FLOWSHOP SCHEDULING WITH SEQUENCE DEPENDENT SET-UP TIME USING IMMUNE ALGORITHM TO REDUCE MAKESPAN IN PT. XYZ BANDUNG AS A TEXTILE INDUSTRY

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Abstract—In manufacturing operations, production system is certainly an important aspect. Thus, company should do the planning and production control well in order to have satisfactory system. One of the production planning process is scheduling. This process is one of the main process in production planning. The urge of doing the scheduling process is due to scheduling is the details of the planning process. The production scheduling in textile industry is considered as the industry with the hybrid flow shop scheduling type. Moreover, in this company there are several machine have the characteristic of sequence dependent setup time. Thus, in order to get the optimal solution this research used Immune Algorithm. This algorithm combines an efficient mutation to cooperate the pursuit for a near-optimal solution.

Keywords—Hybrid flow shops, Sequence Dependent Setup Times, Makespan, Immune Algorithm

I. INTRODUCTION

I.1. Background

In manufacturing operations, production system is certainly an important aspect. Thus, company should do the planning and production control well in order to have satisfactory system. One of the production planning process is scheduling. This process is one of the main process in production planning. The urge of doing the scheduling process is due to scheduling is the details of the planning process.

PT. XYZ is a well-known garment and textile industry. This company is located in Bandung and already expand its business internationally. The customers of this company come from many countries in Europe, Middle East Asia, and South East Asia. Thus, as the company grow larger, it needs good production planning and control to compete with the other textile industries.

PT. XYZ produces a variety of products that can be divided into two general types, they are dyeing fabric and printed fabric. The raw material of these product appeared to be from similar kind of fabric, which is gray polyester. These products pass through several machines with different techniques. Additionally, the type of the fabric can affect the types of machines and techniques that will be passed. Therefore, the importune character of final product alter the machines and techniques used in the production. These matters induce the differences on generating the schedule for every order.

PT. XYZ produces several type of products which also comes from different material. As shown in Fig 1. on January 2016 until August 2017 the Top-3 highest delayed order based on the material are Bubbly Girl, Light Chiffon, and Amunzen, which is has the percentage of delayed delivered order are 23% (3,231,007 m), 7% (983,016 m), and 1% (192,449 m) of all total delayed delivered order (14,351,368 m) in January 2016- August 2017.

The root cause of delayed problem can refer to the production. Some of the causes are reworked product, which leads to defect product, and scheduling method. The problem for defect product has been solved in another research. Then the other reason, current scheduling method in PT. XYZ is not efficient. The current scheduling process is done everyday for every machines.

In addition, the difficulty of designing an efficient scheduling in PT. XYZ is due to considering several constraints. Firstly, considering precedence constraint, the sequence of the job has to meet the flow process of the material. Then, considering the sequence-dependent setup time for each machines in PT. XYZ. Setup time for machine is a notable element for production scheduling in every sequence of flow, and it possible to simply use up 20% even more of usable capacity of machine if not appropriate managed

(Pinedo, 1995). Further, the production completion time and machine setups are impacted by the production mix also production sequence. On the one side, processing in a large batch raise the machine utilization and reduce the total time of setup. Otherwise, it also raises the flow time. Indisputable, the existing of tradeoff amongst machine utilization and flow time by deciding batch size and scheduling. Issues in scheduling with sequence-dependent setup times are by the whole of the most challenging classes of the issues (Pinedo, 1995).

Furthermore, the process in PT. XYZ is not entirely processed by the series machines as if the other general production flow shop. Rather of m machines in series there are c stages which at every stage there are number of parallel exact similar machines (Pinedo, 2016, p. 15). This production scheduling in PT. XYZ is considered as the industry with the hybrid flow shop scheduling type.

As the character of hybrid flow shop scheduling, the machine's setup time in this textile industry is consequently produced time lags for the other machines. A time lag is described as the time between the end of the processing of one job at a certain machine inside one stage and the starting point in the next stage that the job is processed (Javadian, 2012). This impact obtains the waiting time for the work-in-process material because of the setup time and the parallel machines. Also, a job in existence often composes of a massive quantity of products with the equal specifications, like an amount of ceramic tiles or an amount of bolts and nuts. In many industries, the beginning of an operation at a stage has the potency of delay because the preceding operation must need time to dry or cool down. (Javadian, 2012).

As cited from Zandieh et al. (2006) that Mori et al. cited that the benefits of IA and other probabilistic optimization algorithms such as genetic algorithms are elaborated as follows:

1. IA acts on the memory cell, which assures quick convergence against the global optimum.
2. IA has a closeness calculation routine to exemplify the variety of the real immune system.

