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INCREASING UTILIZATION OF PRODUCTION MACHINERY THROUGH LINE BALANCING APPROACH (CASE STUDY ON PHARMACEUTICAL INDUSTRY)

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Abstract: The growth in sales volume of unbranded generic products (considering that drugs served by BPJS Kesehatan refer to the National Formulary and e-catalogs set by the government) has led to a decline in margins as price competition intensifies. The purpose of this research is to optimize the utilization and efficiency of the machine, increase productivity and balance the line. Improvements are made by following the ECRS (Eliminating, Combining, Rearranging, and Simplify) based line balancing concept. From the improvements that have been made to the granulation process, it was found that the time of the wet mixing process, wet sieving, drying, and dry sieving had decreased. Cycle time decreased, output increase, the total granulation process time "Product F" decreased. Line efficiency increased, balance delay decreased and smoothness index decreased. This shows that the granulation line is getting more balanced.

Keywords: Line Balancing, ECRS, Line efficiency

INTRODUCTION

In 2014 the Government of Indonesia introduced the National Health Insurance (JKN) organized by BPJS Health, with the aim of providing access to health services for all Indonesians. This program has experienced very rapid growth in terms of membership. By the end of 2019, the total membership had reached more than 224 million, about 83 percent of the Indonesian population (BPJS Kesehatan, 2020).

The success of BPJS Kesehatan in providing access to health services to more citizens has made the pharmaceutical industry in Indonesia increasingly dominated by the category of unbranded generic products (considering that the types and brands of drugs served by BPJS Kesehatan refer to the National Formulary and e-catalogs set by the government). The growth in sales volume of unbranded generic products has led to a decline in margins as price competition intensifies.

Prescription Medicine Division PT. Kalbe Farma Tbk. recorded a net sales growth of 7,1% at the end of 2019 to Rp5.166 billion. Sales of unbranded generic products achieved sales growth of 15.0% (PT. Kalbe Farma Tbk, 2020). In line with PT. Kalbe Farma Tbk. Net sales of the Prescription Drugs group of PT. Tempo Scan in the domestic market grew by 5.9% compared to 2018 which recorded a decline of 19.8%. Net sales of the Prescription Drugs group of PT. Tempo Scan consisted of net sales of BPJS products which contributed 64% (an increase of 14.2%) while net sales of Non BPJS products contributed 36% in 2019 (decreased 6.2%) (PT. Tempo Scan Pacific Tbk., 2020).

On the other hand, net sales of PT. X, in 2019 was Rp. 247.12 billion or 92.90% of the target of Rp. 266.00 billion. The target was not achieved due to: the decreasing market for prescription drugs, the company being unable to supply drugs for JKN participants and rising production costs. One of the strategies of PT. X to increase the Company's revenue in the following year is by entering new market segments that have not been touched, such as being a supplier for the National Health Insurance and In Health insurance programs.

Research on increasing productivity have been carried out by Vislavath, et al (2016) who conducted a case study in a beverage factory. In his research the initial production line used 23 workers at various stations, after the application of the longest operating quantity heuristic was optimized to 20. They got an increase in utilization from 69,56% to 80%. The total work station was initially reduced from 12 to 10 using the same principle.

Another researcher conducted by Morshed & Kazi (2014) observed a type-1 line balancing problem (minimizing the number of work stations for a given cycle time). The maximum yield was increased to 1,190 pieces of clothing a day, which was previously recorded at 1,100 pieces of clothing a day. Labor productivity has increased from 40 to 50. Line efficiency has been increased from 43% to 53%.

Based on the description above, the authors are interested to optimize the utilization and efficiency of the machine, increase productivity, and balance the line of the production line granulation with a line balancing approach in solving bottlenecks in the production line.

LITERATURE REVIEW

The Lean concept is seen as "a set of management principles and techniques aimed at eliminating waste in the production process and improving the flow of activities, from the customer's point of view, which increases product value" (Ejsmont K, et al, 2020). Waste is defined as human activity that absorbs resources but does not create ‘‘value’’. Value on the other hand in a business sense is defined as 'the capability provided to the customer at the right time at the right price, as determined in each case by the customer' (Sony, M, 2018).

