Comparation of Scheduling Methods: Campbell Dudek Smith, Palmer and Dannenbring to Minimize Makespan

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Abstract. Delays in completing one of production cycle will affect the entire flow of the next production process. DI is a manufacturing company that manufacture aircraft. In 2017 there was a delay in manufacturing processes of A380 aircraft wings, especially in machining parts, which resulted in delays shipping to assembly parts. This delays affected time delivery to customers. So that, scheduling plan was needed in this company. This paper proposes comparation of three scheduling methods, which are Campbell Dudek Smith, Palmer and Dannenbring with the aim of minimizing makespan. Result of this study describes that the best method for minimizing makespan is Campbell Dudek Smith method, with a scheduling sequence starting from job 13-6-5-3-10-4-9-1-7-8-18-11-14-19-17-2- 12-12-15-16, and the makespan value of 46.03 hours taken in constructing both.

1. Introduction
Scheduling for production machinery is an important process to maintain and improve company efficiency and performance. Delays in the completion of one production cycle will affect the entire flow of the next production process. Many companies in Indonesia are still using the First Come First Serve (FCFS) system to schedule flow shop production processes, so companies often fail to complete orders from consumers in accordance with agreements with consumers [1][2][3][4][5][6]. This research proposes a production scheduling scenario with three scheduling methods for machine production with a case study at DI Company. Three methods, which are Campbell Dudek Smith, Palmer and Dannenbring were used. PT DI is an aircraft manufacturing company that implements make to order production system. The increasing number of orders from customers has resulted in difficulty of machines scheduling carried out by planning and production control of PPC department. Various kinds of components produced uses the scheduling role of PPC machining, influence the production success. It is because delay in the component production process will result in delays in the assembly process or even in the shipping process. The scheduling system applies in the Spirit Aerosystem department uses a first come first served (FCFS) system, but the actual production is still not in accordance with the planned production, and there is often a delay in the delivery process to the area assembly. So that the production department needs to make efforts in optimizing the production process. The efforts to meet the production targets are strongly influenced by the preparation of a good production schedule so that the makespan of each product can be minimized. Problems in the production process are very influential on the success of the assembly process, the delivery process of sub-components that have been produced in the detail area of manufacturing parts is carried out according to the order sequence number that has been scheduled, so that the production process is not
in accordance with predetermined targets, then the work contained in the sub assembly will be hampered due to delays in the sub-component.

This paper presents a production scheduling plan that is expected to be able to produce a low makespan value, to minimize delays and be able to meet customer demand in accordance with a mutually agreed schedule. This research is expected to provide an alternative method for companies in conducting production scheduling that can minimize makespan. Hence it can help PPC in making decisions regarding optimal production scheduling. This research also can be used as a reference material for readers in future research.

2. Machine Scheduling in Production Process

Production scheduling is useful for allocating a limited number of machines to do a number of jobs [7]. Scheduling can also be used as a good measurement tool for aggregate planning which is then done sequencing work at each processing center so that it can achieve optimal conditions [8]. Some researchers conducted a comparative study of several scheduling methods to get the minimum value of makespan [7][8][3][9][10][6].

Campbell, Dudek, and Smith (CDS) method were developed by H.G. Campbell, R.A. Dudek and M.L. Smith based on Johnson's algorithm. This method basically solves the problem of n jobs in the flow shop machine into the m-1 set of two machine flowshop problems by dividing the machine m into two groups, sorting jobs on both machines using the johnson algorithm, so that after obtaining as many m-1 alternatives sequence of jobs, continued for sequencing with the smallest makespan value. This CDS algorithm is done for jobs or jobs to be completed must pass the process on each machine. This scheduling is expected to be able to get the smallest makespan from (m-1) the possibility of scheduling. Scheduling with the smallest makespan value is the order of the best job processing. D.S Palmer develops scheduling techniques based on the slope index sorted in descending order. Palmer has the principle that the priority of the strongest job tends to advance from the shortest time to the longest time in the sequence of operations. Hence, Danenbring method is a method developed by D.G Dannenbring with a procedure called Rapid Access which in principle is combining the CDS method and the slop index concept.

