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HAZARD IDENTIFICATION AND RISK ANALYSIS IN REBAR ROLLING PLANT

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Abstract: Employees are constantly in action for the production of goods and services in workplaces. These workplace activities affect the physical and mental health of the employees and cause occupational accidents. Elimination of these negativities is possible with the implementation of occupational health and safety services. Safety organisation is also very important in steel rolling mills so that employees are not exposed to danger. As in any other industry, steel rolling mill workers work with dangerous machinery that causes injury, disability and death. Safe working is an integral part of risk management. Risk management is the process of taking and implementing action to reduce the possibility of an assessed risk occurring. Therefore, known or tolerable risks are managed. In safe workplaces, productivity is high, work accidents and occupational diseases are low. Safe workplaces are only possible with risk management. In this study, the rolling mill area of a workplace producing rebar with the Fine-Kinney Method was analysed and the necessary precautions were listed. These measures are generally listed as; implementation of control protocols for the routine operation of the process, providing necessary occupational health and safety training for the personnel, providing the necessary information, repeating the training at regular intervals, following up the protective clothing and equipment to be used in the process, maintenance/repair of the units and the tools used. As a result of these measures, the degree of risk will be reduced to acceptable levels.

Keywords: Rebar, Steel rolling mill, Occupational health and safety, Fine kinney method, Risk management

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1. Introduction

Due to its high strength, steel is used in all construction works (infrastructure and superstructure), transportation vehicles (ships, trains, cars, etc.), electrical devices and machines, and the weapon industry. The steel used in the construction industry is used as the skeleton of the structure in order to increase the strength of the concrete. While concrete is being used, it remains under tensile and compressive forces. Although the compressive strength of concrete is high, its tensile strength is quite low. Therefore, the concrete that cannot withstand the tensile force cracks. In order to prevent the formation of these cracks and to increase the resistance against tensile strength, steel rods called reinforcement are placed in the concrete. This new element formed is called reinforced concrete. In reinforced concrete, concrete and steel must work together, otherwise the structural element will crack and collapse will occur. Steel has another advantage in the reinforced concrete element; The expansion coefficients of concrete and steel are very close to each other and thermal stresses will not occur in the building element in case of temperature change (Chevreau, 2008). The steel rods used in reinforced concrete are called passive reinforcement, and the steel used in prestressed concrete is called active reinforcement since the structure is stretched before being subjected to loading. Passive reinforcement should be high in tension and ductile in order to be easy to form.

Rebars used in the construction industry are obtained by rolling billets. These billets are obtained from iron ore through blast furnace converters or by melting scrap materials in crucibles. Rebars are produced as round or ribbed with intrusions on the surface. The main purpose of the intrusion is to increase the adherence with the concrete. This adherence is vital for structures against large impact loads during an earthquake (Hafida et al., 2017).

Two common processes are used in steel production: basic oxygen steelmaking (BOS) and electric arc furnace (EAF) steelmaking. In the BOS process, iron ore is first melted in a smelting furnace and transferred to the converter to become steel. After high-speed spraying of oxygen, impure elements are removed and conversion to steel occurs. Because the investment cost is very high, the BOS process is used in large steelmaking businesses with an annual output of several million tons (Hammi and Bouacheria, 2015).

The EAF process, in which scrap is used as raw material for steel production, is a preferred production process today due to its contribution to the environment. Scrap