The holistic approach to creating a lean value stream consists of four main strategies, i.e synchronizing inventory with customers (externally), synchronizing production (internally), creating flows, and building a pull-demand system. To implement these four strategies, five basic diagnostic tools are used, to evaluate the value stream, i.e takt calculations, basic time studies, balancing analysis, spaghetti diagrams, current state value flow maps and future state value flow maps (Wilson, L 2010).

The process of deciding how to assign tasks to workstations is referred to as line balancing. The purpose of line balancing is to obtain a grouping of tasks that represent the same time requirements. This minimizes idle time along the line and results in high labor and equipment utilization. Idle time occurs when the task time is not the same between work stations; some stations are capable of producing at a higher rate than others. This fast station will experience a waiting period for output from the slower station or be forced to not use it to avoid the buildup of work between stations. This unbalanced line is undesirable in terms of inefficient utilization of labor and equipment and therefore can create morale problems at slower stations because workers have to work continuously (Stevenson, 2009).

To produce out put and line balance at the specified level, management must know the tools, equipment, and work methods used. Then the time requirements for each assembly task must be determined. Management also needs to know how the sequence of various tasks that must be done (Heizer and Render, 2016).

Wilson (2010) argues that line balancing studies are conducted to see how well the actual work elements will match the desired cycle time. It is easy enough to calculate the desired cycle time, but often the work elements do not allow for a perfect distribution of work.

All assembly line balancing (ALB) goals are motivated towards improving line efficiency. For a type 1 problem, with a fixed cycle time, costs can be minimized by reducing the total hours worked (eg Number of workers). For the type 2 problem, with a fixed number of stations, the output variable is maximized by minimizing the cycle time. Type 3 problems refer to the economic motivation of both type 1 and type 2 problems simultaneously (Pearce B. 2015).

Research using ECRS based Line Balancing concept was implemented by Ongkunaruk P, & Wimonrat, W (2014), Chueprasert, M. & Ongkunaruk, P, (2015), Yin, M & Wei J (2016), Amran, TG & Novia CW (2018) with the purpose to minimize number of workers (ALB type 1). Tiovani, O & Fakhrina, F (2019), using ECRS based Line Balancing concept to improve line efficiency with fixed cycle time and workstations. Pertiwi, AFO & Rahmaniyah DA (2020), using ECRS based Line Balancing concept to minimized cycle time with fixed number of workers and workstations (ALB type 2) in washing machine production.

Sivasankaran and Shahabudeen (2014) classify assembly line balancing problems based on the number of production line models (Single Model Assembly system and Multi Model Assembly system), the nature of the task time (probabilistic, or deterministic) and the nature of the flow (staraight – type or U-type). On the same assembly line, one or more products can be assembled. If only one model is assembled in the line, then the production system is referred to as a Single Model Assembly system, otherwise it is referred to as a Multi Model Assembly system. Task processing time can be deterministic and probabilistic. If the task is performed using all sophisticated tools and equipment by a highly skilled workforce, then the task processing time can be estimated with a deterministic quantity, since there is less variability in processing time in such situations. But usually, in the assembly line operation, the runtime will vary, which can be characterized in the form of some probability distribution. The workstation arrangement of the assembly line may be in a straight-line layout or in a U-shape layout. In a U-shape layout, the operator can manage more than one workstation.

Operational Definition and Measurement of Variables

Some operational definitions used in this study, among others:

- Work elements are non-divisible units of work, which have been associated with work element time. Work element time is the time required to complete 1 work element.
- A process is a set of work elements that are performed sequentially at a station. Processing time is the time required to complete a set of work elements that have been set.
- Total process time is the sum of time it takes to produce a product in a line that has been divided into a series of processes.
- Workstation (m): is a line component where tasks are processed, and can involve a human or robot operator, certain equipment, and some special process mechanisms (Betancourt, LC, 2007).
- Workstation time t(Sj): is the sum of time for setting, processing, and sanitizing to workstations j. Workstations are arranged in such a way that waiting time between stations is minimal and line efficiency can be optimized.
- Cycle time (ct): is the longest time available at each work station to complete the tasks required to process units of product. Cycle time is also referred to as the workstation time interval between two consecutive units (Betancourt, LC, 2007). The purpose of line balancing in this research is to try to minimize cycle time at the desired work station.
- Takt time (theoretical cycle time) is the time required at a workstation to produce a predetermined number of product units at a predetermined time unit.
- Line balancing efficiency is a line performance parameter that shows the comparison between the total work station time and the longest available time at the work station on the line.

