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Original

Identifying Hazardous Points in Foundry Industry Using a Hybrid Safety Approach

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Abstract

Background: In recent years, the foundry industry has had a significant impact on Iran's economy. However, the health and safety conditions of this industry are in an unfavorable status, and these conditions have caused a lot of accidents. In this regards, one of the most important ways to prevent accidents in this industry can be identifying hazardous points and adopting appropriate control measures. The aim of the study was to identify hazardous points in foundry industry using a hybrid safety approach. **Methods:** This descriptive-analytic study was conducted in the foundry industry of Iran, in 2016. The study method consisted of two parts. First, the accidents of foundry were analyzed. Second, the Energy Trace and Barrier Analysis (ETBA) technique was used to identify hazards and assess the risks. The collected and obtained data of accidents and risk assessment were entered into the statistical SPSS software, version 22, and descriptive statistics (mean, percent) were used for analyzing. Also, Microsoft Excel was used to plot the graphs. **Results:** A total of 128 risks is identified, including 17 unacceptable risks, 93 undesirable risks, 13 acceptable risks with revision and five acceptable risks without revision. The mechanical and physical energies had the highest percentage of hazards. The results of accidents analysis showed that the cause of most accidents (40%) was mechanical, while 23% of them was the potential type. The study results indicated that accidents analysis along with risks identification can be useful in identifying all the dangerous locations (points). **Conclusion:** In addition to validating the results of risk assessment through the analysis of accidents, other causes affecting the occurrence of accidents can also be covered by accident analysis, including unsafe behaviors and organizational causes that are not seen in the risk assessment.

Keywords: Accident analysis; Hazard identification; ETBA

Introduction

Given the increasing advances in technology and the development process of using automated processes, the safety and health of the workplace are introduced as a serious and critical issue in industrial environments. In this regard, accurate study and evaluation of workplace hazards, determining appropriate strategies to deal with potential hazards, planning for training and informing the workforce about the risks seem to be so important.

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It is noteworthy that the lack of adequate attention and poor investment in these areas have always been associated with sustained heavy financial losses, increased production costs, and also it has threatened the people's life.[1] According to available statistics, accidents are the third leading cause of mortality worldwide and the second in Iran.[2] According to the International Labor Organization (ILO), about two million people die in the workplace each year, and thousands of workers are seriously injured. Based on the low death rates statistics due to accidents, Iran is ranked 186 among 190 countries.[3] According to Hamalainen et al. study, about 350,000 occupational accidents resulting in deaths and 264 million non-fatal occupational accidents occurred throughout the world in 1998.[4] According to the OSHA statistics, for 100 full-time employees in the US foundry industry, the fatal accident frequency rate (AFR) were 11.9, 13.1, 14 and 13.5, respectively during 2006, 2005, 2004 and 2003.[5] According to the same organization's statistics, a death occurring in the foundry industry impose a human cost of 182,000 $ to the system.[6] The foundry that can be considered as a primary industry is a manufacturing process in which a liquid material is usually poured into a mold to make a casting piece based on a model.[7] Foundry industry has significantly progressed in Iran in recent years as one of the basic and key industries in the economic growth chart. Nevertheless, the safety and health conditions and environmental considerations related to the work of this industry are still at their lowest level.[1] Foundry industry consists of several parts and various hazards are associated with its different operations.[8] The lack of attention of Foundry industry managers to safety, the use of traditional and inefficient methods to provide safety for working conditions, spending little time and money for planning and executing a developed safety program are the most important factors that have made the working environment in Iran as one of the most accident prone and hazardous working environments.[1]

The accidents can be reduced using preventive measures.[9] Identifying the hazards in the work environment is the primary stage in accident prevention[10] and the most important stage of risk management. The risks cannot be controlled, and the system safety cannot be provided without identifying the hazards.[11] There are several methods for identifying and detecting the dangers and risks.[12] The Energy Trace and Barrier Analysis (ETBA) technique is one of the risk assessment methods.[13,14] This approach assumes that the accident occurs due to the absence and inappropriateness of the barriers and controls and the unwanted energy transfer. The focus of this method is on four factors, including the source or sources of energy in the system, the suitability of the barriers in the path of energy, the human interaction with the system and examining the ultimate goals of unwanted or uncontrolled energy.[11] Risk assessment has great importance in industries, especially in steel casting due to the existence of threating factors to the safety and health of workers.[14] It helps to identify the high-risk, moderate risk and low-risk casting operations and prioritize the risks.[8] Risk assessment is in fact one of the key tools in creating proper performance, which estimates the probability of health damages due to occupational hazards and is effective in achieving the goals by improving the existing conditions.[14]

