Analysis of Potential Occupational Accident Risks In The *Leaf Spring* Production Heating Process Using The HIRARC Method and *Job Safety* Analysis (JSA) At PT XYZ

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Abstract.
The heating process in leaf spring production involves high working temperatures, hot materials, and moving machinery that may cause occupational accidents. This study aims to identify hazards, assess risk levels, and formulate risk controls in the heating process at PT XYZ. by integrating Hazard Identification, Risk Assessment and Risk Control (HIRARC) with Job Safety Analysis (JSA). Data were collected through direct observation, interviews, and questionnaires administered to five production operators from 3 August to 14 September 2026. JSA was used to break the work down into ten job steps across three process stages (Heating Furnace, Press Quenching, and Tempering Furnace), while HIRARC was used to rate risk with R = L × S based on the mode of questionnaire scores. Nine hazards were identified: seven were medium risk (R = 6; 77.78%) and two were high risk (R = 9; 22.22%), namely finger entrapment in the press quenching machine and entrapment in the tempering conveyor. A consistency check of severity scores against the worst credible consequences identified by JSA showed that operators' perceptions tended to underrate severity, moving four hazards (44.44%) into the high-risk category. Controls were arranged according to the hierarchy of controls, prioritising engineering controls (guarding, interlocks, and emergency stops), supported by administrative controls and personal protective equipment (PPE). Integrating HIRARC and JSA proved complementary: HIRARC ranks risk priorities, while JSA links each hazard to specific job steps and preventive actions.

Keywords: *HIRARC; Job Safety Analysis; occupational safety and health; heating; leaf spring and risk matrix.*

I. INTRODUCTION

The metal and automotive manufacturing industries are among sectors with a high risk of workplace accidents due to the use of heavy machinery, hazardous materials, and high-temperature production processes. In Indonesia, the Social Security Agency for Employment (BPJS Ketenagakerjaan) recorded an increase in workplace accidents from 221,740 in 2020 to 265,334 in 2022, with the manufacturing sector being a major contributor (BPJS Ketenagakerjaan). A literature review of ten journals from Indonesia and Malaysia concluded that the failure to use personal protective equipment (PPE), unsafe behavior, and inadequate work conditions were the dominant causes of workplace accidents.(Fadilah & Herbawani, 2022).

PT XYZ is an automotive spring component manufacturer in East Java, which produces leaf springs, among other things. In the leaf spring production process, the heating division has prominent risk characteristics because the material is heated in a Heating Furnace (around 880°C), formed and cooled rapidly in a Press Quenching, then reheated in a Tempering Furnace (around 470°C). Workers interact directly with hot materials, press machines, walking beams, conveyors, and supporting equipment.(Ma'ruf et al., 2022)This condition poses dangers such as burns, heat stress, entrapment, electric shock, slipping, and exposure to steam or gas.

Previous research at a similar leaf spring company found that in the Heating Furnace the danger of hot materials and walking beams was at a moderate level (value 6), while in the Press Quenching (peeled cables) and Tempering Furnace (conveyor) it was at a high level (value 16), and 25 work accidents were recorded in one year.(Setiawan et al., 2022)Another study in the steel industry found 10 hazards with 23 occupational accident and disease risks, five of which were high risk.(Imran, 2023)These findings emphasize the need for a systematic approach to identifying, assessing, and controlling risks in high-temperature processes.

The HIRARC method is widely used because it produces risk rankings and control recommendations based on a hierarchy of controls. However, HIRARC is generally structured per hazard type so that the relationship between hazards and the sequence of operator work steps is not always clear. Job Safety Analysis (JSA) addresses this need because it breaks down a job into steps, identifies hazards at each step, and establishes preventive measures. This study integrates JSA and HIRARC in the leaf spring production heating process at PT XYZ, with the objectives of: (1) identifying potential hazards at each work step, (2) assessing

the risk level of each hazard, and (3) formulating risk control recommendations based on the hierarchy of controls.

