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PREFACE

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EFFECT OF MATERIAL HARDNESS ON ENERGY DISSIPATION FROM A MOVING CRACK IN FIRST MODE

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Abstract. Fatigue crack growth is the reason of failure of mechanical parts under cyclic loading. When a crack forms in material a plastic zone surrounds the tip of the crack. In this paper, a model based on HRR singularity is utilized to find the strain energy dissipation from a crack tip. Material hardness effect on the dissipated strain energy is investigated. It is found that the strain energy dissipation decreases with hardness. The results also show the direct logarithmic relation between the stress intensity factor and strain energy dissipation of fatigue crack propagation.

Keywords : Fatigue, Crack propagation, Plastic dissipation

1. INTRODUCTION

When a component is under cyclic loads, it experiences a degradation process. This degradation is responsible for the final failure of the material when accumulated damage initiates micro cracks which eventually ends up in cracks and the propagation of the macro cracks causes the failure of the part[1].

The crack propagation behavior has been the subject of study for many years. In early days, the propagation of crack was directly related to the loads on the part under cyclic forces. These investigations were started by the well-known Paris law. The problem which can arise in utilizing the concept of load and stress intensity factor (SIF) is the fact that the conventional relations are restricted to small regions of propagation. This has been the incentive for researchers to be after methods which are capable of quantifying the propagation behavior on account of observable system parameters including temperature [2, 3].

The strain dissipation is the source of the heat which is a representation of the degradation occurring during the propagation of the crack. This dissipation is mainly because of the plastic work in the plastic zone ahead of the crack tip. Fig. 1 shows the schematic of a crack loaded in the first mode[4].

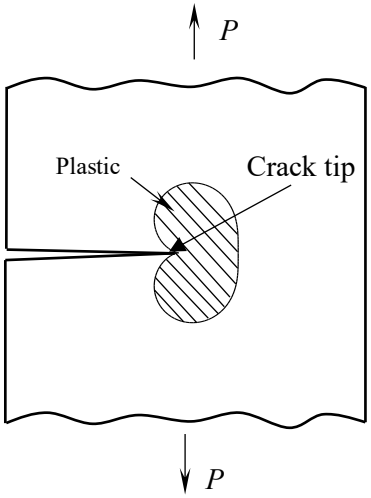

Figure 1. Crack faces loaded in the first mode of crack propagation.

As it is seen in Fig. 1, The butterfly plastic region around the crack is symmetric in respect with the plane of the crack. The plastic strains combined with stresses in the zone act as a source of heat by generating the plastic work. The stress strain distribution around the crack is given by Hutchinsone, Rice and Rosengren [5] which is commonly called HRR singularity.

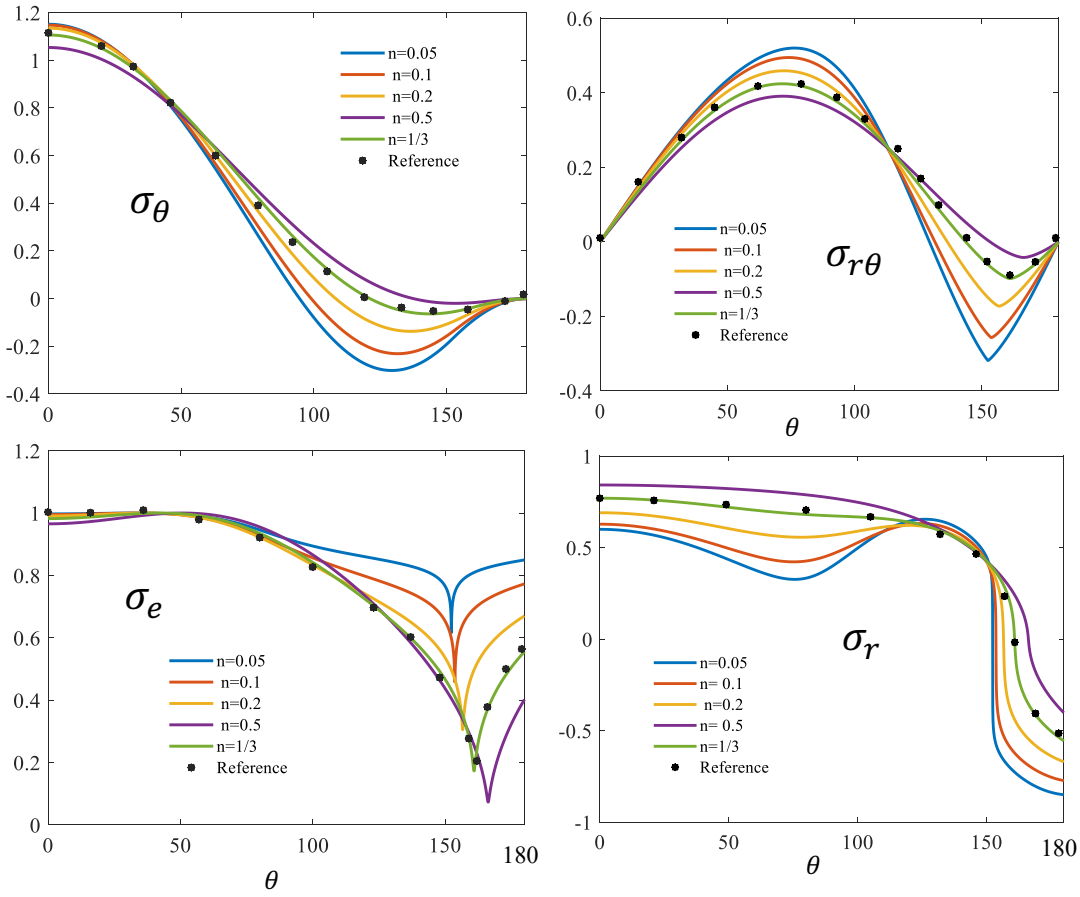

Figure 2. the angular stress distribution solved by Hutchinson

2. METHODS

2.1 Model description

The plastic behavior of a material under uniaxial tension/compression can be given by the following relation [6].

$$\frac{\Delta\epsilon}{2} = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2k'}\right)^{1/n} \quad (1)$$

In this equation, $\Delta\epsilon$ denotes the range of strain, $\Delta\sigma$ is stress range. n is the hardening exponent and E is young modulus. According to Hutchinson [3] the stress ahead of crack tip can be presented by the following relations.

$$\Delta\sigma_{ij} = \Delta\sigma_0 \left(\frac{\Delta K_I^2}{\alpha\Delta\sigma_0^2 I_n r}\right)^{\frac{n}{n+1}} \tilde{\sigma}_{ij}(n,\theta) \quad (2)$$

$$\Delta\epsilon_{ij} = \frac{\alpha\Delta\sigma_0}{E} \left(\frac{\Delta K_I^2}{\alpha\Delta\sigma_0^2 I_n r}\right)^{\frac{1}{n+1}} \tilde{\epsilon}_{ij}(n,\theta) \quad (3)$$

where $\tilde{\sigma}_{ij}$ and $\tilde{\epsilon}_{ij}$ are functions that give the angular distribution of stress and I_n is an integration constant. the cyclic yield stress is shown by σ_0 and α is a dimensionless constant given by Eq. 4.

$$\alpha = \frac{2E}{(2k')^{\frac{1}{n}} \Delta\sigma_0^{\frac{n-1}{n}}} \quad (4)$$

Fig. 2 illustrates the plastic zone ahead of a fatigue crack. Each point in the plastic zone acts as a heat source. A point like A is shown in this figure. For this point, the heat source is given by the following relation.

$$W_p = \left(\frac{n-1}{n+1}\right)\sigma_{eq}\varepsilon_{eq}^p \quad (5)$$

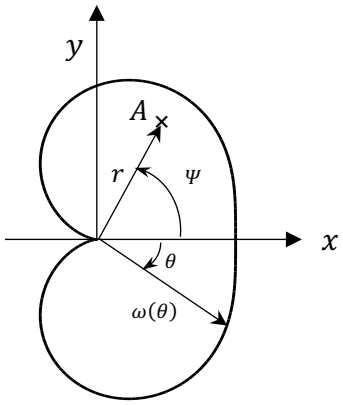

Figure 3. Cyclic plastic zone in front of the plastic zone.

The size of the plastic zone is given by the following relation for plane stress condition.

$$\omega(\theta) = \frac{1}{16\pi}\frac{\Delta K_I^2}{\sigma_0'^2}\left(1 + \frac{3}{2}sin^2\theta + cos\theta\right) \quad (6)$$

W_p given by Eq. 5 can be found for point A shown in Fig. 2.

$$W_p = f\beta\left(\frac{n-1}{n+1}\right)\frac{\Delta K_I^2 \tilde{\sigma}_{eq}(n,\theta)\tilde{\varepsilon}_{eq}(n,\theta)}{EI_n r} \quad (7)$$

$\tilde{\sigma}_{eq}$ and $\tilde{\varepsilon}_{eq}$ are equivalent plastic stress and strain angular distribution respectively and β is the ratio of the plastic strain converted to heat. Frequency is shown by f.

Equivalent stress and strain for plane stress condition are given by the following two equations.

$$\tilde{\sigma}_{eq} = (\tilde{\sigma}_r^2 + \tilde{\sigma}_\theta^2 - \tilde{\sigma}_\theta\tilde{\sigma}_r + 3\tilde{\sigma}_{r\theta}^2)^{\frac{1}{2}} \quad (8)$$

$$\tilde{\varepsilon}_{eq}^p = \frac{2}{\sqrt{3}}(\tilde{\varepsilon}_r^2 + \tilde{\varepsilon}_\theta^2 + \tilde{\varepsilon}_r\tilde{\varepsilon}_\theta + \tilde{\varepsilon}_{r\theta}^2)^{\frac{1}{2}} \quad (9)$$

According to Eq. 5, the local heat generation can be found for each point is plastic zone. The total heat generation is the summation of each point heat sources in this region. This total amount is given by the following relation.

$$W_p = \iint_{plastic\ zone} f\beta\left(\frac{n'-1}{n'+1}\right)\frac{\Delta K_I^2 \tilde{\sigma}_{eq}(n',\theta)\tilde{\varepsilon}_{eq}(n',\theta)}{EI_{n'}r}dA \quad (10)$$

The integration is calculated over the closed area of the plastic zone. Eq. 10 reduces to the following relation.

$$W_p = \int_0^{2\pi}\int_0^{\omega(\varphi)} f\beta\left(\frac{n-1}{n+1}\right)\frac{\Delta K_I^2 \tilde{\sigma}_{eq}(n,\theta)\tilde{\varepsilon}_{eq}(n,\theta)}{EI_n}drd\varphi \quad (10)$$

2.2 Numerical Procedure

The solution procedure is carried out by a MATLAB script. The angular distribution functions of HRR singularity is found by a series of numerical integration using Runge-Kutta approach combined with the shooting method. A Simpson scheme is used for numerical solution of the integration in Eq. 10.

3. RESULTS AND DISCUSSION

Fig. 4 shows the strain energy dissipation as a function of first mode stress intensity factor. It can be seen that the stress intensity directly increases the dissipation and there is a logarithmic relation between the SIF and

the dissipated energy. Furthermore, it is seen that by increasing the hardening exponent, the dissipated energy decreases.

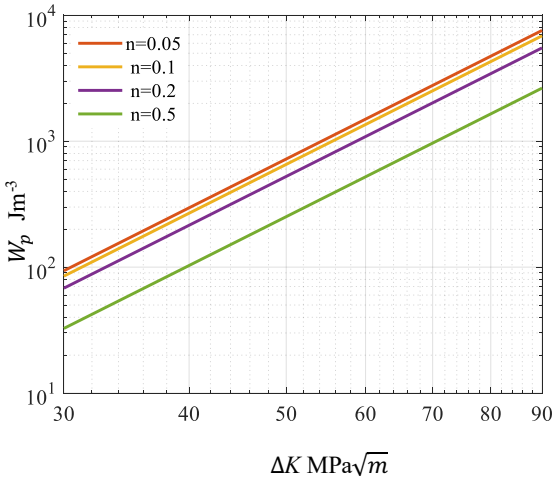

Figure. 4. Strain energy dissipation as a function of stress intensity factor for different strain hardening values *n*.

According to Fig. 4, The strain energy dissipation increases with the stress intensity factor. It is also seen that as the hardness increases, dissipation become smaller. Since the stress intensity factor is directly related to the propagation speed, this result means that heat dissipation increases with propagation rate. This implies that in order to control the propagation speed it is recommended to use material with higher hardness value.

Fig. 5 shows the Dissipated energy as a function of the hardening. It can be seen how hardening exponent is reversely affecting the dissipated strain work

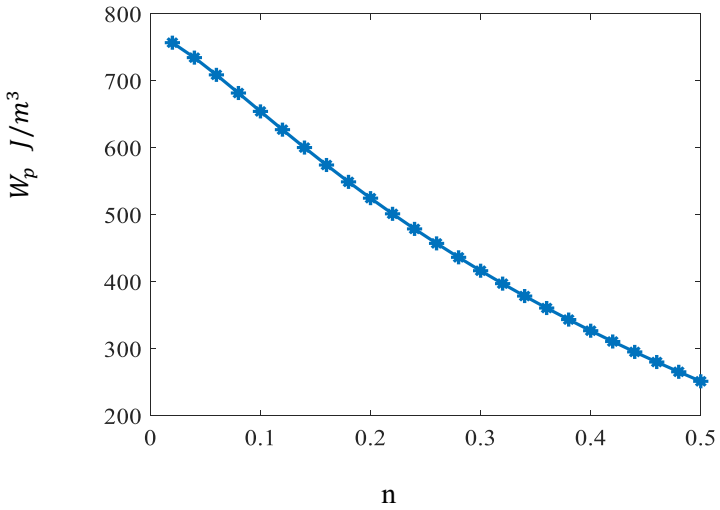

Figure. 5. Strain energy dissipation as a function of hardening exponent *n*.

The result shown in Fig. 5 denotes that in materials with larger hardness, the strain energy dissipation is smaller. This means that temperature rise due to crack propagation is smaller in these materials for the same stress intensity factor.

4. CONCLUSION

A model is presented to calculate the strain energy dissipated from a fatigue crack in cyclic loading. It was found that increasing stress intensity factor is responsible for elevation of dissipated energy, in addition, hardening exponent decreases the strain dissipation. This means that fatigue process is directly related to the material plastic parameter *n* which decide on the degradation happening during the propagation stage of fatigue crack growth.

5. NOMENCLATURE

n	Plastic hardening exponent	$\omega(\theta)$	Plastic region radius at angle θ (m)
r	Coordinate of radius	W_p	Plastic strain energy density (J/m^3)
ΔK_I	First mode stress intensity factor range (MPa.m$^{1/2}$)	k'	Cyclic strength coefficient (MPa)
β	Heat portion of plastic strain	$\tilde{\sigma}_{ij}(n,\theta)$	Dimensionless function of stress
α	Dimensionless constant	$\tilde{\epsilon}_{ij}(n,\theta)$	Dimensionless function of strain
$\Delta\sigma$	Range of stress (MPa)	σ_0'	Cyclic yield stress (MPa)
E	Elastic modulus (GPa)	σ_{eq}	Equivalent stress (MPa)
f	Load frequency	ε_{eq}^p	Equivalent strain

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DIRECT DISPLACEMENT BASED DESIGN AND CAPACITY SPECTRUM METHOD FOR SPECIAL MOMENT RESISTING FRAME

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Abstract. In designing seismic-resistant buildings, it is commonly used Forced-Based Design method. The concept of the Force-Based Design (FBD) method is based on an elastic analysis of the structure and indirectly shows the performance level of the structure towards the effects of the seismic forces. Therefore, it is required an approach that capable of analyzing and evaluating the performance of the inelastic structural response; it is called Performance-Based Design method. This paper uses two methods of Performance-Based Design, there are Direct Displacement-Based Design and Capacity Spectrum Method, by using pushover analysis. The objectives of the research are to analyze and compare performance level of the building in inelastic condition by using these two methods. The structural model reinforced concrete special moment frames. Seismic design code that used in this study is SNI 1726:2012. The reviewed parameter values are displacement and story drift values, estimated plastic hinge response, and performance level of the building from two methods. As the results, all the parameter values of DDBD analysis are more significant than CSM. DDBD produces the drift and displacement values of 0.668 m with the rebar ratio is more significant than 1.00. Meanwhile, the CSM produces the drift and displacement values of 0.501 m with the rebar ratio of 1.00. The failure mechanism of both methods indicates the strong column weak beam where the beams should fail prior to the columns. The structure performance level which refers to ATC-40 indicate that both DDBD method and CSM method are in Damage Control level despite displacement target of the two methods are different which is DDBD produces displacement target of 0.376 m while CSM produces the value of 0.345 m.

Keywords : Building Performance; Capacity Spectrum Method; Direct Displacement-Based Design

1. INTRODUCTION

Earthquake is one of the phenomena potentially to cause considerable damage [1]. If the structure of the building is designed does not take into account when it is planning, maybe collapse when exposed to earthquake loads. One of the systems that can resist lateral loads is the special moment-resisting frame. Building with the special moment-resisting frame consists of column, beam, and beam-column joints. The building with special moment resisting frame is designed in detail for flexural, axial, and shear forces that occur when a building experience shocks due to an earthquake [2]. Loads on buildings with special moment-resisting frame are borne by the frame bearing the moments through a flexible mechanism [3].

At present, commonly used Force Based Design methods for designing earthquake-resistant structures. This concept is based on an analysis of elastic structures and indirectly shows the effects of the seismic forces to the building [4]. This concept triggers the development of the alternative methods for seismic design, called Performance-Based Design. The concept of Performance-Based Design is that the structural components are

analyzed in stages so that it can provide a non-linear (inelastic) behavior of the structure when it first experiences structural failure [4]. This method produces more realistic seismic response analysis compared to elastic models [5].

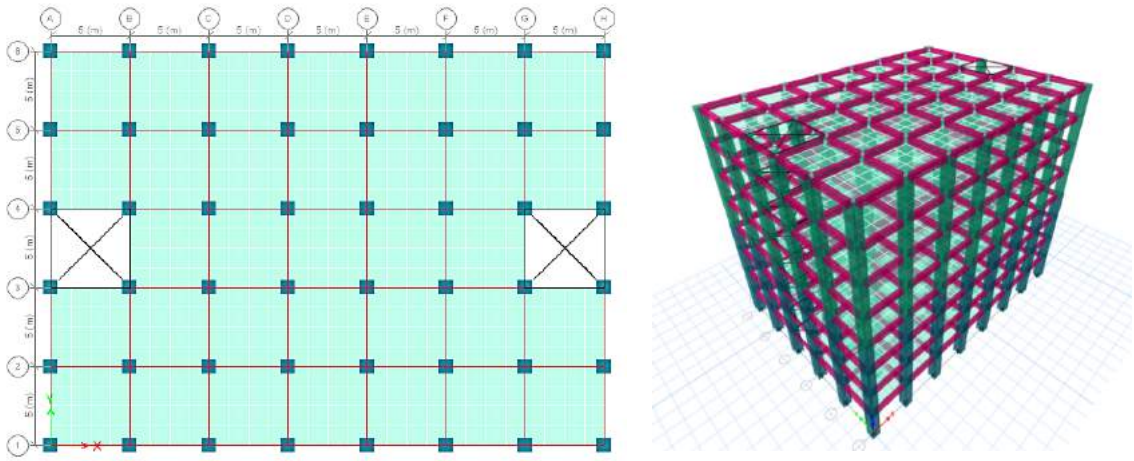
According to Priestley, there are three methods in Performance-Based Design, namely The Capacity Spectrum Approach, The N2 Method, and Direct Displacement Based Design [6]. The Direct Displacement Based Design (DDBD) emphasizes the displacement value as a reference in determining the building strength needed to withstand design earthquake loads [7]. This concept can also give an idea of how the structure's performance against earthquakes occurs [4] while the Capacity Spectrum Method (CSM) method can be known the structure performance points obtained from the intersection between the capacity spectrum curve and the demand spectrum.

There have been several studies analyzing the differences of these methods, including Purba [4] which compared the use of CSM and DDBD methods but on a dual system regular building structure. Therefore, this study is intended to compare the structural performance of the two methods in buildings with special moment-resisting frame systems using pushover analysis. Pushover analysis is used to determine the behavior of the building [8]. This research was conducted to get the value of displacement and story drift value in the structure, to get the value of the reinforcement ratio of both methods, to get the failure mechanism of the structure, and to get the level performance in both methods.

2. METHODS

The structural model used is a special moment resisting frame system with a typical floor plan (Figure 1). The building is assumed to function as an 8-story office building located in Malang city area with soft soil type. The building was designed with two different methods, namely Direct Displacement Based Design (DDBD) and Capacity Spectrum Method (CSM). Although designed with different methods, the floor plan, dimensions of the structures are the same. In buildings designed using the DDBD method, the targeted performance level is the Life Safety condition. Then the building performance is calculated based on FEMA 356 and ATC-40.

The quality of material used is concrete grade 30 MPa and reinforcing steel grade 400 MPa. The objects in this study are only part of the upper structure. The analysis was performed using pushover analysis with the help of software. The earthquake design regulations used to refer to SNI 1726: 2012.



