PRODUCTION SCHEDULING OPTIMISATION USING GENETIC ALGORITHM IN PT. PROGRESS DIECAST

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ABSTRACT

In order to maximise customer order satisfaction, PT. Progress Diecast as a diecast manufacturer of automotive components requires a robust production scheduling system. Recently, this company faces some problems such as production lateness that consequently increases the production cost. The aim of this research is to optimise production scheduling in PT. Progress Diecast by comparing two methods that are: Campbell, Dudek and Smith method and Genetic Algorithm method. The optimum scheduling will help the company to determine the optimum job sequences that can minimise makespan and mean flow time. The output of this research is a scheduling program application using MATLAB software. The results indicate that Genetic Algorithm produce the optimum scheduling results as compared to the actual method which First In First Out (FIFO) and Campbell, Dudek and Smith method. Genetic Algorithm can minimise makespan to 78.136 days and mean flow time to 43.7897 days, while using Campbell, Dudek and Smith method the makespan is 84.47 days and mean flow time is 45.076 days,

Key words: *Scheduling, Genetic Algorithm, Campbell Dudek and Smith*

1. INTRODUCTION

Manufacturing industry in Indonesia has grown very rapidly especially in the automotive and automotive components industry. The increase in the number of automotive vehicles demand in domestic market is one factor that stimulates the growth in this industry.
In order to provide best services to the customer, PT. Progress Diecast as an automotive component manufacturer needs to satisfy customer requirements by providing best cost, quality and time delivery. However, there were some problems such as the limitation of number of machines and order differentiation between one customer and other customer that often leads to the company failed to deliver customer order on time. To overcome this problem, an optimum production scheduling system plan is required.

Scheduling is a sequencing of some job orders to some machines (Baker, 1974). A limited number of resources sometimes lead to a difficulty in determining job sequences. As a consequence, machine utilization is low and sometimes there are some idles in some machines. This situation will cause production lateness and fail to satisfy customer due date.

Some previous research on production scheduling has been conducted by using different scheduling methods. Genetic Algorithm is one method that can be applied to develop an optimum scheduling system besides other techniques such as Campbell, Dudek and Smith. Genetic Algorithm can solve a complex scheduling problem with a lot of number of jobs and many resources faster and accurate. Some previous research that use Genetic Algorithm such as: scheduling optimisation in a knitting factory (Marleen Tatiana, 2010) and flow shop scheduling (Satriawan Nedi, 2010).

The aim of this research is to develop an optimum production scheduling system in PT. Progress Diecast by comparing two methods which are Campbell Dudek and Smith and Genetic Algorithm.

2. THEORITICAL BACKGROUND

2.1. Scheduling

The objectives of job scheduling and sequencing are as follow:

1. To increase machine productivity by reducing machine idle time.
2. To minimise work in process inventory by reducing the number of jobs that are waiting in a machine que.
3. To minimise the production cost.

Some terminations in scheduling (Bedworth, 1987) are as follow:

a. Processing Time (tj) :
time that is required to do an operation process of a job in a machine.

b. Due Date (dj) :
a maximum time limitation to finish a job.

c. Lateness (Lj) :
A difference between a completion time and due date.
Lj = Cj – dj (1)
A job will have a positive lateness if completion time is greater than due date and has a negative lateness if completion time is less than due date.

d. Tardiness (Tj) :
A job with a negative lateness will have zero tardiness. As opposite, a job with positive lateness will have a positive tardiness.
Tj=max{Lj,0} (2)
Tj = 0 if Lj > 0
Tj = 0 if Lj < 0

e. *Slack* (SLj) :
Remaining time that is available to finish a job.
SLj=dj-tj. (3)

f. *Completion Time* (Cj) :
Time range between the job is started (t=0) and until the job is finished or time that is required to finish all the jobs *order* j.
Cj= t1 + t2 +…+ t_j (4)

g. Flow Time (Fj) :
Time range between the job is available to be processed and the job is finished.
Fj = Cj – rj (5)

