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A FLOW SHOP RANK APPROACH TO GT SCHEDULING

أسلوب تفصيلى انسيابى للجدولة فى تكنولوجيا المجموعات

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ملخص

لم تركز الطرق السابقة لتكنولوجيا المجموعات على صياغة المشكلة بل ركزت على قواعد العائلة و الإزاحة و التي قد تؤدي إلى حلول مختلفة حسب نوع المشكلة. هذا البحث يعرض طريقة استاتيكية تفاذية لحل مشكلة نظام الخلية للتشغيل تحت ظروف غير محدودة. و تعتمد أساسا على تحليل العائلة إلى عائلات أصغر وإنشاء شبكة توضح علاقات الإعداد بين الماكينات المكونة للخلية. و الحل مماثل لما يحدث في الخطوط الانسيابية في شكل تطبيقي بسيط. و يعتبر البحث بداية لصياغة مشكلة تكنولوجيا المجموعات في صورة انسيابية لتبسيط تحليل الخلية.

ABSTRACT

Previous group technology heuristics have not focused on the problem formulation: they have focused on family and dispatching rules which lead to different results depending on the type of the problem. The objective of this paper is to present a ***static exhaustive*** heuristic to solve such problem for unlimited job shop manufacturing cell. It is mainly based on decomposing the cell-queue into subfamilies and constructing a graph showing the setup relationships between the machine arrangement and the current partition of subfamilies. The solution is similar to that made in the flow shops in a simple applicable fashion. The heuristic is a trial to formulate the problem in an equivalent flow shop to simplify the cell assessment.

Keywords: SUBFAMILY; CELLULAR, SEQUENCE

1. INTRODUCTION

Group technology is a manufacturing philosophy based on the similarities of production and design requirements exist between parts produced in a manufacturing shop. The concept of group technology (cellular manufacturing) is to segregate a manufacturing system into cells and classifying parts into families via coding schemes and grouping techniques; for a review, see Groover [9]; Xu and Wang [19], Moiser [16], and Askin et al. [2]. A part family is a collection of parts which posses similar manufacturing characteristics. Each cell includes a number of machines which are able to process a family of parts. Cellular manufacturing provides an attractive alternative for manufacturing job shops (Burbidge [4,5], Knox [12], Black [3]), and numerous case studies of actual implementations indicate a substantial increase in efficiency (Allison and Vapor [1], Droy [6]). Benefits mentioned in the literature: lower work-in-process inventory, shorter manufacturing lead times, reducing material handling , and better quality (Greene and Sadowski [8], Suresh and Meredith [18]). The work in **GT** goes into two-class problems; first is the formation of part families and machine cells; second is the scheduling in a manufacturing cell which is the field of interest of this paper. The group scheduling ... in the literature requires a two-stage procedure. The first stage sequences the jobs ... subfamilies while the second sequences the subfamilies in the queue of each machine cell

Vithiananthan and McRoberts [20] reported the first study in group scheduling by de - composing each part family in the queue of the cell based on setup similarities into subfamilies and treating each subfamily like a flow shop problem. Sundaram [17] proposed two *static* heuristics based on minimization of makespan to find a reasonable sequences. Mosier et al. [15] proposed two exhaustive and non-exhaustive queue selection heuristics concerned with the efficiency in the cellular manufacturing shop. Kelly et al. [11] proposed two cost oriented and exhaustive queue selection rules. Flynn [7] proposed a simple queue selection heuristic attempts to minimize the number of setups. This heuristic is based on the repetitive lots concept (Jacobs and Bragg [10]) and the ***FCFS*** dispatching rule. Mahmoodi et al. [13] have used computer simulation to test three queue selection rules in conjunction with three dispatching rules under eight experimental conditions. Mahmoodi and Dooley [14] presented *non-exhaustive* heuristics and compared them with existing exhaustive heuristics in a job shop cell environment using computer simulation.