II. LITERATURE REVIEW

2.1 Occupational Safety and Health and Work Accidents

Occupational Safety and Health (K3) is a systematic effort to protect workers from the risks of work-related injury, illness, and death. The legal basis in Indonesia is Law Number 1 of 1970 concerning Occupational Safety and Government Regulation Number 50 of 2012 concerning the Implementation of the K3 Management System (SMK3), which requires companies to conduct hazard identification, risk assessment, and risk control.(Rojaya Simbolon et al., 2024). A work accident is defined as an unexpected and undesirable event that causes losses in the form of injury, damage to equipment or materials, or disruption to the production process, and the risk can be minimized through hazard identification and assessment using a risk matrix based on severity and likelihood.(Feriyansah et al., 2025). For hot and noisy work environments, threshold values and control requirements are regulated in the Minister of Manpower Regulation Number 5 of 2018 concerning Occupational Health and Safety (K3) in the Work Environment.

2.2 HIRARC Method

HIRARC (Hazard Identification, Risk Assessment and Risk Control) is a systematic method for identifying hazards in routine and non-routine activities, assessing the level of risk, and determining controls based on priority.(Amri Lubis et al., 2024). The hazard identification stage identifies hazard sources in each work area and task. The risk assessment stage assesses the likelihood (L) and severity (S) with a risk value of $R = L \times S$. The risk control stage establishes controls based on a hierarchy: elimination, substitution, engineering, administrative controls, and PPE. This hierarchy also forms the basis of risk control in the ISO 45001:2018 OHS management system standard and is consistently applied in various HIRARC studies, for example in warehousing.(Firman Hadi Setiawan et al., 2020)and ship repairs(Murenda, 2020).

2.3 Job Safety Analysis (JSA)

Job Safety Analysis(JSA), also called Job Hazard Analysis, is a technique that focuses on the relationship between workers, tasks, equipment, and the work environment. The procedure consists of selecting a job, breaking it down into sequential steps, identifying hazards at each step, and establishing preventive measures to eliminate or reduce those hazards (OSHA, 2002). Compared to HIRARC, JSA excels in linking hazards to specific work steps, while HIRARC excels in ranking priorities based on risk value. Therefore, the two can be used together: JSA as a basis for identifying each work step and HIRARC as a tool for assessing and prioritizing controls.

2.4 Heating Process in Leaf Spring Production

The heating process in leaf spring production consists of three stages. First, Heating Furnace: The cut spring steel bar is heated to an austenitization temperature of around 850–900°C to transform into a malleable austenite phase, with a soaking time regulated to ensure even heating without excessive oxidation or decarburization. Second, Press Quenching: The hot material is pressed with a mold to form a camber and rapidly cooled in an oil medium so that the austenite transforms into hard but brittle martensite. Third, Tempering Furnace: The material is reheated at a temperature of around 400–500°C to release internal stresses and reduce brittleness. Each stage involves heat, mechanical energy, and electrical energy, which pose a hazard to the operator.

III. RESEARCH METHODS

3.1 Type, Location, and Time of Research

This research is descriptive with a semi-quantitative approach. The research was conducted in the heating division of leaf spring production at PT XYZ., , during the implementation of the Internship from August 3 to September 14, 2026. The research was limited to the work safety aspects in the Heating Furnace, Press Quenching, and Tempering Furnace areas.

3.2 Data Collection

Primary data were collected through (1) direct observation of operator activities, machines, materials, and work environment conditions; (2) interviews with operators and parties familiar with the production process; and (3) a likelihood and severity assessment questionnaire using a 1–5 scale for five production operators representing the three stages of the process. The final likelihood and severity values for each hazard were determined based on the most frequently occurring value (mode) of the respondents' answers.

3.3 Analysis Stages

The analysis was conducted in five stages. (1) Job description (JSA): the heating process was described into sequential work steps based on the results of observations and interviews. (2) Hazard identification: at each work step, hazards, energy sources, and their consequences were identified. (3) Risk assessment (HIRARC): each hazard was assessed using the formula R = L × S using the scale in Tables 1 and 2, then categorized using the matrix in Table 3. (4) Consistency evaluation: the severity value of the questionnaire results was compared with the scale definition and the worst impact identified in the JSA. (5) Risk control: recommendations were compiled based on the control hierarchy and prioritized on high category risks without ignoring medium risks.