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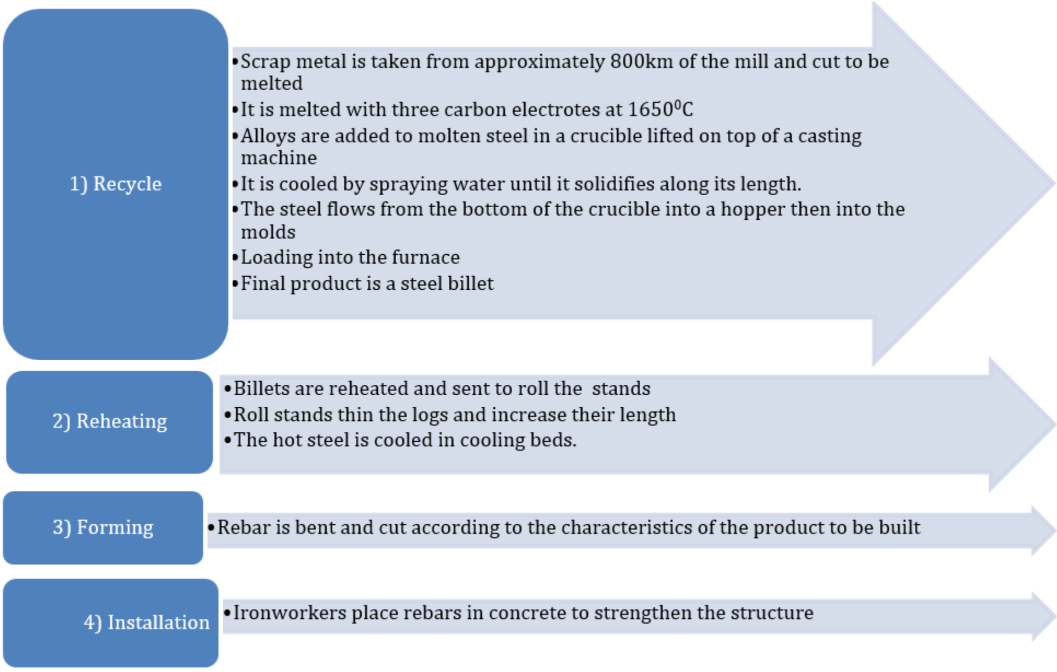
metal is first cut to be melted and brought to the furnace. In the furnace, the scrap is melted by giving heat through the electrodes. Since 0.5-1 million tons of steel is produced annually with the EAF process, it is especially ideal for small-scale production processes where rebar is produced. The EAF process is linked to a specialist rolling mill capable of producing reinforced concrete bars (Kumar, 2021). As a result of such production, the rebar cooled in the cooling beds is packed for delivery and sent to the area to be built. It is installed in the area where the concrete will be poured by cutting and shaping in accordance with the project by the employees (Figure 1).



- Scrap metal is taken from approximately 800km of the mill and cut to be melted
- It is melted with three carbon electrotes at 1650^{0}C
- Alloys are added to molten steel in a crucible lifted on top of a casting machine
- It is cooled by spraying water until it solidifies along its length.
- The steel flows from the bottom of the crucible into a hopper then into the molds
- Loading into the furnace
- Final product is a steel billet

- Billets are reheated and sent to roll the stands
- Roll stands thin the logs and increase their length
- The hot steel is cooled in cooling beds.

- Rebar is bent and cut according to the characteristics of the product to be built

- Ironworkers place rebars in concrete to strengthen the structure

Figure 1. Process flow chart for rebar obtained from steel scraps.

1.1. Definition of Rolling Process

Rolling is used to shape ferrous and non-ferrous metals. The rolled shapes of metals can be like a plate, beam, channel, rail, angle iron, flat and ribbed bar. In the rolling process, the steel is passed between rotating cylindrical rollers (rolls) and plastic deformation is provided (Seuren et al., 2014). There is a fixed distance between the rollers and the system is rotated by the drive system consisting of motor, gearbox, shaft and coupling (Caprilli et al., 2021). The distance between the rolls is less than the thickness of the entering material, and the material entering from one side comes out thinner from the other side. In order for the material to take the desired final shape, it may be necessary to pass it through the rolls several times (Groche et al., 2010).

Hot and Cold Rolling Processes: According to the processing temperature, rolling is classified into two categories as (i) hot rolling and (ii) cold rolling:

Hot rolling: During this process, the material is rolled above its recrystallization temperature. This has two advantages. Since the deformation capacity of the material will increase at the specified temperature, less force will be applied and a smaller rolling stand will be enough. The second advantage is that the desired deformation can be obtained without hardening (Utsunomiya et al., 1998).

Cold rolling: In cold rolling, in contrast to hot one, the material is formed below the recrystallization temperature or at room temperature. Since strain hardening occurs during this process, the degree of deformation of the material increases, while its strength also increases. This type of rolling is used to produce flat products such as plates, sheets and strips (Ray, 2016).

