

## **Optimization of Flow Shop Scheduling in Milling Stoper Production Using Campbell Dudek Smith Algorithm**

**Haposan Vincentius Manalu<sup>1\*</sup>, Insan Kamil<sup>1</sup>, Oki Setiawan<sup>1</sup>, Darti Purnama Sari<sup>1</sup>, Siti Adriani<sup>1</sup>, Ifti Luthviana Dewi<sup>1</sup>, Robi Kurniawan<sup>2</sup>, Lavita Indriani Br. Ginting<sup>1</sup>, Kholilah Nuraini<sup>1</sup>**

<sup>1</sup>Mechanical Engineering Department, Politeknik Negeri Batam, Indonesia

<sup>2</sup>Electrical Engineering Department, Politeknik Negeri Batam, Indonesia

\*Corresponding author: [haposan@polibatam.ac.id](mailto:haposan@polibatam.ac.id)

### **Abstract**

Non-optimal production scheduling in a flow shop system can increase makespan, idle time, and workload imbalance among machines. This study aims to optimize the production scheduling of a milling stopper in a manufacturing workshop using the CDS algorithm. This research contributes to improving the efficiency of production systems, particularly in conventional machining processes. The data used consist of processing times for four jobs. The CDS algorithm generates six alternative scheduling sequences, which are then compared based on their makespan values. The results show that the best job sequence is obtained in the fourth iteration, with the order starting from Top Arm, Bottom Arm, Base, and Silander, resulting in a makespan of 1599 minutes. The Gantt chart indicates that the bottleneck occurs at the conventional milling machine, while idle time arises due to imbalanced processing times among machines. This study demonstrates that the CDS algorithm is effective in minimizing makespan and improving the efficiency of flow shop production systems.

**Keywords :** CDS, Flow Shop, Makespan, Milling Stoper, and Scheduling

### **INTRODUCTION**

The manufacturing industry, particularly in conventional machining processes, relies heavily on the effectiveness and efficiency of the production scheduling system implemented. Poor scheduling can lead to machine idle time, job bottlenecks, and an imbalance of workload among machines. These conditions ultimately increase the total completion time (makespan) and reduce the overall productivity of the system.

Along with the increasing demand for fast and timely production, companies are required to optimally manage their resources, especially machines and labor. One approach used in production systems is the flow shop. Flow shop scheduling is defined as a continuous flow of a number of jobs through several machines under certain conditions (Zaied et al., 2021). This system is commonly found in machining-based manufacturing processes, including the production of components such as milling stopper. In contrast to job shop systems, in this type of production system each machine can only perform a specific type of operation, each operation can only be carried out by a particular machine, and the processing sequence for each job may vary (Guo et al., 2024).

Milling Stoper is a component or fixture used in the milling process to limit or control the movement position of the workpiece or cutting tool, ensuring that the cutting process is performed consistently, precisely, and repeatedly according to the desired dimensions. The production process of milling stopper generally involves several conventional machines, such as bandsaw, milling machine, lathe, and finishing processes such as tapping, chamfering, and sanding. Without proper scheduling, significant waiting time between processes will occur.

The main problem in a flow shop system is determining the job sequence that minimizes the makespan. A large makespan indicates that the total production time is longer than it should be, leading to delays in product completion and low machine utilization. Therefore, a scheduling method that can provide an optimal solution is required (Han & Lee, 2023).

Scheduling to obtain optimal results in production processes usually involves additional algorithms that support production optimization. For example, research on two-machine flow shop scheduling with constraints caused by breakdowns in the first machine uses heuristic algorithms such as Interval Johnson's Order (IJO) and Two-Partition Interval Johnson Order (TPIJO), which have been shown to achieve optimal solutions in reducing makespan under uncertainty conditions (Hnaïen & Arbaoui, 2023). Heuristic algorithms are capable of solving flow shop scheduling problems to minimize makespan (Yang & Li, 2022).

