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A Neighborhood Search for Sequence-dependent Setup Time in Flow Shop Fabrics Making of Textile Industry

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Abstract

This paper proposes a neighborhood search to solve scheduling for fabrics making in a textile industry. The production process consists of three production stages from spinning, weaving, and dyeing. All stages have one processor. Setup time between two consecutive jobs with different color is considered. This paper also proposes attribute's decomposition of a single job to classify available jobs to be processed and to consider setup time between two consecutive jobs. Neighborhood search (NS) algorithm is proposed in which the permutation of set of jobs with same attribute and the permutation among set of jobs is conducted. Solution obtained from neighborhood search, which might be trapped in local solution, then is compared with other known optimal methods.

Keywords*: flow shop, neighborhood search, sequence-dependent setup time, textile industry.*

1. Introduction

Textile industry is one of important industries in Indonesia. There are several characteristics textile industry has which differ from other industries. The main characteristics are intensively machine and labor usage, multi-stage process, and vast variety of finished products. Scheduling in textile industry is challenging because there are many aspects must be taken into account, such as multi-item products and multi-stage process.

In this paper, scheduling-problem for fabrics making in a textile company is discussed. The fabrics making transforms raw material into different types and different colored fabrics, consists of three production stages from spinning, weaving, and dyeing. Every job follows the same routing. Each stage has one processor. Setup time between two consecutive jobs with different color is considered. The characteristics of the scheduling problem are identified as: multi-stage production, single machine flow shop, and sequence-dependent setup times. Attribute's decomposition of a single job is proposed to classify available jobs to be processed and to consider setup time between two consecutive jobs.

This paper is organized as follows: section 2 briefly reviews previous researches in textile industry and related scheduling-problem which similar to real problem; section 3 describes finished products and production system which textile company posses; section 4 introduces the problem formulation and explain the notations used throughout the paper; numerical example is given in section 5 to explain the proposed heuristic algorithm and the result is compared with shortest processing time (SPT) rule; and finally the paper's results is concluded in section 6.

2. Literature Review

In order to solve the real scheduling-problem in fabrics making, literature review is grouped into two broaden subjects: first, previous research in textile industry and second, related scheduling literatures which similar to our problem.

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2.1. Research in Textile Industry

Literatures on textile industry as a case study, especially scheduling problem, are not as many as on other process industry. However, several authors, especially from academia, have contributed to publish their work in textile industry.

Karacapidilis *et al.* (1994) developed Master Production Schedule (MPS) for textile industry. Toni et al. (2000) investigated how decision variables in production planning, i.e. planning period, material availability, effects on apparel industry time performance. Wu et al. (2002) utilized GA method to optimize fiber-dyeing manufacturing process subject to environment regulation, waste minimization alternatives, and resource limitation. Silva et al. (2006) solved lot sizing and scheduling problem found in spinning process. Zarandi et al. (2007) built a systematic fuzzy system modeling for scheduling of fabrics-dyeing manufacturing. Chen (2009) developed scheduling under machine breakdown for yarn making company with minimizes the maximum tardiness. Heuristic and branch-and-bound algorithm was developed to solve the problem. Elamvazuthy et al. (2009) used fuzzy programming to solve production planning model in cutting and sewing department. Hsu et al. (2009) proposed GA methodology to solve sequence-dependent setup time, group-delivery (a group of jobs pertaining to a particular customer order must be delivered together) of yarn-dyed textile production.

To the best to our knowledge, there hasn't been a paper describes the production system similar to our problem completely, particularly in scheduling problem. Some paper described yarn or fibers making, others described garment separately from yarn making. While our production system produces fabrics from raw material.