(a) (b)

Figure 1. (a) Floor plan of the building, (b) building form

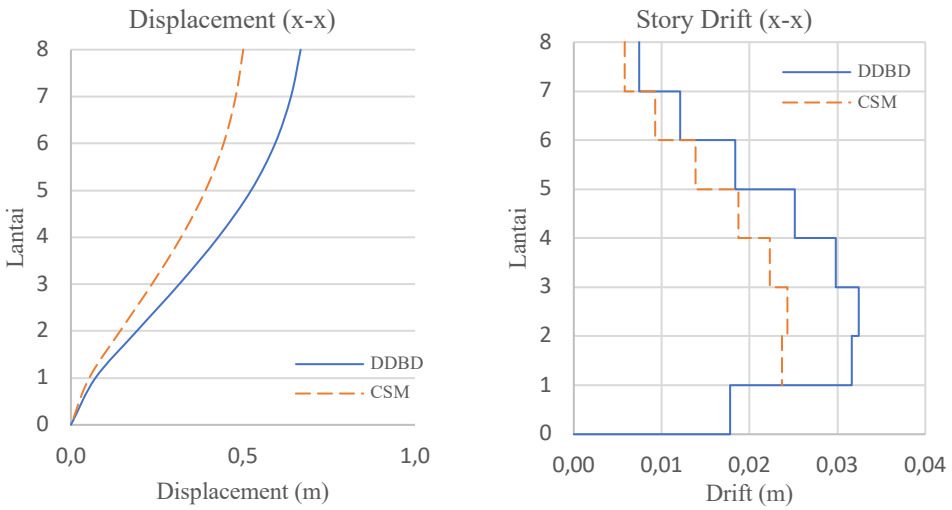
3. RESULTS AND DISCUSSION

3.1. Displacement and Story Drift Value

Dimensions of the calculated structural elements in the preliminary design are presented in Table 1. The structural elements in buildings using the DDBD and CSM methods have the same dimensions, but with different reinforcement details according to the internal forces produced on each element. From the results of the pushover conducted with the help of software, the results obtained in the form of displacement values and story drift in each method contained in Figure 2 and Figure 3.

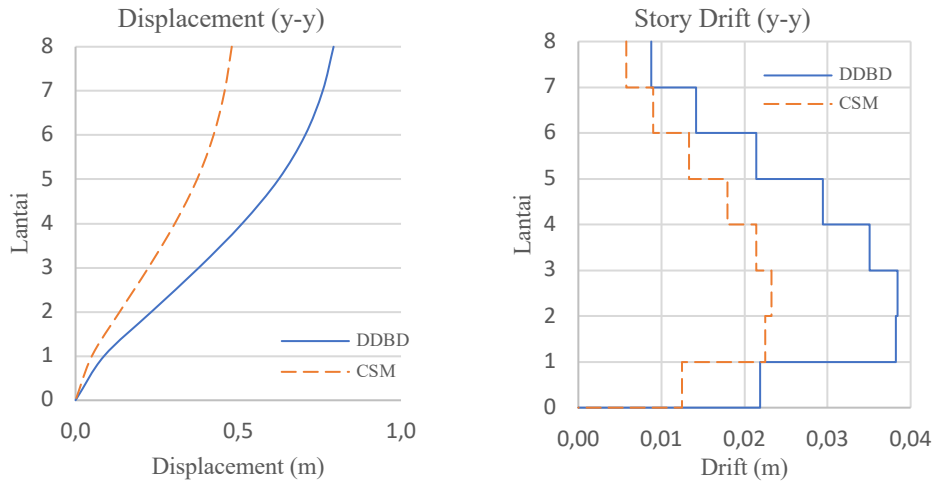
Table 1. Dimensions of the structural elements

Structural Elements	b (mm)	h (mm)	L (mm)
Beam	400	550	5000
Column (Story 1-4)	900	900	3800
Column (Story 5-8)	800	800	3800



(a) (b)

Figure 2. (a) displacement and (b) story drift dir x-x



(a) (b)

Figure 3. (a) displacement and (b) story drift dir y-y

3.2. Reinforcement Ratios

In getting reinforcement ratios, reinforcement area values are required for each structural element, which is the beam and column in both methods. Comparison of the value of the beam reinforcement ratio can be seen in Table 2 and Table 3, while for the column reinforcement ratio can be seen in Table 4. The amount of reinforcement area mounted on the CSM method is assumed to be 1.00 as a reference in the ratio of reinforcement ratio.

Table 2. Reinforcement ratio of beam dir x-x (400 x 550)

Method	I-end and J-end		Middle	
	Reinforcement area installed (mm^2)	The ratio of reinforcement area to CSM	Reinforcement area installed	The ratio of reinforcement area to CSM
CSM	1701.172	1.00	850.586	1.00
DDBD	2268.230	1.33	1134.115	1.33

Table 3. Reinforcement ratio of beam dir y-y (400 x 550)

Method	I-end and J-end		Middle	
	Reinforcement area installed (mm^2)	The ratio of reinforcement area to CSM	Reinforcement area installed (mm^2)	The ratio of reinforcement area to CSM
CSM	1984.701	1.00	850.586	1.00
DDBD	2551.759	1.29	1134.115	1.33

Table 4. Reinforcement ratio of column

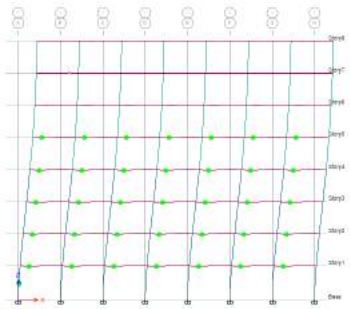
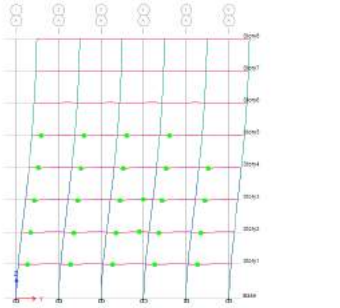
Method	Column Story 1-4 (900x900)		Column Story 5-8 (800x800)	
	Reinforcement area installed (mm^2)	The ratio of reinforcement area to CSM	Reinforcement area installed (mm^2)	The ratio of reinforcement area to CSM
CSM	15714.29	1.00	11785.71	1.00
DDBD	21607.14	1.30	17678.57	1.50

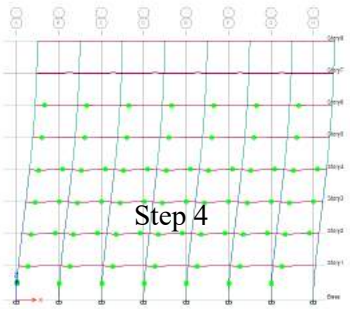
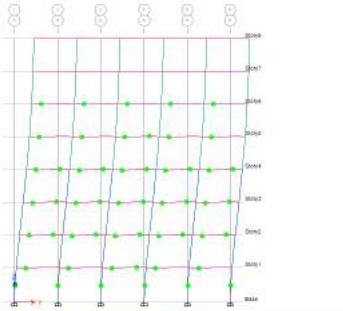
A large number of area reinforcement installed depends on the moment on each element of the structure. The higher the moment, the more reinforcement needed. Tables 2, 3, and 4 show that the DDBD method has more significant reinforcement are than the CSM method.

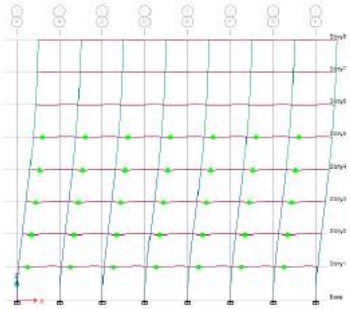
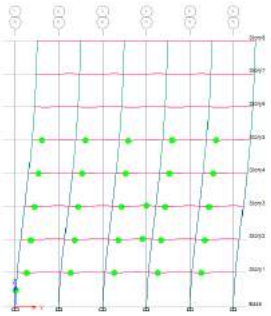
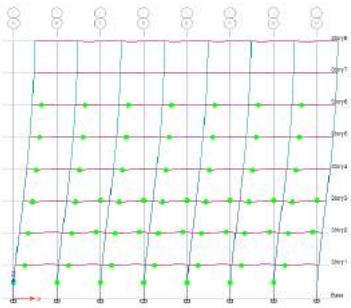
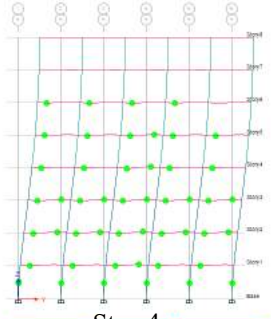
3.3. Failure Mechanism

Table 5 shows the process of the occurrence of plastic joints in the DDBD and CSM method of building structures which were carried out by pushover analysis. In both buildings, the process of plastic joints is expected, which is under the Strong Column-Weak Beam system where the plastic joints start on the beam structure elements first then followed by the column section. The building collapse mechanism also shows a suitable mechanism, namely beam-sway mechanism, because the plastic hinge in the column only occurs in the bottom column.

Table 5. Mechanism for plastic hinge collapse

Method	Direct Displacement Based Design	
Direction	Dir x-x	Dir y-y
	 Step 3	 Step 4

Method	Direct Displacement Based Design	
Direction	Dir x-x	Dir y-y
	 Step 4	 Step 6

Method	Capacity Spectrum Method	
Direction	Dir x-x	Dir y-y
	 Step 3	 Step 3
	 Step 4	 Step 4

3.4. Structure Performance

From the results of pushover conducted using the software, we will get the total displacement value, which can later determine the level of performance in each method. In the DDBD method, pushover is performed on software with the FEMA 356 method reference and produces a binary pushover curve with parameters which are then calculated based on the reference on FEMA 356. In the x-x direction, the displacement target is 0.376 m, and the y-y direction is 0.384 m. Furthermore, to determine the level of performance, the total displacement, according to ATC-40, can be calculated.

$$\text{X-x dir} = \frac{D_T}{H_{Tot}} = \frac{0.376}{30.6} = 0.0122$$

$$\text{Y-y dir} = \frac{D_T}{H_{Tot}} = \frac{0.384}{30.6} = 0.0125$$

Based on ATC-40, the total displacement of x-direction is 0.0122, and the y-direction of 0.0125 is included in the Damage Control performance level.

In the CSM method, the displacement target value is obtained in software using ATC-40 with the value in the x-direction of 0.345 m and the y-direction of 0.352 m. The level of performance in the structure can be calculated as follows.

$$\text{X-x dir} = \frac{D_T}{H_{Tot}} = \frac{0.345}{30.6} = 0.0112$$

$$\text{Y-y dir} = \frac{D_T}{H_{Tot}} = \frac{0.352}{30.6} = 0.0115$$

Based on ATC-40, the x-direction and y-direction are categorized as Damage Control performance levels. The performance level in both DDBD and CSM methods shows the results of damage control with a target value that is not much different. The level of performance on damage control, according to ATC-40, is a building with a level of performance that is still able to withstand earthquakes that occur, and the risk of human casualties is minimal. In the DDBD method, with the level of life safety plan performance and damage control performance categories obtained, the structure has not yet reached the design performance target but has approached the design performance value with a higher level of performance.

4. CONCLUSION

In this research, it has been explained about the results of the analysis in the Direct Displacement Based Design (DDBD) and Capacity Spectrum Method (CSM) methods in buildings with special moment-resisting frame systems. It can be concluded that.

1. The value of story drift and displacement in the DDBD method is higher than in the CSM method.
2. Design using the DDBD method produces more wasteful buildings because the reinforcement ratio in the DDBD method is more significant when compared to the reinforcement ratio in CSM. However, the more excellent reinforcement ratio in the DDBD method makes the building safer than the CSM method.
3. The failure mechanism by using these two different methods results in the same collapse pattern, namely the plastic hinge first occurs in the structural elements of the beam then the column, which means the building complies with the Strong Column-Weak Beam system. The failure mechanism is also following a suitable collapse mechanism, the beam - sway mechanism.
4. Designing using the DDBD and CSM methods shows the level of Damage Control. In the DDBD method, with the level of performance of the Life Safety plan and the performance category obtained by Damage Control, the structure has not yet reached the design performance target but has approached the design performance value with a higher level of performance.

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ANALYZING AND MODELLING PHARMACY QUEUE SYSTEM USING SIMULATION

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Abstract. Waiting time and queue length at the pharmacy are very influential for customer satisfaction. A hospital's pharmacy which the object of this study has a long waiting time. The aim of this study is to analyzing and modelling pharmacy queue using simulation method, then simulating a new scenario as an effort to improve the queue system. The improvement scenario was simulated by adding one server at payment locket. The simulation was carried out using empirical and theoretical approaches. The analysis was conducted based on the results of the simulation. Results showed that based on validity test can be concluded that the simulation using empirical and theoretical approach do not differ significantly from the real system. Based on the experiment from improvement scenario it showed that the addition of payment server did not show a significant difference from origin situation, the waiting time only decreased by approximately 30 minutes.

Keywords : Simulation, Theoretical Distribution, Queue System, Waiting Time

1. INTRODUCTION

Waiting time and queue length at the pharmacy are very influential for customer satisfaction. If the amount of the service unit is sufficient, the queue that occurs will be reduced. To better understand how the queuing system occurs, research and observations on the real queue system are carried out. The problem faced by the real system is a very long and saturating queue time at a hospital's pharmacy. Patients and their relative may easily get tired and impatient when queuing too long for drugs before leaving hospital. Therefore it is necessary to further analyze the queuing system at this pharmacy so that improvements can be made to the system that is not optimal. In this study, a pharmaceutical installation queue system is modeled so that it could be further analyzed. Modelling the real system is done by using simulation methods.

Sridadi [1] revealed that the application of modeling and simulation systems has been so rapidly developing and expanding in various fields both natural knowledge fields, such as physics, chemistry, biology, medicine, to social knowledge fields such us economics, social and politics. Simulation can help the decision maker to determine the optimal improvement scenario with more affordable cost and time. Because testing directly at the real system will be more difficult and takes a lot of energy and money. Therefore a lot of research uses simulation methods, both in products fields and services fields. Nashrudin et al [2] conducted simulation for planning the optimal number of machines to balance the production lines and considered the investment value using NPV, IRR, and BCR. A simulation at services area also has been done a lot. In many cases additional service facilities can reduce queuing, but the cost of providing additional services will result in reduced profits. Therefore to add facilities, the decision maker need to compare and calculate the adventages and disadventages of the scenario [3]. Studies using simulations that compare real systems with comparison to improvement scenario provided information related to the comparison of the advantages and disadvantages of aech scenario, thus the decision maker can be more confident in making decisions [4][5][6].

Studies on outpatient pharmacy also have been done by many researchers, Dan et al [7] states study on outpatient pharmacy is important in many aspects, and it's one of the modern scientific management research objectives. Many studies at hospital pharmacies have found results about things or facilities that need to be

considered for improvement at outpatient pharmacy [8][9][10].

2. METHODS

This research was conducted using simulation method with theoretical distribution, at both the real system simulation and the proposed improvement scenario simulation. The object of this study was the queuing system at one of hospital's pharmacies in Yogyakarta. Observations were made at the queue system from customers coming to the system until they going home with their drugs. The arrival time of each costumers, waiting time between each process, and service time for each process was recorded to be processed at next step. Observation was done from 7 am-11 am and 14 pm-16 pm. Statistical testing was performed on recorded data to make sure that the data set are enough and there is no outliers.

3. RESULTS AND DISCUSSION

3.1 Activity Cycle Diagram

The activity cycle diagram (ACD) is a method to describe the interactions of objects in a system that uses common graphical modeling notation to explain series of activities from real life circumtances [11]. The ACD of process that happen in this research object shown in figure 1. There are 3 locket that are always open at this pharmacy. Locket 2 is a place to submit prescriptions, Locket 1 (BRI Bank counters) for payment process, and Locket 4 for the patient take out their medicine.

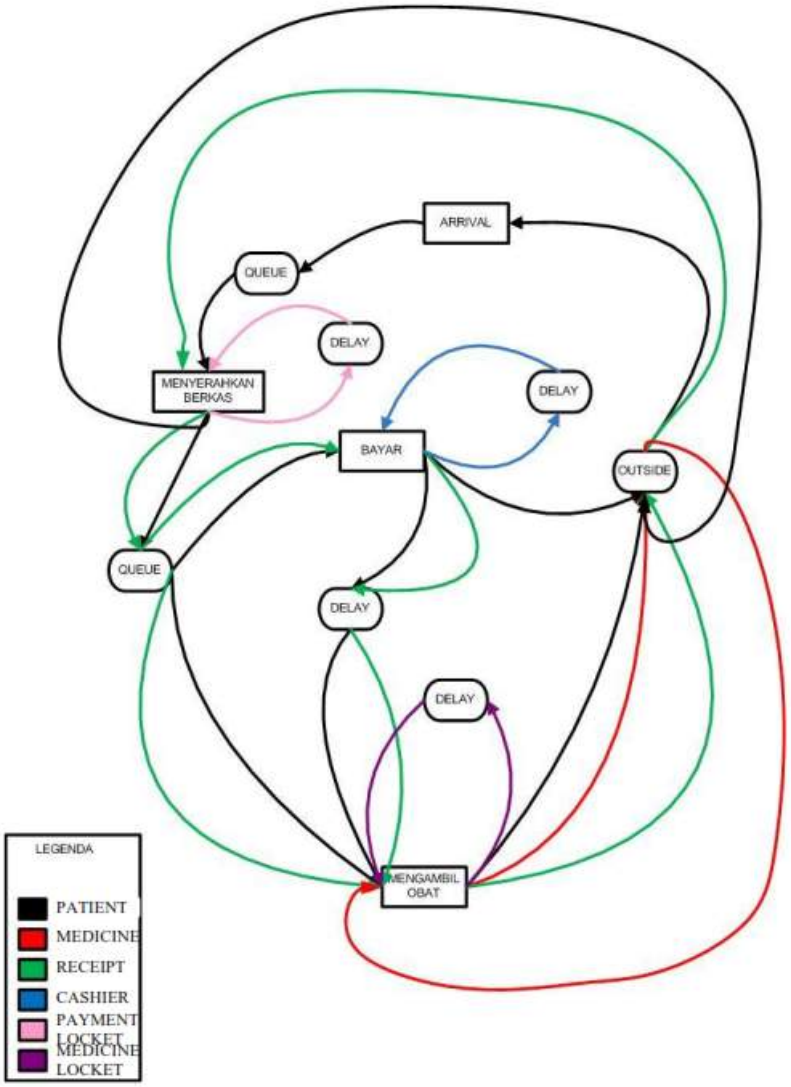

Figure 1. ACD

3.2 Simulation

To make a simulation with theoretical distribution, first we have to find the distribution of each activities. We used StatFit software for finding the distribution. The results of distribution can be seen at table 1. Interarrival activities shows that the arrival of patients into the system follows the Pearson 6 distribution. 1st queue represents the customer's waiting time for entering the prescription file into Locket 2. 2nd queue represents the customer's

waiting time to be called by Locket 1 for payment process. And 3rd queue represents the customer's waiting time to be called by Locket 4 for taking out their medicine.

Table 1. Theoretical Distribution Each Activities

Activity	Distribution
Interarrival	Pearson 6
Submit the receipe	Gamma
Payment	Log-logistic
Take medicine	Log-logistic
1st queue	Pearson 6
2nd queue	lognormal
3rd queue	weibull

We need to find the distribution to determine how many inputs will enter the system and time between arrivals of that inputs, when performing the simulation later. In addition, to ensure the simulation represents the real system.

Random generator is a random number that will be used in simulations which has a same pattern as the pattern of observational data from the real system. Random generator was build using the help of excel software based on input distribution that was obtained with StatFit Software from the previous step. Then simulation was done by using Extend Software. The simulation was carried out following the ACD that has been made and the data entered for each activities also followed the distribution that was previously calculated. The picture of how the simulation using Extend Software for real system can be seen at figure 1, while the proposed scenario can be seen at figure 2.

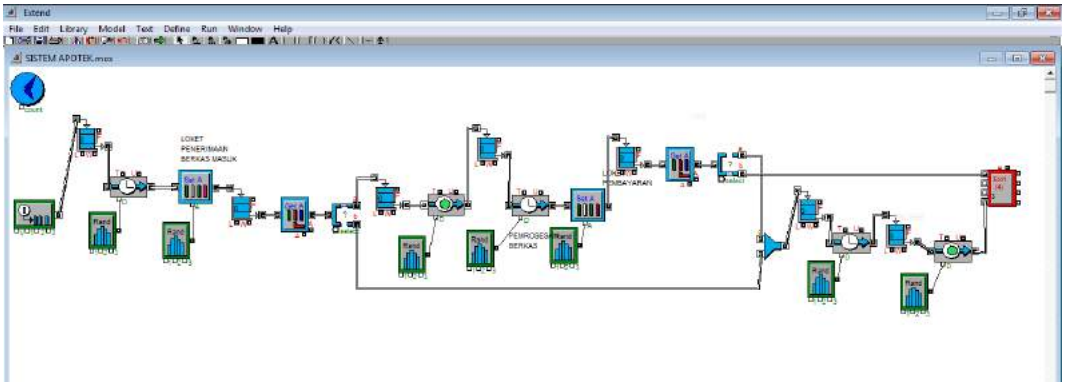

Figure 1. Simulation of The Real System

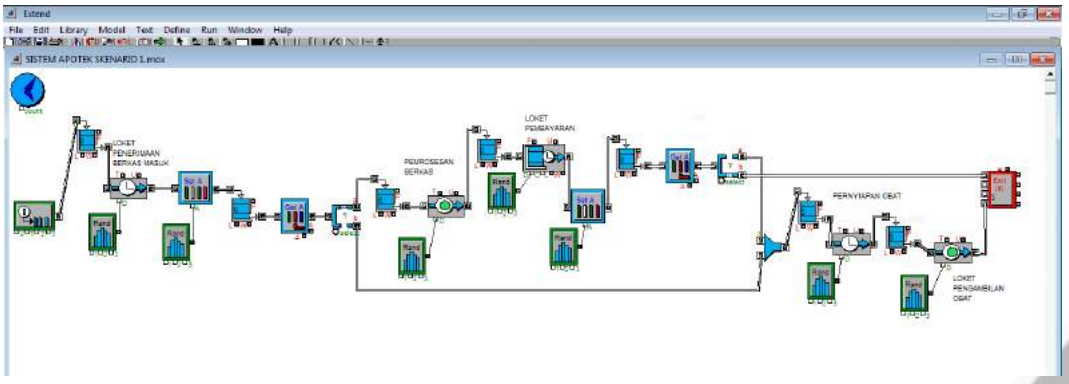

Figure 2. Simulation of The Proposed Scenario

The comparison of the theoretical distribution simulation results compared to the actual system can be seen in the graph of each activities. One of the example can be seen at Figure 3, which displays a comparison of the amount of patient that entered the system between the real system and the proposed scenario. From figure 3 it can be seen that the graph between real and simulations shows an average pattern that is quite similar, although an error still appears. In general, all activities showed that the pattern between the simulation and the real system is quite similar, although the error persists. Big enough error occurs at queue and take medicine activities, as show at Figure 4 and Figure 5. It happened because the amount of data being compared are different. The real system

data had less data compared to the simulation, because some data from the real system need to be discarded at uniformity test because they are identified as outlier. But overall, all the pattern are quite similar. It can be concluded that the simulation using theoretical distribution are quite representative of the real system.

