Work Posture Simulation Using Catia VSR20 at Virgin Coconut Oil Production

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Abstract. This study aims to measure the posture of a worker by analyzing the level of occupational health risk and the level of fatigue of the physical load in a posture with a high level of posture risk and proposes to improve posture to reduce the risk of musculoskeletal disorders. RULA is a method used to evaluate work posture, CATIA V5R20 software is used to simulate workers while doing work, and heart rate are the data used to identify the level of physical workload. The results of the work posture analysis show that the workers at station coconut husk stripping have the highest level of risk with a RULA score of 7 (red), which means that the work is very tiring and at risk of experiencing MSDs and needs to improve immediately. Based on the analysis of the classification of physical workloads, it shows that 76% of the coconut husk stripping work activity is a heavy and tiring workload category for the work. The proposed posture improvement shows a decrease in score.

Keywords. Posture Analysis, RULA, CATIA V5R20, Physical Workload, Musculoskeletas Disorders

1 Introduction

Ergonomic principles must be considered in designing a workstation to increase productivity and reduce health and safety risks. One focus of ergonomics is body posture. Work posture affects work results; postures that are not by ergonomic rules will cause fatigue and are at risk for MSDs. [1] [2]

Many ergonomic methods and techniques can be used to evaluate the workplace, such as the Rapid Upper Limb Assessment (RULA) method. [3] The RULA is amongst the most applied, popular and easy to use ergonomic assessment method. Many researchers have applied it in various sectors and concluded the relative risk levels in various tasks observed. RULA is usually considered as more conservative and strict method for posture evaluation. Similar to many other observational methods, it uses categorizations with the relevant problem of borderline areas.

Some studies used ergonomic assessment in the coconut oil processing industry. The pure coconut oil production process consists of 4 stages: stripping coconut husks, cutting coconut shells, shredding coconut meat, and heating coconut milk using the thermal method. The worker's posture at each workstation experienced bending posture, too high shrugging, wrist rotated repeatedly, and the hand was constantly in a non-neutral position. The working posture can be seen in Figure 1.

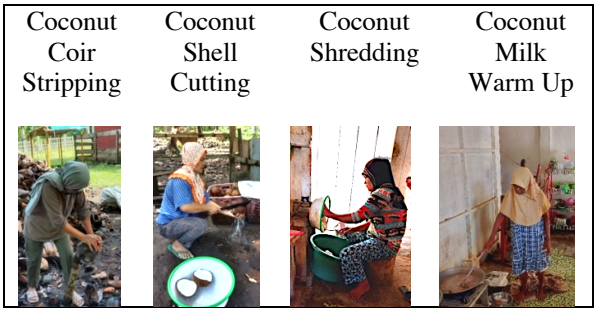

Fig. 1. Four Working Posture Station of Coconut Oil Production

Therefore, it is necessary to do a posture analysis at each workstation to manufacture virgin coconut oil to find out which workstation has the riskiest work posture for MSDs and requires immediate changes or repairs. [4] stated that workers experience a medium level of risk; further investigation and improvement of the working system at the coconut dregs mixing station are needed after boiling. [5] Evaluates the work posture of coconut milling operators. The result is that the work has a high and medium risk level. Based on an analysis of the job strain index, the job is included in the dangerous category.

[6] Designed a human hand graphic model using CATIA on anthropometry of 32 subjects. Human

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modeling using CATIA can help designers visualize handheld products and controls used. [7] conducted an analysis of energy consumption for employees when exercising, based on the classification of the physical workload in terms of heart rate [8], it was found that 76% of tennis is a heavy category for workers.
This study measures posture to determine the level of risk of work posture on the health of the worker's body, to determine the level of fatigue of the physical workload in a posture that has a high level of posture risk, and proposes to improve posture to reduce the risk of musculoskeletal disorders.