Understanding the causes of events will lead to better strategies for preventing them. Accident investigation plays a major role in effective safety management and is implied as an essential basis for learning from accidents and improving safety.[15-17] One of the obstacles to learning from accidents is the gap between the results obtained

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from the analysis of the causes of the accident and the results of the risks assessments made. So, we are still witnessing the occurrence of accidents despite taking risk control measures. This suggests that many of the human and organizational factors involved in the accident are ignored in risk assessment, while their role in the occurrence of accidents can be detected through analysis. This shows that most risk assessments focus on the technical level of the facilities and other causes of accidents are ignored.

Accident analysis, as a reactive method, considers defective safety equipment and relevant corrective actions after the occurrence of any accidents. The proactive approaches identify the risks before the accident occurrence and prevent the happening of the accident. Therefore, in addition to using the reactive attitude to learn lessons from events, the accidents should be prevented before occurring by use of the proactive approach. Hence, in this study, the status of safety was analyzed, the hazards were identified and the risks were assessed in the foundry industry using the ETBA technique. Accident analysis was employed as a complementary method to detect hazardous points.

Methods

This study was a descriptive-analytic conducted in the foundry industry of Iran in 2016. The study method consisted of two parts. First, the accidents of Foundry were analyzed, and then ETBA technique was used to identify hazards and assess the risks. The studied population included 500 workers in the industry who have been working in the company since the beginning (two years). The data on the demographic information of these subjects (such as age, work experience, educational level, marital status, shift work, safety training courses, occurred accident information) were collected and recorded on the worksheet by review of the documents (reports of accidents recorded in the company).

ETBA method assumes that the accident occurs due to the absence and inappropriateness of the barriers and controls and the unwanted energy transfer. The focus of this method is on four factors, including the source or sources of energy in the system, the suitability of the barriers in the path of energy, the human interaction with the system and the examination of the ultimate goals of unwanted or uncontrolled energy.[11] The ETBA worksheet was used in this technique. The data was completed through observation and doing interviews with specialists through the walking-talking process and the review of technical and operational documents and evidence. The steps taken in this study and in the process of using the ETBA method are as follows:[7]

1. Identification of energy sources: This stage involves examining the components of the system and identifying all potential dangerous energy sources. The ETBA energy inventory was used to identify the energies. A checklist of all kinds of energies that were found in the system was used to identify all the energy sources n addition to using the checklist, the review of the reports of accidents were also used.
2. Energy Tracing: At this stage, the energy path from source to target was investigated. This step involves identifying all the targets that may be damaged by hazardous energy sources. All kinds of energies were investigated since the time they have been introduced to or created in the system for the first time until they have been removed from the system or modified and converted into another form of energy.
3. Identification of controlling measures and system assessment: This step was carried out by identifying all existing controls in the path of energy flow and determination of the initial risk as well as controls to prevent the flow of energy and

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determine the secondary risk caused by controlled energies with the participation of experts.

4. Risk assessment of energy in the system: At this stage, the risk of each of the energies were identified and evaluated in the system. The MIL-STD-882B standard[18] was used in risk assessment. In this standard, the severity of the accident was divided into four categories of catastrophic, critical, marginal and negligible, while the probability of occurrence of the accident was also divided into five categories of frequent, probable, occasional, remote and improbable. Using this standard, the severity and probability of the accident occurrence were determined. Finally, the risk level was calculated using the matrix of risk assessment.

5. The controlling solutions were provided to control the identified potential hazards in each section. Assuming the implementation of each solution and its possible effectiveness, the secondary risk analysis was done by the same method used in the initial risk analysis.

