JOB SHOP SCHEDULING AT IN-HOUSE REPAIR DEPARTMENT IN COLD SECTION MODULE CT7 ENGINE TO MINIMIZE MAKESPAN USING GENETIC ALGORITHM AT PT XYZ

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ABSTRACT

PT. XYZ is an aircraft manufacturer that was established to facilitate in terms of maintenance of aircraft engines and industrial machinery which are owned by Indonesia.Based on historical data, PT XYZ has FCFS scheduling type which is conducted by in-house repair department. This research aim is to make an improvement to machine scheduling becomes job shop scheduling using genetic algorithm to minimize makespan of existing scheduling. In conclusion, calculation of makespan, fitness, and utilization of each machine then obtained an improvement scheduling to minimize makespan until 54.5 hours or by 64.38% of the existing condition.

Key words: FCFS, Job Shop Scheduling, Genetic Algorithm, Makespan

1. INTRODUCTION

PT XYZ is a company which focus in the field of maintenance services for turbine engines in aircraft and industrial. Products of PT XYZ is a service which are inspection, modification, repair and overhaul for aircraft turbine engines. Aircraft turbine engines is one of the main components of the aircraft were used as propulsion. Each aircraft at least used a single turbine engine as propulsion and the others uses two turbine engines. Increasing the number of aircraft used will certainly be marked by an increase the amount of use of a turbine engine, the increased demand for turbine engine repair services to ensure readiness in aircraft turbine engines, and flight safety assurance. The increased demand for repair services for aircraft turbine engines, the PT XYZ demand to give products and services of good quality, competitive price in the market and are always trying to ship the order to the customer on time.

PT XYZ services capable for many engines which are CT7, CT7 (PGB), DART7, JT8D, M250, M250 (TRB), PT6, PT6A, PT6T, TAY, and TPE. Figure 1 depicts that an engine type CT7 is an engine which frequently repaired or maintained in PT XYZ.

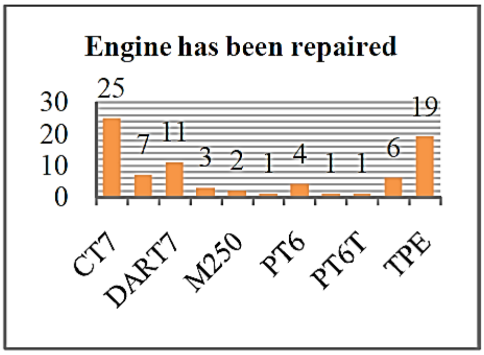

Figure 1. The amount of engine which is arrived at PT XYZ on February 2014 until June 2015 (Source: PT XYZ, 2014)

After going through the overhaul stages, there was the gap between the TAT MPS (Turn Around Time) which has been planned with TAT ACT (Turn Around Time). TAT MPS is lead time that has been scheduled by the companies to accomplish the whole process of service and TAT ACT is real or actual lead time that has been used to accomplish the whole process of service.

Based on Figure 2, it depicts that of all four CT7 engine serial number cannot meet the repair processing time predetermined by the production manager and the customer, resulting in a relatively large gap which causes delay delivery order to the customer.

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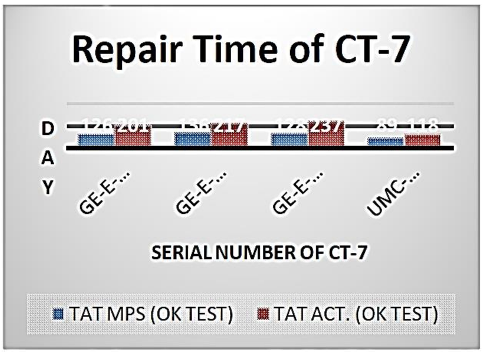

Figure 2 Gap between TAT MPS and TAT ACT in repair process for engine CT7 on March until Mei 2014 at PT XYZ (Source: PT XYZ, 2014)

So there is the problem in repair process of CT7 engine at PT XYZ. Many lateness and many demand in CT7 engine become the reason taking the CT7 as the object of this research. Repair process in PT XYZ conducted depending on the type of engine so there is the problem in CT7 operator team when do the repair process to the engine.

CT7 engine consists of several modules which are propeller gearbox, hot section module, accessory section module, cold section module, and power turbine module. Each module consists of many part. In this research, the object will be focused in cold section module because there are many parts that have high probability to be repaired in PT XYZ compare with other modules. If there are parts will be repaired in another module except cold section module in PT XYZ, they will be done in some method with the cold section method.

