行政院及所屬各機關出國報告

(**出國類別：出席國際會議**)

赴捷克參加生產研究第十六屆國際會議

服務機關：國立屏東科技大學

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出國地區：捷克、布拉格

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摘要

Lot streaming is the process of splitting a given lot or job to allow the overlapping of successive operations in multi-stage production systems, thereby reducing the makespan of the corresponding schedule. Scheduling problems for lot streaming have been discussed for a while. Most of the researchers in this area concentrated on consistent sublot (transfer batch) models. However, the makespan may increase under the constraint of consistent sublots. Recently, variable sublot models have received a lot of attentions. In this research, we develop a heuristic variable sublot procedure (model). This procedure determines machines, on which transfer sublot sizes are reallocated, and transfer sublot sizes for each machine according to machine processing times in the flow shop. The proposed heuristic procedure is tested and evaluated via simulation. Several factors, such as number of sublots, number of machine, processing time, and the ratio of (number of dominant machines / number of machines), are considered in different lot streaming models (equal sublots, consistent sublots, and variable sublots). The results show the variable sublot model outperforms consistent sublot and equal sublot models. When the number of sublots, number of machines, and processing time increase, corresponding percentage of improvement for different lot streaming models increases. In addition, the variable sublot model is more sensitive to the ratio factor than consistent sublot and equal sublot models.

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正文

一、目的：

International Conference on Production Research(ICPR)為兩年舉行一次之國際性會議，目前已舉辦十六屆，本屆會議約有 56 國 688 篇文章發表，為生產管理領域中代表性之會議，主要目的促進生產管理與工業工程領域之研究、產業合作與教學發展，提供製造業與服務業先進之學術理論與實務經驗，以利產業界應用。會議主要探討生產技術、生產資源模式或生產系統設計時資源整合所產生之跨領域問題，對產業升級日益需求之臺灣，為一值得參與之重要研討會，基於上述原因，本人參加 ICPR 會議，期望能獲得較先進之技術與概念，同時於會中發表圓形工件特徵抽取及變動批量分割模式(生產技術)，與其它各國先進互相討論。

二、過程：

The 16th International Conference on Production Research 於民國 90 年 7 月 29 日至 90 年 8 月 3 日在捷克布拉格之 Czech Technical University 舉行，此會議共分五天舉行，第一天晚上(29 日)為開幕式，之後四天分為 10 個議程，32 個主題分組討論，本人在 29 日出發，30 日上午到達布拉格之 Czech Technical University，下午主持一個 Productivity Improvement, Measurement, Management 議程，在主持人與各報告人互相自我介紹後，共有七篇文章發表，發表時間 20 分鐘，討論 5 分鐘，中間有一 coffee break 約十分鐘，最後在熱烈討論中結束。

隔天早上在 Design for Manufacture 議程中發表一篇文章「Feature Extraction and Classification for Rotational Parts」，此議程共有七位報告者，除本人外，其它題目分別為「Vectorial Dimensioning and Tolerancing – Current Limits and Proposed Solutions」、「A New Electromagnetic Actuated Fabric Feeding System on an Industrial Sewing Machine : Evaluation and On-line Efficiency Monitoring」、「Study of Thin Steel Sheet Deep Drawing in the Manufacture of Disposal Gas Containers」、「Designing Problem for Mixed-Model Assembly Line with Bypass Sub-Line to Shorten the total Line Length」、「A Synchronization Mechanism for Distributed Manufacturing Simulation Systems」、「A Novel Design of Domestic Gas Fire with an Aim to Reduce Carbon Monoxide Emissions through the Arrangement of Soft Ceramic Fiber Component」，同樣地，發表時間 20 分鐘，討論 5 分鐘，發表者來自世界各國，歐洲國家居多，除了驚訝歐洲文化之外，其生產管理之研究與技術亦相當先進。第三天早上在 Manufacturing Technology 議程中發表另一篇文章「A comparison for Lot Streaming Models in a Multistage Flow Shop」，此議程共有五位報告者，除本人外，其他四位

報告人都提出一些新的見解，題目分別為「Tooling Requirements for Producing Quality Lightweight Glass Containers using the Narrow Neck Press and Blow Process」、「Nozzle Foulingin Industrial Pneumatic Metrology Applications」、「System and Processes of Ultrasonic Assisted Machining」、「Preliminary Study on Micro Powder Injection Modeling」，因時間充裕，討論時間加長。除了論文報告之外，此會議在每天早上都有一場 Plenary Lecture，題目包含「The Czech Industry on the Threshold of Entry of the Czech Republic into European Union」、「Emerging Trades in Large-Scale Supply Chain Management」、「From Production with Multi-Robots to e-Work – a View Through the PRISM Lab」、「The Triple Algorithm for Dynamic Lotsizing – Complexity Considerations」，因受邀請演講者都是產、官、學知名人士，使演講生色不少，場外同時有各學術單位及廠商的 poster 展覽。

