2	2	4	Moderate	Installing railings and shields
	Ergonomic risks from repetitive actions	Lower back and knee pain	1	2	2	Low	Conduct postural and anthropometric analysis, determine correct working method and minimize repetitive actions
Lifting fiber rolls	Ergonomic risks from repetitive actions	Lower back and knee pain	1	2	2	Low	Conduct postural and anthropometric analysis, determine correct working method and minimize repetitive actions
	Risk of falling	Fatigue	1	3	3	Moderate	Install chains and shields in the printing and rowing section

(*Contd.*)

Table 5 (*Contd.*)

Sub-activity	*Hazardous activity description*	*Hazard effects*	*A*	*B*	*Risk criteria*	*Risk type*	*Corrective measure*
Loosening of upper parts' screws and falling on the operator	Risk of falling	Fracture/ death	3	1	3	Moderate	Appoint a production hall supervisor
	Risks of cuts	Wounds	1	3	3	Moderate	Appoint a production hall supervisor
Standing across the machine shaft	Risk of thrown raw materials amidst shaft rotation	Eye injuries	1	3	3	Moderate	An awards and punishment mechanism to use safety equipment and control by HSE colleagues
Standing under the rolls	Risk of falling upper objects and rolls	Fracture	2	1	2	Moderate	Install nets
	The risk of falling and dispersing silica	Skin sensitivity and respiratory limitations	3	2	6	Clear	An awards and punishment mechanism to use safety equipment
	Risk of contact with produced resin	Skin sensitivity and respiratory limitations	3	2	6	Clear	An awards and punishment mechanism to use safety equipment

Table 6: Frequency and percentage of risks in pipe manufacturing plant

Risk type	*Frequency*	*Frequency percentage*
Low	135	44.85
Moderate	148	49.17
Clear	18	5.98

mode and effect analysis problem-solving technique can be used in all project stages from the planning stage up to the production stage. Today, in implementing industrial designs, namely the early stages of the design stage, the FMEA technique is used to identify and analyze risks which limits and minimizes errors (FAA, 2000).

Osha believes that the risk analysis process should be team driven at an optimal state with the presence of experts in the engineering and process operations field (OSHA, 2000).There should also be at least one labourer present with adequate knowledge and expertise of the method used to identify risks which is also adhered to in this research (Palangi and Omid, 2018).

In a study conducted by Benjamin et al. (1994), it was shown that if during a production process including the start of the process, failure modes and its effects are evaluated and accurately managed, then a significant number of incidents can be prevented. In assessing the 301 risky activities identified in the pipe manufacturing plant using the FMEA method, 5/98 risks were in the unacceptable range with a clear risk rating. Considering that the majority of risks were moderate or low and not significant, it can be expected that by conducting corrective measures, the level of these risks will decrease. For clear risks, immediate corrections were presented to the employer to take immediate actions.

For this purpose, appropriate corrective measures along with implementation methods are determined and presented. Such corrective measures should be continuously and accurately monitored during the plant's activities to ensure the risk number remains at an acceptable level. In the analysis and review of risks associated to pipelines, attention to environmental and regional factors is of significant importance. By paying attention to these points, the risk management process will become more widespread.

The output of an appropriate risk management process may be utilized to design pipeline repair and maintenance models whilst identifying critical points that should be considered for maintenance programmes. This will increase the effectiveness of repair and maintenance activities and, in general, increase the efficiency of pipeline activities by reducing unforeseen errors.

The main limitations of this study include the lack of accurate recording of statistics to identify hazards, lack of labourers' familiarity with the risk management process and the limited number of experts in the evaluation field. On the other hand, presenting a method to quantitatively identify the risks with a quality basis and providing a scientific and systematic approach for risks is an arduous task.

Conclusion

1. Several of the errors identified by group members are preventable and risk management requires more control over various processes to improve efficiency and quality.
2. In order to prevent potential accidents and improve safety in industrial processes, systematic management of safety is essential in these processes.
3. It seems that the implementation of a documentation system for recording equipment deficiencies and events can be basic information needed to assess the subsequent safety ideally.
4. In addition, performing preventive maintenance can reduce the possibility of the equipment defects and their consequences.
5. Our results showed that compared with other methods of risk assessment, FMEA can identify more risks and an important point is that choosing an appropriate method plays a crucial role in identifying more risks.

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