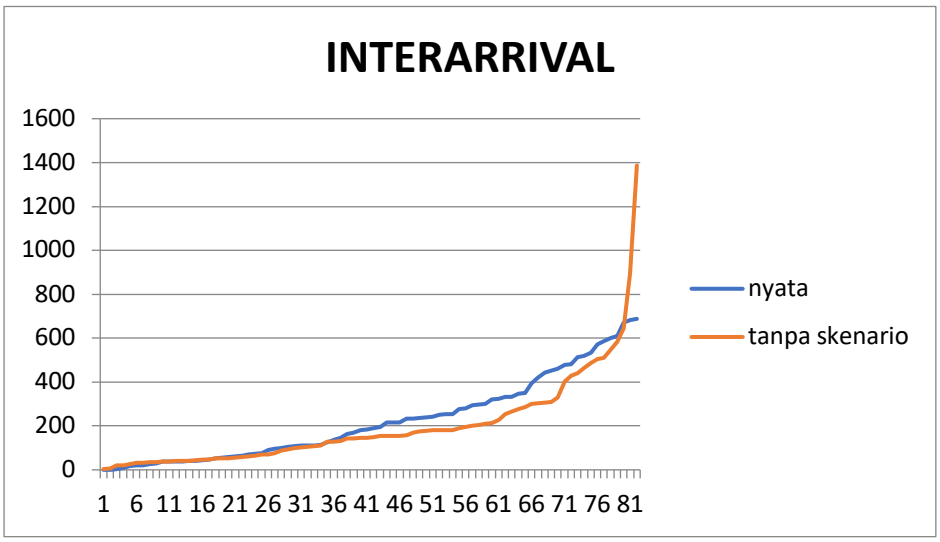

Figure 3. Simulation and The Real System Comparison Graph of Interarrival Activity

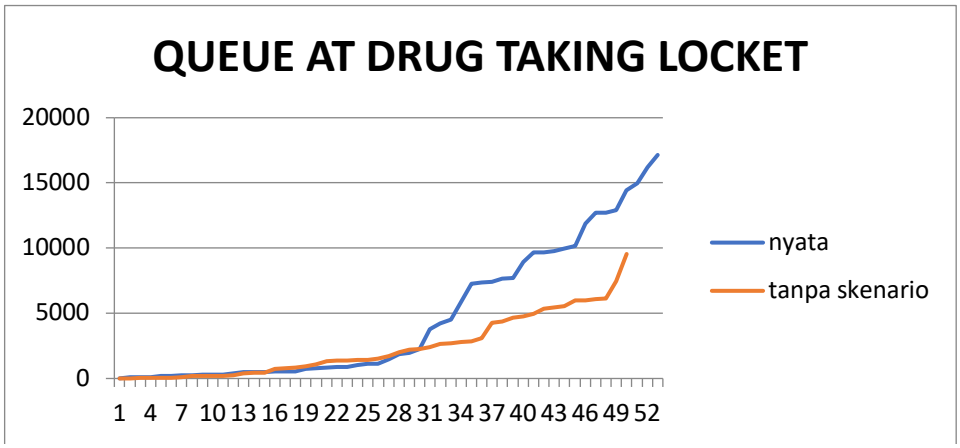

Figure 4. Simulation and The Real System Comparison Graph of Queue 3 Activity

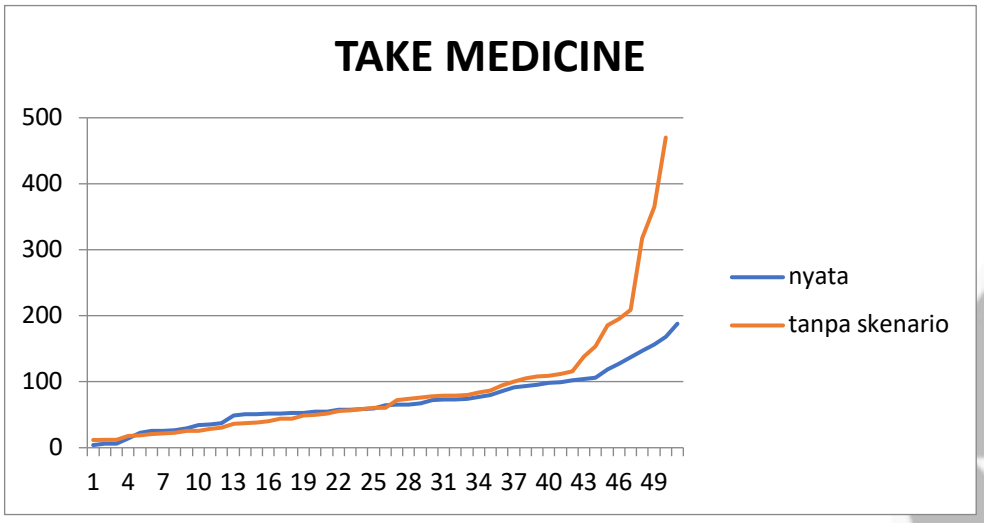

Figure 5. Simulation and The Real System Comparison Graph of Take Medicine Activity

A comparison of the average waiting time from the real system and proposed scenario can be seen at Table 2. It can be seen that the addition of a server causing the average of waiting time to decrease even though the amount is only a little.

Table 2. Comparison of Average Waiting Time for Real System and Proposed Scenario

Item	The Average of Waiting Time
Real System Simulation	504,45
Proposed Scenario Simulation	498,19

Validation to the simulation was carried out to determine whether the simulation that has been done represents the real system or not. Validation was done by comparing the real data to the result of simulation using theoretical approaches. It was done using Kruskal Wallis test on SPSS software. The Kruskal Wallis Test is used because the data are not normally distributed. The result of validation data can be seen at Table 3. It shows that in all activities there is no significant difference in mean between real system data and the simulation. So it can be concluded that the simulation of the real data system is valid and can represent the real system.

Table 3. Validation Results for Real System Simulation

Activities	Normality Test	Kruskal Wallis Test
interarrival	Data is not normally distributed	There is no significant difference in mean
Submit the recipe	Data is not normally distributed	There is no significant difference in mean
Payment process	Data is not normally distributed	There is no significant difference in mean
Take the medicine	Data is not normally distributed	There is no significant difference in mean

Validity test was also performed on scenario simulation. The purpose is to test whether the scenario has a significant effect on the situation before the scenario was carried out. It was done by comparing the queue length at the payment server before server addition to after payment server addition. Scenario validation was performed using Mann Whitney test on SPSS software. The Mann Whitney test is used because the data are not normally distributed. The result can be seen at figure 4. Based on the Mann Whitney test, it can be seen that there is no significant average difference between real data and the theoretical approach. It means the proposed scenario does not have a big influence to the real system simulation.

Table 4. Validation Results for Proposed Scenario Simulation

Activities	Normality Test	Kruskal Wallis Test
Queue length	Data is not normally distributed	There is no significant difference in mean

Verification is a process of checking whether the operational logic of the model is in accordance with the logic of the flowchart, or checking whether the computer simulation program is running as intended with the computer inspection [12]. In this simulation verivication is done by comparing the number of outputs from the real system simulation to the simulation of proposed scenario. Comparison of the output can be seen in Table 5.

Table 5. Verivication Result

Real System Simulation	Proposed Scenario Simulation
83	81

From the results of the experiments, it was decided not to use the proposed scenario. Because the proposed scenario, by adding a server at payment server, did not show a significant difference from origin situation, the waiting time only decreased by approximately 30 minutes. Adding a payment server to the system can not reduce the waiting time, because after further evaluation showed that the actual service time on the payment server is not too long. At the real system, the cause of bottle neck is the processing of recipes performed by employees. But this research was not study more deeply about how the prescription processing works. So we can not make a comparison about the result if we want to make another proposed scenario by adding an employee (a server) at recipes proceesing.

4. CONCLUSION

Results showed that based on validity test can be concluded that the simulation using empirical and theoretical approach do not differ significantly from the real system. And based on the experiment from improvement scenario it showed that the addition of payment server did not show a significant difference from origin situation or the real system, the overall waiting time only decreased by approximately 30 minutes.

5. ACKNOWLEDGEMENT

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Graduation Prediction of S1 Industrial Engineering Students IST AKPRIND by Using Data Mining Method

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Abstract. There is data of students who experience Drop Out which raises the curiosity in IST AKPRIND's industrial engineering study program on students' graduation patterns. It is necessary to have research on how to classify the data held by industrial engineering study programs in order to obtain students' graduation patterns as evaluation material in the administration of study programs. This study also produced a design to set the goals of Educational Data Mining, this case as a student modeling that would be achieved by predicting using the Decision Tree method. The final results showed a mismatch between the general information data passed and the drop out of the rule obtained using the decision tree algorithm in the Rapidminer software which is shown by an accuracy of 95.83%. This value indicates that there is a match between the prediction of student identity data with the rule obtained using the decision tree algorithm.

Keywords :Data Mining, Classification, Decision tree, EDM, Prediction, C4.5 algorithm.

1. INTRODUCTION

Students at the tertiary level of education whose rights are regulated in Law no. 20 of 2003 Chapter V concerning Students. universities should have students' data stored in information systems. The data consists of students' registration data, students' academic data for each semester to students' graduation data. After students graduate, these data tend not to be used optimally. Therefore, these data need to be utilized to obtain deep information. However, it is not easy to make predictions by utilizing various raw data held by the institute, so Educational Data Mining techniques are necessary to help transform raw data from the system into information that has the potential to have a positive impact on education [1]. Data Mining Education is a sub-area of Data Mining Domain. This new area has great potential to mine various aspects for improving the student's quality as well as in decision making by educational institution authorities [2]. "Educational Data Mining is an emerging discipline, concerned with developing methods for exploring the unique types of data that come from educational settings, and using those methods to understand the students better, and the settings which they learn in." [3]

Every educational institution would want to contribute to enhancing the education world, especially in S1 Industrial Engineering Study Program, Faculty of Industrial Technology IST AKPRIND Yogyakarta. The normal time of graduation for a Bachelor's degree is a maximum of 7 years, but not a few students take education by graduating more than 7 years. Hence, in order to improve its quality, study programs issued a policy regarding the maximum graduation limit, since the level of graduation delays can be reduced, but there are students who must Drop Out because they cannot complete their studies. The proportion of students who experience late graduation, until the emergence of students who drop out, encourages research to predict student graduation patterns related to the study period and student performance as evaluation material.

Educational Data Mining has a variety of purposes. Some studies use EDM to predict academic patterns by reviewing the accuracy of the study period of students in their education such as research conducted by [4], [5], [2], [6], [7], [8], [9]. In addition there are studies with the aim of predicting academic patterns by reviewing student performance such as research conducted by [10], [11], [12], [13]. In addition, there are also studies that aim to predict students 'academic patterns based on students' performance on the experiments or scenarios provided as research conducted [14] such as research to predict academic patterns by conducting 3 experiments.

Similar research was also conducted by [15] to predict students' performance by using blended learning scenarios.

Based on the description above, this study aims to examine the data held by the study program to predict students' graduation as an evaluation material for S1 Industrial Engineering Study Program in IST AKPRIND.

2. METHODS

2.1 Data Mining

Data mining is a data collection technique obtained from various sources which is then transformed into very useful information using various predetermined methods. Data mining is a field of several scientific fields that unites techniques from machine learning, pattern recognition, statistics, databases, and visualizations for handling the problem of retrieving information from large databases [16]. In general, data mining can be grouped into 2 main categories, such as descriptive mining and predictive [17]. In doing predictive, data processing techniques that already exist are needed, in order to be collected and processed. The most popular technique used is Data Mining [18]. Several methods in data mining techniques have been used to predict patterns, in this case predict student graduation. According to [18], data mining is the most popular technique used in the last ten years from 2000 to 2011. information in data mining has a different type [19].

2.2 Classification

Data mining classification is the placement of objects into one of several predetermined categories. Classification is widely used to predict classes on a particular label, namely by classifying data (building models) based on training sets and values (class labels) in classifying certain attributes and using them in classifying new data (testing sets) [20].

The data used as input is 360 identity data of S1 IST AKPRIND industrial engineering students regarding 5 variables that are considered to have an influence on student graduation. From 360 criminal report data will be divided into two types of data, such as training set and testing set. Many previous studies have explained the ratio used in determining training sets and testing sets. As much as 60% of all data is used for training data which will result in a rule. The remaining 40% is used as testing data [20].

2.3 Algoritma Decision Tree

Decision Tree (decision tree) is a tree that is in the analysis of problem solving, mapping about alternative solutions to the problem that can be taken from the problem. Decision trees can also be called one of the most popular classification algorithms because they are easy to interpret. The concept of a decision tree is to convert data into decision trees and decision rules. Decision tree is suitable for cases where the output is a discrete value. The main benefit of using a decision tree is its ability to examine and describe complex decision in order to be simpler and easier to interpret the problem solving.

Decision trees are usually used to obtain information for making a decision. The decision tree starts with a root node (starting point) used by the user to take action. Based on this root node, the user solves leaf nodes according to the decision tree algorithm. The final result of composing the root node and leaf node is a decision tree with each branch showing possible scenarios of the decision taken and the results. The concept of a decision tree is to change data into a decision tree (decision tree) and decision rules (rule).

2.4 Research Object

This research was conducted by reviewing and classifying attributes or variables that could affect student graduation rates. The method used in this research is data mining classification techniques with the decision tree algorithm method. The results of the research to be achieved is the rule or the rules of graduate or drop out based on the attributes or variables. Data processing is done with the help of Ms. software. Excel, and Rapidminer. In this preliminary study there were 360 data on the identity of S1 IST AKPRIND industrial engineering students in 2006-2015 which were used as objects in this study.

2.5 Collect Data Method

Quantitative research is research that is intended to obtain data in the form of numbers or qualitative data that has been framed. In this preliminary study, the data obtained are attribute or variable data that might influence student graduation, such as the home province, gender, entry point, GPA, and education background.

2.6 Data Type

Secondary data is data obtained or collected by people who conduct research from existing sources. In this preliminary study, secondary data used are 360 attribute or variable data from student's identity data, such as the home province, gender, entry point, GPA, and education background Other secondary data in this study are previous research related to the problems, such as data mining classification techniques, decision tree algorithm methods with problems related to EDM.

2.7 Flowchart

Figure 1 shows a flowchart of the entire research stage.

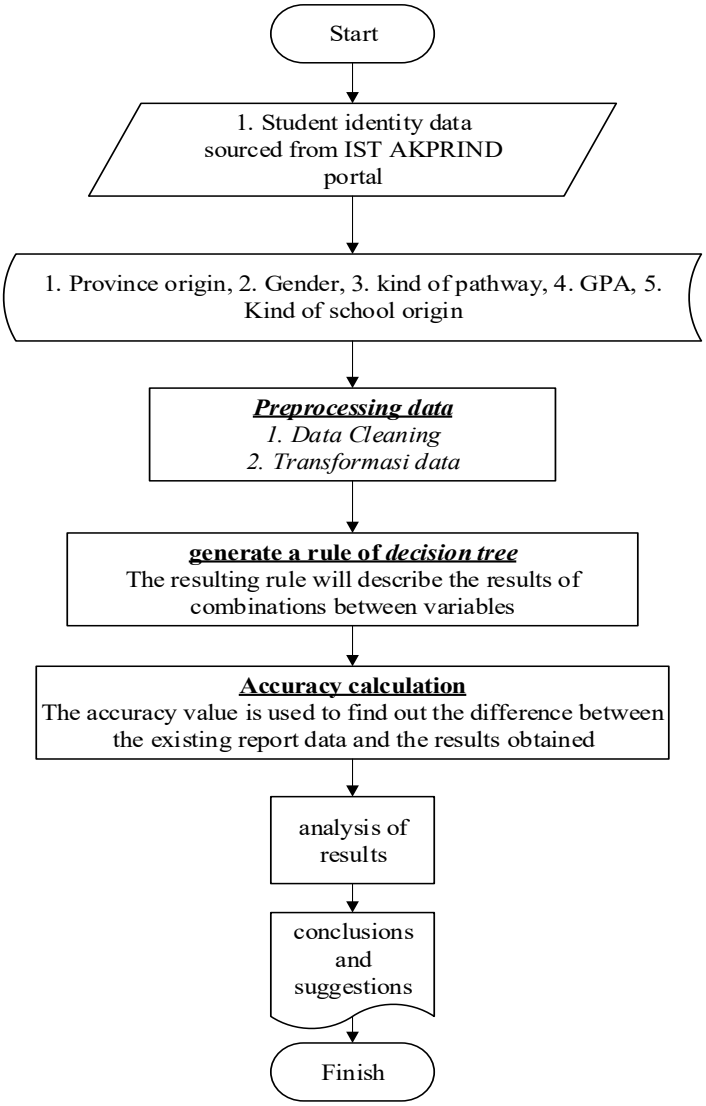

Figure 1. Flowchart diagram

3. RESULTS AND DISCUSSION

The first step was collecting data, such as administrative data of S1 Industrial Engineering students from 2006-2015, from the official website of the IST AKPRIND portal. After the data were obtained, it is necessary to do a selection and transformation of the data. Data selection was condducted to make it more efficient during the classification process, while data transformation was conducted in order to change the shape of the data to be more suitable and can be processed. However, in this initial study, not all data was obtained, therefore the data selection stage could not be carried out yet. If it is assumed that all data needs to be entered into the mining process, then the data needs to be transformed. The following table 1 explains the transformation rules of the temporary data that has been obtained.

Table 1. Transformation Rule

Atribut	Information
Province origin	1-30 (Babel, Bali, Banten, Bengkulu, DIY, Jabar, Jambi, Jateng, Jatim, Kalbar, Kaltara, Kalteng, Kaltim, Kepri, Lampung, Maluku, NTB, NTT, Papua, Riau, Sulsel, Sulteng, Sumbar, Sumsel, Sumut, Timor Leste, Sulbar, NAD, Gorontalo, Jakarta)
Gender	1 dan 2 (Male (M) dan Female (F))
Kind of pathway	1-8 (Transfer path, Scholarship, Camabapres, Transfer, PMB, Readmisi, Regular, Without test)
GPA	1-8 (0-0.5; 0.6-1; 1.1-1.5; 1.6-2; 2.1-2.5; 2.6-3; 3.1-3.5; 3.6-4)
Kind of school origin	1 dan 2 (Public school dan Privat school)
Status	1 dan 2 (Graduate dan Drop out)

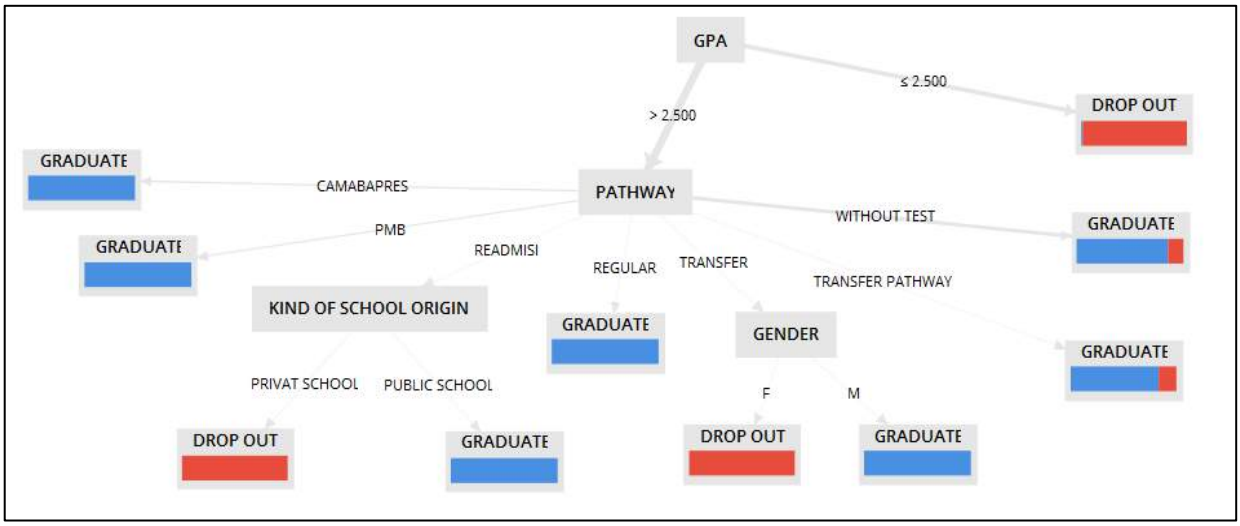

Figure 2. decision tree result

The decision tree above shows that the GPA attribute is the root node since according to manual calculations, the information gain value of the highest GPA attribute from others. The overall picture of the decision tree above can be presented in the form of rules, as follows:

GPA > 2.500
| PATHWAY = CAMABAPRES: GRADUATE {GRADUATE=30, DROP OUT=0}
| PATHWAY = PMB: GRADUATE {GRADUATE=28, DROP OUT=0}
| PATHWAY = READMISI
| | KIND OF SCHOOL ORIGIN = PRIVAT SCHOOL: DROP OUT {GRADUATE=0, DROP OUT=2}
| | KIND OF SCHOOL ORIGIN = PUBLIC SCHOOL: GRADUATE {GRADUATE=2, DROP OUT=0}
| PATHWAY = REGULAR: GRADUATE {GRADUATE=2, DROP OUT=0}
| PATHWAY = TRANSFER
| | GENDER = F: DROP OUT {GRADUATE=0, DROP OUT=2}
| | GENDER = M: GRADUATE {GRADUATE=5, DROP OUT=0}
| PATHWAY = TRANSFER PATHWAY: GRADUATE {GRADUATE=5, DROP OUT=1}
| PATHWAY = WITHOUT TEST: GRADUATE {GRADUATE=54, DROP OUT=9}
GPA ≤ 2.500: DROP OUT {GRADUATE=1, DROP OUT=75}

The above rule explains one root of the decision tree obtained by GPA, to make it easier to read the rule, for example if the GPA is more than 2.5, the entry point taken is transfer path, the gender is male, so what happens is students' graduate, if the sex is female, what happens is the student drop out (DO).