2 Research Methods

The number of workers observed was five people. Every day they work in each part of the workstation. They must finish 60 coconuts to produce 4 liters of virgin coconut oil daily. SOLIDWORKS and CATIA V5R20 software for designing workpieces that workers use to simulate modeling the human when doing work. The Rapid Upper Limb Assessment (RULA) was used to measure the risk of MSDs. The questionnaire Nordic Body Map to find out workers' complaints during work [9]. The Oximeter is used to measure heart rate while working. The Stopwatch measures the processing time of each workstation to manufacture virgin coconut oil. Anthropometry was used to measure the dimensions of the worker's body. Forty-three subjects were used for the anthropometric measurement. Figure 2 shows the anthropometric data as an input in human modeling. The working posture was modeled based on the worker's actual working posture. Furthermore, it was analyzed using the RULA method to measure the risk of MSDs. Figure 2. shows several steps in evaluating posture.

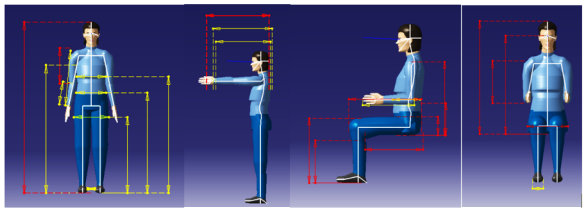

Fig.2. Anthropometric measurement in human modelling

Figure 3 shows the research design, which is divided into two parts: the stage of data collection and data analysis. The data collection stage was carried out by observing work postures, distributing questionnaires, measuring body dimensions, working heart rate, and processing time. The data analysis phase is carried out by analyzing the validity of the data, and used to make a mannequin based on anthropometric measurements in fig 2, after that modeling humans according to the working conditions of workers for posture analysis, then analyzing the level of physical workload fatigue.

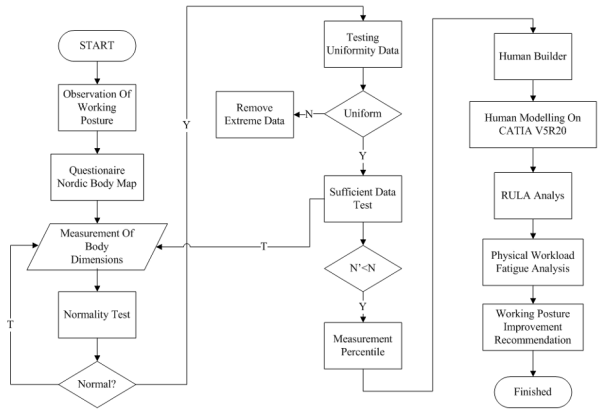

Fig.3. Research Design

3 Result and Discussion

3.1 Existing Posture Simulation and RULA Method Analysis

The formation of human modelling postures in coconut oil manufacturing was simulated using the 50th percentile to accommodate the average body size of workers. The process of traditionally making virgin coconut oil takes place in one cycle of work posture activity: stripping coconut husks, cutting coconut shells, shredding coconut meat, and heating coconut milk to produce pure oil. These activities are assessed with the RULA classification based on human modelling that resembles a worker's posture.

3.1.1 Coir Stripping Work Station

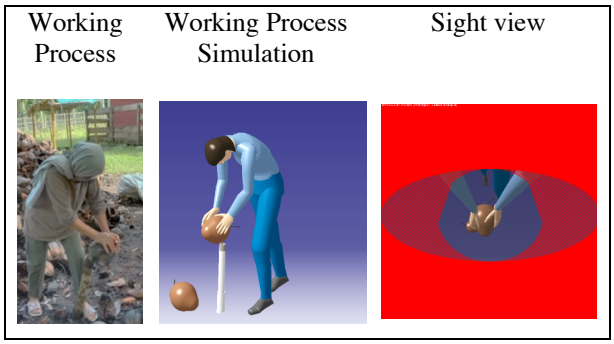

Fig.4. Coconut Coir Stripping Work Posture Workstation

Based on the body posture of stripping coconut husk above, several angles of flexion/extension are formed by the worker's body. The angle formed by lower back 37.40, thoracic 12.60, head 10.50, right thigh -180, left thigh 21.70, left leg 24.20, right arm 74.30, left arm 76.90, right forearm 39.30, left forearm 36.170, right hand -39.60, left hand -37,180. The results of the analysis using CATIA software can be seen in Figure 4.