Another algorithm, which is an extension of Johnson's algorithm, can also minimize makespan in production processes, such as in cookware manufacturing. This algorithm is the Campbell Dudek Smith (CDS), commonly used to solve scheduling problems involving more than two machines. The application of this algorithm in cookware production achieved an accuracy of 99.99% (Mashuri et al., 2020).

Other industries, such as the plastic industry, have also applied the Campbell Dudek Smith algorithm to minimize makespan by obtaining optimal job sequences (Charista Elliani et al., 2021). The CDS algorithm in production scheduling can generate various alternative schedules, from which the best one can be selected. This algorithm is also used to determine the ideal job sequence in a flow shop system. A job is placed at the beginning of the sequence if the shortest processing time is on the first machine, and placed at the end if the shortest processing time is on the second machine (for two-machine cases) (Febianti et al., 2025).

In this study, milling stoper production scheduling is carried out using a flow shop approach with the CDS algorithm. Processing time data on each machine are used to determine the optimal job sequence. The objective of this study is to minimize the makespan and determine the job sequence of the components that make up the milling stoper product. The scheduling results are analyzed using makespan values and visualized in the form of a Gantt chart. Therefore, this research specifically aims to (1) determine the optimal sequence of job processing in the milling stoper production process using the CDS algorithm; (2) minimize the total completion time (makespan) by comparing alternative scheduling sequences; (3) analyze machine utilization and bottlenecks through Gantt Chart visualization. The ultimate objective is to develop a practical scheduling optimization reference applicable to small and medium scale machining industries. This research is expected to contribute to improving the efficiency of production systems, particularly in conventional machining processes in manufacturing workshops, and to serve as a reference for the application of heuristic methods in flow shop scheduling for small- and medium-scale manufacturing industries.

The novelty of this research lies in applying the CDS algorithm to optimize a multi-machine flow shop system within a conventional machining environment, specifically in milling stoper production. Previous studies have mostly focused on large-scale or automated production systems, whereas this research demonstrates how heuristic scheduling can be effectively implemented in small workshop settings that rely on manual and semi-conventional machines. The practical adaptation of CDS in this context contributes new empirical insight into improving operational efficiency in limited-resource environments.

## **RESEARCH METHOD**

The object of this study is a milling stoper product manufactured in the Manufacturing Workshop. This product serves as a fixture in milling operations, functioning to control and limit the position of the workpiece or cutting tool to ensure consistent and precise machining results. The milling stoper consists of several component parts, each of which must be processed through a series of machining and finishing operations before forming the final product.



**Figure 1. Milling Stoper**

In its production, each component undergoes multiple processes using different machines, including bandsaw cutting, conventional milling, lathe machining, drilling, and finishing operations such as tapping, chamfering, and sanding. Due to the involvement of multiple sequential processes, the production system is categorized as a flow shop. In this context, the sequence in which each job (component) is processed becomes a crucial factor, as it directly influences the total production time (makespan) and the efficiency of the overall manufacturing process.

The research data consist of the processing time of each job on every machine or process. These are primary data obtained through direct observation in the workshop and by recording production times at each stage of the process. The objects studied are the component parts of the milling stoper, which consist of four parts—Base, Bottom Arm, Top Arm, and Cylinder—each having varying processing times across different machines.

Data collection was conducted through direct observation and time study procedures in the Manufacturing Workshop. Each processing time was recorded repeatedly for three production cycles to ensure data consistency. The recorded processing times were averaged and tabulated as primary data for the four main components: Base,

Bottom Arm, Top Arm, and Cylinder. This empirical dataset formed the foundation for CDS algorithm computation.

### Campbell Dudek Smith Algorithm

The Campbell Dudek Smith (CDS) method is well-suited for scheduling problems involving multiple stages (Nurfitriah & Rakhmawati, 2024). The CDS algorithm is an extension of Johnson's algorithm, developed to improve scheduling performance in multi-stage flow shop systems. This heuristic approach aims to solve scheduling problems involving multiple jobs ( $n$  jobs) and machines arranged in series ( $m$  machines) by grouping machines into several combinations and determining job sequences based on the shortest processing time at each workstation (Makarim et al., 2023).

