Measurement of Physiological and Psychological Workloads of Mechanical Department Operator PT. XYZ

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Abstract. PT. XYZ is an electrical machinery repair services company. The amount and density of operator activity can affect worker fatigue. This research conducted to calculate the level of physiological and psychological workloads and ideals rest periods for operators in the Mechanical Department of PT. XYZ. The method to calculate physiological workload is direct measurement by measuring heartbeat, whereas the method to calculate psychological workload is NASA-TLX Method. The results show that the most severe physiological workload experienced by Mr. Nur who is a medium-sized lathe operator with a value of energy consumption of 8.497 Kcal/minute before a break and 7.602 Kcal/minute after a break, the ideal rest time for Mr. Nur is 112 minutes with work duration from 07.00-12.00 WIB and 66 minutes with work duration from 13.00-16.00 WIB, while Mr. Supardi and Mr. Didik requires a rest time of 103 minutes and 38 minutes with work duration from 07.00-12.00 WIB and the level of psychological workload for the 12 operators are high and very high. Therefore the company can minimize the level of physiological and psychological workload by calculating the workload of the operator in a balanced manner.

Keywords: physiological and psychological workload, energy expenditure, energy consumption, ideal rest time, NASA-TLX.

1. INTRODUCTION
The development of industry today especially machinery progressing very rapidly, it is because in every production activity is never separated from the use of tools or machines as operational support. The machines will operate in accordance with a properly when supported by the operating standards and the correct treatment to prevent damage to either the light damage or major damage.

As required maintenance for machinery production, also affect the increase in service repairs and installation of machinery and equipment. This is evidenced in the growth of the industry is the highest production increased repair and installation of machinery and equipment, amounted to 13.29% [1]. Each company in the production activities need to pay attention to the machine or tool used remains in good condition. In order to keep the machine in good condition, it needs regular maintenance and service as well as the corrective action on the part that was damaged or had trouble shooting, therefore it is necessary for the continuation of engine repair services production process.

PT. XYZ is an electrical machinery repair services company. The company has three departments, one of them is Department of Mechanics. In this department, there are 12 operators where each
operator doing a different job or more than one job in accordance with the settlement of repair items. Repair items that do require a different time compatible with the problem and dealing between the company and the customer. Many operators and density of activity may impact on worker fatigue.

Based on the results of the questionnaire fatigue, there are three criteria for fatigue experienced by operators such as workload, duration of action and the physical working environment. Out of 12 operators who filled out a questionnaire, 8 operators agreed that fatigue is caused by the criteria of workload, 8 operators agreed that fatigue is caused by the criteria of duration and 5 operators agreed that the fatigue is caused by environmental criteria physical labor.

Based on the information above, this research will focus on the criteria of workload and duration of action in view of these two criteria is fatigue often experienced by the operator. Referring to the results of these studies it is necessary to measure the physiological workload by using direct measurement methods and psychological workload using NASA-TLX method based on the parameters to be measured against the operator so that work can be adapted to the capabilities of the operator, and to compare whether the level of physical fatigue matches the level of mental fatigue of the worker.

2. METHODS

2.1. Workload
Workload is an effort that must be issued by a person to meet the “demand” of the work, the intended workload is the size (portion) of the limited capacity of the operator that required to do a job [2].

2.2. Duration Of Work
The duration is the span of time or the length of time, therefore the duration/hours of work in Indonesia was regulated by Undang-Undang No.13 of 2003 about Manpower [4]. For several companies, working hours, rest periods, and overtime included in the Collective Labor Agreement (CLA). This is according with Clause 77, Verse 1, of UU No.13/2003, which requires each employer to implement the provisions of working hours.

2.3. Physiological Workload
The psychological workload (mental workload) is defined as the evaluation of the hose operator maturity (current capacity is being motivated by the existing workload) when doing a job (metacontroller activity) to achieve specific goals [12]. Some examples of activities that are dominated by mental activity is like a surgical operation, assembly carefully, looking at the target at the time of shooting, see micro-sized object through a microscope and others [3]. Mental burden has a fairly high correlation to the mistakes made (error) or mental workload has a correlation with the level of performance [13].

