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Workload Analysis for Coating Operator in the Quality Control Department Using Cardiovascular Load and NASA-TLX Questionnaire

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Abstract

PT X produces cold-rolled steel coils, followed by a series of testing processes such as cutting, adhesive testing, and X-ray fluorescence (XRF) testing. These testing processes require significant time and effort and must be performed promptly. Additionally, the results need to be delivered on time. In the coating department, there is only one worker. This leads to complaints about the heavy workload, which can impact both the physical and mental health of the worker. Therefore, a workload analysis is necessary to achieve a more optimal performance evaluation. The methods used include cardiovascular load (CVL) measurement and the NASA-TLX questionnaire. The research results show a CVL value of 31.93%. The NASA-TLX score reached 88.75%, indicating a very high workload category. Proposed improvements to reduce physical workload include redesigning the rear part of the cutting machine by adding a trolley. Additionally, solutions to reduce mental workload include hiring additional workers at specific times or redistributing job tasks in the coating area.

1. INTRODUCTION

Companies are responsible for improving performance and achieving optimal goals, especially in a competitive industrial environment. Increased work activities can affect employee productivity, both positively and negatively. The success of a company largely depends on the management of production factors, with human operators playing a crucial role in achieving high-quality outcomes. The accuracy and precision of workers significantly influence the quality of the final results (Sari et al., 2022).

The workforce plays a vital role in an organization. When physical and mental activities are not well-managed, it can lead to reduced stamina, emotional instability, and a lack of enthusiasm for work, ultimately disrupting performance. Mental fatigue often results from excessive workloads, tight deadlines, prolonged physical strain, low motivation, and other factors. Therefore, physical and mental recovery are essential to

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maintaining optimal work performance (Maulana, 2019). Work fatigue is a condition that can lead to reduced well-being and job performance as a result of work-related activities. It is characterized by diminished performance, low motivation, and decreased mental and physical functioning. Fatigue can negatively impact productivity and concentration. Therefore, addressing fatigue is essential, as it can affect workers across various types of jobs (Alfonso et al., 2022).

Workload is a critical factor in evaluating employee performance. It can be defined as the discrepancy between an individual's capabilities and the demands of the job. Workload includes various elements, such as the nature of the tasks to be completed, the time needed to accomplish them, and the expected level of performance. In the context of healthcare workforce planning, the Indonesian Ministry of Health has developed the Basic Personnel Arrangement (DSP) Module, which provides a method for estimating workload for healthcare personnel (Akbar & Sunardi, 2020).

Measuring workload is essential for evaluating the contribution of employees to a company's overall performance. Mental workload is associated with psychological conditions and the need for quick decision-making. Job stress often arises from a mismatch between individual capabilities and job demands, as well as from organizational changes. Assessing mental workload is crucial for maintaining employee health and optimizing performance (Handika et al., 2020).

The analysis method applies Cardiovascular Load (CVL) to assess physical workload and NASA-TLX to measure mental workload. NASA-TLX includes six indicators: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (P), Effort (EF), and Frustration (FR). The temporal demand factor reflects the workload perceived by workers in terms of time pressure; therefore, the work sampling method is also used to measure workers' time-related workload (Maulana, 2019). The NASA-TLX method specifically evaluates mental workload, while the cardiovascular load method categorizes physical workload by comparing the worker's heart rate during tasks to their maximum heart rate (Hardiansyah & Putra, 2022).

In the coating area, there are numerous tasks, but they are handled by only one worker. This leads to complaints about the heavy workload, caused by continuous work and high time demands. As a result, workers in this area experience rapid fatigue, and the lack of adequate rest negatively impacts both their mental and physical health. Therefore, a workload analysis is necessary to support a more accurate and effective evaluation of work performance.

2. METHODS

The data collection methods used in this study included observation, interviews, NASA-TLX questionnaires, and heart rate measurements using an oximeter. A total of four coating operators participated, working across three shifts.

Physical Workload Measurement

Physical workload was assessed using Cardiovascular Load (CVL) from heart rate. Heart rate measurements estimate physical workload by comparing the increase in heart rate from rest to the maximum during work. This is done by detecting the heart rate at the radial artery of the wrist. The measurement helps monitor cardiovascular strain during work activities. When available, telemetry using electrocardiogram (ECG) signals is preferred; otherwise, heart rate is manually recorded for 10 seconds using a stopwatch (Lubis, 2020).

Mental Workload Measurement

Mental workload was measured using the NASA-TLX questionnaire. This method evaluates mental workload across 15 different tasks using a nine-point scale. These are grouped into six factors: mental demand, physical demand, temporal demand, self-performance, effort, and frustration level. NASA-TLX is a subjective method that involves pairwise comparisons and job assessments (Purnawan & Hamali, 2023).