Table 2. Confusion matrix result

	True graduate	True drop out	Class Precision
Prediction graduate	88	0	100%
Prediction drop out	6	50	89.29%
Class Recall	93.62%	100%	

Accuracy: 95.83%

Based on the table above, it can be seen that the discrepancy between the general information data graduate and drop out to the rules obtained using the decision tree algorithm in the Rapidminer software which is shown by an accuracy of 95.83%. This value indicates that as much as 95.83% of the testing data set there is a match between the prediction of students' identity data with the rule obtained using the decision tree algorithm. Class prediction for graduate prediction of 100% shows the classification prediction obtained from the calculation of the decision tree algorithm classification, then it turns out that the system can perform class recall for the graduate prediction of 93.62%. Class prediction for drop out prediction is 89.29% indicating the classification prediction obtained from the calculation of the decision tree algorithm classification, then it turns out the system can do a class recall for drop out by 100%. The prediction results from the decession tree and the previous rule, can be used to predict the graduation of S1 IST AKPRIND Industrial Engineering students by looking at the results that match the prediction rules and testing sets that already exist.

4. CONCLUSION

Based on the results of research, it can be concluded that the decision tree method can find patterns of students' graduation, and can be used as useful information for the Institute and industrial engineering study programs. The generated rules can be new information that is useful in predicting the graduation of IST AKPRIND industrial engineering students. The use of rapidminer software can present data in the form of a tree and the level of accuracy of the suitability between the report data and the rules obtained using the decision tree algorithm. After obtaining the rule result as above, it is hoped that it can be used as a basis for the Institute and industrial engineering study programs in improving the quality of education.

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REDESIGN OF MOBILITY AIDS FOR SPASTIC DIPLEGIC CEREBRAL PALSY CHILDREN THROUGH COLLABORATION AMONG ACADEMICS - MEDICAL DEVICES INDUSTRY AND USER INTITUTIONS

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Abstract.Cerebral palsy (CP) children are part of the neuro disability spectrum in impaired brain function. The etiological understanding of CP children for primary prevention and early treatment can reduce the effects of damage to brain function. CP children with cerebral diplegia are motor developmental disorders caused by damage to the brain characterized by weakness in the lower limbs heavier than the upper limbs. The walker product is designed through a universal design approach to provide as much as possible mobility to CP children in general. A universal design approach to the walker products through the triple helix collaboration included academic, medical devices industry and user institutions. Three subjects with spastic CP cerebral diplegia children underwent gait training using walker. Gait performance (continuous walking distance, and maximum and comfortable walking speed) and energy expenditure are measured at the end of the 1-week training session. The purpose of the pediatric walker redesign is to facilitate mobilization the position of the child's body CP in the anterior and posterior positions. The walker design can be removed from the raft back and forth from both sides at the front. At a certain time, the walker can be positioned behind the user according to the recommendations of some physiotherapy practitioners. This design also facilitates the position of CP children in order to be more precise, reducing double support during ambulation and increasing walking speed. The anterior-posterior walker as ADVANCED walker for CP children provides the most appropriate position because it provides the best gait pattern and consumes less energy.

Keywords : Triple Helix Collaboration, Universar Design, Cerebral Palsy, Walkers, Energy Expenditure.

1. INTRODUCTION

This past year is a time to understand holistically in the field of developing activity aids for children with cerebral palsy (CP). Cerebral palsy cases appear early in infancy and continue throughout the life of the individual affected by this disorder, need to be thought about this condition and managed in the development of the child's growth, function and family role [1]. CP identified part of the spectrum of neuro disability, by understanding the etiological events, the potential for primary prevention and early treatment can reduce the effects of damage to brain function [2]. CP causes motor disorders accompanied by disorders in the form of sensation, perception, cognition, communication, and behavior, the influence of the emergence of epilepsy and secondary musculoskeletal problems [3]. The incidence of CP disorders in some countries according to some researchers found amount vary, such as 1.3 out of 1000 births in Denmark, 5 out of 1000 children in the United States, and 7 out of 100,000 births in America [4]. Data Center for Disease Control explains that in Indonesia, the prevalence of CP disorders is estimated to be around 1 to 5 per 1,000 live births [5]. The incidence of male sex more than female, the prevalence of events is more frequent in the first child. First births are more often due to stagnating births, resulting in a higher incidence than babies born with low weight and multiple births [4].

Whereas children with cerebral diplegia CP are motor developmental disorders in children due to brain damage that occurs in the period before, during and after birth [6]. This condition is characterized by weakness in the lower limbs becoming heavier than the upper limb. Characteristics of CP children such as high postural muscle tone especially in the lower trunk region towards the lower extremities. Therefore the need for CP child aids cannot be separated in daily activities with a multi-disciplinary approach including information ranging from orthopedic, urologic, neurological, and pediatric. Information assistance from paramedics is needed for engineers, physical therapists, and social workers to design aids according to the needs of CP children to be a holistic solution [2].

Mobility aids or known as pediatric walkers or walkers alone are recommended for children with CP [7]. The goal of mobility aids for CP children is to provide additional stability during ambulation. CP disorders in children produce very low productivity because they are limited in activities and rely on others as childminder and walkers to help every day. Generally, mobility aids for CP children in developing countries are widely used in anterior walker types. Located at Yayasan Pembinaan Anak Cacat (YPAC) Surakarta, how to improve the productivity of CP children is done by means of walk rehabilitation using the assistive devices? The design of the walker must meet the requirements of lightweight, easy to move, waist level, made of metal pipes, equipped with two handles that serve as a place to hold, and four legs for support [8]. At this time the walker used for rehabilitation of CP children walking at YPAC Surakarta is a simple anterior walker. The results of visualization observations on this walker can be concluded that the weight of the walker is still quite heavy, there is no handgrip, and the design is not a walker considering anthropometry and the user's walking position. Lack of anterior walker in YPAC Surakarta when used for walking activities, the user's body tends to lean forward while pushing the assistive walker. The use of anterior walkers results in an increase in weight load on the walker and increased hip flexion during gait [9].

Designers can choose all or some principles to evaluate existing designs, guide the design process about the benefits of universally designed products. The universal design approach for designing the walker products aims to make as much mobility as possible to CP children in general in the provision of social welfare services. Universal design is an approach where accessibility for people of all ages and abilities is included in the initial design [10]. The universal design of product functions must meet the man-machine engineering design method. As long as people use products, they must consider human-machine engineering and usage habits [11]. In addition, under the reason of meeting the comfort of the human body, the product design function must also consider the use of different population habits and special requirements, changes in the use of place and time [12]. This mobility aid will be redesigned so that CP children can be used for walking activities. The user's position towards the walker can be in the anterior and posterior areas. Walker design can be removed raft back and forth from the two sides of the front; the resulting walker product is called the ADVANCED Walker.

This collaborative multi-disciplinary approach in redesigning pediatric walker products involves academics - CV. Rigen Sarana Mukti Surakarta and CV. Yoga Mandiri Surakarta as a provider of medical devices and YPAC Surakarta as a Pengabdian Kepada Masyarakat (PKM). Both of these industries are limited partnership companies engaged in manufacturing and trading in medical equipment and precision-engineered. The basis of this collaboration is based on the principles of participatory among academics - producers and user institutions with the aim of moving together holistically to build the excellence of providers of medical devices. A universal design approach to walker products through triple helix collaboration among universities, industry, and user institutions. The triple helix collaboration is in accordance with system theory [13,14] as a set consisting of (1) components (academics, medical devices industry and user institutions), (2) relationships between components (collaboration and conflict moderation, collaborative leadership, substitution, and networking), and (3) function, is described as a process that occurs in what we call knowledge, innovation and implementation. The collaboration among academics, medical devices industry and user institutions in a triple helix system provides a clear view of innovation actors, the relationship between them and the flow of knowledge in the system, in a vision of a dynamic diachronic transition [15]. This collaboration provides an impact at the regional level, which aims to combine local resources to realize shared goals and new formats in the space of new knowledge, innovation, and implementation [16]. This analytical framework, empirical guidelines for policymakers, academics and business managers can be described, to strengthen the collaboration among the triple helix actors and enhance regional development [17].

The purpose of the walker redesign at YPAC Surakarta is to accommodate both the anterior and posterior positions so that the user can place the body in front and back positions. The posterior position for users who have been able to stabilize walking is recommended by some physiotherapists [18]. The results of the designed walker will facilitate the user's position to be more precise, reducing double support during ambulation and increasing walking speed. For children CP for posterior walkers is appropriate because it provides the best gait patterns and less energy consumption [19]. At the end of this collaboration activity will produce a new walker product designed to help and encourage CP children to learn to stand and walk with hands-free support. The benefit of walkers for CP children is to encourage them to increase their physical strength and endurance through increasing the body's load during ambulation.

2. METHODS

Children with CP always face changes in body energy capacity, low energy capacity and increased dependence on the needs of others and the same compensation for the device they find in the following days. Walker must provide solutions for CP children to overcome differences in capacities, abilities, and needs for daily life. Universal design is a concept that extends to the diversity of users who must interact with the surrounding environment [20]. Design activities include documentation of problem solving and communication between the parties involved in the collaboration. To achieve design goals effectively, individual participation to share information, responsibilities, and resources must be organized [21]. Therefore, this paper proposes a Useability, Safety, Efficiently Participatory (USEP) Model based on the triple helix collaboration. Also, case studies were carried out to design walkers and walker features with a participatory design session to test the conceptual design phase of the proposed model. There are five phases of the design model to transform concepts into design descriptions so that artifacts are able to produce agreed-upon functions. The phases of the USEP design model methodology are illustrated in Figure 1.

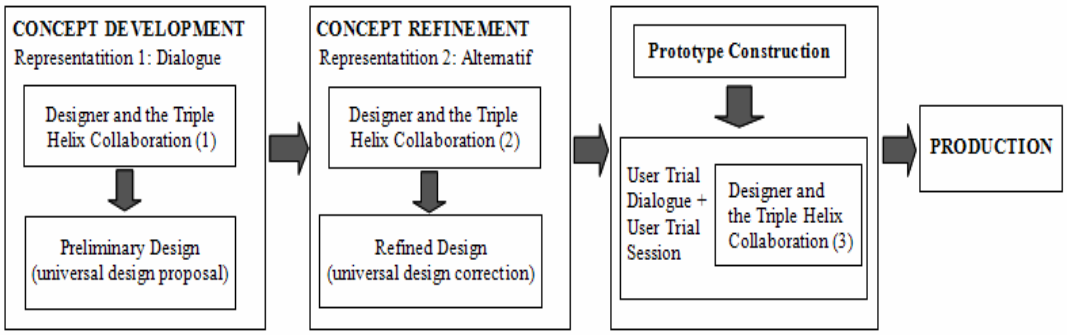

Figure 1 The phases of the USEP design model methodology

2.1 Concept development phase

In the first phase of the design model, where designers and childminder of CP children in YPAC Surakarta and parents of CP children and technicians in the medical devices industry were involved as many as 12 people, participatory design sessions are held with small groups. The techniques that apply in participatory design sessions are making scenarios [22], brainstorming, writing ideas and sketches, unstructured interviews and asking predetermined questions [23]. In this phase, participants generate ideas and determine their exact needs and preferences related to artifacts. Due to difficulties in extracting information from parents, participatory design sessions are a combination of brainstorming, scenario building, and unstructured interviews, with written and oral sections, sketches, or movements. The designer acts as an impartial moderator and the form of participation in this phase is active dialogue [23] where the designer does not make a proposal for the design at first but acts as a facilitator. A childminder of CP children are those who make proposals during the design process.

2.2 Concept refinement phase

In the second phase of the model, conceptual design solutions were introduced to childminder of CP children at YPAC Surakarta and parents of CP children in the second participatory session. During this session, childminder of CP children at YPAC Surakarta and parents of CP children were asked to criticize drawings, modify and make comments about design alternatives made by the designer. In this phase, the form of participation is an alternative [23]. The childminder of CP children at YPAC Surakarta and parents of CP children can see and feel the representation of the ideas and propositions they have made in the first phase and have been filtered through designer knowledge and interpretations based on USEP. The sketch was criticized, corrected and modified by the childminder of CP children at YPAC Surakarta and parents of CP children who acted as jury members. This phase tries to avoid misunderstandings and inaccurate interpretations from the designer, and reinforce the design description through the agreement of the caregivers of CP children at YPAC Surakarta and parents of CP children [24]. Designers are presenters and facilitators.

2.3 Prototype construction

The third phase is the manufacture of walker product planning, with the production of detailed technical drawings. In the end, the prototype walker will be produced. In this phase, the designer works as a team with ergonomists and technicians from the medical devices industry.

Furthermore, there are 3 main dimensions of the size of the walker, namely the height of the walker, the width of the walker and the length of the walker. Determination of walker height takes anthropology data of elbow height, to determine the width of the walker takes hip-width data and for the length of the walker uses

anthropometric data of foot length [25]. This walker design concept uses 5 subject as anthropometric data with a 50% percentile. The anthropometric data from the subjects of walker users were measured as shown in Table 1.

Table 1 Anthropometric data on subjects of prospective pediatric walker users

Subject	Gender	High Elbow (cm)	Hip Width (cm)
Subject 1	F	95	33
Subject 2	M	100	37
Subject 3	F	82	34
Subject 4	F	74	27
Subject 5	F	70	24

Table 1 above explains the significant differences in size between subjects, which can be adjusted according to the size of the user. Walker length data is taken on the average length of the subject's feet which is about 22.5 cm because the length of the walker will later be adjusted to the ADVANCED walker design.

Interviews were conducted with therapists, CP children and parents of CP children to find information about walkers. Identification is done through articles and scientific journals by internet. This design requirement is carried out to determine the ADVANCED walker design criteria. This criterion will be chosen which criteria are suitable for the walker's design. These ADVANCED walker design criteria can be explained in Table 2.

Table 2 Criteria requirements for the ADVANCED walker design

No.	Pediatric Walker Design Criteria
1.	The height can be changed according to interests
2.	Reducing friction on the wheels
3.	The height is adjustable for comfortable walking
4.	Weight of the walker that matches the user's ability
5.	Can be folded, to be easily summarized taken outside the house
6.	If you need to add wheels or baskets
7.	Can maintain body balance when used
8.	There is protection to prevent falls
9.	Made of a strong and rust-resistant material
10.	There is a height adjustment mechanism
11.	Accompanied by basket or seat

Furthermore, this criterion is adjusted to universal design 7's principle and becomes the basis for making a questionnaire, as shown in Table 3.

Table 3 ADVANCED walker design requirements based on universal design

No.	Principles of	Questions of Pediatric Walker Design Needs
1.	Equitable in use	Can be used for all children
2.	Flexibility in use	Can be adjusted according to pediatric users
		The height that can be modified
3.	Simple and Intuitive use	Can be assembled
4.	Perceptible information	Easy to use
5.	Tolerance for error	Can maintain user balance
		No additional brakes are given
		Can protect users from falling
6.	Low physical effort	Use the wheels to reduce friction
		The material used is lightweight and sturdy
7.	Size and Space for Approach and Use	Handlers are made of rubber
		The size of the walker matches the user's size
		Not given additional features (chairs, baskets, etc.)

Table 3 is the basis for making a questionnaire to determine the needs to be developed. The questionnaire was given several statements about the criteria and compared with the condition of the walkers used every day as well as questions about some additional features needed.

2.4 User trial

The fourth phase is the testing of prototype artifacts that have been made by technicians from the medical devices industry to CP children. In this phase, participation takes the form of a user trial [23] combined with a form of participation dialogue. The team consists of a designer and an ergonomist who observes CP children who try prototypes while discussing designs. New comments and ideas from CP children's childminder at YPAC Surakarta and parents of CP children are recorded again to remember all the details and to create a domain of knowledge for similar projects in the future.

Furthermore, gait performance parameters were assessed at the end of the 1-week training program for a anterior walker initial and ADVANCED walker including distance and walking time; and comfortable walking speed [26]. For walking distances, participants are instructed to walk, without rest, at a comfortable pace of their own choosing until they are exhausted. Oxygen consumption and energy expenditure [27] are calculated according to the following equation,

$$VO_2Max = 0{,}019\ HR - 0{,}024\ h + 0{,}016\ w + 0{,}045\ \alpha + 1{,}15 \text{ (liter/minute)} \quad \ldots\ldots (1)$$

$$1 \text{ liter } O_2 = 5 \text{ kkal} \quad \ldots\ldots (2)$$

2.5 Production

The production phase is the final phase of implementation in product planning into product artifacts to be produced and made available to consumers.

3. RESULTS AND DISCUSSION

3.1 The Triple Helix Collaboration Models

The triple helix collaboration embodies a potential for innovation and economic development in the knowledge society lies in a more prominent role for academics. Hybridization of organization of elements included academia, industry and user instutions to produce collaboration and social formats for the production, transfer and application of new knowledge. Creative synergies emerge and drive the process of "innovation in innovation", the creating new interactions and formats, because individual actors and organizations not only perform their own roles. This creative process, the relationship among academic, medical devices industry and user institutions continues to improve innovation, bringing forth new technologies, new companies and new types of relationships in a sustainable manner [16]. The main objective of triple helix collaboration is to create an atmosphere suitable for two-sided and tri-lateral relations so that knowledge sharing can occur among industry, laboratories, and research groups, as in Figure 2.

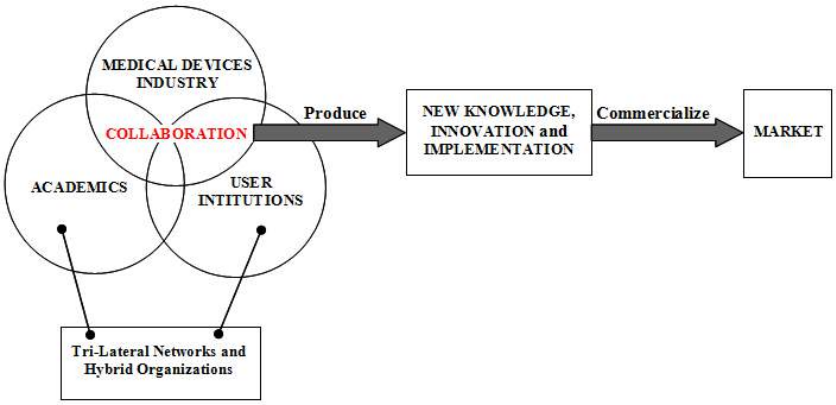

Figure 2 The triple helix collaboration models (academic, medical devices industry and user institutions)

With reference to Figs. 1 above, the triple helix collaboration will produce new formats in the space of new knowledge, innovation, and implementation and then be used to produce competitive advantages. The process for generating new knowledge, innovation, and implementation itself is not linear. Human skills are basic requirements in the production of new knowledge or enhancement of existing knowledge. New knowledge can be generated in a team by its members [28]. Therefore, the collective knowledge of team members (academics) is combined for knowledge users (medical devices industry). Knowledge is produced by three different modes, Mode 1, Mode 2 and Mode 3. In Mode 1, knowledge is produced by each party without collaboration with others (for example, academics), in Mode 2 knowledge is generated through short-term collaboration with other parties (for example, industry), while Mode 3 knowledge is generated through long-term collaboration with other parties to solve certain problems. The collaboration between organizations facilitates the sharing of resources and the creation and transfer of new knowledge, thus helping to produce synergistic solutions [29]. Thus, collaboration not only supports the creation of new knowledge, but also the improvement of skills for effective and efficient innovation [30].

3.2 Universal Design in Advanced Walker Design

In making the design of the questionnaire refers to the principle of product design based on universal design. This concept was chosen to develop products that can be used effectively by everyone. Questionnaire measurements are calculated through the average value of each universal design principle. The calculation results can be known from each universal design principle that has a low rating from user respondents, as can be explained in Table 4.