2.2. Sequence-Dependent Setup Time

In recent years, most of papers in scheduling explicitly consider setup time between jobs. Many papers have assumed setup times depend on the type of job just completed as well as on the type about to be processed. Quadt et al. (2006) gave a complete review about taxonomy of flexible flow line scheduling, including sequence-dependent setup time. Below are examples of authors that include setup time. Gupta et al. (2006) proposed algorithms for single machine total tardiness scheduling with sequence dependent setups. Gicquel et al. (2009) investigate discrete lot-sizing and scheduling problem with sequence-dependent changeover times. For our problem, sequence-dependent setup time is found in dyeing process. Ordering red colored fabrics after black colored fabrics in dyeing process requires more preparation time than ordering red fabrics preceded black fabrics. Preparation in dyeing process such as cleaning the bath from previous usage is a must in order to ensure the color quality of fabrics.

Another feature in our problem is product decomposition into attributes. Silva et al. (2006) used brightness as an attribute to classify the product in spinning process. Gicquel et al. (2009) proposed bottle size and liquid composition as attributes for their work in bottle filling industry. Attribute decomposition in flow shop scheduling that considers setup time also discussed by Kurniawan (2011), which proposed a heuristic approach to solve the corresponding problem. Although it showed that the proposed heuristic was far superior that traditional Shortest Processing Time (SPT), the solution was far from global optimal. Furthermore, no evidence it can be implemented in computer program. This paper tries to extend it by employing local search in which permutation of jobs in a set of jobs with same attribute and permutation of sets are conducted.

2.3. Neighborhood Search

Most scheduling problems are of NP-hard class. For small problems, analytical and enumerative approaches might suffice to solve the problems in reasonable time. However, as the problems get bigger analytical approaches will not be efficient anymore. Heuristics and meta-

heuristics approaches are suitable to solve big scheduling problem although they produce feasible solution. Meta-heuristics algorithm can be categorized as local search and evolutionary search. Neighborhood search (NS), tabu search, and scatter search belong to the first whereas genetic algorithm (GA), particle swarm optimization, to name a few, belong to the later. One disadvantage that many researches try to handle of meta-heuristics approaches is the algorithm might be trapped in local optima solution.

Many researches have been done and reported successfully to solve the scheduling problem with good solution in a reasonable time. Lei and Wang (2011) proposed a neighborhood search algorithm to solve flow shop of batch processing machines. Local search are conducted to make jobs permutation in a batch and batch permutation. The solutions were compared with GA. NS also can be applied to others problem such as cell formulation as proposed by Elbeani, et. al. (2012). NS was combined with GA to get the time-efficient and good solution.

3. Fabrics Making Process

Fabrics making consists of three stages process. Fig.1 depicts fabrics making process and product transformation in textile company. First process is spinning. Spinning process transforms raw material into different diameter of yarn. Currently the company uses three types of raw material to produce yarn: polyester, cotton, and rayon. Furthermore, from these three types of raw material, each of raw materials can be produced into different diameter yarn, namely 20, 32, 40, 50, 55, and 60. Thus from available raw materials, spinning process capable of producing 18 types of yarn, combination of the number of raw material and yarn diameter.

Yarn produced in spinning process then transferred into weaving process. The yarn is woven become fabrics according to the customer specification. Note that in weaving process, we can ignore the fabrics attribute mainly because weaving machine can be adjusted to meet customer requirement.

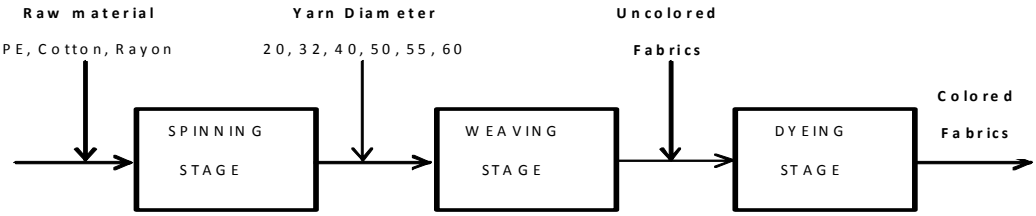

Fig.1. Production Process of Fabrics Making

The last process is dyeing. In this process, uncolored fabrics then are colored as per customer order. There are many possibilities of customer color order. Cleaning dyeing bath is required each time switching jobs with different color. Hence setup times depend on job sequencing.

