



OCCUPATIONAL HEALTH AND SAFETY RISK ANALISYS USING FMEA METHODS (FAILURE MODE AND EFFECT ANALISYS) APPROACH IN INDUSTRIAL ENGINEERING MANUFACTURING PROCESS LABORATORY OF PGRI ADI BUANA SURABAYA UNIVERSITY

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ABSTRAK

Laboratorium Proses Manufaktur Teknik Industri Universitas PGRI Adi Buana Surabaya merupakan laboratorium utama dalam kegiatan produksi dan penelitian. Kesalahan kecil dalam penggunaan peralatan atau prosedur yang tidak dijalankan dengan baik dapat menyebabkan kecelakaan kerja seperti cedera, kebakaran, bahkan kerusakan pada peralatan laboratorium. Analisis risiko K3 sangat diperlukan untuk meminimalisir terjadinya kecelakaan kerja. Dengan metode FMEA (Failure Mode and Effect Analysis) ini untuk menganalisa penyebab yang paling berpengaruh dan kemungkinan terjadinya kegagalan dalam risiko kecelakaan kerja. Penelitian ini menghasilkan: 1) Dapat mengidentifikasi 9 risiko kecelakaan kerja yang teridentifikasi di Laboratorium Proses Manufaktur Teknik Industri Universitas PGRI Adi Buana Surabaya, 2) Kejadian risiko tertinggi adalah terkena percikan gram saat menggunakan gerinda dengan nilai RPN 40,86 dan kejadian risiko tertinggi kedua adalah pendengaran terganggu akibat kebisingan mesin dengan nilai RPN 37,58. Hal ini menunjukkan risiko tersebut memiliki prioritas yang cukup tinggi sehingga perlu mendapat perhatian khusus. Implikasi strategis dari penelitian ini adalah dapat memberikan dasar yang kuat untuk keselamatan yang lebih baik, perbaikan risiko keselamatan yang lebih terstruktur, dan dapat meningkatkan kinerja yang produktif.

ABSTRACT

The Industrial Engineering Manufacturing Process Laboratory of PGRI Adi Buana University Surabaya is the main laboratory in production and research activities. Small errors in the use of equipment or procedures that are not carried out properly can cause work accidents such as injury, fire, and even damage to laboratory equipment. K3 risk analysis is needed to minimize the occurrence of work accidents. With this FMEA (Failure Mode and Effect Analysis) method to analyze the most influential causes and the possibility of failure in the risk of work accidents. This research resulted in: 1) Can identify 9 risks of work accidents identified in the Industrial Engineering Manufacturing Process Laboratory of PGRI Adi Buana University Surabaya, 2) The highest risk event is being exposed to gram sparks when using grinders with an RPN value of 40.86 and the second highest risk event is hearing loss due to machine noise with an RPN value of 37.58. This shows that the risk has a high enough priority that it needs special attention. The strategic implications of this research are that it can provide a solid foundation for better safety, more structured safety risk improvement, and can improve productive performance.

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I. INTRODUCTION

The progress of the industrial and business world today is characterized by adequate science and technology [1]. With technological advances, making the production process more efficient makes it necessary to continue to develop existing variations into new ones, but this can increase the risk of work accidents. The Industrial Engineering Manufacturing Process Laboratory of PGRI Adi Buana University Surabaya is the main laboratory in the field of production and research. This industrial engineering manufacturing process laboratory always emphasizes the importance of work safety in the laboratory environment, especially related to OHS in the production and research process. However, the lack of information about OHS to laboratory users before carrying out activities can cause work accidents. Work accidents occur when behaviors or situations in the production process cause injury [2]. Manufacturing laboratories contain various equipment, machines, and materials that have high supervision in their operation. Small errors in the use of equipment or procedures that are not carried out properly can cause work accidents such as injury, fire, and even damage to laboratory equipment. By applying the concept of OHS in manufacturing laboratories, it can prevent the risk of work accidents that occur [3]. This can minimize work accidents that occur during the production or research process. Using the FMEA approach can analyze the most influential causes and the possibility of failure in the risk of work accidents [4].

Research related to occupational safety risks using the FMEA method is often carried out in laboratories, but there has been no research conducted in its own environment, namely the Industrial Engineering Manufacturing Process Laboratory at PGRI Adi Buana University Surabaya. This is the main key to this research. The purpose of this FMEA method is to minimize the risk of work accidents that occur in the Laboratory so that it can maximize the production or research activities carried out.

II. MATERIALS AND METHOD

Research Time and Location

The research data were collected at the Industrial Engineering Manufacturing Process Laboratory of PGRI Adi Buana University Surabaya in October 2024 every Monday-Jum'at during working hours.