Finally, the collected and obtained data of accidents and risk assessment were entered into the statistical SPSS software, version 22, and descriptive statistics (mean, percent) were used for analyzing. Microsoft Excel was also used to plot the graphs.

Results

Based on the results that were presented in Table 1, a total of 128 risks were obtained, which included 17 (13.5%) unacceptable risks, 93 (72.6%) undesirable risks, 13 (10%) acceptable risks with the need for revision and 5 (3.9%) acceptable risks with no need for revision. The mechanical and physical energies have the highest percentage of risk level. The mechanical energy has the highest percentage of unacceptable risk. Mechanical energy and thermal energy have the highest and lowest percentages of undesirable risk, respectively. Physical and thermal energies have the highest percentage of acceptable risk level with the need for revision, while physical energy has the highest percentage of acceptable risk level without a need for revision.

Figure 1 shows the types of occurred accidents. Based on Figure 1 accident types are struck-by accidents (%42), falling objects (%26), hot fluids and surfaces (%21), falling to a lower level (%10) and electrical (1%).

Table 1. The frequency of identified risks by type of energy

Risk category	Total risk	unacceptable	undesirable	Acceptable with the need for revision	Acceptable without a need for revision
Type of energy	Frequency (percent)	Frequency (percent)	Frequency (percent)	Frequency (percent)	Frequency (percent)
Physical	24 (19.04%)	5 (31.25%)	12 (13.04%)	4 (30.76%)	3 (60%)
Chemical	16 (12.69%)	1 (6.25%)	13 (14.13%)	2 (15.38%)	0 (0%)
Mechanical	36 (28.57%)	7 (43.75)	27(29.34%)	2 (15.38%)	0 (0%)
Heat	8 (6.34%)	0 (0.0%))	2 (2.17%)	4 (30.76%)	2 (40%)
Electrical	12 (9.52%)	0 (0.0%))	12 (13.04%)	0 (0%)	0 (0%)
Natural Factors	4 (3.17%)	0 (0.0%))	3 (3.26%)	1(7.69%)	0 (0%)
Potential	22 (17.46)	3 (18.75)	19 (20.65%)	0(0%)	0(0%)
Other	4 (3.17%)	0 (0.0%))	4 (4.34%)	0(0%)	0(0%)
Total	128 (100%)				

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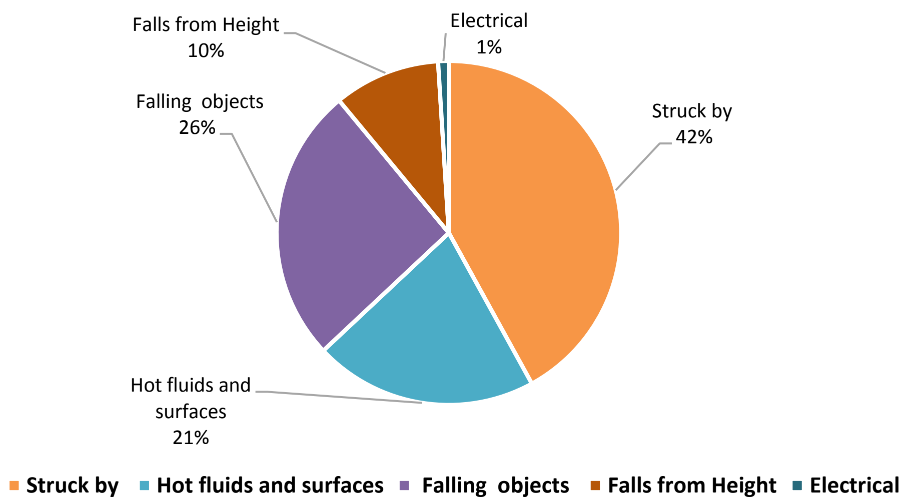

