

Work System Improvement for A Sugarcane Block Enterprise using 10 Physical Ergonomic Principles

Difana Meilani[#], Hilma Raimona Zadry[#], Dina Rahmayanti[#], Dendi Adi Saputra^{*}

[#] Department of Industrial Engineering, Faculty of Engineering, Universitas Andalas,
Kampus Limau Manis, Pauh, Padang 25163, West Sumatera, Indonesia
E-mail: difana.meilani@gmail.com, hilma@eng.unand.ac.id, rahmayantidina@gmail.com

^{*} Department of Mechanical Engineering, Faculty of Engineering, Universitas Andalas,
Kampus Limau Manis, Pauh, Padang 25163, West Sumatera, Indonesia
E-mail: dendiadisaputra05@gmail.com

Abstract—Nagari Bukik Batabuah is located in Agam, West Sumatra is one of the most significant regions, which produces sugarcane block named *saka*. Since the taste is lovely and delicious, the demand for it is high. Unfortunately, the processing of *saka* sugarcane was not supported by excellent facilities and infrastructure. This study analyses the *saka* workstations in Agam, West Sumatra and recommends some improvement to the working system. Ten physical ergonomic principles were applied in sugar mill workstation, boiling workstation, and *saka* molding workstation for improvement. It was found that all the workstations need to have more working facilities. In mining workstation, ergonomic chairs and stacks cane container was designed. Furthermore, an ergonomic cane-grinding machine was also proposed in the milling workstation. Meanwhile in the boiling workstation; cane stirrer, a small stool, and windows were designed. Gloves, lights, tools for changing the working facilities were also proposed to be used. A laying cane, a small stool, and *saka* pouring were designed for molding workstation.

Keywords— Work system; Sugarcane; Ergonomic; Small and Medium Enterprise.

I. INTRODUCTION

Small and Medium Enterprises (SMEs) still become the significant source of income for many people in the countryside [1]. Based on Indonesian Ministry of Cooperatives Small and Medium Enterprises, it is stated that the micro, small, and medium enterprises in Indonesia have contributed to the increase of the gross domestic product [2], [3]. However, most SMEs in Indonesia are generally traditional businesses that function traditionally in manufacture and marketing. Some previous study claimed that frequently difficulties encountered by SMEs are associated with the low labor productivity and skill, as well as the technological backwardness [4], [5]. Furthermore, the use of low process technology, lack of inventory system, secondary packaging of product compounded with marketing problems [6], [7]. Therefore, SMEs need particular attention in order to increase its role in supporting the country's economic growth [8].

Agriculture is a vital area that has the significant effect on the general public thus a program that can preserve its sustainability is necessary, mainly in term of productivity [9],

[10]. The business of sugarcane block called *saka* is one of the micro enterprises, which exist in Nagari Bukik Batabuah, Agam, West Sumatra, Indonesia. Agam is central to sugarcane planting and processing in West Sumatra with 8,274 tons/year sugarcane production from 4,053 hectares of land area [11]. Producing sugarcane block is the main livelihood of people here, which has been done by family farmers and lasts for generations. *Saka* produced in this area is famous for their incredibly sweet and delicious that is in high demand by consumers. Thus, these products are potential to be developed as one of the food and beverage industries, which can contribute to improving the economy of local communities in particular. The excellent potential unfortunately not yet fully supported by the facilities and infrastructure available in the production process of *saka*. *Saka* is produced in three stages starting from sugarcane milling, boiling, and molding process.

In this village, *saka* is produced in a traditional cabin, which is divided into two parts. The first cabin is the sugarcane milling workstation. It uses buffalo as the power of the machine. To get the sauce, the worker must smash the sugarcane first and then put it into the machine (Fig 1). Through Nordic Body Map (NBM) questionnaire, it is

shown that these workers feel pain in all parts of their body except the neck and left hand.



Fig. 1 Real condition of Milling Work Station

The second part is the boiling workstation and the molding workstation. In the boiling process, the workers use traditional firework, which consists of two significant iron works and 100 pieces of coconut shell for molding. Fig. 2 shows the boiling workstation.