  Line Efficiency = $i=1 m t(Sj)$ *Line Efficiency* = $\frac{\sum_{i=1}^{m} t(Sj)}{(m)(ct)}$
- Balance delay (BD) is the ratio between waiting time in line with available time.

  BD = $m\ ct - i=1 m t\ Sj$ *BD* = $\frac{(m)(ct)-\sum_{i=1}^{m} t(Sj)}{(m)(ct)} x100\%$
- Smoothness index (SI) is the relative lead time of an assembly line. A value of 0 indicates perfect balance or in other words the distribution of work elements is even.

  SI = $i=1 m\ (t\ Sjmaks - t\ Sj)$ *SI* = $\sqrt{\sum_{i=1}^{m}(t(Sjmaks)-t(Sj))^2}$
- Utilization (utilization) is the percentage of design capacity that is actually achieved. Utilization = Actual output/Design capacity (Heizer and Render, 2016)
- Efficiency is the percentage of effective capacity that is actually achieved. Efficiency = Actual output/effective capacity (Heizer and Render, 2016).

RESEARCH METHODS

Types of research

The type of research conducted is quantitative research with an experimental methode conducted in the granulation area of the Pharmaceutical industry. This research was conducted by direct observation using a stopwatch.

Population and Sample

The population in this study is the granulation line and the time measurement performed on the sample is 12 times. The criteria for selecting the operators are experienced operators to implement these activities, work without excessive effort throughout the day, master the established work methods, and show sincerity in doing their work.

Product selection is based on the importance of the product to the customer, the potential to improve overall operations, and the potential impact on other products. The product selection method is based on the product-process matrix and the A-B-C analysis (Pareto analysis).

Method of collecting data

Data were obtained either directly (primary data) or through interviews (secondary data). The primary data used is taken from direct observation of the object to be studied, i.e data on work elements, and time measurement data for work elements (using a stopwatch). Secondary data obtained from management and employees used include general production process flowcharts, data of capacity requirements and output/month, data of processing flow for each product, and data of monthly production demand.

Data analysis method

The steps taken in the preparation and processing of data are measuring the working time of each activity using a stop watch measuring instrument. Then each data is analyzed by: finding the average time, calculating the standard deviation, determining the upper acceptance limit and lower acceptance limit, calculates the processing time of each station (the total of processing time elements at each stage of the process), calculate the adequacy of processing time data for each station, calculate workstation time (sum of time for all tasks including settings, processes, and sanitation assigned to workstations), and analyze line performance (line efficiency, balance delay, and smoothness index).

FINDINGS AND DISCUSSION

Findings

As is condiition

Data on the number of monthly production requests is used as a basis for calculating takt time which will become the standard / target to be achieved. The calculation of takt time and standard/target processing time for each batch of products can be seen in table 4.1.

Table 1 Calculation of takt time and standard/target processing time

Number of products per month	:	121 batches
Number of working days at 1 month	:	20 days
Number of working hours at 1 day	:	21,75 hours
Number of working hours at 1 month	:	435 hours
Takt time (a)	:	3,60 hours/product
1 cycle consist of setting, process and sanitation		
Time of setting and sanitation machine for each product (b)	:	1 hours
Time of process for each product (target) (a-b)	:	2,60 hours

Source: Processed Data (2020)

Based on the data on the number of monthly production requests, a Pareto graph is made to see the number of products against the output in the granulation line. Products that have the most monthly production demand are categorized as Pareto A, and can be focused on becoming objects of improvement.

