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Swing Frame Assembly Line Balancing of Excavator PC 200 Using Genethic Algorithm Method at PT Pindad

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Abstract. PT. Pindad (Persero) is a state-owned company (State-Owned Enterprise) that is engaged in the Alutsista (Main Equipment Armament System) and commercial products, such as production or manufacturing, services, trade. One of the products currently produced is heavy equipment in the form of a Excavator PC 200. In carrying out its business, PT. Pindad has not been able to fulfill the demand for Excavator PC 200 from consumers from the private sector or the government. This happens because the station time on assembly lines is not evenly distributed so the workload is not balanced. This results in idle time which makes the operator idle so that the smooth flow of the assembly becomes low. Therefore it is necessary to balance workloads so that there is no idle time and increase the efficiency of the flow of assembly lines so that production output can be increased and production targets can be achieved. Balancing the assembly line was carried out on the swing frame assembly line as the upper frame of the Excavator PC 200 product using the Genetic Algorithm method. In this study the results of line efficiency were 98, 65% which increased by 56.65% with actual line efficiency by 42% with the condition of the number of fixed work stations numbering 4. Balance delay value decreased from 58% to 1.35%. In addition, production output also increased from 1 unit to 3 units.

Keywords: 1 Genetic Algorithm · 2 Line Balancing · 3 Idle Time · 4 Line Efficiency

1. INTRODUCTION

PT. Pindad is a state-owned company that is engaged in the Alutsista (Main Equipment of Armament Systems) and commercial products, such as production or manufacturing, services, trade. One of the products currently made is heavy equipment that Exacavator PC 200. PT. Pindad contracts requests with consumers based on the results of the RKAP. The following is a data demand Excavator PC 200 2018.

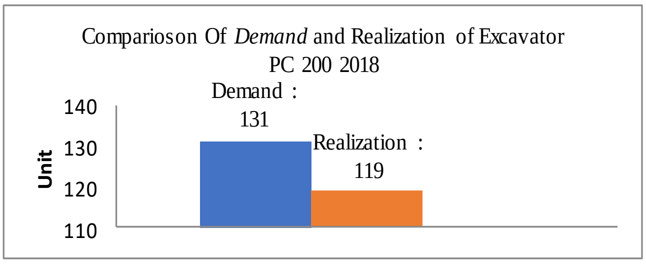

Figure 1. Comparison of Demand and Actual Excavator PC 200 2018.

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Based on Figure 1, that PT. Pindad has not been able to meet consumer demand for 12 units. This happens because the station time on assembly lines is not evenly distributed so the workload is not balanced. This results in idle time which makes the operator idle so that the smooth flow of the assembly becomes low. The line efficiency assembly line is currently worth 42%. The following is a time graph of zone B assembly line stations.

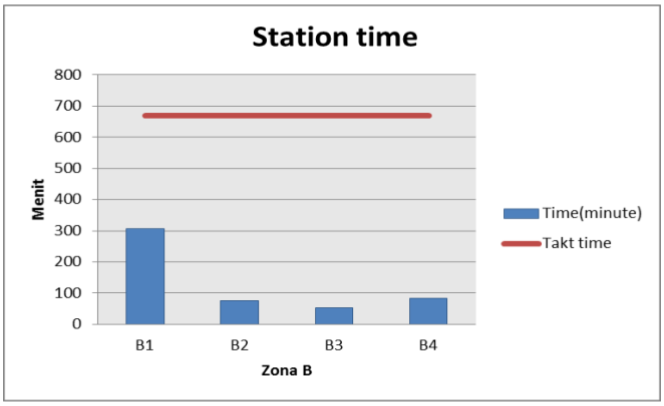

Figure 2. Station Time for Each Workstation

Based on Figure 2, it can be seen that there is an imbalance of process time between workstations which results in idle time. Idle time is an indicator of operational performance efficiency (Damayanti & Toha, 2012). The following is the idle time data on zone B assembly lines.

Table 1. Idle Time of Asssembly Line Zone B

Workstation	Station Time (menit)	Idle time (menit)
WS 1	306	0
WS 2	75,00	231,00
WS 3	52,73	253,27
WS 4	83,20	222,80
TOTAL	516,93	707,07

The idle time on this assembly line causes a bottleneck where the workstation works full and the other workstation is idle because it waits for input to be processed from the previous workstation. The actual balance delay assembly line has a value of 58%. Therefore, the flow of the assembly line becomes hampered, resulting in a production target not being reached. Based on the explanation of the above problems, it is necessary to do line balancing by allocating work elements between stations so that there is no idle time and increase the efficiency of the flow of assembly lines so that production output can be increased and production targets can be achieved. Line balancing in this study used genetic algorithm method with matlab R2018a software. The use of the GA method with the matlab software allows companies to anticipate adjustments to new assembly lines if there are changes in conditions on assembly lines such as changes in the number of workstations, takt time and cycle time because of their ability to have short computation time and conditions of assembly line changes will occur at PT. Pindad because it is planned to change the demand increase by 20% which results in changes in the company's takt time so that it needs to be adjusted to the new assembly line.