3. Research Method

Data collection is carried out in two stages, which are primary and secondary data collection. Primary data was obtained by observe directly into the production process area, then conducting an interview process in the production and production control (PPC) machining, regarding lanning and scheduling issues in the aerosystem spirit department. Secondary data was collected form historical data from the spirit aerosystem department such as the details of each job, the number of production, the products produced, the number and processing time of each product manufacture obtained from PPC machining and general support department of aerosystem spirit. Then, comparing the scheduling results from the Campbell Dudeck Smith, Palmer and Dannenbring methods. The optimal scheduling results compared to the makespan produced by the company.

4. Result and Discussion

The Figure 1 shows one example of the hinge rib sub-component (SP73152). This component is one of the components used in the process of making A380 aircraft wings. It is located at the bottom of the aircraft wing skin.

The stage of the production process in making sub components of the hinge rib are as follows:

a. Issuer Inspection (M1)

This initial inspection process is an initial inspection process before the sub-component enters the machining process, in this process an examination of the material to be used in the process of making a hinge rib, first an inspection of the condition of the material to be used is carried out. Furthermore, an inspection of the material size is also carried out. Inspection is carried out on raw material inspection room.

b. CNC Vertical Milling Machine 3NC (M2)
The process carried out on the CNC Vertical Milling machine is making holes in the material. Hole making consists of drilling and counterboring.

c. Formation Process with CNC Vertical Machine Center MV 184 (M3)
   In this process, shape of the sub component hinge rib will be made. The manufacturing process is carried out mostly with the milling process. This process will be carried out on both media or the side of the component according to the specified size.

d. Smoothing and Fitter Machining (M4)
   In this process, the finishing process is carried out on the material. In this process, steps or waste are removed from the product that have been processed before.

e. Dimension Check and Machining Inspection (M5)
   The process carried out in this operation is to check the dimensions of the sub-components with drawing parts, whether they are in accordance with the specifications specified.

f. Chemical Cleaning for Aluminum (M6)
   In this process cleaning from parts will be carried out. Cleaning is done by dipping material into a chemical liquid and then rinsing it. The results of the cleaning carried out are material that is clean of impurities from the rest of the production process, such as the coolant and marking that has been carried out.

g. Penetrant Inspection or Detection Inspection (M7)
   This process has the main purpose of detecting defects on the surface of the part. This process starts with dipping, coating or spraying the part (depending on the size of the part) with the penetrant search. After that, washing will be done on the part using distilled water. The next process will be carried out drying and sowing powder specifically on the part. In the end, the part will be placed on the table and illuminated with lights. If there are defects in the surface of the part such as cracks, scratches and other defects in the defect, it will turn into yellow.

h. Chromic Acid Anodizing (M8)
   In this process the first cleaning process will be carried out from the previous inspection process. Next, an anodizing process will be used which is useful to avoid parts from corrosion. Another purpose of this process is to prepare parts to enter the painting process by coating parts with chromic acid.

i. Aluminum Treatment Inspection (M9)
   In this process a re-examination of the material is carried out after cleaning. In this process, the material will be ready to enter the next process.

j. Primary Painting (M10)
   In this process the process of painting the parts will be carried out. Primary painting has the main purpose to coat the entire surface of the part before color painting is done on the material. So that the material is not directly exposed to the color paint that could damage the part.

k. Painting Inspection (M11)
   On this inspection process, an inspection to results of the primary painting will be carried out. The checking results will be carried out whether all surfaces have been evenly painted.

l. Marking (M12)
   In this process the recording process will be carried out from parts that have been completed. After that, we also measured the weight of the part produced.

