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Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021)

Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research

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Editors • Ade Gafar Abdullah, Astri Rinanti, Deni Miharja, Erfan Rohadi, Farid Triawan, Muhammad Penta Helios and Sudi Dul Aji

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Symposium on Advance of Sustainable Engineering

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PREFACE: Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021)

Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research

It is with great pleasure to welcome you to Symposium on Advances of Sustainable Engineering (SIMASE) 2021 hosted by Rumah Publikasi Indonesian on August 18-19, 2021. The event aims to a venue for engineers, researchers, scholars, and policy makers to explore the challenges and opportunities from the pandemic on civil engineering, mechanical engineering, manufacturing process and engineering materials, and electrical engineering. For civil engineers, they will play a significant part in the recovery since design and consutrcion services will be needed in the future, and they need to develop new construction methods, materials, and technologies in order to build a sustainable and resilient infrastructure. For manufacturers and engineers, they need to start thinking about the long-term change of their operations and adapt to the "new normal" that has emerged because of the epidemic. We welcome all parties to share their research and thoughts in the symposium.

Participants of the symposium were invited to submit their papers and disseminate them through virtual oral presentation covering such scope as civil engineering, mechanical engineering, manufacturing process and engineering materials, and electrical engineering. To enrich the discussion under the theme of "Post-COVID-19 pandemic: challenges and opportunities in environmental, science, and engineering research', we invited speakers with reputable expertise, namely Dr. Eng. Farid Triawan from Sampoerna University, Indonesia; Prof. Josaphat Tetuko Sri Sumantyo, Ph.D. from Chiba University, Japan; Prof. Andrivo Rusydi, Ph.D. from National University of Singapore (NUS), Singapore; Dr. Eng. Gagus Ketut Sunnardianto from Indosian Institue of Science (LIPI), Indonesia; and Dr. Astri Rinanti Nugroho from Universitas Trisakti, Indonesia. In addition to presenting their research results, the participants of the symposium were also encouraged to submit their papers to be proposed for publication to American Institute of Physics (AIP), one of the world's top publishers as conference proceedings. There were 309 manuscripts submitted to the committee comprising 256 papers of Biology, Chemistry, Computer Science and Technology, Engineering, and General Physics.

Finally, on behalf of the editors of SIMASE 2021, I would like to extend my most sincere gratitude to the organizing committee, co-hosting institutions, and most importantly, participants, speakers, presenters, and authors of the symposium. I do hope the proceedings bring significant contribution, particularly to the field of advances of sustainable engineering. I look forward to seeing you all at the upcoming symposium.

The Editors,
Ade Gafar Abdullah
Astri Rinanti
Deni Miharja
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Farid Triawan
Muhammad Penta Helios
Sudi Dul Aji

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RESEARCH ARTICLE | APRIL 27 2023

Virtual human modelling for work position improvement in cutting process

Winnie Septiani ✉; Novia Rahmawati; Robby Semaldi

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Virtual Human Modelling for Work Position Improvement in Cutting Process

by Anonim Anonim

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Virtual Human Modelling for Work Position Improvement in Cutting Process

Winnie Septiani[a)], Novia Rahmawati[b)] and Robby Semaldi[c)]

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Department of Industrial Engineering, Faculty of Industrial Technology, Trisakti University, Jakarta, Indonesia

[a)] Corresponding author: winnie.septiani@trisakti.ac.id
[b)] novia.rahmawati@trisakti.ac.id
[c)] robby_semaldi@yahoo.com