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Genetic algorithms have the ability to main handle various objective functions and solve complex optimization problems using computer simulations (Sabuncuoglu, Erel, & Tanyer, 2000). Genetic algorithm is an intelligent random search mechanism that is applied to various optimization problems such as scheduling, TSP, and ALB. Genetic algorithm can be used as a search technique that is very effective in solving difficult problems because of its ability to move from one solution to another and the ability to combine specific characteristics of the problem. To achieve this benefit, Operator standards must be designed and adapted to the conditions of the problem. In addition, the computational time of this method is also fast (less than 2 seconds for 50 elements of work) (Sabuncuoglu, Erel, & Tanyer, 2000). Therefore, by doing track balancing with the genetic algorithm method it is expected to increase the efficiency of assembly lines and assembly capacity.

2. LITERATUR REVIEW

Line Assembly

The assembly line is the problem of determining the number of people or machines along with the tasks given to each source. Each workstation on the production line has different production speeds. If no adjustments are made, it will experience a waste of time in the production process (Gasperz, 2001).

Line Balancing

Line balancing is the balancing assignment of task elements from an assembly line to a workstation to minimize the number of workstations and minimize total idle time prices at all stations for a certain level of output (Gasperz, 2001).

Genethic Algorithm (GA)

Genetic algorithms are search and optimization techniques that work in ways that mimic the process of evolution and changes in the genetic structure of living things. The main principle of how the algorithm works is inspired by the process of natural selection and the principles of genetic science. Genetic algorithms can solve optimization problems well developed by John Holland in the 1970s (Arkeman, Seminar, & Gunawan, 2012).

GA Structure in Line Balancing Case

The following is the GA structure in the form of line balancing (Sabuncuoglu, Erel, & Tanyer, 2000).

Chromosome coding

The length of the chromosome represents the number of tasks or elements of work and each gene describes the task (Triki, Hachiha, Mellouli, & Masmoudi, 2015). These tasks are ordered on chromosomes relative to the order of processing tasks. Then the task is allocated to the station so that the number of assignments at each station does not exceed the cycle time.

1. Fitness Function

Value Fitness interprets the efficiency of the average assembly line (Wahyudi, Zalynda, & Pamungkas, 2012). The fitness function can be formulated as follows.

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Minimization workstation

$$fitness\ function = \sqrt{\frac{\sum_{k=1}^{n}(Smax - Sk)^2}{n}} + \frac{\sum_{k=1}^{n}(Smax - Sk)}{n}$$

Where:

n = number workstations

Smax = maximum station time

Sk = station time of workstation k

2. Initial Population

   Generated randomly by ensuring the feasibility of precedence relations.

3. Crossover and mutations

   If the recombination probability is 98%, the probability of mutation is 2%.

4. Scaling

   The fitness score needs to be scaled so that the total fitness score scaled is equal to 1.

5. Election Procedure

   The famous procedure is the procedure for using the roulette wheel selection. Each chromosome in the population occupies a slot on the roulette wheel. The size of the slot is equal to the ratio between the fitness value of a chromosome and the total fitness value of all chromosomes. To produce a number of populations, the roulette is rotated as much as the size of the population.

6. Termination Conditions

   The algorithm ends after a certain number of iterations. The research conducted by Erel and Tanyer used values of 500, 1000 and 2000 for the number of iterative parameters.

3. RESULT AND DISCUSSION

Existing Condition

The following is the data needed to obtain the actual line balance.

1. Station time

   The number of workstations in the assembly line zone B is 4 consisting of B1, B2, B3 and B4 with the time of each work station as follows.

Table 2. Station time of Zone B

Workstation	Waktu (menit)
B1	306
B2	75,00
B3	52,73
B4	83,20
Total	516,93

2. Workday in the assembly line

   Assembly line workdays are 360 minutes / day with a cycle time of 306 minutes and the unit capacity produced is 1 unit of swing frame.

3. Performance indicators

   The following are the actual performance indicators of the efficiency of the actual assembly line.

Table 3. Actual Performance Indicators

Indikator	**Aktual**
Line Efficiency	42%
Balance Delay	58%
Smoothess Index	408,83

Implementing Genethic Algorithm in Assembly Line Balancing of Zone B

The line balancing process in zone B is first identified with the parameters of the genetic algorithm to be applied as follows.

1. Initial Population

   The first step is to make an initial population containing genes that are elements of work that are in accordance with this case. The population made must pay attention to the sequence of work elements. In this study using a large population of 3 different. The small size of the population influences the program running process. The size of the population that is too large allows the computing process to last for a long time while the size that is too small causes the search for space to be wide so the opportunity to get a good solution is very small. The following is the initial population in this study.

```
Populasi = [
1 2 3 4 5 6 ...
7 8 9 10 23 24 ...
25 26 27 28 12 13 ...
14 11 15 16 17 18 ...
19 20 21 22 33 29 ...
30 31 32 34 54 55 ...
56 57 35 50 51 52 ...
53 36 38 42 39 43 ...
40 44 41 45 37 46 ...
48 47 49 58 59 ;
1 2 3 4 6 7 ...
8 5 23 24 9 10 ...
25 26 27 28 12 13 ...
```

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Figure 3. Initial Population

2. Probability of crossover

   The use of crossover probabilities depends on the system design user. In this study the probability of 0.98 was used.

