The Implementation of Operational Risk Management for Reducing the Risk Priority Number in the Metalworking Company

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Abstract. There were 47 work accidents at the studied manufacturing company from 2014 to 2016. The highest number of work accidents occurred in metalworking processes such as forging and casting, where as many as 22 work accidents, or 46.8% of the total number of work accidents, occurred. So it is necessary to identify the causes of work accidents and control the risk of operational work accidents. Accidents that occur include being squeezed, bumped, run over, punctured, cut, scratched, hit by an explosion, involved in traffic accidents, and others. So this study aims to prevent these types of accidents. This study applied hierarchical risk control methodology to provide risk control and reduce the Risk Priority Number (RPN) value for each work activity that has the highest number of work accidents. Recommendations that can be implemented are engineering control, administrative control, and PPE control for melting, furan, disamatic, fettling/clearing, and finishing workstations. The results of the proposed risk control resulted in a decrease in the RPN at each workstation.

Keywords: Work Accident Risk, Operational Risk Management, Hierarchy of Controls, and Risk Priority Number

33. Introduction

Occupational health and safety (OHS) concerns are critical to both society and business. Every year, over 2.78 million people are killed in work-related accidents, and there are approximately 374 million non-fatal work-related injuries, each resulting in more than four days of absence from work [1]. Both management and employees are responsible for ensuring the safety of the working environment. Providing a safe workplace is insufficient if employees do not share the same safety principles [2]. Conditions of work play a central role within the enterprise as determinants of workers' safety, health, and wellbeing [3]. For the company, properly managed health and safety programmes are created with

a favourable and attentive outlook. These programmes can lead to increased productivity while decreasing absenteeism, health expenditures, penalties, and a number of lawsuits [4]. The company already has a division for occupational safety, health, and the environment, where a zero-accident delivery program has been launched. However, because workplace accidents still occur, this program has not been continuously implemented. The company also has a team of Occupational Safety and Health Development Committee members, which implements the policy within the company. However, there are those who have not actively carried out their duties and obligations for the success of the company's policy.

The failure effect is the immediate impact of a failure on operation, function, functionality, or status as perceived or experienced by the user. Some of the consequences include user injury, inoperability of the product or process, deterioration in product quality, noncompliance with specifications, stench and noise emanation, etc. [5]. Failure mode and effects analysis (FMEA) is typically used to analyse manufacturing and assembly processes at the system, subsystem, and component levels. This type of FMEA focuses on potential process failure modes caused by manufacturing or assembly process flaws. FMEA is one of the most effective management tools to analyse potential failure modes within a system under uncertain conditions. FMEA is useful for categorising failure by identifying the likely risks that lead to failure [6]. In general, the potential risk factors for each failure mode assessment are occurrence (O), severity (S) [7], and detection (D). "O" represents the possibility of failure. The letter "S" denotes the severity of the failure. The letter "D" represents the possibility of detecting a failure. [8]. A cross-functional team rated these three risk attributes on a scale of one to ten for each failure mode. These ratings are multiplied to determine the desired RPN. RPN assists in identifying failure modes with a higher severity rating, higher occurrence, and rarer detectability, which can lead to determining the highest risk level [9].

According to the studied company's historical data, it was recorded that there were 47 work accidents from 2014 to 2016. These accidents occurred in several business units and divisions, one of which was in the forging and casting process, with 22 worker accidents in the metalworking process. In the work accident history data documented in 2014 to 2016, it can be seen the types of accidents experienced by workers, including pinched, bumped, run over, punctured, snipped, scratched, struck/ gotten hit by an explosion, traffic accident, and others. Therefore, to prevent and avoid the accidents mentioned above, it is necessary to have good safety management, as well as implement and control hazards. The following are steps that can be taken to support these goals:
- Conduct cause analysis and work accident risk mitigation by considering the current condition of the company's production system.
- Create a risk management plan based on the risk control hierarchy.
- Calculating the new RPN based on the results of the analysis of the work accident risk improvement design


34. Methods

Field studies are carried out through direct observation and field assessment on the company's occupational safety and health conditions, potential hazards, and how many accidents occur. Then, we conducted structured interviews with workers and members of the Occupational Safety and Health Development department. We also collected work accidents from 2014 to 2016 including their accident scenarios. After analysing the conditions of the existing OHS implementation the occupational accident data, this study calculated the risk priority number (RPN). RPN is determined by three parameters: the severity of the failure's effect, the probability of occurrence, and the ease of detection for each failure mode. RPN is calculated by multiplying these three numbers together according to equation 1.

$$RPN = S \times P \times D \qquad\qquad (1)$$

where S is the severity of the effect of failure, P is the probability of failure, and D is the ease of detection.