2. ASSUMPTIONS AND RESTRICTIONS

In order to present the proposed heuristic as clearly as possible, the following assump - tions have been imposed.

1. The main objective is to minimize the setup changeover and the cell makespan.
2. The second objective is to accumulate the idle time before each machine to smooth the time assignments and minimize the machine stoppage.
3. The batch consists of a considerable number of parts and the grouping problem is completed for families and cells. Also, setup requirements of the parts in the queue are defined with a complete process sheet.
4. The family in the queue of a machine cell is decomposed into a number of subfamilies according to the setup similarities; each subfamily parts have the same major setups.
5. All the jobs in each subfamily move together from machine to the next (limiting but practical in motion control). Each of the subfamilies could be treated as a flow shop problem. A machine does not switch from subfamily to another.
6. The reversible routing and cycling is not allowed. In other words, a part visits a machine once a time.
7. The number of machines in each cell is not restricted.

3. DEFINITIONS

Before explaining the procedure, the terms which will be used should be defined. These terms are restricted to the proposed procedure and may be not used in other heuristics.

-Data Sheet-A tabular form, as shown in Table 1, including all parts information about ma chines (**Mi**), tools (**Tj**), and time in seconds.

-Incidence Matrix-Two dimensional array, as shown in Table 2, indicates the machines and tools used for each part. The entry 1 indicates that a machine or a tool is used, ot - erwise it will be 0.

-**Part Setup Matrix (P)**-Two dimensional array, as shown in Table 3, indicates how the family parts share the machines and tools. Each entry of the matrix consists of two digits, the first indicates the machine while the second indicates the tool.

-**Subfamily Basic Part**-The queue part which requires the maximum operation characteristics in the subfamily such as time, tools, and machines. The priority is given to the number of machines and the tie is broken arbitrarily.

-**Subfamily Complement Part**-The queue part which has the nearest characteristics to the basic part. The priority is given to the number of machines and the tie is broken arbitrarily.

-**Snbfamily Setup Matrix (F)**-Two dimensional array, as shown in Table 4, indicates how the subfamilies shares the machines and tools. Each entry of the matrix consists of two numbers, the first indicates the number of shared machines and the second indicates the number of shared tools. This matrix is so helpful for the purpose of finding which subfamily must visit the cell first and which subfamily will follow in order to minimize the tool changeover.

-**Machiue-Subfamily Graph**-A graphical plot, as shown in Fig. 2, for the routes of subfamily parts on the machine cell.

-**Machine Relationship Matrix (M)**-Two dimensional array, as shown in Table 5, ind - cates the dependency relationships between the machines. In other words, it shows if a machine can start directly without waiting for feeding from other machines or it must wait for work-in-process; this depends on the operations of parts. The entry 1 indicates that the machine in column is dependent on the machine in row, otherwise an entry 0 exists.

-**Subfamily Time Cycle (C)**-The central time allocated to each subfamily. It will be used as a decision cut point. It is not an exact quantity, but it is used as a trial to equalize the time allocated to each subfamily.

-**Subfamily Time Content (FT)**-The total operation time of all parts composes each subfamily. It may be around the cycle time by a value specified by the system engineer.

-**Ready Machine List (ML)**-The list of cell machines that can start work at the current machine assignment point. This list is updated each time an assignment decision is intended. In other words, a machine is belonging to this list when all work assigned to the preceding machines is performed.

4. PROCEDURE

This section of the paper describes a new heuristic procedure for solving the problem of machine cell scheduling through an equivalent flow shop image to the **GT** cell. With reference to Fig. 1, it begins with the input of parts and cell information which involves operations, machines, tools, and times (operation and setup time). The procedure is involved in four main parts. In addition, other mechanisms are included in between such as computing, ranking, making decisions, and registering times which are clearly illustrated on the flow chart.

