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IDENTICAL PARALLEL MACHINE SCHEDULING USING GENETIC ALGORITHM TO MINIMIZE TOTAL TARDINESS

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Abstract

in manufacturing operations, fulfilling the demand by the due dates is one way to keep customer satisfaction level. if the demand was delivered after the due dates, the tardiness penalty was occurred due to maintain the customer satisfaction level. scheduling was needed to reduce the tardiness that may occur in manufacturing operations. the production scheduling system in part fabrication is considered parallel machine scheduling due to several machine with same capabilities and characteristic. thus in order to get optimal solution to reduce tardiness, this research used genetic algorithm.

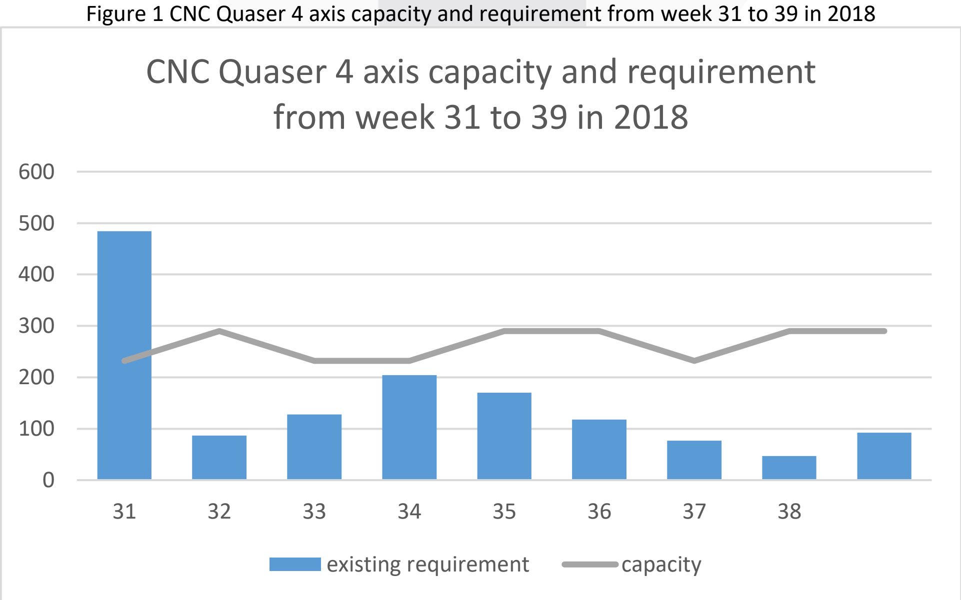
keyword: parallel machine, scheduling, tardiness, genetic algorithm.

1. Introduction

Every manufacturing and service industires have planning to keep their business running and profitable, and one of the main activities in planning stages is scheduling. Scheduling is the process of managing the time and place of operation performed. Scheduling is a decision making process that is used on a regular basis in many manufacturing and services industries with many management level [1].

PT. Dirgantara Indonesia (Persero) have many machine with high capacity which one of them is CNC Quaser 4Axis Machine,it can change any metal blocks into any shape desired with high precision. Machine CNC Quaser 4 Axis process component parts without any further machining processing which makes this machine is can cut multiple fabrication process in multiple machine into one machine and making component parts faster than using multiple machines.Due to CNC Quaser 4 Axis machine capacities which can be see in Figure I-1, this machine had several tardiness problem, the figure I-1 showed that requirement of week 31 are exceeding the capacities due to inaccurate working time between plan and actual. The reason behind inaccurate working time between schedule and actual happened oftenly because there are 2 or more projects that clash schedule between on same machine due to its schedule made in weekly.the other reason is several jobs that passed the its due date are accumulated in next week plan, so its add more time to finish all jobs in corresponding week. Due the problem which stated before, further and more detailed scheduling for this machine to utilization and reducing tardiness are required.

Figure 1 CNC Quaser 4 axis capacity and requirement from week 31 to 39 in 2018



tardy caused by completion times on a job are either before the due dates or exceeds the due dates, when jobs done before its due dates is called earliness and when jobs done exceeds its due dates is called tardiness. Tardiness may caused increased manufacturing cost of the product, the increased cost due tardiness is called tardiness penalties [2]. Tardiness penalties cost incurred from customer losses, damaged reputation, payment delay, and shortages which entails extra costs including late charges, and etc. Table 1 are the tardiness summary data that shows the tardiness that happened in 8 CNC Quaser 4 Axis machine in PT. Dirgantara Indonesia (Persero).