3. Self-adjustment of the immune reaction can be exemplified by the help or elimination of antibodies production.

The suggested algorithm combines an efficient mutation to cooperate the pursuit for a near-optimal solution. The new mutation transfers the best solutions established so far in the following generation. The new mutation redeploys the best solutions found so far in the subsequent generation (Zandieh et al. 2006).

I.2.   Problem Formulations

The problem formulations of this research are stated in the form of question below:

1. How to determine the job and machine sequence in PT. XYZ to reduce the makespan using Immune Algorithm?
2. How is the the comparison between the proposed scheduling and existing scheduling?

I.3.   Research Objectives

As the existing problems have been drawn, the objectives of this research are:

1. Determine the job sequence in PT. XYZ to reduce makespan using Immune Algorithm.
2. Compare the result between the proposed scheduling and existing scheduling.

I.4.   Research Limitation

This research has to meet its limitations; they are:

1. Due date of each order is 3 weeks.
2. The characteristic of material is the same.
3. The characteristic of machines with mutual process is the same.
4. All of existing machines are used.
5. Batch size is specified by the company.
6. Production capacity each day is specified by the company.
7. Do not schedule the printing block.
8. The number of machines are determined by the company.
9. Proposed scheduling is only based on the calculation obtained.

I.5.   Research Benefits

The benefits of this research are:

1. As a suggestion to PT. XYZ in reducing the total makespan in the production process.
2. As a suggestion to reduce delays in deliver product to customer of PT. XYZ.

II. LITERATURE REVIEW

II.1. Scheduling

Scheduling is the procedure of decision-making as the general basis in manufacturing and service industries. Scheduling handles the resources distribution to the jobs over certain time and the goal is to optimize the objectives (Pinedo, 2015).

Based on Sinulingga (2009, pp. 183-184) scheduling is a further activity in the subsystem of production controlling after the order release has been done. Scheduling is concerned on determining which order is actually ready to start its job on each workstation, in case that the period of the execution schedule has been ordered.

A certain priority level also might be launched by each job, likely as a potentially earliest starting time and a due date. The goal of scheduling also can be various, it could be the minimization of completion time and the other could be the amount minimization of the completion of the job after their due dates.

Sinulingga addressed the determination of priority level between the orders is indeed to be done in order to achieve best outcomes. The best outcomes refer to the achievement of whole, or most, objectives based on the 5 criteria, which are; meeting due date, minimum lead time, minimum setup time, minimum work-in-progress, and maximum work center utilization level.

As a procedure of decision-making, scheduling is the crucial element in almost every manufacturing and production systems along with the environment of information processing. However, in order to achieve the 5 criteria based on Sinulingga, in the practice it is hard to meet the priority level that satisfy all of the criteria. Thus, for every order is mostly analyzed the tradeoff analysis between one criteria to the other one. To simplify the problem, only one criteria is considered as the most important as the basis to decide the priority level.

II.2. Hybrid Flow Shop

Hybrid Flow Shop or as known as flexible flow shop is the generalization version of the flow shop and parallel machine environments, in which the same operations can be performed by the parallel machines. Briefly describing (Javadian, et al,. 2012), HFS is a group of jobs that has to be processed on a group of processing work centers. Every work center consists of a group of parallel machines. Each job includes a sequence of operations processed at ensuing centers, and whole jobs go through centers in the equal order. No difference among the machines in a work center; thence, each machine at separately work center may process a job. Several stages in HFS shall have only one facility, but the qualification for the plant to be an HFS, somewhat it has to have several facilities in one stage.

In hybrid flow shop, there are c stages in series with the additional at each stage some numbers of exact machines in parallel. Each job has to be passed based on the sequence stage, such as stage 1, next at stage 2, and so on. The function of a stage is as a group of parallel machines; at every stage, job j involves processing on only one machine and the other machine can do. Additionally, in each stage every single piece of the product is processed at only one facility. Machines can be similar, homogeneous, or even unrelated. Queues amongst the numerous stages may or may not conduct based on the First Come First Served (FCFS) discipline. The products flow in the plant is unidirectional.

II.3. An Immune Algorithm
II.3.1. Immune System in General

Artificial Immune Systems are computational techniques, which is influenced by the biological immune system. This system can be used to deal with complicated problems. This technique also develops upgraded solutions of the problem by means of clonal selection, immune network theory, vaccination, or other immune system concepts.