COMPOSING THE SUBFAMILIES

After inputting the data, the part setup matrix is prepared to determine the setup similarities between parts. The major family of parts is deeomposed, based on setup similarities, into subfamilies, such that scheduling each of the subfamilies could be treated as a flow shop problem. Each subfamily begins with a basic part and followed by the complement parts. A decision cut parameter will be used, the subfamily cycle time, to close each subfamily; this to add some smoothness to the work content and the forced idle time. In other words, this minimizes the work under unpredictable conditions.

INTERACTING CELL AND SUBFAMILIES

The subfamily setup matrix is prepared to determine the setup similarities between subfamilies. Then, the machine-subfamily graph is plotted to illustrate the routes of subfamilies and the conditions of machines. Some machines can be the first host for some subfamilies and other machines must wait until the preceding operations were completed; such conditions are mainly dependent upon the first part in each subfamily in the queue. This graph determines the machine relationship matrix which, in turn, indicates how the machines restrict each others. Thus making it possible to weight and rank each machine according to the number of direct successor machines, **MRn**, and the total processing time allocated, **MRt**, given that the major family will be processed. The machine which registers the maximum number of successors is ranked one and the machine which will be assigned the minimum operation time is also ranked one. The sum of these two ranks, **Mre**, represents the equivalent rank for each machine at this point.

FINDING THE EQUIVALENT FLOW SHOP

An equivalent flow shop could be multi-inlet-outlet depending on the conditions of the processed subfamilies. The machines are sequenced by updating the ready list and using the rank obtained from the previous part. The machine in list which registers the mini - mum equivalent rank will be set at the top of the sequence and so on. The machines are reranked, **MR**, such that the first machine is ranked one and so on. This rank will be constant through the procedure application.

An image is considered such that the machines are arranged in a flow shop where each machine represents a station starting from the first machine which is considered the imaginary inlet and ending to the last machine which is considered the imaginary outlet. If a subfamily will not visit a machine, it is imagined to visit and leave it in an interval zero.

ASSIGNING SUBFAMILIES

Before going to assign the subfamilies in the queue, they are ranked, **FRm**, according to their routes on the machine cell. This rank will not vary in the next steps. Each subfamily rank registers the sum of ranks, **MR**, of all machines be visited minus the number of these machines, **N**; for example if a subfamily will visit the first, the second, and the third machine, it will be ranked three. Considering this rank, in the following steps, making it possible to schedule the cell as a flow shop and trying to operate all machines at the first part of time.

The queue subfamilies are ranked, **FRs**, according to the cell setup already exists for the current subfamily considering the priority for the tools. The nearest subfamily in setup to the current one is ranked one and so on; this rank is updated each assignment decision point. This to help in minimizing tool changing for each next subfamily. Also to keep the advantage of flow shop, this rank is averaged with **FRm** to get the average rank, **FRa**. Each assignment point, the subfamily of minimum **FRa** is selected. When the cell is busy (at least one machine works), the subfamilies in the queue are still registering waiting, but also some machines may register waiting. Every time an assignment is made, the waiting time for both machines and subfamily must be registered to find finally the total time required to get all subfamilies out of cell. The parts in each subfamily are sequenced at each machine according to the current setup, otherwise, the short processing time (***SPT***) rule is applied. The output of the procedure will illustrate the final time schedule.

5. A CASE PROBLEM

Table 1 illustrates the processing data for 15 parts manufactured using a cell consists of 6 machines, each of them can be set with a specified number of tools. The incidence matrix is prepared as shown in Table 2 from which the part setup matrix, Table 3, is prepared. The parts are classified into four subfamilies as shown in Table 4 which also illustrates how the subfamilies share the machines and tools to assess the priority of sequence to minimize the tools changeover between each successive subfamilies. The routes of su - families are plotted on the graph shown in Fig 2 from which Table 6 is prepared. The procedure continues with ranking the machines according to the number of direct suc - cessors and the total processing time allocated to each machine as shown in Table 6. According to the procedure, the equivalent flow line will be machines 1,2,3,4,5, and 6 respectively; this will be different for another group of parts. Begin with the minimum ranked, **MR**, machine which will be machine 1 in this case and select from the queue the minimum ranked, **FRm**, subfamily which starts with this maehine to visit the machine cell. Break the tie by the subfamily which occupies the cell in minimum time; i.e., sub-family 4. If the procedure continues, and each time the machine of minimum **MR** is selected, the subfamilies will be sequenced 4,1,3, and 2 considering the priority in sharing tools to minimize the tool changing. The parts in each subfamily is sequenced according to the current setup rule and/or the *SPT* rule.

