A result of two accrediting agencies:

Integrating machine burden and customer demand analysis into group technology

Yan Liang & Dennis E. Kroll, Ph.D.
Industrial & Manufacturing Engineering & Technology
Peoria, IL, USA

Abstract

This paper is evidence of how solving the problem of two accrediting agencies, at odds with each other, can force engineers to find the diamond in the rough. The research on this paper was fully done by Ms Liang due to the various pressures of course adjustment. The full paper will be submitted to an appropriate journal.

Group Technology is widely applied in industry. However, this method has more complicated steps when it comes to large scale product and machine problems. This study illustrated a simple and new way that implements a VBA program to Group Technology in large scale industrial problems. In this new methodology, parts were grouped based on processes similarity. This study makes the processes similarity flexible so that every company can decide and manage their own processes similarity. After gaining group families, we compared families' cycle time and customer demand (Takt time) to test if the production schedule is able to meet customer demand under current group. Machine burden analysis was performed in this research.

Keywords: Group Technology, VBA, Takt time, Machine burden analysis

1. Introduction

The purpose of Group Technology is to group parts into families and accordingly machines into different machine cells or production lines (Ribeiro et al., 1993). Although Group Technology was introduced by Frederick Taylor in 1919, it is still very helpful in improving productivity today.

Group Technology can be applied in three general ways (Wemmerlov et al., 1989; Srinivasan et al., 1990; Singh et al., 1996). The first one is to rely on part similarities to reduce setup times. This is the simplest way. The second alternative is to formally create families of parts and assign equipment to them, without any layout change. The third one is to build dedicated manufacturing cells.

Mitrofanov presented that Group Technology is to structure a manufacturing task so that it fits into a manufacturing system such that it can be easily decomposed into readily managed subsystems (1966). On the other hand, Group Technology is an approach to manufacturing facilities that seeks to achieve efficiency in high volume production by separating similarities of different products in their production. The products are grouped based on their similarities in the production process (Shabtay et al., 2010).

Wang and Kroll proposed an idea of using group technology to improve quality and response time (1994). They illustrated that Group Technology helps reducing the distance between machines. Reducing the distance between machines makes it convenient for the inspector to check the parts right after they were produced. This contributes to quicker response time as well.

One example of the important manufacturing parameters is Takt time. Takt time is customer demand frequency. It is important that the cycle time of the parts which are grouped in a cell is less than Takt time. Otherwise manufacturers would lose customers. Another one is machine utilization. Balancing workload of machines is a sustaining topic in manufacturing field. The common situation is that one part can be manufactured in different machines. Parts are assigned to machines depending on manufacturing tolerance, cost, distance etc. This distribution way makes some machines have high point of usage but others do not. Missing these analyses may lead to production delay, machine in idle states and machine unnecessary wear.

In this research, we analyzed the relationship between group cycle time and Takt time. If the cycle time is less than Takt time, we analyzed machine's burden in a family. It helps prevent lose sale, back order, machine in idle and overuse.

This project groups parts as families according to the similarities of their process. This research uses VBA to assign parts to families basing on standard Group Technology algorithm. It makes the process similarity manageable. So the managers are able to enter parts' information and Machines' information into excel, including part number, machine number, setup time, process time, process similarity etc. Managers are able to design their process similarity based on their products, machine numbers and facility conditions through VBA computation in excel. The programming will automatically group parts into according families. It saves time and is flexible.

reduction, improved process planning, improved purchasing procedures, and reducing inventory (Snead, 1989). Since Group Technology is useful and practical to manufacturing industries, many researchers have done studies.

Kusiak et al. (1987) presented two efficient algorithms to associate cost with parts and machines. They proposed an algorithm that is able to find optimal machine cells and part families provide that the machine-part incidence matrix has the block diagonal structure embedded. This method was the most efficient algorithm developed at that time.

Arieh et al. (1996) integrated fuzzy code into Group Technology. This methodology considers the range of attributes' values relevant for a set of expected values that represents the population of parts. Using this approach, the codes developed represent the actual population of parts of interest, and not a generic generalization of attributes. This approach enables Group Technology apply to assembly, which are very difficult to code and classify.

Li (2003) offered a new algorithm that is able to solve multi-dimensional Group Technology problems. His algorithm breaks the limits that traditional Group Technology can only solve two dimensions - part and machine.

Naadimuthu et al. (2007) adopted Adaptive Neural Fuzzy Inference System to design two vague systems. These two systems are thermal comfort and group technologies in production and operations management.

Yang et al. (2008) modified an old ART1 model, which integrated Group Technology and neural networks to design a cellular manufacturing system. They apply the proposed algorithm to machine-part cell formation in Group Technology.

Shabtay et al. (2010) studied a single machine scheduling problem in which the scheduler determines due dates for different jobs in a group technology environment. They found out the two classic due date assignment methods may not suffice in a classical Group Technology environment. Their research found the job schedule and the due date for each group that minimizes an objective function, which includes penalties.