1.2. Hazards in Steel Production Workplaces

The steel production sector contains many hazards and risks such as crushing, injury and burning. Therefore, safe working procedures are important. Especially in recent years, many steel companies have adopted a zero work accident and occupational disease policy (Basu et al., 2004). The reason for this is not only the result of a conscientious responsibility or awareness. This is also a legal requirement. Therefore, many steel production companies are in search of excellence in occupational safety. The aim is to achieve zero accidents, zero occupational disease, zero loss of working days, and zero economic loss points (Zhang and Bay, 1997).

The current hazards to which workers in the iron and steel industry are exposed are generally as follows:

1. Physical hazards (noise, vibration, extreme temperatures, ionising and non-ionising radiation, insufficient lighting, insufficient ventilation)
2. Chemical hazards (vapours, gases, dusts and fumes, exposure to carbon monoxide (CO) gas, exposure to asbestos, contact with irritants, solvents, sensitizers and volatile organic carbon).
3. Ergonomic hazards (manual lifting and repetitive work)
4. Falling from high (slips, trips, falling from high and

from the same level, falling objects)

5. Electrical hazards (receive electric shock)
6. Fire hazard (burns due to accidental contact with hot molten metal, unprotected machinery, fire and explosion)
7. Hazards due to lack of organization and supervision (lack of effective supervision regarding the use of personal protective equipment (PPE), inadequate workplace inspections and accident/incident prevention programs, inadequate occupational health and safety training, and lack of effective communication and coordination between various occupational groups)
8. Hazards related to cooling water quality (algae, exposure to pathogens (legionella) (Vivek et al., 2015).

In this study, a risk analysis was carried out using the Fine-Kinney Method for risk assessment in the rolling mill section of a facility that produces construction equipment by hot rolling. The scores obtained according to the risk analysis were ordered from high to low and suggestions were made in order to provide a safe working environment for the employees. If the suggestions presented are carried out, the value at which the risk score will decrease has been recalculated.

2. Material and Methods

2.1. Workspace and Workflow Chart

In the facility chosen as the working area, the drawing-rolling of the reinforcements used in the constructions is carried out. The facility has approximately 1500 employees. The facility has a daily production capacity of approximately 6000 tons of steel billets in its foundry and 4000 tons of ribbed and flat round rebar in its rolling mill. Flat and ribbed reinforcing steel with a diameter of 8 - 40 mm is produced at the facility.

In the production of flat and ribbed rebar with a diameter of 8-40 mm; 130x130, 140x140, 150x150 mm steel billets are used. Iron billets, which have been calculated and cut according to their quality and length, are subjected to the annealing process in the furnace using natural gas as fuel. During this process, the oven is heated up to 1150°C-1300°C. The furnace is a push type furnace; (the logs are stacked side by side and pushed towards the exit with a hydraulic pusher) the annealing time is between 2.5 and 3 hours on average for a billet. In order to obtain the necessary heat for this, natural gas and the air coming from the furnace fan are combined in the burner to burn.

The billets coming to the rolling mill with trucks are brought to the area to be stacked with gantry cranes. Lifting magnets are used in cranes to lift billets. The fact that the magnets have been preferred in such a way as to prevent the deterioration of their magnetism even if the electric current is cut off, is very important for the safety of the log and the safety of the employees. There is a very strong electromagnet field around the magnet and in this way the billets are lifted by the gantry crane and brought to the annealing furnace (Bluff, 2014).

Billet irons, which became incandescent in the annealing furnace in the rolling mill, undergo crushing, drawing and elongation deformation in various rolling stands. Since the width of the annealing furnaces in the rolling mills is usually 6 m; the 12 m long billets coming from the steel mills or through imports must be cut to length. This cutting process is done with an oxy-LPG cutting apparatus if the billet is cold, and with hydraulic shears if it is directly incandescent in connection with the steelworks. The cut logs are pushed into the annealing furnace with the help of a mechanism (Lohmar et al., 2014).