Table 1 Root Cause Contribution

AERO Production Review		
Root Causes Contribution		**%**
Material	17	**68%**
Operation	10	**40%**
CSP	1	**4%**
Business	4	**16%**
Quality (RTS Engine)	1	**4%**
Total Engine	25	1.32

Delays in delivery order to the customer can be caused by several root of the problem. Table 1 shows percentage contribution of the root causes based classification has been done by PT XYZ. There are some root causes which are Material, Operation, CSP, Business, and Quality (RTS Engine). The first root causes are material which has been solved in another research. The second root causes are operation which will be discussed in this research. The elements involved in operation problems which are operator, maintenance of machine, material, part, component, scheduling of repair and engine as the object to be handled.This research will focus on the scheduling engine or workcenter in-house repair.

Based on the problems of delay and lack of scheduling on the part at in-house repair, it is needed a method to determine the exact scheduling workload and the order of each machine or workcenter with makespan minimization criteria. Selection criteria of scheduling to minimize makespan, it because makespan is the total time for completion of works ranging from the first sequence which is done on a first machine or first work center until last work on the last machine or last work center(a). Makespan calculation means has calculated processing time, flow time, and idle time. After finishing work with makespan that has been minimized by scheduling, PT XYZ can reduce the number of lateness or delay of delivery order of the engine and the operator can do other work or allocated to other department that need.

2. THEORETICAL BACKGROUND

2.1. Scheduling

Scheduling is the process of manufacture or workmanship sort an overall product that worked on some machines or workcenter(a). So scheduling is the process of finding the appropriate sequence of operations of some job which to be done on the machine or workcenter existing or limited.

2.2. Job Shop Scheduling

Job Shop Scheduling is a scheduling to handle the variety of products that a lot of the process with different flow, machine or workcenter used jointly by a variety of processes and jobs that exist have a process flow that is free or has different priority process flow. Those things that make the job shop scheduling has a lot of possibilities for any combination of loading tasks to each machine or workcenter (loading) and the sequence of each job process (sequencing)(a). The job shop is a set of machines and workers who use the machines. Jobs may arrive all at once or randomly throughout the day. The relevant characteristics of the sequencing include(c):

- The pattern arrivals
- Number and variety of machines
- Number and types of workers
- Patterns of job flow in the shop
- Objectives for evaluating alternative sequencing rules

2.3. Genetic Algorithm

The genetic algorithm is a heuristic method was first developed by John Holland in 1970 in New York, United States. Genetic algorithms are a sub-class of evolutionary algorithms that have individual representation of binary strings. Genetic algorithm is a global optimization method based on simulation of evolution which simultaneously evaluates a lot of value in the solution space, and this algorithm is much convergence global solutions. In a genetic algorithm, a set of variables to the problem given encoded into a string resemble natural chromosomes. Each string contains an optimal solution to the problem(e).

Naturally all organisms are composed of cells, within each cell consists of a set of chromosomes. Chromosomes are formed of a set of genes, creating a unity that is arranged in a linear sequence. Each gene has its own location in the chromosome, called a locus. Genes are made of DNA that carries the properties of descendants. Each gene encodes a specific protein trait. Certain parts of the genes in the genome is called genotype. Some trait that showed differences are in the genes and different parts are called alleles(e).

3. RESEARCH METHOD

This research begins by defining the input parameters which are the number of types of machines or workcenter, the amount of job, processing time, and the amount of each job operations. Parameters such as the number of machines or enter workcenter to be used and the number of the type of job is done, and the number of operations of each job will be encoded into the genes in the chromosomes. In data processing, the number of genes will be input for the Genetic Algorithm, in accordance with the probability of crossover, probability of mutation, maximum generation and the size of the population. Processing time will be used to decode so as to produce a new machine scheduling. From a new machine scheduling, it will be able to calculate the total makespan. The amount of job operations will be the constraints for each operation of jobs.

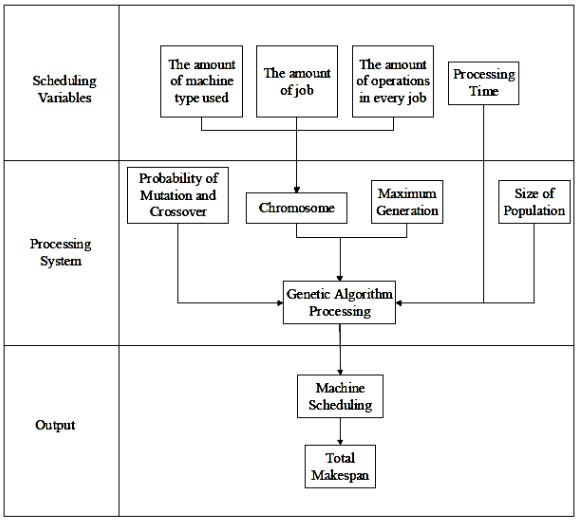

Figure 3. Conceptual Model

The following predetermined statement are made in in this paper:

- CT7 engine repair process is sequential.
- Module engine is cold section modules.
- Using Matlab software in the process of iteration.
- The processing time of each machine deterministic (not using the element of probability).
- Data to be processed is the historical data from 2014 and includes machine types, job number, type of job, and the job order.
- The amount of each type machine is one and each machine can only execute one operation at a time
- All machines are available at time t=0 s.

