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Analyzing job shop scheduling problem by using dispatching rules

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Abstract

Job shop scheduling is one of the most typical and complicated manufacturing environments in production scheduling problems. As a result of this complexity, Akaki spare parts share company (ASPSC) has faced problem of scheduling jobs in the machining shop, therefore as to reduce the make span of the jobs in the machining shop, the aim of the research paper is to assess scheduling job shop sequencing of jobs in the machining shop by using dispatching rule, so as to minimize the total make span of the jobs. Secondary data of five jobs that processed on six machines in the machining shop was collected from the production planning and control system unit catalog. By using lekin scheduling software we can obtain the result using alternative dispatching rules based on processing time of each jobs. From these result the longest processing time can give the best possible make span which is 1426 minute relative to shortest processing time and first come first serve rule.

Key words: Job shop scheduling; make span, Dispatching rule, and Lekin scheduling software.

1. Introduction

Scheduling is a decision making practice used on a regular basis in most of the manufacturing industries. Its aim is to optimize the objectives with the allocation of resources to tasks within the given time periods. The resources and tasks in an organization can take a lot of different forms. The resources may be machines in a workshop, processing units in a computing environment and so on. The tasks may be jobs or operations in a production process, executions of computer programs, stages in a construction project, and so on. The objectives can take many different forms and one objective may be the minimization of total completion time of jobs [2].
Scheduling exists in most manufacturing and production systems, as well as in most information-processing environments. In production management, scheduling plays a vital role that is important to ensure the production system runs orderly and explores its potential capacity [6]. The job shop scheduling problem (JSP) is one of the most popular scheduling problems in the world. It has attracted many researchers due to its wide applicability and inherent difficulty. In the $n \times m$ classical JSP, set of n jobs must be processed on a group of m machines, where the processing of each job i consists of Ji operations performed on these machines. Each job has a pre-specified processing order on the machines, which is fixed and known in advance, i.e., each operation needs to be executed on a given machine. Moreover, the processing times of all operations are also fixed and known in advance. Each machine is continuously available from time zero and can process at most one operation at a time. The operations are processed on all machines without interruption. A common objective function is to minimize the make span, which is the time needed to complete all the jobs [16].
The Akaki spare parts share company (ASPSC) is a big complex, comprising of foundry, forging, machining, and heat treatment and quality control shops. The company is dedicated to manufacture and supply parts, components and machines for sugar, textile, Transport, agriculture, construction material industries and other sector locally and to neighboring countries. Currently, ASPSC (specially, machine shop) has a big problem in meeting the delivery dates. Though there are a number of reasons for this problem, urgent jobs and the existing scheduling technique employed in production planning and control contributes major proportion. Since, ASPSC will use only FCFS (first come first served) rule basis. Basically, FCFS rule scores poorly in average completion time and average job lateness criteria. The advantage of FCFS is it appears fair to customers, which is important in service organization rather than manufacturing.
In this paper, the common dispatching rule such as shortest

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processing time (SPT) and longest processing time (LPT) by using Lekin scheduling software and compared each dispatching rule in order to find the best possible scheduling was analyzed. The reasons for selecting these rules it bases on processing time of the jobs. Primary objective is to generate such a schedule in the process of job shop scheduling using LEKIN® scheduling software using dispatching rules as mentioned above and to explore the chances to minimize the make span i.e. the time length of the schedule, in which all the operations of each job is finished for an ASPSC (machining shop).

2. Literature Review

There is vast literature in the area of scheduling, job shop, and dispatching rules in the manufacturing systems of a job shop production. Scheduling is the allocation of resources (e.g. machines) to tasks (e.g. jobs) in order to ensure the completion of these tasks in a reasonable amount of time (Pinedo, 2001) [9]. Job shop scheduling (JSS) is one of the most typical and complicated manufacturing environments in production scheduling problems. A job shop consists of a set of n jobs {1, 2 . . . n} that have to be processed by at most a set of m machines {1, 2 . . . m}. Each job i has a specific operation order Oi (Oi1, Oi2. . . Oil), where Oij represents the jth machine that job i must be processed on, and $l \leq m$. Machines are continuously available (i.e. there is no machine breakdown). Each machine can process only one job at a time and each job can be processed by only one machine at a time. Preemption of jobs is not allowed, which means that the processing of jobs cannot be interrupted [3].

