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GREEN FLEXIBLE JOB SHOP SCHEDULING WITH GREY PROCESSING TIME USING NSGA-II

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ABSTRACT

Carbon emissions have become a popular topic of research recently due to the increase on the earth's surface temperature. One of the major contributors to carbon emissions is industry. Therefore, one of the most effective ways to reduce carbon emissions is by making the efficient utilization of the machine. This can be done by forming an optimal machine scheduling. This research will use two objective functions in Flexible Job Shop (FJSP) scheduling, namely makespan and carbon emissions. This research will also use grey numbers to accommodate the uncertainty in the processing time of the job. To solve this FJSP case, the NSGA-II algorithm is used. The algorithm is an extension of Genetic Algorithm and often used for multiobjective cases. This research has a goal to obtain optimal scheduling both in terms of company operations and environment.

Keywords: NSGA-II, Flexible Job Shop, Carbon, Emission, Makespan.

I. INTRODUCTION

Carbon emissions have become a popular topic of research recently due to the increase on the earth's surface temperature. One of the major contributors to carbon emissions is industry [1]. Industry contributes to carbon emissions by using energy for machines. Thus, one of the actions that can be taken to reduce carbon emissions is to make efficient utilization of the machine.[2]. This can be done by forming optimal machine scheduling [3].

Flexible Job Shop is a type of machine scheduling which is an extension of Job Shop scheduling where there is a multi-purpose machine that can complete more than one type of operation. Therefore, in Flexible Job Shop, decision makers are not only consider the order of work but also the assignment of machines [4]. Usually, the objective function of a Flexible Job Shop is to determine the final completion time of the job called makespan, but later, the performance of a scheduling involves more than one objective function [5]. One of the objective functions that is often discussed lately is related to environmental factors such as energy consumption, carbon emissions or machine noise. [6].

However, most previous studies assume a definite processing time by the machine, which is in practice, some factors like human involvement, conditions of the machine can make the processing time of the job to be uncertain, to accommodate this, this research will use grey numbers on the processing time, grey numbers which are interval forms of values are quite effective in measuring uncertainty[7].

A research related to the use of grey numbers in FJSP has been conducted [8] and solved using the Elitism Strategy Genetic Algorithm, but this research only uses one objective function, makespan, thus this research will focus on solving FJSP scheduling with two objective functions, makespan and carbon emissions using the Non-Sorting Genetic Algorithm (NSGA-II) algorithm. This algorithm was chosen because it is designed to solve multiobjective problems and has been used previously in the case of FJSP [9]. The use of these two objective functions will provide a scheduling that is not only concern in terms of operations but also the environment.

II. METHODOLOGY

This research will form the NSGA-II algorithm and use the algorithm to solve some Flexible Job Shop cases, in forming the NSGA-II algorithm, the following steps are taken:

a. Determine the parameters which will be used such as Population Size, Number of Iterations, Crossover Probability and Mutation Probability

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b. Generate a number of chromosomes according to the number of populations, for Flexible Job Shop there are two types of chromosomes such as job ordering chromosomes and machine assignment chromosomes. Figure 1 show two types of chromosomes.

3	1	2	2	1	3	1	3

1	1	2	3	2	2	3	2

Figure 1: Chromosome

c. Perform the evaluation of solutions using the concept of grey numbers by comparing each solution in terms of grey numbers properties[10]. Rank the solutions on the pareto front, based on the level of dominance of a solution over the other solutions.

d. Determine the survival solution by performing tournament selection where two solutions are randomly selected and will be competed based on their position in pareto front and crowding distance.

$$cd(i) = \sum_{i=1}^{k} \frac{f_j^{i+1} - f_j^{i-1}}{f_j^{max} - f_j^{min}}$$

where $cd(i)$ shows the i-th solution of crowding distance, f_j^{i+1} shows the-$i+1$ solution on j-th pareto front, f_j^{max} and f_j^{min} show extreme solution for each j-th pareto front

e. Any solution that has smaller random numbers than the crossover probability will undergo the crossover process. The crossover process is done by exchanging each gene from the parent chromosome. An example of two parent chromosomes as shown in Figure 2

3	1	2	2	1	3	1	3

2	1	3	2	1	3	1	3

Figure 2: Parent Chromosomes

The result of offspring chromosome as shown in Figure 3

3	1	3	2	1	2	1	3
2	2	1	3	3	1	1	3

Figure 3: Offspring Chromosomes

f. The mutation process is performed by exchanging the genes on the chromosome itself. Figure 4 shows the chromosome and the result of the mutation.

1	2	2	1	3	3	3	1

1	2	1	3	3	3	2	1

Figure 4: Mutation

g. If the number of iterations has been reached then the iteration process stops otherwise return to step c.

