Improvement Analyst of Two Tube Washing Machines Production using Line Balancing Method at PT. PMI

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Abstract. Currently, PT PMI produce Twin Tub Washing Machine with production time is 8 hours for 1 shift with normal time at 480 minutes. By 2021 the demand for Twin Tub Washing Machine products increased by 9% than 2020 with highest production capacity of 942 units per day. The production line at PT PMI consists of 22 work stations, with the longest cycle time is Motor Assy with 55 seconds and material movement between work station to uses a roller conveyor or manually. This research aims to analyse total cycle time and increase line efficiency in the production line using line balancing method. The total cycle time to make one unit Washing Machine before and after improvement is 657 and 642 seconds. Line balancing method will increase efficiency in the production line such as improving work methods and work stasion tools to reducing cycle time, also by reducing and moving work operations. By implementing this improvement activities will increase of line efficiency from 54% to 82%, Balance Delay reduced from 46% to 18%, Smoothing Index reduced from 33 to 17, and production capacity increased by 90%, from 508 to 963 units per day with an efficiency target of 97%.
Keywords: Line Efficiency, Production Capacity, Line Balance, Cycle Time, Production Line, Improvement Activities.

6. INTRODUCTION

One of Indonesian manufacturing industry companies in electronics field is PT. Panasonic Manufacturing Indonesia. One of its business units is a 2 Tube Washing Machine. Production time is 8 hours for 1 shift starting from 07.00 to 16.00, with normal production time of 480 minutes and number of employees is 96 people. The people of Indonesia and several Asian countries still use a lot of 2-tube washing machines for the reason that the price of washing machines is cheaper, washing and drying can be done at the same time, washing is cleaner, saving water, easier to use, and also easy to maintain. Demand for 2 tube washing machine products at PT. PMI has increased in the 2021 fiscal year, experiencing an increase of 9% from the 2020 fiscal year, the company targets sales of 2 Tube washing machines to reach 210,200 units. Companies need to know their production capabilities or capacities to achieve the target in the 2021 fiscal year. The company needs to make improvements in production line by carrying out line balancing to overcome line imbalance and low capacity. Line balancing is balancing the assignment of work elements from an assembly line to a work station to minimize total idle time price at all work stations for a certain level of output (Boysen et al, 2007) which in balancing this task, time requirement per product units specified for each task and sequential relationships must be considered, so as to obtain a smooth production flow in order to obtain high utilization of facilities, labour and equipment [1]. Based on field observations on April 1, 2021 at PT. PMI, the production line consists of 22 work stations. The mechanism for moving material from one work station to another works using a roller conveyor or manually. The production line layout can be seen in Figure 1.

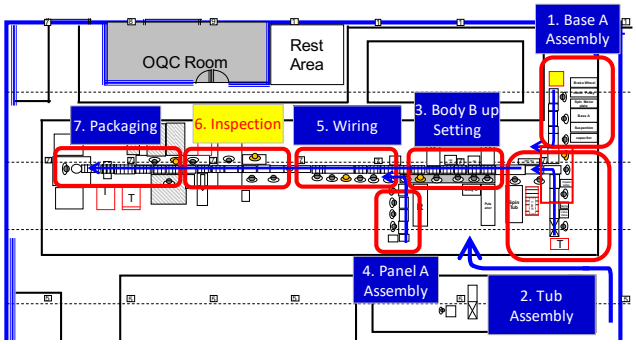

Figure 1 Production Line Layout
Source: Production Department of PT. PMI

The work station that has the longest cycle time is the Motor Assy work station with the amount of time needed to process each cycle for 55 seconds. Meanwhile, the fastest cycle time was at the Specification Plate Setting work station, which was 22 seconds. Because the longest process cycle time is 55 seconds, the production speed to produce 1 unit of product is 55 seconds. The cycle time at each work station can be seen in Figure 2.