The objective of CDS scheduling is to obtain the minimum makespan from the  $(m-1)$  possible scheduling alternatives. The sequence that produces the smallest makespan is considered the optimal job sequence (Utami et al., 2020). The CDS algorithm is particularly appropriate for multi-stage problems using Johnson's rule and is applied to newly formed problems derived from initial processing time sequences, namely (Nurfitriah & Rakhmawati, 2024):

$$t_{j,1}^k = t_{j,1} \text{ dan } t_{j,2}^k = t_{j,2} \quad (1)$$

As a representation of the processing time on the first machine and the last machine. For the second sequence, it is formulated as follows.

$$t_{j,1}^k = t_{j,1} + t_{j,2} \quad (2)$$

$$t_{j,2}^k = t_{j,m} + t_{j,m-1} \quad (3)$$

The processing time representing the last two machines in the  $k$ -th iteration is denoted as expressed in the following equation.

$$t_{j,1}^k = \sum_i^k = 1^{t_{j,1}} \quad (4)$$

$$t_{j,2}^k = \sum_i^k = m + 1 - k^{t_{j,1}} \quad (5)$$

The following are the descriptions of the variables in the equation above:

- $i$  : job
- $j$  : machine
- $t_{j,1}^k$  : processing time of job  $i$  on the first machine (in iteration  $k$ )
- $t_{j,2}^k$  : processing time of job  $i$  on the second machine (in iteration  $k$ )
- $m$  : number of machines used
- $n$  : Iterations ( $k=1,2,3, \dots(m-1)$ )

### Flow Shop Scheduling

Scheduling can be defined as a decision-making process aimed at allocating resources to various activities while considering a number of existing constraints. The development of scheduling concepts has been largely influenced by the manufacturing sector. Flow shop scheduling problems are a class of combinatorial optimization problems commonly found in production systems. These problems are categorized as NP-hard (Nondeterministic Polynomial), indicating a high level of complexity and significant theoretical as well as practical importance (Liang et al., 2022).

In a flow shop scheduling system, the sequence of job processing has a substantial impact on system performance, particularly on the makespan value. Makespan is defined as the total time required to complete all jobs, calculated from the start of the first job to the completion of the last job (Chen et al., 2023).

This study examines the production system of milling spotter, which involves several conventional machines such as bandsaw, milling machine, lathe, drilling machine, and finishing processes. Each component—consisting of the base, bottom arm, top arm, and cylinder—has different processing times. Therefore, to determine the optimal production scheduling sequence for these components, a heuristic algorithm, namely the Campbell Dudek Smith (CDS), is applied.

### Research Stages

This study was conducted on the production process of milling stoper with flow shop system characteristics, where each job passes through the same sequence of machines. The data used consist of processing times on each machine, obtained through direct observation. In this study, it is assumed that all jobs are available at the initial

time (ready time = 0), no machine breakdowns occur, and each machine processes only one job at a time. The stages of this research are illustrated in Figure 2.

Data processing was conducted using Microsoft Excel to calculate the cumulative processing times for each fictitious machine combination in every CDS iteration. Each iteration generated a unique job sequence based on Johnson’s rule. Subsequently, makespan values were computed for each sequence and Gantt charts were constructed to visualize the processing order and identify idle and bottlenecks periods. The optimal sequence was determined as the one with the smallest makespan across all iterations.

