Improving Work System Design using Macro-Ergonomics Approach in Rubber Processing Plant

D Wahyuni*, I Budiman, H Nasution and K Wijaya
Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, North Sumatra, Indonesia

*diniwahyuni2015@gmail.com, irwanb01@gmail.com

Abstract. This study was conducted at an RSS (Ribbed Smoked Sheets) manufacturer in North Sumatra. In the preliminary observation, manufacturer encountered some problems such as machine breakdown (43 times in 2016 with 98 hours of downtime), scattered equipment, high temperature at all workstations, odor, disobedience against company regulations, and delay in product delivery. The aim of this research is to improve work design with variables such as machinery and equipment, physical environment condition, layout, working method, and organizational regulation, and worker with macro-ergonomic technique. There were 25 samples in total sampling technique used in this research and data collected through observation, open and closed questionnaire distribution to the respondent and measuring heat stress index felt by the worker. The results of the analysis showed two work design variables that had the highest severity, they are improvements to machinery and equipment variables by doing preventive maintenance while improving working environment conditions by installing turbine ventilator.

1. Introduction
Work system design discusses technical and social aspects of a work. Technical aspect refers to process, while social aspect refers to the workers. Work system design can describe number and modification of a work and the impact to the worker, group of the workers, and organization. Work can be re-design to change structure and content in a work to increase work outcomes [1].

This research was conducted on a company that moves in the production of rubber processed especially RSS (Ribbed Smoke Sheet). The RSS production process includes latex dilution, latex mixing, coagulant milling, filling of coagulant sheets that have been milled, then sorted according to the quality of RSS that has been done and done the packing.

Based on preliminary observations, there were some workstations in the aspects of work design that need to be repaired, such as Guthrie sheeter machine that often breakdown or damaged (43 times in 2016, with 98 hours downtime), scattered equipment, heat (34 °C-35 °C in all workstations) and odor, lack of awareness of workers in compliance with company rules, and 4 cases of lateness in delivery of RSS. If these problems were not fixed, then the company will suffer losses due to decreasing of employee productivity or in other words the workers will not reach the target to complete works at the time specified.

The purpose of good work design is to improve the productivity and profit of the company. The benefits of a good work design are to reduce the potential danger for workers from injury, illness, to death. In
addition, it can improve innovation, quality, and efficiency through effectiveness and continuous improvement [2, 3, 4].

Previous research of work system design using Macro-eronomic Analysis and Design (MEAD) method at Merpati Maintenance Facility to analyze problems occurred. Problems that occur is the desire of the company so that the company can run smoothly, effectively and efficiently, and giving high profits; while the employees wish to get standard amount of work, comfortable working environment, welfare and high salaries. The results showed that companies should pay attention to human as employees to be able to work comfortably and companies as stakeholders can also benefit in the long term. The way to optimize the work design system by using macro-ergonomics approach. According to Henrik and Kleiner, Macro-Ergonomics is an approach that studies how to optimize the organization and design of the work system by considering human, technological, and environmental variables, as well as interactions between these variables and ensuring the work system in harmony, [2, 5, 6, 7, 8]

Moist work environment, heat, dust, and the lack of air circulation in the production section make the operator uncomfortable for work. Mudji state that the physical work environment affects health and indirectly influences productivity and occupational safety [9, 10].

The aim of this research is to improve work design with variables such as machinery and equipment, physical environment condition, layout, working method, and organizational regulation, and worker with macro-eronomic technique.

2. Methods
This research included in the type of descriptive research. Based on the analysis and type of data, this study was included in the combined study because this study used quantitative and qualitative data. While the observed objects of research are machine and equipment, physical work environment conditions, layouts, work methods, organization policy, and workers within the scope of rubber processing plants [5, 6, 7, 8]. There were 25 samples in total sampling technique used in this research and data collected through observation, open and closed questionnaire to the respondent and measuring heat felt by the worker using Heat Stress Index. Instruments used in this study are 4 in 1 environmental, globe thermometer, anemometer, and questionnaire [11, 12].

The variables found in this research are: machine and equipment, physical work environment conditions, layout, work methods, organization policy, worker, and work design.

Steps of using Macro-Ergonomic Analysis and Design (MEAD) methods in this research are [11, 12]:
1. Assessment of environmental conditions and organizational subsystem
2. Defining the type of production system and setting performance expectations
3. Defining of operating units and work processes
4. Identification of variance
5. Preparation of variance matrix
6. Creating a key table setting variance and network rules work
7. Testing of functional allocation and joint design
8. Explanation of rules and perceptions of responsibility
9. Design/redesign of supporting subsystems
10. Implementation, iteration, and change of the system

3. Results and discussion
3.1. Actual condition of production floor
Step 1 until step 3 of the MEAD method, is the examination of environmental conditions, the definition of the type of production system and the definition of the operating unit is applied through an observation to determine the current condition of the production floor. These data were resumed in data collected, which is:

a. Worker profile data, machine and equipment data, working hours, and organizational data.
b. There are 4 types of rubber processed products with standard specification which refers to Green Book and SNI namely SIR I, SIR II, SIR III, and Crumb Rubber
c. The company has 6 operating units namely latex reception, latex dilution, latex milling, latex fogging, latex sorting, and latex packing.
3.2. Identification of variance and preparation of variance matrix

This is step 4 to step 5 of MEAD method. The instrument of data collection used in step of the variance identification is an open questionnaire. Sampling technique used in the spread of questionnaires is the method of total sampling because the entire population which will be examined can be accessed easily by researchers, which amounted to 25 people. The result obtained from open questionnaire recapitulation are used as reference questions for closed questionnaires as can be seen in Table 1.