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- All jobs are released at time t=0 s.
- Jijj : job i and operation jj.
- Transportation or repositioning time and layout are ignored.

4. RESULT AND DISCUSSION

4.1. Existing Data

The sample data that is used in this research is showed in Table 2. The demand arrived on September 11st 2015. PT XYZ used FCFS (First Come First Serve) rule when make the schedule to completed all demand. It is showed in Figure 4. The makespan of existing repair process is 84,65 hours. The sequence of operation when do the repair process is depending on job which come at the first time. So the second job and the others should wait until the first job is completed.

Table 2. Part Has Been Repaired

No	Part Name
1	Case Compressor
2	Ring Stg 2 Vane Actuating
3	Centrifugal Impeller
4	Blade Disk Stg 5 Comp
5	Scroll Case
6	Nut Comp Tie Rod
7	Blade Disk STG 3 & 4 Comp. RTR
8	Blade Disk Stg 5 Comp

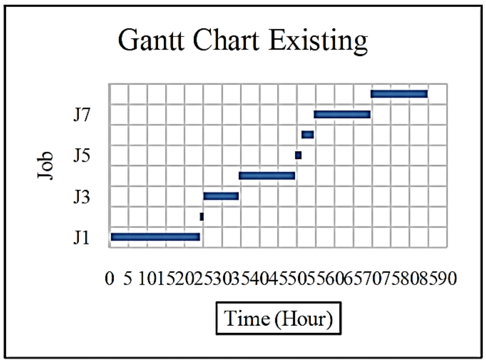

Figure 4. Existing Gantt Chart

4.2. Optimization of Job Shop using Genetic Algorithm

Optimization job shop scheduling is a type of optimization that concern with the precedence constraint. So it will be the input to be processed using genetic algorithm so do processing time and the amount of machines or workcenters. That inputs will be represented in genetic algorithm. Table 3 will show the representated data form job shop scheduling problem to genetic algorithm rule(e).

After job shop scheduling is represented in genetic algorithm, the inputs and parameter will be run in matlab program. The flow of process genetic algorithm is showed in Figure 5. The flow process of genetic algorithm will be explained as follows.

Table 3. Representation of Job Shop Scheduling in Genetic Algorithm

Evolution Theory	Job Shop Scheduling	Genetic Algorithm
Gen	Operations and Jobs	Coding scheme
Chromosome/Individual	Sequence of operations	Solution
Population	Types of operation sequence combinations	Population of solution
Environment	Makespan	Objective Function

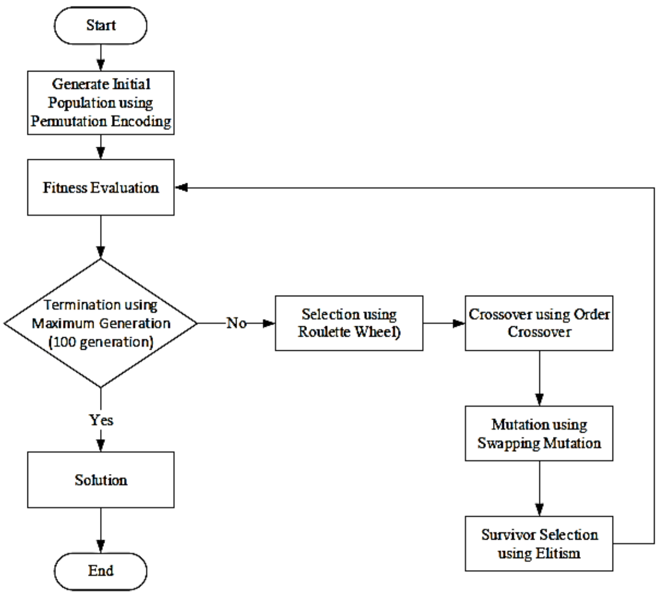

Figure 5. Flow Chart of Genetic Algorithm

4.2.1. Generate Initial Population

Before initiate the population, the first step is generate the chromosome through permutation encoding(d). Genes which is generated in every chromosome is permutation from number 1 until 123. Number 1 until 123 is gotten from the amount of operations from first job until eighth job.