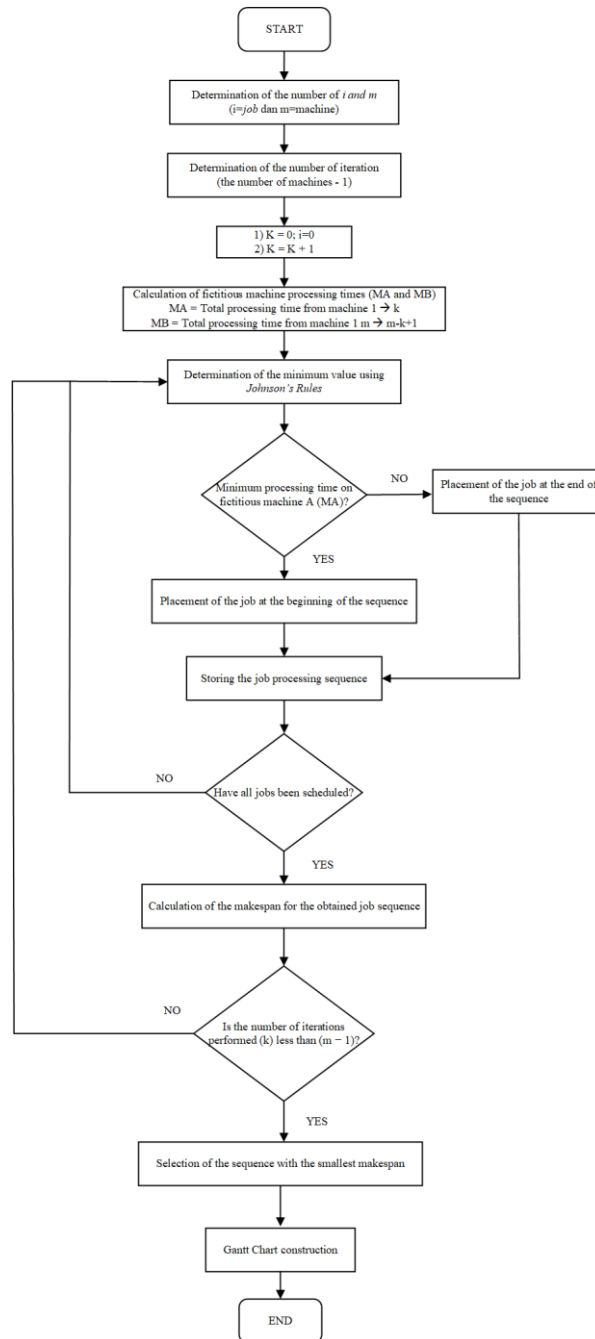


Figure 2. Flowchart of CDS Scheduling Algorithm

## RESULTS AND DISCUSSION

### Observed Data Results

Observations conducted on the milling stoper production process in the Manufacturing Workshop yielded the product processing times, as presented in Table 1.

**Table 1. Processing Time for Each Job or Part in Milling Stoper**

| <b>Machine</b><br><b>Job</b> | <b>M1</b><br><b>(min)</b> | <b>M2</b><br><b>(min)</b> | <b>M3</b><br><b>(min)</b> | <b>M4</b><br><b>(min)</b> | <b>M5</b><br><b>(min)</b> | <b>M6</b><br><b>(min)</b> | <b>M7</b><br><b>(min)</b> |
|------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| <i>Top Arm</i>               | 5                         | 366                       | 0                         | 108                       | 45                        | 33                        | 48                        |
| <i>Silinder</i>              | 3                         | 0                         | 182                       | 0                         | 0                         | 0                         | 5                         |
| <i>Bottom Arm</i>            | 10                        | 618                       | 0                         | 29                        | 30                        | 25                        | 72                        |
| <i>Base</i>                  | 6                         | 510                       | 0                         | 53                        | 15                        | 20                        | 7                         |

The descriptions of the machine symbols used in Table 1 for the milling stoper production process are as follows:

- M1: Bandsaw
- M2: Conventional Milling
- M3: Lathe
- M4: Drilling Machine
- M5: Tapping
- M6: File for Chamfering
- M7: Manual Sanding

### Results of CDS Algorithm Iterations

The number of iterations obtained from the CDS algorithm, with a total of 7 machines and 4 parts, is 6 iterations. This number of iterations is determined by subtracting one from the total number of machines. The results of the first iteration are presented in Table 2.