The common immune system is a complex adaptive arrangement identification system that preserves the body from external pathogens (bacteria or viruses). It has tense and complex system that recombine the gene in order to confront with the penetrating antigens, generate the antibodies, and eliminate the antigens. The process of infection includes the infiltration of a pathogen and its propagation in the organism. Pathogens are correlated with certain proteins (antigens). The immune system consists of cells that adequate to perceive antigens and kill pathogens. All these cells, then introduced to as immune cells (antibodies), are irregularly assigned throughout the immune system. Each of the particular immune cell involved in adjusting immunity is able to recognize only one kind of antigen. When there is a case of infection, partially, only a small rate of immune cells would react. This synergy provokes the quick duplication pf these certain cells (clonal proliferation). The amount of immune cells that able to perceive the exact antigens and kill the exact pathogen raises by many orders. Thence, the immune system becomes tuned to battle not only incidental pathogens but in specific the one that actually infected.

How the immune system reacts to pathogens and how it develops its potential of recognizing and killing pathogens are explained by the clonal selection and affinity maturation principles. Clonal selection describes that when a pathogen penetrates the organism, some immune cells that recognize these pathogens will propagate; some will become effecter cells, otherwise the others will be preserved as a memory cells.

The effecter cells excrete antibodies in enormous numbers, furthermore the memory cells have long life spans thence act more effectively and more rapid in forthcoming liabilities to the exact or an identical pathogen.

Throughout the reproduction of cellular, the cells experience somatic mutations at extreme rates, with a careful force; the cells with higher affinity to the penetrating pathogen separated into memory cells.

All of these processed of somatic mutation as well as the selection are known as affinity maturation. From the information processing perspective, the immune system is a considered as an adaptive system and can implement several important aspects in computation. When incorporated with evolutionary algorithms, the immune system can improve the search ability during the evolutionary process [1].

II.3.2. Immune Algorithm Approach to Hybrid Flow Shop Scheduling

In Immune Algorithms, the antigens indicate the objective function that has to be optimized. The antibodies indicate the solutions possibility to a

problem. Generally, the basic antibodies are randomly developed on an attainable slot. The analysis of new antibodies is usually implemented by attaining a group of solutions possibility in an iterative approach until a pre-determined amount of generations have been obtained. A calculation compatibility amongst antibodies is also entrenched within the algorithm to restrain similar antibodies. As a result of Immune Evolutionary Algorithm (IEA) computation, the most qualified antibody to the antigen is recognized as the solution to hybrid flow shop scheduling with SDST.

1) Initialization:
   a) Parameter setting: Set the number of the primary population (n_p), number of generation (n_g), possibility of crossover (p_c), possibility of mutation (p_m), affinity threshold (a_t), and affinity adjustment (a_a).
   b) Primary population generation:
      (b-1) Randomly generate an primary population of (n_p-3) antibodies.
      (b-2) Generate an antibody with SPTCH.
      (b-3) Generate an antibody with FTMIH.
      (b-4) Generate an antibody with g/2, g/2 Johnson's rule.
2) Objective function evaluation: Evaluate the fitness function for each of the antibodies.
3) Mating pool generation:
   a) The best one selection: Record the most-preferred antibody according to fitness in a mating pool (accelerating mechanism).
   b) Affinity evaluation: Evaluate the correlation between each antibody with the most-preferred antibody achieved so far.
   c) Similar antibodies suppression: If some antibodies have an affinity value higher than a prescribed threshold (a_t), then reduce the probability assigned to those and normalize the probability (restraining mechanism).
   d) Mating pool expansion: Select with replacement ($n_p - 1$) antibodies from the full population (including the best antibody). The antibodies are selected according to their fitness, with those antibodies having a higher fitness value being selected more often.
4) Crossover operation: Select ($n_p \times p_c$) pairs of parents from the mating pool and perform crossover on the parents randomly.
5) Replacement: While retaining the best antibody from the previous generation, replace the remaining ($n_p - 1$) antibodies with the current population of clones (or offspring) from step 3.
6) Mutation operation: Select ($n_p \times p_m$) antibodies from the mating pool and mutate the individual bits.
7) Fitness evaluation: Compute the fitness values for the new population of (n_p) antibodies.
8) Termination test: Terminate the algorithm if the stopping criterion is met; else, return to step 2.