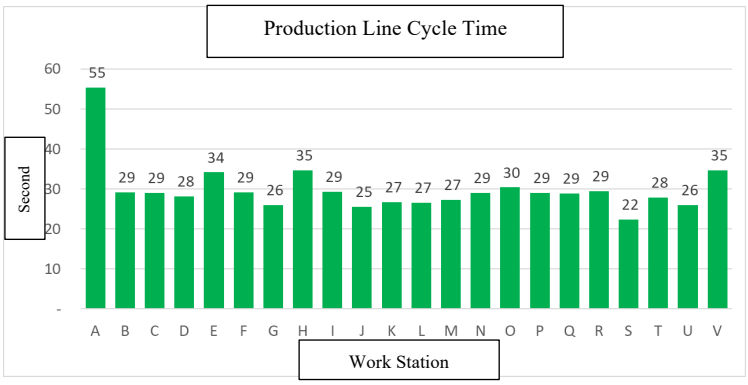

Figure 2 Production Line Cycle Time
Source: Production Department of PT. PMI

Appendix:

A:	*Motor Assy*	F:	*Mechacase Setting*	L:	*OTC Setting*	Q:	*Switch Cover Setting*
B:	*Base A Assy 1*	G:	*Tub A Setting 1*	M:	*Spinnerlid Setting*	R:	*Panel A Assy*
C:	*Base A Assy 2*	H:	*Tub A Setting 2*	N:	*Safety Switch Setting*	S:	*Spec.Plate Setting*
D:	*Capacitor Setting*	I:	*Spintub Setting*	O:	*Panel A Setting*	T:	*Wiring 1*
E:	*OTB Setting*	J:	*Pulsator Setting*	P:	*Switch Cover Assy 1*	U:	*Wiring 2*
						V:	*Connector Setting*

From the data presented in Figure 2, the difference in time between the longest cycle time and the fastest cycle time is obtained for 33 seconds, resulting in an unbalanced work process and causing idle activity at some work stations, while other work stations continue to work full. The target tack time for each work station is 33.97 seconds. This is caused by the time needed by a work station to complete work faster than the predetermined trajectory speed. The track speed is determined from the level of capacity, demand, and the longest operating time (Kusuma, 2007) [2]. Based on problem occurrence, Analysis will be carried out by repairing all activities to increase line efficiency using line balancing method so that in the end PT PMI can fulfil customer requests and implement line balance improvements on the production line.

Research Purposes and Limitations

Based on data and description the problem that has been stated from figure 1 and figure 2, it necessary for company to improve line efficiency by using the *line balancing* method on the production line for

‘2 tube washing machine’ products through escalate improvements in production line. There is also several limitations when conducting this research, which is: (1) This research was conducted at the work station section of the production line of PT. The PMI for the 2-tube washing machine is the 7kg model.
(2) Estimated consumer demand data will be used as a reference in determining production starting from April 2021 – June 2021. (3) The cycle time used in this study was taken through direct measurement using a *stopwatch* [3]. (4) Assuming every worker at every work station has the same skills and there is no damage to the machine. (5) The discussion only focuses on improving work processes, which consist of process flow, workload, and working hours on the production line.

2. METHODS

This research was conducted at PT. PMI with the aim of increasing line efficiency with the line balancing method and implementing improvement ideas in the production line. **Data Collection** include: A. work operation to Identify work operations at each work station, B. Number of workstations and operators, C. Current production layout, D. Operation cycle time; Observations were made by measuring the time directly using a stopwatch 20 times, E. Line cycle time, F. Available capacity from April 2021 – March 2022, G. The amount of production or production output.

Data Processing include: A. Calculate the current line efficiency, B. Cycle time and number of work stations needed for production activities in April 2021 – March 2022, C. Improvements were made to work methods, layout and to the tools used, D. Cycle time of each work station after repair, E. Calculate line efficiency after repair.

Comparative analysis from before the repair was carried out with after the repair was carried out:

a. Line Fficiency

$$\text{Line Efficiency} = \frac{\sum_{i=1}^{n} \text{Sti}}{(K) \times (CT)} \times 100\% \quad (1)$$

STi = Workstation time from to-i.
K = Number of work stations.
CT = Cycle Time.

b. *Balance Delay*

$$D = \frac{n.C - \sum_{i=1}^{n} ti}{(n \,.\, ti)} \times 100\% \quad (2)$$

D = Balance delay (%).
C = Cycle Time.
N = Number of work stations.
∑ti = Total operating times.
ti = Operation Time.

c. *Smoothing Index*

$$SI = \sqrt{\sum_{i-1}^{N} (Sti_{max} - St_i)^2} \quad (3)$$

STmaks = Maksimum time in workstation.
Sti = Station time in workstation-i.