Fig. 2 Real condition of Boiling Work Station

Since the traditional fire using sugarcane waste, the temperature in the workstation reaches approximately to 380C, and it raises between 14.00-14.30. This condition made the workers' sweater and exhausted, while the normal workstation temperature recommended by the Ministry of Health, Republic of Indonesia is around 26oC to 28oC [12]. It means that the temperature of the boiling workstation is over the setting. In addition, based on the NBM questionnaire, it is shown that the workers who stir the sugarcane sauce feel pain nearly in all part of the body except the top part of the neck.

In the molding workstation, the process is being done on a pile of waste sugarcane that is not being used, and it is arranged as a mat. The work position of the workers is sitting cross-legged makes the pain appears from the back until the leg. Coconut shell is used in the molding process. The workers pour sugarcane sauce, which has turned thick into the coconut shell, which is laid on the mat. There is no any particular place to arrange the saka tidily. Fig. 3 shows the real condition of the molding workstation and the workers' position.



Fig. 3 The real condition of Molding Work Station

A good work system will support the workers' physic. The improvement of the work system can be made by using the 10 physical ergonomics principles [13], as followed:

- a. Work in neutral postures. The posture provides a good starting point for evaluating the tasks that are done. The best position to work is by keeping the body "in neutral."
- b. Reduce excessive force. Excessive force on the joints can create a potentiality for fatigue and injury. In practical terms, the action item is to identify specific instances of excessive force and think of ways to make improvement
- c. Keep everything in easy reach. The next principle deals with keeping things, which can be reached easily. In many ways, this principle is redundant with posture, but it helps to evaluate a task from this specific perspective.
- d. Work at proper heights. Working at the right height is also a way to make things easier.
- e. Reduce excessive motion. The number of motions made throughout a day, whether with fingers, wrists, arms, or back.
- f. Minimize fatigue and static load. Holding the same position for a period is known as a static load. It creates fatigue and discomfort and can interfere with work.
- g. Minimize Pressure points. Excessive pressure points, sometimes called "contact stress."
- h. Provide clearance. Having enough clearance is a concept that is easy to relate.
- i. Move exercise, and stretch. The human body needs to be exercised and stretched in order to be healthy.
- j. Maintain a comfortable environment. This principle is more or less a catch-all that can mean different things depending upon the nature of the types of operations being done.

The purpose of this research is to analyze the *saka* workstations in Agam, West Sumatra. Another purpose is to recommend some improvement of the working system such as designing and adding more work facilities.

II. MATERIAL AND METHOD

A preliminary survey was conducted to observe the actual conditions of saka industry in Bukik Batabuah. Each work system was observed by using 10 physical ergonomics principles and NBM. The anthropometric data were also collected in order to design work facilities. Measuring was

done to workers in several positions such as sitting upright, sideways, and both hands outstretched. The data was also collected through measuring the dimension of the workstation, and the dimensions for all work equipment.

The data was processed by making work system checklist. Ten physical ergonomics principles are implemented for each workstation. It shows design and recommendation that are needed for improvement. The design was the result of the analysis in each principle. This design was performed using AutoCAD 2012.

III. RESULTS AND DISCUSSION

Ten physical ergonomics principle checklist is a tool that is used to determine the actual condition of the working system in saka industry to find out an improvement that is needed for increasing the productivity and efficiency of the working system. The checklist was also based on the result of the NBM, which was given to the workers in the preliminary survey. The work system checklist for milling, boiling, and molding workstation is shown in Appendices A, B, and C. The result of the checklist is the recommendation of the workstation design and the additional tools.

The facilities are designed based on the result of the checklist for each workstation. The design is also based on the anthropometric data of the workers. The milling workstation is the first workstation, which was observed. There is some improvement have to be made. The principles which are working in a neutral posture and reducing excessive force principle shows that the workers working gesture is not yet ergonomic. Workers still have to sit in cross-legged position and smashing the cane only with the right hand. This can also be seen from the NBM questionnaire results where the worker feels pain in all parts of the arm and right hand, waist, back, and entire legs.