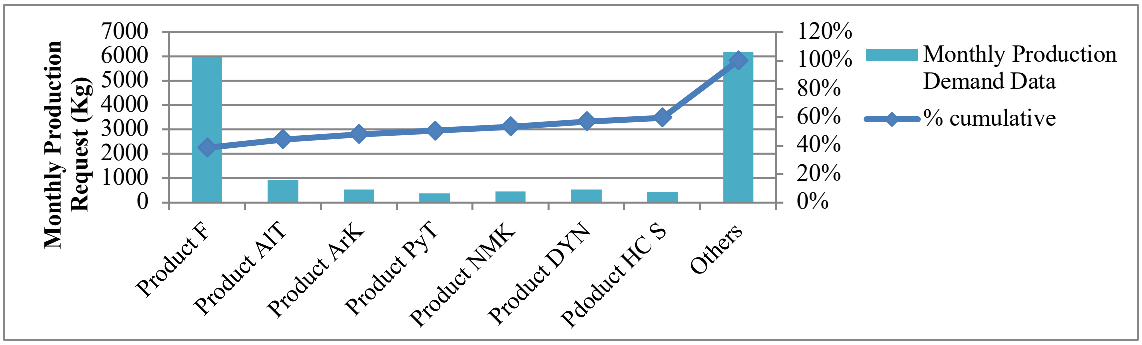

Figure.1 Pareto diagram of monthly production demand data.
Source: Processed Data (2020)

From Figure 1, it can be seen that the most processed product is the “Product F”. The demand for “Product F” has a cumulative percentage of 39% of the monthly production demand. The processing time of each granulation stage of "Product F" can be seen in Table 2.

Table 2 Work Sequence & Time for "Product F" Granulation Process As is Condition

No.	Time (Second)	No.	Time (Second)	No.	Time (Second)	No.	Time (Second)	No.	Time (Second)	No.	Time (Second)
A1	387	B29	55	B30	386	E4	268	E5	2712		
A2	91	B28	161	B31	300	E3	81	E6	314		
A3	267	B27	153	B32	300	E2	85	E7	289		
A4	120	B26	300	B33	272	E1	627	E8	143		
A5	332	B25	277	B34	120	D22	258	E9	2684		
A6	300	B24	120	B35	384	D21	449	E10	586		
A7	192	B23	450	B36	267	D20	625	E11	155		
A8	59	B22	163	B37	210	D19	505	E12	76	G11	273
A9	150	B21	207	B38	211	D18	936	F1	246	G10	496
A10	272	B20	263	C1	392	D17	580	F2	82	G9	568
A11	120	B19	400	C2	1835	D16	276	F3	51	G8	750
A12	271	B18	120	C3	538	D15	576	F4	129	G7	300
A13	300	B17	282	C4	240	D14	198	F5	206	G6	390
A14	174	B16	300	C5	161	D13	638	F6	98	G5	1200
A15	56	B15	300	C6	1814	D12	154	F7	309	G4	1237
B1	884	B14	391	C7	538	D11	337	F8	862	G3	130
B2	51	B13	46	C8	223	D10	456	F9	315	G2	60
B3	45	B12	138	C9	156	D9	627	F10	202	G1	717
B4	332	B11	167	D1	389	D8	514	F11	611	F18	95
B5	511	B10	300	D2	688	D7	755	F12	559	F17	288
B6	147	B9	274	D3	198	D6	565	F13	61	F16	430
B7	456	B8	120	D4	618	D5	276	F14	59	F15	120

Source: Processed Data (2020)

Note: Colors indicate repairs to be made.

Eliminating Combining Rearrangging Simplif

Table 3 Processing Time for Granulation "Product F" As is Condition

Operator	Work station	Process	Processing Time (second)
Op 2	2	Preparation of Binder Solution (A1-A15)	3090
Op 1	1	Wet Mixing (B1-B38)	9864
Op 2	2	Wet Sieving (C1-C9)	5896
Op 3	3	Drying (D1-D21)	10618
Op 4	4	Dry Sieving (E1-E12)	8020
Op 4	4	Dry Mix Sieving (F1-F18)	4722
Op 5	5	Dry Mixing (G1-G11)	6120
5	5	Total	48330

Source: Processed Data (2020)