6. CONCOLUSION

If the proposed heuristic is traced from the beginning, its effectiveness will be obvious in sub-familiarization and scheduling. It tries to mix all the advantages of minimizing the tool changeover by picking up the similarities between queue subfamilies in setup in addition to the similarities between the parts in the same subfamily, and the total shop visiting time. From the results, it is seems that the cell works as a station in a nearly bal - anced flow line because the subfamilies are grouped in nearly equal times. And more, the difference in setup is not significant in the sequence of all subfamilies which, in turn, regulates the tool changeover.

Most of the heuristics concerning the group technology scheduling is no longer applic - ble to the real large GT problems. They introduced theoretical solutions which are mainly dependent upon the cell type and the number of machines included. The GT problem is very difficult to formulate, therefore, the current heuristic is considered the first one finding an approximation to the problem formulation as those of the flow lines. The cur - rent heuristie is not limited to specific characteristics of the GT cell as in the literature. The proposed heuristic may be an integral algorithm actuating other tools to deal with the GT problem such as networks and linear programming.

TABLES

Table 1. Processing data. (M :machine: T :tool).

Part No	Opr.1		Opr.2		Opr.3		Opr.4		Opr.5		Opr.6		Opr.7		Total Time (seconds)
1	M1		M1		M3		M5		M6						340
	T1	90	T2	60	T5	40	T1	100	T1	50					
2	M2		M4		M5		M6								215
	T1	40	T1	50	T2	70	T3	55							
3	M1		M2		M4		M4		M5						316
	T2	45	T3	65	T2	100	T3	40	T2	66					
4	M3		M3		M5		M6								235
	T1	30	T4	80	T1	55	T2	70							
5	M1		M3		M4		M5		M6						302
	T3	48	T1	87	T2	67	T1	40	T2	60					
6	M1		M3		M5		M6								227
	T4	92	T2	35	T2	43	T3	57							
7	M1		M2		M3		M3		M4		M5		M6		424
	T4	47	T2	60	T3	52	T4	88	T1	102	T1	30	T1	45	
8	M1		M2		M4		M5		M6						377
	T1	92	T3	82	T3	72	T2	61	T3	70					
9	M2		M3		M4		M5								265
	T1	69	T5	58	T2	106	T1	32							
10	M3		M4		M5		M6								214
	T3	100	T1	37	T2	48	T1	29							
11	M1		M2		M3		M4		M5		M6				392
	T2	85	T3	56	T1	48	T2	62	T2	37	T2	104			
12	M1		M1		M3		M5		M6						316
	T1	59	T2	82	T5	54	T1	89	T1	32					
13	M1		M2		M4		M5								292
	T2	81	T3	51	T2	100	T2	60							
14	M1		M2		M3		M3		M4		M5		M6		433
	T4	63	T2	42	T3	56	T4	67	T1	107	T1	43	T1	5	
15	M2		M3		M4		M5		M5		M6				378
	T1	45	T5	60	T3	40	T1	82	T2	47	T3	104			

Table 2. Incidence matrix of machine-tool.