In the Job Shop Problem(JSP) a set 'J' of 'n' jobs J1, J2, J3, … Jn have to be processed on a set 'M' of 'm' different machines M1, M2, M3, … Mm. Job Jj consists of a sequence of mj operations Oj1, Oj2, Oj3,….., Ojmj, which have to be scheduled in this order. Moreover, each operation can be processed only by one machine among the 'm' available ones. Operation 'Ojk' has a processing time 'Pjk'. The objective is to find an operating sequence for each machine such as to minimize a particular function of the job completion times, and in such a way that two operations are never processed on the same machine at any time instant [1].

The job shop problem studied in the present paper consists in scheduling a set of jobs on a set of machines with the objective to minimize the make span, i.e., the maximum of completion times needed for processing all jobs, subject to the constraints that each job has a specified processing order through the machines and that each machine can process at most one job at a time [5].

The JSP has been proven to be NP-hard. Therefore, only small size instances of the JSP can be solved optimally with good computational time using exact solution methods. When the problem size increases, the computational time of exact algorithms grows exponentially. Heuristic algorithms have generally acceptable time and memory requirements to obtain a near-optimal or optimal solution. During the past few decades, most researches on the JSP have been concentrated on developing heuristic algorithms [16].

A job-shop does not have the same restriction on workflow as a flow-shop. In a job-shop, jobs can be processed on machines in any order. The usual job shop, from a research standpoint, is one in which there are m machines and n jobs to be processed. Each job requires m operations, one on each machine, in a specific order, but the order can be different for each job [5]. The processing times needed for the jobs on the machines are denoted as pij, where i = 1… n and j = 1. . .m; these times are fixed, known in advance and non-negative. There are several assumptions that are made regarding the problem in job shop: Machines are available all times. A jobs are available at a time $t_0 = 0$ and $r_j = 0$. The set-up times of the jobs on machines are included in the processing times. There are no precedence constraints among the operations of different jobs. Each machine can process only one job at a time. Each job can be processed by only one machine at a time [9].

The job-shop scheduling problem (JSP) is one of the most difficult production scheduling problems. It aims to allocate a number of machines over time to perform a set of jobs with certain constraint conditions in order to optimize certain criterion, e.g., minimizing the make span. Traditionally there are three kinds of approaches for solving JSPs: dispatching priority rules, combinatorial optimization and constraints analysis. In this study dispatching priority rules was used due to the job shop operation practice of the case company.

2.1 Dispatching Rule

Dispatching rule is a rule that prioritizes all the jobs that are waiting for processing on a machine. The prioritization scheme may take into account the jobs' attributes, the machines' attributes as well as the current time. Whenever a machine has been freed a dispatching rule selects, among the jobs waiting, the job with the highest priority [10].

Classified over 100 scheduling rules and attempted to explain the general idea behind different rules. These rules classified into static and dynamic rules. Static rules are the ones in which the job priority values do not change as a function of the passage of time, i.e. it is not time dependent. They are just a function of a job and/or machine data. Dynamic rules are time dependent [8].

Dispatching rules are better than genetic algorithms in three respects. They found that dispatching rules are able to create various solutions to solve many problems observed, whereas genetic algorithms only provide one solution to minimize make span. In addition, solutions obtained by genetic algorithms yielded scattering results, whereas the solutions obtained by dispatching rules yielded steady results. Thirdly, genetic algorithms require the use of a computer because of the large number of parameters to specify, whereas dispatching rules can obtain simple solutions in an urgent production situation [6].

Research in dispatching rules has been active for several decades and many different rules have been developed. The dispatching rules we use for these study are:-

2.1.1 First come – First Serve Rule (FCFS)

The job which arrives first enters service first. It is simple, fast and fair to the customer. The major disadvantage of this rule is that it is least effective as measured by traditional performance measures as a long job makes others wait resulting in idle downstream resources and it ignores job due date and work remaining [12]

2.1.2 Shortest Processing Time (SPT)

The job which has the smallest operation time enters service first. Advantages of this rule is that it is simple, fast, generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in- process inventories (less shop congestion) and downstream idle time (higher resource utilization), and usually lower average job tardiness and disadvantages is, it ignores downstream, due date information, and long jobs wait (high job wait –time variance) [12].

