International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:3, No:1, 2009

Production Planning and Measuring Method for Non Patterned Production System Using Stock Cutting Model

S. Homrossukon, and D. Aromstain

***Abstract*—**The simple methods used to plan and measure non patterned production system are developed from the basic definition of working efficiency. Processing time is assigned as the variable and used to write the equation of production efficiency. Consequently, such equation is extensively used to develop the planning method for production of interest using one-dimensional stock cutting problem. The application of the developed method shows that production efficiency and production planning can be determined effectively.

***Keywords*—**Production Planning, Parallel Machine, Production Measurement, Cutting and Packing.

I. Introduction

CUTTING and packing problems appear under various name, such as cutting stock problem, bin packing problem, pallet container loading problem, knapsack problem, etc. [1]. It can be classified using four characteristics; 1) Dimension start with the simplest, one-dimensional model [2], [3] to the complicated multiple-dimensional model, 2) Assignment of large objects and selection of small items or a selection of large objects and small items, 3) Assortment of large objects having one large object, many identical large objects, few group of identical large object and different large object, and 4) Assortment of small objects having few item of different dimensions, many items of many different dimensions, many item of relatively few dimensions and many identical items [4], [5].

This is an applied research focusing on non patterned production system especially in garment industrials, the small and medium enterprises (SME's) in Thailand. Their products are made to order, which have arbitrary styles and are changed with the customer satisfaction, the fashion and the season. They also have to face with two important problems of (1) lacking of man power during rice growing season and (2) changing of due date as customer request. These raise the problem in their production planning resulting in the problem of delayed production and late delivery to the customer, consequently. With the nature of such industrial, it is an identical parallel machine system [6], [7]. One worker operates one machine. The work could be planned via the assignment of process to each machine. Such manner could imply the conditions that (1) the whole processes are cut off and assigned to each machine, according to cutting problem [8]-[14] and (2) the processes are packed in the machine, according to bin packing problem [1]. The latter problem is mostly used to determine the minimum number or the maximum capacity of bin. Therefore, this work will apply the stock cutting model to develop the planning method which provides the maximum efficiency for each machine. Such plan should be simple and flexible in order to overcome the limitation of garment industrial such as investment, man power and their potential, customer dependent order, etc. The dimension of the problem of interest will be determined using the definition of working efficiency. Consequently, the simple planning model can be developed from such definition and solved by the stock cutting problem.

S. Homrossukon is with the Industrial Engineering Department, Thammasat University, Bangkok Thailand (e-mail: tsamerji@engr.tu.ac.th).

D. Aromstian is graduate student with the Industrial Engineering Department, Thammasat University, Bangkok Thailand (e-mail: blossom_tu17@hotmail.com).

II. Model Development

A. Determination of Dimension

If the stock is determined from the whole processes, the complexity will be the difference in stock length since the number of process and order number are different. If the stock is determined from daily maximum working time of machine, this case can be viewed as how to cut the daily maximum or available working time of each machine by assigning the processing time for it. Therefore, processing time will be used as the variable for cutting off or selecting the work for each machine. In this case, theory of one-dimensional [2], [3], [15], [16] cutting [1], [4] and packing [17] problems are applied in planning model.

B. Data Preparation

As the style of product of interest is always changed, the processing time might not be suitable variable. With the nature of industrial of interest, there will be a number of processes used to complete one product but the method of all processes are the same, sewing method. Therefore, by applying the comparative working time determination technique which is the same the working detail, the same the time consumed will be [18], such difficulty is solved. In this case, working data are needed to suitably prepare in the form of processing time data structure (the standard process and its processing time). The whole processes used for all products are clearly declared at first, then, the processing time of each process is collected and prepared as the data file. This file will be used as an input of processes required for each product during production planning calculation.

C. Model Development

As discuss previously, maximum or available time of machine can be determined as stock length. Such time is one working day interval which is constant and equal for each machine. In this case, the selection of processing time is suitable since the planning model can be formulated in a simple form.

The maximum the efficiency, the maximum the available time have to be cut off or replaced by assigned processing time. On the other hand, this means that the processing time have to occupy the available machine time *(TT)* as much as possible. From the definition of working efficiency [18], therefore; production efficiency *(Ef)* can be determined as in (1)

$$Ef = \left\lceil \left(\sum_{k}^{K} t_k \cdot N \right) \times 100\% \Big/ TT \right\rceil \tag{1}$$

where t_k is processing time of process k and N is total number of product or order number.