Table 1. Likelihood Scale

Scale	Category	Description
1	Rare	Almost never happens
2	Unlikely	Rarely happening
3	Moderate	It happens sometimes
4	Likely	Often occur
5	Almost Certain	Almost certain to happen

Table 2. Severity Scale (Consequences)

Scale	Category	Description
1	Insignificant	Does not cause injury
2	Minor	Minor injuries/first aid
3	Moderate	Moderate injury/requires medical attention
4	Major	Serious injury/partial disability
5	Catastrophic	Fatal/permanent disability

Table 3. Risk Matrix

L \ S	1	2	3	4	5
5	5 (S)	10 (T)	15 (E)	20 (E)	25 (E)
4	4 (S)	8 (T)	12 (T)	16 (E)	20 (E)
3	3 (R)	6 (S)	9 (T)	12 (T)	15 (E)
2	2 (R)	4 (S)	6 (S)	8 (T)	10 (T)
1	1 (R)	2 (R)	3 (R)	4 (S)	5 (S)

Description: R = low (1–3); S = moderate (4–6); T = high (8–12); E = extreme (15–25). Risk value = likelihood × severity.

IV. RESULTS AND DISCUSSION

4.1 Job Safety Analysis Results

Based on observations and interviews, the heating process is broken down into ten work steps spread across three process stages. Each step is linked to a hazard (coded H1–H9), consequence, and precautionary action, as shown in Table 4.

Table 4. Heating Process Job Safety Analysis Worksheet

No	Work stages/steps	Danger (code)	Consequence	Preventive measure
1	*Heating Furnace*: moving material (flat bar) to the furnace area using a forklift	Hit by material from a forklift (H3)	Severe musculoskeletal injury, head injury	Dedicated forklift and pedestrian lanes, load stability checks, signage, safety shoes
2	*Heating Furnace*: input of material into the furnace and is near the furnace	Hot material, heat radiation (H1)	Burns, heat stress, dehydration	Material handling aids, heat source isolation, ventilation, work-rest, hydration, heat-resistant PPE
3	*Heating Furnace*: material moves on the walking beam	Hit/pinched by walking beam (H2)	Musculoskeletal injuries due to impact	*Barrier*and safety zone markings, interlocks if available, SOPs, signage
4	*Press Quenching*: transfer of hot material from the furnace to the press	Hot material/surface contact (H6)	Skin burns	Transfer aids, access restrictions, heat resistant gloves
5	*Press Quenching*: material placement and press operation	Machine clamp point (H5)	Pinched finger/hand, amputation	*Guarding*, interlock, placement aids, no hands entering pinch point, training
6	*Press Quenching*: quenching in oil media	Hot material/oil splash (H6)	Skin burns, corneal irritation	Isolation/guarding, face and eye protection, SOP
7	*Press Quenching*: operation and maintenance of machine installations	Cable/electrical (H4)	Internal burns, cardiac arrhythmia, fire	Periodic inspection, cable repair, electrical protection, LOTO during maintenance
8	*Tempering Furnace*: material input via conveyor	Conveyor movement (H7)	Pinched or dragged fingers/hands, amputations	*Guarding*pinch points, emergency stops, inspections and preventive maintenance
9	*Tempering Furnace*: walk and clean the work area	The floor is slippery with scale and oil (H8)	Musculoskeletal injuries, back pain	Housekeeping (5R), scheduled cleaning, safe passage, signage
10	*Tempering Furnace*: monitoring in the furnace area	Chemical vapor/gas (H9)	Irritation of the respiratory tract and eyes, dizziness, shortness of breath	Ventilation/vapor extraction, training, respiratory PPE if necessary

Source: results of observations and interviews, processed by the author.

4.2 Risk Assessment Results (HIRARC)

The results of the likelihood and severity assessment based on the five operators' answer modes are presented in Table 5. All risk values are calculated using R = L × S and categorized using the matrix in Table 3.