Working physiological (physical) is a work that requires physical energy of human muscle as a source of energy (power). Physical work is often referred to as "manual operation" which is the work performance will entirely depend on a man who serves as a source of energy (power) or job control. In terms of the physical work, the energy consumption are the main factors and benchmarks used as a determinant of weight/lightness of the physical work [5].

Factors that affecting the workload is ratings physical workload can be done by two methods objectively, is direct assessment methods and indirect assessment methods [6].

Direct measurement method is to measure the energy expended (energy expenditure) through the intake of oxygen during the work. The more weight the more work energy expended [7]. The amount of energy expended for a job can be measured by calculating the heart rate and demographic factors. Research on the measurement of energy one of which is expressed Keytel [8]:

\[
EE = -20.4022 + (0.4472 \times HR) - (0.1263 \times w) + (0.074 \times A)
\]  

(2.1)

Where:
EE = Energy expenditure (kcal/min)
HR = Heart rate (beats/min)
w = Weight (kg)
A = Age (years)

With a linear relationship between heart rate and energy absorption, one can generally use heartbeat to build a "heavy" work. In Table 1 lists the severity of work with energetic demands and blood circulation [9].

| Classification Profession | Total Energy Expenditure (KJ/minute) | Heart Rate (beats/minute) |
|---------------------------|--------------------------------------|---------------------------|
| Light                     | 10                                   | ≤ 90                      |
| Moderate                  | 20                                   | 90-100                    |
| Weight                    | 30                                   | 100-120                   |
| Very Heavy                | 40                                   | 120-140                   |
| Extreme Weight            | 50                                   | 140-160                   |

After doing the calculations above, we can calculate the energy consumption (K) using the following formula equation [10]:

\[ K = E_t - E_i \]  

Where:
K = Energy Consumption (kcal / min)
Et = Energy expenditure on certain working time (kcal/min)
Ei = Energy expenditure at a time before work (kcal/min)

2.4. Work Break Cycle
Humans are unable to maintain the level of physical activity for a longer period. They need a break periodically to recover from the effects of the work performed. Throughout the years, various studies offer suggestions for the rest period permitted ie [11]:

\[ RT = 0 \text{ for } K < S \]  
\[ RT = \frac{K - S}{S} \times 100 + \frac{T(K - S)}{K - BM} \]  
\[ \text{for } S \leq K < 2S \]  
\[ RT = \frac{T(K - S)}{K - BM} \times 1.11 \text{ for } K \geq 2S \]  

Where:
RT = Rest required (minutes)
K = Expenditure of energy to work (Energy expenditure) or consumption energy (kcal/min)
S = Recommended energy expenditure average (4 kcal/min for women, 5 kcal / min for men)
T = Expected total work time (minute)
BM = Basal metabolism, is the energy required by the body in a state of rest total both body and spirit (BM for women = 1.4 and BM for male = 1.7)

2.5. Measurement Method of NASA-TLX
NASA-TLX (National Aeronautics and Space Administration-Task Load Index). This method is a questionnaire developed by the emergence of subjective measurement needs an easier but more sensitive to the measurement of workload. NASA-TLX method is a multidimensional rating procedure, which divides the workload on the basis of the average loading of six dimensions, namely
the Mental Demand, Physical Demand, Temporal Demand, Effort, Own Performance, and Frustation Level. NASA-TLX is divided into two phases, a comparison of each scale (Paired Comparison) and giving value to the job (Event Scoring).

3. RESULTS AND DISCUSSION

3.1 Measurement Of Physiological Workload Experienced By The Operator Of The Mechanical Department PT. XYZ

Data processing carried out in this study is to calculate the physical workload by operators in the Department of Mechanical PT. XYZ. In the data processing, calculating physical workload experienced by operators in the Department of Mechanical PT. XYZ, which consists of several stages:

1. Take measurements of heart rate to 12 mechanical operators by using Polar M200.
2. Asking for general information such as weight and age of the mechanical operators where these data as variables to be taken into the calculation.
3. Calculate the energy expenditure obtained from the heart rate measurements, body weight and age of the mechanical operators.
4. Calculate energy consumption based on reducing energy expenditure after work and before work with.
5. Classifying the types of work 12 operators with energy consumption has been calculated.