3. RESULT AND DISCUSSION

Physical workload

Table 1 presents the results of the respondents' heart rate measurements. The average resting heart rate was approximately 75 beats per minute (bpm), ranging from 66 to 82 bpm. The average working heart rate was around 113 bpm, ranging from 106 to 118 bpm, while the average maximum heart rate across all respondents was approximately 195 bpm, with a range of 193 to 197 bpm. The table also displays the results from the Cardiovascular Load (CVL) calculations. Among the four respondents, Respondent 4 recorded the highest CVL score. Overall, the analysis revealed an average CVL score of 31.93%, indicating a need for improvements in the working conditions of the coating area to reduce the physical workload experienced by these workers.

Table 1. Heart Rate Measurement and Cardiovascular Load Calculation

No	Resting Heart Rate/Minute	Working Heart Rate/Minute	Maximum Working Heart Rate	%CVL	Remarks
1	66	106	193	31,49%	Requires Improvement
2	82	116	197	29,56%	No Fatigue Occurred
3	71	112	195	33,06%	Requires Improvement
4	80	118	193	33,62%	Requires Improvement
Average	78	99,5	194,5	31,93%	Requires Improvement

Based on the observations and CVL calculations, the average %CVL of 31.93% is classified as requiring improvement, primarily due to the fast-paced nature of the tasks, which leads to worker fatigue. Furthermore, the non-ergonomic posture observed during the clearing of scrap behind the shearing machine has contributed to complaints of lower back pain. Tasks that require prolonged standing and rapid execution can result in fatigue. Previous studies have shown that workers who adopt abnormal postures during their tasks are 2.5 times more likely to suffer from lower back pain than those who maintain proper posture (Sulaiman & Sari, 2018). As illustrated in Figure 1, unnatural body postures, combined with repetitive lifting over an 8-hour shift involving 35 scrap handling cycles, lead to significant physical fatigue, reinforcing the need for improvements in CVL scores. Arum (2023) also found that tasks involving non-ergonomic postures and repetitive movements place stress on muscles, leading to discomfort and fatigue.

Fig 1. Awkward Posture for the Coating Operator

To address the high physical workload, a redesign of the rear section of the shearing machine is proposed. The solution involves placing a scrap trolley behind the machine, eliminating the need for workers to reach behind it to clear scrap. Figure 2 provides a side view of the shearing machine area before the proposed improvement, showing the respondents in bent, abnormal postures while picking up scraps, which can contribute to lower back pain. Prolonged unnatural postures can lead to both physical fatigue and discomfort (Hijah et al., 2021).

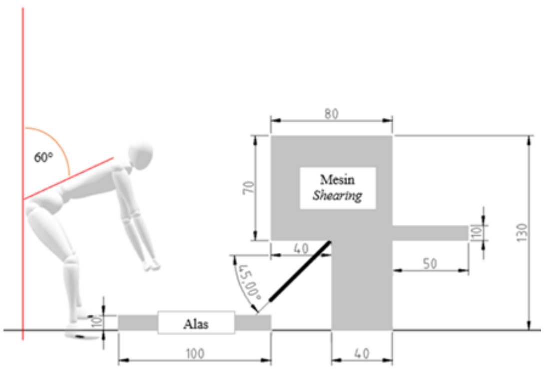

Fig 2. Side View of the Shearing Machine Before the Improvement

Figure 3 shows a side view of the shearing machine area after the improvement. Respondents no longer need to bend to pick up scraps from behind the shearing machine, as the scraps can now be directly transferred into the scrap trolley. This modification helps prevent lower back pain, significantly reduces physical strain on workers, and enhances overall operational efficiency.

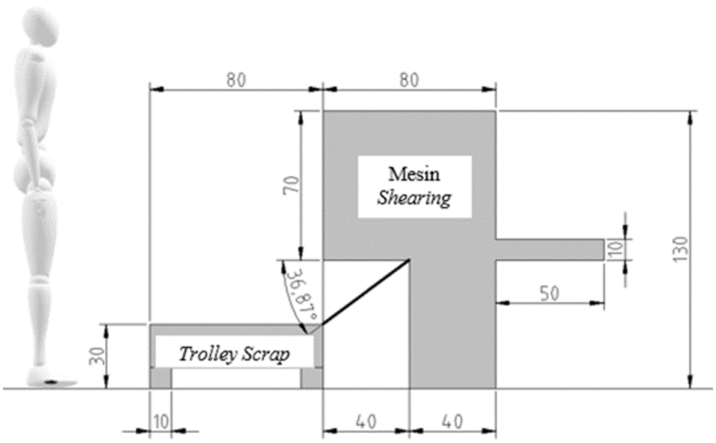

Fig 3. Side View of the Shearing Machine After the Improvement

Working with a proper ergonomic posture generally leads to better outcomes, while operators are more likely to experience fatigue when their posture is not ergonomically aligned (Sulaiman & Sari, 2018). By redesigning the rear section of the shearing machine—such as adding a trolley and adjusting the angle of the plate—respondents no longer need to bend repeatedly to collect scraps and place them into the trolley during an 8-hour shift, performed up to 35 times. This improvement can help prevent lower back pain and reduce the physical workload perceived by the workers.