4.2.2. Fitness Evaluation

The objective function of job shop scheduling problem in this research is makespan so makespan will be criteria which is used in counting the fitness value each of chromosome. This research objective is minimize the makespan so function of fitness is one divided by makespan (b).

$$Fitness = \frac{1}{makepan} \quad (1)$$

4.2.3. Selection

Parent selection is the step to select the chromosome which will be used to do the crossover operation. The selection is done by roulette wheel selection. Roulette wheel selection process is same like the roulette wheel in real life. The whole chromosomes get the pieces in wheel according to their fitness value. Higher fitness value which are had by the chromosomes, bigger pieces proportion that can they get. The range of value is 0 until 1. Then, the random number will generate to select the chromosome according to piece that each chromosome get. Finally, the chromosome which has been selected will be done the crossover operation to them.

4.2.4. Crossover

Crossover operation objectives is to get the best chromosomes from their parents. Best chromosomes will direct to the result of the objective. Method of crossover operation will be used is order crossover(d) where the crossover according to order or sequence of genes in chromosome. The first and chromosomes will be splitted in to two section, then the first chromosome will get one section of second chromosome so do second chromosome. The parent of chromosome which will be done the crossover operation is selected from random number. Every chromosome will get the random number, then the chromosome which get the number more than probability of crossover, will not be crossed with the others. The chromosome which get less random number from probability of crossover, it will be crossed with others. The probability of crossover is 0,8. Finally the genes will be same but they has different sequence or order.

4.2.5. Mutation

The method of mutation is swapping mutation. This method will be generated the random number in every genes. If the their random number is less than probability of mutation, the genes will be swapped with the other genes. The probability of mutation is 0,1. The result of mutation will be same with the previous chromosome but different sequence of genes.

4.2.6. Termination

The termination criteria which is used in this research is maximum generation. The maximum generation is 100. After get the 100th generation, the iteration will be terminated and the last chromosome, hopefully the chromosome which can solute the objective function. There are two types of termination, first, set the fitness value, second, set the maximum generations.

4.3. Experimental Results

The job shop scheduling result will generate different fitness value, routing job or sequence of operation and total makespan. So it makes many posibilities of job shop scheduling result. In this research, job shop scheduling using genetic algorithm in Matlab will be done in 30 times experiments which can generate some result and some best solution. Table 4 shows 30 experiments has been done in Matlab.

The optimum solution from 30 times experiments is 21st experiment. On its experiment is generated 30,15 hours as lowest makespan and 0,0332 as the highest

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fitness value. After do the selection in 20 populations and 100 generations then the chromosome that generate the optimum makespan as follows (from left to right):

1	7	1	7	8	3	1	5	4	6
1	8	2	8	4	7	1	1	2	3
3	8	3	3	7	5	8	1	7	4
1	4	8	3	8	7	8	4	4	1
7	8	2	7	6	5	8	6	7	4
8	3	7	4	1	8	1	4	4	8
8	3	8	7	4	4	2	3	4	1
1	5	6	1	1	7	4	8	4	8
7	4	3	4	1	1	4	1	1	3
4	1	3	3	7	4	7	1	3	8
7	3	8	5	4	2	7	7	1	4
1	8	1	8	6	7	7	7	5	8
1	2	7							

Table 4. Genetic Algorithm Experiments

No	Experiment	Fitness Value	Makespan (hours)
1	Experiment 1	0,0327	30,55
2	Experiment 2	0,0327	30,55
3	Experiment 3	0,0322	31,1
4	Experiment 4	0,0329	30,35
5	Experiment 5	0,0324	30,9
6	Experiment 6	0,0324	30,9
7	Experiment 7	0,0329	30,4
8	Experiment 8	0,0327	30,55
9	Experiment 9	0,0327	30,55
10	Experiment 10	0,0322	31,1
11	Experiment 11	0,0327	30,55
12	Experiment 12	0,0327	30,55
13	Experiment 13	0,0322	31,1
14	Experiment 14	0,0327	30,55
15	Experiment 15	0,0329	30,35
16	Experiment 16	0,0329	30,35
17	Experiment 17	0,0324	30,85
18	Experiment 18	0,0326	30,7
19	Experiment 19	0,0327	30,6
20	Experiment 20	0,0331	30,25
21	Experiment 21	0,0332	30,15
22	Experiment 22	0,0326	30,65
23	Experiment 23	0,0331	30,25
24	Experiment 24	0,0328	30,45
25	Experiment 25	0,0328	30,45
26	Experiment 26	0,0324	30,85
27	Experiment 27	0,0329	30,4
28	Experiment 28	0,0328	30,5
29	Experiment 29	0,0326	30,65
30	Experiment 30	0,0326	30,65