Table 2. The Results Of The Calculation Of Energy Expenditure, Energy Consumption and Workload Categories Of 12 Mechanical Operators

| No. | Operator Name | Time Measurement | Energy Expenditure (Kcal/min) | Energy Consumption (Kcal/min) | Workload Category |
|-----|---------------|------------------|-------------------------------|-------------------------------|------------------|
| 1   | Mr. Jumali    | Before Work (07.00 WIB) | 19.768                        | -14.758                       | -                |
|     |               | After Work (12.00 WIB)  | 5.010                         | -14.758                       | -                |
|     |               | Before Work (13.00 WIB) | 17.085                        | -10.286                       | -                |
|     |               | After Work (16.00 WIB)  | 6.799                         | -10.286                       | -                |
|     |               | Before Work (07.00 WIB) | 8.964                         | 2.236                         | Light            |
| 2   | Mr. Satimin   | After Work (12.00 WIB)  | 11.200                        | -4.472                        | -                |
|     |               | Before Work (13.00 WIB) | 14.331                        | -4.472                        | -                |
|     |               | After Work (16.00 WIB)  | 9.859                         | -4.472                        | -                |
|     |               | Before Work (07.00 WIB) | 6.714                         | 1.342                         | Light            |
|     |               | After Work (12.00 WIB)  | 8.056                         | 1.342                         | Light            |
| 3   | Mr. Johannes  | Before Work (13.00 WIB) | 11.633                        | 5.814                         | Moderate         |
|     |               | After Work (16.00 WIB)  | 17.477                        | 5.814                         | Moderate         |
|     |               | Before Work (07.00 WIB) | 11.303                        | -2.683                        | -                |
|     |               | After Work (12.00 WIB)  | 8.620                         | -2.683                        | -                |
| 4   | Mr. Suryanto  | Before Work (13.00 WIB) | 9.514                         | 1.789                         | Light            |
|     |               | After Work (16.00 WIB)  | 11.303                        | 1.789                         | Light            |
|     |               | Before Work (07.00 WIB) | 5.052                         | 8.497                         | Weight           |
| 5   | Mr. Nur       | After Work (12.00 WIB)  | 13.549                        | -7.062                        | Weight           |
|     |               | Before Work (13.00 WIB) | 13.102                        | -7.062                        | Weight           |
|     |               | After Work (16.00 WIB)  | 20.704                        | -7.062                        | Weight           |
|     |               | Before Work (07.00 WIB) | 5.705                         | 8.050                         | Weight           |
|     |               | After Work (12.00 WIB)  | 13.755                        | 8.050                         | Weight           |
| 6   | Mr. Supardi   | Before Work (13.00 WIB) | 18.227                        | 2.236                         | Light            |
|     |               | After Work (16.00 WIB)  | 20.463                        | 2.236                         | Light            |
|     |               | Before Work (07.00 WIB) | 11.954                        | 1.342                         | Light            |
|     |               | After Work (12.00 WIB)  | 13.296                        | 1.342                         | Light            |
|     |               | Before Work (13.00 WIB) | 8.824                         | -3.578                        | -                |
|     |               | After Work (16.00 WIB)  | 5.246                         | -3.578                        | -                |
|     |               | Before Work (07.00 WIB) | 12.078                        | -3.130                        | -                |
| 7   | Mr. Kinan     | After Work (12.00 WIB)  | 8.948                         | -4.919                        | -                |
|     |               | Before Work (13.00 WIB) | 15.209                        | -4.919                        | -                |
|     |               | After Work (16.00 WIB)  | 10.289                        | -4.919                        | -                |
| 8   | Mr. Pras      | After Work (12.00 WIB)  | 8.948                         | 2.236                         | Light            |
|     |               | Before Work (13.00 WIB) | 15.209                        | 2.236                         | Light            |
|     |               | After Work (16.00 WIB)  | 10.289                        | 2.236                         | Light            |
Table 2. The Results Of The Calculation Of Energy Expenditure, Energy Consumption and Workload Categories Of 12 Mechanical Operators