三、心得：

本會議為兩年舉行一次之國際性會議，約有 56 國 688 篇文章發表，為生產管理領域中代表性之會議，本屆會議於捷克布拉格舉行，主要目的促進生產與工業工程領域之研究與教學發展，提供製造業與服務業先進之學術理論與實務經驗，以利產業界應用。會議主要探討生產技術、生產資源模式或生產系統設計時資源整合所產生之跨領域問題，對產業升級日益需求之臺灣，為一值得參與之重要研討會。同時臺灣若能爭取舉辦這類研討會，經由政府主辦，各大學協辦，定能提高國際知名度、研究水準及產業知識水準。

此次會議地點選擇在布拉格，為一風景優美、文化古蹟特別多的地方，非常適合開會及旅行，對於歐洲文化亦有其代表性，可讓遠地而來的參與者快速瞭解其文化。很高興見到多位世界各地知名學者參與，共同討論目前生產管理中重要議題如供應鏈等，不但可認識其他國家之文化，也可瞭解目前最先進之生產技術。臺灣學者有 34 人參加，是此次會議參加人數第六多的國家，樂於見到國科會(及教育部)能支持學者參與此會議，對國家聲譽有極大的幫助，相信這些學者在未來研究或教學上，定能有所進步，最後承蒙國科會支持，參與此會議發表研究成果，獲益良多，在此致謝。

附錄：

論文” A Comparison for Lot Streaming Models in a Multistage Flow Shop”**內容。**

A Comparison for Lot Streaming Models in a Multistage Flow Shop

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Abstract

Lot streaming is the process of splitting a given lot or job to allow the overlapping of successive operations in multi-stage production systems, thereby reducing the makespan of the corresponding schedule. Scheduling problems for lot streaming have been discussed for a while. Most of the researchers in this area concentrated on consistent sublot (transfer batch) models. However, the makespan may increase under the constraint of consistent sublots. Recently, variable sublot models have received a lot of attentions [1, 11]. In this research, we discuss the variable sublot model and then compare different lot streaming models in a multi-stage flow shop. Several factors, such as number of sublots, number of machine, processing time, and the ratio of (number of dominant machines / number of machines), are considered in different lot streaming models (equal sublots, consistent sublots, and variable sublots). The results show the variable sublot model outperforms consistent sublot and equal sublot models. When the number of sublots, number of machines, and processing time increase, corresponding percentage of improvement for different lot streaming models increases. In addition, the variable sublot model is more sensitive to the ratio factor than consistent sublot and equal sublot models.

1. Introduction

In the current competitive environment for manufacturing, greater and greater emphasis is being placed on reducing lead times and lowering work-in-process (WIP) inventory levels, both for filling orders for existing products and for bringing new products to market. Therefore, compressing manufacturing lead times and lowering work-in-process inventory levels has given rise to new research problems in planning and scheduling for batch production environment [11].

A technique known as lot streaming or lot splitting has received attention as a scheduling tool to help reduce makespan (i.e., manufacturing lead time) in a batch production environment. Lot streaming is the process of splitting a given lot or job to allow the overlapping of successive operations in multi-stage production systems, thereby reducing the makespan of the corresponding schedule. Scheduling problems for lot streaming have been discussed for a while [1, 2, 3, 4, 5, 8, 9, 10, 11, 12]. Most of the researchers in this area concentrated on consistent sublot models. However, the makespan may increase under the constraint of consistent sublots. Recently, variable sublot models have received a lot of attentions. Trietsch and Baker [11] proposed a variable sublot model for lot streaming that can deal with a three-machine problem to minimize the makespan. Baker and Jia [1] compared different lot streaming models such as equal sublots, consistent sublots, and variable sublots for a three-machine flow shop and found the performance of variable sublots is better than others. However, the variable soblot model for a multi-stage flow shop is rarely discussed. In this research, we will discuss the variable sublot model and then compare different lot streaming models in a mult-stage flow shop.