4. Mathematical Formulation

Scheduling problem is built on several assumptions. First, job pre-emptive is not considered. Second, material shortage never occurs. Third, there are no machine breakdowns. Lastly, we don't consider order change for all jobs. The problem is formulated using the following notations:

Indices

i Job index.
j Attribute: raw material index.
k Attribute: yarn diameter index.
l Attribute: color index.

Parameters

n	Number of jobs.
f	Number of raw materials.
g	Number of yarn diameters .
h	Number of colors.
J^{i}_{jkl}	Job *i*, with attribute *j*, *k*, and *l*.
p^{s}_{ijkl}	Processing time of job *i*, with attribute *j*, *k*, and *l* in the first stage process.
p^{w}_{ijkl}	Processing time of job *i*, with attribute *j*, *k*, and *l* in the second stage process.
p^{d}_{ijkl}	Processing time of job *i*, with attribute *j*, *k*, and *l* in the third stage process.
s_i^{k*}	Setup time if job *i* with attribute *k* is processed after job with attribute *k**.
s_i^{l*}	Setup time if job *i* with attribute *l* is processed after job with attribute *l**.

Objective function

Minimize

$$Z = \sum_{i=1}^{n}\sum_{j=1}^{f}\sum_{k=1}^{g}\sum_{l=1}^{h}\left(p^{s}_{ijkl} + s_i^{k*}\right) + p^{w}_{ijkl} + \left(p^{d}_{ijkl} + s_i^{l*}\right) \quad (1)$$

An NS algorithm is proposed as a solution approach for the problem formulation above. Next section will discuss the proposed algorithm along with the numerical example.

5. Results and Discussions

Proposed NS algorithm is tested using processing time data in Table 1 whereas Table 2 presents matrix of sequence-dependent setup time for spinning process and sequence-dependent setup time data for dyeing process is presented.

Table 1. Processing time of available jobs

Job *i*	1	2	3	4	5	6	7	8
p^{s}_{ijk}	23	33	30	36	40	28	24	22
p^{w}_{iik}	88	86	61	67	81	72	67	85
p^{d}_{iik}	38	32	22	33	44	39	42	28

There are 8 jobs that must be processed in three flow shop machines. Each stage has single processor. The list of the corresponding jobs as follows:

Job 1: Yellow fabrics made from rayon-yarn diameter 40
Job 2: Red fabrics made from polyester-yarn diameter 40
Job 3: Blue fabrics made from cotton-yarn diameter 20
Job 4: Red fabrics made from polyester-yarn diameter 32
Job 5: Blue fabrics made from rayon-yarn diameter 20
Job 6: Yellow fabrics made from cotton-yarn diameter 32
Job 7: Blue fabrics made from polyester-yarn diameter 20
Job 8: Blue fabrics made from rayon-yarn diameter 40

Table 2. Sequence-Dependent Setup Times

	Follower attribute *k*		
Attribute *k*	1	2	3
1	0	7	11
2	7	0	10
3	11	10	0

	Follower attribute *l*		
Attribute *l*	1	2	3
1	0	8	14
2	7	0	5
3	13	14	0

5. 1. Neighborhood Search (NS) Algorithm

The proposed NS algorithm is as follows.

Step 0. Initialize the solution with attribute decomposition. Compute Z and denote the incumbent solution x* as optimal solution.*

Step 1. For each job in the set of attribute, do the local search. Compute Z_1 for this sequence. If Z_1 is better than Z, set Z_1 as the new incumbent of optimal solution. Go to step 2.a. Otherwise, go to step 2.b.*

Step 2.a. For each set of jobs, do the local search. Compute Z_2 for this sequence. If Z_2 is better than Z_1, set Z_2 as the new incumbent of optimal solution. Go to step 3. Otherwise, go to Step 2.b.
Step 2.b. Set Z as the optimal solution from Step 1 and Step 2.a. Go to Step 3.*
Step 3. Repeat Step 1 through Step 2.b. until no better solution found.