Thus, one of the solutions is providing ergonomic sugarcane grinding machine, where the machine can indirectly improve the work gesture of the workers to stand. In addition, with this machine, the workers no longer need to do the job of hitting the cane, because the sugarcane will be directly inserted into the grinding machine. The engine height is adjusted to the waist height of the workers so that the workers can insert the cane easily.

Another designed facility is the sugarcane container. The purpose of the container is to arrange the sugarcane neatly before being milled and can facilitate the workers in working. The material for the sugarcane containers is *Meranti* wood. Fig. 4 shows the design of the sugarcane container. The bottom part of the sugar cane container is designed with a slope of 11° , which allows the cane to roll down and makes it easier for the workers in picking up the cane. The front part is given a cavity with a height of 7 cm; this size is obtained from the diameter of sugarcane, which is 5 cm, so, only one cane can roll through this cavity. Wood with a length of 7 cm will accommodate sugarcane after passing through the cavity. It is also given a retaining timber at the end of the container so that the sugarcane can be restrained and not fall. The sugarcane can be taken directly by the workers and put it into the grinding machine. When the workers pick up the sugarcane, then automatically the cane that accumulates behind it will fall one by one.

In the boiling workstations, there are some given recommendations and suggestions. The ideal operator's working posture is the neck and back in a straight line, and the legs are not bend based on the principle of work in a neutral posture and reduce excessive force. NBM questionnaire results show that the workers feel pain in all parts of their body except the upper neck. In addition to the use of the work equipment, the workers should use the work equipment in a comfortable state.



Fig. 4. Sugarcane Container

The recommendation is designing a stirrer and massive spoon tool, which is adapted to the height of the workers and the high of the stove, as well as the handgrip of the workers. The principle of maintaining a comfortable environment is that the physical environment of the sugarcane boiling workstation must be standard. From the observation, the temperature at this workstation is hot since the temperature reaches 380°C and humidity reaches 23% during the boiling process. Therefore, the recommendation is adding more work facility in the form of windows so that workers will not feel overheat or sweating while working. For the lighting variable, which has not reached the standard of 71 lux, the suggestion is to add lights on that workstation.

Furthermore, besides a sugarcane container, seats can also be used on sugarcane milling workstations. Seats are designed with considering to the worker's body dimensions. Chairs are designed using anthropometric variables of popliteal height, shoulder width, the height of backrest, and popliteal back operator. The material used for this chair is meranti wood. The recommendation is the workers work in a standing position, but the seat will still be placed in the workstation if the operator feels tired and want to rest for a moment. The height of the chair is 35 cm adjusted to the height of the popliteal operator, so the foot of the workers can still touch the ground while sitting on a chair. The height of the back of the chair is 44 cm, according to the back of the worker. The height of the seat is 50 cm, the length of the seat base is 43 cm, and the width is 41 cm.

From the actual condition of the saka molding workstation, it is seen that the work position of the workers is cross-legged sitting. Based on the principle of work in a neutral posture, the workers' leg and backbone are in an ideal position. Meanwhile, the result of NBM questionnaire is the workers feel pain at their back, waist, and all parts of legs. So it is recommended to design a chair, which can be adjusted with the workers' anthropometric.

The molding workstation is located at the back of the factory. Since the condition of the floor factory is not flat, a

small bench is recommended to help the work (Fig. 5). A small bench is designed for the molding workstation by using anthropometry variable, which are popliteal height, hip wide, and popliteal bottom of the operator. The type of the material that is used for this small bench is polyethylene. The height of the small bench is 20 cm, which the size is adjusted with 57.15% from the operator popliteal height, so the leg of the operator can still be bend while sitting. The length of the bench is 32.5 cm, and the width is 35 cm.



