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Analysis and improvement of working methods to increase productivity (case study: float glass collecting process)

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Abstract. One of the most demanded products from glass manufacturers is 2mm float glass size 48x20cm. In its packaging process, the time required to collect and pack the glass is generally longer than the speed of its production. To balance the productivity, companies ended up increasing the number of operators to collect and pack the glass. By applying time study and motion study, this research examines operators' activity to discover the most effective working method of glass collecting. Improving the working method is done by optimizing the working element that takes the longest time to finish and eliminating working element that contains non-value movement. Particularly, the improvement attempts include changing the positioning of the paper layer and the counter to the front of the operators. With the new positioning, operators' trajectories can be shortened. When implemented, this refined method has successfully reduced operators' working time from 15.64 seconds to 12.27 seconds. The decrease of working time by 3.07 seconds has also effectively reduced the number of operators by 5 people, specifically from 23 to 18 operators. Keywords: Working element, time measurement, movement analysis, refinement of working method

1. Introduction

Glass material has been essential in fulfilling people's needs. The rapid growth of property sector has increased the needs of glass material usage [1], which results in the inflating demands of glass. As glass manufacturers keep working on providing customers' needs, there is one particular product that is generally higher in demand compared to the other, namely 2mm float glass or FL 2.2mm float glass comes in several sizes, including size 44x36 cm, 48x20 cm, 48x24 cm, 48x34 cm, 50x30 cm, and 50x20 cm. From all the sizes available, the one with the shortest cycle of production or "glass cycle time" is size 48x20 cm. Unfortunately, the fast production of size 48x20 cm glass is not compensated by the speed of glass collecting done by the operators. Compared to other sizes, the collecting FL 2 size 48x20 cm glass takes longer time despite the fact that the particular size being the smallest one. Longer time to collect the glass has caused the need to increase the number of operators, so that manufacturers can achieve the production target. Meanwhile, adding more employers would rise the cost of production. Other than that, companies are also required to allocate more budget to train them. Therefore, improving the efficiency of the working process becomes crucial. One of the steps to enhance the productivity is by determining the maximum number of operators, which will reduce companies' expense in operational sector in the production process [2]. Improving productivity can also be done by reducing the standard



time of working element. Refining the working method is necessary in order to reduce the time cycle to collect glass. Rearranging operators' working trajectories and reducing the moving distance of materials can also boost productivity [3]. Therefore, this research aims to improve the glass collecting method. Firstly, the chain of activities in collecting glass type FL 2 size 48x20 cm is being classified into several working elements. The time required to finish each working element is measured throughout the process using the stopwatch [4]. Working element that takes the longest time is to be examined in detail based on "therblig" or elemental motions in order to be improved later on. Time measurement is applied on regular workers with average skills. Next, refining the method is done by shortening or eliminating motions that inflict longer time in glass collecting process. Reduction of the pick-up time cycle will decrease the number of pick-up men.

2. Research Method

This study aims to discover the best refinement method to improve the work of glass collecting. This section will explain the whole elements being improved, suggestions, working method enhancement, and implementation.

The data for this research includes the working element and the time of each working element. The working element from the process of glass collection is obtained based on field observation and interview with operators. The activity of glass collecting is explained in 8 motions in detail. The elements are taking the glass, bringing the glass, putting the glass, tidying up the glass, pushing the counter, taking the paper layer, and waiting. Each element is measured based on its working time. Stopwatch is being used to measure the time, and the total time measurement in 30 times.

There are three types of data examination, namely data sufficiency test, uniformity test, and normality test.

Data sufficiency test is implemented to understand whether the collected data is representative enough or not. If the result of the count shows the data have not met the minimum criteria, thus data collection will be done again until it reaches the minimum needs for observation. The total minimum data needed for counting based on the following formula [1]:

$$N' = \left[\frac{k \sqrt{N \sum Xi^2 - (\sum Xi)^2}}{\sum Xi} \right]^2 \dots\dots\dots (1)$$

with: N' : Total observation required
 k : Confidence level X_i : Time data
 s : Accuracy level N : Total observed

This data sufficiency test uses 95% confidence level. Meanwhile, accuracy level being used is at 10%. The result of this calculation can be found in Table 1.

