Calculation of Physiological Load and Energy Consumption of Warehouse Operators in Manufacturing Companies

Nismah Panjaitan¹, Listiani Nurul Huda¹, Arnita Rahmi¹
¹Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jl. Almamater Kampus USU Medan 20155, Indonesia

E-mail: nismahpjt@gmail.com, Lnurul@gmail.com, tarnitarahmi@gmail.com

Abstract. The modest workload provided by operators is the responsibility of every manufacturing company. Operators with excessive workload on an ongoing basis will cause discomfort and even abnormalities in the physiological operator, especially in the muscles and joints. In this study, workload, work frequency and work posture become independent variables while energy consumption becomes the dependent variable that will be reviewed thoroughly to see the workload of operators. Data collected directly about the operator's energy consumption indicates the operator is experiencing a heavy workload. Lifting and moving activities carried out by operators must be immediately carried out repairs. In the near future the improvement of operator activities when lifting must be fixed immediately because it exceeds the energy consumption limit of 8.63 Kcal / minute, 8.063 Kcal/minute dan 8.175 Kcal/minute.

Keywords: Musculoskeletal, Work Posture, Physiological, Workload and Cardiovascular Load (% CVL).

1. Introduction
Manual removal of containers such as wheeled racks, trolleys, hand trucks and socket pallets can cause fatigue and discomfort, such as injuries to the back, shoulders, hands, wrists, or other body parts that can occur if done repeatedly. If this happens in a long time, it will cause musculoskeletal or MSDS (Cal / OSHA, 2007). Lifting activities that provide a great compressive force on the spine and pushing or pulling activities can create a large shear load on the spine and will cause pain in the lower back, consequently it can cause rotating postures that refer to body rotation or torque [1]. Working in an improper position will cause discomfort and greatly endanger workers just to maintain high levels of productivity such as bending and squatting [2].

Manufacturing company engaged in the production of PVC (PolyVinil Chloride) and HDPE (High density polyethylene) pipes. The product transfer activities are carried out manually by the warehouse worker with the help of a four-wheeled manual trolley, the workers carry out work activities such as raising the pipe over the trolley, pulling the trolley containing the pipe from the temporary stacking place, lowering the pipe from the trolley to the finished product warehouse. workers must bend to reach the HDPE (High density polyethylene) pipe roll which is on the floor in a temporary piling up, and then place the HDPE (High density polyethylene) pipe roll over the trolley with a height of 22 cm.

Interesting activities are activities that cause workers to do pull activities with one hand and this will cause the inconvenience of workers' work postures while working. On this basis, a research on the
design of a pipe hauling facility in the form of a trolley is needed to create convenience and improvement to the work methods of warehouse workers when carrying pipes and analyze the burden received by workers and improve the design of pipe transportation facilities used by warehouse workers.

2. Literature Review

2.1. Manual Material Handling (MMH)

The United States Department of Labor defines handling as reaching, holding, grasping, rotating, or working with one hand or two hands. The ability of workers to perform work tasks can vary due to differences in age, physical condition, strength, gender, stature, and other factors. There are five things that need to be done to improve work stations so as to create a good working atmosphere, including:

- Reduce or prevent injury
- Reducing workers' efforts by reducing strength in lifting, handling, pushing, and pulling material
- Reducing risk factors for musculoskeletal disorders (for example, awkward postures to reach into containers)
- Increase productivity, quality products and services, and employee morale.
- Reduce costs by reducing or eliminating production delays, error or disability rates, use of medical services due to musculoskeletal disorders, workers compensation claims, excessive employee turnover, absenteeism, and training

The use of muscle power can be optimal, so the regulation of how muscles work must be considered properly. In this case also the muscle activity can be distinguished in 2 ways, namely:

- Dynamic muscle work (rhythmic)
- Static muscle work (work stance / fixed)

Muscles will tighten and contract (loosen) alternately or rhythmically in dynamic work. Whereas static work or attitude here will be in a position to tighten for quite a long time.

Muscles will work alternately in accordance with the tense / compressive and loose rhythm like the work of a "pump" that has an impact on the smooth flow of blood during dynamic work takes place. Muscles will carry a lot of / receive glucose and oxygen when tightening and then discarding metabolism (the result of combustion or metabolism) when loosening because the mechanism of tightening and loosening of muscles occurs alternately. Then the circulation of blood flow + O2 and metabolic will take place smoothly.

3. Method

This type of research is descriptive research that is classified into research work and activity analysis (Job and Activity Analysis). Work and activity analysis research is a descriptive study aimed at investigating in detail the activities and work of a person or group of people in order to obtain recommendations for various purposes. The object of research is the work method and the burden received by warehouse operators who work to transport pipes. The various variables used in the study are as follows:

- Independent Variable: This variable consists of: Load Weight, Transport Frequency, Work Posture
- Dependent Variable: This variable consists of: Energy consumption

4. Discussion

Conduct direct observations of warehouse workers tasked with transferring pipes from temporary stockpiles to the finished product warehouse, obtain information through direct interviews and filling out questionnaires by workers regarding complaints against parts of his body due to carrying out activities as well as personal data from the worker concerned. The activities that take place on the production floor are as follows:
Figure 1: Load Transfer Activity Scheme

Information figure 1:
- Lifting the finished product in the form of a pipe from the temporary stacking place on the trolley.
- Transport the finished pipe from the temporary storage area to the finished product warehouse using a trolley.
- Bring down the pipe from the trolley and arrange it into the finished product warehouse.