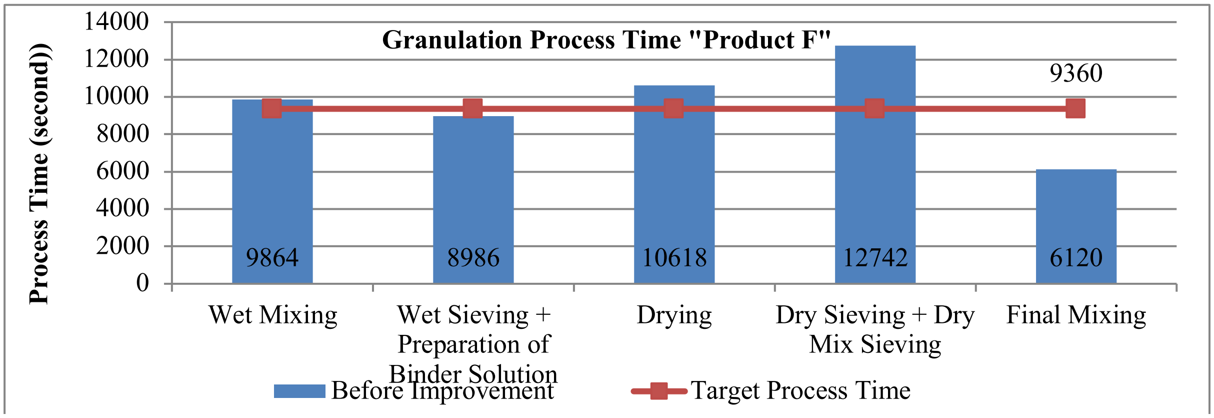

Figure 2 Granulation process time for "Product F" As is Condition
Source: Processed Data (2020)

From Figure 4.3, it is known that there are several granulation processes for "Product F" which have a processing time > standard/target processing time, such as wet mixing (B1-B38), drying (D1-D21), and dry sieving (E1-E12) + dry mix sieving (F1-F18).

Table 4 Workstation Time As is Condition.

Workstation	Process	Processing Time	Setting & Sanitation Time	Workstation Time
WS1	Wet Mixing	9864	3600	13464
WS2	Binder Preparation + Wet Sieving	8986	3600	12586
WS3	Drying	10618	3600	14218
WS4	Dry Sieving	8020	3600	16342
	Dry Mix Sieving	4722		
WS5	Dry Mixing	6120	3600	9720
Total		48330	18000	66330
Efficiency Line				81,18%
Balance Delay				18,82%
Smoothness Index				8411 Second

Source: Processed Data (2020)

Note: Workstation Time = processing time + setting & sanitation time (1 hour)

Condition After Improvement-1

In improvement-1, several optimalization were made, i.e eliminating preparation of binder solution , combining lot-1 & lot-2 in wet mixing process, wet sieving, drying, and dry sieving were implemented 1 time (not divided by 2 lots), and rearangging process dry mix D2 (table 4.5) was oscillated before oscilating the dried granules.

Table.5 Sequence & Time of "Product F" Granulation Process after Improvement-1

No.	Time (second)	No.	Time (second)	No.	Time (second))	No.	Time (second)	No.	Time (second)	No.	Time (second)

A1	878	C2	775	C3	618	E11	568	E12	77		
A2	54	C1	392	C4	847	E10	612	E13	56		
A3	43	B5	115	C5	318	E9	200	E14	120		
A4	315	B4	265	C6	860	E8	318	E15	435		
A5	494	B3	528	C7	778	E7	840	E16	268		
A6	167	B2	3174	C8	1079	E6	101	E17	87		
A7	888	B1	378	C9	533	E5	211	F1	692		
A8	300	A19	202	C10	340	E4	137	F2	53		
A9	261	A18	325	C11	330	E3	53	F3	137		
A10	201	A17	583	D1	515	E2	77	F4	1227	F11	269
A11	252	A16	613	D2	297	E1	255	F5	1200	F10	506
A12	138	A15	120	D3	4175	D6	153	F6	392	F9	571
A13	739	A14	600	D4	878	D5	336	F7	300	F8	747

Source: Processed Data (2021)

Note: Colors indicate repairs to be made.

Simplify & Rearrangging   Rearrangging

Table 6 Granulation Process Time "Product F" after Improvement-1

Operator	Work station	Process	Processing Time (second)	Setting & Sanitation Time	Workstation Time
Op1	1	Wet Mixing (A1-A19)	7171	3600	10771
Op2	2	Wet Sieving (B1-B5)	4459	3600	8059
Op3	3	Drying (C1-C11)	6870	3600	10470
Op4	4	Dry Sieving (D1-D6)	6354	3600	14369
Op4	4	Dry Mix Sieving (E1-E17)	4415		
Op5	5	Dry Mixing (F1-F11)	6094	3600	9694
5	5	Total	35363	18000	53363
Line Efficiency				74,28%	
Balance Delay				25,72%	
Smoothness Index				9477 second	