Abstract. Virtual human modeling is one of the effective options to improve work position. Human behavior that is very dynamic in carrying out its work activities can be more easily captured by using this simulation. This study aims to design a work position improvement in the cutting department by using virtual human modeling. The simulation is carried out using a software jack that is integrated with AutoCAD. The indicators to be evaluated are Low Back Analysis (LBA), Ovako Working Analysis System (OWAS), Rapid Upper Limb Assessment (RULA), and Posture Evaluation Index (PEI). Initial identification with Nordic Body Map identified complaints on the right shoulder, back, right upper arm, waist, left knee, and right knee. Simulation of the initial conditions using four established posture risk indicators shows that the cutting process has a high work risk and needs immediate improvement. Proposed improvements in adding a workbench for cutting operators are evaluated with a software jack simulation. The results show that the LBA, OWAS, and RULA indicators are declining. In addition, PEI became smaller than the previous value of 2,726 to 1,592. The Evaluation results can be considered in the company's decision to add a workbench facility in the cutting process to minimize the risk of posture to the operator.

INTRODUCTION

Posture risk is a risk that occurs a lot in various activities carried out by humans. One example is the risk of posture in the cutting section of furniture manufacturing. The operator works by using a manual cutting tool in a working position that bends on the floor. This activity is carried out about 7-8 hours per day. That makes the operator work with an uncomfortable working posture. Uncomfortable work posture, if done continuously and repeatedly and for a long time, can lead to the risk of Musculoskeletal Disorders (MSDs). Previous research has been done for the cutting process at one of the leather tanning automotive companies in Jakarta, Indonesia [1]. Initial complaints identified using Nordic Body Map (NBM) showed right shoulder pain, back pain, right upper arm pain, back pain, right-hand pain, left knee pain, and right knee pain, as shown in Fig.1.

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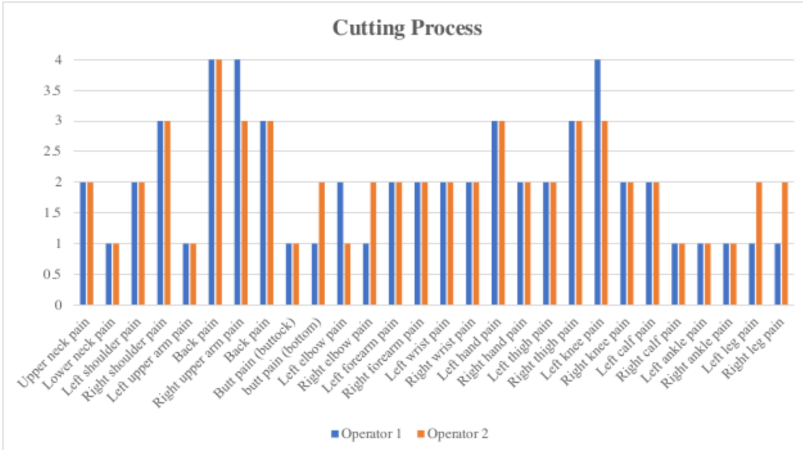


FIGURE 1. Identify complaints using Nordic Body Map

This research aims to analyze the risk of Musculoskeletal Disorders (MSDs) that occur to the operator of the cutting process by using virtual modeling. Based on the results of this ergonomic simulation, we propose work aids to reduce the risk of ergonomics. The tool used to model and analyze ergonomic risks in this research is JACK software version 8.3. JACK Software is one of the ergonomic software that can simulate how human models (virtual humans) located in the virtual environment can interact with objects and environments, as well as get the correct response from manipulated objects [2]. JACK's simulation software is also capable of performing sophisticated predictions based on empirical data and biomechanical models. This software model input uses CAD computer tools to create and manipulate human models in a virtual 3-dimensional form [3]. Computer-aided design (CAD) is applied to create a virtual digital prototype of a workstation/ product/ weapon system for useful ergonomic assessment [4].

Zhang et al. [5] mentioned that JACK software simulation is a comprehensive ergonomic evaluation method, which allows users to simulate various working conditions. JACK software is a professional software to evaluate the problem of ergonomic [6]. JACK produces a 3D graphical environment capable of mimicking virtual worlds with human simulations [7]. 3D modeling, design, and scientific simulation is finished on graphic workstations using JACK 3D ergonomic simulation [8]. The use of JACK digital modeling environment in the simulation and analysis of ergonomics problems is studied, which is an efficient, effective method Paul and Lee [9] and Mei-Ni [10].