m. Final Inspection (M13)
   In the final process, a final inspection of the part will be carried out. In this process an examination of the results of each production process will be carried out on the part to find out whether the part meets the specifications of each production process. The part that meets the specifications will pass the inspection and proceed to the assembly process. Table 1 shows the hinge rib sub-component data which will be scheduled for three proposed methods.
Table 1. Sub-Components of Hinge rib

| No | Serial Number | Sub-Components |
|----|---------------|----------------|
| 1  | L574573152001 | SP73152        |
| 2  | L574515182001 | SP15182        |
| 3  | L574515172001 | SP15172        |
| 4  | L574515002001 | SP15002        |
| 5  | L574514602001 | SP14602        |
| 6  | L574515022001 | SP15022        |
| 7  | L574515202001 | SP15202        |
| 8  | L574515032001 | SP15032        |
| 9  | L574515042001 | SP15042        |
| 10 | L574515452001 | SP15452        |
| 11 | L574514582001 | SP14582        |
| 12 | L574515462001 | SP15462        |
| 13 | L574514612001 | SP14612        |
| 14 | L574515012001 | SP15012        |
| 15 | L574574632001 | SP74632        |
| 16 | L574514562001 | SP15562        |
| 17 | L574522382001 | SP22382        |
| 18 | L574574342001 | SP7434         |
| 19 | L574574322001 | SP7432         |
| 20 | L574515192001 | SP15192        |

**Figure 1.** Sub Component of the Hinge Rib

Data of processing time for each job is obtained from the company's information system. Data have been integrated with several related parties such as PPC machining and with general support of the Aerosystem Spirit Department. Table 2 shows processing time of each job in sub-components of the hinge rib production.

4.1 Scheduling Using Campbell Method Dudek Smith Method

The results of the calculation of the scheduling algorithm with the CDS method obtained the sequence of work starting from job 2-17-4-7-19-3-18-13-20-8-5-9-11-16-1-10-15-6-12-14. There are 12 alternative scheduling in Campbell Ddekk Smith (CDS) method which have different makespan values, so that the most optimal sequence of scheduling (the smallest makespan) uses the CDS method is the 12th alternative sequence with a makespan value of 46.03 hours, as shown in Table 3.

4.2 Scheduling Using

Table 4 shows a recapitulation of calculation result the slope index value. The calculation of the slope index is used to determine the order of scheduling so that makespan calculations can be done. Ordering the slope index value is done from the largest value, so that from the table it can be seen that the scheduling sequence can start from job 13-18-6-9-10-19-5-8-20-17-3-4-7-11-1-4-15-12-16-2.

4.3 Scheduling using Dannenbring Method

The average value of the overall waiting time in the dannenbring method is 23.48 hours. If the average waiting time on the machine time is smaller, it could result in smaller idle time of the machine, and vice versa if the waiting time longer for each job on next machine.

4.4 Comparison of the three proposed methods

Table 5 shows is comparison of makespan value, utility and average waiting times of the three proposed methods. Scheduling using the campbell dudek smith method produces a makespan value of 46.03 hours. Then the palmer method produces makespan values of 46.49 hours, and Dannenbring method produces a makespan value of 46.36 hours.
It can be seen that the most optimal methods are the Campbell Dudek Smith method with the smallest makespan value of 46.03 with the utility level of 27.44% and the average waiting time in the process of making the hinge rib sub-component of 19.55 hours.

Table 6 shows that there is a difference in makespan value between the campbell dudek smith (CDS) method and the first come first serve (FCFS) method applied to the company. The difference between the two methods amounted to 1.96 hours, this can be interpreted that in the making of the entire sub component of the hinge rib the CDS method was able to save 1.96 hours of time with the utility percentage of 27.44% and the average waiting time.