Bohnen et al. (2011) used clustering techniques to group product types into families. After grouping, a family-based leveling pattern is generated. They presented a systematic procedure for leveling low volume

and high mix production based on the principles of Group Technology. The paper also describes which grouping criteria can be chosen and how product families can be formed for leveling.

Even though much research have focused on Group Technology, most proposed ideas about how to improve the efficiency of Group Technology. They improve the traditional Group Technology algorithm, so the new algorithms integrated new theories, such as fuzzy systems, neural networks etc. In this case, the new algorithms are able to associate costs in Group Technology, or solve other multi-dimensions problems, etc. But the former researches tend to lack practice. Industrial people couldn't use these algorithms directly. Moreover, no studies analyze Takt time and machine burden after utilizing Group Technology.

2.Group Technology methodology

2.1 The Standard Group Technology problem

The Group Technology problem is typically formulated as follows (Kusiak et al., 1987):

Given a binary part-machine incidence matrix A= $[a_{ij}]$, where:

a_{ij} = 1 if machine i is used to process part j

a_{ij} = 0 otherwise

The purpose of this project is to simplify an operator's work by providing them a VBA based Group Technology method to sorting families. After implementing Group Technology, the operators are able to analyze Takt time and machine burden of the products' families. This study used the algorithms Duggan presented in 2002.

Duggan (2002) presented a method to group a high number of products into potential product families using a spreadsheet. This method is able to be used when there are too many products to sort visually from the process map.

The method Duggan proposed is practical because operators or managers are able to implement it in a excel sheet. However, it goes through many iterations, which makes it harder to follow up. This study improves the algorithm so that this algorithm could be easier to integrate into VBA program.

2.3 An improved algorithm based on Kevin J. Duggan's method.

Kevin J. Duggan's algorithm is easy to understand. The algorithm can be implemented simply in the problem of small number of products and machines. However, in reality, it is not feasible if the company has large number of variable products and machines. So this paper developed an algorithm which is easier for operators to use. The improved algorithm use 1 when product i is manufactured in machine j. That is

a_{ij} = 1. Otherwise a_{ij} = 0. The program will record 1 and 0 in sequence at the end of each row and column, instead of sum the numbers up. Then we sort the rows and columns in descending order until there are no changes in families.

The new algorithm sorts rows and columns from "1" to "0", then recording content in each cell in sequence in the last row/column. After recording content in each cell in sequence, we compare the similarity of the contents in two cells to decide if they should be the same family. For example, for product i and product i+1, the process strings of product i is (00111010), and the process strings of product i+1 is (00111011). We use VBA program to identify the process similarity of this two products. Since they have seven processes are the same (eight processes in total), process similarity= 7/8= 0.875. We make the process similarity manageable. It means the managers or operators are able to group products based on their similarity. If we set the process similarity as 70%, the product i and product i+1 in this case should be grouped in the same family.

2.4 VBA case study demonstration

For the input excel sheet we have three main input interfaces. These include machine information, setup information, and raw data. Machine information sheet requires that operator fills in machine unique number, machine name, overall equipment efficiency, and machine nick name. For setup information sheet, it requires operator fills in coordinate machine setup time. There is a machine-product matrix shows products' processes and setup time. Figure 2 shows an example of machine-product setup time matrix. The third input interface is raw data sheet. It has another matrix shows products' process time

Setup information would not be used in sorting product families. However, this setup matrix is important because it would be used in customer demand (Takt time) analysis. We used product cycle time plus setup time as group families' cycle time. In order to test if the group families meet the customer demand, this study compares group cycle time with Takt time. The production schedule is able to meet customer demand, if group cycle time < Takt time. Production schedule is not able to meet customer demand, if group cycle time > Takt time.

A raw data input sheet is used to create families that has the manager's desirde process similarities. In the raw data sheet, we could simply put a symbol to indicate that the part have to be manufactured in a specific machine. However, we put the process time in the matrix instead of a symbol. This is because we need to calculate parts' cycle time to identify if it meets customer demand.

3 Takt time and Machine burden analysis

This study presented a new method of sorting families bya VBA program.. This section demonstrates a case study of Takt time and machine burden analysis.

In order to perform Takt time and machine burden analysis, information of parts demand and available time in a certain time period are needed. Weekly demand is shown in Table 1. Available time per week is illustrated in Table 2.

Table 1. Parts weekly demand information

Parts	Weekly Demand
Part 1	4
Part 2	20
Part 3	17
Part 4	12
Part 5	6
Part 6	50
Part 7	15
Part 8	35
Part 9	6
Part 10	13
Part 11	78
Part 12	58
Part 13	14
Part 14	8
Part 15	46
Part 16	70

Table 2. Weekly available time information

# of Shifts/Day	# of workdays/Week	Minutes per shift	Available time per week
1	5	450	2250

With customer demand and available time per week we can easily calculate Takt time. Takt time = available time per period/customer demand per period.

