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# PRODUCTION SCHEDULING OF BIG PART AT MACHINING DEPARTMENT IN PT. XYZ

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**_ABSTRACT_**

*The company run a job order production scheduling as in First Come First Serve (FCFS) so that the scheduling experienced a long makespan then a lateness was occurred. This research is proposing a scheduling from the heuristics methods which were Active Schedule Generation Short Processing Time priority (SPT) Algorithm, Non Delay Schedule Generation SPT priority and Tabu Search (TS) The existing makespan was 114.4 hours. The result from Active Schedule Generation Short Processing Time priority (SPT) Algorithm was 103.1 hours, Non Delay Schedule Generation SPT priority was 103.4 hours, and TS was 82.9 hours. Compared to the existing scheduling, Active Schedule Generation Short Processing Time priority (SPT) Algorithm produced a makespan 9.843% lower, Non Delay Schedule Generation SPT priority produced a makespan 9.6% lower, and TS produced a makespan 27.6% lower. Viewed from due date, the existing scheduling has 4 jobs lateness for 33.2 hours, Active Schedule Generation Short Processing Time priority (SPT) Algorithm has 4 jobs lateness for 21.9 hours, Non Delay Schedule Generation SPT priority has 4 jobs lateness for 22.2 hours, and TS has 5 jobs lateness for 1.6 hours. This Research chose TS because it can reduce makespan for 27.6% from the existing scheduling.*
*Keywords: Active Schedule Generation, Makespan, Non Delay Schedule Generation, SPT, Tabu Search (TS)*

## 1. INTRODUCTION

PT. XYZ is Indonesian aircraft manufacturer and civilian and military aircraft design developer. It has many production departments and the main department is machining department. Production in machining department is to process the raw materials into parts using numbers of machine which will be assembled in assembly department.

One of the problem in this company is order lateness. The lateness was caused by big part jobs delay compared to other parts. Big part is a core part in every product which were produced by the company that has long processing time than another part. One of the lateness was caused by ineffective scheduling, and it is shown on Table 1. Table 1 shows that the lateness part, which was Hinge Rib 4, cannot be assemble. Figure 1 shows the lateness of big part, the number of first order which was not provided was affecting to the next order so that it may cause a systemic lateness.

Table 1. Part Lateness

| HR4 STBD L574 57377 001 | | | | No. Order 200 | No. Order 201 | No. Order 202 | No. Order 203 |
|---|---|---|---|---|---|---|---|
| No | Part Name | Part Number | Qty | | | | |
| 1 | PLATE SPREADER | L574-51545-20101 | 1 | Finish | Finish | Finish | Finish |
| 2 | PLATE SPREADER | L574-51546-20101 | 1 | Finish | Finish | Finish | Finish |
| 3 | PLATE LANDING | L574-51610-20101 | 1 | Finish | Finish | Finish | Finish |
| 4 | PLATE SPREADER | L574-52238-20101 | 1 | Finish | Finish | Finish | Finish |
| 5 | REINFORCEMENT ANGLE | L574-52612-200 | 1 | Finish | Finish | Finish | Finish |
| 6 | REINFORCEMENT ANGLE | L574-52612-201 | 1 | Finish | Finish | Finish | Finish |
| 7 | PLATE SPREADER | L574-57437-20101 | 1 | Finish | Finish | Finish | Finish |
| 8 | HINGE RIB 4 | L574-57443-20101 | 1 | Finish | Finish | Delay | Delay |
| 9 | ANTI ROTATION BLOCK | L579-50556-200 | 2 | Finish | Finish | Finish | Finish |
| 10 | UPSTOP | L579-50557-200 | 1 | Finish | Finish | Finish | Finish |
| 11 | BRACKET ELECTRIC ASSY | L579-50735-000 | 1 | Finish | Finish | Finish | Finish |
| 12 | BRACKET ELECTRIC ASSY | L579-52422-000 | 1 | Finish | Finish | Finish | Finish |
| 13 | BRACKET ELECTRIC ASSY | L579-52422-001 | 1 | Finish | Finish | Finish | Finish |
| | Jumlah Pending | | | 0 | 0 | 1 | 1 |

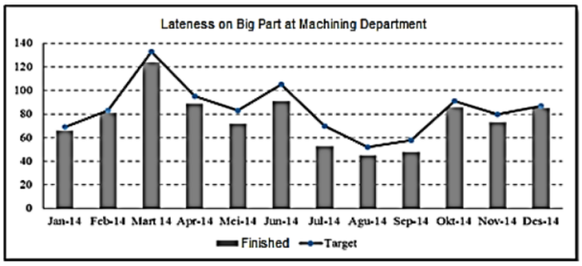


Figure 1. Big Part Lateness at Machining Department

The company was experience a problem on determining job priority in a scheduling, especially in producing big part due to limited time to complete the production process and limited number of machine. In a present time, the company using First Come First Service (FCFS) on the production scheduling which was ineffective.