Low Back Analysis (LBA) analysis on the back body of the operator and Ovako Working Analysis System (OWAS) to evaluate the comfort of work posture at different working positions for each operator, then analyze using PEI from the results of RULA, LBA, OWAS. PEI is a method of calculation that determines the level of comfort of human postures [11,12]. The RULA tool, based on values, deviates from the upper and lower limbs, neck, and trunk to finalize the risk [8].

The proposed improvements are simulated using JACK software, which is expected to minimize repair failure time, cost, and risk.

METHODS

This research was conducted on the cutting process at a furniture manufacturing company in Jakarta. Data was collected directly by observing the production floor activity, shooting the operator's work position, and interviews with the operator about complaints felt. In addition, data is also obtained by taking measurements directly on cutting operator activity. The working position of the observed cutting operator is divided into two positions:

Working Position When Cutting Raw Materials

The position of the operator's body working at the time of cutting tends to bend. In this position, the force and moment will be more significant when cutting. If the value of the angle of bending is getting smaller, then a more significant force and moment are required.

Working Position When Lifting the Cut Raw Materials

In this position, the operator changes the position of his body more bends down after doing two cuts.
This research was conducted through the following stages:

- Observing the activities carried out in the Cutting Division. The first stage analyzes the work environment, including operator movement, operator posture, and movement speed. At this stage, the critical point of the operator is identified to reach his work.
- Virtual Human Modeling for Cutting Process, using the CAD drawing input to design a virtual environment according to the desired layout and location components.
- Assessment level of MSDs using JACK software.
  Indicators used:
  - Low Back Analysis (LBA) to analyze the condition or pressure that occurs to the operator's spine in various working posture conditions.
  - Ovako Working Analysis System (OWAS) is used to evaluate the convenience of working postures in different work positions for each operator. The OWAS assessment indicates the posture scores of the back, arms, legs, and weights received by the body during certain work. OWA's value is determined by a risk score of 1 to 4. Where is score 1 indicates "normal posture", "slightly harmful" (score 2), "distinctly harmful" (score 3), and "extremely harmful" (score 4).
  - Rapid Upper Limb Assessment (RULA), this **analysis refers to the risk** of **Musculoskeletal Disorders (MSDs) in the upper body. The risk is given a value between 1 to 7. The value indicates the level of danger from risk along with corrective steps to be taken.**
  - Posture Evaluation Index Analysis (PEI). **Pei values integrate the results from LBA, OWAS, and RULA analysis. The lowest value configuration is the most optimal configuration. Pei value is the total number of three variables I_1, I_2, and I_3.**

$$PEI = \left(\frac{LBA}{3400}\right) + \left(\frac{OWAS}{4}\right) + [\left(\frac{RULA}{7}\right)\ 1{,}42] \quad (1)$$

  - Proposed improvement of work facilities to reduce posture risk of cutting operators.
  - Evaluation of proposed improvements using simulation JACK Software.

RESULTS AND DISCUSSION

Identification of Activities Performed at The Cutting Department

The process in the cutting division is activities of cutting from raw materials into appropriate parts. The cutting process has four stages, as shown in Fig. 2. It is carried out using a manual saw so that it takes a long time. The last stage after the cutting process is the inspection process to inspect the results of the cuts.