**Table 2. First Iteration of the CDS Algorithm**

| <b>Job</b>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 5               | 48              |
| <i>Silinder</i>   | 3               | 5               |
| <i>Bottom Arm</i> | 10              | 72              |
| <i>Base</i>       | 6               | 7               |

Table 2 consists of two fictitious machines, namely MA and MB. In this iteration, MA represents M1, while MB represents M7. This iteration is carried out to determine the job sequence based on Johnson's rule, where if the minimum processing time is found on fictitious machine B, the job is placed at the end of the sequence. Conversely, if the minimum processing time is found on fictitious machine A, the job is placed at the beginning of the sequence (Zhou et al., 2023). The first CDS iteration produces the job sequence: Cylinder – Top Arm – Base – Bottom Arm. Based on this sequence, the total processing time (makespan) obtained is 1658 minutes.

**Table 3. Second Iteration of the CDS Algorithm**

| <b>Job</b>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 371             | 81              |
| <i>Silinder</i>   | 3               | 5               |
| <i>Bottom Arm</i> | 628             | 97              |
| <i>Base</i>       | 516             | 27              |

In Table 3, the fictitious machines are constructed such that MA represents the combination of M1 + M2, while MB represents M6 + M7. The results of the second iteration of the CDS method produce the job sequence: Cylinder, Bottom Arm, Top Arm, and Base, with a makespan value of 1602 minutes.

**Table 4. Third Iteration of the CDS Algorithm**

| <b>Job</b>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 371             | 126             |
| <i>Silinder</i>   | 185             | 5               |
| <i>Bottom Arm</i> | 628             | 127             |
| <i>Base</i>       | 516             | 42              |

Table 4 presents the calculation results of processing times on two fictitious machines, where MA is a combination of M1, M2, and M3, while MB is a combination of M5, M6, and M7. The third iteration of the CDS

method produces the job sequence: Bottom Arm, Top Arm, Base, and Cylinder. This sequence results in a makespan of 1604 minutes.

**Table 5. Fourth Iteration of the CDS Algorithm**

| <i>Job</i>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 479             | 234             |
| <i>Silinder</i>   | 185             | 5               |
| <i>Bottom Arm</i> | 657             | 156             |
| <i>Base</i>       | 569             | 95              |

Table 5, corresponding to the fourth iteration of the CDS method, is also used as a reference in determining the job sequence for milling stoper production. The fictitious machine MA is formed by combining M1, M2, M3, and M4, while the fictitious machine MB is formed by combining M4, M5, M6, and M7. Based on the results of this fourth iteration, the job sequence obtained is: Top Arm, Bottom Arm, Base, and Cylinder. This sequence yields a makespan of 1599 minutes.

**Table 6. Fifth Iteration of the CDS Algorithm**

| <i>Job</i>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 524             | 234             |
| <i>Silinder</i>   | 185             | 187             |
| <i>Bottom Arm</i> | 687             | 156             |
| <i>Base</i>       | 584             | 95              |

The fifth iteration of the CDS method also produces a job sequence for milling stoper production. Based on Table 6, the resulting job order is: Cylinder, Top Arm, Bottom Arm, and Base. This sequence yields a makespan of 1854 minutes.

**Table 7. Sixth Iteration of the CDS Algorithm**

| <i>Job</i>        | <b>MA (min)</b> | <b>MB (min)</b> |
|-------------------|-----------------|-----------------|
| <i>Top Arm</i>    | 557             | 600             |
| <i>Silinder</i>   | 185             | 187             |
| <i>Bottom Arm</i> | 712             | 774             |
| <i>Base</i>       | 604             | 605             |

In Table 7, the fictitious machine MA is composed of M1, M2, M3, M4, M5, and M6, while MB is formed by M2, M3, M4, M5, M6, and M7. The sixth iteration of the CDS method produces the job sequence: Cylinder, Top Arm, Base, and Bottom Arm. This sequence results in a makespan of 1915 minutes, which is the largest makespan obtained among all CDS iterations.