The performance of scheduling is evaluated by 2 criteria as follow (Kusiak, 1990) :

a. *Makespan*
Cmax = max {Cj} . (6)

b. *Mean flow time*
$$F = \frac{1}{n}\sum_{j=1}^{n} F_j \quad . \qquad (7)$$

2.2. Campbel, Dudek and Smith Method (CDS)

Campbell, Dudek, Smith (CDS) method was introduced in 1970. This method is an extension of Johnson rule that is used to solve scheduling problem with m machines (i=1, 2,…., m). If there are n jobs, (j = 1,2,...,n), then K iteration will be performed to determine:

t'j1 = number of processing time for job j at first machine.
t'j2 = number of processing time for job j at last machine.

After m-1 iteration, a schedule that has the best makespan is chosen from m-1 schedules that are obtained. In general CDS algorithm is as follow:

1. Start from K = i = 1
2. Determine for job j, whereas j = 1,2,3,...,n.

$$t_{j1} = \sum_{k=1}^{i} t_{jk}$$

And

$$t_{j2} = \sum_{k=1}^{i} t_{j,m-k+1}$$

3. Apply Johnson algorithm for problem with two machines and determine makespan from the results.
4. If k = m-1, then find the best scheduling result with the best makespan and stop iteration. If the best result is not achieved, continue iteration to K = i+1 and turn to step 2.

2.3. Genetic Algorithm (AG)

Genetic Algorithm is developed by John Holland in 1960. This method is an evoluationary computation algorithm that has objective to model adaptation capability of a system, for example in production scheduling system. Scheduling procedure with Genetic Algorithm is as follow :

1. Initiation is a step to define fitness (objective function), problem constraints and number of initial population. The generation of initial population is conducted by generate some chromosomes. Each chromosome

consists of individual genes that represent each input variable.
2. Fitness value is evaluated for each chromosome in initial population.
3. Selection process is performed by selecting some best chromosomes called elite chromosomes. Elite chromosomes directly enter to the next generation. Other chromosomes in the next generation are produced by crossover and mutation process.
4. Crossover is gene changes between two chromosomes (parents) to produce off springs (child). Chromosomes that will be crossover have random number generated during crossover is less than crossover probability (pc). Some cross over methods are: one point cross over, two point crossover, order crossover and etc.
5. Mutation is process to develop offspring by change a gene from one parent. This process will reconstruct genes in each chromosome. Individual gene that will be mutation is a gene that has random number generated during mutation is less than mutation probability (pm).
6. One criteria to stop iteration is based on parameter number of generation that is initially defined. If iteration exceeds parameter number of generation then the iteration process will be stopped.
7. The best chromosome is chosen among chromosomes that produce the best fitness.

3. RESEARCH METHOD

Research was conducted in PT. Progress Diecast that is located in East Jakarta Industrial Park from November to December 2011.

Primary and secondary data are collected based on direct observation and interview with production personells. Data that were collected such as: existing scheduling system in PT. Progress Diecast, process flow, number of machines, standard processing time and set up time in each machine, number of job orders in observation period,

Scheduling model is constructed by comparing 3 (three) methods, which are: First In First Out (FIFO) as the existing scheduling system, Campbell, Dudek, and Smith method and Genetic Algorithm.

Genetic Algorithm procedures are as follow:
1. Define number of jobs, number of machines, processing time for each machine.
2. Initiation process: define fitness function, constraint and number of initial population.
3. Fitness value is evaluated for each chromosome.
4. Select 10 elite chromosomes as best chromosomes from the population.
5. Construct crossover by using order cross over method.
6. Develop mutation process.
7. Calculate fitness value for new offsprings that are produced from crossover and mutation. Select chromosomes with the best fitness to enter the next generation.
8. Generation will continue until number of generation parameter (N) is reached. The best chromosome is selected based on the best fitness criteria.