To solve this problem, a research was conducted using Tabu Search (TS) algorithm. TS was proved as better way from the other algorithms to solve scheduling problem of job shop and flow shoo, also it gives a better makespan compare to other algorithms (Betrianis, 2003, Hasanudin, 2011, Salam, 2013). TS is grouped into meta-heuristic because TS always searching procedure oriented (Ginting, 2009). As a comparison, this research also using Non Delay Schedule Generation and Active Schedule Generation.

### 1.1 Research Identification

Makespan of the first order was influence to the next order. This means if there is work in process on the first order, so it will generate a queueing or delay to the next order.

To overcome that problem, so the research identification will be how to do a production scheduling of big part order at machining department regards to the capacity, so that it will be obtained a minimum makespan and to minimized lateness.

### 1.2 Research Objective

To sequencing and job scheduling on existing machines to minimize makaspan to obtain a minimized lateness.

## 2. THEORETICAL BACKGROUND

### 2.1. Tabu search approach

Tabu search (TS) is an iterative improvement algorithm based both on the neighborhood search methods along with the use of different types of memories and strategies to guide this search. The basic form of TS is founded on ideas proposed by Glover [28].

Starting with an initial solution, neighborhood moves are examined at each iteration and the best candidate move is selected and applied to generate a new solution. This is repeatedly applied until a predetermined stopping condition occurs.

In order to prevent TS from cycling (i.e. repeating the same neighborhood moves continuously), a short term memory called the tabu list is designed to store a number of previous moves. The local search algorithm will seek a best solution in its neighborhood provided that it is not found in the tabu list. A move is not allowed for a certain number of iterations provided that it is in the tabu list. If the tabu list is full, then the move that has been in the list the longest is removed. It may happen that in certain iteration all possible moves are forbidden or tabu. In this case, the algorithm has to be follow a predetermined strategy that either selects the oldest move stored in the tabu list or stops the algorithm.

The TS procedure receives six parameters as input. These parameters are the initial solution generated by the DS/RANDOM algorithm (S0), the evaluated lower bound (LB), the tabu list size (tsmax), the maximum number of iterations permitted without improving the current solution (itrmax imp), the total number of iterations allowed (itrmax), and the computational time limit allowed for one run of the algorithm (rtmax). The algorithm starts at step 1 by defining an empty tabu list (T), and initializing the values of the current schedule (S), the best schedule (Sbest), the current schedule’s makespan (Cmax), the iteration counter (itr) and the number of iterations conducted without improving the current solution (itrimp).

Steps from 2 to 13 represent the main iteration loop of the algorithm. In step 2, the optimality condition of having a current makespan equal to the lower bound is checked.

### 2.2. Schedule Generation Schemes

A general framework for a SGS is provided in Algorithm 1: given a task order $\pi$ (which can be interpreted as a priority vector), it allows to build different types of schedules, depending on the actual instantiation of some of its actions.

The generic algorithm builds the schedule in $N$ iterations. At each iteration, the SGS computes a set of *eligible* tasks, $E$,

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which is a subset of the set of *available* tasks, *A*, containing the tasks that are candidates to be scheduled at the current iteration. In steps 3 and 4 the SGS selects the operation $o(j*, l*) \in E$ with the highest priority according to $\pi$ and computes its *Earliest feasible Starting time* (*ES*) based on an *Appending* (*ESA*) or *Insertion* (*ESI*) strategy.

This framework covers a wide range of interesting SGSs, as we shall see in the sequel. However, it does not comprise all possible SGSs, in particular those where a non-available operation may be selected for scheduling or where starting times may be later modified in the schedule-building process.

## 3. RESEARCH METHOD

### 3.1. Active Schedule Generation Algorithm

This is a partial scheduling. This research was using Short Processing Time (SPT) priority, it means that the priority is given to the shortest process time.