4.1. Workload Data Processing Using Physiology
Physiological data processing is carried out to determine the amount of energy consumption needed to carry out HDPE (High density polyethylene) pipe transportation activities. This processing stage is carried out as follows:

4.1.1. Direct Assessment Method
The valuation method is directly used in determining the amount of energy used during work. The amount of energy can be calculated by the follows:

\[ E = 1.80411 - 0.0229038 X + 4.71711 \times 10^{-4} X^2 \]  \hspace{1cm} (1)

Information:
- \( E \) = Energy (kcal / minute)
- \( X \) = heart rate (beats / minutes)

Workload categories based on energy consumption are as follows (Minister of Labor Regulation Number 51 of 1999):
- Light workload : 100–200 kcal / hour
- Medium workload : > 200–350 kcal / hour
- Heavy workload : > 350–500 kcal / hour

| No. | Worker | DNK (X) (Pulse/minute) | Energy \( E \) (kcal/minute) | Energy (E) (kcal/hour) | Workload Category |
|-----|--------|------------------------|-------------------------------|------------------------|-------------------|
| 1   | 1      | 108                    | 4.833                         | 289.952                | Medium            |
| 2   | 1      | 110                    | 4.992                         | 299.544                | Medium            |
| 3   | 1      | 138                    | 7.627                         | 457.599                | Hard              |
| 4   | 1      | 155                    | 9.587                         | 575.213                | Hard              |

Table 1. Recapitulation of Calculation Results of Energy Consumption and Workload Categories for Pipeline Transport Activities
Table 1 above shows that the activities of lifting pipes ¾ "and 1" are included in the activity with moderate workload categories and the activities of lifting pipes 1½ "and 2" are included in the category of heavy workloads.

4.1.2. Indirect Assessment Methods
Calculation of% CVL, Cardiovascular Load (% CVL) can be calculated using the following formula:

\[
\% CVL = \frac{100 \times (\text{worker's pulse} - \text{PulseInitiated})}{\text{Maximumpulse} - \text{PulseInitiated}}
\]

Table 2. Recapitulation of Calculation Results of% CVL and Workload Classification in Pipeline Transport Activities

| No. | Worker | DNI | DNK | DN max | %CVL | Information      |
|-----|--------|-----|-----|--------|------|------------------|
| 1   | 1      | 108 | 83  | 195    | 22.321| No Fatigue       |
| 2   | 1      | 110 | 138 |        | 24.107| No Fatigue       |
| 3   | 1      | 155 |     |        | 49.107| Repair Required  |
| 4   | 1      | 110 | 155 |        | 64.285| Work in Short Time |
| 5   | 1      | 110 | 88  | 193    | 24.107| No Fatigue       |
| 6   | 1      | 114 | 140 | 193    | 27.678| No Fatigue       |
| 7   | 1      | 162 |     |        | 50.892| Repair Required  |
| 8   | 1      | 162 |     |        | 70.535| Work in Short Time |

Table 2. shows that HDPE (High density polyethylene) pipe lifting activities ¾ "and 1" are activities that do not cause fatigue to workers who do, HDPE (High density polyethylene) pipe lifting activities 1½ "are activities that require repair and HDPE (High density polyethylene) 2 pipe lifting activities" are activities that can be carried out in short time

5. Conclusion
Physiological data processing results show that the activities of lifting pipe 2 "and transporting pipes dan" and 2 "exceed the average energy consumption limit 405.57 Kcal / hour and 429.47 kcal / hour and categorized as work with heavy workloads. The proposed design improvement is the improvement of the pipe haul trolley which data is pulled with two hands and has an electric drive on the wheels so as to reduce energy consumption.

References
[1] Battini D 2017. Ergo-lot-sizing: An approach to integrate ergonomic and economic objectives in manual materials handling. International Journal of Production Economics. 185, issue C, 230-239.
[2] Cal/OSHA Consultation Service, Research and Education Unit, Division of Occupational Safety and Health, California Department of Industrial Relations. Ergonomics Guidelines for Manual Material Handling. 2007. California: California Department of Industrial Relations.
[3] Gyemi D 2016 3D Peak and Cumulative Low Back and Shoulder Loads and Postures During Greenhouse Pepper Harvesting Using A Video-Based Approach. Kanada: Department of Kinesiology, University of Windsor, Windsor 51. Issue 4.
[4] Harris C 2016 Ergonomic evaluation of standard and alternative pallet jack handleless. San Francisco: International Journal of Industrial Ergonomics 61. pp 113-116.
[5] Iridiastadi H 2014 Ergonomi Suatu Pengantar Bandung: PT. Remaja Rosda Karya.
[6] Callaghan J 2012 Possible mechanisms for the reduction of low back pain associated with standing on a sloped surface. Ontario: University of Waterloo 58 pp 281-286.
[7] Knapik G 2009 Spine Loading at Different Lumbar Levels During Pushing and Pulling. Ohio: Biodynamics Laboratory, The Ohio State University, Columbus. 2009. Vol 21 pp 75-89.
[8] Majid A 2016 Musculoskeletal Model of Awkward Carrying Postures. Sarawak: Universiti Malaysia Sarawak.. 3. pp 1-9.
[9] Niebel B and Andris F 2007 Methods Standards and Work Designs. 2007. New York: McGraw-Hill.
[10] Rahmat R F, Herly E T, Siregar B, Syahputra M F, Sitompul O S, 2018 RFID presence monitoring system as an input to measure the workload of employee 4th International Conference on Computer Applications and Information Processing Technology, pp. 1-6
[11] Vecchio L 2017 Choosing a Lifting Posture: Squat, Semi-Squat or Stoop. Australia: Department of Medical and