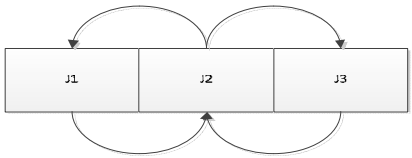

Fig.2. Local Search in A Set With Same Attribute

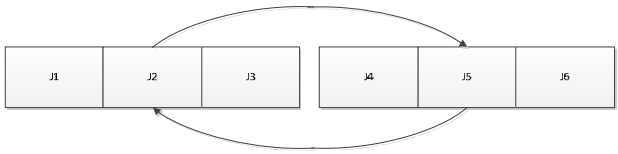

Fig.3. Local Search between Set with Same Attribute

5. 2. Results and Discussions

In this section, we present the numerical examples to test the proposed algorithm. First, the problem presented in the previous section is solved using the proposed algorithm and then the results are compared with integer programming (IP) solution obtained by IBM ILOG CPLEX solver. Time processing and solution are chosen as comparison. Second, experimental is conducted using hypothetical data. The proposed algorithm is implemented using C++ and running on Pentium 4 1 GB RAM. The experimental is running 50 times for each set hypothetic data. Table 3 shows the results of experiment based on the hypothetic data. Time computation is taken from the average of 50 data. The best solution from the 50 run is taken as the comparison with optimal solution from ILP formulation. Deviation of the NS solution is computed with respect to optimal solution.

Table 3. Results comparison

Number of jobs	NS			IP Solver	
	Time average (s)	Best Solution	Deviation from optimal solution	Time (s)	Optimal Solution
8	1.02	56	19.15%	1.00	47
9	1.50	62	8.77%	1.03	57
10	1.98	52	13.04%	2.05	46
11	2.00	43	13.16%	2.23	38
12	2.18	47	11.90%	2.21	42
13	2.20	45	9.76%	3.05	41
14	2.21	43	13.16%	3.12	38

Fig. 4 shows the time computation by NS and IP. It can be seen that for a small number of job instances, i.e. less than 10, IP solved by solver outperform the NS. However for relatively larger instances, time computation performed by NS is more superior to ILP. In the real system, number of jobs that must be scheduled commonly more than 20 even hundreds of jobs. This brings implications that our proposed NS might be suitable for real system condition. However as we depict in Fig. 5 the pitfall of NS in finding optimum solution. The proposed NS deviation is ranged between 8-19% bigger than the optimum solution. This means there are many things that must be improved in order the proposed NS can be applied into practice.

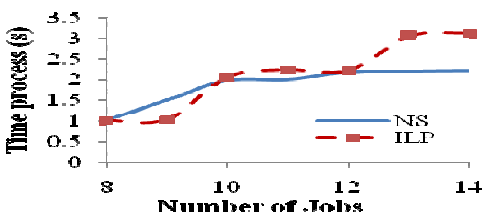

Fig.4. Time Computation Comparison

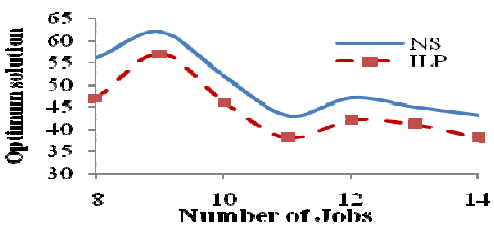

Fig. 5. Solution Comparison

6. Conclusions

The neighborhood search (NS) algorithm is proposed to solve the flow shop multi stage process which considers sequence-dependent setup time in fabrics making. The experiment showed the proposed NS algorithm must be improved in order to be implemented to solve real scheduling problems. Although time computation is more reasonable than IP for a large number of jobs instances, the solution gap is still wider from optimum solution. The proposed NS can be improved so as to avoid early local optima trap in the future research.

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