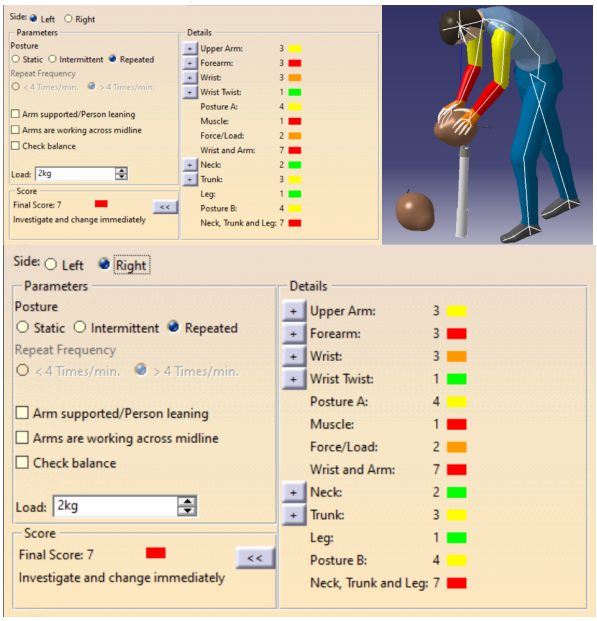

Fig. 5. RULA Analysis of Coconut Coir Stripping Work Posture

The body position of workers stripping coconut husks in a bent position can cause thoracic muscle fatigue in the left and right body muscles. That is because the lower back muscles are pulled up when bending over. Tabel 1. is a description of the results based on the RULA analysis output.

Table 1. Description of RULA Analysis of Coir Stripping Work Station Posture

Segmentasi	Score										
	1	2	3	4	5	6	7	8	9	10	>10
Upper Arm			√								
Forearm			√								
Wrist			√								
Wrist Twist	√										
Posture A Wrist and Arm							√				
Posture B Neck,Trunk,Leg							√				
Final Score							√				

Based on the results of the RULA analysis, the upper arm gets a value of 3 (yellow), meaning that this part of the body does not receive excessive muscle tension but must be considered. The forearm scores 3 (red) because it is experiencing muscle fatigue in doing work, so it requires immediate corrective action. The wrist has a value of 3 (orange) which means that the wrist experiences muscle fatigue and has the potential to cause wrist injury due to pressure from repeated movements, so changes in action are needed shortly. The neck, body, and legs have a value of 7 (red) which means the work has muscle fatigue and has the potential to experience MSDs if the work posture lasts for a long time. The final analysis of the working posture of coconut husk stripping has a value of 7 (red). Overall, this posture is very tiring and risky for workers and must be repaired immediately.

3.1.2 Coconut Shell Cutting Workstation

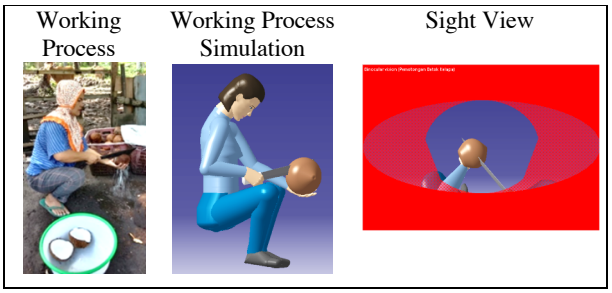

Fig. 6. Coconut Shell Cutting Workstation

In cutting the coconut shell above, several flexion/extension angles are formed by the worker's body. The angle formed by the thoracic is 10.60, head 17.40, right thigh 1130, left thigh 1130, left leg 131.90, right leg 1350, left arm 53.70, right forearm 108.50, left forearm 28.30. The results of the analysis using CATIA software can be seen in Figure 6.