Genetic Algorithm process flow is depicted in Figure 1.
Fitness function is developed based on two objective functions which are: to minimise makespan and to minimise mean flow time. Two constraints are formulated based on policy in PT. Progress Diecast. Makespan is maximum 86 days, while mean flow time also cannot exceed 61 days. Number of jobs in the observation period is 26 jobs. Using weighting method the multi objective problem is modified into single objective problem by giving weight 0.5 for each objective. The model is as follow:

Minimise: *fitness* = 0.5 * *makespan* + 0.5 * *mean flow time*

Minimise: *fitness* = 0.5 * (max {Cj} + $\frac{1}{n}\sum_{j=1}^{n} F_j$ (8)

Subject to :

Max{Cj} ≤ 86 (9)

$\frac{1}{n}\sum_{j=1}^{n} F_j \le 61$ (10)

1≤ j ≤ 26, j € integer (11)

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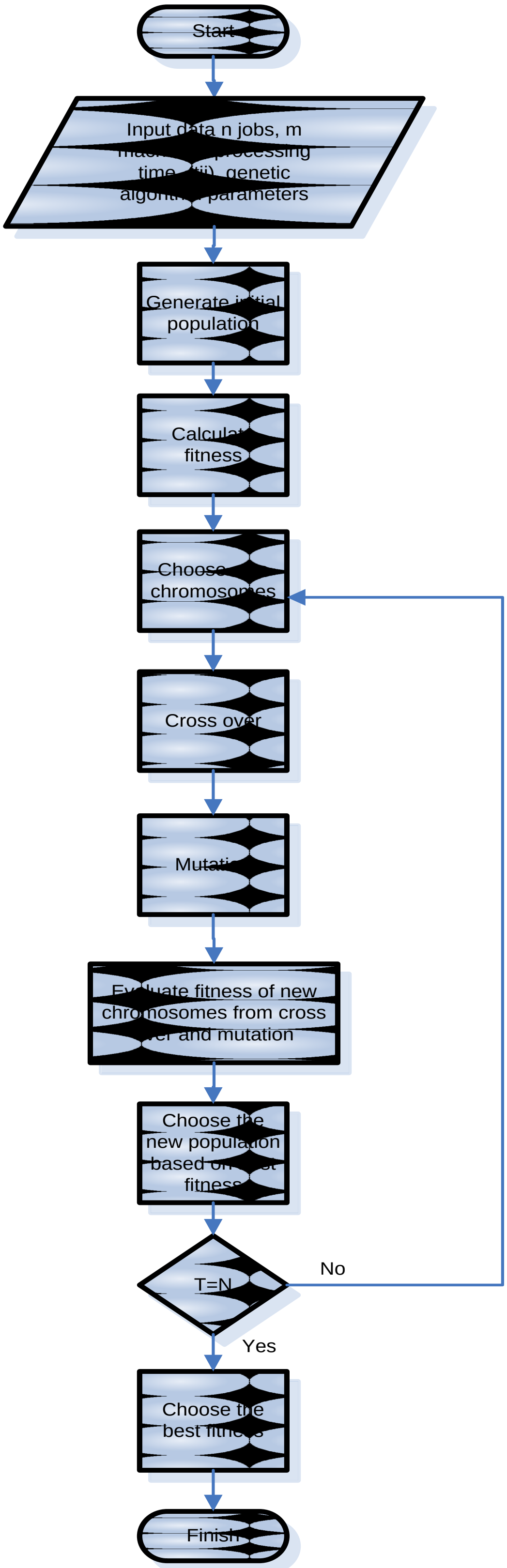

Figure 1. Genetic algorithm procedure

4. RESULTS AND DISCUSSION

Within one month observation period, there were 26 job orders that are required to be scheduled. Cycle time and set up time for each job in each machine can be seen at Table 1. For example, number of order for job 1 is 34512 pieces and process flow of job 1 is through process casting I, deburring, then shot blasting and finally go to visual inspection. Based on cycle time and set up time, process time for job 1 in casting I is 6.033 days, debburing 3 days, shotblasting 1.081 days and visual inspection 4.674 days, etc.