Equation (1), then, will be extensively used to develop the planning model as following procedures;

Step1. Total number of machines determination

The maximum or available machine time *(TT)* in (1) implies the working hour for each machine and it is identical for all machines. In this case, the number of machine *(I)* according to number of stock unit required to complete the job can be determined from (2).

$$I = \left\lceil \left(\sum_{k}^{K} t_k \cdot N \right) \Big/ WH \right\rceil \tag{2}$$

Step2. Planning model

From (1), in order to get the maximum efficiency of the production, the term of $[\sum_{k}^{K} t_k \cdot N]$ should be maximized. The latter will be achieved when the total completion time is maximized. Therefore, the objective of this model can be written as in (3). The constraints for the model are determined from the nature of industrial. Constraint in (4) is that each machine can not work longer than working hours. Equation (5) represent that every process must be finished but not necessary found within one machine. Equation (6) is the number of production in process k which must equal to an order number (N). Most of processes assigned to the machine have no standardized sequence. In this case, (7) is effective if there is a constraint of sequential process. All productions are an integer as specified in (8).

The parameters of production model are listed below:

WH = working hours (8 hrs/day or 28800 sec/day)
I = total number of machines used
t_k = processing time of process k
N = total number of product or order number.
K = total number of processes
p_k = total number of production in process k

To determine the maximum total completion time, one more decision variable, x_{ik}, is defined. It is the number of production in process k assigned to machine i.

Then, production model can be formulated and solved using linear programming approach [2],[3].

$$\text{Maximize } \sum_{i}^{I}\sum_{k}^{K} x_{ik} \cdot t_k \tag{3}$$

(maximize total completion times)

$$\text{S.T. } \sum_{k}^{K} x_{ik} \cdot t_k \le WH, \quad \text{for all } i \tag{4}$$

(all machines can not work longer than working hours)

$$\sum_{i}^{I} x_{ik} = P_k, \quad \text{for all } k \tag{5}$$

(every process must be finished)

$$P_k = N, \quad \text{for all } k \tag{6}$$

(number of production must equal an order number)

$$x_{ia} \ge x_{ib}, \quad \text{for all } i \tag{7}$$

(sequential constraints)

$$x_{ik} \ge 0, \text{ integer} \tag{8}$$

III. Computation Results

Firstly, the processes used to complete the required product are manually determined and will be used as one input for the calculation. Consequently, the working time, t_k, of each process are selected from the time data file as assigned functional program. Accompanying with an order number, the production plan is computed. For example, the case which K and N are 24 and 125, respectively, the total number of machines required (I) can be calculated from (2) which is 10 machines. Equations (3) to (8), then, are applied and solved by LINGO [19] with processing time less than 1 second. The results are found as in Table I (for non sequencing, skip (7)) and Table II (for sequential constraint of process at which process 4 have to be performed before process 5).

Both cases provide the average of machines efficiency, calculated from (1) are 99%, approximately, as shown in Fig. 1 and Fig. 2. From this result, the due date of the specific order or the daily number of machine required (I) can be determined. From an example, if the processing times need to be finished within 3 day, the factory needs to assign at least 4 machines for this customer order.

IV. Model Validation and Application

A. Validation and Application

The computed plan in Table I was assigned to the production of interest. The number of work in process from each process was counted for the end of working day. It was found that such plan was effective as the production efficiency was achieved at 99%, approximately. The results are shown in Table III. From the table, since the product style* is always changed, therefore; the comparison have to be performed between the most similar style and the closed order number. It is found that the production following the plan constructed by model does not only improve the production efficiency, but the number of machine required is also smaller even though an order number is larger. This could provide more benefit as production resources are more utilized.

In reality, the enterprise will have more than one order and more than one customer at a time. From the model, the number of machine required completing each model and the production plan with the best efficiency is determined individually for each one. Applying the total number of machine that the enterprise have and the order due date, the production plan of all order can also be simply determined. In case of the problem of man power changed, the plan is still effective. The enterprise knows the maximum machined used for a specific day and a due date, in this case they can relocate the operator to finish each order whereas all orders can be finished in time as required by customer. The flexible plan can solve the problem of lacking of man power.