Table 4 Average results of testing the ADVANCED walker design questionnaire

No.	Principles of universal design	Questions	Average	Sum of Average
1.	Equitable in use	Q10	1.75	1.75
2.	Flexibility in use	Q11	1.75	2.00
		Q9	2.25	
3.	Simple and intuitive use	Q8	2.75	2.75
4.	Peceptible information	Q5	5.50	5.50
5.	Tolerance for error	Q6	6.00	5.60
		Q13	5.25	
		Q7	5.50	
6.	Low physical Effort	Q2	6.00	4.80
		Q1	3.50	
7.	Size/space, approach/use	Q3	2.25	3.80

The value generated from the questionnaire according to the universal design principle can be seen that low values such as the principle of equitable use, flexibility in use and simple and intuitive use, all three attributes of the universal design principle have an average total value of 1.75, 2.00 and 2.75. Equitable in use attribute has the lowest value so that the use of equitable in use has not been felt by the user. The principle of equitable use which is the main focus in designing walkers together with principles that have a low mean value is flexibility in use and simple and intuitive use.

3.3 Making Advanced Walker at Medical Devices Industry

The design phase of the ADVANCED walker starts with comparing a number of reference walkers in the market followed by the design phase. Information from the design reference and comparing the previous walker then made ADVANCED walker that is able to meet user needs. The assistive walkers designed with user anthropometric measurements, so that the walker is made according to the user's posture size so that when used the walker feels more comfortable. The results of anthropometric measurements obtained by ADVANCED walker specifications are height (750 cm), width (550 mm), length (600 mm), weight (7 kg), front-wheel diameter (7 cm), and rear-wheel diameter (14 cm). The advantage of this ADVANCED walker is that it can be used anteriorly and posteriorly, thus adjusting the user's pediatric. This design is divided into four main sections and these parts are connected by bolts, can be assembled and can be folded as shown in Figure 3.

Figure 3 The prototype ADVANCED walker is designed with the universal design principles

Based on Figure 4 above, the frame structure is the main part of the walker that forms the overall construction of the walker. The frame walker made through the process of bending and drilling for mounting nuts and bolts, the bottom for walker's feet and mounted wheels. Right and left frame, this frame consists of two

separate parts. This frame is connected to the mainframe using bolts. The top of the frame functions as a hand handle when used, and then the bottom of the frame functions as a walker's legs and is given a pair of wheels. Walker is design with wheels that serves to reduce the friction when used. Wheels are used as many as four, where the size of the front wheels and rear wheels are the same size. The front wheels function as a steering wheel, counterweight and so that the walker is lighter when turning. After the ADVANCED walker design process with the material in making this tool is to use aluminum pipe iron with a diameter of 16 mm. The choice of aluminum material as material in the process of making this tool is because aluminum has properties including rigid, lightweight and not easy to rust.

3.4 Testing Gait Performance in CP Children

After the manufacturing process, the ADVANCED walker is tested which aims to evaluate so that when testing aids walk smoothly and get good results. ADVANCED walkers are anterior-posterior walkers with four wheels. ADVANCED walkers are anterior-posterior walkers with four wheels. The ADVANCED walker prototype test is done by comparing the previous walker with gait performance parameters is how much energy consumption. All subjects tested can walk independently without the help of an assistant, and can use a walker. Under the guidance of a physical therapist at YPAC Surakarta, ambulation with an anterior-posterior walker is carried out with this type of walking aid. The test of the design of the walker design was carried out on 3 subjects with an age range between 12-13 years, as shown in Table 5.

Table 5 Demographics of test subjects walking in using a walker

Subject	Gender	Height (cm)	Weight (kg)	Age (yr)
Subject 1	F	110	33	12
Subject 2	F	120	38	13
Subject 3	F	115	35	12

They walk with or without orthosis feet with hinged joints at a comfortable pace of their own choosing. After each test, the children rest at least 15 minutes so that their heart rate returns to the basal level. The purpose of this test is to analyze the energy consumption of CP children when walking straight as far as 2 meters.

Figure 4 Anterior walkers initial

The results were compared between using an anterior walker initial and an ADVANCED walker, as shown in Figure 4 above and Table 6.

Table 6 Results of measurements of oxygen consumption in using a walker

Subject	Anterior Walker Initial (liter/minute)	ADVANCED Walker	
		Anterior Walker (liter/minute)	Posterior Walker (liter/minute)
Subject 1	1,193	1,098	0,984
Subject 2	0,945	0,830	0,736
Subject 3	1,390	1,257	1,143

Table 7 is a comparison of energy expenditure results in using a walker between using an anterior walker initial and ADVANCED walker.

Table 7 Results of energy expenditure measurements in using a walker

Subject	Anterior Walker Initial (kkal)	ADVANCED Walker	
		Anterior Walker (kkal)	Posterior Walker (kkal)
Subject 1	5,96	5,49	4,92
Subject 2	4,73	4,15	3,68
Subject 3	6,95	6,28	5,70

The results explained in Table 6 and Table 7 show that energy consumption and energy expenditure show that using a posterior walker, where subjects require less energy expended than using an anterior walker initials. The use of ADVANCED walkers during testing is done that subjects are more comfortable The anterior intestinal walker causes an increase in body weight against the walker and an increase in hip flexion during the walking gait. Posterior walkers in most CP children are the most appropriate because the best walking gait pattern and less spending on body energy consumption. Options for rehabilitation for CP children of walked in cases where extensor spasticity predominates. CP children have problems with posterior balance and tend to fall backwards. In this case, it will benefit from the posterior walker as an aid to improve its balance.

4. CONCLUSION

The triple helix collaboration among academics, medical devices industry and user institutions to redesign walkers for CP children, especially in the city of Surakarta in the province of Central Java, is important because of knowledge-based innovation. Our collaborative process models among academics, medical devices industry, and user institutions are designed to highlight the roles and responsibilities of each actor at different stages in generating knowledge and commercialization. The government in Indonesia funds projects at universities and thus creates a research environment that meets flexible industry requirements and policies. In such collaborations, academics and research groups can use resources such as skilled personnel, laboratories, and equipment to complete assignments within a specified time period. The participatory design model is proposed using a universal design approach in designing safe and functional walkers that will promote and sustain the lives of CP children independently. Collaboration among academics, medical devices industry, and user institutions is a suitable way to incorporate the needs of CP children into the design process. The use of the USAP methodology model has proven to be a potential source for designers to be able to explore more deeply. ADVANCED walkers are designed to help individuals with CP children with spastic diplegic. The results show the effectiveness of a better ADVANCED walker, relative to the initial anterior walker, with respect to comfort and provide the best gait pattern and consume less energy.

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DESIGN OF ARRANGEMENT OF WORKING TIME TO INCREASE PRODUCTIVITY OF THE WORKERS BY USING FLAT IRON AT GARMENT "A"

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Abstract. The garments businesses in Bali grow quickly in line with the growth of tourism industry. These are proven by presence of many garment businesses in big scale investment with hundreds of workers or small -scale investments of home industries. However, the level of awareness and the failure of the business managers to seek for comfort, health, and safety for their workers remains very low. One of many problems that important in garment business for the workers in flat iron is musculoskeletal disorder. Generally, the working position is in the standing position for long time, and the hot temperature of environment resulted in the flat iron radiation. Workers that use flat iron work 9 hours per day including the lunch break and 7 day a weak, except for the big holidays or when there is less order. They start working at 08.00 a.m. until 17.00 p.m. with lunch break at 12.00 until 13.00 p.m. Arrangement for the working time and the break time, holiday, working shifts, are one of the many aspects in organization that needs to be paid attention because by arranging the working time, it may make them comfortable, safe, healthy, so it can increase the work productivity. Increasing the working time will cause the accumulating fatigues and in turn, it will decrease the productivity. Therefore, to solve that problems, this research has been done experimentally by arranging the working time, namely by providing 10 minute-breaks every two hours of working time while drinking tea. This research was conducted to 12 female workers who used flat iron in "A" garment, of Tabanan Regency, Bali, with treatment by subject design. The indicated workload was measured by heart rate with pulse meter. Musculoskeletal disorder was predicted by Nordic Body Map questionnaire. Data were analyzed by t test on 5% significant. The result of analysis showed that there was a decrease of workloads and the subjective disorders significantly before and after treatment as well as the increase of the working productivity significantly ($p<0,05$).

Keywords : arrangement of the working time, work load, musculoskeletal disorders, work productivity.

1. INTRODUCTION

In Bali, the garment businesses developed rapidly along with the development of the tourism industry. This is proven by the number of garment companies ranging from large-scale investment with hundreds of workers to garment companies as home industry. Nevertheless, the level of awareness and the company managers fault in taking any efforts to protect workers by assuring comfort, health and safety is still very low.

In preparing a job, unnatural posture should be avoided; an unnatural working position can be a cause of various disorders of the musculoskeletal system [1], [2]. One of the important problems in the garment business especially in ironing is the musculoskeletal complaints. Musculoskeletal groups, based on the location consists of a group of muscles of the neck, back, chest, shoulders, upper arms, forearms, hands, buttocks, pelvic floor, thighs, calves and feet. By knowing the function and location of

musculoskeletal, it is known which parts are experiencing pain or musculoskeletal disorders of the group, mainly due to inadequate working conditions, causing muscle fatigue and discomfort. The average working hours of the workers in the garment ironing section is 9 hours per day including lunch break, 7 days a week except on national holidays or other public holidays or when there is little order. They work from 08.00 pm until 17.00 pm with a break at 12:00 pm until 13:00 pm. The working conditions are in hot ambient temperatures, due to the influence of heat radiation from the ironing tool. The working position of the ironing workers in the garment is with the position of standing, bending and sitting. The poor working position and lengthy working hours cause the strain (reaction) of the musculoskeletal system and as well as causing negative effects to health. The ability of humans is determined by the profile factors, physiological capacity, the psychological and biomechanical capacity, while the demands of the task are influenced by the characteristics of the material work, and the tasks to be performed, the organization and the environment in which the work being performed [3], [4].

The arrangements of working hours and breaks, holidays, job rotation are one of the many important aspects of the organization, because the regular working time arrangements that can provide security and comfort, efficiency and health so as to increase productivity. The increase in working hours will lead to the accumulation of fatigue, which in turn could reduce productivity. So to address the above issues, some efforts needs to be done to harmonize these works with the human resources through research on the appropriate timing of work, so that complaints on the musculoskeletal of the ironing garment workers who work in the village of Kediri of Tabanan Regency can be reduced.

2. METHODS

The research was performed experimentally by applying the design of "Treatment by Subject" (the design of similar subject). This research was conducted in the Tabanan Regency. The research samples were 12 ironing workers given two treatments namely P0 group (ironing with the old system) and P1 group (ironing with additional short break). The predicted workload of the pulse rate which was calculated by the pulse meter. The ambient temperature is measured with a sling Psychrometer. Indication of the level of of fatigue and musculoskeletal disorders obtained through questionnaires, 30 items of fatigue, and the Nordic body map, before and after work. While the labor productivity was calculated based on the ratio of the output (the amount of clothes that were ironed) to the input (the average of pulse of labor and time used). The statistical analysis to determine the significance of differences between the data obtained P0 and P1, were analyzed by t- Paried test, at a significance level of 5%.

3. RESULTS AND DISCUSSION

3.1 Microclimate in the Workplace

The results of the average microclimatic measurements in the workplace of the ironing garment workers in the village of Kediri, Tabanan is as follows.

Table 1 The Results of Analysis of the Working Environment Measurement during the Research

No.	Variable	P0		P1		t	p
		average	SD	average	SD		
1	Wet Temperature (°c)	27,74	0,31	27,82	0,24	1,892	0,219
2	Dry Temperature (°c)	32,34	0,15	32,69	0,22	2,465	0,421
3	Relative Moisture (%)	75,12	2,38	74,89	1,92	3,362	0,392
4	ISBB (°C)	28,19	0,59	28,69	0,42	0,813	0,473
5	Light intensity (Lux)	467,86	13,84	475,22	17,02	2,621	0,266
6	Sound Intensity (dBA)	78,12	1,96	78,86	1,26	94,729	0,319

Note : SD = Standard Deviation

Table 1 above shows that the environmental conditions between the two treatments did not differ significantly ($p > 0.05$) or can be declared to be the same. wet temperature, dry temperature, humidity, WBGT, light intensity, and the intensity of the sound were still considered to be in the normal range for the work environment. The threshold for the intensity of the sound / noise is 85 dB [5].

The work environment can affect the workload of workers [6], [7]. The temperature of the hot working environment resulted in the decreasing work performance. Warmer temperatures reduce agility, prolong reaction time and decision-making time, disrupting the accuracy of the brain, disrupting the coordination of sensory and motor nerves, and make it easy to be stimulated. Therefore, the intervention of ergonomics is needed namely to be performed by arranging the time for a lunch break or a short break. In this study, the workers were given a 60-minute lunch break for recovery from fatigue, provided that the workers take a short 10 minutes break (break) while drinking tea in the morning (at 10.00 pm) and afternoon (15:00 pm).

3.2. Workload

The workload is determined by calculating the pulse rate of work on the subject before work and after work. The pulse rate before working is referred to as the pulse rate of breaks. The measurement results of the pulse rate are as follows.

Table 2. The result s of the calculation of the pulse rate the workers

Variable	Control		Treatment		t	p
	Average	SD	Average	SD		
Break time Pulse rate	71,69	4,144	71,84	4,269	-0,910	0,393
Working Pulse rate	126,84	2,113	119,14	1,291	5,935	0,001

The Table 2 above shows that the pulse rate of the workers during the break time both in the control and treatment groups did not differ significantly ($p > 0.05$). This suggests that the initial condition of the workers' pulse rates are the same. While the pulse rates of working between control and treatment groups were significantly different ($p < 0.05$). Seen from the average of pulse rates of work, there was a decline of 126.84 beats per minute into 119.14 beats per minute.

By doing arrangements of working hours namely by the provision of a short break of 10 minutes, while drinking tea every two hours. It was found a decrease in workload, as shown in table 2. The average pulse rate before the improvement of working arrangements on workers working hours in the ironing section of the garment company is 126.84 (± 2.113) pulse / minute which is considered as a heavy workload category [8]. The volume of work was due to workers worked continuously without a break and under hot working environment due to hot radiation from the ironing tools resulted in increased workload. After the improvement by providing a short break every two hours while drinking tea, it was obtained decrease in pulse rates of 119.14 (± 1.291) or a decline of 6.1%. heavy workloads must be reduced and improved with ergonomic interventions [9], [10].

3.3. Subjective complaints

The subjective complaints were predicted from the skeletal musculoskeletal disorders and the general fatigue. Complaints of musculoskeletal was measured by using a questionnaire of Nordic Body Map, whereas fatigue was measured by the 30 item questionnaires of general fatigue. The results of the analysis of subjective complaints are presented in Table 3 below:

Table 3: Results of Analysis of the subjective complaints

Variable	Control		Treatment		z	p
	Average	SD	Average	SD		
General fatigue	69,00	2,390	53,88	2,100	-1,333	0,009
Musculoskeletal Complaints	79,88	5,194	65,75	3,655	-2,521	0,012

The difference of significance between the untreated and treated were tested with non-parametric statistics by using the Wilcoxon test with the results as shown in Table 3 above. It can be seen from the table that there was a significant difference between the control and treatment groups, either on the general fatigue or the musculoskeletal complaints. Seen from the average scores, there was

decrease of fatigue and muscle complaints. General fatigue scores decreased from 69.00 into 53.88 or decreased by 21.9%. There was decline of musculoskeletal disorders from a score of 79.88 into 65.75 or decreased by 17.69%.

Some studies mention that the work posture, equipment, and work environment will give effect to worker fatigue from mild to severe, and need for intervention in order to suppress or decrease the fatigue [11]–[13].

3.4. Working Productivity

The working productivity in the ironing section of garment "A" in Tabanan was calculated based on the number of pieces of clothing that can be divided by the workload and working time. The significance difference test between the control group and the treatment group was done by using the t-test pair. The results of the analysis of productivity in the ironing section of the garment company X in Tabanan is shown in Table 4 below.

Table 4 Results of the analysis of working productivity

Variable	Control		Treatment		t	p
	Average	SD	Average	SD		
Work Productivity	0,07884	0,00921	0,10072	0,00821	1,910	0,000

Table 4 showed that there were significant differences in working productivity between the control group and the treatment group ($p < 0.05$). And an increase in working productivity of the control group from 0,07884 into 0.10072 in the treatment group or an increase of 27.75%.

Manuaba [14] mentions that the intervention of ergonomics is needed in industry or company to be able to increase the productivity of workers. Adiputra [15] also mentions that by ergonomics intervention in small industry, for instance, through the intervention of using appropriate anthropometric work chair and so on will be able to decrease the workload or subjective complaints as well as it can increase work productivity. This research proved that by ergonomics intervention, it is able to increase productivity in the ironing section of the garment company in Tabanan.

4. Conclusions and Suggestions

4.1 Conclusions

It can be drawn from the results and analysis of this study the following conclusions.

a. The arrangements of working hours by providing a short 10 minutes break and tea break every two hours can reduce the workload on the ironing workers of the Garments.
b. The arrangements of working hours by providing a short 10 minutes break and tea break every two hours can reduce the subjective complaints on the ironing workers of the Garments.
c. The arrangements of working hours by providing a short 10 minutes break and tea break every two hours can increase the working productivity on the ironing workers of the Garments.

4.2 Suggestions

a. It is suggested to apply a short break and drinking during the working time in the morning and in the afternoon, in addition to the lunch break. It could also be applied to other home industries.
b. The needs for further research on the reduction of heat and static working positions on the ironing workers in the garment companies.

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HORIZONTAL COFFEE ROASTER DESIGN WITH TEMPERATURE AND TIME CONTROL

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Abstract. National coffee have bean production reaches 600,000 tons for a year, only 20% that can be processed and marketed in to secondary products by roasted coffee, ground coffee, fast food coffee, and several types of secondary products derived from its derivatives and processing. The factors need to be considered when roasting, including temperature, time, expertise, and roasting techniques with a tool that is designed has dimension length 50 cm width 45 cm and height 110 cm. Coffee beans are roasted using a teflon griddle without a 25 cm cover diameter and Teflon griddle with a 16 cm cover diameter. The treatments studied were temperatures around 180 to 215°C with 12 minutes roasting time. The temperature treatment and roasting time affect the changes in mechanical physical properties of the coffee, namely a faster decrease in water content, increased fragility and accelerate changes in the color of darkness. Roaster machine based on microcontroller using gas fuel is made only 3 settings of coffee profile results, namely light, medium and dark with a light time of 12.8 minutes, medium 17 minutes and dark 25 minutes with a temperature setting of 245 degrees Celsius. The price of "roaster" is still very high because all the roasted tools in Indonesia are mostly imported so that they are not affordable by the household industry scale in relatively low income. A prototype of the horizontal roaster model has been created while emphasizing the traditional method of temperature and time control. Temperature and time control can be used to obtain the desired coffee profile quality to reproduce creations roasted results. The dimensions are also small with a height of 60 cm, a width of 50 cm and a length of 60 cm and a frying pan diameter of 30 cm to hold 2 kg of coffee. This tool is designed with stainless steel and other parts used easily found on the market with the aim of facilitating maintenance and the main point is the application of appropriate technology with to increasing economic value. The results of testing the tool with a robusta coffee sample of 2 kilograms obtained the conclusion that the temperature and roasting time affect the profile of coffee produced and the roasting process can reduce the moisture content of coffee beans produced to improve quality of coffee profile.

Keywords : coffe roaster, temperature, time control

1. INTRODUCTION

Coffee is a commodity plantation found in Bali. Coffee that develops in Bali is robusta type, the word robusta comes from the word "robust" which means strong. This is consistent with the description of the body or a strong level of thickness. This coffee is a derivative from coffea canephora species. Robusta can grow in the lowlands, but the best location to cultivate this plant at an altitude of 400-800 meters above sea level. The optimal temperature of robusta coffee growth ranges from 24-30°C with 2000-3000 mm of rainfall a year. The roasting of traditional coffee beans is still done using traditional tools usually made of clay or steel of pan and stirrer, as well as a furnace and firewood, before roasting the wet process is carried out for coffee fruit.

National coffee bean production reaches 600,000 tons a year, only 20% that can be processed and marketed in secondary products include roasted coffee, ground coffee, fast food coffee, and several types of secondary products derived from its derivatives and processing [1]. Roasting is very important to result of coffee (steeping coffee). The factors need to be considered when roasting include a roasting machine system, a roasting tube plate material, the stability of the roasting tube fire source, and the type of coffee raw material and its characteristics. In addition rooster factor, other important aspects are temperature, time, expertise, and roasting technique with the designed tool having a dimmer length 50 cm width 45 cm and height 110 cm [2].

Coffee beans roasted using a teflon griddle without a 25 cm cover diameter and teflon griddle with a 16 cm cover diameter. This treatments studied were temperatures around 180 to 215ºC with 12 minutes roasting time. The results showed that roasting process using conduction heat with a covered roaster caused the heat to spread evenly so that roasting process runs faster. The temperature treatment and roasting time affect the changes in mechanical physical properties of the coffee, namely a faster decrease in water content, increased fragility and accelerate changes in the color of darkness [3]. The studies stated that the quality of roasted coffee beans is determined in terms of roasting method and temperature and time, but the equipment used still has quite large dimensions and relatively high prices where the frying pan uses teflon material.