3. RESULTS AND DISCUSION

3.1 Current Production Line Efficiency

The current efficiency of the production line at each work station is the ratio between the operating time at each work station and the largest work station time [4]. The work station that has the longest time is the Motor Assy work station with a time of 55 seconds which has an efficiency of 100%. With current conditions or before repairs with a total of 22 work stations, the line cycle time needed to make one unit of washing machine is 657 seconds with a line efficiency of 54%, Balance Delay of 46%, and Smoothing Index of 33.

3.2 Cycle Time and Work Stations Required for Production Activities in April 2021 – March 2022
Demand for production of washing machines from April 2021 to March 2022 with a production capacity of 524 units per day is obtained from the calculation that in 1 day there are 8 hours of work divided by the maximum cycle time of 55 seconds. Using compassion in the number of product requests with the available production line production capacity from April 2021 to March 2022, it is certain that the required production time to meet demand per day ranges from 674 minutes to 863 minutes. To be able to meet customer demand, efforts that can be made are by adding work stations, subcontract station, and carrying out an analysis of improvements to the line. In order to meet customer demand from April 2021 to March 2022, it is necessary to calculate the required cycle time based on the speed of demand as follows:

Normal production time per day : 480 minutes or 28.800 second
Highest requests per day : 942 Unit
With an efficiency level of 100% production time usage:

$$\text{Cycle Time} = \frac{\text{Total production time}}{\text{Highest requests per day}}$$

$$= \frac{28.800}{942} = 30{,}57 \text{ second / unit}$$

With an efficiency level of 97% production time usage:

$$\text{Cycle Time} = \frac{28.800}{942} \text{ x } 97\% = 29{,}66 \text{ second / unit}$$

As for the calculation of the ideal work station needed, it can be seen in the following calculation:

$$\text{WorkStation Needed} = \frac{\text{Total washing machine running time}}{\text{Required Cycle Time}}$$

$$= \frac{657 \text{ second}}{31 \text{ second}} = 22 \text{ Workstations}$$

3.3 Looking for Improvement Ideas and Repair Activities
From the data presented in Figure 2, the difference in time between the longest cycle time and the fastest cycle time is obtained for 33 seconds, resulting in an unbalanced work process and causing idle activity at some work stations, while other work stations continue to work full. The target tack time for each work station is 33.97 seconds. Work stations that work fully include *Motor Assy* for 55 seconds, *Outer Tub Buffer* Setting for 34 seconds, *Tub A* Setting 2 for 35 seconds, and *Connector Setting* for 35 seconds, while work stations with idle activities include *Tub A Setting 1* for 26 seconds, *Pulsator Setting* for 25 seconds, and *Specification Plate Setting* for 22 seconds. The processing time improvement that will be carried out is to classify work stations that have a long total processing time and a short total processing time. Then in work operations it is classified into movements that have added value to the product, movements that do not have added value to the product, and movements in the form of walking or changing positions without doing work. Based on the results of analysis and observations in the field, to reduce the total cycle time, repair activities will be suggested to be carried out at work stations that have the potential to have the greatest losses. Improvement activities carried out on the production line include improving work methods, repairing work station tools, reducing and moving work operations.
The work stations that will be repaired are the *Motor Assy* work stations, *Outer Tub Buffer Settings*, *Tub A Settings 2*, *Connector Settings*, *Panel A Assy*, and *Pulsator Settings*. The following is the condition before the repair and the condition after the repair of the selected work stations.

1. Workstation *Motor Assy*

The repair activity carried out is dividing the work operating load of the *Motor Assy* work station into 2 work stations, namely *Spin Motor Assembly* work station and *Wash Motor Assy* work station with aim of breaking Bottle Neck and increasing production line capacity. The actual value of the cycle time at *Spin Motor Assembly* workstation is 29.29 seconds and *Wash Motor Assy* workstation is 21.08 seconds.