B. Production Measurement

Furthermore, the nature of this production is that there will be no finished good at the early stage of production. On the other hand, work in process (WIP) is only presented. In this case, it will be difficult to measure daily working condition comparing to the standardized production system. From this model, it is also possible to measure the work thru the percentage of the completion of work in process which can be calculated from (9). Such equation is adapted from (1) and (3), instead of measurement that from the number of finished goods.

$$\textit{Daily completion time} = \sum_{i}^{I}\sum_{k}^{K} x_{ik}\cdot t_k \tag{9}$$

Total required time *(TOT)* for an order can be calculated from an order number and the cycle time of product.

$$TOT = \sum_{k}^{K} t_k . N \tag{10}$$

Then, production condition can be measured thru the work completion using (11).

$$\%completion = \left[\sum_{i}^{I}\sum_{k}^{K} x_{ik}\cdot t_k \times 100 \Big/ \left(\sum_{k}^{K} t_k \cdot N\right)\right] \tag{11}$$

The daily number of WIP is counted for each process. Accompanying with the processing time data and (11), the production following the plan in Table I can be measured as in Table IV. This raises the potential of work monitoring or measuring and the capability of making decision for enterprise when customers demand to receive their product sooner.

V. Conclusion

The simple method used to plan and to measure the production of small and medium garment enterprise are developed and used effectively. The application of this work dissolves the problem of late production. Even though it is a singular computed plan but this planning model can provide the most advantage used for SME's having non patterned production system. It is very easy to implement and to understand, flexibly used and cheap to invest. The larger the size of enterprise, the larger the order number and the more the product style will be. The complexity of planning will be increased definitely. The variable might be the same as in this research but the difference among each condition, the difference the constraint will be. This could challenge the future research.

TABLE I
Example of Production Planning (Non Sequencing)

	Machine Number									
t_k	1	2	3	4	5	6	7	8	9	10
1	0	125	0	0	0	0	0	0	0	0
2	0	0	0	0	0	125	0	0	0	0
3	0	0	0	0	0	0	0	0	0	125
4	0	0	0	0	0	0	0	0	60	0
5	3	0	0	0	0	0	0	75	47	0
6	0	0	82	0	0	0	0	0	5	0
7	30	95	0	0	0	0	0	0	0	0
8	32	0	0	0	0	89	0	0	4	0
9	0	0	125	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	90
11	0	0	0	0	0	125	0	0	0	0
12	0	0	0	0	0	0	0	0	125	0
13	125	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	90	0	0	35
15	0	0	0	0	125	0	0	0	0	0
16	0	0	0	0	0	0	0	0	125	0
17	0	0	0	125	0	0	0	0	0	0
18	0	85	0	0	0	0	0	0	0	40
19	0	0	125	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	125	0	0
21	0	0	125	0	0	0	0	0	0	0
22	0	0	0	0	125	0	0	0	0	0
23	0	0	0	125	0	0	0	1	0	0
24	0	0	0	0	8	0	12	0	0	0
$\%E_f$	99.95	99.91	99.99	100	99.99	99.93	99.98	99.93	99.97	99.69

$\%Ef$ = percentage of machine efficiency
Average $\%Ef$ = 99.937
C_{max} = 28800 sec.

TABLE II
EXAMPLE OF PRODUCTION PLANNING FOR SEQUENTIAL CONSTRAINT
(SEQUENCE 4 BEFORE 5)

	Machine Number									
t_k	1	2	3	4	5	6	7	8	9	10
1	0	0	0	39	0	0	0	0	67	19
2	0	0	0	4	0	0	21	0	100	0
3	0	0	0	62	62	0	1	0	0	0
4	125	0	0	0	0	0	0	0	0	0
5	119	0	0	6	0	0	0	0	0	0
6	124	0	1	0	0	0	0	0	0	0
7	0	0	125	0	0	0	0	0	0	0
8	0	0	0	8	8	0	0	0	0	109
9	0	0	0	78	0	0	47	0	0	0
10	0	0	0	90	11	0	2	0	22	0
11	0	1	0	0	65	0	0	59	0	0
12	0	0	0	0	0	0	0	125	0	0
13	16	102	7	0	0	0	0	0	0	0
14	0	0	0	0	0	96	29	0	0	0
15	0	0	125	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	125	0
17	0	0	0	0	0	0	0	0	0	125
18	0	0	0	0	125	0	0	0	0	0
19	0	125	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	125
21	0	0	0	0	0	0	0	125	0	0
22	0	0	0	47	0	0	78	0	0	0
23	0	0	0	0	0	1	0	0	120	4
24	0	0	125	0	0	0	0	0	0	0
$\%E_f$	99.98	99.91	99.93	99.99	99.93	99.81	99.98	99.97	99.98	99.84

$\%Ef$ = percentage of machine efficiency
Average $\%Ef$ = 99.937
C_{max} = 28799.52 sec.