Table 2. Data Processing Time of Overall Job

| No | M1  | M2  | M3  | M4  | M5  | M6  | M7  | M8  | M9  | M10 | M11 | M12 | M13 |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 0.13| 0.77| 2.26| 1.25| 0.69| 0.28| 0.09| 0.07| 0.04| 0.12| 0.12| 0.11| 0.09|
| 2  | 0.06| 1.37| 2.52| 1.39| 0.70| 0.32| 0.14| 0.05| 0.05| 0.15| 0.09| 0.10| 0.06|
| 3  | 0.08| 1.26| 1.64| 1.20| 0.81| 0.10| 0.07| 0.06| 0.03| 0.18| 0.17| 0.10| 0.12|
| 4  | 0.07| 0.77| 2.17| 1.19| 0.74| 0.28| 0.20| 0.07| 0.03| 0.13| 0.07| 0.16| 0.08|
| 5  | 0.10| 0.51| 1.92| 1.39| 0.82| 0.19| 0.06| 0.08| 0.17| 0.18| 0.11| 0.12| 0.12|
| 6  | 0.18| 0.69| 1.52| 1.52| 0.53| 0.27| 0.11| 0.05| 0.06| 0.10| 0.16| 0.14| 0.20|
| 7  | 0.08| 0.89| 2.47| 1.24| 0.37| 0.18| 0.14| 0.06| 0.03| 0.30| 0.05| 0.21| 0.12|
| 8  | 0.10| 0.84| 1.61| 1.52| 1.09| 0.09| 0.17| 0.08| 0.09| 0.39| 0.10| 0.13| 0.12|
| 9  | 0.10| 0.58| 1.43| 1.67| 0.97| 0.32| 0.14| 0.06| 0.04| 0.24| 0.15| 0.18| 0.07|
| 10 | 0.13| 0.52| 2.34| 0.87| 0.79| 0.10| 0.22| 0.21| 0.06| 0.34| 0.06| 0.17| 0.08|
| 11 | 0.11| 0.90| 2.55| 0.97| 0.58| 0.38| 0.09| 0.13| 0.02| 0.29| 0.18| 0.19| 0.11|
| 12 | 0.29| 1.50| 2.12| 1.74| 0.33| 0.33| 0.15| 0.08| 0.10| 0.36| 0.07| 0.21| 0.09|
| 13 | 0.09| 0.54| 0.97| 1.51| 0.46| 0.37| 0.21| 0.15| 0.11| 0.25| 0.08| 0.16| 0.11|
| 14 | 0.29| 1.22| 1.72| 1.27| 0.85| 0.32| 0.08| 0.18| 0.10| 0.48| 0.10| 0.10| 0.08|
| 15 | 0.13| 1.42| 2.39| 1.15| 0.99| 0.40| 0.13| 0.06| 0.06| 0.44| 0.16| 0.12| 0.13|
| 16 | 0.12| 0.46| 4.00| 1.02| 1.17| 0.34| 0.12| 0.11| 0.06| 0.63| 0.06| 0.15| 0.09|
| 17 | 0.07| 0.81| 2.41| 1.08| 0.88| 0.45| 0.19| 0.11| 0.05| 0.44| 0.17| 0.14| 0.18|
| 18 | 0.09| 0.37| 2.14| 1.46| 0.57| 0.25| 0.13| 0.15| 0.23| 0.47| 0.22| 0.25| 0.06|
| 19 | 0.08| 0.65| 2.26| 1.40| 0.66| 0.36| 0.24| 0.12| 0.10| 0.44| 0.20| 0.24| 0.16|
| 20 | 0.10| 0.63| 2.40| 1.49| 0.90| 0.28| 0.30| 0.15| 0.15| 0.63| 0.12| 0.13| 0.15|