Source: Processed Data (2021)

In improvement-1, it was found that the total processing time < total target processing time in all granulation stations. The line performance parameters after improvement-1 getting worse, among others: line efficiency decreased from 81,18% to 74,28% (line was getting less efficient), balance delay increased from 18,82% to 25,72% (waiting time increasing) and the smoothness index increased from 8411 seconds to 9476 seconds (line is getting unbalanced). The condition of the increasingly unbalanced line is certainly not expected. In improvement-1, the longest workstation time is still in the dry sieving and dry mix sieving area, the total processing time is

14369 seconds, so this is still not able to meet the demand for 121 batches (target processing time at each work station < 9360 seconds or 02 hours 36 minutes).

Condition after Improvement-2

The author proposes to simplify the process for the activities carried out by operator 4 and rearrange the sieving process at point E1-E17, where E7 (manual sieve using mesh 30) is preceded by a dry sieving process using an oscilating granulator. In simple terms, the flow of the granulation process after a change in the sequence of the dry mix sieving process is as shown in Figure 4.4.

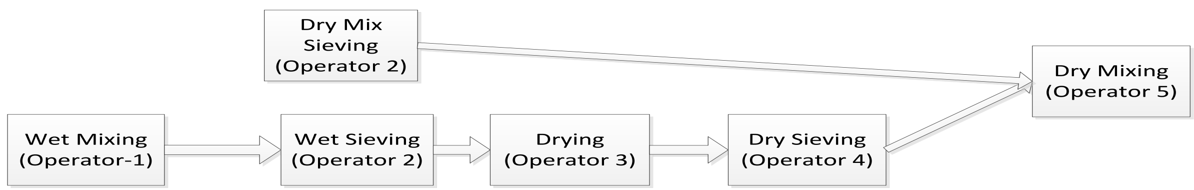

Figure 4 Process flow diagram after rearrangging of the dry mix sieving process.
Source: Processed Data (2021)

Table 7 Sequence & Time of Work for "Product F" Granulation Process After Improvement-2

No.	Time (second)	No.	Time (second)	No.	Time (second)	No.	Time (second)	No.	Time (second)	No.	Time (second)
A1	878	E7	318	E8	200	D1	515	D2	297		
A2	54	E6	101	E9	612	C11	330	D3	840		
A3	43	E5	211	E10	568	C10	340	D4	4175		
A4	315	E4	137	E11	77	C9	533	D5	878		
A5	494	E3	53	E12	56	C8	1079	D6	336		
A6	167	E2	77	E13	120	C7	778	D7	153		
A7	888	E1	255	E14	435	C6	860	F1	692		
A8	300	A19	202	E15	268	C5	318	F2	53		
A9	261	A18	325	E16	87	C4	847	F3	137		
A10	201	A17	583	B1	378	C3	618	F4	1227	F11	269
A11	252	A16	613	B2	3174	C2	775	F5	1200	F10	506
A12	138	A15	120	B3	528	C1	392	F6	392	F9	571
A13	739	A14	600	B4	265	B5	115	F7	300	F8	747

Source: Processed Data (2021)

Table 8 Granulation Processing Time for "Product F" After Improvement-2

Operator	Work station	Process	Processing Time	Setting & Sanitation Time	Workstation Time
Op1	1	Wet Mixing (A1-A19)	7171	3600	10771
Op2	2	Dry Mix Sieving (E1-E16)	3575	3600	11634
Op2	2	Wet Sieving (B1-B5)	4459		
Op3	3	Drying (C1-C11)	6870	3600	10470
Op4	4	Dry Sieving (D1-D7)	7194	3600	10794

Op5	5	Dry Mixing (F1-F11)	6094	3600	9694
5	5	Total	35363	18000	53363
Efficiency line				91,74%	
Balance Delay				8,26%	
Smoothness index				2563 second	

Source: Processed Data (2021)

Discussion

The Elimination of activities carried out in the process of making binder solutions A1-A15 (in table 4.2), wet mixing activities of B10, B17, B18, B26, B33 and B34 (in table 4.2) and activities of taking granules from the product storage room (E2-E4 in table 4.2) cause granules send by drying operator. Elimination was also implemented in filling line clearance lot 2 in the wet mixing process B22 (in table 4.2), wet sieving C5 (in table 4.2), drying D12 (in table 4.2), and dry sieving E8 (in table 4.2).