4.1 The Actual Scheduling System

The actual scheduling system in PT.. Progress Diecast use FIFO (*First In First Out)* method. Based on this system, it is obtained that the makespan is 100.387 days and *mean flow time* is 61.103 days for those 26 jobs (see Table 2).

4.2. Campbell, Dudek and Smith method

Based on previous literatures, Campbell Dudek and Smith (CDS) is one best method for scheduling. Table 3 show the scheduling result using CDS method. There are 3 (three) job sequences that have smallest makespan value which are at iteration-2, iteration-5 and iteration-6. The makespan value from CDS is 84.472 days that is lower than the actual system (FIFO). However, this method can only minimise makespan and does not consider other performance criteria such as mean flow time or due date.

Tabel 3. Results from CDS method

K	Makespan	Job sequences
1	84.644	9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24-25-26-4-3-2-1-5-6-7-8
2	84.472	12-11-16-18-21-22-14-15-17-13-23-24-9-10-25-26-19-20-4-3-2-1-5-6-7-8
3	91.040	19-20-4-3-2-1-26-25-9-10-24-23-5-6-7-8-22-21-13-15-17-14-16-18-11-12
4	91.040	19-20-4-3-2-1-26-25-9-10-24-23-5-6-7-8-22-21-13-15-17-14-16-18-11-12
5	84.472	12-11-16-18-14-15-17-13-21-22-23-24-9-10-25-26-19-20-4-3-2-1-5-6-7-8
6	84.472	12-11-16-18-14-15-17-13-21-22-23-24-9-10-25-26-19-20-4-3-2-1-5-6-7-8

4.3. Genetic Algorithm

Genetic Algorithm program for scheduling system in PT. Progress Diecast was developed using MATLAB software. GUI program can be seen in Figure 2. The excellence of Genetic Algorithm as compared to other methods is GA can solve the complex scheduling problem with many variables and constraints more accurately. The optimum sequence is determined based on model that is formulated in equation 8 to 11.

In these equations, the fitness function is to minimise makespan and mean flow time. The model is constrained by makespan is maximum 86 days and mean flow time is maximum 61 days. There are 26 jobs and the order of job in each machine follow the process flow in Table 1.

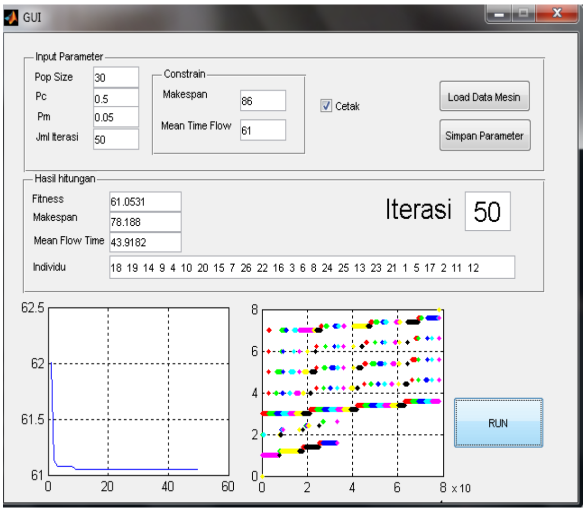

Figure 2. Scheduling program using MATLAB

The set up of parameters of Genetic Algorithm such as number of generation, number of population, cross over and mutation probabilities will influence the results of GA. Therefore, to find the optimum GA parameters, trial and error is conducted by combining some parameters value as follow :

1. Number of generation : 50, 100, 500, and 750.
2. Number of population : 50, 100, 150 and 200.
3. Crossover probability : 0.2, 0.45, 0.65 and 0.8.
4. Mutation probability : 0.01, 0.05, 0.07 and 0.0.9.

To find the best fitness, every combination is repeated 3 (three) times. As searching mechanism in GA is based on random searching, more repetition will lead to more chance to find the best fitness. GA result indicates that the minimum fitness is 60.9628 days. At this fitness value, the minimum makespan is 78.136 days and the minimum mean flow time is 43.7897 days. The minimum fitness that is achieved by GA can be seen in Figure 2.