RPN may not play a significant role in the selection of an action against failure modes, but it will assist in indicating the threshold values for determining the failure modes that we need to focus. In other words, a failure mode with a high RPN number should be given the highest priority in the analysis and corrective action. Figure 1 depicts the relationship between the previously mentioned FMEA parameters.
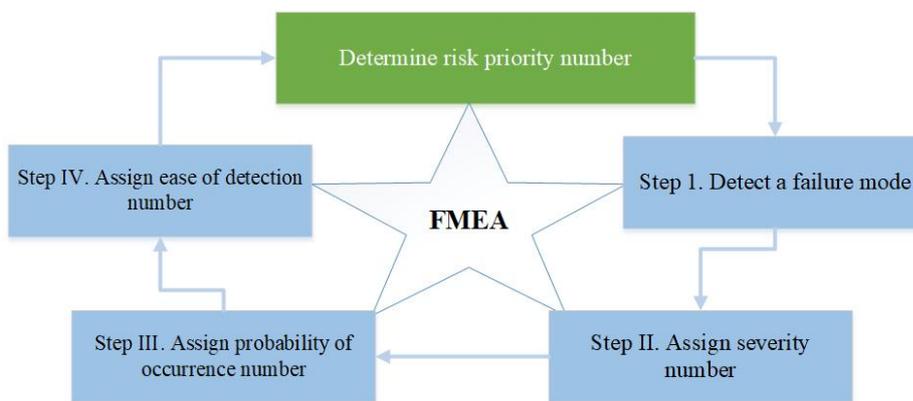
Figure 1. The Five Basic steps of FMEA

2.1. Metalworking process

The research was conducted in a company's department that produces cast products by using five machines to manufacture the cast products. These machines include an induction furnace with a capacity of 2 tons, a disamatic machine, a mold shaking machine to separate the mold from the casting object (engine), a shot blasting machine, a welding machine, and a grinding machine. Metal processing is divided into five work step, as illustrated in the diagram on Figure 2.
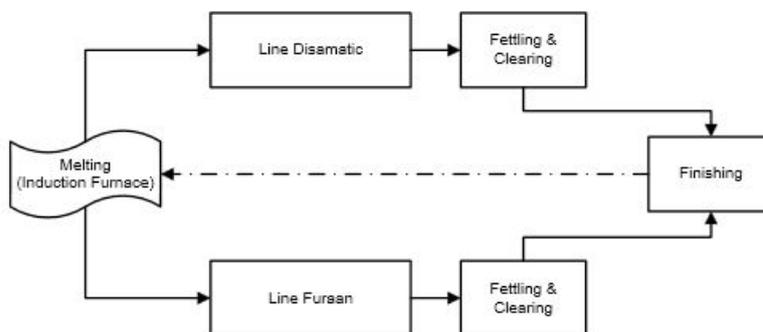
Figure 2. Metal Processing

1. Melting (Induction Furnace)

Scrap metal is melted into metal slurry at the melting work station. The smelting process is carried out in three combustion units. These units are heated by an induction furnace MF 2000 engine with capacity of 2 tons per hour and an induction furnace MF 500 unit with capacity 500 kg/hour. Steel cranes equipped with magnets are used to transport scrap around the burning area. The cranes at the Melting Area work station can lift to 3.2 and 6.3 tons. Each crane is controlled by a single operator, who uses a remote control located both beneath and above the crane. This station also includes a ladle, which is used to pour the melted product into the mold.

2. Disamatic workstation

The Disamatic work create molds automatically using a disamatic molding machine and casting process. The resulting mold has a relatively small size. Disamatic molding machine can print 150 parts per hour without a core and 100 parts per hour with a core. After the mold is ready to be poured into the induction combustion melt, the casting process begins. After the product is completed, the remaining molding sand is recycled as a mold-making material.

3. Furan workstation

The furan work station is where molds are made and casting processes are carried out. A furan machine is used to make the molds. This machine can print molds six times per day. In general, these workstations could generate large amounts of output.

4. Fettling & Clearing workstations

At the fettling and clearing work station, the cleaning process is carried out on the casting results for removing the adhering sand.

5. Finishing workstations

Cast products that have been cleaned with a shot blasting machine are cut and smoothed at the finishing work station. Cutting is done with an electric welding device (arc welding), and a grinding machine is used to smooth out the casting results (for example, from mold cracks) that remain on the workpiece after the casting. There are 2 types of grinding machines used. For grinding castings produced at the furan work station, a hand grinding machine is used which could be operated flexibly by workers. While for casting objects at the Disamatic workstation, a fixed table grinder (surface grinding machine) is used.