Figure 1. Types of occurred accidents

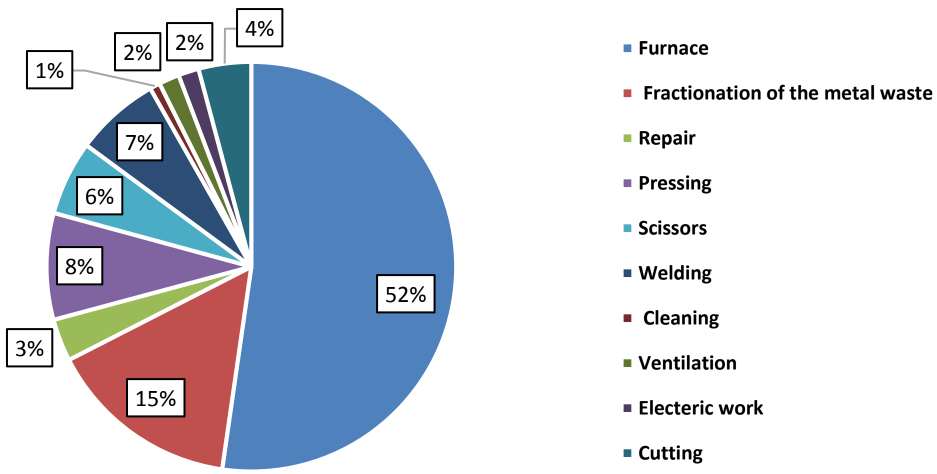

Figure 2. Places of the occurred accidents

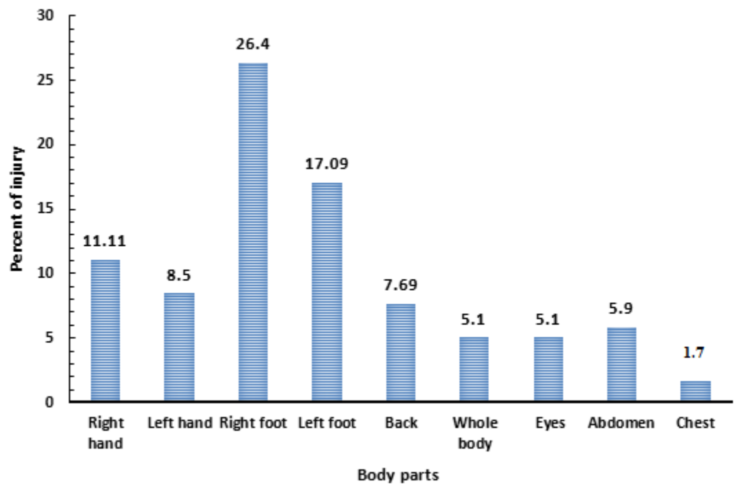

Figure 3. Injured parts of the body

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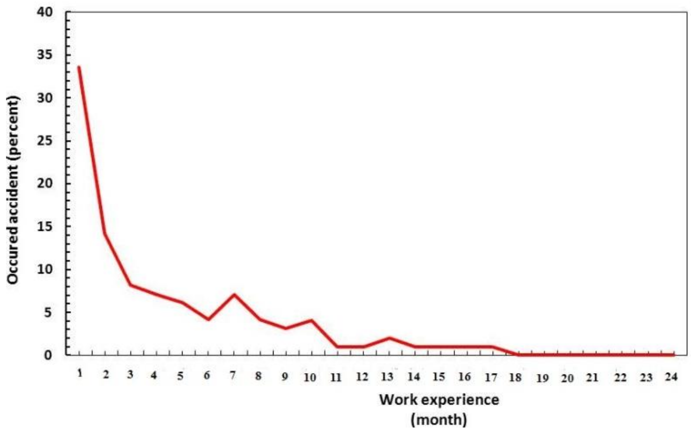

Figure 4. Occurrence of accidents on the basis of work experience in months

Figure 2 shows the places that the accidents occurred. According to Figure 2, the furnace section with 48.3% and the fractionation of the metal waste section with 15% had the highest percentages of risk in comparison with other sections.

Figure 3 presents the injured part of the body caused by accidents. Based on Figure 3 the right foot with 26.4% and the left foot with 17.09% had the largest number of accidents. The right hand (11.11%), left hand (8.5%), back (7.69%), abdomen (5.9%), eyes (5.1%), whole body (5.1%) and chest (1.7%) were in the next ranking, respectively.

Figure 4 shows the occurrence of the accident based on the worker's experience. This trend is according to a survey of accidents over two years. Figure 4 indicates that most accidents have occurred among the people that had low work experience. 33.6% of the accident occurred among the people who had about one-month work experience.