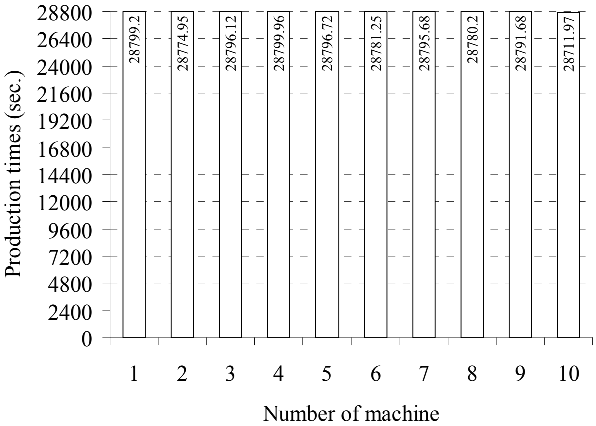

Fig. 1(a) Production Time for Non Sequential Production

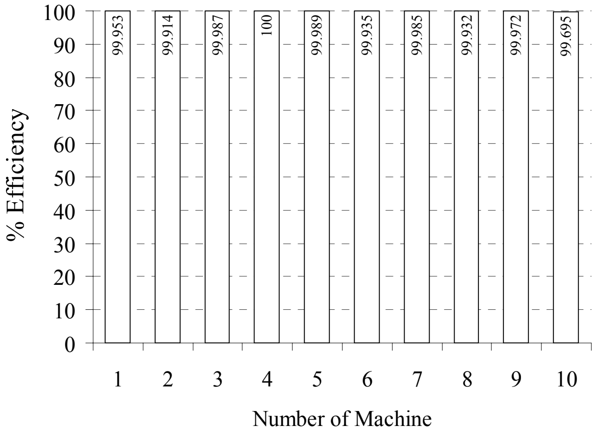

Fig. 1 (b) Production efficiency for non sequential production

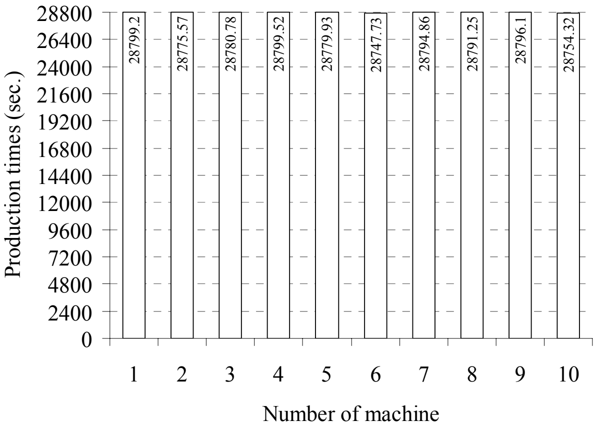

Fig. 2 (a) Planning of Production time for sequential constraint

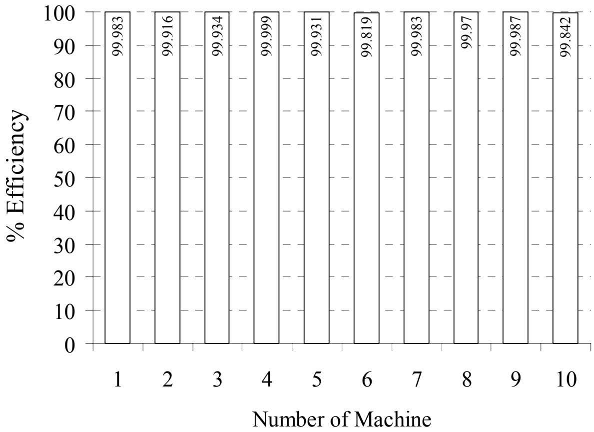

Fig. 2 (b) Production Efficiency for Sequential Constraint

TABLE III
COMPARISON OF PRODUCTION FOLLOWING CURRENT PLAN AND MODEL PLAN

Condition	Product*	Average efficiency	No. of machines used
current plan	1 order = 120	65.5%	14
	2 order = 720	60.7%	80
	3 order =305	80.3	29
Model plan	1 order =125	99.94%	10
	2 order =734	99.94%	59
	3 order =305	99.98%	22

TABLE IV
DAILY PRODUCTION EFFICIENCY MONITORING

PROCESS	ACCUMULATIVE NUMBER OF WIP		
T_K	DAY1	DAY2	DAY3
1	125	125	125
2	0	125	125
3	0	0	125
4	65	65	125
5	3	78	125
6	120	120	125
7	125	125	125
8	32	121	125
9	125	125	125
10	33	33	125
11	0	125	125
12	0	0	125
13	125	125	125
14	0	90	125
15	0	125	125
16	0	0	125
17	125	125	125
18	85	85	125
19	125	125	125
20	0	125	125
21	125	125	125
22	0	125	125
23	125	125	125
24	0	125	125
%COMPLETION	37.19	77.19	100