2.1.3 Longest Processing Time (LPT)

The job which has the longest operation time enters service first. Advantages of this rule is that it is simple, fast, generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in- process inventories (less shop congestion) and downstream idle time (higher resource utilization), and usually lower average job tardiness and disadvantages is, it ignores downstream, due date information, and long jobs wait (high job wait –time variance) [12].

3. Methodology

The research paper is carried out in Akaki spare parts share company (ASPSC), to identify the problem and understand the nature of the problem that faced by the industrial unit, which related to scheduling of the job shop, field work has been conducted. Then, once the problem is identified, secondary data has been collected from the production planning and control system unit catalog. On the other hand, necessary literature is reviewed to select the dispatching rule that are suitable for developing the job shop scheduling and by selecting common dispatching rule, we can find the make span, other performance measuring variable and compare each value in order to obtain best possible solution and in order to suggest some point about scheduling. The make span and other performance measuring variable are obtained by using Lekin scheduling software.

4. Results and Discussions

In this study five jobs which were processed on six machines studied. The jobs are selected from many jobs that are carried out in Akaki spare parts Share Company (machining shop). The factory contains foundry, forging, machining, and heat treatment and quality control shops. The study focuses on the scheduling sequence of five common jobs on six machines in the machining shop, all the jobs were available t=0. The jobs are manufacturing of, Helical Gear (J1), Wheel Nut M22*2*25(J2), Castel Nut(J3), Drive shaft which have 8 teeth(J4) and PTO Splines gear hub(J5). These jobs were processed on machines; Power hack saw (M1), Lathe machine (M2), Milling machine (M3), Drilling machine (M4), Gear Hoobing machine (M5) and Grinding machine (M6). The routing and processing time matrix of visiting the jobs in each machine is given in the table below:

Table 1 Routing of the job in each machine.

Jobs	Machine				
J1	1	2	3	5	6
J2	1	2	3	4	-
J3	1	2	4	3	-
J4	1	2	4	5	6
J5	1	2	5	6	-

Table 2 Processing Time matrix of the jobs (Minute

Jobs	Machine				
J1	38	318	138	306	33
J2	9	11	32	18	-
J3	56	14	47	51	-
J4	56	278	194	338	108
J5	48	174	206	48	-

Considering the matrix given in tables, it is clear that the problem is Job shop scheduling problem. Hence, Dispatching was able to provide not only a good solution but also the best solutions for the system practical. Using LEKIN® scheduling software using various dispatching rules we can find the make span, different performance measure and compare each other and we can recommended the best dispatching rule for ASPSC (machine shop).

In Generic job shop scheduling system, it contains a number of scheduling & heuristics algorithms, & it's allow the user to link and test his own heuristics and compare their performance with the heuristics algorithms that are embedded in the system. The Lekin system can be accommodating various machine environments: (1) Single machine (2) Parallel machine (3) Flow shop (4) Job shop (5) Flexible flow shop (6) flexible Job shop (SH). Basically our focus is in job shop scheduling and we can select job shop scheduling and feed the processing time of each job to the lekin scheduling software and we can compare each value depending upon the result from the lekin software [7].