This automatic roaster and grinder uses a microcontroller as an electric controller. To roasting process, dried coffee beans are inserted into roasting tube then set the temperature and press the start button then the heating element and the stirrer will rotate to the desired temperature. When the roasting process is finished this tool will turn on the buzzer as a sign to start the grinding process. The grinder rotates according to the desired timer set [4]. Roaster machine based on microcontroller using gas fuel is made only 3 settings of coffee profile results, namely light, medium and dark with light time 12.8 minutes, medium 17 minutes and dark 25 minutes with a temperature setting of 245 degrees Celsius [5]. This research has applied an automatic system which is limited to the microcontroller so that the desired profile quality can be determined. However, the weaknes of tools made with this technology are felt to be inappropriate applied into home industry because maintenance costs will be higher and can only create three types of coffee profiles while the needs of consumers now determine and create their own desired of coffee profiles.

Modern coffee processing methods use modern tools or what is commonly referred to as "roasters" have been highly developed, but the prices it is still very high because all the roasted tools in Indonesia are mostly imported so that they are not affordable by the household industry in relatively low income. A prototype of a horizontal roaster model has been created while still emphasizing traditional methods equipped with temperature and time control. Temperature and time control here can be used to obtain the desired coffee profile quality to reproduce creations from roasted. The planned dimensions are also small with a height of 60 cm, a width of 50 cm and a length of 60 cm and a 30 cm diameter skillet to hold 2 kg of coffee. This tool is designed with stainless steel and other parts are used easily found on the market with the aim of facilitating maintenance and the main point is the application of appropriate technology. Applying appropriate technology for handling post-harvest being to increasing economic value.

2. RESEARCH METHOD

2.1. Design

To make coffee powder there are several stages, namely: roasting coffee beans traditionally using traditional tools usually made of clay or steel in frying pan and stirrer, as well as a furnace and firewood, before roasting, a wet process is carried out to remove the skin before being dried by the sun, after being dried is stored for fermentation process, after that the coffee beans are roasted using a constant fire and stirred evenly so that the beans are not charred.

Figure 1. Traditional coffee roasters in Pupuan-Tabanan

The problems occur where the roaster that is sold relatively high, even though the equipment has temperature control, it is not affordable by the home industry. Terdapat banyak model roaster, salah satunya adalah model

roaster horizontal [6,7]. A horizontal roaster model with a capacity of 2 kg was designed can be applied to village communities.

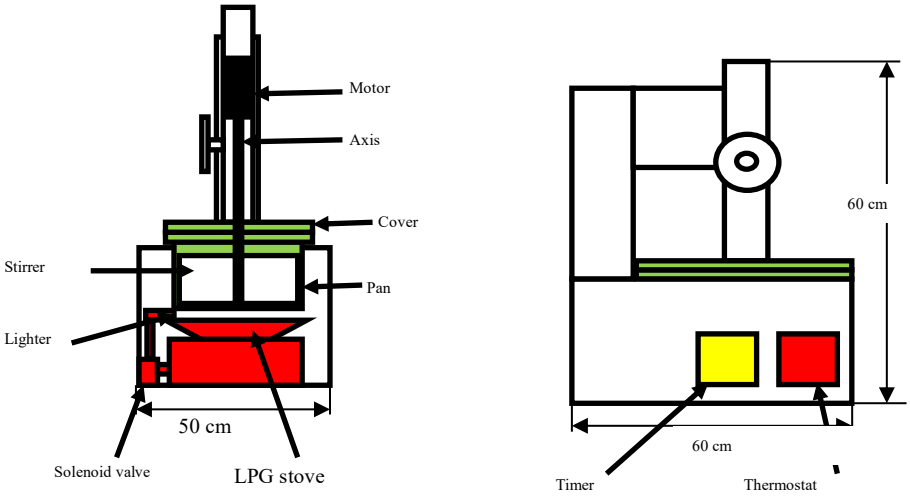

Figure 2. Design of a horizontal coffee roaster

2.2. Methods

The flow of research can be explained as follows.

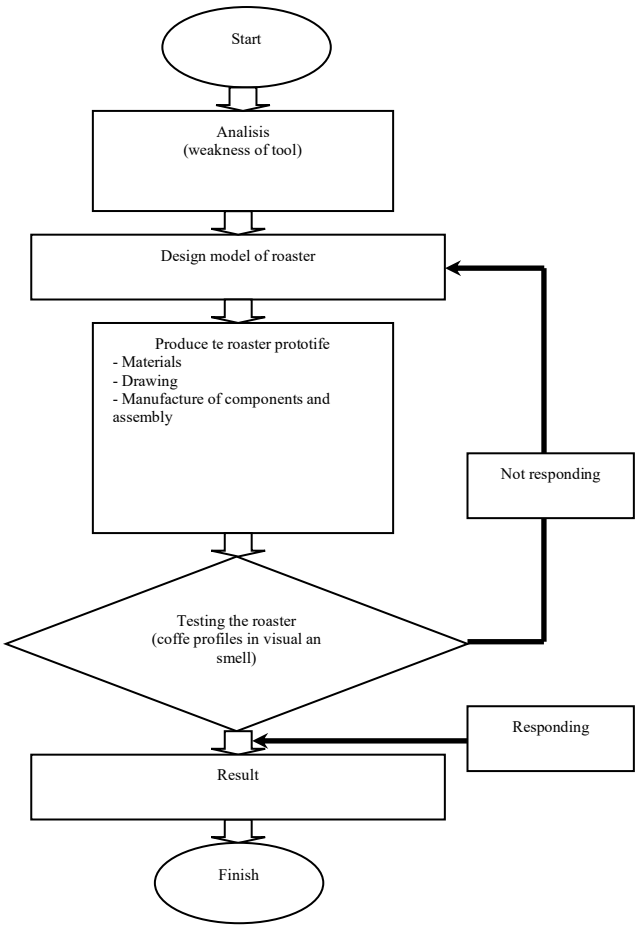

Figure 3. Research flow

Making and testing of tools is carried out at the Mechanical Workshop Department of Mechanical Engineering because all facilities support the process. Coffee samples are taken from the Pupuan area because later the tool will be applied in that area. The profile of roast results based on variable temperatures 80^0 C-220^0 C and the setting time of 15 minutes-30 minutes.

3. RESULTS

3.1. Roasting Tools

Roasting equipment is equipped with temperature and time control to regulate the temperature of the sangria room and the roasting time. The working principle of the tool uses rotation. The rotation is obtained from the electric motor to rotate the stirring blade. Roasting equipment is equipped with temperature and time control to regulate the temperature of the sangria room and the roasting time.

Figure 4. Roasting tools

The working principle of the tool uses rotation. The rotation is obtained from the electric motor to rotate the stirring blade. The process of working the roaster is to turn on the burner and set the room temperature as needed. The roasted chamber is left empty for preheating so that the temperature is reached as needed. Room temperature will be maintained by the control. Entered the coffee when the temperature has been reached and pressing the start button to start the process. The start button will signal the electric motor to spin and start time as needed. Time control will stop all control systems to stop the roasting process.

3.2. Test result

After making and assembling the coffee roaster, it is tested with 2 kg of robusta coffee samples each time.

Tabel 1. Results of test roaster design

Temperature (^{0}C)	Time (minute)	Coffe profile	Visual	Coffee Weight (grams)	
				Before	After
80	15		-cinnamon -aroma kopi sedikit-cinnamon - a little coffee aroma	4,5	4
	30		- city -aroma kopi sedikit-cinnamon - a little coffee aroma	4,5	3,2

Temperature (^{0}C)	Time (minute)	Coffe profile	Visual	Coffee Weight (grams)	
				Before	After
100	15		-city coffee aroma began to smell	4,5	3,9
	30		- city coffee aroma began to smell	4,5	3
120	15		-city + coffee smellted coffee aroma	4,5	3,9
	30		-city + smellted coffee aroma	4,5	3,5
140	15		-vienna or full city ++ -aroma kopi tercium	4,5	3,6
	30		- vienna or full city ++ smellted coffee aroma	4,5	2,9
160	15		- Italian smellted coffee aroma	4,5	3,4
	30		-italian smellted coffee aroma	4,5	3
180	15		-french smellted coffee aroma	4,5	2,5
	30		-french smellted coffee aroma	4,5	2,2
220	15		-nearly black smellted coffee aroma	4,5	2

Compared using the journal results obtained during testing found that at temperatures (190 ℃ -195 ℃) roasted coffee beans can only be called light roast. Whereas the designer found / found that at the temperature (80 ℃ -100 ℃) the roasted coffee beans were already on the maturity of the light roast.

In accordance with coffee standards issued by: BSN, 2017 [8] that the water content can be measured from the initial weight loss and the final weight of a coffee process. In accordance with table 5.2, at a roasting temperature of 80 ° C within 15 minutes there was a decrease in weight of coffee beans by 11%. At a roasting temperature of 220 ° C with 15 minutes there was a significant decrease in weight of coffee beans by 55.56%. This proves that the heat process can reduce coffee weight.

4. CONCLUSION

After designing and testing the tool it can be concluded as follows:

1. Temperature and roasting time affect to the profile of coffee product.
2. The roasting process can reduce the moisture content of coffee beans produced to improve the quality of the coffee profile.

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THE DEVELOPMENT OF GREEN TECHNOLOGY MODEL IN THE PROCESS OF MAKING *GAMELAN*, KLUNGKUNG REGENCY, BALI

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Abstract. The work bent on the smelting process which is very low and with the flame still open so that the heat from combustion is wasted into the environment has the potential to pollute the environment and expose the craftsmen to cause an increase in workload, subjective disorders and a decrease in work productivity. For this reason, one short case study was conducted with a pre and pos test group design that was carried out observationally on craftsmen in the bronze smelting process for gamelan raw materials. The workload was predicted by calculating the working pulse, fatigue and complaints of skeletal muscle craftsmen recorded by questionnaire. The results of the research data were analyzed descriptively to obtain a new design of the bronze metal smelting furnace model so that the work posture was more ergonomic. The results showed that the work pulse increased to 132.42 ± 4.41 per minute or increased by 58.21 beats per minute, including in the category of "heavy" workload. The mean score of musculoskeletal disorders after work increased to 49.30 ± 4.98 and the mean score of fatigue complaints after work also increased to 50.12 ± 1.23. Work productivity decreased from 101.21 ± 5.21 at the beginning of work to be 95.42 ± 2.12 at the end of work. For that, a bronze metal smelting furnace is redesigned, namely redesigning the height of the work field to 60-65 cm from the floor so that the worker's work posture becomes natural and the top of the smelting furnace is equipped with a canopy to remove dust and heat from the workplace.

Keywords : work posture, subjective disorders, and work productivity.

1. Introduction

The process of *gamelan* making in Tihingan Village consists of: the first phase; the process inside *perapen* (hearth furnace) and the second phase; the process outside the *perapen.* The processes inside *perapen* include smelting process (*nglebur*) of raw materials, and formation process (*nguwad*), meanwhile the processes outside the *perapen* are final settlement processes; i.e. the processes of shape refinement and sound alignment until the desired quality of *gamelan* is achieved.

The working process inside the *perapen* is accompanied by heat exposure of open flames and the workers' non-ergonomic work posture due to the use of non-ergonomic work stations. Hot ambient temperature and dust exposure result in an increase in the workload of the craftsmen as well as an increase in subjective complaints of fatigue and skeletal muscle complaints, therefore the craftsmen's work productivity gets lower and the dust exposure causes an increase in air pollution. The open flames cause more and more burning fuel. In the processes outside the *perapen,* the refinement process (*manggur*) and the alignment process of *gamelan* sound are carried out in non-ergonomic work posture due to the use of work tools and work places that do not consider the crafters' anthropometry.

Related to this case, workers need working procedure, posture, tools, environment, and organization that are according to their abilities and limits, so that they can work safely, comfortably, and healthily. This will result in the increase of work quality and productivity. One way to make this out is by implementing green technology

in the production process. This is in line with the presidential decree number 28 year 2008 about the policy of industrial development. The purposes of industrial development are maintaining the balance of ecosystem, maintaining sustainable resources, health improvement and environmental conservation. The efforts in applying green technology in the process of *gamelan* production is really needed considering that Bali is one of the provinces that contribute to the main emission of waste (reaching 87%) and Bali is one of the ten provinces with the highest emission [1]. The implementation of alternative solution of green technology in form of green productivity model in the leather tanning industry in PT.PQR, Malang can reduce the volume of sludge waste up to 70% so that it gives increase to the index of EPI (Environmental Performance Indicator) from 34,89 to 37,33 [2]. It is the same for the application of clean technology in brass industry, it can increase the production, reduce defective products as well as pollution, so that production costs can be saved up to 85% [3].

The main problems of this research include: green technology model design and the making process of *gamelan* that is environmentally friendly. Solving these problems are very important because the process of *gamelan* production in Tihingan village is not ergonomic yet because there is increase of work load, environmental pollution, and the work productivity is low, meanwhile the requests of *gamelan* products are increasing every year. The special specification of the output of this research is green technology model which is a superior applied products in ergonomic production process; safe, comfortable, healthy, and productive.

2. METHODS

2.1 Framework

The production process of Balinese *gamelan* consists of smelting, formation, and finishing process. In the smelting process, bronze material is needed, in which bronze is a combination between copper (*Cu*) and white tin (*Sn*). To obtain good quality, it is needed right proportion of copper and white tin. From the result of phase diagram, it is obtained good composition of 80% Cu – 20% Sn. The next process is formation process by heating/ burning the raw material (copper) which has been molded to be particular form of *gamelan.* The last process is *manggur,* i.e. smoothen the shape of *gamelan* until it produces particular sound. Considering that many factors are involved in the production process if *gamelan,* it is needed efforts toward the management of environmental condition so that the production can be sustainable through the concept of green technology or clean production. Cleaner production concept was proposed by United Nation Environmental Program (UNEP) in May 1989. UNEP stated that Cleaner Production was an environment management strategy which is preventive, integrated, and implemented continuously in the process of economy and production benefit, products and services increase eco-efficiency, reduce the risk of human and environment health [4].

Green technology concept – which is also named as clean technology/ environmental technology – is a concept emerged from human awareness toward the needs of sustainable natural resources. Therefore, the initial design of green technology process can save the needs of raw materials and the process, so that overall it can save the costs in manufacture industry [5]. In the process of *gamelan* production, the craftsmen workloads can be from the activities done and the influence of environment condition. Workloads are generally divided into two groups namely [6]:

1) External workloads (stressor) are workloads from the works done. External loads include task, organization, and environment.
2) Internal workloads are workloads emerged from the craftsmen individual factors which are somatic (gender, age, body size, health condition and nutrition status) and psychic (motivation, perception, desire, and others)

The increased body activities cause body metabolism to increase which makes the needs of O_2 and heart pulse increasing. Physiological complaint is body adaptation mechanism to remain in homeostatic state [7]. Workloads are very affected by work postures during work activities. Human work postures are affected by four factors: (1) physical characteristics, such as age, gender, anthropometry size, body weight, physical health, joint movement ability, musculoskeletal system, vision sharpness, overweight problem, disease history, and so on; (2) kinds of work requirements, such as work that requires accuracy, hand strength, task turn, break time, and so on; (3) work station design, such as seat size, work foundation height, condition of work fields or surfaces, and work environment factors; and (4) environment: lighting intensity, environment temperature, air humidity, air speed, noise, dust and vibration [8]. These workloads will be able to affect work productivity. The increasing workloads along with work duration cause a decrease in productivity. In order to increase the productivity, it is needed efforts to harmonize various factors such as: work tools, procedures, and environment with the abilities, skills, and limits of workers. One of the efforts is by implementing green technology through the approach of SHIP (systemic, holistic, interdisciplinary, and participative [9].

2.2 Research Method

This research is a one short case study research with the design of pre and post test design group which is carried out observationally toward the craftsmen during the smelting process of bronze as the raw materials of the *gamelan* [10]. This can be illustrated through the following chart:

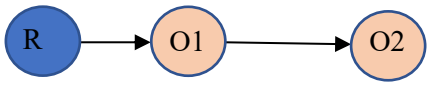

Figure 1 Research Design

Description:
R = Random sample.
O1 = result from pretest of the experiment units measured
O2 = result from posttest of the experiment units measured.

The research stages in redesigning smelting furnace are examining the current use of the furnace (open furnace) to the work productivity of craftsmen and examining the current use of the furnace to the work posture of craftsmen so that ergonomic furnace design in accordance to the more natural craftsmen's posture is obtained.

3. RESULT AND DISCUSSION

3.1 The Condition of Smelting Furnace of *Gamelan* Raw Material

Based on the observation result of smelting process of *gamelan* raw materials in Tihingan village toward 4 craftsmen who work using the furnace, smelting furnace which is too low makes the craftsmen bow. Besides, the metal-smelting furnace that is still opened makes the craftsmen exposed to heat radiation from the burning process of the fuel during the smelting process. Work posture and condition of the craftsmen are presented in figure 2.

Figure 2. Smelting Furnace with the Craftsmen's Work posture

3.2 Subject Characteristic

Subjects in this research are totally 4 men. All subjects followed the research in accordance with the provisions of the research protocol, so that no subject was declared dropped out. The average of subject ages are 43,36 ± 3,41 years and the age range was 28 – 53 years. This age range is still included in the working age group. This age range is still included in the labor force according to the Central Statistics Agency (BPS). The age limit of the labor force in Indonesia is from 15 to 64 years. The average age of the subjects of this research viewed from muscle strength has decreased because the optimum muscle strength for working that is recommended is between 20 to 30 years (Reenen, *et al.*, 2009).

3.3 Work Environment Conditions

The average air temperature was 32,06 ± 0,32 ^{0}C, the average temperature of the ball was 31,34 ± 0,53^{0}C, the average relative humidity was 64,21 ± 0,38%, the average WBGT index was 29,84 ± 0,49 ^{0}C. The threshold value for the category of heavy work with a WBGT of 30,5^{0}C is that the working time per hour is only allowed to reach 25%, while the threshold value for the medium workload with the WBGT reaching 29^{0}C is allowed for the working time setting of 50% - 75% per hour. The intensity of lighting 332,21 ± 6,23 lux, the value of this intensity is in the safe category based on the decision of the Minister of Health Republic of Indonesia number 405 year 2002 concerning the requirements and procedures for the implementation of industrial work environment health, where for rough work requires a minimum light intensity of 100 lux. Inadequate lighting of lighting which is below the required threshold will cause work fatigue as Tarwaka (2010) states that the lack of light intensity in the workplace results in the decreased eye sight and work fatigue. The average noise intensity reached 85,75 ± 2,21 dBA. Suma'mur (1982) stated that work place noise was still at normal limit when it was below 85 dBA. The air velocity was 0,75 ± 0,63 m/sec. Grandjean (1993) and Manuaba (2003b) stated that the movement of air in the room is recommended not more than 0,2 m/ sec, so that air movement does not cause adverse effects on workers, while for work environments exposed by heat requires higher wind velocity.

Table 1. The Work Environment Condition of *Gamelan* Craftsmen

Description	n	Minimum	Maximum	Mean	Std. Deviation
Air Temperature (^{0}C)	4	32.10	32.90	32.06	0.32
Ball Temperature (^{0}C)	4	30.80	33.00	31.34	0.54
Humidity ($^{\%}$)	4	61.90	66.60	64.21	0.38
WBGT (^{0}C)	4	28.16	30.01	29.21	0.49
Lighting Intensity (lux)	4	331.20	341.40	332.21	6.23
Noise Intensity (dBA)	4	84.31	86.32	85.75	2.21
Air Velocity (m/sec)	4	0.70	1.14	0.75	0.64

The value of air velocity in this research is at a comfortable working conditions to work based on the statement of Grandjean and Manuaba stating that it is recommended that the movement of air in the room is no more than 0.2 m/s so that air movement does not cause adverse effects on workers, while for the work environment exposed by heat, it is required higher wind velocity [11], [9]. The results of Listiani Nurul Huda & Kristoffel Colbert Pandiangan's research through the improvement of work environment exposed by heat by redesigning ventilation can increase wind velocity up to 0,7 m/sec [12].

3.4 Workload Condition, Percentage of CVL, ECPT, ECPM, and Skin Surface Temperature

Subject workloads in the smelting process are recorded with work pulse (DNK) and resting pulse (DNI) before work. The resting pulse rate is measured by the 15-second palpation method while the working pulse is measured by the 10-pulse palpation method. The measurement results obtained an average resting pulse rate of 74,21±0,57 per minute and increased after work to 132,42±4,41 per minute or an increase of 58.21 beats per minute. This workload classification is included in the category of "heavy" workloads because they are in the range of 125-150 per minute [13]. The increase in pulse causes the ECPT to 18.00±1,23 per minute and ECPM by 16.21±2,07 per minute. The average cardiovascular load (%CVL) also increased to 56.34 and the average surface temperature of the skin increased to 38.05^{o}C. The increase of CVL percentage which reached 56.34 with WBGT of 29.21 resulted in craftsmen being only allowed to take 50% work and 50% rest. Adiputra states that the higher activity of the body causes the body's metabolism to increase impact on the need for greater O_2 and the frequency of pulse will increase [6]. Increased metabolism causes increased body temperature. ECPT values that are higher than ECPM indicate a higher workload due to environmental factors, so there needs to be improved environmental conditions.

