Minimizing makespan on flow shop scheduling using Campbell Dudek and Smith, particle swarm optimization, and proposed heuristic algorithm

A Irman*, E Febianti and U Khasanah
Industrial Engineering, University of Sultan Ageng Tirtayasa, Indonesia

*Email: irman@untirta.ac.id

Abstract. Scheduling is defined as the process of allocating resources over time to perform a collection of tasks within a certain period of time. PT KHI Pipe Industries in Cilegon Indonesia, has been producing high quality longitudinal and spiral weld steel pipes. The company uses FCFS (first come first serve) rule for scheduling their jobs, which means that job processing based on the first incoming prioritizes orders. In October 2018 there was delay in their production, namely 1771 pipes are still in work in process (WIP) of total demand is 6,296 pipes. Based on these problems, this research tries to determine a better production scheduling by getting minimum makespan as scheduling performance. Heuristic and metaheuristic methods used in this research for minimizing the makespan, there are Campbell Dudek Smith (CDS) for heuristic and Particle Swarm Optimization (PSO) for metaheuristic. We also proposed a new heuristic algorithm for this problem. The results show the makespan of each method, there are CDS method: 742.87 hours, PSO method: 711.96 hours, Proposed Heuristic Algorithm method: 694.64 hours, and existing production scheduling of FCFS rules is 746.43 hours. Based on the results, the Proposed Heuristic Algorithm has smaller makespan than the others.

1. Introduction

This research is conducted in order to determine the minimum makespan using the Campbell Dudek Smith (CDS) method, Particle Swarm Optimization (PSO), and proposed heuristic algorithms, on production scheduling in PT KHI Pipe Industries. CDS as heuristic method will be compare with PSO as metaheuristic method. PSO is powerful tool for optimization problem such as scheduling problem [3-5].

PT KHI Pipe Industries is a subsidiary of PT Krakatau Steel group which produces high quality spiral and longitudinal welding steel pipes. It has two production lines that are ERW (Electric Resistance Welding) line, used for manufacturing of longitudinal pipe steel and SPM (Spiral Pipe Machine) line for the spiral pipe steel. This research focuses on longitudinal steel pipe Products (ERW) due to the high demand for this product in 2018 for 52,203 units of pipe. On October 2018, the demand for this type of pipe is 6,296 units, which means the production schedule must be created to catch up the production target. The production type in this company is in flow shop type. The flow shop is a common pattern in manufacturing companies [1, 2].
2. Methodology
This section contains the data collection and method which is used in this research.

2.1. Data Collection
The data contained in this study are primary and secondary data. The primary data is the machining time from the observation and the secondary one is the number of jobs, and machines. In October 2018, there were six jobs that should be done in ERW line that contains of six machines. The processing time came from 20 sample of observations. It is shown in table 1.

| Job | Size | Processing Time (Hour) |
|-----|------|------------------------|
|     |      | ST 1 U | ST 2 RF | ST 3 SS | ST 4 FC | ST 5 H | ST 6 AU |
| Job 1 | 168.3 x 7.10 x 12 | 11.67 | 31.46 | 50.34 | 12.53 | 154.20 | 103.10 |
| Job 2 | 168.3 x 7.10 x 6 | 10.84 | 29.22 | 46.70 | 11.59 | 143.26 | 95.79 |
| Job 3 | 168.3 x 4.50 x 6 | 11.24 | 30.23 | 48.32 | 12.04 | 148.49 | 99.35 |
| Job 4 | 168.3 x 4.50 x 4.4 | 1.74 | 4.78 | 7.65 | 1.91 | 23.54 | 15.75 |
| Job 5 | 168.3 x 4.80 x 6 | 4.53 | 12.19 | 19.47 | 4.84 | 59.78 | 40.00 |
| Job 6 | 219.1 x 8.20 x 12 | 4.21 | 11.44 | 19.09 | 4.45 | 58.85 | 39.37 |

2.2. Method
There are 3 methods which is use in this research and can be done in parallel. The first method is CDS methods, and the second one is PSO. We use sheet calculation in microsoft excel for this methods to get the solutions. For PSO, we has assumption for the initial parameter, as follow: Number of iterations is 10; Total Particle (N) is 10; Initial Speed (v0) is 0.8; Inertia Weight (w) is 0.8; Cognitive Learning Factor (c1) is 2; and Social Learning Factor (c2) is 2.