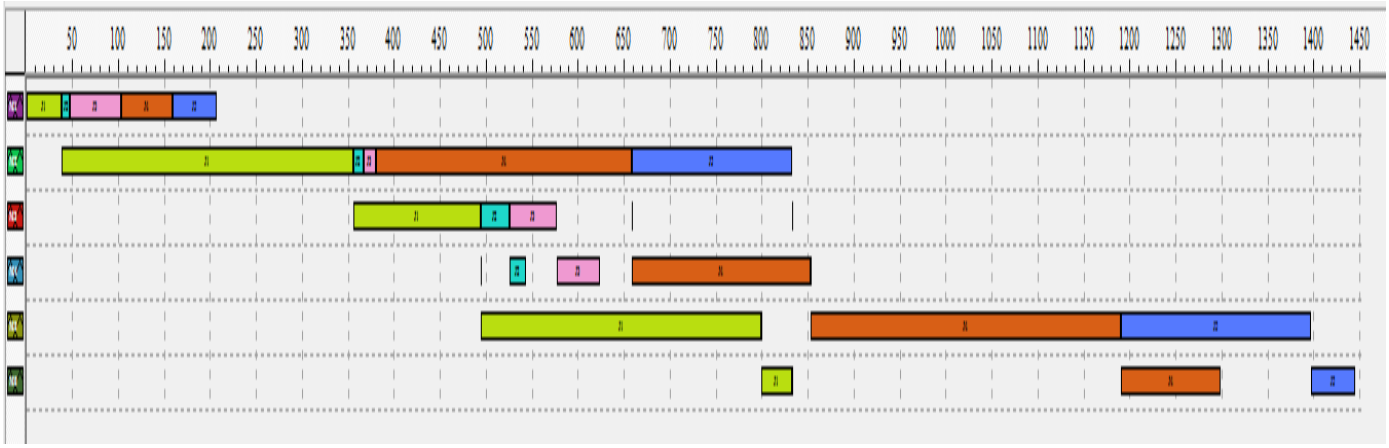

Figure 1 First Come First Serve Rule base

Output from the Gantt chat of the fist come first serve rule based on the job sequence which means the job enter the first job is not based on the length or shorten of the job time rather if the job comes fires enter the operation. As we can see the make span found is 1445 minute for the jobs and the sequence of jobs are J4-J1-J5-J3-J2.

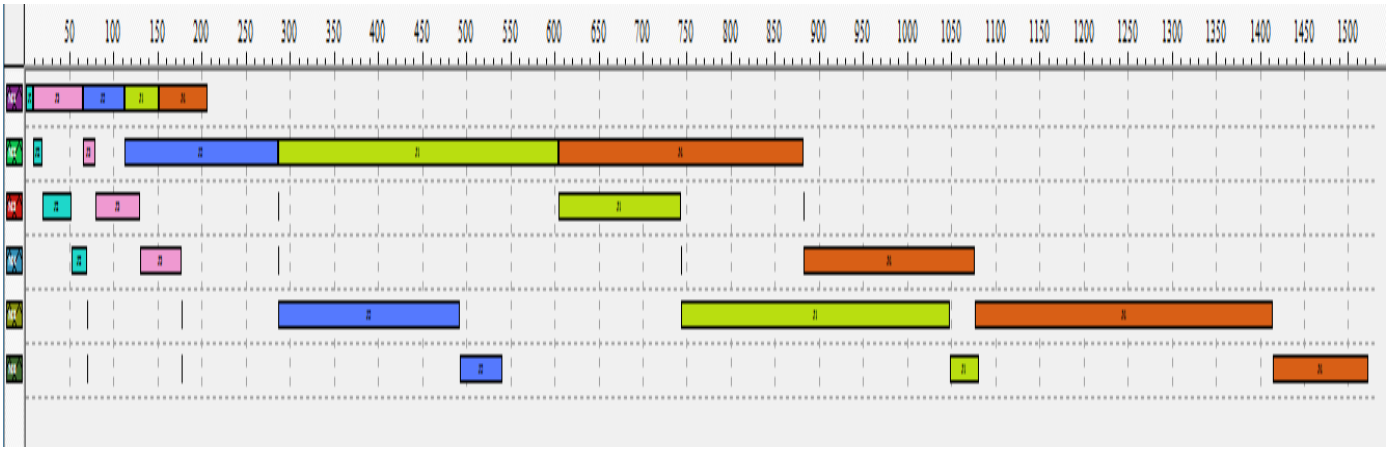

Figure 2 Shortest Processing Time Rule base

Figure 2 shows that Gantt chart by using shortest processing time and don't leave the machine idle while jobs are available for processing: dispatching rule. Jobs are completed in the following Sequences J2-J3-J5-J1-J4. And have the make span of 1523 min.