2.2. Hierarchy of Controls

For determining recommendations for improving risk control at all workstations, this study employed the hierarchy of control principles. The approach is proposed by a national initiative leaded by NIOSH called Prevention through Design (PtD) which has goals to prevent or reduce work-related injuries, illnesses, and deaths through the inclusion of precautionary considerations in all designs that impact workers. The hierarchy of controls (Figure 3) is the operational strategy from the PtD. The idea behind this hierarchy is that the control methods at the top of the list are more effective and protective than those below them. The strategy will be used to develop and implement national PtD initiatives by the industry sector in four functional areas, such as research, education, practice, and industry policy.
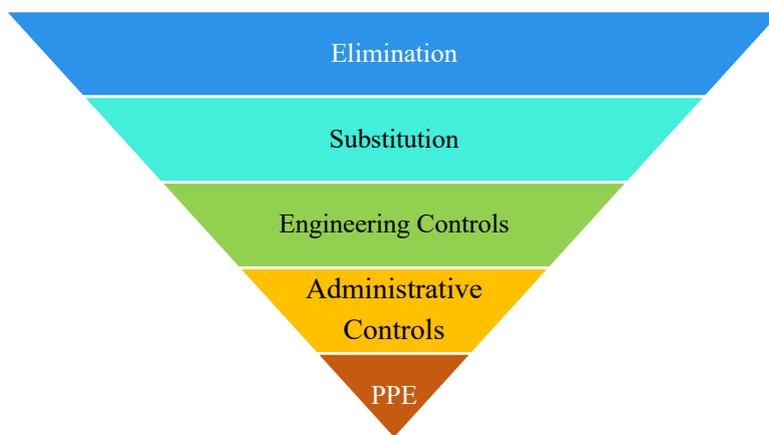
Figure 3. Hierarchy of Control

35. Result and Discussion

Based on data collection, a risk priority number is obtained at each workstation. Based on the results of the risk assessment carried out for each work activity as shown in Table 4, the station with the greatest level of risk is the melting area workstation with a total risk level value of 192. The risk of workers experiencing work accidents is caused by the physical environment that can cause work accidents. After that, the work stations that have a large risk are the furan line and the disamatic line, where each has a total risk value of 126 and 124, respectively. The risk value for the finishing work station is 85, and the risk value for the fettling and clearing work station is 54. This assessment serves as a guideline for making improvements and managing identified risks.

Table 4. Risk Assesment at the workstations

Station	Workstation	RPN
1	Melting Area	192
2	Furan Line	126
3	Disamatic Line	124
4	Fettling/Clearing	54
5	Finishing	85

Activities that have a large risk value are obtained by looking at the results of a risk assessment, where each activity has a different RPN value depending on the number of potential hazards that cause risk and hazard exposure that may occur to workers. Controls that need immediate action are activities that have an RPN value of 4-5. Data on work accidents that occur in metalworking companies can be grouped according to the type or nature of the accidents that occur, as shown in Table 5. The characteristics of these accidents are based on the type of activity that causes a worker have work accident.

Table 5. Work Accidents

| No. | Accident | Periode (year) | | | Total |
		2014	2015	2016	
1	Truncated	1	0	0	1
2	Finger Torn	2	1	1	4
3	Scratched	1	1	0	2
4	Pinched	7	3	0	10
5	Struck Down	6	3	2	11
6	Metal Splash	1	0	1	2
7	Run over	1	0	0	1
8	Explosion	1	0	0	1
9	Traffic	1	3	4	8
10	Punctured	0	1	0	1
11	Collide	1	3	2	6
12	Another Accident	0	0	0	0
	Total	22	15	10	47

From the data on work accidents in Table 5, it can be seen that work accidents in metalworking companies are dominated by being struck down by 11 cases and pinched by 10 cases. Due to the fact that it is necessary to design engineering that improves tools and processes, with a focus on equipment that can cause workers to be struck down or pinched, the data can be used as evidence for study and analysis. Furthermore, the provision of personal protective equipment to workers at risk of being pinched and struck down, such as helmets and gloves that are adapted to the functions and needs of workers in carrying out their work, requires attention. The contact of workers with the machines used is a factor that causes many workers to face accidents. Risk management is used to reduce the number of accidents and thus avoid workplace accidents. based on the calculation of the risk RPN in each work activity at each work station. The four elements will obtain a risk-management programme that will inform the risk management of the overall health and safety programme, which will include a strong management commitment to workplace health and safety and to building and sustaining an effective health and safety programme; employee engagement in the workplace health and safety programme; and effective measures for documentation, communication, and training [10].