**Table 8. Comparison of Makespan Values for Each Iteration**

| <b>Iteration</b> | <b>Urutan Job</b> |            |            |            | <b>Makespan (Menit)</b> |
|------------------|-------------------|------------|------------|------------|-------------------------|
|                  | <b>1</b>          | <b>2</b>   | <b>3</b>   | <b>4</b>   |                         |
| 1                | Silinder          | Top Arm    | Base       | Bottom Arm | 1658                    |
| 2                | Silinder          | Bottom Arm | Top Arm    | Base       | 1602                    |
| 3                | Bottom Arm        | Top Arm    | Base       | Silinder   | 1604                    |
| 4                | Top Arm           | Bottom Arm | Base       | Silinder   | 1599                    |
| 5                | Silinder          | Top Arm    | Bottom Arm | Base       | 1854                    |
| 6                | Silinder          | Top Arm    | Base       | Bottom Arm | 1915                    |

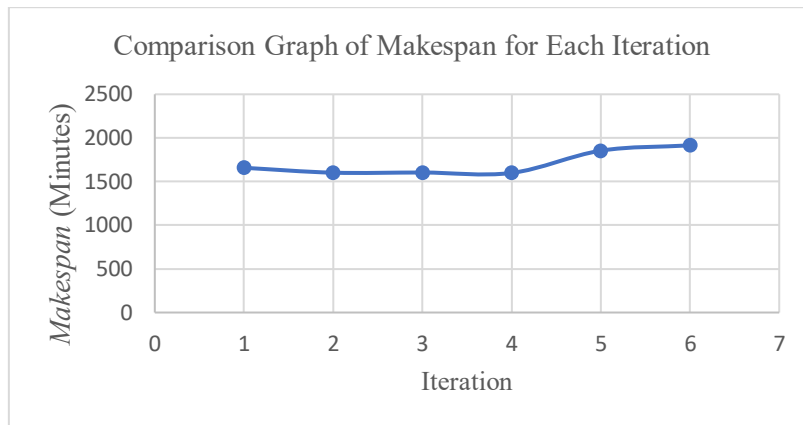


Figure 3. Comparison Graph of Makespan for Each Iteration

Based on Table 8 and Figure 3, the best makespan value is obtained in the fourth iteration, which is 1599 minutes. This iteration produces the job sequence: Top Arm, Bottom Arm, Base, and Cylinder. This indicates that the combination of fictitious machines in the fourth iteration is able to generate the most optimal production sequence in minimizing the total completion time (makespan). Meanwhile, Figure 3 shows that in the fifth and sixth iterations, there is a significant increase in makespan, reaching 1854 minutes and 1915 minutes, respectively. This indicates that the job sequences generated in these iterations are not optimal for minimizing makespan. This suboptimality may be caused by an imbalance in the distribution of processing times across machines, which increases waiting time (idle time) and extends the overall production time.

**Gantt Chart of the Optimal Sequence**

The job sequence for the milling stoper production process is obtained from the fourth iteration of the CDS algorithm. This job order is presented in the form of a Gantt chart. Based on the Gantt chart, the start and completion times of each job on every machine can be observed, making it easier to identify waiting times (idle time), bottlenecks, and the efficiency of conventional machine utilization.