Part	M1				M2			M3					M4			M5		M6			M 1	M 2	M 3	M 4	M 5	M 6
	T1	T2	T3	T4	T1	T2	T3	T1	T2	T3	T4	T5	T1	T2	T3	T1	T2	T1	T2	T3						
1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0	1	1
2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	1	1	1
3	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	0	1	1	0
4	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	1	1
5	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	1	1	1
6	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	1	1
7	0	0	0	1	0	1	0	0	0	1	1	0	1	0	0	1	0	1	0	0	1	1	1	1	1	1
8	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	0	1	1	1
9	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	0
10	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1	1
11	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	1	0	1	1	1	1	1	1
12	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0	1	1
13	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	1	1	0
14	0	0	0	1	0	1	0	0	0	1	1	0	1	0	0	1	0	1	0	0	1	1	1	1	1	1
15	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	1	1	1	1

Table 3. Part setup matrix (P).

Part	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	20	21	31	41	40	42	31	22	31	41	45	21	42	32
2		31	20	30	22	41	42	31	32	41	20	31	41	42
3			10	31	21	40	43	31	21	44	21	44	40	32
4				33	30	32	20	21	30	32	31	10	32	31
5					40	51	40	32	40	53	41	31	51	41
6						41	32	20	31	41	40	21	40	32
7							50	41	43	60	42	40	67	51
8								30	31	52	31	42	50	43
9									30	41	22	31	41	43
10										41	31	21	43	41
11											41	44	60	51
12												21	42	32
13													40	31
14														51

Table 4. Subfamily setup matrix (F).

Subfamily	1	2	3	4
Parts	7, 14, 11	15, 8, 9, 2	5, 12, 1, 6	3. 13. 10, 4
Part Time	424,433,392	378,377,265,215	302,316,340,227	316,292,214,235
Total Time	1249	1235	1185	1057
Subfamily 1		6,4	5,8	6,11
Subfamily 2			5,6	6.6
Subfamily 3				5,7

Table 5. Machine relationship matrix (M).

Machine	1	2	3	4	5	6
1		1	1	1	1	1
2			1	1	1	1
3				1	1	1
4					1	1
5						1

Table 6. Machine ranking.

Machine	1	2	3	4	5	6
Time sec.	844	510	855	883	903	731
MRn	1	2	2	2	2	2
MRt	3	1	4	5	6	2
MRc	4	3	6	7	8	4
MR	1	2	3	4	5	6

Table 7. Ranking subfamilies according to machines.