The third method is our proposed heuristic method which is combination between grouping and dispatching rule. Because of there is dependent setup time, we use jobs grouping into 2 families and dispatching rule use to generate job schedule on each families, after that we use permutation to the families to get the minimum makespan. We also use sheet calculation for this method.

3. Result & discussion
The result for this case show that proposed heuristic method has smaller makespan than existing, CDS, and PSO method with given parameter.

3.1. Existing (FCFS) Method
The existing scheduling that use First Come First Serve (FCFS) method, generates a 746.43-hour makespan with a job sequence is Job1-job2-job3-job4-job5-job6.

3.2. Campbell Dudek Smith (CDS) Method
We have 5 iterations for the CDS and it produced a makespan of 742.87 hours with a job sequence of Job1-job3-job2-job5-Job6-job4. Table 2 is the recapitulation of the CDS method.

| Iteration | Jobs Sequence | Makespan (Hour) |
|-----------|---------------|-----------------|
| 1         | job 4-job 6-job 5-job 2-job 3-job 1 | 803.22 |
| 2         | job 4-job 6-job 5-job 2-job 3-job 1 | 803.22 |
| 3         | job 1-job 3-job 2-job 5-job 6-job 4 | 742.87 |
| 4         | job 1-job 3-job 2-job 5-job 6-job 4 | 742.87 |
| 5         | job 4-job 6-job 5-job 2-job 3-job 1 | 803.22 |
3.3. Particle Swarm Optimization (PSO) Method

Generated random number creates the initial position. 10 particles were created from 60 random number. The best initial position is found in sequence job 5 – job 3 – job 1 – job 4 – job 2 – job 6 with makespan 711.96 hours.

The final stage of the scheduling process using the PSO algorithm is to see the convergences of the iterations result. Figure 1, shows the result of the PSO algorithm in this case.

![PSO Convergence Graph](image)

**Figure 1.** The convergence of pso result

The convergence of PSO signifies particles leading to the best solution space or makespan. It is shown that the PSO convergence occurs at the time of iteration 3. In the iteration 3 to iteration 10 shown that the results has the same makespan for 727.73 hours. Because we only go for 10 iterations, the minimum value is not come from the iteration 3 – 10, but the smallest makespan comes from the initial position which is generate 711.96 hours of makepan, so it can be said that the PSO method in this case has 711.96 hours of maksepan with a 5-job 3-Job, 1-Job 4-Job, 2-job 6 job sequence. There is still a chance when we make greater the number iteration to get smaller value of makespan.

3.4. Proposed heuristic algorithms

The proposed heuristic algorithm uses combination of Grouping, SPT and permutation rules. The proposed heuristic algorithm was developed to minimize the setup time used. The following are the steps of this method:

1. Grouping Job based Family (Diameter) to reduce setup time is on table 3.

| Group A (Diameter 168.3 mm) | Group B (Diameter 219.1 mm) |
|-----------------------------|-----------------------------|
| Job 1                       | Job 3                       |
| Job 2                       | Job 4                       |
| Job 5                       | Job 6                       |