Fig. 5. Small bench

The coconut shell is placed in molding workstation in order to help the workers in molding the saka. The place is made from wood named miranti. Fig. 6 presents the place to put the coconut shell. The place for the coconut shell has the length of 76 cm x 76 cm. This measurement considers the workers' hand in reaching something in the front side, which is 80cm, so it will have left out 4 cm more. The size of each coconut shell to be placed is 8 cm x 8 cm. This measurement considers the length of the coconut shell, which is 11 cm, so it leaves 1.5 cm of the right, and left the side of the coconut shell place. This condition makes the coconut shell stand and can be quickly taken by the workers.



Fig. 6. Coconut Shell Place

The workers use the pouring saka spoon for pouring the saka into the coconut shell; then it is ready to be mold. The material of the spoon is polyethylene. It looks like a scoop that has a width of diameter 9 cm and has the depth of 5 cm. Fig. 7 shows the design of the pouring saka spoon. The last design is the workstation design layout for all of the workstations. The design shows in Fig. 8.



Fig. 7. Pouring Saka Spoon



Fig. 8. Recommendation Design of the Workstation

IV. CONCLUSIONS

The conclusions of this study are: the work system in *saka* manufacturing industry in Bukik Batabuah, Agam, West Sumatra still needs some improvement regarding ergonomics such as position and work attitude of the operator, work facilities, and also the physical work environment.

Recommendation for improvement for every workstation is: at the milling workstation, it was designed the ergonomic chair and the sugarcane container. Then, it was proposed the addition of work facilities in the form of ergonomic grinding machine; at the boiling workstation, it was designed the small stool and wood stirrer; at the molding workstation, it was designed the place for coconut shell and the pouring spoon; The study has also proposed the improved layout for each workstation.

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APPENDICES

Appendix A. Work System Checklist for Milling Work Station

No	Principle of Ergonomic	Specific Rule	Yes	No	Actual Condition	Recommendation	Suggestion
1	Work in neutral posture	Operator`s leg is on the ideal position		√	Operator work in cross-leg sitting condition	The operator should be comfortable in doing their work	Provide an ergonomic sugarcane milling machine and proposed a layout to correctly placed the machine
		Operator`s neck in straight position		√	Operator`s neck is bend while beating the sugarcane		
		Operator`s shoulders and wrists in relax the condition		√	Operator repetitively beats the sugarcane using a 2 kg beating tools in 5 hours		
		Operator`s left and right hands are working in balance		√	Operator use a 2 kg beating tool	The operator should use an ergonomic sugarcane milling machine	
2	Reduce Excessive Force	Operator`s left and right hands are working in balance		√	Operator use a 2 kg beating tool	The operator should use an ergonomic sugarcane milling machine	
3	Keep Everything in Easy Reach	Ready-To-Mill sugarcane is placed within reach	√		Ready-To-Mill sugarcane is placed near operator but staked up.	Designing a sugarcane container and placed near the operator	The sugarcane container should be designed according to the operator`s anthropometry
4	Work at Proper High	Sugarcane milling machine is not too high or too low	√		Sugarcane milling machine is at a proper height	The operator should use an ergonomic sugarcane milling machine	The machine should be placed at the proper height by considering the anthropometry of the operator in order for the operator to be able to work in a standing position without bending himself/herself too much
		The height of the sugarcane`s stake is not too high and not too low either		√	The sugarcane is messily staked as high as the operator`s head	Designing a container to stack the sugarcane	The design of the container should consider the operator`s anthropometry covering several variables such as reach and height of waist in order for the operator can be able to work comfortably in standing position without bending himself/herself too much
5	Reduce Excessive Motion	The beating process should be done in the most minimum time		√	The beating process is done repetitively for 5 hours	The operator should use an ergonomic sugarcane milling machine	Provide an ergonomic sugarcane milling machine, which also eliminates the beating process because operator just have to put the sugarcane stem into the machine
6	Minimize Fatigue and Static Local	Operator work in standing or sitting position in a short period		√	Operator work in sitting position for 5 hours and stands up once in a while	A designing chair that can be used by the operator to take a rest	The design of the chair must be appropriate to the operator`s anthropometry
		The beating process should be done in the most minimum time		√	The beating process is done repetitively for 5 hours	The operator should use an ergonomic sugarcane milling machine	Provide an ergonomic sugarcane milling machine, which also eliminates the beating process because operator just have to put the sugarcane stem into the