Table 2 Resting Pulse, Work Pulse, %CVL, ECPT, ECPM, and Skin Surface Temperature

Description	N	Minimum	Maximum	Mean	Std. Deviation
Resting Pulse (/minute)	4	64.00	78.00	74.21	0.57
Work Pulse (/minute)	4	130.05	134.33	0.58	5.89
ECPT (/minute)	4	15.67	22.24	18.00	1.22
ECPM (/minute)	4	15.67	23.33	16.23	3.77
%CVL	4	49.93	66.32	56.34	5.25
Skin temperature (^{0}C)	4	37.90	39.50	38.05	0.61

The workload in this research is in accordance with the Sitepu's research that simultaneous workload has a significant effect on employee performance [14]. This improved performance is also influenced by changes in the body metabolism, as Adiputra argues that the higher activity of the body causes the body metabolism to increase the impact on the need for greater amount of O_2 and the pulse rate will increase [6]. The percentage of change in workload in this research is consistent with other similar researches such as the research conducted by Artayasa, et al. which reported that the total ergonomics approach can reduce workload by 10.61% [15], while the results of Muliarta's research to improve working conditions, it is obtained workload reduction of 8,24% [16]. Likewise, the percentage of decrease in workload of research result reported by Purnomo; repairing work system through a total ergonomic approach; it is reported a decrease in workload by 21.69% [17], as well as the result of Setiawan's research in making improvements to work station design reported a reduction in workload by 24.39% [18]. This difference in change percentage is due to differences in the characteristics of the task, work organization,

and work environment, as well as the choices of intervention given to subjects that are characteristic of work improvement in each research.

3.5 Subjective Complaint Condition

The results of the average musculoskeletal complaints score before work were 29,60±0,69 and after work increased to 49,30±4,98. The average score of complaints of fatigue before work by 31.59±1,21 increased to 50,12±1,23. The increase in the average score of musculoskeletal complaints and complaints of fatigue is due to the bowing posture of the craftsmen and environmental heat exposure due to radiation from the smelting furnace. The posture of bowing repeatedly for a long time is a non-physiological work posture. Non-physiological work postures can be caused by characteristics of task demands, work tools, work stations, and work postures that are not in accordance with the abilities and limitations of workers [13], [9]. Non-physiological work posture carried out for years can cause bone abnormalities for the workers [13], and couse subjective disorder of workers [19,20].

Table 3 Scores of Musculoskeletal and Fatigue Complaints

Description	N	Minimum	Maximum	Mean	Std. Deviation
Scores of musculoskeletal complaints before work	4	29.00	32.00	31.5900	1.2192
Scores of musculoskeletal complaints after work	4	42.00	58.00	48.2000	2.3421
Fatigue before work	4	31.00	32.00	31.3000	0.4830
Fatigue after work	4	43.00	55.00	49.2000	3.3214

3.6 Design of Green Technology Furnace Model

Based on figure 1, the current condition of furnace is 18 cm in height from the floor where the craftsman stands. Very low work area causes the work posture of the craftsman to bow with the bowing angle of more than 30 degrees. An unnatural work posture for a long time is a non-physiological work posture. Non-physiological work postures can be caused by characteristics of task demands, work tools, work stations, and work postures that are not in accordance with the abilities and limitations of workers [9]. Non-physiological work postures carried out for years can cause bone abnormalities for workers [13]. The worker's posture to the smelting process needs to be improved towards a physiological work posture so as to reduce the complaints of the craftsman's skeletal muscles. The work posture of the craftsman should be sought in a physiological position as when standing, so as not to cause a forced posture that exceeds the physiological ability of the body [13].

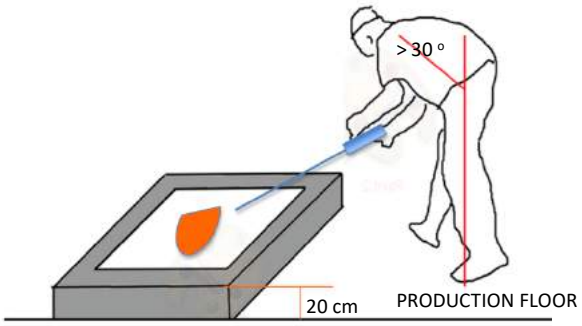

Figure 3 Sketch of Craftsman's Work posture (Before Improvement)

Panjang alat culik ini sekitar 60 cm, sehingga ketinggian bidang permukaan tungku dirancang dengan tinggi 65-70 cm di atas lantai tempat perajin berdiri. Hasil rancangan disajikan Gambar 4.

Considering the data of craftsmen's anthropometry, the average height of the craftsmen's elbows is 105.82 cm. To design a more natural work posture, the height of the work field is obtained 20 cm below the height of the standing elbow which is 85.82 cm. In the smelting process, the craftsman uses a tool to clamp the mass, and a tool to stir or arrange the position of charcoal with a tool called *culik* (Balinese language), which is a kind of straight iron rod used to stir or remove impurities on raw materials that have been smelted. The length of *culik* is about 60 cm, so that the height of the furnace surface area is designed with a height of 65-70 cm above the floor where the craftsman stands. The results of the design are presented in Figure 4.

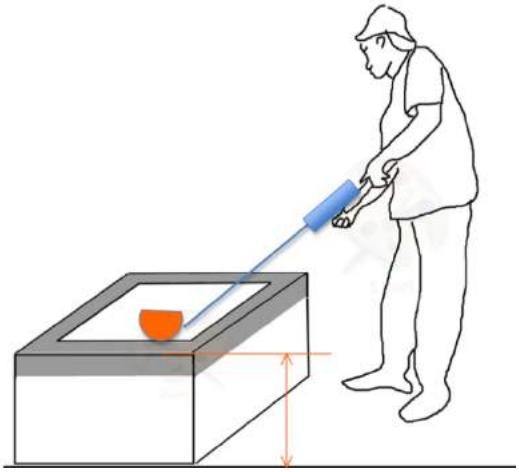

Figure 4 Improvement Sketch of Furnace Height and Craftsman's Work posture

3.7 Green Technology Canopy System Models

The combustion air produced in the smelting process is wasted around the workplace and resulting in an increase of the furnace dust content. In addition, the exposure of heat resulted from the combustion causes the skin surface temperature of the craftsman to increase; therefore it is necessary to design a canopy model to remove dust and heat from the combustion out of the workplace. The design result is presented as follows.

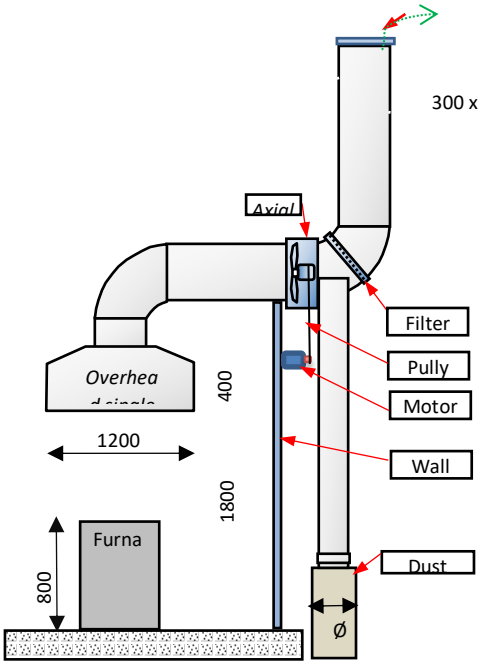

Figure 5 Design of Hot Gas and *Perapen* Dust Exhaust System

4. Conclusion and Suggestion

4.1 Conclusion

Based on the result of the research and the analysis of the obtained data, it can be drawn conclusion as follows:

1. Craftsmen's workload increases by 58.21 pulses per minute. This workload classification is included in the category of "heavy" workload because it is in the range of 125-150 per minute.
2. Pulse increase causes ECPT to become 18,00±1,23 per minute and ECPM is as much as 16,21±2,07/ minute. The average of cardiovascular load (%CVL) increases as well to be 56,34 and the average of skin surface temperature increases to be 38,05°C. The increase of %CVL reaches 56,34% with the WBGT of 29,21 that makes the craftsmen are merely allowed to take 50% work and 50% rest.
3. Designs of bronze smelting furnace model result with green technology concept are such as: a. Improvement of

the height of combustion field in the furnace to 60-65 cm above the height of the floor where the craftsman stands. b. Improvement of craftsmen's work posture into a natural standing work posture. c. Repair the furnace by giving the top canopy for channels of the hot air from combustion and dust.

4.2 Suggestion

Berdasarkan atas hasil simpulan maka dapat disarankan kepada perajin gamelan di Desa Tihingan untuk melakukan perbaikan desain tungku sehingga sikap kerja perajin lebih alamiah, proses pembakaran bahan bakar pada tungku dapat berlangsung sempurna dan udara panas serta debu tidak lagi memapar perajin.

Based on the conclusion, it can be advised to *gamelan* craftsmen in Tihingan village to repair of village furnace so that the work posture of the workers. The process of burning fuel can take place perfectly and the hot air and dust cannot expose the craftsmen.

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MODELLING OF PHOSPHORUS AND BORON DOPING CONCENTRATION ON SOI WAFER BASED DIFFUSION PROCESS

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Abstract. High concentration of Boron and Phosphorus elements are required in diffusion process during the fabrication of semiconductor devices such as diode and transistor based on Silicon On Insulator (SOI) wafer. Achieving high level of these elements' concentration are the entry point for further research in the field of electronics. For this reason, the concentration of the both elements was tested by flowing Boron and Phosphorus gas with flow rate of 1.5 litre per minute into the Nitrogen furnace for 5 minutes towards the surface of the SOI wafer samples at temperatures of 880, 900 and 950 degrees Celsius. This test was carried out at Michiharu Tabe Laboratory, Research Institute of Electronics, Shizuoka University, Hamamatsu, Japan. Furthermore, the resistivity measurements of samples with Boron and Phosphorus doping were carried out. The results of resistivity were then converted to obtain the concentrations of Boron and Phosphorus on the surface of SOI wafer sample. From the concentration and temperature data, it is obtained the modelling of concentration to temperature function for Boron and Phosphorus. The modelling results show that there are linear correlation between high concentrations of Boron and Phosphorus to temperature.

Keywords : Diffusion, Boron, Phosphorus, Concentration, SOI.

1. INTRODUCTION

Phosphorus and Boron are important elements in the fabrication of semiconductor devices. Both elements are used as doping material in semiconductor such as Silicon to produce certain electrical, optical and structural properties. The Phosphorus element function is to produce n-type semiconductor materials, while the Boron element function is to produce p-type semiconductor materials. To produce n-type semiconductor material, Phosphorus vapor is flowed on the surface of a Silicon wafer. Likewise, to produce p-type semiconductor material, Boron vapor is flowed on the surface of the Silicon wafer. To maintain the purity of the results, this diffusion process is carried out in a clean room using a nitrogen furnace with temperature regulation. This research is focused on the concentration of Phosphorus and Boron obtained from the diffusion process in the Silicon On Insulator (SOI) wafer layer, which is a wafer consisting of successive layers from top to bottom namely, Silicon, Insulator, and Silicon Substrate.

Research on SOI-based semiconductor devices has been conducted by several researchers. In 2015, research on tunneling transport in SOI wafer-based diodes was carried out by measuring current-voltage at several temperature levels [1], also research on negative diferential conductance in SOI-based Esaki diodes [2] and research on characteristics voltage-current with very low temperature conditions on SOI wafer-based PIN diodes [3]. In 2016, research on SOI-based lateral Esaki diodes was conducted to analyze interband tunneling currents [4]. SOI wafer-based research in 2017 was conducted on negative differential conductance in Esaki diodes with co-dopants in the Silicon channel [5], also research on the probability of donor atom distribution with Boron

concentrations of 1 × 10^{20} cm^{-3} and 2 × 10^{20} cm^{-3} [6], as well as a simulation of MOSFETs with doping concentrations in the source and drain area reaching 1 × 10^{20} cm^{-3} [7]. In 2018 a study was conducted on SOI wafer-based electro-absorption modulators with a Boron concentration of around 10^{18} cm^{-3} [8].

Based on the research that has been carried out, this paper examines the doping concentration of Phosphorus and Boron in the SOI wafer-based diffusion process in a furnace using Nitrogen gas. This study aimed to produce a mathematical model that applies to the doping concentration of Phosphorus and Boron elements in the range of 10^{19} cm^{-3} to 10^{20} cm^{-3} in the fabrication process of SOI wafer-based electronic devices, especially in the diffusion process using furnaces with Nitrogen gas based on several experiments at temperatures different. The SOI wafer used in this study consists of a p-type Silicon substrate layer and coated by SiO_2 with a thickness of 150 nm and a Silicon layer with doping Phosphorus and Boron. High concentrations of the two elements are needed in the diffusion process in the fabrication of semiconductor devices such as diodes and transistors in nanometer dimensions based on SOI wafers. Achieving a high level of concentration is an entry point for further research in the electronics field.

2. METHODS

This research is a development of research on diode fabrication located at the Michiharu Tabe Laboratory, Research Institute of Electronics (RIE), Shizuoka University, Hamamatsu, Japan. The diode fabrication process is carried out using Phosphorus gas into a diffusion furnace in Nitrogen with a 1.5 liter / minute discharge for 5 minutes to the surface of the SOI wafer sample at 880 ºC, 900 ºC and 950 ºC. The same treatment for Boron gas using a diffusion furnace in Nitrogen. Figure 1 shows the diffusion furnace at Michiharu Tabe Laboratory.

Figure 1. The diffusion furnace at Michiharu Tabe Laboratory.

After the Phosphorus and Boron diffusion process are completed, the next step is to measure the resistivity of the silicon sample using the four-point probe method. This method is an impedance measurement technique using a pair of electrodes to measure current and a pair of electrodes to measure voltage. With this method, the resistivity measurement results are obtained in units of Ω.cm which then converted to doping concentrations of Phosphorus and Boron in cm^{-3} units using the p-Si graph for 300K room temperature in Figure 2. This is in accordance with the temperature conditions at the time of measurements were made and accordance with wafer material that uses p-type Silicon. The final step is to determine a mathematical model for the concentration of Phosphorus and Boron that can be used in various fabrication processes for devices, especially for fabrication of SOI wafer-based devices. Mathematical modeling is done through a linear fit process to determine the value of the intercept and slope and calculate the adjusted R-square value.

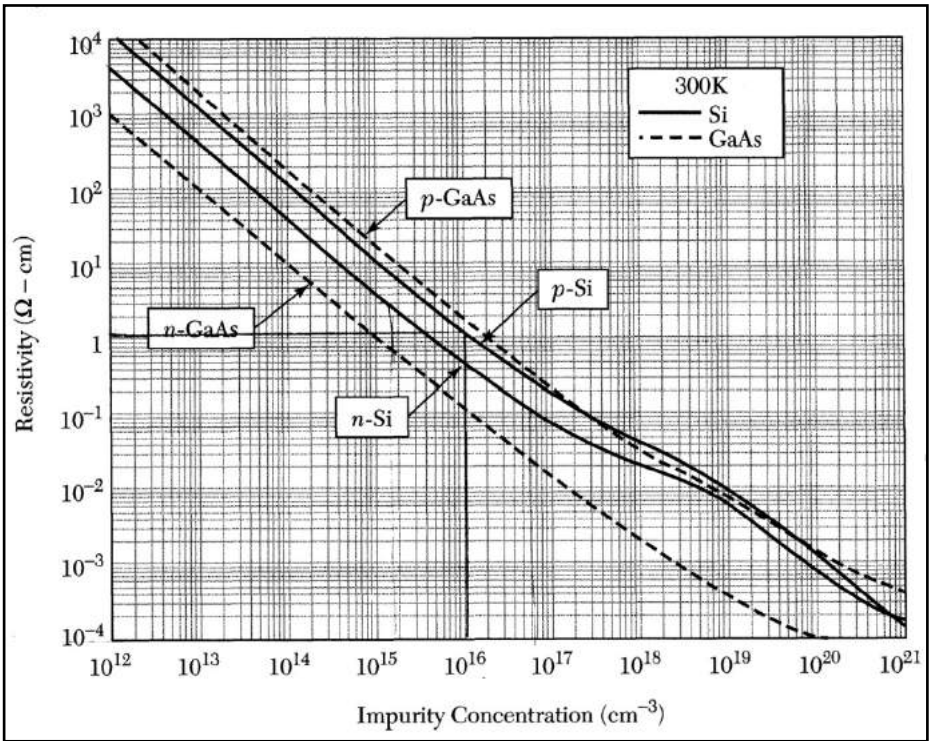

Figure 2. Impurity concentration vs resistivity [9].

3. RESULTS AND DISCUSSION

The results of resistivity measurement using the four-point probe method that has been converted to doping concentrations in cm^{-3} units of Phosphorus and Boron samples are shown in Figure 3. Phosphorus concentrations at 950 °C reach 2×10^{20} cm^{-3} while Boron concentrations at temperatures that are the same reaches 1×10^{20} cm^{-3}. From the experimental results, no good results were obtained for temperatures higher than 950 °C. Higher temperatures cause damage to the surface of the SOI wafer. Based on the Phosphorus and Boron doping concentration data in Figure 3, the linear fit process is then performed to obtain the appropriate modelling. The concentration of Phosphorus and Boron obtain the value of intercept, slope and R-square adj. as stated in Table 1 and Table 2.

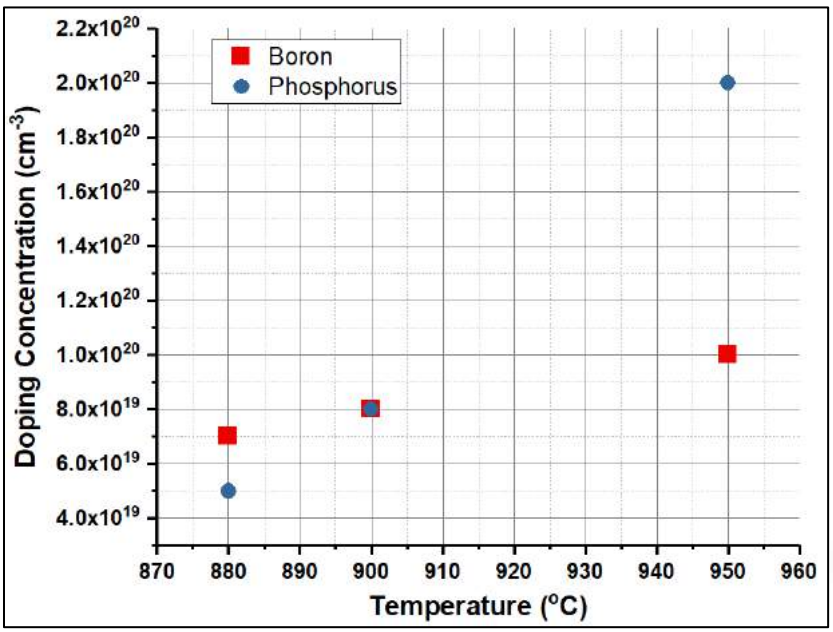

Figure 3. The results of Phosphorus and Boron concentration.

Table 1. Value of Intercept, Slope and Adj. R-square for Phosphorus

Sample	Intercept		Slope		Adj. R-square
	Value	Standard Error	Value	Standard Error	
Phosphorus	-1.885×10^{21}	1.8196×10^{20}	2.19231×10^{18}	1.99852×10^{17}	0.98352

Table 2. Value of Intercept, Slope and Adj. R-square for Boron

Sample	Intercept		Slope		Adj. R-square
	Value	Standard Error	Value	Standard Error	
Boron	-3.01667×10^{20}	2.02178×10^{19}	4.23077×10^{17}	2.22058×10^{16}	0.99451

From the results of primary data processing in Table 1 and Table 2, it is known that the concentration of Phosphorus doping has a linear correlation with temperature (T) accompanied by intercept, slope and adjusted R-square values of -1.885×10^{21}, 2.19231×10^{18}, and 0.98352 respectively. While Boron doping concentration has a linear correlation with temperature (T) accompanied by intercept, slope and adjusted R-square values of -3.01667×10^{20}, 4.23077×10^{17}, and 0.99451 respectively. Thus a linear equation for doping concentration of Phosphorus (CP) and Boron (CB) is obtained according to Equations (1) and (2) as shown in Figure 4. CP and CB are stated in cm^{-3} and T are stated in °C.

$$CP = 2.19231 \times 10^{18} \times T - 1.88500 \times 10^{21} \quad (1)$$

$$CB = 4.23077 \times 10^{17} \times T - 3.01667 \times 10^{20} \quad (2)$$

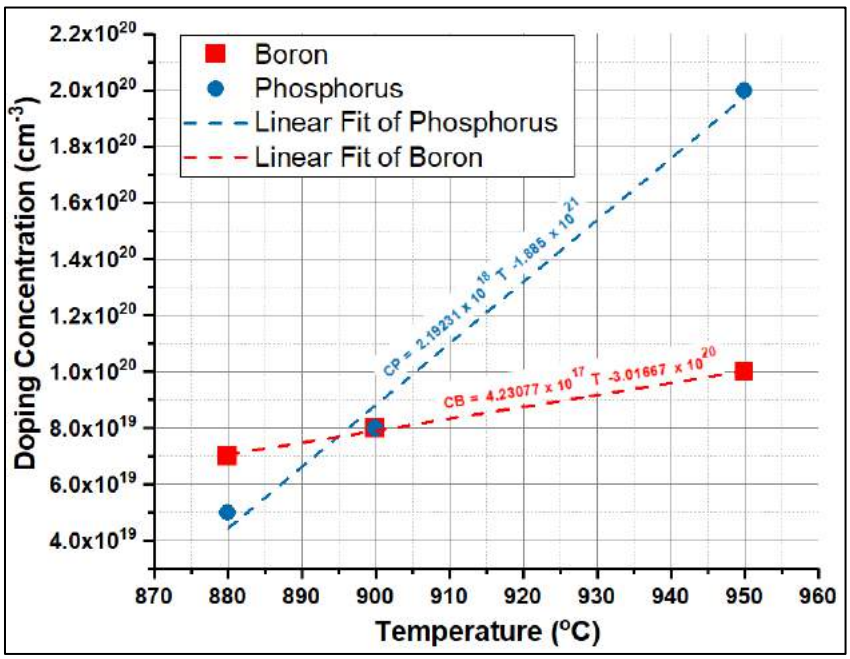

Figure 4. The Linear Equation of Doping Concentration and Temperature.