Identification Using the FMEA Method

This research begins by identifying various activities that cause the risk of work accidents that can occur. Occupational safety and health itself is where workers are protected from physical and mental disorders caused in the work environment [5].

The first stage carried out is field observation by distributing questionnaires to laboratory users such as laboratory assistants and students. Furthermore, the data presentation stage is carried out in the form of structured tables. The data that has been obtained from the questionnaire is managed using SPSS software. The sample used was 15 respondents with each severity value of 1 to 9. The data obtained was identified using the FMEA (Failure Mode and Effect Analysis) method which aims to analyze the risk of work accidents and severity in the Industrial Engineering Manufacturing Process Laboratory. All severity levels are evaluated based on three criteria. The first criterion, the severity of the risk obtained or Saverity (S) [6], the second criterion, the frequency of occurrence of the cause of failure or Occurrence (O) [7], and the third criterion, the cause of the detected failure or Detection (D) [8] from the assessment, can be calculated to get the RPN (Risk Priority Number) value to identify the most important risks to be addressed [9]. The following is a table of RPN values.

Table 1. RPN Scale

RPN Value	Conditions
1-26	Acceptable Risk
27-60	The seconde risk that number be addressed
61-94	The third risk that must be addressed
95-125	The most important to be addressed

Validity and Reliability Test

Survey or question items are considered valid if the value and questionnaire are considered reliable by having a Cronbach's value > 0.6 . Based on the calculation of the validity of measuring the expectation of the risk value of work accidents and quality has a corrected value above 0.3, it can be declared valid. The Cronbach's Alpha value for expectations and quality is 0.76 and 0.73. This can be a reliable questionnaire.

III. RESULT AND DISCUSSION

Based on the graph of the work accident situation in the Industrial Engineering Manufacturing Laboratory from January to December 2023, it generally shows an increase and decrease in the number of accidents. The increase or decrease in the number of work accidents is partly due to the lack of personal protective equipment provided in the laboratory, with these conditions, the number of work accidents will continue to increase from time to time. From the identification of the Pareto diagram, it is known that the types of work accidents on each machine have increased and decreased from January to December. Experienced an increase and decrease from January to December. This allows researchers to analyze the types of accidents that have increased and decreased every year, so that researchers can provide suggestions for improvements to the laboratory to minimize the occurrence of accidents in all operations in the laboratory. The following is data on work accidents in manufacturing laboratories in the past year:

Table 2. Work Accident Data in the Industrial Engineering Manufacturing Process Laboratory

No	Types of Accidents	Causes of Accidents	Jumlah Kejadian Kecelakaan Kerja
1	Exposure to gram splash when using the grinder	Not using protective goggles, gloves, shoes, clothes, helmets	96
2	Hand scratched by burrs	Not wearing a welding helmet	63
3	Eyes exposed to Welding Fumes	Not using protective gloves	87
4	Hand blistering from hot iron	Not using protective gloves	59
5	Hand cut by a sharp object	Not using protective gloves	52
6	Hearing loss due to machine noise	Engine noise	63
7	Eyes splashed with iron chips	Not using protective eyewear	72
8	Impaired breathing due to engine performance	Not using a mask	67
9	Leg crushed by heavy equipment	Not wearing protective shoes	90

Saverity (S) risk assessment. or severity score is obtained on the severity level. Possible values are 1 to 9. The following is the risk assessment data:

Table 1. Severity risk assessment data

No	Risk Event Type	Respondents									Average
		1	2	3	4	5	6	7	8	9	
1	Exposure to gram splash when using the grinder	2	3	2	4	2	3	5	4	1	2,89
2	Hand scratched by burrs	3	2	7	2	4	2	2	3	2	3,00
3	Eyes exposed to Welding Fumes	2	8	2	1	2	4	5	4	1	3,22
4	Hand blistering from hot iron	3	2	1	4	1	7	3	2	4	3,00
5	Hand cut by a sharp object	1	2	4	5	1	2	3	3	1	2,44
6	Impaired hearing due to engine noise	2	3	6	2	3	4	2	4	8	3,78
7	Eyes splashed with iron chips	2	4	3	1	7	1	2	5	1	2,89

8	Impaired breathing due to engine performance	3	7	5	8	7	2	3	3	2	4,44
9	Leg crushed by heavy equipment	3	2	3	2	1	2	2	3	1	2,11

Occurance (O) risk assessment or frequency of occurrence score of the cause of failure. Possible values are 1 to 9. The following is the risk assessment data:

Table 4. Occurance risk assessment data

No.	Risk Event Type	Respondents									Average
		1	2	3	4	5	6	7	8	9	
1	Exposure to gram splash when using the grinder	1	3	8	3	5	4	7	4	2	4,11
2	Hand scratched by burrs	2	5	2	1	4	3	3	4	2	2,89
3	Eyes exposed to Welding Fumes	1	2	5	1	6	2	3	2	5	3,00
4	Hand blistering from hot iron	2	2	3	1	3	4	3	5	2	2,78
5	Hand cut by a sharp object	1	2	3	1	4	4	3	4	2	2,67
6	Hearing loss due to machine noise	2	3	3	2	4	5	1	4	2	2,89
7	Eyes splashed with iron chips	2	3	2	1	5	4	6	4	2	3,22
8	Impaired breathing due to engine performance	1	2	3	1	3	7	1	4	2	2,67
9	Leg crushed by heavy equipment	2	2	3	2	5	4	6	1	2	3,00

Occurance (O) risk assessment or frequency of occurrence score of the cause of failure. Possible values are 1 to 9. The following is the risk assessment data:

Table 4. Occurance risk assessment data

No.	Risk Event Type	Respondents									Average
		1	2	3	4	5	6	7	8	9	
1	Exposure to gram splash when using the grinder	1	3	8	3	5	4	7	4	2	4,11
2	Hand scratched by burrs	2	5	2	1	4	3	3	4	2	2,89
3	Eyes exposed to Welding Fumes	1	2	5	1	6	2	3	2	5	3,00
4	Hand blistering from hot iron	2	2	3	1	3	4	3	5	2	2,78
5	Hand cut by a sharp object	1	2	3	1	4	4	3	4	2	2,67

6	Hearing loss due to machine noise	2	3	3	2	4	5	1	4	2	2,89
7	Eyes splashed with iron chips	2	3	2	1	5	4	6	4	2	3,22
8	Impaired breathing due to engine performance	1	2	3	1	3	7	1	4	2	2,67
9	Leg crushed by heavy equipment	2	2	3	2	5	4	6	1	2	3,00

Risk assessment detection (D) or based on existing prevention. Possible values are 1 to 9. The following is the risk assessment data

Table 5. Detection risk assessment data

No.	Risk Event Type	Respondents									Average
		1	2	3	4	5	6	7	8	9	
1	Exposure to gram splash when using the grinder	2	5	3	6	1	4	2	1	7	3,44
2	Hand scratched by burrs	2	6	2	1	3	1	3	4	1	2,56
3	Eyes exposed to Welding Fumes	1	2	4	1	3	4	5	7	1	3,11
4	Hand blistering from hot iron	2	4	3	1	3	1	2	5	1	2,44
5	Hand cut by a sharp object	1	2	3	1	7	1	3	4	2	2,67
6	Hearing loss due to machine noise	2	4	3	7	5	4	1	3	2	3,44
7	Eyes splashed with iron chips	2	3	2	1	4	1	1	3	2	2,11
8	Impaired breathing due to engine performance	1	2	3	2	5	4	3	2	1	2,56
9	Leg crushed by heavy equipment	2	2	3	3	1	2	2	3	2	2,36

Based on the results of the questionnaire we made through google form and interviews with workers, we got 15 respondents and 9 potential OHS risk events in the Industrial Engineering manufacturing process laboratory. The nine potentials are as follows:

Table 6. Risk events in the manufacturing process laboratory

Unit Kerja	Kejadian Risiko
Use of welding machine, lathe, grinder, paint compressor	Exposure to gram splash when using the grinder
	Hand scratched by burrs
	Eyes exposed to Welding Fumes
	Hand blistering from hot iron

Hand cut by a sharp object
Hearing loss due to machine noise
Eyes splashed with iron chips
Impaired breathing due to engine performance
Leg crushed by heavy equipment

To determine the Risk Priority Number (RPN) for each accident risk event, use the following formula:

$$RPN = Severity \times Occurance \times Detection \quad (1)$$

Table 7. RPN Result

No.	Risk Event	S	O	D	RPN
1	Exposure to gram splash when using the grinder	2,89	4,11	3,44	40,86
2	Hand scratched by burrs	3,00	2,89	2,56	22,19
3	Eyes exposed to Welding Fumes	3,22	3,00	3,11	30,04
4	Hand blistering from hot iron	3,00	2,78	2,44	20,35
5	Hand cut by a sharp object	2,44	2,67	2,67	17,39
6	Hearing loss due to machine noise	3,78	2,89	3,44	37,58
7	Eyes splashed with iron chips	2,89	3,22	2,11	19,64
8	Impaired breathing due to engine performance	4,44	2,67	2,56	30,35
9	Leg crushed by heavy equipment	2,11	3,00	2,36	14,94