The flattened material is then drawn in the system with 6 rolling stands. After leaving this system, there is an intermediate group rolling stand, which consists of two stands. Intermediate group pre-bench material again enters the cutting shears. After the intermediate group stand, there is the finishing rolling stand group. After this group rolling stand, the construction rods take their final shape (Ikumapayi et al., 2020).

The rods, which take their final shape, enter the Thermex unit, where the outer surface hardens and the core part retains its hardness. Pressurised water with a temperature of about 20°C circulates in this unit. After the Thermex unit, there are flying shears. The flying shears allow the material to be cut in accordance with the length of the cooling platform. The cooling platform is a scalloped mechanism in which the rolled and brought to the desired diameter construction bar is cooled (Jenkouk et al., 2012).

The material coming to the cooling platform goes through quality control. Various tests are made on the material and its dimensions are checked (Figure 2). The irons coming out of the platform are cut in 12 m lengths by cold shears. From here, the irons coming to the transfer table are counted and the number that should be in the package is adjusted. The irons are packed in flat or hairpins and brought to the stock area or shipped directly for sale (Hirt and Senge, 2014).

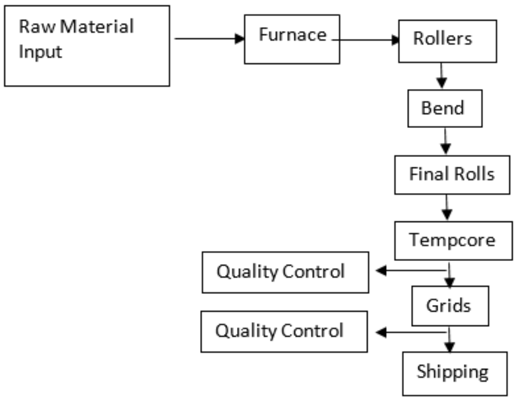


Figure 2. 8-40 mm diameter straight and reformed rebar work flow chart.

2.2. Fine-Kinney Method

In this study, the precautions that can be taken by carrying out a risk analysis study were evaluated in order to prevent work accidents and occupational diseases that may occur in rolling mills during the production of rebars used in rebar structures. Fine-Kinney method was used for risk analysis. This method was first suggested by Fine in 1971 (Fine, 1971), then it was reconsidered by Kinney and Wiruth in 1976 and turned into a more detailed risk analysis method (Kinney and Wiruth, 1976).

Much as these resources are old, it is still a method that experts and analysts use actively. In the method, the risk score (R) is obtained by multiplying the three risk factors; these are Frequency (F), Probability (P) and Intensity (I). ıts formula is: R= F*P*I.

The greater the exposure to a potentially hazardous situation, the greater the risk, of the factors required for calculating the risk score in Table 1, Table 2, Table 3 and Table 4. To ensure this, a value of 1 is assigned to an extremely rare exposure, perhaps only a few times a year. A value of 10 is assigned for continuous exposure (Table 1).

For Probability factors, they range from a value of 10 for an almost impossible event to a value of unity for an unexpected but remotely probable event, and a value of 10 for an expected event (Table 2).

Damage from a dangerous event can range from minor damage that is barely noticeable to catastrophic. This very wide range is accepted as a range exceeding twenty years in numerical values. Thus, a reference value of 1 for detectable and 100 for disaster is assigned (Table 3).

Risk score 20 represents an accepted low-risk situation. Such a risk is much less than the risks we normally accept in everyday situations, for example, when driving to work, mowing the lawn with a lawn mower or riding a bicycle for exercise. A condition with a risk score between 70 and 200 is a condition with significant risk for which correction is necessary. A risk score between 200 and 400 indicates that correction is urgently needed. A very high risk score above 400 indicates a situation so risky that stopping the operation should be considered, at least until temporary measures are taken to remedy the deficiency or if the operation cannot be made safe, perhaps permanent shutdown may be necessary (Table 4).