7	Minimize Pressure Point	The beating process should be done in the most minimum time		√	The beating process is done repetitively for 5 hours	The operator should use an ergonomic sugarcane milling machine	machine
8	Provide Clearance	Have a working flexibility	√		The workspace is in excellent condition, and wide enough for the operator to be working comfortably.	Workspace design which takes clearance for the operator and space between operators along with the space for staking the ready-to-mill sugarcane	
9	Move Exercise, and Stretch	The operator can work in both standing or sitting position	√		The operator is working in a standing position during the beating process, and standing once in a while to gather up the sugarcane to be put into the machine	A designing chair that can be used by the operator to take a rest	The design of the chair must be appropriate to the operator's anthropometry
		Operator have a well understanding about how to use the machine and how to make him/herself comfortable during working		√	The operator still working against the rule of ergonomic	Provide counseling on how to use the machine correctly and how is the excellent work posture in order to improve the operator's understanding in how to make themselves comfortable at work along with minimizing the possibility of accident happened	
10	Maintain a Comfortable Environment	Standard temperature (18-30°C)	√		Room temperature around 29°C	The physical environment of the sugarcane milling work area is already fulfilling the standard and doesn't need further improvements or suggestion	
		Standard lighting (>= 100 lux)	√		Lighting around 1916,7 lux		

Appendix B. Work System Checklist for Boiling Work Station

No	Principle of Ergonomic	Specific Rule	Yes	No	Actual Condition	Recommendation	Suggestion
1	Work in neutral posture	Operator's leg is on the ideal position		√	Operator stir the sugarcane in a squat position	The operator should use supporting tools and work in a sitting position	Designing a small chair for the operator to work in an ideal position
		Operator's spine is on the ideal position		√	Operator move the sugarcane from the 1st heating pot to the 2nd one in bending position		
		Operator's neck in relax position		√	Operator's neck is bent to move the sugarcane from the 1st heating pot to the 2nd one		
		Operator's shoulders and wrists in relax the condition		√	Operator stirs the sugarcane for 15 minutes.		
2	Reduce Excessive Force	An ergonomic design of the mixer		√	The current mixer used is in a cylinder shapes, 138 cm long and 4 cm in diameter	A mixer design that can be used in a standing position and compatible with operator's anthropometry	Designing a mixer based on operator height, heating pot, and using the operator's anthropometry data
		An ideal condition of operator's hand on gripping the mixer	√		The current mixer diameter is 4 cm	Mixer diameter that compatible with operator's grip	Designing a mixer which diameter is compatible with operator
3	Keep Everything in Easy Reach	Work facilities and supporting tools used is placed near the operator	√		The work facilities are messily hung on the ceiling, and It is within the operator's reach	Arranging the supporting tools placement in order to make it neat and comfortable to find	Recommend a hanger to hang the supporting tools
4	Work at Proper High	Operator's shoulder should not be rise to height or spin too much while stirring		√	Operator stirs the sugarcane in fast circular motion for 15 minutes	Operator's shoulder should not rise too high, and not spinning	Provide counseling regarding the correct way to use the supporting tools in order to avoid or minimize accident
		The mixer height is compatible with operator's height	√		It is already in a proper height, but operator work in a squat position	Design of the mixer which can be used in squad position compatible with operator's height	Designing a mixer based on operator height, heating pot, and using the operator's anthropometry data
5	Reduce Excessive Motion	Stirring the sugarcane in relax the condition		√	Operator stir the sugarcane in a squat position		
6	Minimize Fatigue and Static Local	There should be no pressure on the operator's leg during the work		√	Operator stir the sugarcane in a squat position	A designing chair that can be used while stirring the sugarcane	The design of the chair must be appropriate to the operator's anthropometry