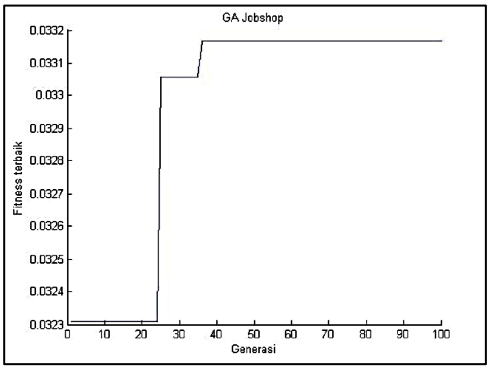

Figure 6. Fitness Value Graphic in 21st experiment

4.4. Analysis

Comparison between existing and proposed scheduling are shown in Table 6 and Table 7. There show the makespan of existing scheduling is 84,65 hours and makespan of proposed scheduling is 31,15 hours. The proposed scheduling can decrease the makespan until 54,5 hours from existing scheduling or in percentage, it is 64,38%. The makespan is occured in Machine 2.

In utilization of machines, the proposed scheduling can improve the percentage of utilizations in many machine but there are the decreasing percentage of machine utilization that happened in Machine 3, Machine 6 and Machine 7. Percentage of Machine 11 utilization increase from 11,54% to 91,24%. It is occurred because of the sequence of operation that change from existing to proposed. The decreasing and increasing value of machine utilization is occurred because the differences of flow process or routing job each operation in job shop scheduling. In summary the changes of flow process or sequence in job shop scheduling determine the makespan and machine utilization.

Table 6. Existing Scheduling Result

Machine	Existing Scheduling			
	Total Processing Time	Total Idle Time	Total Time	Utilization (%)
M1	1,6	82,95	84,55	1,89%
M2	0,8	83,85	84,65	0,95%
M3	2	19,5	21,5	9,30%
M4	1,25	82,45	83,7	1,49%
M5	12,5	70,4	82,9	15,08%
M6	1	19,45	20,45	4,89%
M7	1	26,8	27,8	3,60%
M8	7,5	70,15	77,65	9,66%
M9	2,25	75,65	77,9	2,89%
M10	8,6	75,85	84,45	10,18%
M11	6,25	47,9	54,15	11,54%
M12	24,25	59,7	83,95	28,89%
M13	1,6	29,45	31,05	5,15%
M14	7,75	76,45	84,2	9,20%
M15	3	71,65	74,65	4,02%
M16	3,3	72,35	75,65	4,36%
Makespan	84,65 hours			

*time in hours

Table 7. Proposed Scheduling Result

Machine	Proposed Scheduling			
	Total Processing Time	Total Idle Time	Total Time	Utilization (%)
M1	1,6	28,45	30,05	5,32%
M2	0,8	29,35	30,15	2,65%
M3	2	24,25	26,25	7,62%
M4	1,25	27,95	29,2	4,28%
M5	12,5	15,9	28,4	44,01%
M6	1	24,6	25,6	3,91%
M7	1	27,9	28,9	3,46%
M8	7,5	12,4	19,9	37,69%
M9	2,25	12,5	14,75	15,25%
M10	8,6	21,35	29,95	28,71%
M11	6,25	0,6	6,85	91,24%
M12	24,25	5,2	29,45	82,34%
M13	1,6	11,65	13,25	12,08%
M14	7,75	21,95	29,7	26,09%
M15	3	6,35	9,35	32,09%
M16	3,3	7,05	10,35	31,88%
Makespan	30,15 hours			

*time in hours

5. CONCLUSION

Implementation of Genetic Algorithm approach in Matlab with the inputs are the amount of machine or workcenter, the amount of machine type, processing time, maximum generation is 100 generations, size of populations is 20 chromosomes, mutation probability is 0.1, crossover probability is 0.8 and considerations to machine utilizations, it is generated the new scheduling to do the repair process of cold section module of CT7 engine at PT XYZ. The proposed scheduling has 31,15 hours as the makespan and 0,0332 as the fitness value. The improvement scheduling can minimize the existing makespan from 84,65 hours to 31,15 hours. Then the proposed scheduling that using Genetic Algorithm in repair process in cold section module of CT7 engine at PT XYZ can minimize makespan by 54,5 hours or 64,38% from existing condition.

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