Table 1. Frequency classification

Frequency (F)	F Value
Continually	10
Frequently (Once a day)	6
Occasionally (Once a week)	3
Not Often (Once a month)	2
Infrequent (several times a year)	1
Very Rare (Annually or less frequently)	0.5

Table 2. Probability classification

Probability (P)	P Value
Expected / Certain	10
Quite possible (50%-50%)	6
Infrequent but possible	3
Low probability but possible	1
Very unlikely, not expected	0.5
Practically Impossible	0.2
Almost impossible	0.1

Table 3. Severity classification

Severity (S)	S Value
A Disaster with Many Deaths	100
Accident involving multiple death	40
Very Serious Injury which may cause Death.	15
Serious injury (limb loss, permanent health problems/incapacity)	7
Significant Injury (external first aid required)	3
Minor Injury, need first aid	1

Table 4. Risk classification

Risk (R)	R Value
Very Big Risk: Necessary measures should be taken immediately and stopping the process should be considered.	R> 400
Fundamental Risk: Immediate action must be taken	200≤R≤400
Significant Risk: Needs precaution	70≤R<200
Possible Risk: Process should be implemented under supervision	20≤R<70
Minor Risk: Prevention Is Not Priority	R<20

2.3. Risk Assessment

2.3.1. Identification of hazards and degrees of risk

The risk analysis of the mill rolling section of the study area was made according to the Fine-Kinney method. Rolling department consists of 4 units, namely Rolling Mill, Mechanical Maintenance and Repair, Workshop and Quality Control Department. The risk levels of these units were determined according to the probability, frequency and severity values (Han-Kai and Jong-Ning, 2019).

In the rolling mill unit, there are 23 fields of activity in total;

1. Working in the environment,
2. Used Hand Tools and Other Devices,
3. Stacking the billet in the stock area,
4. Charging the billet from the grid to the furnace,
5. Movement and annealing of the billet in the furnace,
6. Discharge of the billet from the furnace,
7. Programmed Stop (stopping the process),
8. Transfer of the Billet to the Workbench,
9. Rolling the Billet,
10. Pass Change,
11. Runner, Drinker Change,
12. Rolling mill bend,
13. Thermex Process,

14. Sending the rod to the Cooling platform,
15. Rod coming from the cooling platform,
16. Transfer of the Rod to the Cold Shears,
17. Transfer of the Rod from the Cold Shears to the Tying Machine,
18. Hairpin Making,
19. Loading the Product to the Vehicles,
20. Stacking of the Products,
21. Dyeing the Ends of Irons,
22. Storage of Dye Beck,
23. Loading Packages to the Vehicle

According to these fields of activity, 29 hazards have been identified. Of these hazards, 11 were identified as "No Tolerance Risk", 15 as "Major Risk" and 3 as "Significant Risk" (Supplementary Table 5).

2.3.2. Corrective/preventive actions

The risks that may occur in the rolling unit during the production of rebar have been determined in the table above. Corrective/preventive actions that can be taken against these risks are listed below:

1. Due to the hot working environment, the working hours of the employees in this environment will be reduced, local ventilation fans will be placed in some areas, and air-cooled warm environment clothes will be provided to the employees when necessary. The climate value of the environment will be kept under constant control.
2. Worn out hand tools and all other equipment will be replaced with new ones and periodic controls will be made.
3. The rotating parts of the machines will be enclosed, the machines will not be approached as much as possible during the production flow, they will be surrounded by barricades and warning signs will be placed, and necessary training will be given on the subject.
4. The cables of power tools will not be attached and exposed, they will be enclosed.
5. In order to prevent the billets brought to the stock area from falling from the truck, a fall prevention protection will be provided to the truck chassis, the surrounding of the truck will be closed to human entrance, and necessary training will be given on the subject.
6. The crane carrying the billets will be carried by those who have an operator certificate, and one person will be assigned to control the billet during transportation.
7. During the loading of the billet onto the furnace loading platform, the protruding tie wires remaining on the billets will be cut from the bottom and corrected with a hammer to prevent snagging.
8. A person will be assigned to ensure that the billet is properly placed on the grid.
9. In order to prevent unbalanced annealing of the billet in the furnace, the annealing temperature will be controlled from the control panel and training will be given on the subject.
10. Since it may cause injuries when the billet is loaded in the furnace exit, guards will be made on the edges of the belt at the furnace exit, the employees will stay at a certain distance and the necessary training will be given.
11. According to the intensity of the light emitted by the furnace, a screen protector of appropriate darkness will be placed on the glass, and eye protection will be provided for the furnace workers.
12. During the programmed stop of the process, warning signs will be posted and unauthorized persons will be prevented from entering this area.
13. In order to prevent the billets from falling on the relay path, a guarded passageway will be established on the relay path.
14. During the whole process, employees will stay at a certain distance from the process, personal protective equipment will be used, and rolling mill operating instructions will be communicated to all employees.
15. Heavy runners will not be allowed to be carried by hand, they will be carried with mechanical equipment and experienced people will be assigned for this job.
16. At the rolling mill bend, the area where the embers can spread by whipping will be surrounded by mobile barricades and warned.
17. Railings in accordance with the standards will be built around the water pits on the sides of the Thermex unit, which reduces the temperature of the outer surface of the iron and causes it to harden by giving pressurised water to the hot rolled and ember rebar.
18. After the Thermex unit, the irons cut in the desired sizes by flying shears come to the cooling platform. Metal armour of a certain height should be used to prevent the splashing of iron coming at high speed on the railway leading to the cooling platform, and there should be no openings at the joints of these metal armours. Openings will be repaired immediately.
19. One person works continuously on the cooling platform. This person takes the curved and short irons on the platform by pulling them with the iron clamp. The curved ones are cut into small pieces by cutting them with iron cutters. These iron cutters will be checked frequently, worn cutters will be replaced with new ones to prevent the compressing of fingers.
20. While the irons coming from the cooling platform and falling to a certain temperature are cut in 6 m length in the cold shears, the leftover irons are poured into the boiler under the cold shears. While this boiler is being transported by crane, employees will be prevented from being under load and it will be ensured that the iron that splashes around during cutting will be collected

frequently in terms of ground safety.

21. Separation of the irons that are counted automatically with the help of an automatic counting machine is made by automatic separators with triangular cross sections that suddenly rise from bottom to top. Employees will be warned to prevent these separators from hitting the people there.
22. Dyeing masks will be provided to the employees in order to prevent occupational diseases during the dyeing of the ends of the listed irons before they are packaged, and their working hours will be shortened.
23. It will be ensured that the paint cans are not left open and the lighting system of the room where they are stored will be ex-proof.
24. During the loading of the prepared iron packages to the truck, the driver of the truck will not be in the vehicle and will work in accordance with the instructions.

3. Results and Discussion

In order for steel rolling mill employees not to be exposed to work accidents at work and not to get occupational disease, it is important to identify and recognize the existing hazards, risks such as injuries and health problems that they may be exposed to. In this study, a risk analysis of the rolling mill of a facility that produces construction iron in Mersin was conducted. As a result of the risk analysis, a total of 29 risks were observed, 11 of which are intolerable risks, 15 of which are fundamental risks, and 3 of which are significant risks. Risks with a score of less than 70 that should be monitored and determined as acceptable are not considered here. Considering the risks that may arise from the existing hazards in the facility, the cause of the problem is that the operating instructions of the rolling mill were not communicated to the employees and that the employees were not given sufficient information and occupational health and safety training about the risks of their work. However, the reason for providing occupational health and safety training to employees in workplaces is to obtain noticeable results in minimizing work accidents and occupational diseases as well as to create a safety culture in the workplace. Therefore, in workplaces with a high degree of risk, such as rolling mills, the guards of moving or rotating machines are attached. It is very important to cover the edges of the process path and passageways with a protector, to keep the personnel at a certain distance, to place the necessary warning signs, to ensure the use of personal protective equipment, and to provide information and training to employees about occupational health and safety risks. Even if the necessary precautions are taken for the risks in the workplace examined within the scope of this study, the risks will not be reduced to the level of possible or insignificant risk. Implementation and monitoring of corrective/preventive actions will continue.

Author Contributions

A.U. (50%) and G.U. (50%) design of study. A.U. (50%) and G.U. (50%) data acquisition and analysis. A.U. (50%) and G.U. (50%) writing up. A.U. (50%) and G.U. (50%) submission and revision. All authors reviewed and approved final version of the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

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