Table 5. Risk Assessment Results Based on Questionnaire Mode

Code	Process	Danger	L	S	R	Category
H1	*Heating Furnace*	Hot material (burns, heat stress)	3	2	6	Currently
H2	*Heating Furnace*	Hit/pinched by walking beam	3	2	6	Currently
H3	*Heating Furnace*	Hit by material from a forklift	2	3	6	Currently
H4	*Press Quenching*	Exposed to electric shock	3	2	6	Currently
H5	*Press Quenching*	Finger caught in machine	3	3	9	Tall
H6	*Press Quenching*	Burns caused by hot materials	3	2	6	Currently
H7	*Tempering Furnace*	Stuck in the conveyor	3	3	9	Tall

Code	Process	Danger	L	S	R	Category
H8	*Tempering Furnace*	Slipping on slippery floor (crust and oil)	3	2	6	Currently
H9	*Tempering Furnace*	Exposed to chemical vapors/gases	2	3	6	Currently

Of the nine potential hazards, seven hazards (77.78%) are in the medium category with a risk value of 6, and two hazards (22.22%) are in the high category with a risk value of 9, namely fingers being caught in the quenching press machine (H5) and being caught in the tempering conveyor (H7). There are no hazards in the low or extreme categories (Table 6).

Table 6. Distribution of Risk Levels

Risk level	Amount	Percentage
Low (1–3)	0	0%
Medium (4–6)	7	77.78%
Height (8–12)	2	22.22%
Extreme (15–25)	0	0%
Total	9	100%

4.3 Severity Consistency Evaluation

The JSA identifies the worst credible consequence for each work step. These impacts are compared to the severity scale definitions in Table 2. Four hazards were identified whose severity values from the questionnaire were lower than the scale definitions. Amputation of a finger or hand (H5, H7) constitutes partial or permanent disability and is therefore equivalent to a scale of 4 (major) or greater, rather than a scale of 3 (moderate injury). Electric shock with cardiac arrhythmia (H4) does not correspond to a scale of 2 (minor injury/first aid), and severe musculoskeletal injury and head injury due to falling material (H3) correspond to a scale of 4. This adjustment is conservative because it uses a scale of 4 rather than 5, and the results are presented in Table 7 for sensitivity analysis, while the main results remain consistent with the questionnaire data in Table 5.

Table 7. Sensitivity Analysis of Severity Values

Code	Danger	S questionnaire	S according to scale	R start	R evaluation	Evaluation categories
H3	Hit by material from a forklift	3	4	6	8	Tall
H4	electric shock	2	4	6	12	Tall
H5	Finger caught in machine	3	4	9	12	Tall
H7	Stuck in the conveyor	3	4	9	12	Tall
H1, H2, H6, H8, H9	Five other dangers	still	still	6	6	Currently

After evaluation, four hazards (44.44%) were categorized as high and five hazards (55.56%) as moderate. This difference indicates that operator perception-based assessments tend to underestimate the severity of infrequent but high-impact hazards, so control priorities should be based on a combination of questionnaire results and the worst-case scenario evaluation from the JSA.

4.4 Risk Control

Control recommendations are arranged based on the control hierarchy in Table 8. Priority is given to H5 and H7 which are categorized as high in both assessments, then H4 and H3 which move up a category in the sensitivity evaluation, without ignoring hazards in the moderate category.

Table 8. Control Recommendations Based on the Control Hierarchy

Danger (R)	Elimination / substitution	Engineering	Administrative	PPE
H5 Pinched finger (9→12)	A tool to help place materials so that hands do not enter the clamping area.	*Guarding*pinch point, interlock	Prohibition of hands entering pinch point, SOP, training	Gloves according to work
H7 Conveyor stuck (9→12)	Minimize manual contact with the conveyor	*Guarding*pinch point, emergency stop is easy to reach	Scheduled inspection and preventive maintenance, SOP	Risk-appropriate work clothing
H4 Electric shock (6→12)	Repair/replacement of damaged cables	Electrical protection	Periodic inspection, LOTO during maintenance	PPE according to electrical work regulations
H3 Crushed by forklift material (6→8)	Material handling tools	*Barrier*and dedicated forklift lanes	Checking the stability of loads, signage, markings	*Safety shoes*
H1 Hot materials and heat stress (6)	Material handling tools	Heat source isolation, ventilation	Access restrictions, work-rest, hydration, monitoring of working conditions	Heat resistant gloves, safety shoes, face/eye protection, work clothes
H2 Walking beam (6)	–	*Barrier*, interlock if available	Safe zone, markings, signage, SOP	*Safety shoes*
H6 Press quenching burns (6)	Material moving aids	Isolation/guarding hot areas	SOP, access restrictions	Heat resistant gloves, face/eye protection
H8 Slipped (6)	Removes limescale and oil from floors	–	Housekeeping (5R), scheduled cleaning, safe passage, signage	*Safety shoes*
H9 Chemical vapors/gases (6)	–	Ventilation/vapor extraction	Training, monitoring	Respiratory PPE if necessary, eye protection