Step 1: $t = 0$, $PS_t = 0$ (partial schedule that contain a scheduled $t$ operation). Set $S_t$ (a set of operation that ready to be scheduled) is equal to all without predecessor operation.

Step 2: Set $r^* = \min(r_j)$, is the very first $j$ operation that can be completed ($r_j = c_j + t_{ij}$). Set $m^*$, all machines where $r^*$ can be realized.

Step 3: For all operations in $PS_t$ that need machine $m^*$ and has $c_j < r^*$ for all certain priority rules. Add an operation with the biggest priority into $PS_t$ so that a partial schedule is formed for the next step

Step 4: Make a new partial schedule $P_{t+1}$ and update the set to omitting the operation $j$ from $S_t$ then make $S_{t+1}$ by adding successor operation $k$ that has been omitted then add one to $t$.

Step 5: Back to step 2 until all jobs is scheduled.

### 3.2. Non Delay Schedule Generation Algorithm

Is an active scheduling method that will not let machines to be idled when the operation starts. Priority is using Short Processing Time (SPT)

Step 1: $t = 0$, $PS_t = 0$ (partial schedule that contain a scheduled $t$ operation). Set $S_t$ (a set of operation that ready to be scheduled) is equal to all without predecessor operation.

Step 2: Set $c^* = \min(c_j)$, is the very first $j$ operation that can be processed. Set $m^*$, is machines where $c^*$ can be realized.

Step 3: For all operations in $PS_t$ that need machine $m^*$ and has $c_j = c^*$ for all certain priority rules. Add an operation with the biggest priority into $PS_t$ so that a partial schedule is formed for the next step.

Step 4: Make a new partial schedule $P_{t+1}$ and fix the set to omitting the operation $j$ from $S_t$ then make $S_{t+1}$ by adding successor operation $k$ that has been omitted then add one to $t$.

Step 5: Back to step 2 until all jobs is scheduled.

### 3.3. Tabu Search Algorithm

Is a meta-heuristic method, using short-term memory to keep the process will not have stuck on local optimum value dan tabu list to save a set of solution that just be evaluated

Step 1: Choose initial solution $i$ in set $S$. Determined $i^* = i$ and $k = 0$, where $i^*$ is the best solution and $k$ is the number of repetitions when searching the best solution $i^*$.

Step 2: Set $k = k+1$ dan come up with subset $V^*$ from a solution in set $N(i,k)$ so that tabu condition will not be provided and aspiration conditions will.

Step 3: Set the best solution $j$ in subset $V^*$ and set $i = j$.

Step 4: if $f(i) < f(i^*)$ then set $i^* = i$.

Step 5: Update tabu and aspiration conditions.

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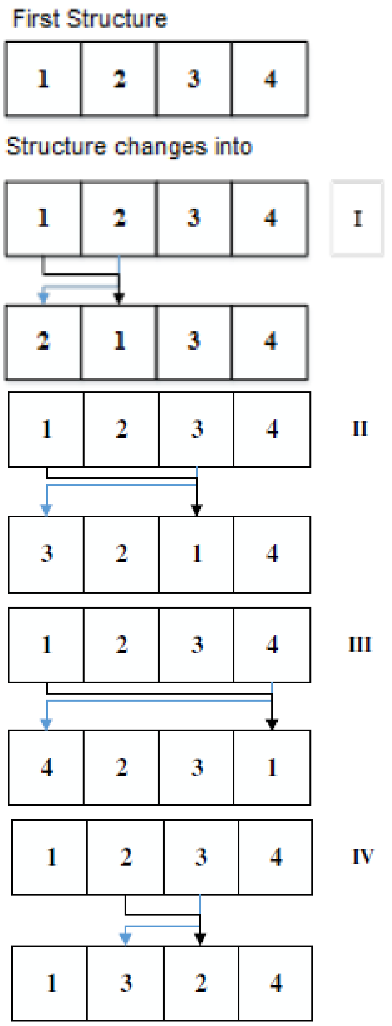
Step 6: If stopping condition is provided, then searching stops, else do step 2.

Where:

*i* = Initial solution or a found solution.
*i** = Best solution from found solution.
*k* = Repetition or iteration.
*j* = Neighbor solution from V* or a found solution for repetition.
*S* = A Set from all objective function or a set of possible solution.
*V** = Optimum subset value from N(i,k) or subset of N(i,k).
*N*(*i,k*) = A set of possible solution for all repetitions.
*f*(*i*) = Function value with variable i.
*f*(*i**) = Function value with optimum variable.