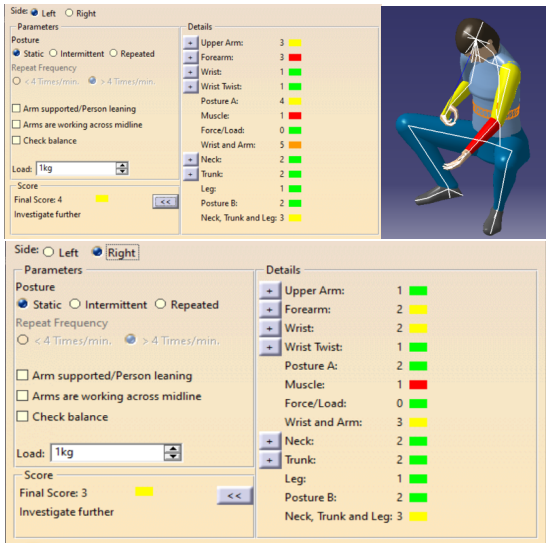

Fig. 7. RULA Analysis of Coconut Shell Cutting Working Posture

The position of the worker cutting coconut shells in a squatting sitting position can cause thoracic muscle fatigue and leg muscles on both the left and right sides of the body. That is because the lower back muscles are pulled up when a bent sitting position is squatting. The following describes the results based on the RULA analysis output.

Table 2. Description of RULA Analysis of Coconut Shell Cutting Workstation Posture

Segmentasi	Score										
	1	2	3	4	5	6	7	8	9	10	>10
Upper Arm	√		√								
Forearm		√	√								
Wrist	√	√									
Wrist Twist	√										
Posture A Wrist and Arm			√		√						
Posture B Neck,Trunk,Leg			√								
Final Score											

Based on the results of the RULA analysis, the upper arm received a value of 1 (green) and 3 (yellow),

which means that this part of the body does not receive excessive muscle tension but must be considered. The forearm scores 2 (yellow) and 3 (red) because it is experiencing muscle fatigue at work, so it requires immediate corrective action. The wrist has a value of 1 (green) and 2 (yellow), which means that the wrist does not experience fatigue but must be considered. Overall the posture of the upper arm, forearm, and wrist for the right side of the body does not have significant muscle fatigue. However, the arms and wrists on the left side of the body have muscle fatigue potential to get injured due to pressure from repetitive movements and need to change in the future. The neck, body, and legs have a value of 3 (yellow), meaning that the body part does not have muscle fatigue. The final analysis of the working posture of cutting coconut shells has a value of 3 and 4 (yellow), which means that overall, this posture is quite tiring and needs attention.

3.1.3 Coconut Shredding Work Station

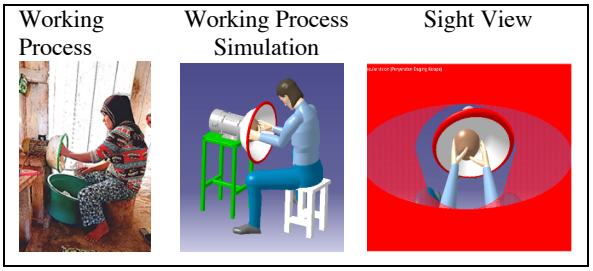

Fig. 8. Coconut Meat Shredding Work Posture Simulation

Based on the posture of shaving the coconut meat above, several angles of flexion/extension are formed by the worker's body. The angle formed by the lower back is 3.60, thoracic 14.80, head 13.090, right thigh 900, left thigh 900, left leg 900, right leg 900, right arm 53.70, left arm 58.80, right forearm 660, left forearm 550, right hand 0, left hand -16,40. The results of the analysis using CATIA software can be seen in Figure 14.