2. The Variable Sublot Model

2.1 Notation and Definitions

The following notation and definitions for this model are defined as follows:

Makespan: Makespan;

M : number of machines;

N : number of sublots;

D : Demand;

i : machine number ; $1 \le i \le$ M;

j : sublot number ; $1 \le j \le$ N;

t_i : processing time per unit on machine i;

$q_j^{(i)}$: quantity in sublot j from machine i to machine $(i+1)$;

$S_{i,j}$: start time of sublot j on machine i;

$r_{i,j}$: the size range of sublot $(j-1)$ from machine $(i+1)$ to machine $(i+2)$; $1 \le i \le \text{M} - 2, 1 \le j \le (\text{N} - 1)$;

After the notation is defined, the formulation for this variable sublot model is developed as follows:

$$\textit{Minimize} \quad \textit{Makespan} = S_{\text{M,N}} + t_{\text{M}} \times q_{\text{N}}^{(\text{M}-1)} \quad \text{(1)}$$

$$\sum_{y=1}^{r_{(i-1),j}} q_y^{(i\text{-}1)} < \sum_{y=1}^{j} q_y^{(i)} \le \sum_{y=1}^{r_{(i-1),j}+1} q_y^{(i\text{-}1)} \text{ for } 2 \le i \le (\text{M}-1), 1 \le j \le (\text{N}-1); \quad \text{(2-1)}$$

$$S_{i,j} \ge S_{i-1, r_{(i-2),j}+1} + t_{i-1} \times \left(\sum_{y=1}^{j} q_y^{(i\text{-}1)} - \sum_{y=1}^{r_{(i-2),j}} q_y^{(i\text{-}2)} \right) \text{for } 3 \le i \le \text{M}, 1 \le j \le (\text{N}-1); \quad \text{(2-2)}$$

$$S_{2,j} \ge S_{1,j} + t_1 \times q_{\text{j}}^{(1)} \quad \text{for } 1 \le j \le \text{N}; \quad \text{(3)}$$

$$S_{i,N} \ge S_{i-1,N} + t_{i-1} \times q_{\text{N}}^{(i-2)} \quad \text{for } 3 \le i \le \text{M}; \quad \text{(4)}$$

$$S_{1,j} \ge S_{1,j-1} + t_1 \times q_{j-1}^{(1)} \quad \text{for } 2 \le j \le \text{N}; \quad \text{(5)}$$

$$S_{i,j} \ge S_{i,j-1} + t_i \times q_{j-1}^{(i-1)} \quad \text{for } 2 \le i \le \text{M}, \ 2 \le j \le \text{N}; \quad \text{(6)}$$

$$\sum_{j=1}^{N} q_j^{(i)} = D \quad \text{for } 1 \le i \le \text{M}-1; \quad \text{(7)}$$

$$q_j^{(i)} \ge 0 \quad \text{for } 1 \le j \le \text{N}, \ 1 \le i \le \text{M}-1; \quad \text{(8)}$$

$$S_{i,j} \ge 0 \quad \text{for } 1 \le i \le \text{M}, \ 1 \le j \le \text{N}; \quad \text{(9)}$$

Expression (1) is the objective function that minimizes makespan. Expression set (2-1)、(2-2) defines the size range of each sublot. Expression set (3)、(4) constraint the start time of each sublot. Expression set (5)、(6) constraints the start time of each machine. Expression (7) enforces the total amount of sublot must be equal to the demand. Expression (8) represents each sublot must be greater than or equal to zero. Expression (9) represents the start time for any sublot must be greater than or equal to zero.

This is an NP problem. Computational complexity increases when number of machines or sublots increases. Hence, it won't be feasible to find the solutions based on the model mentioned above. We use a heuristic method proposed by [6, 7] which has been proved better than the optimal solution of consistent sublot model in terms of makespan. The steps are as follows:

Step 1：Initialization

(1). $m_i \leftarrow i$ for $1 \le i \le m$;

(2). $q_i \leftarrow p_i$ for $1 \le i \le m$;

(3). $l_i \leftarrow 0$ for $1 \le i \le m-1$;

(4). $m' \leftarrow m$;

(5). $f \leftarrow 2$。

Step 2：Identifying dominated machine

If $\dfrac{l_{f-1} + q_f}{q_{f-1} + l_{f-1}} \le \dfrac{l_f + q_{f+1}}{q_f + l_f}$ then set follows:

(1). $l_{f-1} \leftarrow l_{f-1} + q_f + l_f$;

(2). $m_{i'} \leftarrow m_{i'+1}$ for $f \le i' \le m'-1$

(3). $q_{i'} \leftarrow q_{i'+1}$ for $f \le i' \le m'-1$

(4). $l_{i'} \leftarrow l_{i'+1}$ for $f \le i' \le m'-2$

(5). $m' \leftarrow m'+1$; $f \leftarrow \max\{1, f-2\}$。

Step 3：Loop and termination

If $f = m'-1$, then execution step 4.