The problem raised in this research can be stated formally as a mixed integer program. Let g be the number of stages, n be the number of jobs to be scheduled, and m^t be the number of machines at stage t. Those machines are set up beforehand for a nominal job 0 and should finish setup for a teardown job n + 1, which is assumed at every stage. We have the following definitions:

n	Number of true jobs to be scheduled
g	Number of serial stages
g_j	Last stage visited by job j
m^t	Number of machines at stage t
p^t_i	Processing time for job i at stage t (assumed to be integral)
s^t_{ij}	Setup time from job i to job j at stage t
S_i	Set of stages visited by job i
S^t	Set of jobs that visit stage t, $S^t = \{i : p^t_i > 0\}$
c^t_i	Completion time for job i at stage t
x^t_{ij}	1 if job i is scheduled immediately before job j at stage t and 0 otherwise
l^t_j	Time lag of job j from stage t to stage $t+1$

The jobs 0 and $n+1$ are counterfeits and their processing times are scened to be 0; the setup times are recognized as the mobilize time from and to the ostensible set point condition. It is presumed that at every stage, all ongoing jobs should be finished before the jobs demanded scheduling may start setup. The finishing time of job 0 at every machine at every stage is scened to be the earliest setup time and allowed to start at that stage. The limit carried is that every stage have to be entered by the jobs at least as many as the number of machines in that stage.

This is stated by the inequality $|S^t| \geq m^t$, $t=1,2,...,g$, so $n \geq \max_{t=1,2,...,g}\{m^t\}$. Assuming that a stage is entered by less than the number of machines, there is not a complicated sequencing determination to be made because every job is able to be charged to its own machine. It is also presumed that a job does not enter a stage with a processing time 0. That is, $p^t_i = 0$ if $i \notin S^t$. Additionally, it is presumed that $p^t_i \geq 1$ if $i \in S^t$.

III. RESEARCH METHODOLOGY

The beginning process of this research started with deciding of the input parameter, which are number of jobs, number of operations in each job, number of machines, processing time, setup time for each machine, and flow process.
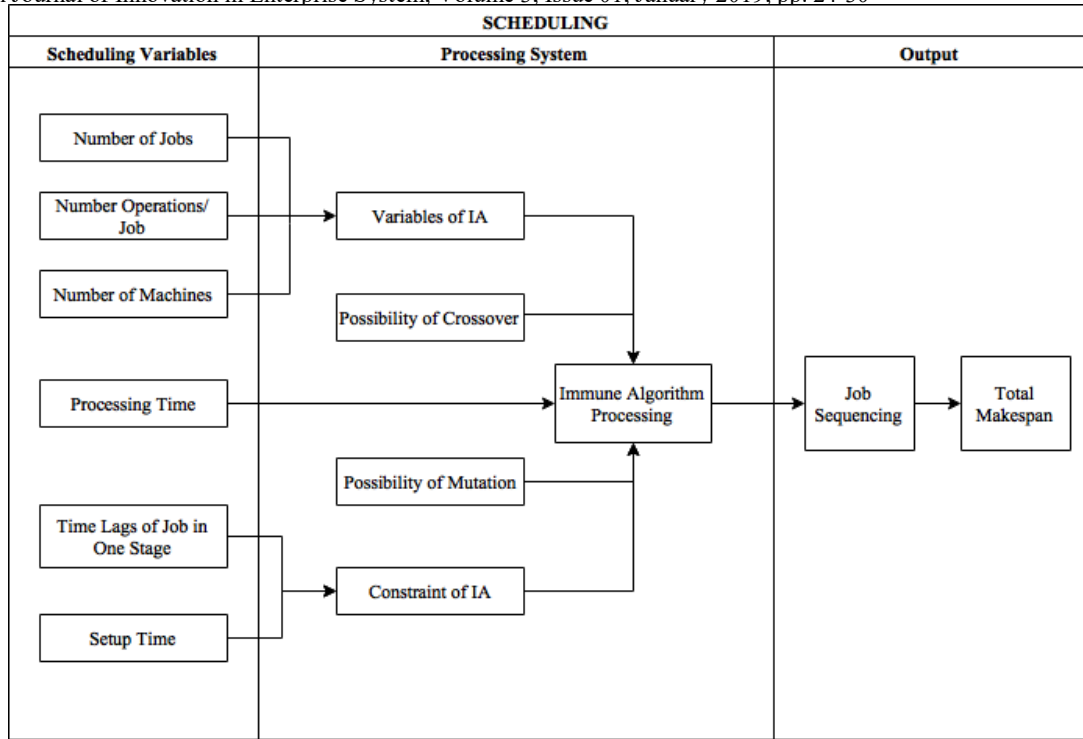
Fig 1. Conceptual Model

Based on the Fig 1. the scheduling variables or as known as the input are various. The number of jobs, number operations per job, and number of machines are set to be the parameter setting of the immune algorithm. The constraints of the problems raised, time lags of job in one stage and setup time, become the constraint of the algorithm. Therefore, to process the algorithm, all these inputs are composed altogether with the processing time, possibility of crossover, and possibility of mutation. Thence, it is obtained the expectedly optimize machine scheduling which lead into the optimal total makespan.