The arrows indicate the risk values of the questionnaire results and the values of the sensitivity evaluation results.

4.5 Discussion

The JSA results show that hazards in the heating process originate not only from the process temperature, but also from operator interaction with machines, materials, transport vehicles, electrical installations, and floor conditions. These hazards originate from thermal, mechanical, and electrical energy as well as the working environment. By describing each work step, each hazard can be directly linked to a specific operator activity, allowing preventive measures to be written into concrete work instructions, such as prohibiting hand entry into the clamping area in step 5 or checking the stability of the load in step 1.

The HIRARC results indicate a dominance of moderate risks (R = 6) and two high risks (R = 9), both related to pinch points. This pattern aligns with Setiawan et al. (2020), who also found walking beams and hot materials in the moderate category (value 6) and conveyor tempering in the high category. The difference is that in that study, the danger of cable peeling during press quenching was categorized as high, whereas in this study, the electrical hazard was categorized as moderate in the questionnaire results and only increased to high after the sensitivity evaluation. This difference emphasizes the importance of local electrical installation conditions and the need for field verification of cables and electrical components.

Evaluation of severity consistency is a key finding from the integration of the two methods. Likelihood assessments based on operator experience tend to be influenced by the frequency of previous events, while rare but severe events, such as amputations or electric shocks, are easily assessed as less severe. Because JSAs require researchers to list the worst-case scenario for each work step, discrepancies with the scale definition

can be detected. This reinforces the argument that HIRARC should be complemented by task-based analysis, and that controls should focus on moderate to high risks (Setiawan et al., 2020).

In terms of control, engineering priorities at pinch points (guarding, interlock, emergency stop) are in accordance with the hierarchy principle that controls that reduce the source of danger are prioritized over reliance on worker behavior or PPE. For heat hazards, the implementation of ventilation, work-rest, and hydration needs to be adjusted to the provisions of the work climate threshold value in Permenaker No. 5 of 2018, and environmental measurements (e.g. WBGT and noise) are needed so that occupational health assessments are not only based on perception. This recommendation is in line with company obligations under Law No. 1 of 1970 and PP No. 50 of 2012.

This study has limitations. Only five operators were interviewed, making the mode values subjective and prone to bias. The observation period was only about six weeks. Historical accident and near-miss data were not analyzed, and residual risk after control measures were not assessed. Future research is recommended to increase the number of respondents and observation periods, supplement accident data, measure the work environment instrumentally, and reassess risk after recommendations are implemented.

V. CONCLUSION

Based on the research results, it can be concluded that: (1) JSA describes the heating process into ten work steps and identifies nine potential hazards at three process stages, namely hot material and heat stress, walking beam, being hit by forklift material, electric shock, quenching press machine pinch point, quenching press burns, tempering conveyor, slippery floor, and chemical vapor/gas; (2) HIRARC assessment based on questionnaire mode produces seven medium category hazards (R = 6; 77.78%) and two high category hazards (R = 9; 22.22%), namely fingers being caught in the quenching press machine and being caught in the tempering conveyor, while the severity evaluation of the worst impact raises four hazards (44.44%) to the high category; and (3) risk control is prioritized in engineering in the form of guarding, interlock, and emergency stop at the pinch point, supported by administrative control (SOP, inspection, preventive maintenance, LOTO, housekeeping, training) and PPE as the final layer. The integration of HIRARC and JSA is complementary because JSA links hazards to work steps, while HIRARC establishes control priorities.

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