III. RESULTS AND DISCUSSION

The testing of the algorithm is performed based on data adopted from Brandimarte [11] [12] where additional data is given on the time interval for the transition from one operation to the other operation (time-interval), processing time interval and carbon emissions on each machine as follows::

Time-Interval : $[p, p+q]$, where p and q respectively are distributed uniform random number p: 2~4 and q: 1~2

Processing Time : $[r, r+s]$ where q are processing time used from Brandimarte [11] while s is distributed uniform random number s: 2~5

Carbon Emission : emission for idling machine t: 0,01~0,03 and emission for working machine u: 0,1~0,3 [13]

Some Brandimarte Instance used as follows MK-1, MK-3, MK-4, MK-7, MK-10, MK-11, MK13 with the extension data, then becoming N-MK-1, N-MK-3, N-MK-4, N-MK-7, N-MK-10, N-MK-11, N-MK13

Parameters that are used:

Population Size : 100-200

Maximum Iteration : 100-300

Probability Crossover : 0.5-0.8

Probability Mutation : 0.4-0.7

After running the NSGA-II algorithm, the results are shown in Table 1.

Table 1: Case of FJSP with Grey Number

Case	NSGA-II		Makespan [11]
	Makespan	Carbon Emission	
N-MK1	[50,92]	[21.55, 45.51]	36-40
	[44,79]	[23.14, 46.88]	
	[43,86]	[22.82,49.25]	
	[42,74]	[21.78,47.32]	
N-MK3	[207,275]	[193.5,280.3]	204
N-MK4	[85,140]	[79.34,137.94]	48-60
	[92,159]	[76.5,134.75]	
N-MK7	[159,247]	[145,67,207,83]	133-139
N-MK10	[303,393]	[469.02,615.0944]	165-197
N-MK11	[739,879]	[595.5,708.9]	594-649
N-MK13	[462,563]	[900.2,1083.3]	353-478
	[463,570]	[898.4,1082.3]	

Table 1 shows the results obtained by the NSGA-II algorithm which is the minimum value of both the makespan and carbon emissions, for the makespan value in cases N-MK1. As an example: the first solution is makespan [50,92], this shows the range of makespan job completion time is within the range of 50 ~ 92, while In the N-MK1 case, there are four solutions that do not dominate each other. The first solution with makespan [50,92] and carbon emission [21.55,45.51] is not dominated by the fourth solution with a makespan [42,74] and carbon emission [21.78,47.32], because although the fourth solution has a smaller makespan but the first solution has a smaller carbon emission. Meanwhile, Makespan[11] shows the range of solutions obtained by previous researchers related to the case, it can be seen that the solution using NSGA-II is larger due to the addition of time interval variables, the range of completion time and the existence of carbon emission variables.

However, in some cases such as N-MK3, the makespan solution obtained is [207,275], the lower bound on the grey number is 207 which is quite close to the results obtained by previous researchers, 204.

To test how the effect variation of population and maximum iteration on makespan and carbon emission , the following test was executed on the N-MK10 case:

Table 2: Several Population and Maxgen for Case N-MK04

Populasi	MaxGen	Makespan	Carbon Emission
100	50	[85,147]	[81.09,140.1]
		[90,143]	[81.38,139.69]
	100	[84,155]	[77.72,136.14]
	150	[85,141]	[78.22,138.44]

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	200	[88,145]	[79.02,139]
	250	[86,147]	[73.97,131.55]
50	100	[88,148]	[81.89,140.95]
100		[95 157]	[83.67,141.1]
150		[91,148]	[76.35,133,64]
200		[90,147]	[76.66,134.73]
250		[82,148]	[77.11,134.47]

Based on these solutions, a pareto front is constructed for each solution.

Table 3: Pareto Front for N-MK04 Solution

Pareto Front	Population	MaxGen	Makespan	Carbon Emission
1	100	150	[85,141]	[78.22,138.44]
	100	250	[86,147]	[73.97,131.55]
	250	100	[82,148]	[77.11,134.47]
2	150	100	[91,148]	[76.35,133,64]
	200	100	[90,147]	[76.66,134.73]
	100	50	[85,147]	[81.09,140.1]
	100	50	[90,143]	[81.38,139.69]
	100	200	[88,145]	[79.02,139]
3	100	100	[84,155]	[77.72,136.14]
	50	100	[88,148]	[81.89,140.95]
4	100	100	[95 157]	[83.67,141.1]

From Table 3, it can be seen that the influence of Maximum Iteration is greater than the Population, the solution provided by Maximum Iteration of 150 and 200 are on the first front. It can be concluded that in order to get a better solution, the maximum iteration should be increased.

IV. CONCLUSION

The rising concern for the environment has led to the emergence of scheduling that involves the environment. In this scheduling, uncertainty in the processing time is also involved. The NSGA-II algorithm that is used has been proved to deliver good results in obtaining makespan and carbon emissions. It is shown by several cases where NSGA-II provide some results that are close enough to the benchmark, the difference in results with the benchmark is due to the use of other variables in this scheduling, to improve the performance of the NSGA-II method, the number of iterations is prioritized to be increased.

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