Table 6. Risk Management

Workstation	Activities	Proposed Improvements

		Engineering Controls	Administrative Controls
Melting Area	Cutting scrap with oxyacetylene	Isolating oxygen and acetylene cylinders	Provide warning boards, the use of personal protective equipment (PPE), and information on hot molten metal, molten metal splashes, and molten metal hazards.
	Melting Scrap with an Induction Furnace	Installing alarms, sirens, and warning lights when smelting, and designing induction furnaces by adding hinged lids and water-cooled copper coils.	
Furan Line	Prepare the mould frames, make patterns, and fill with sand.	Add a push button or two-handed button, isolate the area when the coating process	Provide warning signs; workers must wear PPE and be aware of signs warning of hot molten metal hazards, as well as noise and dust hazards.
	Filling the mould with molten metal	fills the mould with melted metal	
	Separation of sand moulds from castings	Make a cover to protect the Shake Out/Sand Reclaimer machine,	
Disamatic Line	Filling the mould with molten metal	Install alarms, sirens, and warning lights at the time of smelting. Make a guardrail.	Provide warning boards for chemical hazards, noise hazards, and dust hazards.
	Separation of sand moulds from castings	Create local exhaust vents.	
Fettling/Clearing	Operate the shot-blasting machine.	Repair of existing blowers, installing engine vibration dampers with rubber bearings.	Provide noise and dust exposure warning boards.
Finishing	Cutting parts with electric welding (arc welding)	Make a solid foundation. Perform the insulation welding process.	Provide warning boards using personal protective equipment.
	Smooth the part with a grinding machine.	Modification of the hand grinding machine by putting a cover on the grinding head	

The proposed improvements, as shown in Table 6, focused on improvements in terms of engineering and administrative controls. The lower incidence of occupational accidents in the company indicates that effective OHS training has been provided for the workers. As a result, it is critical to increase OHS precautions, training, and audits [11]. Engineering solutions either control or place a barrier between a worker and a hazard. Engineering controls that are well-designed are typically independent of worker interactions or are easily integrated into tasks and provide a high level of protection. According to the OSHA Hazard Communication Standard (HCS), at a minimum, training should: give employees a good level of awareness about the potential exposure hazards; Inform employees of knowledge gaps where hazard information is lacking or unknown, explain how to use

personal protective equipment (PPE) correctly, and review the importance of cleaning contaminated surfaces or clothing [12]. Based on the risk control hierarchy, it was found that the RPN value decreased at each work station, which was quite significant.

Table 7 is the summary data for the total RPN value from the results of the proposed improvement.

Table 7. Results of the improvement

No	Activity	RPN
1.	Melting Area	120
2.	Furan Line	86
3.	Disamatic Line	80
4.	Fettling/Clearing	39
5.	Finishing	56

Nevertheless, this study has some limitations. First, we have not considered the financial consideration in improving the studied company's occupational safety and health system. Considering financial aspects in developing safety improvement programs will help highlight the opportunities and challenges in their implementations. Next, this study focuses on engineering, administration, and personal protective equipment improvements among the five levels of hazard controls. Third, the health protection of workers has yet to be explicitly considered in this study. For future studies, we suggest considering the factors affecting the working environment and specific demographic characteristics (such as, age, sex, health state, tribes) in determining workers' health situation and evaluating healthy behaviours. Sociodemographic characteristics such as elderly, divorce or single status, and female gender could also be identified as influential factors. Longer work hours, occupation type, a lack of good physical workplace conditions, and unemployment have all been identified as negative factors in health behaviour [13]. A variety of safety, health, and well-being outcomes are influenced by the design of a job, including the tasks, work processes, demands, work hours and shifts, and the extent to which physical, cognitive, and emotional efforts are required of the job [14].

36. Conclusion

The results of this study obtained a new RPN value based on an analysis of improvements in work accident risk reduction at five work stations. The results of this risk control proposal can reduce the RPN value at each work station, consisting of smelting, furan, disamatic, fettling/clearing, and finishing work stations. The decline in the RPN value was influenced by proposed improvements to administrative, technical, and personal protective equipment (PPE) risk management, and it would be even better if workers were disciplined and cared about their own safety and the surrounding environment, for a smooth production process and company profits. A good health and safety programme can increase productivity and efficiency and should not be considered an additional burden but a key component of good business culture.

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