The combination of activities carried out in the wet mixing process (B7-21 & B23-B37 in table 4.2), wet sieving (C2-C6 & C4-C8 in table 4.2), drying (D2-D11 & D13-D22 in table 4.2), and dry sieving (E5- E12 in table 4.2) where the process is divided into 2 lots, each with 66.69 kg. The optimization carried out is the mixing process is carried out 1 time (not divided by 2 lots), with the amount of material mixed 133.38 kg and the results can be seen for wet mixing (A7-A19 in table 4.5), wet sieving (B2-B5 in table 4.5), drying (C2-C11 in table 4.5), and dry sieving (D2-D6 in table 4.5).

The rearrangging of activities is carried out on the dry mix sieving process points F7 (in table 4.2) and E7 (in table 4.5) into a sub-section of the dry sieving process in D2 and D3 (in table 4.7).

The Simplify of activities carried out at workstation 4, namely the dry mix sieving process which was originally carried out after dry sieving (E1-E6 and E8-E17 in table 4.5), to be carried out at workstation 2 by operator 2 (E1-E16 in table 4.7), while waiting for the results of wet mixing**.** Simplify activities in C9 (in table 4.2)-check completeness of process documentation (as effect of reduced documentation lot-2) and result in B5 table 4.5. Simplify activities in E1 (in table 4.2)-Filling Line Clearence of dry sieving process as the dry sieving operator doesn't search and retrieve the batch processing record (batch processing record send by drying operator together with the granules).

From the improvements that have been made, it is found that the process of each stage has decreased. The total time before improvement is 13 hours 25 minutes 30 seconds, and after improvement-1 and improvement-2, the total processing time is 9 hours 49 minutes 23 seconds. The total reduction in granulation processing time for "product F" 3 hours 36 minutes 07 seconds ~ 3.6 hours, which was converted to currency values (operator wages Rp. 15,088.09/hour) to Rp. 54,317.12/batch. The cost savings generated for a year (480 batches/year) from the balancing line granulation product F is Rp. 26,072,219.52.

Table.9 Comparison of Line Performance Before and After Improvement

Parameters	As is Condition	Improvement-1	Improvement-2
Cycle Time Actual	16342 second	14369 second	11634 second

Output (Produck/month)	96	108	133
Number of operators	5	5	5
Number of workstations	5	5	5
Total workstation time	66330 second	53363 second	53363 second
Total Processing Time	48330 second	35363 second	35363 second
Line Eficiensi	81,18%	74,28%	91,74%
Balance Delay	18,82%	25,72%	8,26%
Smoothness Index	8411 second	9477 second	2563 second

Source: Processed Data (2021)

In repair-2, the expected optimal condition has been reached, i.e output > 121 products/month, with line efficiency increasing from 81.18% to 91.74%, balance delay decreasing from 18.82% to 8.26% and fluency index decreased from 8411 seconds to 2563 seconds. This shows that the granulation line is getting more balanced and the expected results are achieved.

From the combination of lot-1 and lot-2, the actual output increase for one mixing process is obtained. This causes an increase in the utilization and efficiency of the machine. Heizer and Render, 2016 stated that utilization is the percentage of design capacity that is actually achieved. Machine utilization = Machine's actual output/Machine design capacity. Efficiency is the percentage of effective capacity that is actually achieved. Machine efficiency = Actual machine output/effective machine capacity.

Figure.4. Granules from wet mixing in a super mixer 150 Kg (before improvement).
Source: Processed Data (2021)

Figure 4.6 Granules from wet mixing in a super mixer 150 Kg (after improvement)
Source: Processed Data (2021)

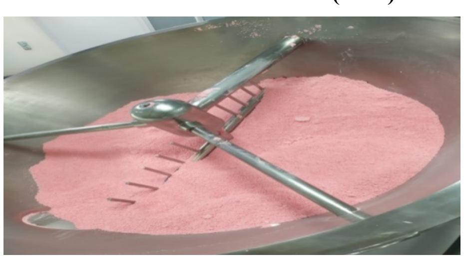

Figure 5 Granules being dried in FBD 150 Kg (before improvement)
Source: Processed Data (2021)