**Table 1. Recapitulation of Open Questionnaire.**

| No. | Questions                                                                 | Answers of the Respondents |
|-----|---------------------------------------------------------------------------|----------------------------|
|     |                                                                           | Description               | Percentage |
| 1   | The difficulties of workers in handling the machine.                       | Care                      | 52%         |
|     |                                                                           | Repair                    | 40%         |
|     |                                                                           | Others                    | 8%          |
| 2   | The difficulties of workers in handling equipment.                         | Care                      | 40%         |
|     |                                                                           | Storage                   | 28%         |
|     |                                                                           | Others                    | 32%         |
| 3   | Environmental factors that impede the work.                               | Hot                       | 40%         |
|     |                                                                           | Smelly                    | 28%         |
|     |                                                                           | Dark                      | 20%         |
|     |                                                                           | Others                    | 12%         |
| 4   | The suitability of the layout work.                                        | Not well-arranged         | 24%         |
|     |                                                                           | Limited space             | 20%         |
|     |                                                                           | Material handling         | 16%         |
|     |                                                                           | Others                    | 40%         |
| 5   | The difficulties experienced by workers in implementing the SOP or work instruction. | Field conditions         | 40%         |
|     |                                                                           | Difficult to understand   | 28%         |
|     |                                                                           | Lack of experience        | 28%         |
|     |                                                                           | Others                    | 4%          |
| 6   | The company’s efforts to maintain the safety and occupational health.      | Personal Protective       | 52%         |
|     |                                                                           | Equipment                 | 28%         |
|     |                                                                           | Warning                   | 28%         |
|     |                                                                           | Briefing                  | 20%         |
| 7   | The company’s efforts to control the work.                                 | Supervise                 | 64%         |
|     |                                                                           | Expert Analyze            | 28%         |
|     |                                                                           | Lab test                  | 8%          |
| 8   | The difficulties in increasing workers’ job skills.                        | Lack of experience        | 52%         |
|     |                                                                           | Type of job               | 28%         |
|     |                                                                           | Difficult to understand   | 20%         |

The result from Open Questionnaire is then re-confirm by using Closed Questionnaire to determine variances. The respondents’ answers, especially for Agree and Strongly Agree answer are then calculated as can be seen in Figure 1.
From the figure above, determination of key variance based on agreed mode and strongly agree with the answer by a closed questionnaire is overheated work area and no SOP of Machine Treatment (no machine maintenance schedule and no maintenance for tools) as can be seen in Figure 1.

3.3. Compilation of alternative settlement

There are 3 MEAD steps (step 6 until step 8) in the preparation of alternative solutions:

1. Preparation of variance control tables of key and role network to find ways of controlling variance that able to do by the company in order to eliminate or minimize the frequency of the variance’s occurrence.
2. Testing the allocation of combined functions and designs as well
3. Explanation of rules and perceptions of responsibility.

To find ways of controlling variance to eliminate and minimize variance, key variance control tables and role analyzes are composed of:

a. The operating unit where the variance occurs includes:
   - Who is responsible
   - What control activities are performed
   - What equipment, interfaces, and technologies are required to support control activities.
   - What information, special skills, or knowledge are required to support control activities.

b. Alternative problem solving is a diagram where each variance has 2 alternative solutions. Solution tree combination diagram can be seen in Figure 2.
Work Design improvements in Rubber Processing Industry

Combination 1
- Create a maintenance program
- Analysis and improvement of working thermal conditions
- Make SOP treatment
- Repair of ventilation system

Combination 2
- Create a maintenance program
- Do work rotation
- Make SOP treatment
- Create a work rotation schedule

Combination 3
- Create a maintenance department
- Analysis and improvement of working thermal conditions
- Hiring and training new employees
- Repair of ventilation system

Combination 4
- Create a maintenance department
- Do work rotation
- Hiring and training new employees
- Create a work rotation schedule

Figure 2. Solution Tree Combination Diagram

The tree diagram above illustrates possible combinations of solutions so that 4 alternative combinations are obtained. Then evaluated using the weighting scores based on the criteria that have been prepared. The criteria for assessment are divided into two sections: positive criteria and have a positive scoring weight of scope (S) and benefit (B), and unfavorable criteria and negative weight score consisting risk of failure (R) and Costs (C). The criteria of the weight alternative assessment can be seen in Table 2 and the recapitulation of the scoring weights can be seen in Table 3.