Figure 5 delineates the group cycle time and Takt time. Group cycle time in this case equals maximal processing time in the family. Take time = Available time/Group demand. Different families are presented in different color in Figure 5. Group Takt time is lower than Group cycle time in Family 1 to 6. However,

Takt time is faster than cycle time in Family 7. So it is necessary to reschedule family 7. In this case, since Takt time is slightly faster than group cycle time, you can either plan overtime or add working shift. However, if the available time reaches its maximum and there are no other resources to add, the company may have to divide the family into several smaller ones.

Parts	Weekly Demand	Machine1	Machine5	Machine3	Machine4	Machine6	Machine7	Machine2	New Family	Group Cycle Time	Group Demand	Takt Time
Part 14	8	5.88	8.9	15.55					1	15.55	8	281.25
Part 6	50	4.1694	4.704		13.7082				2	13.7082	50	45
Part 15	46	11.79	2.69						3	11.79	46	48.913
Part 5	6	4.1694				1	1.878		4	9.57	119	18.908
Part 8	35	2.22				1	3.7278		4			
Part 11	78	7.24				9.57	6.25		4			
Part 1	4		5.52		8.8566				5	22.8948	24	93.75
Part 2	20		4.803		22.8948				5			
Part 3	17		3.528			1		6.9174	6	17.8488	23	97.826
Part 9	6		2.403			1		17.8488	6			
Part 4	12			4.6		1	2.61		7	12.56	182	12.363
Part 7	15			2.4642		1	3.5		7			
Part 10	13			2.31		1	8.56		7			
Part 12	58			2.8		7.64	3.55		7			
Part 13	14			6.88		3.21	5.67		7			
Part 16	70			12.56		2.44	3.33		7			

Figure 5. Group cycle time and Group Takt time calculation

Weekly available time is calculated for Takt time analysis. Due to resources, people, and space constraints, weekly available time is limited. Machine burden analysis prevents machine overload. Moreover, in many cases, there are more than one machine is capable to process the same part. The difference may be the manufacturing costs. However, parts may not be scheduled evenly to capable machines. So some machines are overload, but some are idle. Machine burden analysis helps balance machine load.

To perform machine burden analysis, one way is to calculate machine efficiency. Table 3 illustrates Machine efficiency calculation process. Process time on each machine based on weekly demand equals to summation of parts demand multiply corresponding machine processing time. Machine efficiency = (process time + setup time) /Available time.

Table 3. Machine efficiency calculation

Parts	Weekly demand	Machine1	Machine5	Machine3	Machine4	Machine6	Machine7	Machine2
Part 14	8	5.88	8.9	15.55				
Part 6	50	4.1694	4.704		13.7082			
Part 15	46	11.79	2.69					
Part 5	6	4.1694				1	1.878	

Part 8	35	2.22				1	3.7278	
Part 11	78	7.24				9.57	6,25	
Part 1	4		5.52		8.8566			
Part 2	20		4.803		22.8948			
Part 3	17		3.528			1		6.9174
Part 9	6		2.403			1		17.8488
Part 4	12			4.6		1	2.61	
Part 7	15			2.4642		1	3.5	
Part 10	13			2.31		1	8.56	
Part 12	58			2.8		7.64	3.55	
Part 13	14			6.88		3.21	5.67	
Part 16	70			12.56		2.44	3.33	
Available time per week		2250	2250	2250	2250	2250	2250	2250
Process time on each machine based on forecast demand		1465.286	622.674	1384.513	1178.732	1509.32	855.221	224.6886
Setup time		632	180	125	720	1356	96	277
Total planned burden		2097.286	802.674	1509.513	1898.732	2865.32	951.221	501.6886
Machine efficiency		93%	36%	67%	84%	127%	42%	22%

We briefly analyze the machine burden and Takt time after VBA based sorting family. These two parameters are both important for scheduling because Takt time analysis present back order and lost sale, on the other hand, machine burden analysis help balance workload in a complicated large scale manufacturing process.

4 Conclusion

One main objective in this paper is to provide an easier way to implement Group Technology. This study proposed a new method that integrating VBA program for Group Technology. This method simplifies the operator's input interface. Operators only need to input necessary data and then get sorting output. Furthermore, this research uses a case study to further analyze Takt time and machine burden during processes. Takt time and machine burden analysis prevents products delay and machine overload.

Further research could be done in the reschedule of families when the family cycle time couldn't meet customer demand. Parts reschedule to capable machines is another potential research area.

5 How I feel as the only graduate student

This senior production planning class was designed for both undergraduate and graduate levels. We have two criterion for under and graduate students. The professor designed an individual study for graduate

students. I am the only graduate student in this class. As the only graduate student in the class, I got to experience undergraduate students' learning method, for example, their teamwork discussion, and thinking method. I feel undergraduate students are more creative. It helps me broaden my mind and catch new ideas when working on my individual project. Since I am a graduate student, I cannot stop at where other students stay. The individual project helps me keep learning after class. It is a good way to improve self-learning skill. It requires a lot of time to look up materials besides textbook. This individual project definitely improves my self-learning, research, and communication skills.

As the instructor forced to meet conflicting requirements of agencies, this student's paper with original work is a hard won, but now required, problem for regional masters level Universities. Smaller schools will need to deal with this problem; there may be blessings hidden behind the fog of agencies.

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