In doing local iteration, a calculation were made using neighborhood search, so that this searching technique, every possible attributes and structures can be moved using combination rules, as seen on Figure 2.



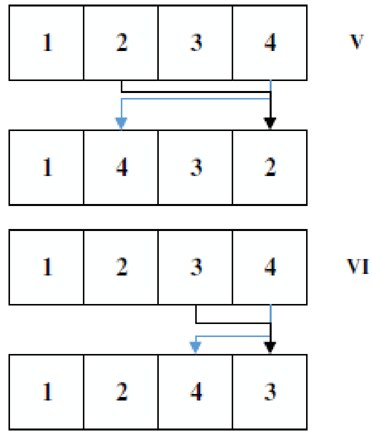




Figure 2. An illustration of n-Change Neighborhood Move

Stopping conditions on TS will be provided if:

Stage 1: *N*(*i, k+1*) = *Ø* or ther is no possible solution on solution *i*.
Stage 2: *k* value is greater than allowed maximum repetitions.
Stage 3: Number of repetitions from updating solution *i* is number of repetitions.

## 4. RESULT AND DISCUSSION

Table 2 shows the data of jobs, Table 3 shows routing process, Table 4 shows processing time for each operation, and Table 5 shows name and number of machines.

Table 2. Data of Jobs

| No | No Job | JID No | Part Number | Part Name | Position | Qty | Start Date | Finish Date |
|---|---|---|---|---|---|---|---|---|
| 1 | Job 1 | 20187032 | L5725200820002 | FRONT SPAR R8-R14 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 2 | Job 2 | 20187030 | L5725200820002 | FRONT SPAR R8-R14 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 3 | Job 3 | 64749828 | L5745747320001 | HINGE RIB 3 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 4 | Job 4 | 20188985 | L5745747320001 | HINGE RIB 3 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 5 | Job 5 | 64749851 | L5745747320001 | HINGE RIB 3 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 6 | Job 6 | 20152673 | L5745744220001 | HINGE RIB 1 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 7 | Job 7 | 20152672 | L5745744220001 | HINGE RIB 1 | Right | 1 | 07/09/2015 | 11/09/2015 |
| 8 | Job 8 | 20174974 | L5745744220101 | HINGE RIB 1 | Left | 1 | 07/09/2015 | 11/09/2015 |
| 9 | Job 9 | 20174977 | L5745744220101 | HINGE RIB 1 | Left | 1 | 07/09/2015 | 11/09/2015 |
| 10 | Job 10 | 20186593 | L5745747220101 | INTERMEDIATE RIB | Left | 1 | 07/09/2015 | 11/09/2015 |
| 11 | Job 11 | 64749426 | L5745746720001 | DRIVE RIB 1 INBOARD | Right | 1 | 07/09/2015 | 11/09/2015 |
| 12 | Job 12 | 64749487 | L5745746720101 | DRIVE RIB 1 INBOARD | Left | 1 | 07/09/2015 | 11/09/2015 |
| 13 | Job 13 | 64749501 | L5745746820001 | DRIVE RIB 1 OUTBOARD | Right | 1 | 07/09/2015 | 11/09/2015 |
| 14 | Job 14 | 64749589 | L5745746920001 | DRIVE RIB 2 INBOARD | Right | 1 | 07/09/2015 | 11/09/2015 |
| 15 | Job 15 | 20191846 | L5745746920101 | DRIVE RIB 2 INBOARD | Left | 1 | 07/09/2015 | 11/09/2015 |
| 16 | Job 16 | 64749648 | L5745747020001 | DRIVE RIB 2 OUTBOARD | Right | 1 | 07/09/2015 | 11/09/2015 |
| 17 | Job 17 | 64749884 | L5745747420001 | DRIVE RIB 3 INBOARD | Right | 1 | 07/09/2015 | 11/09/2015 |
| 18 | Job 18 | 20191125 | L5745747320101 | HINGE RIB 3 | Left | 1 | 07/09/2015 | 11/09/2015 |
| 19 | Job 19 | 20191126 | L5745747320101 | HINGE RIB 3 | Left | 1 | 07/09/2015 | 11/09/2015 |
| 20 | Job 20 | 64686674 | L5744016820001 | SUB SPAR | Right | 1 | 07/09/2015 | 11/09/2015 |