3. Available time

   Available time is effective working hours per day. Input available time on this program is 360 minutes or 6 hours. This program is also designed to find out the swing frame output that is produced.

4. Task time
   Task time contains the processing time of each element of work. The following task time is inputted into the program.

```
TaskTime = [15; 15; 20; 12; 12;
 5; 20; 20; 5; 5;
 2; 10; 10; 18; 21;
 21; 21; 21; 21; 21;
 5; 6; 30; 15; 30;
 5; 5; 5; 10.02; 2.75;
 4.98; 4.98; 15; 3; 3;
 3; 3; 3; 3; 3;
 3; 3; 3; 3; 3;
 3; 3; 3; 3; 3;
 3; 3; 3; 3; 3;
 3; 3; 1.2; 10]; % Waktu elemen pekerjaan
```

Figure 4. Task Time

5. Stopping Criteria

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The algorithm ends after a certain number of iterations. The research conducted by Erel and Tanyer used values of 500, 1000 and 2000 for the number of iterative parameters.

Result Program Genethic Algorithm Using Matlab

Performance Indicator

After calculating and running the program in matlab the results of the assembly line performance indicators are obtained which will be compared with the actual conditions to determine the changes in the performance of the assembly line. In this study, several experiments were conducted, namely the proposal of 1 workstation in achieving the company's takt time of 667.78 minutes, an increase in demand of 20% and the last experiment was the number of fixed workstations. The following is a table of comparison of actual and proposed assembly line performance indicators.

Table 4. Comparioson of Proposed and Actual Performance Indicators

Indicator	Actual	Proposal		
		Takt time of company	Increasing demand 20%	Fixed station
Line Efficiency	42%	100%	100%	98,65%
Balance Delay	58%	0%	0%	1,35%
Smoothess Index	408,83	0	0	4,64

Based on table 4, it can be seen as a whole that there is an increase in line efficiency between actual and some proposed program results. In addition, the balance delay and smoothess index values fall. This shows that the proposed assembly line is better because the allocation of workload is evenly distributed so that leisure time can decrease and assembly lines can run more smoothly.

In achieving the company's takt time, the proposed line assembly line efficiency has increased by 58% compared to the actual assembly line. The value of balance delay and smoothess index decreased to 0. In the condition of a 20% increase in demand, the assembly line has 100% line efficiency in achieving the new company takt time. Balance delay and smoothes index have a value of 0. In the condition of the number of fixed workstations, the line efficiency of the proposed assembly line has a higher value than the actual assembly line which is equal to 98.65% and has increased by 56.65%. The value of balance delay and smoothess index decreased to 1.35% and 4.64.

Output Results of Various Conditions

This study conducted experiments on three conditions including based on company takt time, increased demand and the number of fixed workstations. This has an impact on assembly lines such as the number of workstations, cycle times and assembly capacity which will be explained as follows.

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Table 5. Result Program

Condition	Number of *workstation*	Cycle time (minute)	Assembly capacity (unit)
Takt time of company	1	667,78	1
Increasing demand	1	553,67	1
Fixed station	4	131	3

Based on table 5, the condition of the proposed assembly line in achieving the company's takt time requires 1 workstation with a cycle time of 667 minutes and produces 1 unit per day. In the condition of a 20% increase in demand, the number of workstations needed is 1 workstation with a cycle time of 556.48 minutes and produces 1 unit per day. While the condition of the number of workstations still has a 131 minute cycle time and produces 3 units per day. In actual conditions the assembly capacity can only produce 1 unit of swing frame in a day. This is due to a decrease in cycle time so that it can increase the production rate. Therefore, the expected cycle time to be implemented is 131 minutes because it can increase the assembly capacity to 3 units per day with the number of fixed workstations.

4. CONCLUSION

Based on the results of data processing in this study the conclusions are as follows.

1. The actual swing frame assembly line with 4 workstations has a line efficiency of 42% and balance delay of 58% and smoothess index of 408, 83. After balancing the assembly line with the number of fixed workstations, the line efficiency is 98.65% and balance delay down to 1.35% and the smoothess index to 0. This indicates that the proposed assembly is better because the line efficiency has increased and the value of the balance delay and smoothess index has decreased. Then in the condition of achieving company takt time and based on the increase in demand, line efficiency has a value of 100% and balance delay 0% and smoothess index is 0.

2. The experiment of this study was carried out in 3 conditions, namely based on takt time and a 20% increase in demand which requires 1 workstation and produces 1 unit. Then in the condition of the number of fixed workstations, the assembly line produces 3 units which have increased from 1 unit. This is due to a decrease in cycle time so that it can increase the production rate.

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