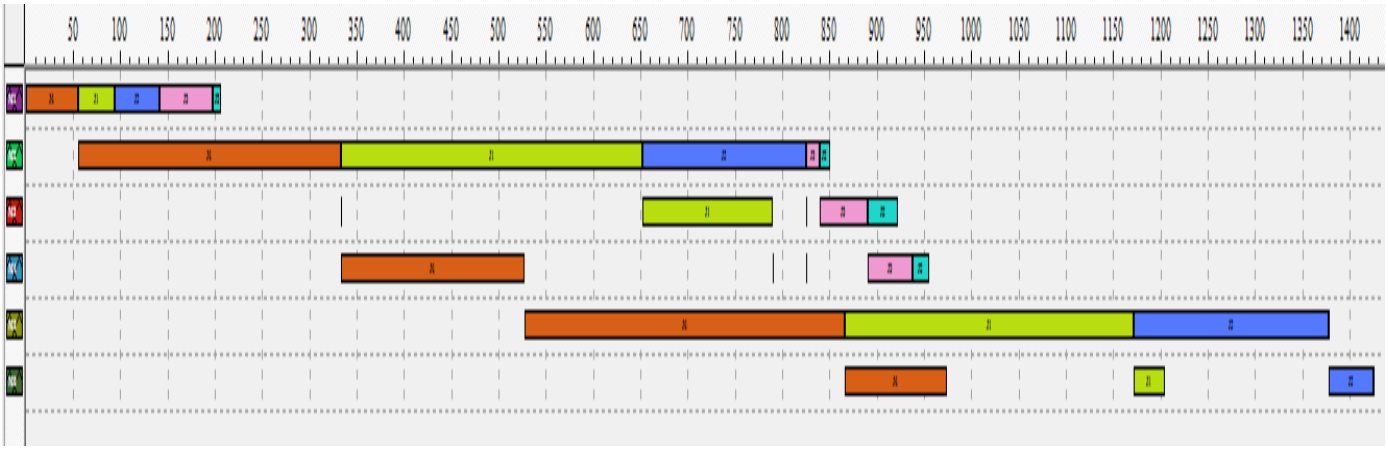

Figure 3 Longest Processing Time Rule base

Figure 3 shows that Gantt chart by using longest processing time and don't leave the machine idle. While jobs are available for processing: dispatching rule. Jobs are completed in the following sequences J4-J1-J5-J3-J2. And have the make span of 1426 minute.

Here in this study different dispatching rule are used and the result of the output are put in table form. The following three dispatching rule has been utilized in the study and resulting in performance measurement of the case.

- First come first serve rule (FCFS).
- Shortest processing time (SPT).
- Longest processing time (LPT.

There are different performances measuring variable, these are:

- Make span as C_{max}.
- The Maximum Tardiness as T_{max}.
- The Total Number Of Late Jobs$\sum Uj$.
- The Total Flow Time$\sum Cj$.
- The Total Tardiness$\sum Tj$.
- The Total Weighted Flow Time $\sum WjCj$ and Total Weighted Tardiness as$\sum WjTj$

Table 3 Output from lekin scheduling software using different alternative Dispatching rule.

Jobs-sequence	Dispatching rule	C_{max}	T_{max}	∑Uj	∑Cj	∑Tj	∑WjCj	∑WjTj
J1-J2-J3-J4-J5	FCFS	1445	1445	5	5243	5243	5243	5243
J2-J3-J5-J1-J4	SPT	1523	1523	5	3393	3393	3393	3393
J4-J1-J5-J3-J2	LPT	1426	1426	5	6457	6457	6457	6457

The results from the table's shows that longest processing time have good value of the make span relative to the other. So the best possible job sequence of this rule is J4-J1-J5-J3-J2 with minimum make span of 1426 minute and also Gantt chart is shown in fig 3. The company must try other dispatching rule in order to satisfy the need of customer. As we can see other result from the table for instance we can get good value of total flow time, total weighted flow time and total weighted tardiness from shortest processing time but it's make span is very large relative to other dispatching rule. Finally the first come first serve rule it give us the next good result of make span but it is not best possible.

5. Conclusions

Job shop scheduling (JSS) is one of the most typical and complicated manufacturing environments in production scheduling problems. This research paper aim at scheduling of 5-jobs and 6-machines using different dispatching rule such as FCFS, SPT, and LPT construct in Lekin scheduling software based on secondary data collected from ASPSC (machine shop) production planning and control system unit catalog. From this the longest processing time gives best poss ible makespan relative to the others which is 1426 minute. From these we can conclude that ASPSC (machine shop) must try other dispatching rule in order to optimize production planning and control system good as well as in order to satisfy customer need and to increase the productivity of the company by allocating the resource with optimal base.

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