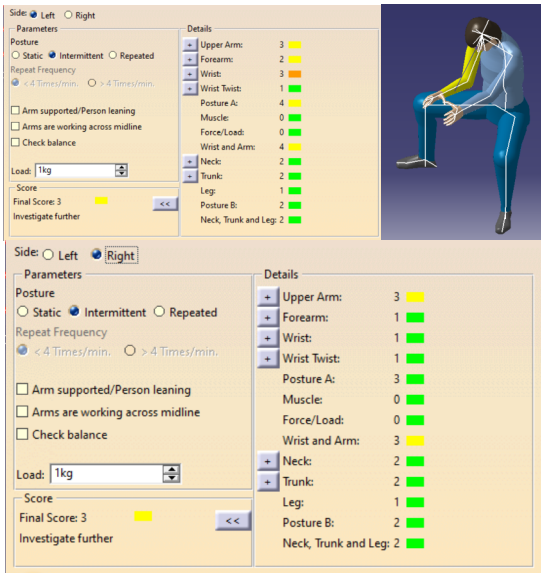

Fig. 9. RULA Analysis of Coconut Meat Shredding Working Posture

The position of the body of the worker who is shaving the coconut meat with the position of the hand holding and directing the coconut on the shaved knife causes muscle fatigue in the left wrist. That is because the muscles of the left wrist are flexed, so they are attracted when the wrist position presses the coconut on the drawstring knife. The following is a description of the results based on the RULA analysis output.

Table 3. Description of RULA Analysis of Coconut Meat Shredding Workstation Posture

Segmentasi	Skor										
	1	2	3	4	5	6	7	8	9	10	>10
Upper Arm			√								
Forearm	√	√									
Wrist	√		√								
Wrist Twist	√										
Posture A Wrist and Arm			√	√							
Posture B Neck,Trunk,Leg		√									
Final Score			√								

Based on the results of the RULA analysis, the upper arm gets a value of 3 (yellow), which means that this part of the body does not receive excessive muscle tension but must be considered. The forearm scores 2 (yellow) and 1 (green), meaning this body part does not receive excessive muscle tension. The wrist has a value of 1 (green) and 3 (orange), which means that the left wrist experiences muscle fatigue when holding the wrist in a retracted position to press the coconut shell on the grated knife so that the working position needs to be considered. Overall the posture of the upper arm, forearm, and wrist for the right side of the body does not have significant muscle fatigue. However, on the contrary, the wrist on the left side of the body has muscle fatigue. It has the potential for injury due to pressure from repetitive movements, so action is needed to change. The neck, body, and legs have a value of 2 (green), meaning that the body part does not have muscle fatigue. The final result of the analysis of the working posture of shaving coconut meat has a value of 3 (yellow) which means that overall, this posture is quite tiring and needs attention.

3.1.4 Coconut Milk Into Coconut Oil Heating Workstation

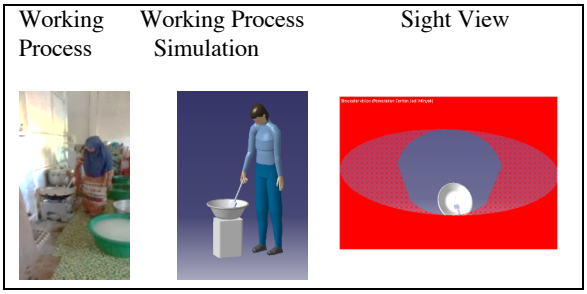

Fig. 10. Working Posture Simulation of Heating Coconut Milk into Coconut Oil

Based on the posture of shaving the coconut meat above, several angles of flexion/extension are formed by the worker's body. The angle formed by the lower back is 40, thoracic 90, head 18250, right thigh 0, left thigh 0,

left leg 0, right leg 0, right arm 31.70, left arm 17530, right forearm 7150, left forearm 0, right hand 0, left hand 0. The results of the analysis using CATIA software can be seen in Figure 16.