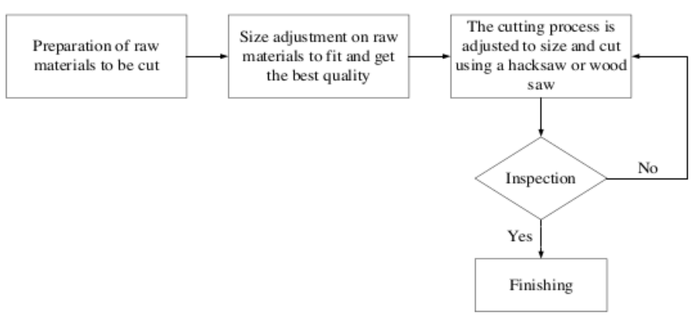
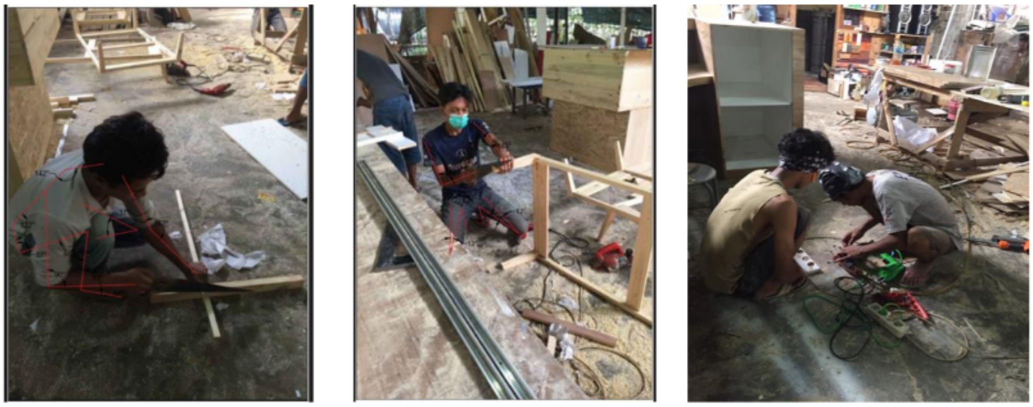


FIGURE 2. Process flow in cutting division

The identification of posture risk from observing 3 different positions on activity in the cutting division is shown in Fig. 3. Operators work in squat and bent positions for a long time, the head is lowered, the back is bent, the squat rests on the knee, and one hand is above the shoulder or parallel.

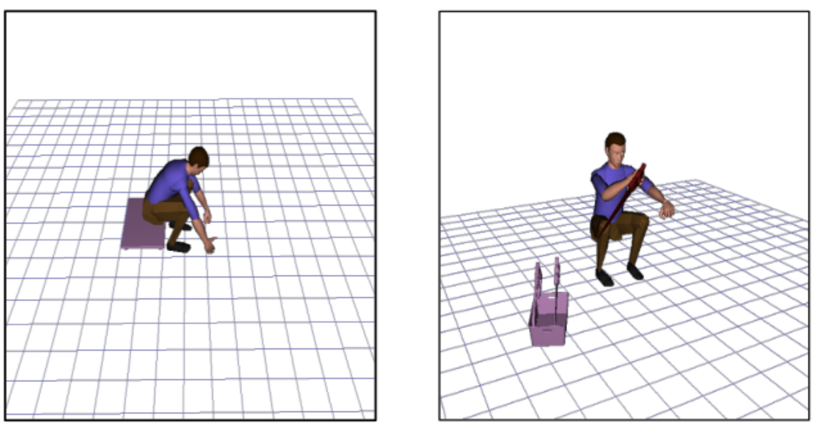


(a) Operator work in squat and bent position | (b) The squat rests on the knee | (c) The back is bent while work

FIGURE 3. Operator's working posture (existing)

Virtual Ergonomic Analysis

The initial stage of making Virtual Human in the cutting division workstation uses AutoCAD software to design the virtual environment. Then, the virtual environment design with .dwg format is converting to .stl so that it can be imported into JACK Software. Furthermore, a virtual human is created according to the actual state of cutting division. Figure 4 depicts the working posture of the operator 1 (a) and 2 (b) using JACK Software.