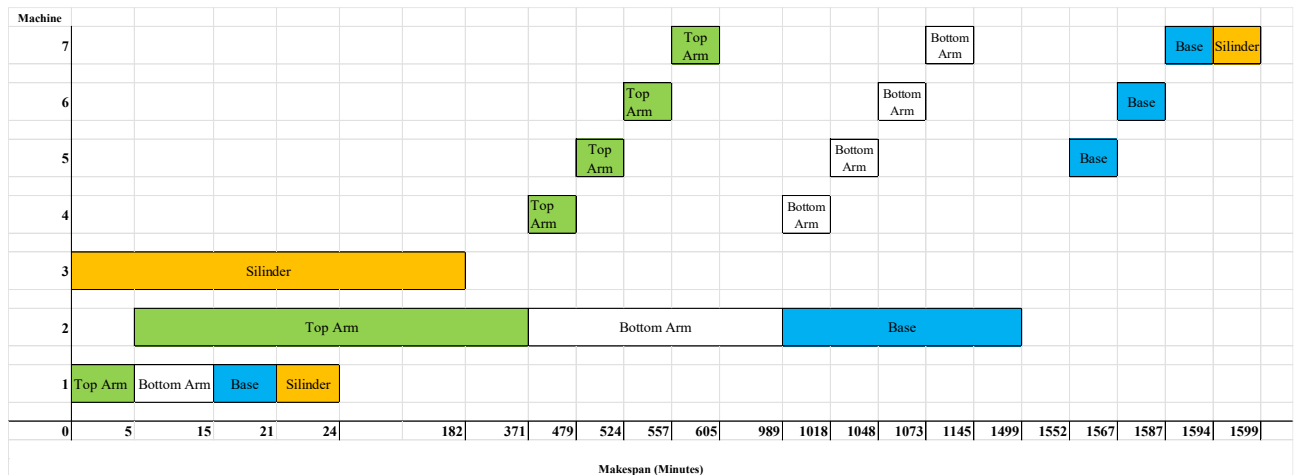


Figure 4. Gantt Chart of Iteration 4 Results

Based on Figure 4, the job sequence shows a structured flow of processes from the first machine to the last machine. Each job is processed sequentially according to the flow shop principle, ensuring that there is no overlap in the processing order. Figure 4 also indicates the presence of waiting time (idle time) on several machines, which is caused by the imbalance of processing times across machines as well as the dependency between operations in a flow shop system. Machines with shorter processing times tend to experience idle time because they must wait for the completion of processes on preceding machines.

From the Gantt chart in Figure 4, the bottleneck in the production system can be identified as the machine with the longest processing duration and the highest utilization level compared to others. It can be observed that the conventional milling machine (M2) has the most dominant processing time, as indicated by the longest processing blocks with almost no idle time. This condition forces other jobs to wait before they can proceed to the next machine, making M2 the main constraint in the production flow.

Figure 4 also shows that the lathe machine (M3) is not classified as the primary bottleneck of the system, but rather as a critical process for certain jobs. According to reference (Rossit et al., 2020), a critical process or critical path is a set of activities that determines the makespan of a schedule. This means that a delay in any of these activities will extend the makespan of the resulting schedule. In flow shop scheduling, however, the interpretation of a critical process or path is not straightforward, since the scheduling focuses on jobs rather than individual operations.

## CONCLUSION

Based on the scheduling results using the CDS algorithm, the optimal job sequence obtained is Top Arm, Bottom Arm, Base, and Cylinder, with a makespan of 1599 minutes. This result indicates that selecting an appropriate job sequence has a significant impact on minimizing the total production completion time. Compared to other iterations, the sequence from the fourth iteration produces the most efficient makespan and is therefore selected as the best solution for flow shop scheduling in the milling stoper production process at the Manufacturing Workshop.