Table 2. The Weight Alternative Criteria.

| Scope (S)                           | Benefits (B)                               | Risk of Failure (F)                           | Costs (C)                         |
|------------------------------------|--------------------------------------------|----------------------------------------------|----------------------------------|
| Improve the quality of service     | Increase the reliability of the production system | Less participating employees apply improvements | The cost of providing facilities |
| Improve employee welfare           | Improving employee comfort in work         | The required technology is not available      | Cost of material procurement     |
| Helping the production process run more efficiently | Preventing occupational injuries and occupational diseases | Difficult to change the habit/work culture | Cost of Production downtime |
| Raise awareness of safety          | Improve the quality of human resources of the company | The lack of discipline of workers follows the rules | The cost of hiring experts |

Table 3. Alternative Scoring Weighted Recapitulation.

| Alternative | S  | B  | R  | C  | Total |
|-------------|----|----|----|----|-------|
| Alternative 1 | 4  | 3  | -3 | -1 | 3     |
| Alternative 2 | 3  | 3  | -3 | -1 | 2     |
| Alternative 3 | 3  | 3  | -2 | -2 | 2     |
| Alternative 4 | 3  | 3  | -3 | -3 | 0     |
3.4. Re-Designing supporting subsystems

3.4.1. Analysis and evaluation of workplace thermal conditions. A thermal condition in the workplace is calculated by the Heat Stress Index (HSI) which describes the thermal conditions of the sorting station. HSI for the actual condition was 95.11%. From the HSI value in actual condition, ventilator turbine installation design is proposed and recommended 4 units of type L-60 for ventilator turbine with the suction capacity of 75.36 m³ and 10 minutes of circulation time. With the addition of 4-unit-turbine ventilator, then the value of HSI (Heat Stress Index) will be decreased to 80.98%.

3.4.2. Maintenance Program. Modern maintenance programs will be focused more on predicting and preventing failure than improvements when damage occurs. In practice, it is necessary to design a set of schedules, coordinate with the operation manager and provide support to maintain the smoothness of production. To do so, it should be stated when creating SOP of Guthrie sheeter machine maintenance.

4. Conclusion
The conclusions obtained from this research are:

1. Work design variances studied is machine and equipment, physical work environment conditions, layouts, work methods, organization policy, and workers. Two variances that have the highest severity are selected to solve the problem that is the variance of physical work environment condition and variance of machine and equipment.
2. Improvement for the variance of physical work environment condition in the form of installation of 4-turbine-ventilator which impacts on the decrease of air temperature and the decrease of heat stress index value received by the operator from 95.11% to 80.98%.
3. Improvement for machine and equipment variance is done by the preventive and predictive maintenance program for the machine which includes details of maintenance activity and creating SOP of Guthrie sheeter machine maintenance.

References
[1] Grant A M 2012 Giving Time, Time After Time: Work Design And Sustained Employee Participation In Corporate Volunteering (The Wharton School: University Of Pennsylvania)
[2] Rositaningrum A 2014 Analisa Implementasi Ergonomi Makro Terhadap Keuntungan Perusahaan (Studi Kasus : Merpati Maintenance Facility Juanda -Surabaya) (Surabaya: ITS)
[3] Mayang S 2013 Evaluasi Tracer Study Untuk Pembelajaran dengan Pendekatan Ergonomi Makro. (Serang: Universitas Sultan Ageng Tirtayasa)
[4] Mukti I F 2013 Desain Perbaikan Lingkungan Kerja Guna Mereduksi Paparan Panas Kerja Operator di PT. XY (Medan: Universitas Sumatera Utara)
[5] Morel G, Amalberti R and Chauvin C 2009 How Good Micro/Macro Ergonomics may Improve Resilience, but not Necessarily Safety J. Safety Science 47 2 285-294
[6] Azadeh A, Roudi E, and Salehi V 2017 Optimum Design Approach Based on Integrated Macro-Ergonomics and Resilience Engineering in a Tile and Ceramic Factory J. Safety Science 96 62-74
[7] Azadeh A, Shabanpour N, Gharibdousti M S, and Nasirian B 2016 Optimization of Supply Chain Based on Macro Ergonomics Criteria: A Case Study in Gas Transmission Unit J.Loss Prev.in Proc. Ind. 43 332-351
[8] Azadeh A, Haghigi S M, and Shabanpour N 2016 Optimization of Health Care Supply Chain in Context of Macro-Ergonomics Factors by a Unique Mathematical Programming Approach J. App. Ergonomics 55 46-55
[9] Auliciems, Andris and Steven V S Thermal Comfort (Brisband)
[10] Parsons K 2003 Human Thermal Environments: The Effect of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance. Second Edition (London: Taylor & Francis)
[11] Hendrik H W 2001 Macro-ergonomics (Santa Monica: HFES)
[12] Stanton N 2005 Handbook of Human Factor and Ergonomic Method (USA: CRC Press)