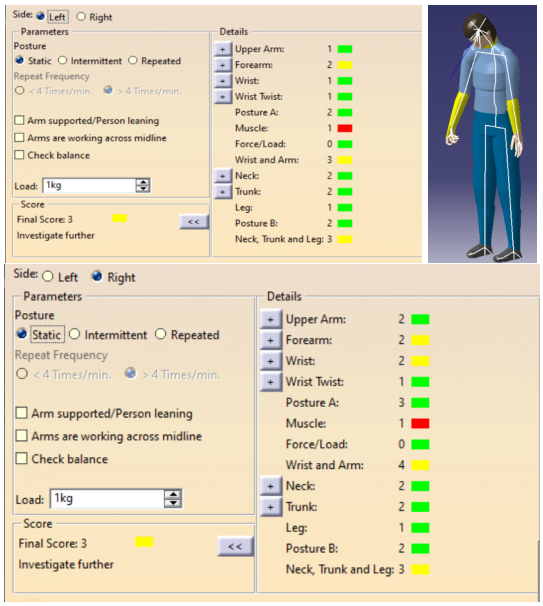

Fig.11. RULA Analysis Workstations for Cooking Coconut Milk into Coconut Oil

The body of the worker who is heating coconut milk to become coconut oil with the position of the hand holding the spatula, stirring the coconut milk, and standing for ± 1 hour causes muscle fatigue in the lower arm and right wrist. This is because the muscles of the forearm and right wrist experience repeated flexion and twists. The following describes the results based on the RULA analysis output.

Table 4. Description of RULA Analysis of Workstation Posture Heating Coconut Oil into Coconut Oil

Segmentasi	Skor										
	1	2	3	4	5	6	7	8	9	10	>10
Upper Arm	√										
Forearm		√									
Wrist	√	√									
Wrist Twist	√										
Posture A Wrist and Arm		√	√								
Posture B Neck,Trunk,Leg			√								
Final Score			√								

Based on the results of the RULA analysis, the upper arm received a value of 1 and 2 (green), which means that this part of the body does not receive muscle tension. The forearm scores 2 (yellow), meaning this body part does not receive excessive muscle tension. The wrist has a value of 1 (green) and 2 (yellow), meaning that the right wrist experiences muscle fatigue when stirring the coconut milk, so the working position must be considered. Overall, the posture of the upper arms, forearms, and wrists for the right and left sides of the body did not have significant muscle fatigue. The neck, body, and legs have a value of 3 (yellow), meaning that the body part has muscle fatigue needs to be considered. The final result of the work posture analysis for heating coconut milk into coconut oil has a value of 3 (yellow) which means that overall, this posture is quite tiring and needs attention.

3.2 Heart Rate Measurement While Working

From the ergonomics viewpoint, every workload a person receives must be appropriate or balanced in terms of physical, cognitive, and human limitations who receive the load. Assessment of workload levels is carried out at workstations that have the highest risk of work posture. The risk value is obtained from the final results of posture analysis at each workstation. From the analysis results, the workstation with the highest risk is the coconut husk stripping workstation, so it is necessary to measure heart rate to determine the level of physical workload fatigue experienced by workers at the workstation. Measurements were carried out using a stopwatch and an oximeter in each work cycle to complete the stripping of 30 coconuts. The following is the heart rate measurement data in Table 5.

Table 5. Working Heart Rate Measurement Data (Pulse/Minute)

No	Heart rate	No	Heart rate
1	100	16	123
2	105	17	119
3	100	18	120
4	108	19	124
5	112	20	125
6	112	21	120
7	108	22	128
8	116	23	128
9	100	24	125
10	108	25	122
11	118	26	125
12	120	27	128
13	115	28	123
14	126	29	126
15	128	30	128

3.3 Fatigue Level Analysis

Heart rate measurement is one tool to determine workload because heart rate is used to analyze and evaluate workload. The heavier person's physical load makes the work of the heart heavier, which is indicated by an increase in the heart rate value. Job classification according to workload criteria can be seen in table 6.