Otherwise, execution follows:

(1). Let $f \leftarrow f+1$

(2). GOTO step 2

Step 4：Calculating allocation ratio in each critical block

$$R_{i'} \leftarrow \frac{l_{i'} + q_{i'+1}}{q_{i'} + l_{i'}} \text{ for } 1 \le i' \le m'-1$$

Step 5：Calculating transfer batch sizes in each critical block

If $R_{i'} = \dfrac{l_{i'} + q_{i'+1}}{q_{i'} + l_{i'}} \ne 1$, then execution follows:

(1). Calculating the first transfer batch size

$$L_1^{i'} \leftarrow \left(\frac{1-R_{i'}}{1-R_{i'}^n} \right) D$$

(2). Calculating the other transfer batch sizes

$$L_j^{i'} \leftarrow L_1^{i'} R_{i'}^{j-1} \text{ for } 2 \le j \le n$$

Else $R_{i'} = \dfrac{l_{i'} + q_{i'+1}}{q_{i'} + l_{i'}} = 1$, then

(1). Calculating each transfer batch sizes

$$L_j^{i'} \leftarrow \frac{D}{n} \text{ for } 1 \le j \le n$$

3. Computational Results

For the purpose of comparing different lot streaming models (equal sublots, consistent sublots, and variable sublots), we design several experiments to test. Each batch is assumed 100 units. Processing time is assumed uniform distribution. The test factors for different lot streaming models are as follows (Table 1):

Table 1 Levels of designed factors

Designed Factors	Levels
Number of sublots	2, 5, 8
Number of machines	6, 8, 10
Processing time	1~5, 6~10, 1~10
The ratio of dominant machines to total machines	0%, 50%, 100%

We generate 81 (=3×3×3×3) test sets for each model. Each set contains 30 problems that are randomly selected from the range of the corresponding processing time. For each test, we compute the difference between the makespan obtained by the model and makespan without lot-splitting and expressed it as a percentage of the latter. Table 2 shows the results for different test sets. We find the improvement for three models is from 36% to 79%. The variable sublot model outperforms consistent sublot and equal sublot models in terms of average improvement.

Table 2 Average improvement for three models

Number of sublots	Number of machines	Processing time	Ratio	Equal	Consistent	Variable
2s	6m	1~5	0%	0.365	0.380	0.380
			50%	0.360	0.368	0.410
			100%	0.375	0.381	0.430
		6~10	0%	0.398	0.402	0.402
			50%	0.393	0.397	0.422
			100%	0.396	0.400	0.430
		1~10	0%	0.364	0.381	0.381
			50%	0.363	0.373	0.405
			100%	0.373	0.380	0.423
	8m	1~5	0%	0.401	0.407	0.407
			50%	0.394	0.400	0.436
			100%	0.402	0.403	0.455
		6~10	0%	0.419	0.423	0.423
			50%	0.420	0.423	0.444
			100%	0.421	0.424	0.450
		1~10	0%	0.396	0.403	0.403
			50%	0.395	0.401	0.435
			100%	0.401	0.405	0.453
	10m	1~5	0%	0.423	0.425	0.425
			50%	0.417	0.420	0.456
			100%	0.417	0.417	0.470
		6~10	0%	0.436	0.438	0.438
			50%	0.434	0.436	0.456
			100%	0.436	0.436	0.463
		1~10	0%	0.412	0.417	0.417
			50%	0.412	0.414	0.452
			100%	0.421	0.425	0.467
5s	6m	1~5	0%	0.577	0.596	0.596
			50%	0.595	0.610	0.642
			100%	0.594	0.615	0.657
		6~10	0%	0.631	0.639	0.639
			50%	0.629	0.640	0.664
			100%	0.633	0.646	0.680
		1~10	0%	0.573	0.592	0.592
			50%	0.568	0.593	0.625
			100%	0.577	0.600	0.641
	8m	1~5	0%	0.642	0.651	0.651
			50%	0.633	0.646	0.687
			100%	0.646	0.663	0.711
		6~10	0%	0.673	0.677	0.677
			50%	0.670	0.678	0.702
			100%	0.672	0.686	0.715
		1~10	0%	0.632	0.648	0.648
			50%	0.628	0.643	0.678
			100%	0.645	0.659	0.701
	10m	1~5	0%	0.678	0.681	0.681
			50%	0.668	0.678	0.715
			100%	0.667	0.681	0.735
		6~10	0%	0.695	0.699	0.699
			50%	0.696	0.702	0.724
			100%	0.696	0.707	0.736
		1~10	0%	0.664	0.673	0.673
			50%	0.655	0.665	0.702
			100%	0.678	0.691	0.730
8s	6m	1~5	0%	0.648	0.669	0.669
			50%	0.647	0.663	0.685
			100%	0.656	0.679	0.710
		6~10	0%	0.687	0.698	0.698
			50%	0.689	0.701	0.723
			100%	0.695	0.710	0.737
		1~10	0%	0.617	0.648	0.648
			50%	0.627	0.653	0.674
			100%	0.644	0.666	0.697
	8m	1~5	0%	0.708	0.718	0.718
			50%	0.682	0.701	0.728
			100%	0.702	0.725	0.763
		6~10	0%	0.735	0.741	0.741
			50%	0.732	0.742	0.766
			100%	0.736	0.751	0.777
		1~10	0%	0.675	0.697	0.697
			50%	0.681	0.701	0.725
			100%	0.701	0.720	0.752
	10m	1~5	0%	0.738	0.744	0.744
			50%	0.731	0.743	0.771
			100%	0.729	0.748	0.789
		6~10	0%	0.763	0.766	0.766
			50%	0.760	0.768	0.789
			100%	0.761	0.775	0.801
		1~10	0%	0.720	0.733	0.733
			50%	0.724	0.738	0.766
			100%	0.741	0.757	0.790