| No. | Operator Name | Time Measurement | Energy Expenditure (Kcal/min) | Energy Consumption (Kcal/min) | Workload Category |
|-----|---------------|------------------|-------------------------------|-------------------------------|------------------|
| 9   | Mr. Sabar     | Before Work (07.00 WIB) | 15.950                        | -5.814                        | -                |
|     |               | After Work (12.00 WIB) | 10.136                        | 10.136                        | -                |
|     |               | Before Work (13.00 WIB) | 22.658                        | -7.155                        | -                |
|     |               | After Work (16.00 WIB) | 15.503                        | -                              | -                |
|     |               | Before Work (07.00 WIB) | 10.321                        | 4.472                         | Light            |
|     |               | After Work (12.00 WIB) | 5.849                         | 5.849                         | Light            |
| 10  | Mr. Royyan    | Before Work (13.00 WIB) | 14.346                        | 0.447                         | Light            |
|     |               | After Work (16.00 WIB) | 14.793                        | 14.793                        | -                |
|     |               | Before Work (13.00 WIB) | 16.971                        | 2.873                         | Light            |
|     |               | After Work (16.00 WIB) | 2.873                         | 2.873                         | Light            |

3.2 Calculate The Ideal Rest Time for Operators in The Mechanical Department PT. XYZ

After knowing the results of the Energy Consumption (K) is obtained, and then calculated the ideal rest time (RT) for the operator. In the calculation of rest time by using equations 2.3 and 2.4, this is in accordance with the provisions of K < S dan S ≤ K < 2S. Then for Work Expected Total Time (T) at 07.00-12.00 WIB taken for 5 hours or 300 minutes and at 13.00-16.00 WIB for 3 hours or 180 minutes because total hours worked when the operator. In the Table 3 is the calculation of ideal rest time obtained for each operator.

Table 3. Ideal Resting Time Calculation Results

| No. | Operator Name | Measurement Time | RT (min) | Information          |
|-----|---------------|------------------|----------|----------------------|
| 1   | Mr. Jumali    | Before Work (07.00 WIB) | -        | Not Defined           |
|     |               | After Work (12.00 WIB) | -        | Not Defined           |
|     |               | Before Work (13.00 WIB) | -        | Not Defined           |
|     |               | After Work (16.00 WIB) | -        | Not Defined           |
|     |               | Before Work (07.00 WIB) | 0        | Enough Rest Time     |
|     |               | After Work (12.00 WIB) | -        | Not Defined           |
|     |               | After Work (13.00 WIB) | -        | Not Defined           |
|     |               | After Work (16.00 WIB) | -        | Not Defined           |
|     |               | Before Work (07.00 WIB) | 26       | Require additional rest time of 26 minutes |
|     |               | After Work (12.00 WIB) | -        | Not Defined           |
|     |               | After Work (13.00 WIB) | -        | Not Defined           |
|     |               | After Work (16.00 WIB) | -        | Not Defined           |
|     |               | Before Work (07.00 WIB) | 112      | Require additional rest time of 112 minutes |
|     |               | After Work (12.00 WIB) | 66       | Require additional rest time of 66 minutes |
|     |               | After Work (13.00 WIB) | 103      | Require additional rest time of 103 minutes |
|     |               | After Work (16.00 WIB) | 0        | Enough rest time     |