2. Sort Group A And B By Short Processing Time (SPT) Rules

Table 4 and 5 shows the processing time for group A and B:
Table 4. Job Completion time group a (diameter 168.3 mm)

| Job | Group A (Diameter 168.3 mm) | Total Time |
|-----|-----------------------------|------------|
|     | ST 1 U          | ST 2 RF      | ST 3 SS  | ST 4 FC | ST 5 H | ST 6 AU |       |
| 1   | 11.67           | 31.46        | 50.34    | 12.53   | 154.20 | 103.10  | 363.30 |
| 2   | 10.84           | 29.22        | 46.70    | 11.59   | 143.26 | 95.79   | 337.41 |
| 3   | 11.24           | 30.23        | 48.32    | 12.04   | 148.49 | 99.35   | 349.67 |
| 4   | 1.74            | 4.78         | 7.65     | 1.91    | 23.54  | 15.75   | 55.37  |
| 5   | 4.53            | 12.19        | 19.47    | 4.84    | 59.78  | 40.00   | 140.80 |

Table 5. Job completion time group b (diameter 219.1 mm)

| Job | Group B (Diameter 219.1 mm) | Total Time |
|-----|-----------------------------|------------|
|     | ST 1 U          | ST 2 RF      | ST 3 SS  | ST 4 FC | ST 5 H | ST 6 AU |       |
| 6   | 4.21            | 11.44        | 19.09    | 4.45    | 58.85  | 39.37   | 137.40 |

Based on the table 4, the SPT rules generates jobs sequence as follow: job 4 - Job 5 - Job 2 - Job 3 - Job 1. On the group B in table 5, there is only 1 job that exist, there is job 6,

3. Sort Groups A And B Based On Permutation Rules
   The rules of permutation are used only for the group, so there is 2! for two group A and B, there are A-B and B-A.

4. Select The Job Sequence with The Smallest Makespan
   The following is the final result of the proposed heuristics algorithms:

Table 6. Result of proposed heuristic algorithms

| Permutation | Rule | Sequence | Makespan (hour) |
|-------------|------|----------|-----------------|
| A-B         | SPT  | 4 5 2 3 1 6 | 694.64         |
| B-A         | SPT  | 6 4 5 2 3 1 | 731.48         |

According to the final result of the proposed heuristics algorithms, it can be seen that the sequence of the job with the smallest makespan is in the order as follow job 4 – job 5 – job 2 – job 3 – Job 1 – Job 6. It generate 694.64 hours of makespan.

4. Conclusion
   Based on the results and discussion in this research, we can draw some conclusion for this case that the best job sequence is job 4 - Job 5 - Job 2 - Job 3 - Job 1 - Job 6, produced by the proposed heuristic method. The makespan value from each methods are the Campbell Dudek and Smith method has 742.87 hours, the Particle Swarm Optimization with given parameter (N=10) has 711.96 hours, and the proposed heuristic algorithm method has 694.64 hours.

   The existing scheduling produces makespan 746.43 hours with a job sequence 1-Job 2-Job 3-Job 4-Job 5-Job 6. The Campbell Dudek and Smith method improves 0.48% from the existing, the Particle Swarm Optimization method improves 4.62%, and the proposed heuristic algorithm method improves 6.94%. The proposed heuristic algorithms in this research has a better result from the other, although there is still so many chance for the Particle Swarm Optimization to get more better result, when the parameter is changed.
References

[1] Allahverdi A, Al-Anzi F 2002 *J. Comput. Oper. Res* **29**, 971-994

[2] Baker Kenneth R and Trietsch 2009 *Principles of Sequencing and Scheduling* (America: John Wiley & Sons, Inc)

[3] Hsieh Ling Feng, Huang Chao Jung Huang and Chienlin Lin Huang 2007 *Asian J. of Management and Humanity Sciences* **1**, 558-576

[4] Suraj Pandey, Linlin Wu, Siddeswara Mayura Guru and Rajkumar Buyya 2010 *Proc. 24th IEEE Int. Conf. on Advanced Information Networking and Applications* (Australia: Perth)

[5] Tuegeh, Soeprijanto and Purnomo. 2009 *Modified Improved Particle Swarm Optimization for Optimal Generator Scheduling* (Yogyakarta: SNATI)