Based on the results of this study, accidents occurred among single and married people with 29.1% and 74.1%, respectively. The occurrence of accident at night shift and day were 60% and 40%, respectively. It was shown that unsafe behavior and unsafe conditions were the immediate causes of 40% and 60% of accidents, respectively.

Discussion

The results of hazard identification by ETBA method indicated that 85% of the identified hazards were in the category of unacceptable and undesirable risks. Mechanical energy and thermal energy had the highest and lowest percentages of undesirable risk, respectively. According to the study, the occurred accidents in the foundry were struck-by accidents, falling objects, hot fluids, and surfaces, falling to a lower level and electrical. Higher struck-by accidents confirm the higher mechanical risks in the foundry. The furnace and the fractionation of the metal waste sections had the highest percentages of risk in comparison with other sections. The right foot and the left foot had the highest number of accidents, respectively. Based on the present study results, most accidents occurred among the people who had low work experience. Unsafe conditions were the immediate causes of more accidents comparing unsafe acts.

A study by Zarroshani et al. in the foundry industry reported the identification of 108 cases (70.12%) of unacceptable and unacceptable risks.[7] In a risk assessment by ETBA technique in another foundry company, 16 risks were identified, including four unacceptable risks, six undesirable risks and six acceptable risks with the need for revision. [19] Therefore, based on the results of this study and other similar studies, the foundry is one of the high-risk industries. According to this study, the greatest number of injuries have occurred in the feet. In Bayong study, the greatest number of

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injuries have been reported in hands and fingers (45.7%) and feet and toes (13.8%).[20] Muhammad Fam also reported that the most damaged organs were feet (31.7%) and hands (23.7%). [21]

Based on the results of the present study the most accidents occurred among people who had low work experience. Several studies have shown that newly employed workers are at the highest risk of occupational accidents. [22] It was also found in a study that about 50% of all injuries occur in the first year of employment of workers (20). In a study, out of 10583 accidents, 4011 accidents happened among the people with a work experience of under one year, 2937 accidents occurred among the people with a work experience of 1-5 years, 1747 accidents among the people with a work experience of 5-10 years, 727 accidents among the people with a work experience of 10-15 years and 1161 accidents among the people with a work experience of more than 15 years.[4] The results of the present study have been confirmed in other studies.

The current research indicated that the number of accidents in married individuals was more than the number of accidents in single people. In a study done on a review of occupational accidents, out of 10583 accidents, 7254 accidents had occurred in married people and 3329 accidents had happened in single people.[4] In another study, out of 533 injured people, 134 were single, and 399 were married.[23]

The results of the accident analysis indicated that the number of night shift accidents was higher than the day shift. Mehrparvar et al. referred to the higher number of occupational accidents in the night shift than the day shift in their study.[23] According to the results, working in the night shift can be considered as an effective factor in the occurrence of the accidents.

In the present study, unsafe behavior and unsafe conditions were the causes of 40% and 60% of the accidents, respectively. Although due to the nature of foundry industry the unsafe conditions are expected to be the cause of most accidents, but the results indicated that unsafe behaviors also are involved in the occurrence of the accidents. In the study by Mohammad Fam and Zaman Parvar on the casting industry, 573 unsafe activities were examined, and it was shown that 59.2% of worker's activities are unsafe.[24]

Conclusion

In the present study, first, the accidents of Foundry were analyzed. Second, the ETBA technique was used to identify hazards and assess risks. The results of this study showed that accident analysis accompanied by risks identification can be useful in identifying all dangerous points of the foundry industry. Since, in addition to validating the results of risk assessment through the analysis of accidents occurred, the accident analysis can cover other causes of accidents, including unsafe behaviors which are not addressed in the risk assessment by ETBA method. Based on the results of this study, identifying the causes and characteristics of accidents, the places where most of the accidents happen, the type of accident, the characteristics of the body organs injured along with identifying the existing energies in the industry can provide an appropriate controlling solution to prevent the release of energy and the occurrence of accidents.

Conflict of interest

The authors did not report any contradiction of interests.

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