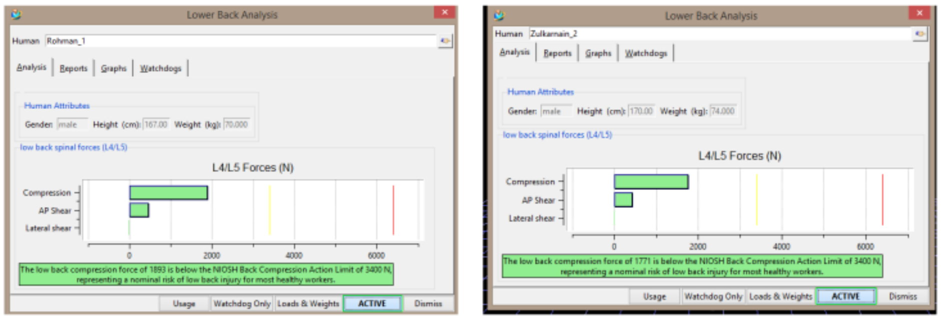
(a) operator 1 | (b) operator 2

FIGURE 4. Working posture of cutting operator using JACK software

Assessment Level of MSDs Using JACK Software

Low Back Analysis (LBA)

The results of the calculation of the LBA value of the two Cutting operators are 1893 N. The LBA score is relatively small because the operator does not lift or support heavy loads so that the operator's back is not too burdened. However, it cannot be ignored because the operator performs work for 8 hours and repeatedly so that it can pose a risk of spine injury. The LBA scores of operator 1 (a) and operator 2 (b) can be seen in Fig. 5.

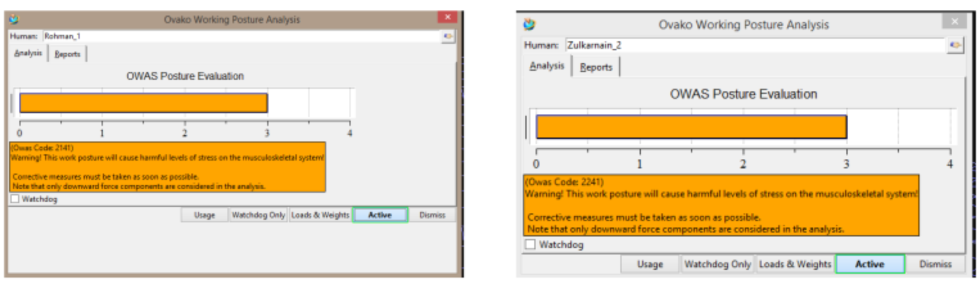


(a) operator 1 (b) operator 2

FIGURE 5. LBA score results from JACK software

Ovako Working Posture Analysis (OWAS)

The Calculations using Ovako Working Posture Analysis (OWAS) tools produce an output in the graph form that describes the level of fatigue from the operator's work posture. The level of fatigue is obtained based on the posture of the back, arms, legs, and the amount of load supported by the operator's body.



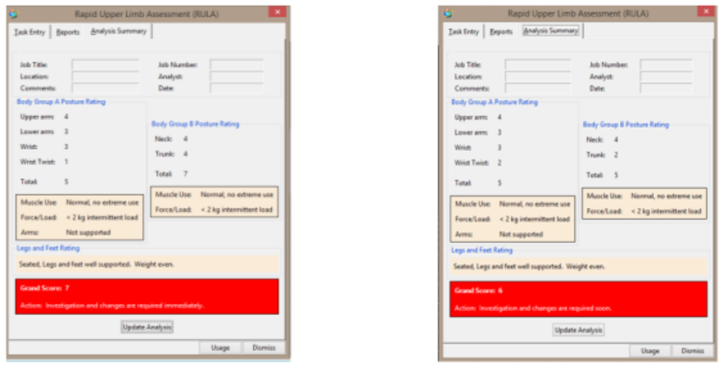
(a) operator 1 (b) operator 2

FIGURE 6. Calculation results OWAS operator 1 (left) and operator 2 (right)

Figure 6 shows the result of calculating the Ovako Working Posture Analysis (OWAS) value obtained based on the work postures carried out by operator 1 and operator 2. From the graph, it can be seen that the operator performed the work posture. Operator 1 got an OWAS value of 3 with OWAS code 2141, and operator 2 got an OWAS value of 3 with OWAS code 2241.