Table 3. Routing Process

| | | | Pre Operation | | Main Operation | | Next Operation | |
|---|---|---|---|---|---|---|---|---|
| No | No Job | Total Operation | Facing | Tooling Hole | Milling 1 | Milling 2 | Fitter | Drilling |
| 1 | Job 1 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 2 | Job 2 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 3 | Job 3 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |
| 4 | Job 4 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |
| 5 | Job 5 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |
| 6 | Job 6 | 6 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 7 | Job 7 | 6 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 8 | Job 8 | 6 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 9 | Job 9 | 6 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 10 | Job 10 | 6 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 11 | Job 11 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 12 | Job 12 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 13 | Job 13 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 14 | Job 14 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 15 | Job 15 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 16 | Job 16 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 17 | Job 17 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | | 3A,3B | 4A, 4B, 4C, 4D, 4E |
| 18 | Job 18 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |
| 19 | Job 19 | 5 | 1A, 1B, 1C, 1D | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |
| 20 | Job 20 | 4 | | 1A, 1B, 1C, 1D | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 2A, 2B, 2C, 2D, 2E, 2F, 2G | 3A,3B | |

Table 4 Processing Time for Each Operations

| | | | Pre Operation (Jam) | | Main Operation (Jam) | | Next Operation (Jam) | |
|---|---|---|---|---|---|---|---|---|
| No | No Job | Total Jam | Facing | Tooling Hole | Milling 1 | Milling 2 | Fitter | Drilling |
| 1 | Job 1 | 31,027 | 7,017 | 2,500 | 19,890 | | 0,420 | 1,200 |
| 2 | Job 2 | 31,027 | 7,017 | 2,500 | 19,890 | | 0,420 | 1,200 |
| 3 | Job 3 | 27,085 | 3,863 | 1,663 | 8,504 | 12,205 | 0,850 | |
| 4 | Job 4 | 27,085 | 3,863 | 1,663 | 8,504 | 12,205 | 0,850 | |
| 5 | Job 5 | 27,085 | 3,863 | 1,663 | 8,504 | 12,205 | 0,850 | |
| 6 | Job 6 | 62,398 | 4,596 | 3,792 | 20,800 | 31,200 | 1,550 | 0,460 |
| 7 | Job 7 | 62,398 | 4,596 | 3,792 | 20,800 | 31,200 | 1,550 | 0,460 |
| 8 | Job 8 | 62,398 | 4,596 | 3,792 | 20,800 | 31,200 | 1,550 | 0,460 |
| 9 | Job 9 | 62,398 | 4,596 | 3,792 | 20,800 | 31,200 | 1,550 | 0,460 |
| 10 | Job 10 | 26,439 | 4,892 | 2,375 | 11,141 | 6,761 | 0,520 | 0,750 |
| 11 | Job 11 | 24,230 | 3,942 | 0,745 | 17,596 | | 1,387 | 0,560 |
| 12 | Job 12 | 24,230 | 3,942 | 0,745 | 17,596 | | 1,387 | 0,560 |
| 13 | Job 13 | 22,338 | 4,353 | 0,827 | 15,006 | | 1,592 | 0,560 |
| 14 | Job 14 | 21,065 | 3,524 | 0,661 | 15,142 | | 1,178 | 0,560 |
| 15 | Job 15 | 21,065 | 3,524 | 0,661 | .15,142 | | 1,178 | 0,560 |
| 16 | Job 16 | 23,132 | 3,797 | 0,716 | .16,744 | | 1,315 | 0,560 |
| 17 | Job 17 | 18,587 | 2,366 | 0,413 | .14,543 | | 0,705 | 0,560 |
| 18 | Job 18 | 27,085 | 3,863 | 1,663 | . 8,504 | 12,205 | 0,850 | |
| 19 | Job 19 | 27,085 | 3,863 | 1,663 | . 8,504 | 12,205 | 0,850 | |
| 20 | Job 20 | 38,143 | | 2,821 | .17,089 | 17,000 | 1,233 | |