As seen as Table 1, N' value in every working element is smaller than N value, which can be concluded that the time data in every element represents sufficient data to be analyzed further.

After that, normality test is implemented. Normality test is applied by using *Kolmogorov-Smirnov* method with the help of *software Minitab 16.0 for Windows*. This research uses confidence level at 95%. Therefore, this normality test uses comparative significance (α) = 0,05 for every working element.

If p -value is the result of a higher calculation from comparative significance α , then hypothesis. H_0 is accepted, specifically the normally distributed data.

3. Results and Discussion

3.1. Results of Sufficiency, Normality Test Calculation on Working Elements

Table 1. Results of Sufficiency, Normality Test Calculation on Working Elements

No.	Working Element	Mean	Standard deviation	P-value	Mean	UCL	LCL	N' N=30	Information
1	Taking the glass	1,175	0,1532	0,150	1,1753	1,6319	0,7188	6,3067	*
2	Bringing the glass	2,015	0,2333	0,150	2,0150	2,5990	0,4310	4,9077	*

No.	Working Element	Mean	Standard deviation	P-value	Mean	UCL	LCL	N' N=30	Information
3	Putting the glass	1,390	0,1890	0,150	1,3897	1,8526	0,9267	6,8702	*
4	Tidying up the glass	1,757	0,1880	0,150	1,7567	2,1720	1,3414	4,2528	*
5	Pushing counters	1,237	0,1425	0,125	1,2370	1,6028	0,8712	4,9293	*
6	Taking papers	2,954	0,3528	0,150	2,9543	4,0187	1,8899	5,2960	*
7	Spinning the body	1,601	0,1867	0,150	1,6007	2,0976	1,1038	5,0508	*
8	Waiting	1,306	0,1290	0,127	1,3057	1,6990	0,9124	4,3540	*

* Normal/ Uniformed and Sufficient data

Based on Table 1 above, each working element has *p-value* which is bigger than $\alpha = 0,05$, which means the time data of each working element is normally distributed. The last data test is uniformity test. Uniformity test aims to test whether the data is homogenous. A data can be called uniformed if they are within the control limit. There are two types of control limit, namely Upper Control Limit (UCL) and Lower Control Limit (LCL).

Based on the calculation of control chart, each time data of working element is within the upper control limit and lower control limit. Therefore, the time data of each element is already uniformed.

3.2 Calculation of Standard Time

The following is the steps of doing calculation of standard time.

- 1) Count the time cycle, the mean of finishing time during measurement [4]:

$$W_s = \frac{\sum X_i}{N} \dots\dots\dots (2)$$

with W_s : Time cycle X_i : Acquired time data N : Total data acquired

- 2) Count the normal time ^[4]

$$W_n = W_s \times P \dots\dots\dots (3)$$

with W_n : Normal time W_s : Time cycle P : Adjustment factor

- 3) Count the standard time

$$W_b = W_n (1 + Allowance) \dots\dots\dots (4)$$

with W_b : Standard time W_n : Normal time

Based on the formula above, adjustment and allowance factors are counted first before counting the standard time. Adjustment is determined by Westinghouse method. The calculation of adjustment factor in the collecting glass activity based on observation as follows skill good (+0,03), Effort good(+0,02), working environment fair (-0.03), Consistensy good(+0,01), total 0.03

Meanwhile, allowance factor in glass collecting process based on the condition 6% Low required energy, 1% bending working habit, 0% normal working movement. 0% good lighting, 0% high temperature, 0% good atmosphere, 0% normal environment condition, 1% personal needs (male), 5% inevitable hindrance, total 13%.