Rapid Upper Limb Assessment (RULA)

Calculations using the Rapid Upper Limb Assessment (RULA) tool on the JACK Software produce the total RULA value output. It is used to identify the risk of injury due to the operator's upper body working posture.



(a) operator 1 (b) operator 2

FIGURE 7. Rula calculation results operator 1 (left) and operator 2 (right)

Figure 7 shows the Rapid Upper Limb Assessment (RULA) obtained based on the work postures carried out by operator 1 and operator 2 in the cutting division. From the graph, it can be seen that operator 1 gets a total RULA value of 7 with a score for body group A is 5 and body group B is 7. The value of Rapid Upper Limb Assessment (RULA) obtained by operator 2 is 6 with a score for body group A is 5 and body group B is 6. The results of the total RULA value illustrate that the work postures carried out by operator 1 and operator 2 must be in further investigation and must be improved to avoid the risk of Musculoskeletal Disorders (MSDs). The evaluation results of the 3 indicators in the current condition can be seen in Table 1.

TABLE 1. Evaluation of MSD risks (Existing posture)

Operator	Parameters		
	LBA	**OWAS**	**ROLL**
Operator 1	Safe	It may have a harmful effect on MSD	Investigation and changes are required immediately
Operator 2	Safe	It may have a harmful effect on MSD	Investigation and changes are required immediately

Posture Evaluation Index (PEI)

The calculation of the Posture Evaluation Index (PEI) is carried out after obtaining the values of the three tools contained in the JACK Software, namely Low Back Analysis (LBA), Ovako Working Posture Analysis (OWAS), and Rapid Upper Limb Assessment (RULA). The result of calculating the Posture Evaluation Index (PEI) of operator 1 and operator 2 is shown in Table 2.

$$PEI = I1 + I2 + Mr * I3 \tag{2}$$

$$PEI = \frac{LBA}{3400} + \frac{OWAS}{4} + 1.42\left(\frac{RULA}{7}\right) \tag{3}$$

TABLE 2. Result of PEI calculation (Existing)

Operator	I_1	I_2	I_3	Mr	PEI
1	0.556	0.75	1	1.42	2.726
2	0.520	0.75	1.16	1.42	2.917

Improvement of Work Facilities

Based on the analysis results of current conditions and the ergonomic assessment with the JACK software, it is proposed to improve the form of a workbench for the operator. Essential factors for designing workbench facilities are operator anthropometric data, material size, and tool size (cutting tools with wood and stainless steel types). The anthropometric data used are height, elbow height, forward arm span, and sidearm span. The dimensions of the work table required are the length, width, and height of the table.