2. Workstation *Outer Tub Buffer Setting*

The improvement activity carried out is to move more work operating loads from the *Outer Tub Buffer Setting* work station to the *Tub A Setting 1* work station with less work operating loads.
The actual value of the cycle time at the *Outer Tub Buffer Setting* work station becomes 28.90 seconds and the *Tub A Setting 1* work station becomes 31.20 seconds.

3. Workstation *Tub A Setting 2*
The improvement activity carried out is to move more work operating loads from the *Tub A Setting 2* work station to the *Tub A Setting 1* work station with less work operating loads. The actual value of the cycle time at the *Tub A Setting 2* work station is 32.41 seconds and the *Tub A Setting 1* work station is 33.43 seconds.

4. Workstation *Connector Setting*
The improvement activity carried out is to move more work operating loads from the *Connector Setting* work station to *Spec Plate Setting* work station with less work operating load. The actual value of the cycle time at *Connector Setting* workstation is 28.91 seconds and *Spec Plate Setting* workstation is 28.91 seconds.

5. Workstation *Panel A Assy*
In the *Panel A Assy* work station line there are several work stations, including *Switch Cover Setting* work station and *Switch Cover Assy* work station which have the potential to be difficult to increase production targets. The actual value of the cycle time at *Panel A Assy* workstation is 29.44 seconds, *Switch Cover Setting* workstation is 28.85 seconds and *Switch Cover* workstation is 29.04 seconds. To increase production capacity, the improvement activity carried out is to divide the workload into new work stations. The actual value of the cycle time at the *Panel A Assy* workstation is 24.49 seconds, *Switch Cover Setting* workstation is 25.44 seconds, *Switch Cover* workstation is 19.23 seconds and *Timer Knob Setting* workstation is 17.17 seconds.

6. Workstation *Pulsator Setting*
Preparation of the *Guide Shaft* is carried out in the preparation area, so that there is a process of supplying raw materials to be supplied to the main line. To increase production capacity and reduce raw material supply time, the repair activity carried out is to carry out the *Guide Shaft* assembly process carried out at the *Pulsator Setting* work station. The actual value of the cycle time at the *Pulsator Setting* work station is 25.47 seconds.

In order to determine the impact result of shifting workload on work stations where workload is added or reduced, cycle times are observed and measured at each work station and calculating line efficiency after corrective actions and workload balancing are carried out. The following is the result of observing the cycle time after the repair can be seen in Figure 3 below.

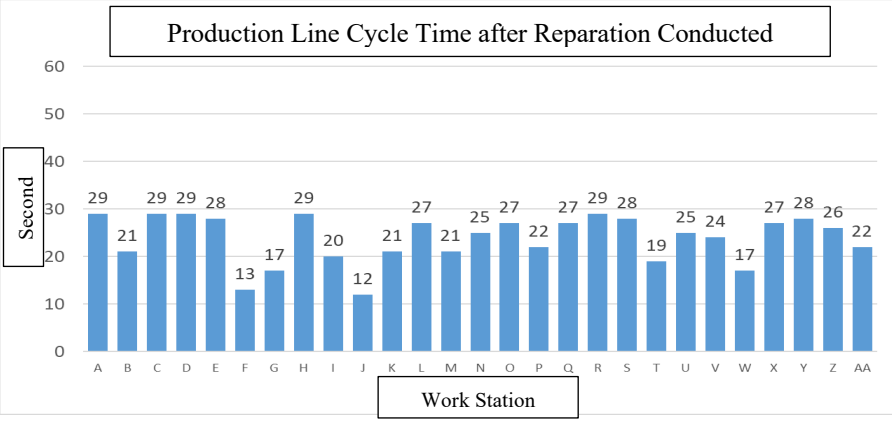

Figure 3 Production Line Cycle Time after Reparation
Source: Data Processing

Appendix:

A:	*Spin Motor Assembly*	G:	*OTB setting*	N:	*Pulsator Setting*	T:	*Switch Cover Assy*
B:	*Wash Motor Assy*	H:	*Mechacase Setting*	O:	*Body B Setting*	U:	*Switch Cover Setting*
C:	*Base A Assy 1*	I:	*Tube A Setting 1*	P:	*OTC Setting*	V:	*Panel A Assy*
D:	*Base A Assy 2*	J:	*Power Cord Setting*	Q:	*Spinner Lid Setting*	W:	*Timer Knob Setting*
E:	*Capacitor Setting*	K:	*Tube A Setting 2*	R:	*SF Switch Setting*	X:	*Spec.Plate Setting*
F:	*C. Valve Checking*	L:	*Spin Tub Setting*	S:	*Panel A Setting*	Y:	*Wiring 1*
		Z:	*Wiring 2*	AA:	*Connector Setting*		

The following is the result of the layout after the repair can be seen in Figure 4 below.

