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Analyzing the Makespan using Processing Time Splitting Technique in Permutation Flow Shop Scheduling Problems

Baskar A[*] and Sreenivasan K
Apollo Engineering College, Chennai, India
GKM College of Engineering and Technology, Chennai, India

Abstract

In the shop floor, the production target is always a challenging job for any planning engineer. Meeting the due date is critical for the financial claims and marketing purposes. While scheduling, sometimes two or more operations are combined for processing and considered as a single job. Similarly, one machine may be overloaded with longer processing times. Some may be intentional, whereas, some may be unknowingly done. Clear definition of the processes and the corresponding spans before scheduling the jobs is highly significant for the speedy completion of all the jobs. In this paper, both the situations are analyzed with a numerical example. The effects of splitting the processing times and introducing an additional similar machine in the production line are studied for a permutation flow shop scheduling problem.

Keywords: Heuristics, Permutation Flow Shop Scheduling, Makespan, Processing Time Splitting.

Introduction

In any shop floor, the problem of a planning engineer is to schedule ‘n’ jobs in the available ‘m’ number of unrelated machines. Completing the processing of all the jobs within the due date is critical as it may lead to financial losses and other imposed penalties. Optimization of total completion time has been studied by many researchers for the past six decades. Johnson’s algorithm yields the optimum solution for any permutation flow shop scheduling problem with 2 machines and ‘n’ jobs [1]. The problem is NP-hard if the number of machines exceeds two [2]. For smaller problems, exact methods are proposed and are effective. As the problem size increases, exact methods become complicated and also the computation time increases exponentially. Many simple heuristics have been proposed over the years which are approximate methods. Most of them give reasonably accurate solutions for varying situations. Many researchers like Ruben Ruiz [3] accept that among the available simple heuristics, the one proposed by Nawaz et al. [4] performs better for the makespan minimization. Practical situations vary involving many constraints. Many heuristics consider splitting the transportation times from the processing times, and propose the procedures for makespan minimization like the ones by Chandramouli, Pandian and Rajendran [5, 6]. The authors have also proposed an algorithm to optimize the problem with known transportation time spans [7]. Splitting the processing times further has been analyzed in this paper.

In most of the small scale units, with the available resources, the planner has to complete the processing within the minimum possible time. They are forced to use the available machines to complete all the processes. In many occasions, they try to combine the operations (1) which can be carried out separately and independently also, that increases the processing time when it is considered as a single job and (2) those are possible in a machine to reduce the number of machines. However, this has an impact on the makespan while scheduling the jobs.

Computational results

For the analysis, one permutation flow shop scheduling problem with 5 machines and 5 jobs is considered as shown in Table 1. For computing the makespans and the corresponding sequences using NEH algorithm, codes are generated in MATLAB 2008a and run in an i5 PC with 4 GB RAM.

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Table 1, Sample 5 M/C, 5 Jobs PFSP

Jobs					
Machine ,M	Processing Times				
1	8	10	4	9	5
2	5	4	6	3	7
3	2	5	3	6	3
4	8	4	2	5	8
5	9	8	7	8	11

Using the popular NEH heuristic algorithm, the solution sequence and the corresponding makespan have been computed as 3-5-4-2-1 and 64 time units respectively. Now, job number one has been replaced by two jobs. Subsequently, the processing times have been split equally for ease of analysis. As a result, the 5 machine, 5 jobs problem has been converted to a new 5 machine, 6 jobs problem as shown in Table 2.

Table 2, 5 M/C, 5 Jobs problem converted to a 5 M/C, 6 Jobs problem (First Case)

	Jobs					
Machine ,M	Processing Times					
1	4	4	10	4	9	5
2	2.5	2.5	4	6	3	7
3	1	1	5	3	6	3
4	4	4	4	2	5	8
5	4.5	4.5	8	7	8	11

Again, using the NEH algorithm, the solution sequence and the corresponding makespan have been computed as 2-4-1-6-5-3 and 62 time units respectively. It may be noted that, though the total processing times do not change, the makespan changes. Similarly, when the other jobs are replaced in the similar way, the sequences and the corresponding makespans computed are:
4-2-6-3-5-1 with 64 time units, 4-3-6-5-2-1 with 63 time units; 3-4-6-5-2-1 with 63.5 time units and 6-5-3-1-4-2 with 57 time units. The last case is shown in Table 3 for the reference.

Table 3, 5 M/C, 5 Jobs problem converted to a 5 M/C, 6 Jobs problem (Last Case)

Jobs						
Machine ,M	Processing Times					
1	8	10	4	9	2.5	2.5
2	5	4	6	3	3.5	3.5
3	2	5	3	6	1.5	1.5
4	8	4	2	5	4	4
5	9	8	7	8	5.5	5.5

In the second phase, machine number one has been replaced by two similar machines. Subsequently, the processing times pertaining to the first machine have been split equally once again for ease of analysis. As a result, the 5 machine, 5 jobs problem has been converted to a new 6 machine, 5 jobs problem as shown in Table 4. As before, using the NEH algorithm, the solution sequence and the corresponding makespan have been computed as 3-4-5-2-1 and 61 time units respectively. It may be noted that, here also, though the total processing times do not change, the makespan changes. Similarly, when the other machines are replaced in the similar way, the sequences and the corresponding makespans computed are:

3-5-4-2-1 with 63 time units, 3-5-4-2-1 with 64 time units; 3-5-4-2-1 with 64 time units and 4-5-1-2-3 with 56.5 time units. The last case is shown in Table 5 for the reference.

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Table 4, 5 M/C, 5 Jobs problem converted to a 6 M/C, 5 Jobs problem (First Case)

Machine ,M	Jobs Processing Times				
1	4	5	2	4.5	2.5
2	4	5	2	4.5	2.5
3	5	4	6	3	7
4	2	5	3	6	3
5	8	4	2	5	8
6	9	8	7	8	11

Table 5, 5 M/C, 5 Jobs problem converted to a 6 M/C, 5 Jobs problem (Last Case)

Machine ,M	Jobs Processing Times				
1	8	10	4	9	5
2	5	4	6	3	7
3	2	5	3	6	3
4	8	4	2	5	8
5	4.5	4	3.5	4	5.5
6	4.5	4	3.5	4	5.5

Conclusion

The problem has been modified in ten ways by splitting the processing times in different ways. Whether the jobs are increased or the number of machines is increased, the total processing time remains the same. For ease of analysis, the processing times are split into two equal parts only. For a particular analysis, only one processing time is split at a time. The original problem has a makespan of 64 time units. When the jobs are increased, the makespans obtained are: 62, 64, 63, 63.5 and 57 time units. In the other case, when the machines are increased, the makespans obtained are: 61, 63, 64, 64 and 56.5 time units.

It is clear that the makespan cannot exceed that of the original in any case. But, when the processing times are split, the makespans get reduced. The reduction is up to 7.5 time units, that is, 11.7% in this analysis. Hence, in the shop floor, the processes should be split wherever possible. At the same time, the additional resources required if any, are also to be considered before making the final scheduling. If the reduction in maklespan is significant, then only we can go for it. It is proposed to analyze the real impact of this concept for more number of benchmark problems with varying size.

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