APPENDIX

The processing time (seconds) are; t_k = 102.9, 63.5, 57.9, 68.34, 74.16, 67.19, 35.84, 125, 66.66, 55.41, 77.5, 150.84, 187.91, 298.34, 21.25, 12.09 52.5, 148.34, 76.25, 49.59, 42.91, 198.75, 107.09, 162.09

ACKNOWLEDGMENT

The authors would like to thank Department of Industrial Engineering, Faculty of engineering, and Thammasat University for their financial and academic support in conducting this research. Finally, this research goal could not be achieved without the help from our case of studies, small and medium size of garment enterprise in Thailand, who would like not to be specifically mentioned here.

REFERENCES

[1] H. Dykhoff, "A typology of cutting and packing problem," *European Journal of Operational Research, 44*, 1990, pp. 145-159.
[2] P. C. Gilmore, R. E. Gomory, "Linear programming Approach to the cutting-stock problem," *Operation Research, 9(6)*, 1961, pp. 849-859.
[3] P. C. Gilmore, R. E. Gomory, "Linear programming Approach to the cutting-stock problem-part II," *Operation Research, 11(6)*, 1963, pp. 863-888.
[4] M. Gradišar, G. Resinovič, M. Kljajić, "Evaluation of algorithms for one-diamensional cutting," *Computer & Operations Research*, 29(9), 2002, pp. 1207-1220.
[5] T. Gau, G. Wäscher, "CUTGEN1: A problem generator for the Standard One-dimensional Cutting Stock Problem," *European Journal of Operational Research, 84*, 1995, pp. 572-579.
[6] D. R. Sule, "Parallel Processing and Batch Sequencing," *Industrial Scheduling*, Boston, MA: PWS Publishing Co., 1997, pp. 81-111.
[7] M. Pinedo, "Parallel Machine Model (Deterministic)," *Scheduling Theory, Algorithm, and Systems*, 2nd ed., Upper Saddle River, NJ: Prentice-Hall, Inc., 2002, pp. 93-128.
[8] T. Aktin, R. G. Özdemir, "An integrate approach to the one-dimensional cutting stock problem in coronary, " *European Journal of Operation Research*, 2008, doi:10.1016/j.ejor.2008.04.005
[9] H. H. Yanasse, M. J. P. Lamosa, "An integrated cutting stock and sequencing problem," *European Journal of Operational Research, 183*, 2007, pp. 1353-1370.
[10] P. Trkman, M. Gradisar, "One-dimensional cutting stock optimization in consecutive time periods," *European Journal of Operational Research, 179*, 2007, pp. 291-301.
[11] A. C. Cherri, M. N. Arenales, H. H. Yanasse, "The one-dimensional cutting stock problem with usable leftover– A heuristic approach," *European Journal of Operation Research*, 2008, doi:10.1016/j.ejor.2008.04.039
[12] A. C. Dikili, A. C. Takinaci, N. A. Pek, "A new heuristic approach to one-dimensional stock-cutting problems with multiple stock lengths in ship production," *Ocean Engineering, 35*, 2008, pp. 637-645.
[13] M. C. N. Gramani, P. M. França, "The combined cutting stock and lot-sizing problem in industrial processes," *European Journal of Operational Research, 174*, 2006, pp. 509-521.
[14] M. Gradišar, M. Kljajić, G. Resinović, J. Jesenko, "A sequential heuristic procedure for one-dimensional cutting," *European Journal of Operation Research, 114*, 1999, pp.557-568.
[15] G. F. Cintra, F. K. Miyazawa, Y. Wakabayashi, E. C. Xavier, "A note on the approximability of cutting stock problem," *European Journal of Operation Research, 183*, 2007, pp. 1328-1332.
[16] J. Rietz, S. Dempe, "Large faps in one dimensional cutting stock problems," *Discrete Applied Mathematics, 156*, 2008, pp. 1929-1935.
[17] E. G. Coffman, Jr., M. R. Garey, D. S. Johnson, "Bin Packing Approximation Algorithms: A Survey," *Approximation Algorithms for NP-Hard Problems*, D. Hochbaum, Ed. Boston, MA: PWS Publishing Co., 1996.
[18] Kanawaty, G., Introduction to Work Study, 4th eds, 1992, International Labor Office Geneva.
[19] L. Schrage, *Optimization Model with LINGO*, 6th. ed, Available: http://www.lindo.com