Calculation of cycle, normal time, and standard time of each working element is shown in Table 2 below:

Tabel 2. Results of Cycle Time, Normal Time, and Standard Time Calculation

No.	Element	Cycle Time (secs)	Normal Time (secs)	Standard Time (secs)
		W_s	$W_n = W_s \times P$	$W_b = W_n(1+Allowance)$
1	Taking the glass	1.1753	1.2106	1.3679
2	Bringing the glass	2.0150	2.0755	2.3453
3	Putting the glass	1.3897	1.4314	1.6175
4	Tidying up the glass	1.7567	1.8094	2.0446

No.	Element	Cycle Time (secs)	Normal Time (secs)	Standard Time (secs)
		Ws	Wn =Ws X P	Wb= Wn(1+Allowance)
5	Pushing counters	1.2370	1.2741	1.4397
6	Taking papers	2.9543	3.0429	3.4385
7	Spinning the body	1.6007	1.6487	1.8631
8	Waiting	1.3057	1.3449	1.5197
Time in Total		13.4344	13.8374	15.6363

P=1.03 Allowance = 0,13

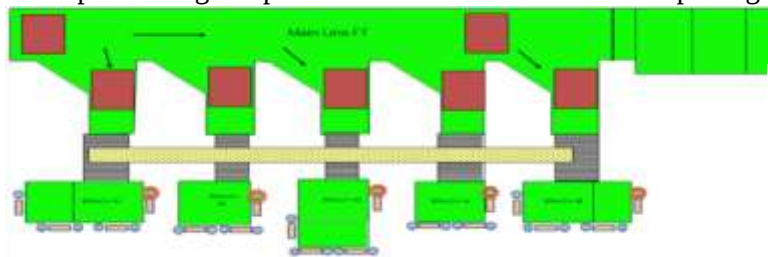
Based on the calculations in Table 5, an operator needs 15.64 seconds to take a glass. The calculation of total operators is as follows:

Production capacity = 3.802.050 glass/month = 126.735 glass/day

Working hours = 24 hours/day Speed of pick-up operator = 15.64 secs/glass

Total operators needed = $\frac{126.735 \text{ glass/day} \times 15.64 \text{ secs/glass}}{24 \times 3600 \text{ seconds}} = 22,94 \approx 23 \text{ operators}$

In the production process of 2mm float glass size 48x20 cm, glass is distributed to five branches. Thus, pick-up operators need to be positioned in the five branches. From total 23 operators, 5 of them should be placed in each of the three branches, namely branch 1, branch 2, branch 3. Next, 4 operators each is positioned in branch 2 and branch 4. Distributors are also placed in each branches. Illustration of the positioning of operators and distributors can in the packaging area can be found in Figure 1.



Information :

- 😊 : Pick up operator 3 branches need 5 people each and 2 branches need 4 people each
- 😬 : Distributor

Packaging Working Area

Distributors and pick-up operators work together. Operators can take the glasses transferred by the distributors. Analysis towards the operators' and distributors' job can be implemented by using Group Flow Chart. Analysis of working time from each working group is branch 1,3, 5 need for 5 Operator cycle time 15,64 minutes, And branch 2,4 need for 4 operator cycle time 14,12 minutes operating time 14,12. There is still waiting time when operators are working. Waiting time is an unproductive activity that results in nothing, and therefore it can be eliminated. Table 2 shows that working element that has the longest working element is taking the paper as the location of paper layer is placed on pallet. Operators need to bend their bodies or step up to take the layer which increase operators' moving distance and increase time required to do the job. The activity operators working area it is shown how paper layer and counter position is placed behind the operator. As a result, operators need to turn their body first in order to push the counter. The clear layout of operators' working area can be seen in Figure 5.

As a result, improvement can be done specifically on the working method of taking the paper and pushing the counter. Improvement is implemented in order to reduce non-value body movement. By reducing non-value movement, the standard time of work can be shortened so that operators can work faster. If they can work fast, then the number of workers can be reduced.

Improvement can be done by changing the position of paper container and counter. Placing paper position near the counter will minimize operators' distance when they have to push the counter and take the paper. Therefore, after pushing the counter they do not need to go back and reach the paper. The position of paper and counter being moved close to each other also so that operators will not need to turn their body. As a result, trajectories are shorter which will also shorten the working time of the operators.

The container of the paper layer is designed using a hand lift which is no longer used. The bottom part of the hand lift is put inside the pallet hole (as if we are trying to lift up the pallet). Hand lift is modified so that the paper layers can lean on top of it. Other than that, the positioning of the counter is also placed near the paper layer. The counter is put in the right corner of the paper later. The design of the paper layer and counter can be seen in Figure 2 and Figure 3. In addition, operators' working area layout after improvement can be seen in Figure 6.