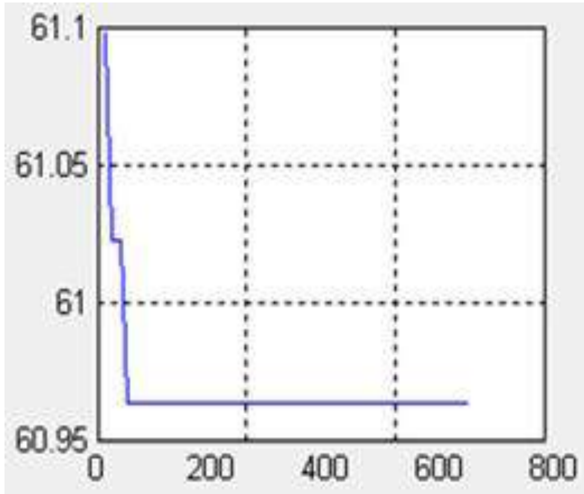

Figure 2. The optimum GA result

The optimum sequence of jobs is : job 11 - 21 - 17 - 24 - 7 - 15 - 23 - 3 - 14 - 8 - 13 - 9 - 1 - 22 - 10 - 26 - 2 - 20 - 6 - 18 – 25 - 4 - 5 - 19 - 16 – 12.. Gantt chart of the optimum job sequences obtaining from GA can be seen at Figure 3.

GA produces the minimum result as compared to the actual method (FIFO) and Campbell Dudek and Smith (see Table 4). By using GA, makespan can be minimised to 78.136 days and mean flow time is minimised to 43.79 days. Genetic Algorithm also reduces total lateness to 41 days, therefore the production cost can be decreased. As a conclusion, Genetic Algorithm is the best method to solve the scheduling problem in PT. Progress Diecast as compared to FIFO and Campbell, Dudek and Smith.

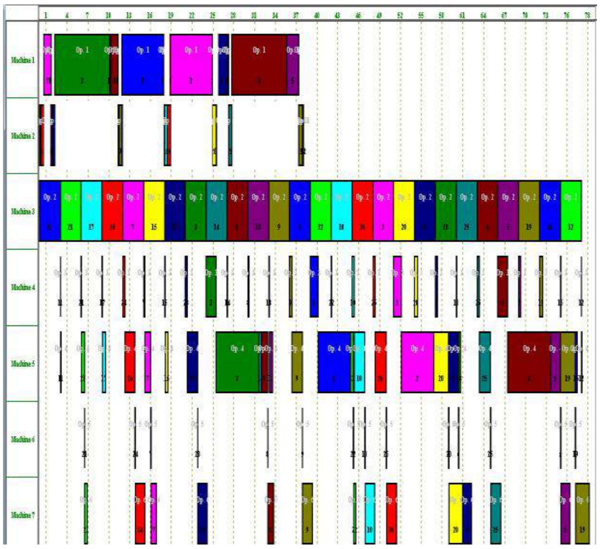

Figure 3. The optimum job sequences from GA

Table 4. Summary of results

Methods	Makespan (days)	Mean flow time (days)	Lateness (days)
FIFO	100.387	61.103	63
CDS	84.472	45.076	47
GA	**78.136**	**43.7897**	**41**

5. CONCLUSION

The actual scheduling system in PT. Progress Diecast that using FIFO method has yet to be optimum. This method leads to the highest makespan dan mean flow time as compared to Campbell, Dudek and Smith (CDS) method and Genetic Algorithm (GA). GA provides the best optimum results in solving scheduling problem in PT. Progress Diecast. GA can minimise makespan to 78.136 days as compared to 100.387 days resulted from FIFO and 84.472 days from CDS method. GA can also minimise mean flow time and lateness to 43.79 days and 41 days. This will lead to an increase in customer satisfaction and a decrease in production cost.