When number of sublots increases, the percentage of improvement for different lot streaming models increases and relative improvement for different lot streaming models decreases (Table 3). For evaluating the effectiveness of the variable sublot model, we calculate the difference between the makespan obtained by the given model and the makespan obtained by the variable sublot model and express it as a percentage of the latter. We find the average relative optimality increases when the number of sublots increases (Table 4).

Table 3 Average improvement for three models under different numbers of sublots

	2s	5s	8s
Equal sublots	0.402	0.641	0.701
Consistent sublots	0.407	0.654	0.717
Variable sublots	0.431	0.678	0.735

Table 4 Average relative suboptimality under different numbers of sublots

	2s	5s	8s
Equal v.s Variable	0.052	0.117	0.134
Consistent v.s Variable	0.044	0.078	0.076

When number of machine increases, the percentage of improvement for different lot streaming models increases and relative improvement for different lot streaming models decreases (Table 5). In addition, we find the average relative optimality increases when the number of machines increases (Table 6).

Table 5 Average improvement for three models under different numbers of machines

	6m	8m	10m
Equal sublots	0.543	0.587	0.614
Consistent sublots	0.559	0.598	0.621
Variable sublots	0.580	0.620	0.644

Table 6 Average relative suboptimality under different numbers of machines

	6m	8m	10m
Equal v.s Variable	0.097	0.103	0.104
Consistent v.s Variable	0.056	0.067	0.074

When processing time increases, the percentage of improvement for different lot streaming models increases. The range of processing time increases, the percentage of improvement for different lot streaming models decreases (Table 7).

Table 7 Average improvement for three models under different processing times

	1~5	6~10	1~10
Equal sublots	0.574	0.604	0.566
Consistent sublots	0.586	0.611	0.581
Variable sublots	0.612	0.628	0.604

When the ratio of (number of dominant machines / number of machines) increases, the percentage of improvement for the variable sublot model increases. However, the other models seem indifference (Table 8). In addition, Table 9 shows when the ratio increases, the average relative suboptimality also increases.

Table 8 Average improvement for three models under different ratios

	0%	50%	100%
Equal sublots	0.580	0.578	0.586
Consistent sublots	0.591	0.589	0.598
Variable sublots	0.591	0.618	0.636

Table 9 Average relative suboptimality under different ratios

	0%	50%	100%
Equal v.s Variable	0.027	0.117	0.158
Consistent v.s Variable	0.000	0.083	0.114

4. Conclusions

In this paper, the variable sublot model is discussed. After the experimental design is conducted, results are as follows:

1. The variable sublot model outperforms consistent sublot and equal sublot models.
2. If the number of sublots, number of machines, and processing time increase, the corresponding percentage of improvement for different lot streaming models increases and relative improvement for different lot streaming models decreases.
3. If the ratio of number of dominant machines / number of machines increases, the percentage of improvement for the variable lot streaming models increases. The other models seem indifference. The variable sublot model is more sensitive to the ratio factor than the other models.

Two related research directions are as follows:

1. Develop an algorithm for the optimal variable sublot model for a single job in a flow shop.
2. Find the relationship between the ratio of (number of dominant machines / number of machines)

and the variable sublot model.

Acknowledgement

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