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Table 3. Ideal Resting Time Calculation Results

| No. | Operator Name | Measurement Time | RT (min) | Information          |
|-----|---------------|------------------|----------|----------------------|
| 7   | Mr. Kinan     | Before Work (07.00 WIB) | 0        | Enough rest time     |
|     |               | After Work (12.00 WIB) | -        | Not Defined          |
|     |               | Before Work (13.00 WIB) | -        |                       |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
|     |               | Before Work (13.00 WIB) | -        |                       |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
| 8   | Mr. Pras      | Before Work (13.00 WIB) | -        |                       |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
|     |               | Before Work (13.00 WIB) | -        |                       |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
| 9   | Mr. Sabar     | Before Work (13.00 WIB) | -        |                       |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
| 10  | Mr. Royyan    | Before Work (13.00 WIB) | 0        | Enough rest time     |
|     |               | After Work (16.00 WIB) | 38       | Require additional rest time of 38 minutes |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
| 11  | Mr. Didik     | Before Work (13.00 WIB) | -        | Not Defined          |
|     |               | After Work (16.00 WIB) | -        |                       |
|     |               | Before Work (07.00 WIB) | -        |                       |
|     |               | After Work (12.00 WIB) | -        |                       |
| 12  | Mr. Novianto  | Before Work (13.00 WIB) | 0        | Enough rest time     |
|     |               | After Work (16.00 WIB) | -        |                       |

3.3 Measurement Of Psychological Workload Experienced By The Operator Of The Mechanical Department PT. XYZ

Counting mental workload experienced by operators in the Department of Mechanical PT. XYZ, which consists of several stages:

1. Counting the number of tally of any indicators that have been selected by the operator which serves as a weight.
2. Calculating the value of the product.
3. Calculating Weighted Workload (WWL).
4. Calculate the average WWL.
5. Interpretation score to determine the workload generated category.

Data processing is performed using the NASA-TLX method, the following is the result of mental workload calculation for each operator.

Table 4. Results of Product Value and WWL

| No. | Operator Name | MD | PD | TD | OP | FR | EF | WWL |
|-----|---------------|----|----|----|----|----|----|------|
| 1   | Mr. Jumali    | 160| 450| 240| 70 | 0  | 360| 1280 |
| 2   | Mr. Satimin   | 100| 165| 50 | 180| 50 | 300| 845  |
| 3   | Mr. Johannis  | 210| 240| 120| 180| 100| 240| 1090 |
| 4   | Mr. Suryanto  | 140| 100| 400| 0  | 20 | 360| 1020 |
| 5   | Mr. Nur       | 240| 400| 0  | 160| 70 | 320| 1190 |
| 6   | Mr. Supardi   | 285| 160| 375| 85 | 70 | 270| 1245 |
| 7   | Mr. Kinan     | 80 | 0  | 340| 360| 320| 150| 1250 |
| 8   | Mr. Pras      | 0  | 80 | 350| 320| 80 | 240| 1070 |
| 9   | Mr. Sabar     | 0  | 80 | 350| 320| 80 | 240| 1070 |
| 10  | Mr. Royyan    | 55 | 325| 120| 195| 0  | 150| 845  |
| 11  | Mr. Didik     | 60 | 140| 400| 240| 40 | 140| 1020 |
| 12  | Mr. Novianto  | 240| 400| 0  | 160| 70 | 320| 1190 |
Table 5. Mental Workload Score of The Mechanical Department Operator PT. XYZ

| No. | Operator Name | Score Of WWL | Workload Category |
|-----|---------------|--------------|-------------------|
| 1   | Mr. Jumali    | 85.333       | Very high         |
| 2   | Mr. Satimin   | 56.333       | High              |
| 3   | Mr. Johannis  | 72.667       | High              |
| 4   | Mr. Suryanto  | 68           | High              |
| 5   | Mr. Nur       | 79.333       | High              |
| 6   | Mr. Supardi   | 83           | Very high         |
| 7   | Mr. Kinan     | 83.333       | Very high         |
| 8   | Mr. Pras      | 71.333       | High              |
| 9   | Mr. Sabar     | 71.333       | High              |
| 10  | Mr. Royyan    | 56.333       | High              |
| 11  | Mr. Didik     | 68           | High              |
| 12  | Mr. Novianto  | 79.333       | High              |

In this study, the result of the level of physical work load felt by the operator will affect the level of fatigue, ideal rest time is required to restore the energy that has been taken out by the operator while performing the work and the level of workload that operator mentally experienced, is very important because in addition to the physical workload, mental workload can affect the level of operator fatigue.