Subfamily	1	2	3	4
N	6	6	5	6
FRm	15	15	15	15

FIGURES

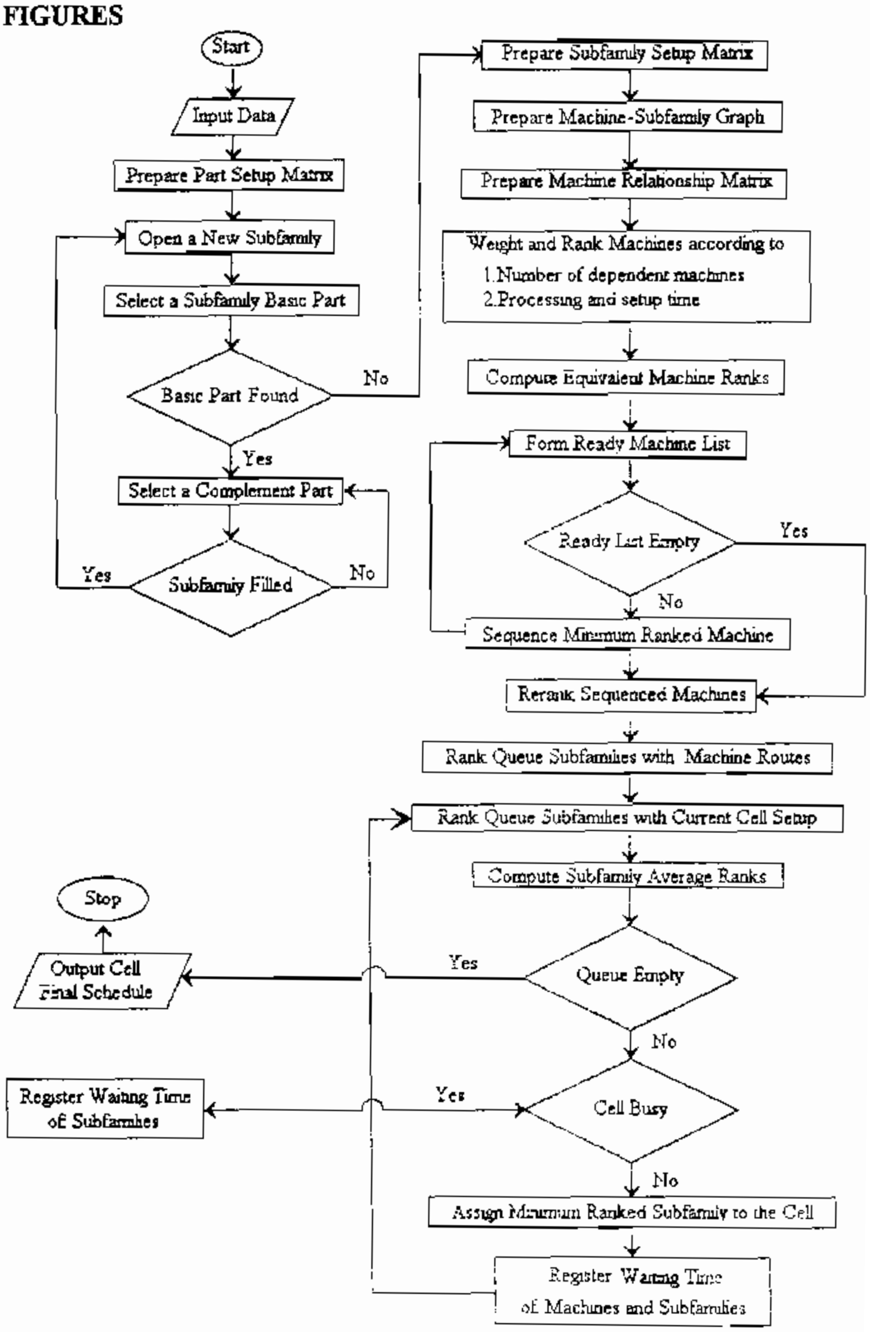

Fig. 1 The flow chart of a GT scheduling heuristic.

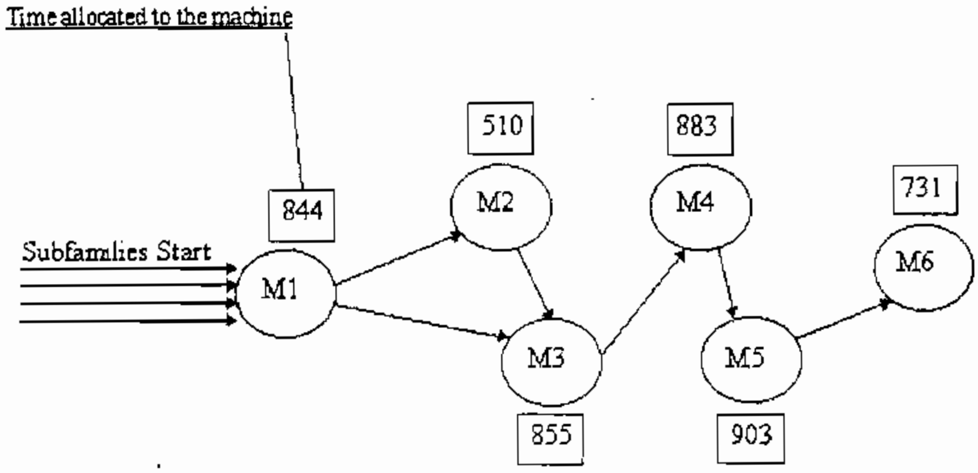

Fig. 2 Machine-Subfamily graph. (Time in seconds).

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