## REFERENCES

- Charista Elliani, M. F. G., Gozali, L., Daywin, F. J., & Doaly, C. O. (2021, March 7). Flowshop Scheduling Using Cds Algorithm, Bat Algorithm, And Tabu Search Algorithm At PT. Dynaplast Jatake. *Proceedings of the International Conference on Industrial Engineering and Operations Management*. 11th Annual International Conference on Industrial Engineering and Operations Management. <https://doi.org/10.46254/AN11.20210493>
- Chen, C., Han, J., Liu, Z., & Tiong, R. L. K. (2023). Flow shop scheduling of hybrid make-to-stock and make-to-order in a distributed precast concrete production system. *Cleaner Logistics and Supply Chain*, 7, 100106. <https://doi.org/10.1016/j.clscn.2023.100106>
- Febianti, E., Sudarsana, D. K., Susihono, W., Komaladewi, A. A. I. A. S., Mutaqin, A. I. S., Kurniawan, B., & Anugerah, A. B. (2025). Scheduling Flow Shop Project Sign Board Using the Campbell Dudek Smith and Cross Entropy Genetic Algorithm Method. *Proceedings of the 10th International Conference And Exhibition on Sustainable Energy and Advanced Materials*, 265. [https://doi.org/10.1007/978-981-96-5063-7\\_22](https://doi.org/10.1007/978-981-96-5063-7_22)
- Guo, H., Liu, J., Wang, Y., & Zhuang, C. (2024). An improved genetic programming hyper-heuristic for the dynamic flexible job shop scheduling problem with reconfigurable manufacturing cells. *Journal of Manufacturing Systems*, 74, 252–263. <https://doi.org/10.1016/j.jmsy.2024.03.009>
- Han, J.-H., & Lee, J.-Y. (2023). Scheduling for a flow shop with waiting time constraints and missing operations in semiconductor manufacturing. *Engineering Optimization*, 55(10), 1742–1759. <https://doi.org/10.1080/0305215X.2022.2124406>
- Hnaïen, F., & Arbaoui, T. (2023). Minimizing the makespan for the two-machine flow shop scheduling problem with random breakdown. *Annals of Operations Research*, 328(2), 1437–1460. <https://doi.org/10.1007/s10479-023-05324-3>
- Liang, Z., Zhong, P., Liu, M., Zhang, C., & Zhang, Z. (2022). A computational efficient optimization of flow shop scheduling problems. *Scientific Reports*, 12(1), 845. <https://doi.org/10.1038/s41598-022-04887-8>
- Makarim, R. A., Maksum, A. H., & Rachmat, M. T. (2023). Optimization of Scheduling using Heuristic Approach with Campbell Dudek Smith Algorithm (CDS) at PT OSIN. *Jurnal Rekayasa Sistem & Industri (JRSI)*, 10(01), 25. <https://doi.org/10.25124/jrsi.v10i01.583>
- Mashuri, C., Mujiyanto, A. H., Sucipto, H., & Arsam, R. Y. (2020). Penerapan Algoritma Campbell Dudek Smith (CDS) untuk Optimasi Waktu Produksi Pada Penjadwalan Produksi. *JURNAL SISTEM INFORMASI BISNIS*, 10(2), 131–136. <https://doi.org/10.21456/vol10iss2pp131-136>
- Nurfitriah, R., & Rakhmawati, F. (2024). Optimization Of Crude Palm Oil Production Machine Scheduling Using The Campbell Dudek Smith (CDS) Method. *Advance Sustainable Science Engineering and Technology*, 6(3), 02403012. <https://doi.org/10.26877/asset.v6i3.731>
- Rossit, D. A., Tohmé, F., Frutos, M., Safe, M., & Vásquez, Ó. C. (2020). Critical paths of non-permutation and permutation flow shop scheduling problems. *International Journal of Industrial Engineering Computations*, 281–298. <https://doi.org/10.52677/j.ijiec.2019.8.001>
- Utami, I. D., Kuswandi, I., & Wibowo, D. E. (2020). Comparison of Scheduling Methods: Campbell Dudek Smith, Palmer and Dannenbring to Minimize Makespan. *Journal of Physics: Conference Series*, 1569(3), 032019. <https://doi.org/10.1088/1742-6596/1569/3/032019>
- Yang, Y., & Li, X. (2022). A knowledge-driven constructive heuristic algorithm for the distributed assembly blocking flow shop scheduling problem. *Expert Systems with Applications*, 202, 117269. <https://doi.org/10.1016/j.eswa.2022.117269>
- Zaied, A. N. H., Ismail, M. M., & Mohamed, S. S. (2021). Permutation Flow Shop Scheduling Problem With Makespan Criterion: Literature Review. . . *Vol.*, (4).

Zhou, X., Liang, W., Yan, K., Li, W., Wang, K. I.-K., Ma, J., & Jin, Q. (2023). Edge-Enabled Two-Stage Scheduling Based on Deep Reinforcement Learning for Internet of Everything. *IEEE Internet of Things Journal*, 10(4), 3295–3304. <https://doi.org/10.1109/JIOT.2022.3179231>