The conclusions of this research are formulated to answer the problem is to know how big physical workload and mental workload accepted by the operator during the work, how the ideal breaks time for operators.

Further studies are needed on the factors that affect physiological and psychological workloads, especially the physical work environment, the relationship between the two workloads and observation not only for the operators of the Mechanical Department but also for another Departments, to know that there are comparisons of which Department operators are most heavy workload, and it is necessary to measure the operator's work productivity before and after adding the rest period so the effect of the rest time can be seen on the productivity produced.

4 CONCLUSIONS

Based on the results of data processing and analysis has been done, it can be concluded as follows.

1. The level of physiological workload heaviest suffered by Mr. Nur before the break with a KE of 8.497 kcal/minutes and 7.602 kcal/minutes after the break when operating a medium-sized lathes. While other operators produce KE varying between light and undefined.

2. Work breaks are ideal for operators who categorized the heavy workload that Mr. Nur requires 112 minutes to break from 07.00-12.00 WIB and 66 minutes from 13.00-16.00 WIB. Then, while working from 07.00-12.00 WIB, Mr. Supardi takes 103 minutes for break and Mr. Didik takes 38 minutes for break. While the other operators has already sufficient so it does not need to increase the rest time.

3. The level of psychological work load experienced by all operators belong to the criteria of high and very high with the highest indicator is Effort (EF) with a value of 2770.

5. REFERENCES

[1] Admin, 2019 Manufacturing Industrial Production Growth fourth quarter 2018, the Central Bureau of Statistics, Jakarta.

[2] R. A. M. Puteri and Z. N. K. Sukarna, 2017 Workload Analysis Method Using CVL and NASA-TLX at PT. ABC, Spectrum of Industry, XV(2), p. 212.
[3] P. Fithri and W. F. Anisa, 2017 Measurement of Psychological and Physiological Workload Workers in Textile Industry, *Journal of Industrial System Optimization*, XVI(2), pp. 120-130.

[4] Admin, 2003 Law of the Republic of Indonesia Number 13 of 2003 on Labor, pp. 1-50.

[5] S. Wignjosoebroto, 2003 *Ergonomics, Motion and Time Studies*. 3rd ed., (Surabaya: Widya Guna), p. 272.

[6] T. Sholichul and L. Sudiajen, 2004 *Ergonomics for Occupational Health, Safety and Productivity*, (Surakarta: UNIBA Press).

[7] P. Suma'mur, 1982 *Ergonomics For Work Productivity* (Jakarta: Yayasan Karya Swabhawa).

[8] L. Keytel, J. Goedecke, T. Noakes, H. Hiiloskorpi, Laukkanen R. and L. V. D. M. E. Lamber 2005 Prediction of energy expenditure from heart rate monitoring during submaximal exercise, *Journal of Sports Sciences* XXIII(3).

[9] K. H. E. Kroemer, H. J. Kroemer and K. E. Kroemer-Elbert, 2010 *Engineering Physiology*, 4th ed., (Heidelberg: Springer).

[10] S. Widodo, 2008 Determination of the Old Breaks Based on Workload Using Physiological Approach (Case Study: Oil Mill White Wood Krai), Department of Industrial Engineering, Universitas Muhammadiyah Surakarta, Surakarta.

[11] B. M. Pulat, 1992 *Fundamentals of Industrial Ergonomics*, (USA: Waveland Press, Inc.)

[12] P. A. Hancock and N. Meshkati, 1988 “Human Mental Workload”, Amsterdam: North-Holland.

[13] R. Asdyanti, 2011 “Analysis of Mental Workload Relationship with Employee Performance Category Management Department Contract Business Unit at Chevron Indonesia”.