Table 3. Recapitulation of Makespan components of Hinge rib

| Alternative | Sequencing of scheduling | Makespan (Hour) |
|-------------|--------------------------|-----------------|
| 1           | 2-17-4-7-19-3-18-13-20-8-5-9-11-16-1-10-15-6-12-14 | 47.28 |
| 2           | 2-14-1-3-16-4-5-10-9-8-15-13-20-11-12-18-7-6-19 | 47.62 |
| 3           | 1-14-16-10-4-1-13-8-5-12-7-3-20-9-15-11-17-6-18-19 | 47.62 |
| 4           | 2-1-4-5-3-13-6-9-10-7-8-12-11-14-15-16-17-18-20-19 | 47.62 |
| 5           | 2-4-1-3-6-9-13-5-10-7-11-8-12-14-15-16-17-19-20-18 | 47.47 |
| 6           | 2-4-1-3-6-9-7-7-13-28-11-10-15-14-16-17-19-20-18 | 47.47 |
| 7           | 1-2-3-4-6-5-9-7-11-12-13-8-15-14-10-16-17-19-20 | 48.44 |
| 8           | 3-1-2-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20 | 49.01 |
| 9           | 7-1-6-3-2-12-4-5-13-11-10-9-8-14-15-18-19-17-16-20 | 46.92 |
| 10          | 7-3-1-10-11-4-2-6-5-13-12-14-15-17-16-8-18-9-19-20 | 46.92 |
| 11          | 13-3-6-1-4-5-7-10-9-14-8-11-2-12-18-15-17-19-20-16 | 47.58 |
| 12          | 13-6-5-3-10-4-9-1-7-8-11-14-19-17-2-20-12-15-16 | 46.03 |
Table 4. Value of Slope index of Jobs

| Job | Slope Index Value |
|-----|-------------------|
| 1   | -16.97            |
| 2   | -21.30            |
| 3   | -16.12            |
| 4   | -16.20            |
| 5   | -14.09            |
| 6   | -13.39            |
| 7   | -16.42            |
| 8   | -14.87            |
| 9   | -13.70            |
| 10  | -14.04            |
| 11  | -16.42            |
| 12  | -20.67            |
| 13  | -10.07            |
| 14  | -17.32            |
| 15  | -19.72            |
| 16  | -21.22            |
| 17  | -15.56            |
| 18  | -12.22            |
| 19  | -14.08            |
| 20  | -15.51            |

Table 5. Comparison of the Three Proposed Methods

| No. | Criteria          | Campbell Dudek Smith | Pallmer | Dannenbring |
|-----|-------------------|-----------------------|---------|-------------|
| 1   | Makespan (hour)   | 46.03                 | 46.49   | 46.24       |
| 2   | Utilitas (%)      | 27.44%                | 26.55%  | 22.81%      |
|     | Average waiting time (hour) | 19.55   | 19.98   | 23.48       |

Table 6. Comparison with FCFS Company Methods

| No. | Criteria          | FCFS   | CDS    | Differences |
|-----|-------------------|--------|--------|-------------|
| 1   | Makespan (hour)   | 47.99  | 46.03  | 1.96        |
| 2   | Utility (%)       | 24.95% | 27.44% | 2.49%       |
| 3   | Average waiting time (hour) | 21.45  | 19.55  | 1.89        |

5. Conclusion

Based on the processing and results of discussion of the data, it can be concluded that the best method in minimizing makespan is Campbell Dudek Smith method, with a scheduling sequence starting from job 13-6-5-3-10-4-9-1-7-8-18-11-14-19-17-2-20-12-15-16. The company’s scheduling using the FCFS method has a makespan value of 47.99 hours to 46.03 hours. So it can be concluded that the Campbell Dudek Smith method can minimize makespan by 1.96 hours or 117.84 minutes. The makespan value of the best method also produces the largest utility value compared to Palmer and Dannenbring methods. Utilities using the FCFS method are 24.95%. While using the CDS method can increase utility to 27.99%, and the value of waiting jobs decreases from 21.45 to 19.55, which means that using the CDS method is able to minimize waiting time amounting to 1.89 hours or 113.58 minutes. For further research, data relating on human resources, could be included, such
as performance rating and allowances, so that the company could identify the average condition of the operator in the production process. As well as data regarding on cost analysis is also important in making decisions to determine the next policy for the A380 program.

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