Mental workload

Table 2 presents the results of the questionnaire distribution and the NASA-TLX indicator scores for each respondent. The Temporal Demand indicator recorded the highest total score of 1685, with an average of 421.25, indicating that time-related pressures are a significant source of complaints among the respondents.

Table 2. The values of the indicators from each respondent

No	Indicators of NASA-TLX					
	MD	PD	TD	P	E	F
1	0	370	380	190	100	340
2	0	290	450	90	340	170
3	340	295	380	100	90	100
4	0	370	475	190	95	340
Total	340	1155	1685	570	625	950
Average	85	288,75	421,25	142,5	156,25	237,5

The chart below illustrates the percentage distribution of each NASA-TLX indicator, showing that Temporal Demand has the highest percentage at 31%. This reflects the perceived pressure to complete tasks quickly. However, the nature of the work involves relatively long processes, which further heightens the time pressure experienced by employees.

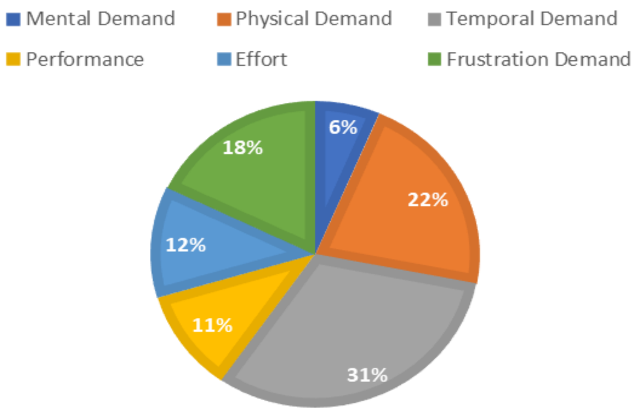

Fig 4. Comparison of the total percentage of each NASA-TLX indicator

Table 3 provides a concise summary of the NASA-TLX calculations for all respondents. Notably, Respondents 1 and 4 recorded the highest Weighted Workload (WWL) scores, with the average WWL across all four respondents being 1331.25. Additionally, the average NASA-TLX score was 88.75. The lowest NASA-TLX score, 86, was recorded by Respondent 2, while the highest score, 91.33, was observed for respondents 1 and 4. These results indicate that all respondents experienced a very high level of mental workload. Therefore, improvements in the coating area are necessary to reduce the mental workload perceived by the workers.

Table 3. Summary of NASA-TLX Calculation Results

No	WWL	Score NASA-TLX	Category
1	1370	91,33	Very High
2	1290	86	Very High
3	1295	86,33	Very High
4	1370	91,33	Very High
Average	5325	88.75	Very High

Based on observations and mental workload calculations, respondents' mental workload ranged from 86.33% to 91.33%, with an average NASA-TLX score of 88.67%. These results indicate that all respondents experienced a very high level of mental workload, particularly due to time pressure. This elevated workload is driven by the rapid arrival cycle of testing samples, continuous work activities, a heavy job desk, and intensive time demands during the testing process. These factors contribute significantly to the workload perceived by coating area workers, leading to rapid fatigue. According to Negara & Ningrat (2022), extended working hours, especially in monotonous tasks, increase the risk of fatigue, health issues, work-related illnesses, and even workplace accidents.

The calculated standard workforce of 1.5 indicates that the current workload in the coating area exceeds the capacity of a single worker. Therefore, a proposed improvement involves adding one additional worker when PT X produces galvanized steel, or alternatively, dividing the job tasks within the coating area. Arasyandi & Bakhtiar (2016) suggest that reducing mental and physical demands can be achieved through task allocation and job rotation, supported by additional manpower during galvanized steel production. By distributing job tasks more evenly, the workload can be better managed, reducing both physical and mental strain—particularly time-related demands—in the quality control section of the coating area.

4. CONCLUSION

The results of the physical workload analysis using Cardiovascular Load (CVL) indicate the need for improvements in working conditions. During the scrap handling process behind the shearing machine, workers were observed to adopt abnormal postures, particularly in their backs, which contributed to low back pain and rapid fatigue. The mental workload analysis at PT X, conducted using the NASA-TLX method, revealed very high scores, indicating that all respondents experienced a significant level of mental workload. The most influential factor was time demand, driven by the rapid arrival cycles of testing samples, continuous work activities, numerous job tasks, and intensive time usage during the testing process. To reduce physical workload, it is proposed to redesign the rear section of the shearing machine, allowing scraps to fall directly into a scrap trolley. This modification would eliminate the need for workers to bend and repeatedly transfer scraps into the trolley during their 8-hour shifts. To alleviate mental workload, it is recommended to redistribute job tasks or add additional workers in the coating area during peak times. This would allow tasks to be shared more effectively, significantly reducing the mental strain on individual workers.

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