IV. COLLECTING DATA AND PROCESSING

IV.1. Initial Scheduling

The existing scheduling system that is implemented in PT. XYZ is the First Come First Serve system. Thus, the job is sorted based on the date of entry, then the job with the earliest date of entry will be processed first. On August 2017 in PT. XYZ the makespan is 67.79 hours or more than 2 days 19 hours to produce 2400m length per job.

IV.2. Initial Population Generation

The initial population are generated randomly in feasible space and by SPTCH order which is proposed by Kurz and Askin. By using 101 intial population, obtained the antibody as follow,

VI.2.1. Job sequence (1 row [left to right] 1 antibody) Randomly Generated, with 100 times iteration.
Each job is scheduled to be processed in machine sequence.

VI.2.2. Machine sequence (1 row [left to right] 1 antibody) Randomly Generated.
Each machine processes the job sequence as the order that has been obtained. The first number in the machine sequence defines the machine, and the number after comma (",") defines the fractional number which is uniformly distributed.

IV.3. Fitness Value

Fitness Value is obtained using the formulation $f(i)$. Thence, the fitness value is as follow, with 100 population

$$f(i) = \frac{\frac{1}{C_{max}(i)}}{\sum_{i=1}^{N} \frac{1}{C_{max}(i)}}$$

Best fitness value is then obtained. For minimization, a high fitness indicates a low makespan, and on the other hand, a candidate solution with a low fitness value indicates a high makespan.

IV.4. Antigen Based on the Best Fitness value Makespan

Antigen 1: 52.09 hours
Antigen 2: 54.21 hours
Antigen 3: 50.42 hours
Antigen 4: 52.71 hours

V. DATA ANALYSIS

V.1. Initial Scheduling Analysis

Existing Scheduling in PT. XYZ is designed based on the First Come First Serve system. The total makespan for the existing scheduling is 67.79 hours to produce 18 jobs for 2400m length each job.

Although, the demand is already determined every month, the job is assigned based on the first in ordered. It can be seen, that in some machines there are many idle time, specifically in machine BO Fact, Stenter (presett), Washer, Stenter (Heatsetting), Jet (Dyeing), in which causes low machine utilization.

The poor job sequence causes idle time on the machine and effects the total producion makespan which in many times exceed the due dates.

V.2. Selected Proposed Scheduling

Based on the makespan that has been obtained from the proposed scheduling, then the Antigen 3 can be chosen as the selected proposed scheduling. The proposed scheduling then can be implemented in PT. XYZ to produce the products.

V.3. Comparison Between Intial Scheduling Makespan and Proposed Scheduling Makespan

The makespan of existing scheduling is 67.79 hours or more than 2 days 19 hours to produce the 2400m length of each job. While on the selected proposed scheduling the makespan is 50.42 hours to produce the same length of products per job. This signifies that the proposed scheduling can decrease the production leadtime by 25.62%.

VI. CONCLUSION AND FUTURE WORK

This research implement the Immune Algorithm to solve a hybrid flowshop scheduling. After the calculation using the algorithm, the proposed scheduling is compared to the existing scheduling.

The proposed machine sequence is as follow,
1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 4, 4, 4, 4
The proposed job sequence is as follow,
1, 7, 13, 5, 6, 12, 4, 10, 11, 3, 9, 15, 2, 8, 14
The makespan of existing scheduling is 67.79 hours or more than 2 days and 19 hours to produce

the 2400m length of each job. While on the selected proposed scheduling the makespan is 50.42 hours to produce the same length of products per job. This signifies that the proposed scheduling can decrease the production leadtime by 25.62%.

In addition, the proposed scheduling has less idle time compare to the existing scheduling. Thus, the machine utilization in proposed scheduling is higher than in existing scheduling.

For the future work, can be suggested;

1. Increase and or decrease number of machine to reduce makespan and idle time.
2. Using different parameter, to get nearer-optimal solution.
3. Using another meta-heuristic algorithm, and compare to IA to get nearer-optimal solution.

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