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Table 1. Process time for each job in each machine

Job Order	No of order	Process time (days)						
		Casting I	Casting II	Deburring	Shot-blasting	Reaming	Washing	Visual inspection
1	34512	6.033	0	3	1.081	0	0	4.674
2	34608	6.05	0	3	1.084	0	0	4.687
3	45504	7.942	0	3	1.424	0	0	6.162
4	45568	7.953	0	3	1.426	0	0	6.171
5	9600	1.708	0	3	0.302	1.433	0.07	1.3
6	9600	1.708	0	3	0.302	1.433	0.07	1.3
7	5664	1.025	0	3	0.179	0.846	0.067	0.767
8	5664	1.025	0	3	0.179	0.846	0.067	0.767
9	10080	0	0.392	3	0.317	1.505	0.07	1.365
10	10080	0	0.392	3	0.317	1.505	0.07	1.365
11	480	0	0.058	3	0.017	0	0	0.065
12	456	0	0.058	3	0.016	0	0	0.062
13	3120	0	0.15	3	0.1	0	0	0.423
14	3048	0	0.148	3	0.097	0	0	0.413
15	3072	0	0.148	3	0.098	0	0	0.416
16	1980	0	0.11	3	0.064	0	0	0.268
17	3072	0	0.148	3	0.098	0	0	0.416
18	1980	0	0.11	3	0.064	0	0	0.268
19	14232	0	0.536	3	0.447	2.125	0.073	1.927
20	14280	0	0.538	3	0.448	2.132	0.074	1.934
21	2568	0	0.131	3	0.082	0.383	0.064	0.348
22	2640	0	0.133	3	0.085	0.394	0.065	0.358
23	9648	0	0.377	3	0.304	1.441	0.07	1.307
24	9720	0	0.379	3	0.306	1.451	0.07	1.316
25	10512	0	0.407	3	0.331	1.57	0.071	1.424
26	10560	0	0.408	3	0.332	1.577	0.071	1.43

Table 2. FIFO Results

FIFO	Machine (days)						
Job	1	2	3	4	5	6	7
1	6.033	6.033	9.033	10.114	10.114	10.114	14.787
2	12.083	12.083	15.083	16.167	16.167	16.167	20.853
3	20.025	20.025	23.025	24.449	24.449	24.449	30.611
4	27.978	27.978	30.978	32.404	32.404	32.404	38.575
5	29.686	29.686	33.978	34.290	35.713	35.783	37.083
6	31.394	31.394	36.978	37.280	38.713	38.783	40.083
7	32.419	32.419	39.978	40.157	41.003	41.069	41.836
8	33.444	33.444	42.978	43.157	44.003	44.069	44.836
9	33.444	33.836	45.978	46.295	47.800	47.870	49.235
10	33.444	34.228	48.978	49.295	50.800	50.870	52.235
11	33.444	34.296	51.978	51.995	51.995	51.995	52.060
12	33.444	34.344	54.978	54.994	54.994	54.994	55.056
13	33.444	34.494	57.978	58.077	58.077	58.077	58.500
14	33.444	34.641	60.978	61.075	61.075	61.075	61.488
15	33.444	34.789	63.978	64.076	64.076	64.076	64.492
16	33.444	34.900	66.978	67.042	67.042	67.042	67.310
17	33.444	35.048	69.978	70.076	70.076	70.076	70.492
18	33.444	35.159	72.978	73.042	73.042	73.042	73.310
19	33.444	35.694	75.978	76.425	78.550	78.623	80.550
20	33.444	36.232	78.978	79.426	81.558	81.632	83.565
21	33.444	36.363	81.978	82.06	82.444	82.508	82.856
22	33.444	36.496	84.978	85.062	85.457	85.521	85.879
23	33.444	36.873	87.978	88.281	89.722	89.792	91.098
24	33.444	37.252	90.978	91.284	92.735	92.805	94.121
25	33.444	37.659	93.978	94.308	95.878	95.948	97.372
26	33.444	38.067	96.978	97.31	98.887	98.957	100.387