Table 5 Name and Number of Machines

| Proses | Work Center | Nama Mesin | Jumlah Mesin (Unit) | Kode Mesin | ID Mesin |
|---|---|---|---|---|---|
| Pre Operation | 1 | CNC Machine DGMP | 4 | DGMP 1 | 1A |
| | | | | DGMP 2 | 1B |
| | | | | DGMP 3 | 1C |
| | | | | DGMP 4 | 1D |
| Main Operation | 2 | CNC Machine SGAL | 1 | SGAL | 2A |
| | | CNC Machine JOBS | 1 | JOBS | 2B |
| | | CNC Machine MATEC | 1 | MATEC | 2C |
| | | CNC Machine DGAL | 4 | DGAL 1 | 2D |
| | | | | DGAL 2 | 2E |
| | | | | DGAL 3 | 2F |
| | | | | DGAL 4 | 2G |
| Next Operation | 3 | Fitter Steel Cell | 2 | Fitter 1 | 3A |
| | | | | Fitter 2 | 3B |
| | 4 | Drilling Machine | 5 | DM 1 | 4A |
| | | | | DM 2 | 4B |
| | | | | DM 3 | 4C |
| | | | | DM 4 | 4D |
| | | | | DM 5 | 4E |

Makespan for big part scheduling for each method were,

a. Active Schedule Generation SPT =103.1 hours
b. Non Delay Schedule Generation SPT = 103.4 hours
c. Tabu Search = 82.9 hours

The existing scheduling was having the biggest lateness which was 33.1 hours on job 7 and job 9. While for Active Schedule Generation SPT was 21.9 hours on job 9, Non Delay Schedule Generation SPT was 22.2 hours on job 9, and Tabu Search was 1.6 hours on job 19. Lateness value in Tabu Search was the smallest compare to other methods and existing method.

Job sequencing on Tabu Search also better than other methods and existing method, as seen on Figure 3. Tabu Search was doing scheduling not only on the job with the smallest operation time, so that the job will be advanced to be early processed like Active Schedule Generation SPT and Non Delay Schedule Generation SPT did. Tabu Search conduct every combination of job processing on every possible operation on regards to achieved minimum makespan and the smallest lateness. Tabu Search was having lateness for 5 jobs which were on job 2 with lateness 1.4 hours, job 4 with lateness 1.5 hours, job 5 with lateness 0.6 hours, job 10 with lateness 0.5 hours, and job 19 with lateness 1.6 hours.

This method has 1 job lateness more than other scheduling methods. However, the lateness on Tabu Search was smaller than other scheduling methods, due to job sequencing and loading to machines was balance.

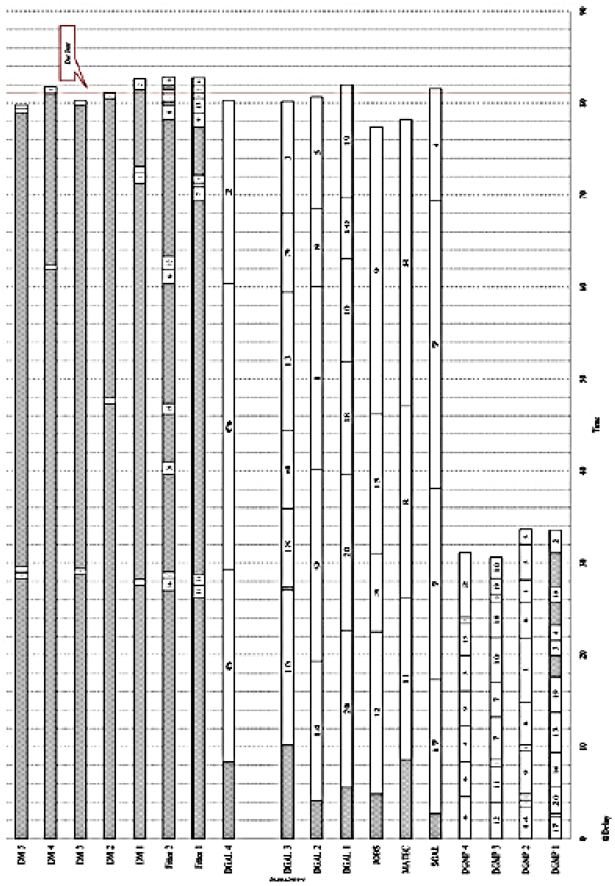


Figure 3. Gantt Chart for Tabu Search Scheduling

## 5. CONCLUSION

Scheduling for big part with makespan criteria by Tabu Search method has makespan 82.9 hours and can save makespan for 27.6% from the existing method. Tabu Search method has a better job sequencing compare to other methods. Tabu Searc can raise machine effectivity, it means machine loading was more balance. Lateness on Tabu Search was 5 jobs with the longest lateness was 1.6 hours on job 19. This lateness was smaller compare to other methods, and can be overcame by conducting only 1 time of over time, so that there will be no lateness on Tabu Search.

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