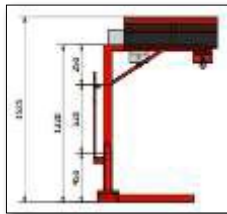


Figure 2(a)

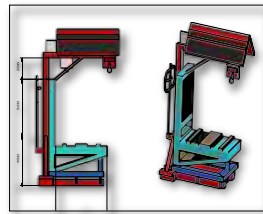


Figure 2(b)



Figure 3

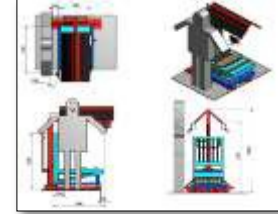


Figure 4

Figure 2(a). Modified hand lift

Figure 3 Design of Paper Layer Placement and Counter

Figure 2(b). Hand lift and Pallet

Figure 4. Operators' Working Area Layout after Improvement

After positioning of paper layer and counter is improved, the distance between the counter and the paper has become shorter than before. Distance to the counter is reduced by 10 cm, from 20 cm to 10 cm. In addition, distance of paper layer is reduced by 13 cm, from 38 cm to 25 cm. The design is then to be implemented in the branches with 5 operators and branches with 4 operators. The activity of taking the paper and pushing the counter can be seen in Figure 6.

This implementation is intended to figure out whether the arrangement of the new design really help in reducing the standard time based on the design. Therefore, operators' working time is being measured one more time. The standard time will be calculated based on the working time that has passed data sufficiency test, normality test, and uniformity test.



Figure (5)



Figure (6a)



Figure (6b)

Figure 5. Pick-up Operators Working Area

Figure 6(a). Taking the paper

Figure 6(b). Pushing the counter

After the improvement, the amount of time needed to take the paper is 1.95 seconds, while the time it takes to push the counter is 1.08 seconds. The comparison of working time between the prior condition and the condition after new arrangement. After the improvement, the standard time of one working cycle becomes 12.27 seconds, which is 3.07 seconds or 19.23% faster than before. Reduced standard time results in less workers needed for the job, specifically 5 less people needed to do the job which results in total 18 operators. These 18 operators will be divided into branches, with two alternatives of division. The first alternative is with 4 operators in branch 1, 3, and 5, meanwhile 3 operators in branch 2 and 4. The second alternative is assigning 5 operators in branch 1 and 3, meanwhile 4 people is placed in branch 2 and 4. To find out the best alternative, this research uses Group Flow Chart method, elaborated in Table 3.

Table 3. Analysis of Alternative1&2

	Branch	Operator	Time (seconds)			
			Cycle Time	Operator Time	Distributor Time	Waiting Time
Al	1, 3, 5	4 people	12,51	12,27	12,51	Operator: 0,26
	2, 4	3 people	12,51	12,27	9,38	Distributor: 1,608
Alt	1, 3	5 people	15,64	12,27	15,64	Operator: 3,37
	2, 4	4 people	15,64	12,27	12,51	Distributor: 0,24

Based on Table 3, it can be found that Alternative 1 results in less waiting time compared to Alternative 2. Therefore, Alternative 1 becomes the chosen design to be applied in the company, specifically by assigning 4 people in branch 1, 3, and 5, while also placing 3 operators in branch 2 and 4 Working area illustration with 4 operators and 3 operators after the improvement.

4. Conclusion

The process of collecting glass takes a long time because the placement of paper layer is far from the operators, and the positioning of the counter is put behind the operator. The solution to reduce cycle time to take the glass is by refining the working method. Improvement is done by designing a new place for the paper layer by using a modified hand lift. With the design, the positioning of the paper is right in front of the operator and the positioning of the counter is near the paper layer. After implementing the improvement, the working element of the operators has reduced. The time to take the paper decreases from 3.44 seconds to 1.96 seconds. The time to push the counter also decreases from 1.44 seconds to 1.08 seconds. Therefore, the arrangement has improved working efficiency by 19.23% or (3.07 seconds), specifically from 15.64 seconds to 12.27 seconds. The reduction of time results in the reduction in the number of operators from 23 people to 18 people.

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