Table 1 Tardiness summary on CNC Vertical Mach. Center Quaser 4 Axis machine on 2018

Machine	job (qty)	tardy jobs (qty)	Tardiness (hours)
1	24	5	528
2	24	4	432
3	24	2	232
4	24	4	248
5	23	3	248
6	23	4	304
7	23	4	280
8	23	4	312

The total tardiness occurred is 2584 hours with the amount of tardy jobs is 20. The highest tardiness occurred in machine number 1 with 528 hours of tardiness and 5 tardy jobs. To minimize tardiness, minimization of tardiness must be done. The scheduling problem is NP-Hard due to many scheduling problems do not have a polynomial time algorithm [3] To solve the parallel machine scheduling problem to minimize tardiness, the proposed techniques is Genetic Algorithm to minimize the tardiness in CNC quaser 4 axis machine.

2. Reseacrh Method

2.1 Parallel Machine Scheduling

Parallel processing scheduling is allocation of jobs which can processed by one from several identical machines, allowing reduction in makespan or tardiness [4].The scheduling of parallel machines has two main step process. First step is to determine which jobs have to be allocated to which machines. Second step is to determine the sequence of the jobs that has been allocated to each machine, with the tardiness or makespan reduction as objective for parallel machine scheduling [3]. The calculation of tardiness of each jobs can be seen in equation (1):

$$T_i = max(0, C_{im} - D_i) \quad (1)$$

Subject to:

$$ST_{1m} = 0 \quad (2)$$
$$ST_{im} = C_{(i-1,m)}\ ;\ i>1 \quad (3)$$
$$C_{im} = ST_{im} + P_i \quad (4)$$
$$P_i = S_i + (R_i \times Q_i) \quad (5)$$

With following definition:

i	Index of job i
m	Index of machine m
ST_{im}	Starting time of job i in machine m
C_{im}	Completion time of job i in machine m
P_i	Processing time of job i
Si	Setup time of job i
Ri	Machining runtime of job i for one pieces
Qi	Quantity pieces requirement of job i
T_i	Tardiness of job i
C_i	Completion time of job i
D_i	Due date of job i

Parallel machine scheduling problem is development from the detailed single machine scheduling which parallel machine has more wider scope of the problem. The parallel machines scheduling problem are classified into three main cases based on the type of the machine, which is unrelated, uniform or identical parallel machines scheduling problem:

1. Unrelated parallel machine scheduling
There is no relation between the processing times of the jobs and machines in unrelated parallel machines. This may be due to technological differences of the machines, different features of the jobs, etc.
2. Uniform parallel machine scheduling
Uniform parallel machines scheduling has characteristic which each machine has different time to finish same process. The speed different of each machine differs by a constant factor for the individual machines.
3. Identical parallel machine scheduling
The characteristic of identical parallel machine scheduling, every machine can working same jobs with same processing time [5] ,due to same setting and capabilities of each machine.

2.2 Genetic Algorithm

Solving NP-hard discrete optimization problems to optimality is often an immense job requiring very efficient algorithms, genetic algorithm (GA) may be one of efficient algorithm because GA are very effective at performing global search for combinatorial optimization such as parallel machine scheduling problem [6] GA has several steps to find optimum solution which can be seen in Figure II-1. The detailed how GA works in each step to find optimum solution as follow [7]:

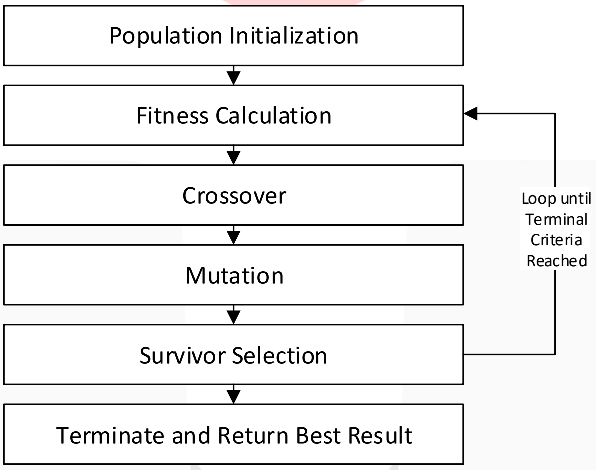


Figure 2 Genetic Algorithm Flowchart *[7]*

1. Population Initialization
Generate random population of n chromosomes. A population is composed of chromosomes where each chromosome represents one potential solution [8].
2. Fitness Functions
Evaluate the fitness f(x) of each chromosome x in the population. Fitness value is a measure of how well the individual optimizes the function. The fitness value calculation for this research is using equation 6 to minimize total tardinesswhich can be seen below:

$$Fv = \sum Ti \quad \text{……(6)}$$

Subject to:

$$T_i = max\,(0, C_{im} - D_i) \quad \text{……(7)}$$

$$\sum_{i=1}^{M} \sum_{k=1}^{i} U_{(i,m,x)} = 1 \quad \text{……(8)}$$

$$\sum_{k=1}^{i} U_{(i,m,x)} = 1 \quad \text{……(9).}$$

With following definition:

i	Index of job *i*
m	Index of machine *m*
T_i	Tardiness of job *i*
C_{im}	Completion time of job *i* in machine *m*
D_i	Due date of job *i*
Fv	Fitness Value

3. Crossover
   Crossover is process to produces two new chromosomes which called offspring based two previous generation of chromosomes which called parent. By copying selected bits from each parent, then the selected bits form two new chromosomes called offspring with bits of parent chromosome is in new position .
4. Mutation
   Mutations is process to produces offspring from a single parent. In particular, the mutation produces small random changes to maintain the diversity of population by choosing the bit string at random, then changing its position.
5. Survivor Selections
   Survivor selections is process to select several elitist chromosomes as in current population for parents in next generations. The selections of chromosome is based on fitness value of each chromosome has.
6. Terminate and Return Best Result
   When the GA reach specific number of iterations, the optimum solutions are the chromosomes in the last iteration with highest fitness value, thus ending the GA iterations.

3. Calculation Result

3.1 Existing Schedule

Due to same machine type which is CNC Quaser 4 axis, the parallel machine scheduling type is identical. In Table 2 shows the existing tardiness:

Table 2 CNC quaser 4 axis machine workhours and tardiness

Machine	total (hours)	Job (qty)	tardy jobs (qty)	Tardiness (hours)
1	158,386	24	5	528
2	151,392	24	4	432
3	129,498	24	2	232
4	227,189	24	4	248
5	134,696	23	3	248
6	121,897	23	4	304
7	228,371	23	4	280
8	193,886	23	4	312

3.2 Genetic Algorithm Parameter

GA for parallel machine scheduling in this research is using Python Programming language. The applied parameter for GA is:

1. Initial Populations
   The default amount of chromosomes in initial populations is 100 then, each of chromosomes is generated randomly except one chromosome that can be arranged based on the SPT then EDD rules to get better solution later.
2. Crossover Probability
   Default crossover probability is 0,8.
3. Mutation Probability
   Default mutation probability is 0,2.
4. Amount of Iterations
   Default amount of iterations is 100.
5. Amount of machine
   Default amount of machine is 8 machine.

3.3 Genetic Algorithm Result

The result of GA for parallel machine scheduling using Python programming language can be seen below:

1. Optimal Value
   The optimal value of tardiness of all machine is 557,6 hours.
2. Average Tardiness
   The average tardiness of each machine is 69,7 hours
3. Number of Tardy
   The number of tadry jobs is 30 jobs

4. Elapsed time
   The elapsed running time is 00:31:32
5. Proposed schedule

Table 3 Proposed Schedule

machine	Total (hours)	job (qty)	tardy jobs (qty)	Tardiness (hours)
1	222,85	24	8	119,922
2	232,37	24	7	103,008
3	164,231	24	7	116,408
4	154,725	24	1	11,388
5	150,1	23	1	16,472
6	154,656	23	2	16,582
7	128,023	23	2	20,81
8	205,385	23	2	24,54

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4. Conclusions

The comparison between exsisting schedule and proposed schedule can be seen below in Table 4:

Table 4 Tardiness comparison of each machine between existing and proposed schedule

machine	Existing (hours)	Proposed (hours)	Tardiness reduction (%)
1	528	36,16	93,2
2	432	85,754	80,1
3	232	170,092	26,7
4	248	30,47	87,7
5	248	59,416	76,0
6	304	67,518	77,8
7	280	108,19	61,4
8	312	0	100,0
Total	2584	557,6	78,4

With the total tardiness of exsisting schedule is 2584 hours, the GA can minimize the total tardiness for 78,4% to 557,6 hours. The tardiness of all machine has been minimized with the highest percentage is machine 8 with 100% to 0 hours.

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