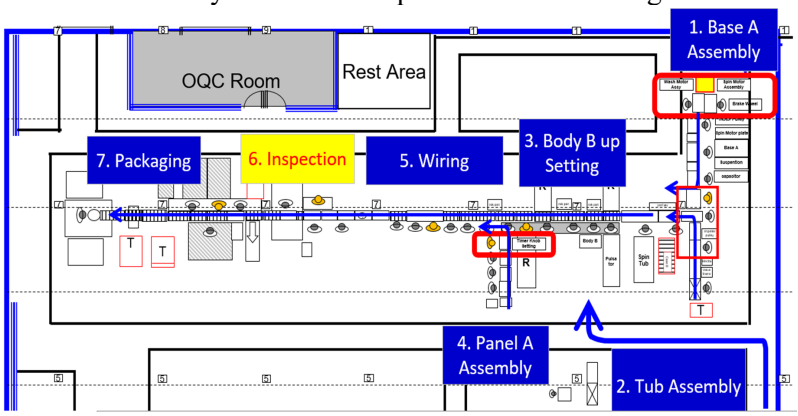

Figure 4 Production Line Layout after Reparation Conducted
Source: Production Department of PT. PMI

3.4 Production Line Efficiency After Repair

The efficiency of the production line after repairs at each work station is the ratio between the operating time at each work station and the largest work station time [5]. With the condition after the repair with a total of 27 work stations, the line cycle time needed to make one unit of washing machine is 642 seconds with a line efficiency of 82%, Balance Delay of 18%, and Smoothing Index of 17.

3.5 Comparison of Conditions Before and After repair

Comparison of the condition of the number of work stations, total cycle time, percentage of line efficiency, percentage of waiting time and the smoothing index before and after repair can be seen in Table 1 as follows.

Tabel 1 Comparison of Conditions Before and After Repair

	Before repair	**After repair**
Number of Work Stations	22	27
Total Cycle Time (Second)	657	642
Efficiency Line (%)	54%	82%
Balance Delay (%)	46%	18%
Smoothing Index	33	17

Source: Data Processing

Even though the level of efficiency after repair activities and job balancing is carried out does not reach 100%, this is the best result through trial-and-error approach in grouping operations into work stations, besides that the balanced delay time at each work station becomes smaller [6]. Line efficiency is the ratio between the time used at a work station and the time available. After carrying out repair activities,

line efficiency increased by 52% compared to before repairs from 54% to 82%. From the results of the analysis above, the higher the percentage of line efficiency, the more optimal the production process of the Two Tube Washing Machine.

3.5 Increase in production capacity and production achievement in April – March 2021

After there were activities to improve cycle time reduction and workload balancing, the production capacity increased by 90% as can be seen in Table 2.

Tabel 2 Production Capacity Before and After Repair

	Before repair		**After repair**	
Cycle Time Line	55		29	
Production Normal Hours / Day (seconds)	28.800		28.800	
Production Time Usage Efficiency Target	100%	97%	100%	97%
Output / Day (unit)	524	508	993	963

Source: Data Processing

4. CONCLUSION

Based on the results of the research that has been done, it can be concluded that:

1. The total cycle time needed to make one unit of washing machine before repair is 657 seconds and after repair is 642 seconds.
2. Improving line efficiency by using the line balancing method in the production line for *twin tube washing machine* products can be carried out with improvement activities in the production line including reducing cycle time by improving work methods, improving work station tools, reducing and moving work operations. By carrying out these repair activities, line efficiency increased by 52% from 54% to 82%, Balance Delay from 46% to 18%, and Smoothing Index from 33 to 17, and production capacity increased by 90% from 508 units per day. to 963 units per day with an efficiency target of 97%.

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