7	Minimize Pressure Point	The operator used a glove during the work		√	The operator did not use a glove during work	Provide gloves for operators to use while stirring	
8	Provide Clearance	Workspace design that appropriate and giving clearance for the operator to move		√	A narrow workstation with an uneven floor	Designing workspace by considering the distance between operator and heating, while the operator is sitting above the small chair while stirring the sugarcane	
9	Move Exercise, and Stretch	The operator can work in comfortable		√		A designing chair that can be used by the operator to take a rest	The design of the chair must be appropriate to the operator's anthropometry
10	Maintain a Comfortable Environment	Standard temperature (18-30°C)		√	Room temperature around 38°C	Recommend the additional windows	
		Standard humidity (65%-95%)		√	Humidity around 23%		
		Standard lighting (>= 100 lux)		√	Lighting around 71 lux	Recommend the additional lamp to light the operator during work	

Appendix C. Work System Checklist for Saka Molding Work Station

No	Principle of Ergonomic	Specific Rule	Yes	No	Actual Condition	Recommendation	Suggestion
1	Work in neutral posture	Operator's leg is on the ideal position		√	Operator stir the sugar cane in a squat position	The operator should use supporting tools and work in a sitting position	Designing a small chair for the operator to work in an ideal position
		Operator's spine is on the ideal position		√	Operator move the sugar cane from the 1st heating pot to the 2nd one in bending position		
		Operator's neck in relax position		√	Operator's neck is bent to move the sugar cane from the 1st heating pot to the 2nd one		
		Operator's shoulders and wrists in relax the condition		√	Operator stirs the sugar cane for 15 minutes.		
2	Reduce Excessive Force	An ergonomic design of the mixer		√	The current mixer used is in a cylinder shapes, 138 cm long and 4 cm in diameter	A mixer design that can be used in a standing position and compatible with operator's anthropometry	Designing a mixer based on operator height, heating pot, and using the operator's anthropometry data
		An ideal condition of operator's hand on gripping the mixer	√		The current mixer diameter is 4 cm	Mixer diameter that compatible with operator's grip	Designing a mixer which diameter is compatible with operator
3	Keep Everything in Easy Reach	Work facilities and supporting tools used is placed near the operator	√		The work facilities are messily hung on the ceiling, and it is within the operator's reach	Arranging the supporting tools placement in order to make it neat and comfortable to find	Recommend a hanger to hang the supporting tools
4	Work at Proper High	Operator's shoulder should not be rise to height or spin too much while stirring		√	Operator stirs the sugar cane in fast circular motion for 15 minutes	Operator's shoulder should not rise too high, and not spinning	Provide counseling regarding the correct way to use the supporting tools in order to avoid or minimize accident
		The mixer height is compatible with operator's height	√		It is already in a proper height, but operator work in a squat position	Design of the mixer which can be used in squad position compatible with operator's height	Designing a mixer based on operator height, heating pot, and using the operator's anthropometry data
5	Reduce Excessive Motion	Stirring the sugar cane in relax the condition		√	Operator stir the sugar cane in a squat position		
6	Minimize Fatigue and Static Local	There should be no pressure on the operator's leg during the work		√	Operator stir the sugar cane in a squat position	A designing chair that can be used while stirring the sugar cane	The design of the chair must be appropriate to the operator's anthropometry
7	Minimize Pressure Point	The operator used a glove during the work		√	The operator did not use a glove during work	Provide gloves for operators to use while stirring	
8	Provide Clearance	Workspace design that appropriate and giving clearance for the operator to move		√	A narrow workstation with an uneven floor	Designing workspace by considering the distance between operator and heating, while the operator is sitting above the small chair while stirring the sugar cane	
9	Move Exercise, and Stretch	The operator can work in comfortable		√		A designing chair that can be used by the operator to take a rest	The design of the chair must be appropriate to the operator's

No	Principle of Ergonomic	Specific Rule	Yes	No	Actual Condition	Recommendation	Suggestion
							anthropometry
10	Maintain a Comfortable Environment	Standard temperature (18-30°C)		√	Room temperature around 38°C	Recommend the additional windows	
		Standard humidity (65%-95%)		√	Humidity around 23%		
		Standard lighting (>= 100 lux)		√	Lighting around 71 lux	Recommend the additional lamp to light the operator during work	