Based on Sze [9], Phosphorus (P) element has linear diffusion coefficient with slope is greater than Boron (B) element in bulk Silicon as shown in Figure 5. At higher temperature, with a higher diffusion coefficient will result higher doping concentration. This is consistent with the results of this study, in SOI wafer, the Phosphorus element produces doping and slope concentrations greater than the Boron element.

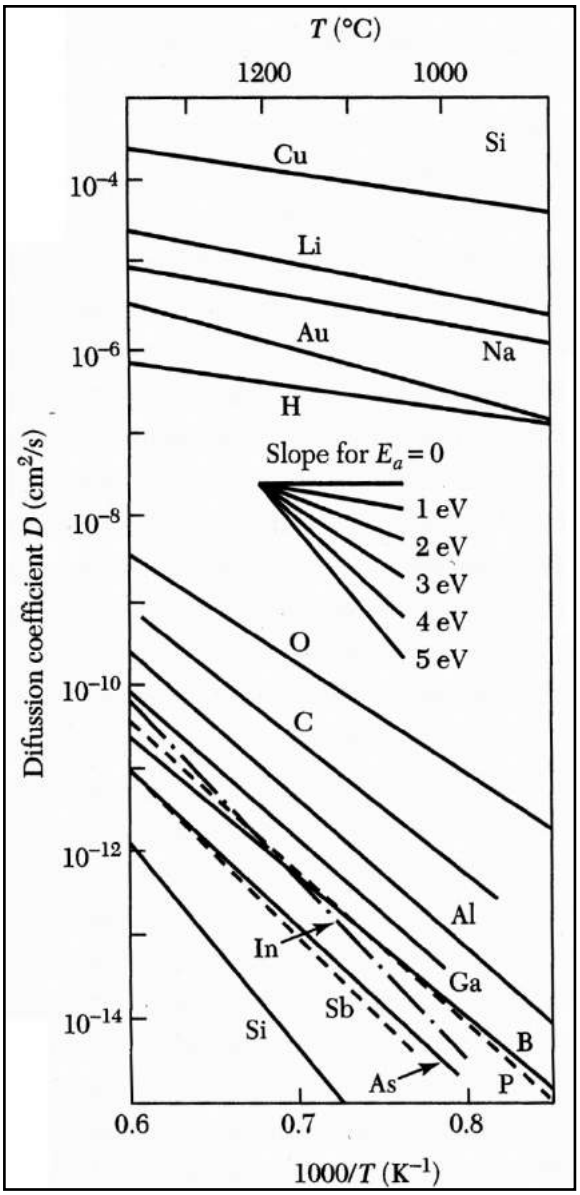

Figure 5. Diffusion coefficient in Silicon.

4. CONCLUSION

This research has shown that the concentration of Boron and Phosphorus in the SOI wafer-based penetration process has a linear correlation to the temperature at temperatures from 880°C to 950°C. The research conducted at the Michiharu Tabe Laboratory, Research Institute of Electronics (RIE), Shizuoka University, Hamamatsu, Japan shows that the concentration of Phosphorus reaches 2×10^{20} cm^{-3} and Boron reaches 1×10^{20} cm^{-3} at 950°C by entering gas Phosphorus and Boron gas separately in the Nitrogen furnace with a debit of 1.5 liter / minute for 5 minutes to the surface of SOI wafer sample. The linear correlation between doping concentration of Phosphorus with temperature is shown in Equation (1) with an adjusted R-square value of 0.98352. Meanwhile the linear correlation between Boron doping concentration and temperature is shown in Equation (2) with an adjusted R-square value of 0.99451.

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POSTURE IMPROVEMENT AND STRETCHING TREATMENT BASED ON PARTICIPATORY ERGONOMIC DECREASE RISK OF WORK POSTURE AND LOW BACK PAIN INTENSITY ON BRICK WORKERS IN KUPANG, NTT

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Abstract. Low Back Pain (LBP) is widely experienced by many brick workers who generally carry out repeated physical activities of lifting-and-carrying with non-ergonomic postures. Such condition can increase the risk of work posture and LBP intensity which if continued can disrupt the continuity of production, increase the risk of injury, and reduce worker productivity. Simultaneous intervention of posture improvement and stretching is conducted with the aim of reducing the risk of work posture and LBP intensity. This research was a quasi-experimental study using pre and post test design. Nineteen males brick workers from the brick production business unit sample in Kupang City who met the eligibility criteria participated in this study. They were determined as samples using purposive sampling technique. Simultaneous improvement of posture and stretching treatment is the selected intervention model agreed upon by researchers, workers and business owners to reduce the risk of work posture and LBP intensity for 5 weeks. The risk of work posture was measured by Rapid Entire Body Assessment (REBA) while LBP intensity was measured using a modified Oswestry questionnaire. Five main activities were measured for LBP intensity i.e. lifting, standing, sitting, walking, social life and sleeping. Measurements the risk level of work posture and LBP intensity were taken before and after the intervention. The data were analyzed by paired t test with a significance level of 5%. The results showed that posture improvement and stretching treatment reduced the risk level of brick workers' work posture from the average score of 9.25 to 5.0 or a decrease of 45.95% and reduced the intensity of LBP from 3.53 to 2.54 or a decrease 28.05%. The highest decrease in the pain intensity was found during sleep i.e. 39.19% and the lowest during lifting activity i.e. 15%. The conclusion is the improvement of posture and stretching treatment base on participatory ergonomic can reduce the risk of work posture and LBP intensity of brick workers.

Keywords : low back pain; work posture, stretching

1. INTRODUCTION

Brick production business is one of the informal sector businesses that is widely spread in various sub-districts in Kupang City. Its development continues to increase yearly with an average increase of 15%. The increase in the number of the business is in line with increasing demand for bricks by communities, industries and developers that has grown rapidly in the last 10 years [1].

Units of brick production business in Kupang City can be found in the subdistricts of Alak, Kota Raja, Kota Lama, Kelapa Lima, Oebobo, and Maulafa. In general, brick making businesses in the five sub-districts are grouped into 3 categories, i.e. small, medium and large scale. This categorization is based on production system,. production level and number of workers [2]. In small-scale units, production is done manually, while in medium and large-scale business production is done semi-automatically. Level of brick production varies for each category

i.e. 1,000 pcs per day, 5,000 pcs per day, and 7,000-10,000 pcs per day for large scale. From the aspect of workers, each respective business unit employs 1-4 people, 5-10 people and 10-20 people or more.

Even though more business units have utilized machines, brick making still done by manual handling. Work that relies on physical exertion includes mixing raw materials, inserting the mix to the machine, pressing, lifting printouts out to drying place and storing and arranging bricks that are ready to sell to storage location. The use of human labor in the production process can increase the risk of work postures on the workers resulting in early fatigue, musculoskeletal complaints, and low back pain [3] - [5]. Therefore, brick making work has very high health risk, while the attention of management or business owners on workers' health and safety is still minimal [6].

Preliminary studies showed that the workers often work with awkward postures such as bending and twisting. The awkward posture is caused both by incompatibility of tools dimension with workers and lack of skills of workers on how to work with neutral posture. Working in a bent position for an extended period will increase pressure on the nerve bearing and can increase the risk of LBP events [7], [8]. Low Back Pain is a phenomenon that is often found in work is done manually. Generally, LBP is felt as discomfort in the lower back [6], does not result in disability, but its effects can reduce concentration, productivity, and quality of work, and increase the risk of accidents [9], [10].

There were 60% of workers often take ‘stolen’ breaks in the middle of activities, even though they have been given sufficient ‘official’ break by the management. From the ergonomic point of view, breaks that are often taken in the middle of activities indicate that excessive fatigue or complaints have occurred [11]. The survey also indicated that stolen breaks were taken to reduce back pain felt during and after the activities.

Workers who are exposed to LBP rarely seek medical treatment for reason of expensive medical costs. Efforts that are often done by workers to overcome LBP are through massage, taking painkillers, smearing with massage oil or leaving to heal by itself. This shows that workers, including business owners, lack knowledge and skills to overcome the causes of LBP. Working with bent work postures, twisting with repetitive movements are ergonomic factors that cause LBP that workers rarely know of [12] - [14]. On the other hand, efforts to get used to stretching before and after the activity to strengthen the muscles of the lower back are minimal. These reasons can make handling of LBP complaints workers not optimal.

Impovement of work posture and stretching treatment is one type of Ergo-physiology intervention. Ergo-physiology intervention is a model that combines improvement of work posture and physical physiotherapy in the form of stretching to reduce risk of back troubles [15]. Work posture improvement is intended to minimize the potential risk of LBP and physical training in the form of stretching is intended to strengthen and flexibilities muscles of the lower back i.e. the muscles that reflect the lumbo-sacral spine, especially abdominal muscles and maximus gluteus muscles; and stretch extensor groups in the lower back. Previous studies have shown that combined posture improvement and physiotherapy training can reduce the risk of work posture and LBP [15]. However, improvements to work posture and stretching that have been made need to be redesigned in accordance with task specifications and posture position as well as the level of complaints experienced by workers. At the same time, in order to obtain optimal results, to be needed active participation of workers and other stakeholders. In this study, workers and business owners were involved in the whole process from planning to implementation of interventions. Based on such deliberation, both workers and business owners agreed on the improvement of work posture and the provision of stretching simultaneously as the chosen intervention model to reduce the risk of work posture and LBP of brick workers.

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2. METHODS

This research was a quasi-experimental study using pre and post test design. A total of 19 males brick workers from the brick production business unit sample in Kupang City who met the eligibility criteria (i.e: perform manual handling tasks as part of their work activity, have history of low back pain within the last three months) participated in this experiment. They were determined as samples using purposive sampling technique. Selected intervention model, i.e: improving work posture and stretching treatment simultaneously was carried out three times a week for 5 weeks. There were 4 (four) stages to this process. The first: Retrieval of employee posture data during the stage of activity (i.e mixing materials, put the materials into the molds, carry out the brick and pull down it on place of drying) using video assistance, determined the angles of the worker's body parts and then it was calculated by REBA value for the relevant posture and LBP assessment were identified. The second, subjects were trained how to work with the ergonomic posture and stretching using the William flexion method. The third was implementation phase for 5 weeks, i.e: subjects worked with ergonomic posture and stretching under the supervision of tim. Stretching treatment was done before and after the activity for the duration of 30 minutes with a frequency of 3 (three) times a week. The last step is the assessment of work posture risk using REBA and LBP using the Oswestry questionnaire which was modified using a four-level scale (not painful, rather painful, painfull, and very painful). Five main activities were measured for LBP intensities namely lifting, standing, sitting, walking, social life and sleeping. Data before and after the intervention were analyzed using paired t-test with a significance level of 5%.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Subjects

The characteristics of the research subject were explained as follows, their mean age was 28.03 ± 7.25 years, classified as productive ages. Their mean height and weight were 159.44 ± 15.25 cm, and 51.18 ± 6.25 kg, respectively, and their mean body mass index was 20.05 ± 3.22 kg / m2. was in a normal nutritional status. The Subjects have a mean work experience as brick worker is 13.13 ± 6.45 years, classified as skilled workers. Most of the subjects (78.50%) had junior high school education.

3.2 Effect of Posture Improvement on Reduction of Work Posture Risk

Work posture is position of body parts when doing activities. Due to physical stress during activities, the body responds by forming certain postures [11],[16], [17]. Based on the agreement with workers and business owners, improvement of work posture was chosen as a form of intervention to reduce the risk level of work posture. Correction of work posture is intended to change and improve the position of worker's body parts when mixing materials, inserting mix into molds, carrying and laying bricks molds to be more natural than the initial condition. The main problem of these forms of activities, however, is not the heavy load on the muscle, but much more the wear and tear on the intervertebral disc. Results of analysis show difference in work posture scores before and after the intervention as shown in Figure 1.

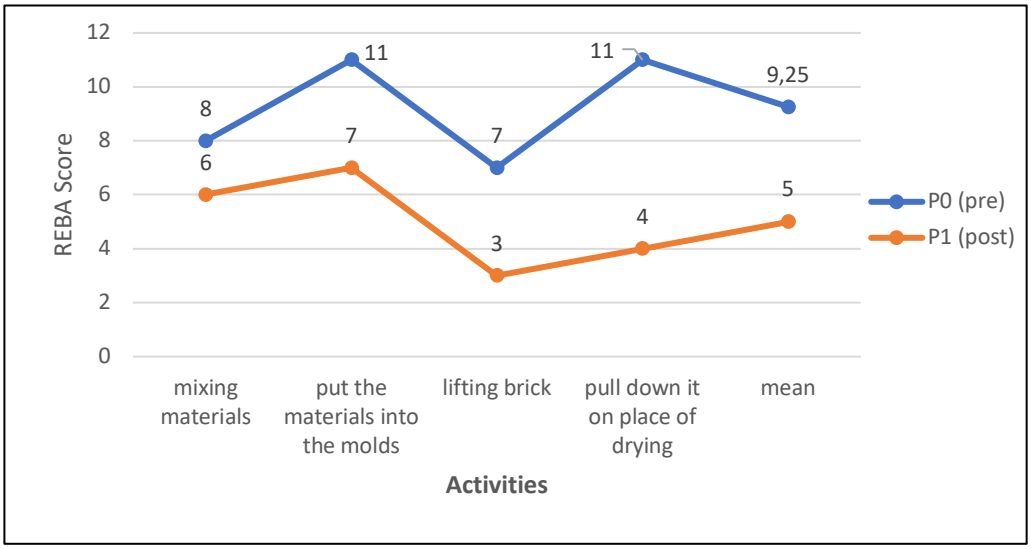

Figure 1. Risk Level of Work Posture Period P0 (pre) dan P1(post)

Results showed that in Period P0 the average work posture score was at 9.25 which is categorized as high level of risk [18]. This was due to working in a bent and squatting position. Such positions may help finish the task faster but typically requires more energy. A prolonged bending position can increase muscle tension and further effects cause fatigue and muscle aches more quickly [17], [19]. Back position when bending exceeded the normal elevation angle of 20⁰. The high elevation angle will increase the risk score. The highest score occurred in the sub-activity of inserting material into a mold and pressing, and carrying the printed bricks into a drying area with the score of 11, i.e. very high-risk level [18]. Working in a bent position can increase resting pulses and reduce work productivity [20]. To make matters worse, works do a lots of sideway turning (left or right, or toward the back) while bowing/bending. Working with this posture can increase lumbar lordosis and kyphosis in the upper back (thorax) [21]. The presence of back hyperextension and hyperflexion interferes with the nucleus pulposus on the Intervertebral discs, thereby increasing the risk of back injury [22].

After impovement of posture, the risk level of work posture decreased significantly ($p = 0.001$). Decrease of work posture risk was at the level 5.0 (medium level) or 45.95%. This reduced level of posture risk was greater than in a previous study which found a reduction of LBP in red soil excavation workers after ergo-physiological intervention by 34.56% [15]. Interventions with a participatory ergonomic approach can change the position of the body, especially the position of the back and neck so that it can perform activities in a more natural/ergonomic position. Results also presented a reduction in the bending motion of the back by 30^0-35^0 and neck flexion movements of 10^0-15^0 when carrying and placing printouts to the drying area. The greatest decrease in risk level occurred in the sub-activity of carrying printouts to the drying area which was 7 points or 63.64%, followed by the activity of bringing the printouts down by 4 points or 57.14%, and putting the material into the mold and pressing

by 4 points or 36.36%. Improved work posture characterized by a reduced level of risk of posture can reduce fatigue and musculoskeletal complaints [12], [15], [17].

3.3 Effect of Work Posture Improvement and Stretching Treatment on Decrease of LBP

Low Back Pain is a feeling of pain and discomfort that is localized in the lower back region i.e. below the last rib angle (costal margin) and above the lower buttocks (gluteal inferior fold) with or without pain in the legs [9], [22]. Based on the agreement with both workers and business owners stretching training was set as the chosen intervention model to reduce LBP. The effect of correcting work posture and stretching on LBP can be seen in Figure 2.

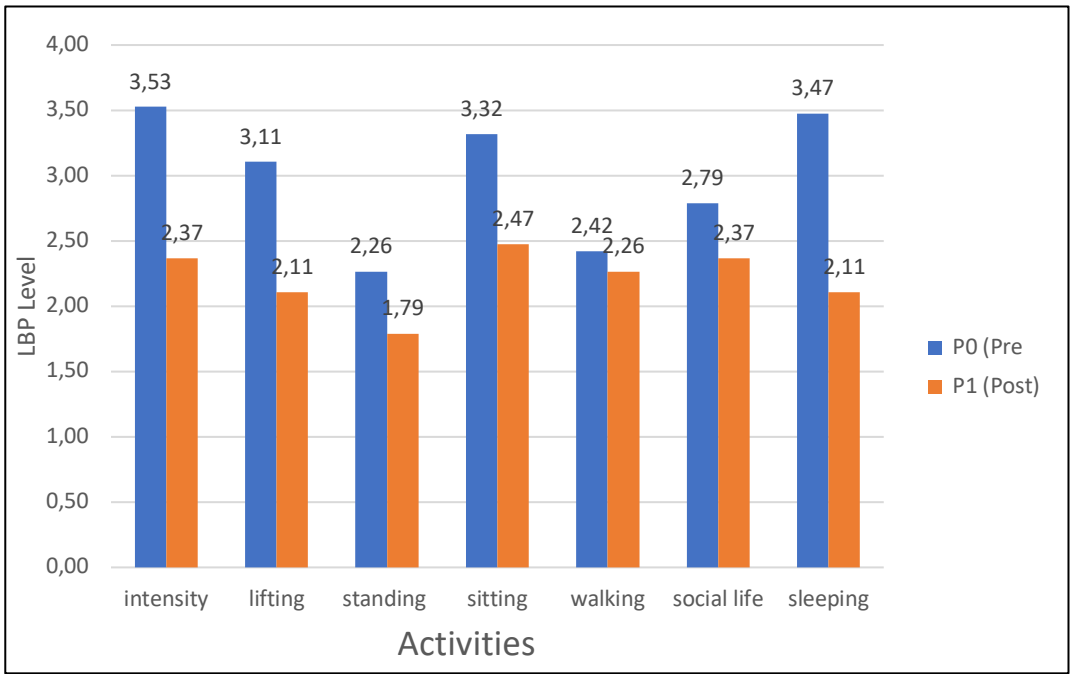

Figure 2. Difference in Intensity of LBP Before and After Intervention

The results showed that subjects had had a history of LBP before, and it classified as chronic pain. Chronic pain is a type of pain caused by a prolonged non-ergonomic way of work [22], [23] and lasts for a longer duration of 1-3 months or even more [7]. [16]. Measurements using the Oswestry questionnaire found that the average LBP intensity of was 3.35 (very painful) with a range of categories from mildly to very painful. LBP experienced by subjects is mostly related to lifting and moving materials manually with odd work positions [23], [24] - [27]. LBP intensity was felt when the workers performed activities such as lifting weights, standing, sitting, walking, doing social activities and sleeping. The pain intensity was felt to be higher when the subjects slept (sleeping activity) with the pain score of 3.47 (very painful), followed by sitting activity with score of 3.22 and lifting activity 3.11.

Analysis showed that work posture correction and stretching administration could significantly reduce LBP ($p = 0.02$). Decrease of LBP intensity after intervention was 2.54 or 28.05%. Decrease in the intensity of complaints also occurred when subjects performed lifting, standing, sitting, walking, doing social activities and sleeping. The highest decrease in LBP intensity occurred during sleep activity, i.e. 1.36 (39.19%), lifting activity i.e. 1.0 (32.15%), sitting activity i.e. 0.85 (23.29%) and the lowest during walking activity with the score of 0.18 (6.61%).

Simultaneous provision of posture improvement and stretching is an effort to eliminate the main causes of pain (casual) or relieve pain (symptomatic). Improvement of posture become neutral can reduce the compression load on the lower back when over-flexing and over-extending due to demanding tasks. Reducing the compression load will prevent excess pressure on the lumbar intervertebral disc including the nucleus pulposus and the annulus fibrosis and ligament that are the sources of pain [22], [28]. Correction of work posture to be more ergonomic can prevent the use of excessive muscle strength and muscle tension. Correcting posture by reducing the angle of back elevation when lifting or lowering the load can minimize low back pain [29], [30].

Stretching is effective in reducing LBP [15], [31], [32]. It can stretch the abdominal and back muscles so as to smooth the lymph system and circulation system, activate the parasympathetic system and will indirectly reduce stress level in the lower back region. Stretching exercises can reduce the impact of shock due to static load on the back [16], [30]. *William Flexion Exercise* adequately can increase the flexibility of lower back muscles which is characterized by increased joint motion in the lumbar region [31]. Improvement of range of motion in the lumbar will stimulate the Golgi tendon so that relaxation on related muscles occurs [32], [33]. Strength and

flexibility of the back muscles are increased so as to minimize pain and stress on the spine. Stretching can also improve the muscle pump which results in increase in blood circulation in the back-muscle tissue. Thus, supply of food and oxygen in the muscle tissue gets better and the pain caused by spasm will decrease [33] - [35]. Previous studies have also shown that conducting regular physiotherapy training in the form of stretching with the frequency of 3-5 times a week can reduce the risk of low back pain [15].

4. CONCLUSION

Imporvement of work posture and stretching treatment base-on participatory ergonomic could decrease the risk of work posture and LBP intensity on brick workers as compared to conditions before the intervention. The acquired reduction of work posture risk level is by 45.95% and LBP intensity by 28.05%. It is necessary to redesign equipment used in brick press especially the material mix and the pressing equipment so the decrease of posture risk level and LBP intensity more effectiveness.

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