After the RPN calculation, the next step is sorting the highest RPN value to the lowest RPN value. The following is a risk ranking table:

Table 8. Risk Rating

No.	Risk Event	RPN
1	Exposure to gram splash when using the grinder	40,86
2	Hearing loss due to machine noise	37,58
3	Impaired breathing due to engine performance	30,35
4	Eyes exposed to Welding Fumes	30,04
5	Hand scratched by burrs	22,19
6	Hand blistering from hot iron	20,35
7	Eyes splashed with iron chips	19,64
8	Hand cut by a sharp object	17,39
9	Leg crushed by heavy equipment	14,94

Based on the identified risk rating, the next step is to develop a mitigation strategy. Mitigation strategies are needed to avoid the negative impact of risks and improve work safety [10]. In addition, efficiency and effectiveness in implementing mitigation strategies require strengthening in the areas of technology, human resources, and infrastructure. The following is a table of risk mitigation based on risk rating:

Tabel 9. Risk Mitigation Strategy

No	Kejadian Risiko	Parties Involved	Mitigation Activities
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1	Exposure to gram splash when using the grinder	Lecturer, Head of Laboratory, Laboran	<ul style="list-style-type: none"> • Using protective eyewear • Cut-resistant gloves • Mask or respirator • Closed work clothes
2	Hearing loss due to machine noise	Lecturer, Head of Laboratory, Laboran	<ul style="list-style-type: none"> • Moving noisy machinery to a special isolated room • Using earmuffs or earplugs
3	Impaired breathing due to engine performance	Lecturer, Head of Laboratory, Laboran	<ul style="list-style-type: none"> • Install an air filter or scrubber system to reduce air pollution from engine emissions, • Use an N95 mask for small particles, • Wear protective clothing to prevent particles or pollutants from sticking to the body.
4	Eyes exposed to Welding Fumes	Lecturer, Head of Laboratory, Laboran	Using welding goggles, Automatic welding helmet that covers the entire face,
5	Hand scratched by burrs	Lecturer, Head of Laboratory, Laboran	Using cut-resistant gloves
6	Hand blistering from hot iron	Lecturer, Head of Laboratory, Laboran	<ul style="list-style-type: none"> • Using heat-resistant gloves • Using protective clothing
7	Eyes splashed with iron chips	Lecturer, Head of Laboratory, Laboran	<ul style="list-style-type: none"> • Using safety goggles • Using a Face shield • Make sure the PPE is in good condition and not damaged.
8	Hand cut by a sharp object	Lecturer, Head of Laboratory, Laboran	Using cut-resistant gloves
9	Leg crushed by heavy equipment	Lecturer, Head of Laboratory, Laboran	Wear safety shoes with steel toe guards on the front to protect the feet from heavy loads

IV. CONCLUSIONS

Based on the data calculations carried out, it can be concluded that the OHS risk analysis using the FMEA method can identify 9 risks of work accidents identified in the Industrial Engineering Manufacturing Process Laboratory. From the results obtained, the highest RPN value from the FMEA method analysis on the risk event of being exposed to gramature sparks when using a grinder with an RPN value of 40.86 and the second highest risk event is hearing loss due to machine noise with an RPN

value of 37.58. This shows that the risk has a high enough priority in risk management efforts that it needs special attention.

Based on the results of the analysis and the results of the interviews, it shows that the main risk factors are factors originating from humans or behavior and the environment. Based on the results of the interview, human or behavioral factors were found in mental problems, namely lack of concentration, in the problem of lack of caution found not using complete Personal Protective Equipment, in environmental factors found the problem of messy work environment conditions.

Recommendations based on this risk analysis are to provide the necessary facilities and infrastructure, such as safety glasses, special work clothes, gloves, earplugs, and other personal protective equipment in the workplace. In addition, it is recommended to provide training, especially to laboratory assistants, to improve their perception of the importance of occupational safety and health. Laboratory users are also encouraged to increase their vigilance, awareness, and understand the importance of using personal protective equipment to prevent adverse impacts on themselves. This recommendation aims to reduce the risk of getting gram splashes when using the grinder and hearing loss due to machine noise.

Suggestions for future research consider the application of other methods, such as Fault Tree Analysis (FTA) or Fault Tree Method, which can provide additional perspectives in risk identification and mitigation. In addition, further research can also be continued in other industrial engineering laboratories, such as quality testing laboratories, to explore the relationship between product quality standards and occupational accidents, as well as to test the implementation of a more holistic safety management system.

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