Figure.7 Granules being dried in FBD 150 Kg (improvement)
Source: Processed Data (2021)

Table 10 Output & Capacity machines after and before improvement

Station	Machine	Actual Out Put (after improvement)	Actual Out Put (before improvement)	Desain Capacity	Effective Capacity
St.1	SM150Kg	133,38 Kg	66,69 Kg	150 Kg	120 Kg
St.3	FBD150Kg	121,84 Kg	60,92 Kg	150 Kg	120 Kg
St.5	Double Cone	149,4 Kg	149,4 Kg	200 Kg	160 Kg

Source: Processed Data (2021)

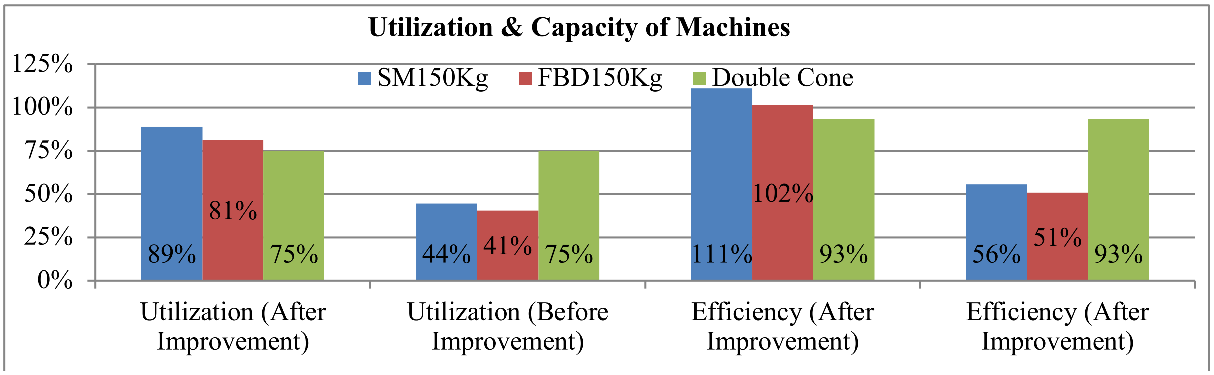

Figure 4.8 Comparison of utilization & Efficiency granulation machine on "Products F"
Source: Processed Data (2021)

CONCLUSION AND RECOMMENDATION

Conclusion

The purpose of this research is to optimize the utilization and efficiency of the machine, increase productivity and balance the line. Improvements are made by following the ECRS (Eliminating, Combining, Rearranging, and Simplify) based line balancing concept. From the improvements that have been made to the granulation process, it was found that the time of the wet mixing process, wet sieving, drying, and dry sifting had decreased. The cycle time decreased from 04 hours 32 minutes 22 seconds to 03 hours 13 minutes 54 seconds (the maximum workstation time was below the takt time, which was 3 hours 36 minutes), so that the original 96 product batches/month could increase to 133 product batches/month. The total granulation process time (excluding setting and sanitation) "Product F" decreased from 13 hours 25 minutes 30 seconds to 9 hours 49 minutes 23 seconds (saving processing time 3 hours 36 minutes 07 seconds ~ 3.6 hours). The cost saving generated for a year (480 batches/year) from the balancing line granulation product F is Rp. 26,072,219.52. Line efficiency increased from 81.18% to 91.74% and balance delay decreased from 18.82% to 8.26% and smoothness index from 8411 seconds to 2563 seconds. This indicates that the granulation line is getting more balanced and the expected results have been achieved.

Recommendation

1. Products that have a theoretical weight of wet mixing in the range of 50-66.69 kg can be increased the total theoretical weight to reach 89% of the design capacity (150 Kg) so that the utilization and efficiency of the machine is maintained in the range >80%.

2. To ensure that the improvements that have been made can continue, the work sequences that have been compiled in table 4.7 are included in the procedures and records for processing product batches.
3. In the condition that the number of workstations is fixed, the number of operators per workstation is only 1 person and the total processing time > total takt time in all workstations, Eliminating and Combining processes must be carried out (before rearranging and simplifying) until the total processing time < total takt time in all workstations.

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