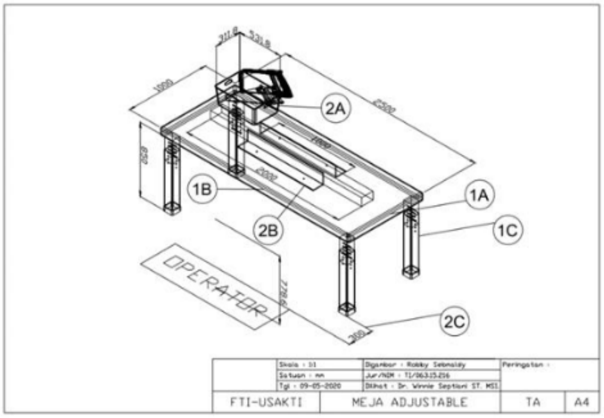
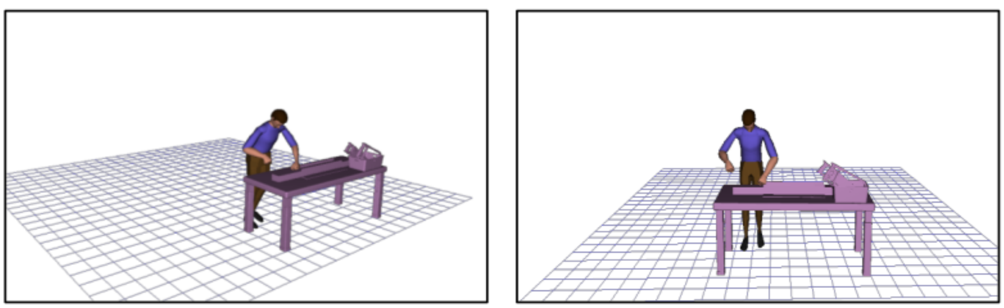


FIGURE 8. Proposed workbench figures for cutting process

Figure 8 shows a workbench design with length, width, and height according to the dimensions of the operator's body. This workbench is equipped with supports for raw materials for easy cutting. This workbench can be used for large raw materials and small raw materials according to customer requests.

Workstation Simulation After Repair

The initial process is to convert files with .dwg formatted into .igs, .iges, or .stl so that they can be used in JACK Software. Then the converted file is imported into JACK Software. Figure 9 shows the results of the operator's working posture after improvements from the side position (a) and front position (b).



(a) side position (b) front position

FIGURE 9. Working posture of cutting operator in JACK Software with workbench

Calculation of the Posture Evaluation Index (PEI) can be done if the values from Low Back Analysis (LBA), Ovako Working Posture Analysis (OWAS), and Rapid Upper Limb Assessment (RULA) have been obtained. Table 3 shows the calculation result of the Posture Evaluation Index (PEI).

$$PEI = I1 + I2 + Mr * I3 \quad (4)$$

$$PEI = \frac{LBA}{3400} + \frac{OWAS}{4} + 1.42\left(\frac{RULA}{7}\right) \quad (5)$$

TABLE 3. Result of PEI calculation (Improved posture)

Operator	I_1	I_2	I_3	Mr	PEI
1	0.42	0.5	0.428	1.42	1.527
2	0.485	0.5	0.428	1.42	1.592

For operator 1, there was a decrease in the Posture Evaluation Index (PEI) from 2,726 to 1527. And also, for operator 2, from the previous 2,917 to 1592. The decrease in the Posture Evaluation Index (PEI) value can be proven that the proposed improvement in the form of adding a work desk (scenario 1) in the cutting division minimizes the risk of Musculoskeletal Disorders (MSDs) when doing work.

CONCLUSION

From the results of this research obtained the following conclusions:

- The level of MSDs risk using LBA, OWAS, and RULA shows a high level of MSDs risk and needs improvement as soon as possible to reduce MSDs risk complaints. Operators in the cutting division perform wrong work postures. Therefore, operators feel many complaints such as right shoulder pain, back pain, right upper arm pain, back pain, right-hand pain, left knee pain, and right knee pain. These complaints were obtained from the Nordic Body Map (NBM) questionnaire.
- The proposed improvement is the design of work desk facilities to minimize the risk of Musculoskeletal Disorders (MSDs). The data used are elbow height, forward arm span, and sidearm span. In addition, it also uses the dimensional data of cutting tools and dimensions of raw materials to make sofas.
- Proposed improvements in the form of a simulated workbench on the JACK Software and a re-measurement of the risk level of Musculoskeletal Disorders (MSDs). There was a decrease in the value of LBA, OWAS, RULA, and PEI, which indicated that the proposed improvement in adding a work table in the cutting division could minimize the risk of Musculoskeletal Disorders (MSDs).

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