Table 6. Job Classification by Type of Workload Criteria

Workload	Energy Expended		Heart Rate (beats/minute)	VO_2 (L/Min)
	Kj/ minute	Kkal/ minute		
Easy	10-20	< 2.5	≤ 90	< 0.5
Normal	20-30	2.5 - 5.0	90-110	0.5 – 1.0
Difficult	30-40	5.0 - 7.5	110-130	1.0 – 1.5
Very Difficult	40-50	7.5 - 10	130-150	1.5 – 2.0
Extreme	50-60	>10	150-170	>2.0

Based on the heart rate data from the table above, the frequency of data using SPSS using the easy category is coded (1) if the heart rate is 90 beats/minute, normal with code (2) if the heart rate is between 90 to 110 beats/minute, heavy with code (3) if the heart rate ranges from 110 to 130 beats/minute, very heavy with a score of (4) if the heart rate ranges from 130 to 150 beats/minute, and extreme severe with code (5) if the heart rate ranges from 150 up to 170 beats/minute.

Table 7. Output Heart Rate of Coconut Coir Stripping Workers

Heart Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	7	23.3	23.3	23.3
	Heavy	23	76.7	76.7	100.0
	Total	30	100.0	100.0	

The workload classification analysis using SPSS in table 10 shows the results of the moderate and heavy categories of frequency. Medium category with a total of 7 and heavy with 23. So that 76% of the coconut husk stripping work activity is a category of heavy and tiring workload for the work.

3.4 Posture Improvement Recommendations

Recommendations for improving posture are carried out by human simulations and integrated into the tool by considering the angular limitations and the preferred angles. The recommended tool height is 90 cm so that the worker does not bend his body to extremes when using the tool. The position of the lever adjusts to the length of the reach of the worker's hand so that the worker's shoulder is not lower and the worker's hand does not experience excessive flexion and rotation. The following are recommendations for improving posture considering the angular limitations and the preferred.

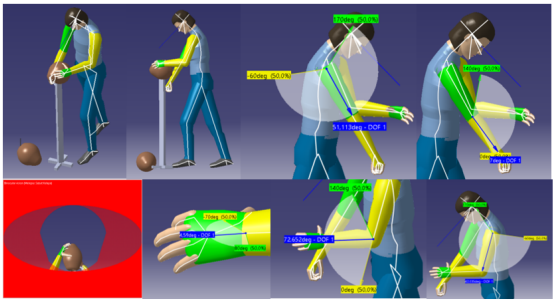

Fig. 12. Simulation Posture Improvement Recommendation

Based on the proposed body posture improvement above, several flexion/extension angles are formed by the worker's body. The angle formed by the lower back is 6.310, thoracic 9.210, head 14.130, right thigh -180, left thigh 21.70, left leg 24.270, right leg 0, right upper arm 51.10, left upper arm 420, right forearm 70, left forearm 72.650, right hand 0, left hand 4,590. The results of the analysis using CATIA software can be seen in Figure 12.

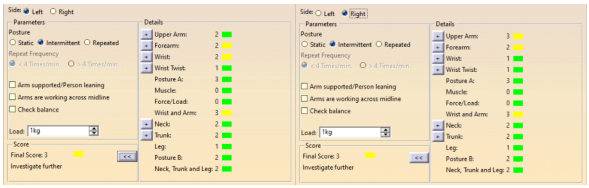

Fig. 13. RULA Analysis Result Posture Improvement

Table 8. Description of RULA Analysis of Posture Improvement

Segmentasi	Skor										
	1	2	3	4	5	6	7	8	9	10	>10
Upper Arm		√	√								
Forearm											
Wrist	√	√									
Wrist Twist	√										
Posture A Wrist and Arm			√								
Posture B Neck,Trunk, Leg		√									
Final Score			√								

4 Conclusions

The work posture analysis results show that workers carrying out coconut husk stripping activities have the highest risk level, with a RULA score of 7 (red). This means that the work has the highest risk of fatigue and MSDs, so repairs must be made immediately. Based on the analysis of the classification of physical workloads, it shows that 76% of the coconut husk stripping work activity is a heavy and tiring workload category for the work. The proposed improvement in posture shows a decrease in the score to 3 (yellow), which means the work is quite tiring. However, the workers do not accept excessive muscle tension hence the proposal can reduce the level of posture risk from high to low.

Acknowledgements

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