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Dispatching Rule-Based Single Machine Static Scheduling of Crankcase Covers

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Abstract. The research focuses on the multi-objective single-machine static scheduling problems of motorcycle crankcase cover. To solve these static scheduling problems, dispatching rules are used. Various dispatching rules used in this study are the earliest due date (EDD), shortest processing time (SPT), critical ratio (CR), longest processing time (LPT), weightage shortest processing time (WSPT), cost over time (COVERT), and hodgson's algorithm. The objective of the paper is to sequence the different crankcase covers and to minimize average flow time, an average hour early, and an average hour past due, etc. This study helps us to obtain optimal job prioritization of two-wheeler crankcase covers in the automobile industry. Results show that shifting the production system from WSPT approach scheduling to the EDD scheduling approach, minimizes the mean flow time by 2.75%, weighted mean flow time by 27.91%, and maximum lateness by 21.87%.

Keywords. COVERT; Dispatching rules; EDD; Machine Scheduling; SPT; WSPT.

1. Introduction

Production Scheduling is a very important decision-making process that includes the proper allocation of all the available resources for performing all tasks [1]. On-time delivery of products or services provides customer satisfaction and scheduling helps in achieving on-time delivery [2]. The primary objective of scheduling includes determining the job processing time, due date, and sequence of jobs [3]. Scheduling problems can be stratified into static and dynamic scheduling problems [4]. Figure 1 shows the stratification of scheduling problems and dispatching rules.

[1]These rules can be classified into single and multi-dimension rules. Single dimension rules consist of SPT, EDD, and first come first serve (FCFS). The due date can be calculated with computerized methods like material requirement planning (MRP) or it can be determined from the customer directly. Multi-dimension rules consist of CR and slack per remaining operations. These dispatching or sequencing rules can also be classified based on priority determination of each job, dynamics of the information base, or maybe based on machine and job selection. Dispatching rules can be stratified into local and global rules as shown in Figure 1. Local rules used only limited available information, but global rules used all information present on the shop floor. Dispatching rules can be classified into static and dynamic rules as shown in Figure 1. Static rules do not depend on time, but they depend on the machine or job data e.g., EDD, earliest release date (ERD), and WSPT rule. The dynamic rule is time-dependent e.g., SPT and MDD (Modified due date), etc.

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The MDD Rule is a combination of EDD and SRPT (shortest remaining processing time) which is effective in minimizing mean tardiness [5]. Dispatching rules can also be stratified based on job and machine selection as shown in Figure. 1. Dispatching rules based on job selection are SPT, EDD, etc. LUS (utilization is lowest), NINQ (Number in next queue), MDD (Modified due date), and TSPT are some rules based on machine selection [6].

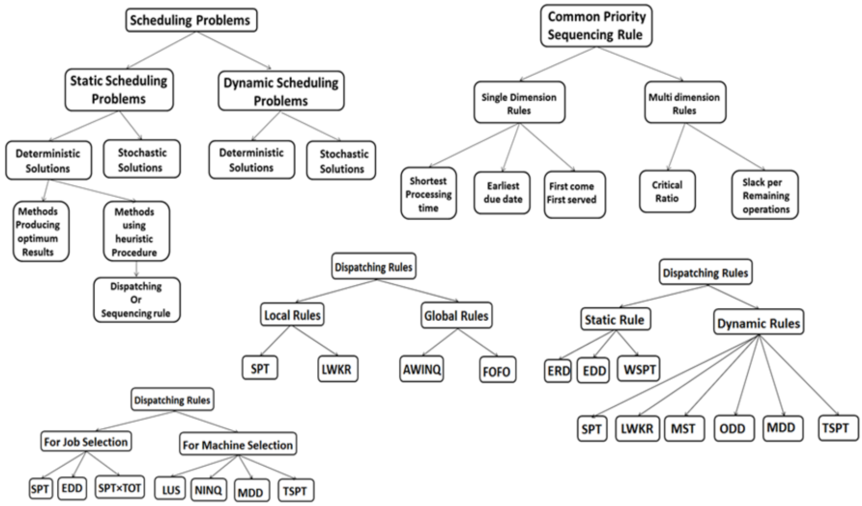

Figure 1. Stratification of scheduling problems and dispatching rules

The dispatching rule gives good results only in the case of a single objective but in real problems, combinations of objectives are present which is tackled by a combination of dispatching rules. These combinations of dispatching rules are called composite dispatching rules [2]. Q. Zhou et al. analyzed the dynamic priority scheduling problem of data dissemination systems [7]. Real-life applications of scheduling include manufacturing scheduling, scheduling in a service industry, and scheduling in a computer system [2]. This paper is organized as follows. Section 2 presents the literature review. Section 3 describes the general process sequence for crankcase cover manufacturing. In section 4, materials and methods are defined and the common priority sequencing rule approach is applied, and their results and discussion part are shown. Section 5 concludes the paper based on results obtained using different dispatching rules.

2. Literature Review

Production managers face difficulties in optimizing resource utilization as well as on-time delivery of products [1]. With these dispatching rules we can optimize resource utilization and on-time delivery together. Dispatching rules can be effectively used in job sequencing problems in single machine scheduling and can also include parameters like setup time and energy consumption [8]. Selected criteria of a performance play a significant role in the results obtained through these dispatching rules. [9]. Lu et al. studied the dynamic dispatching problem using a fuzzy inference rule-based approach under several performances affecting variables. [6]. Choi et al. considered single-machine scheduling problems under energy and set up time constraints with the objective of minimization of mean tardiness and energy consumption [8]. Pfund et al. considered unrelated parallel machine scheduling under stochastic uncertainty with the objective of minimization of makespan, machine utilization, finishing time, and over time [10]. Zuo et al. solved the job shop scheduling problem using scheduling methods based on several machine constraints. [11]. Restrepo et al. considered flexible manufacturing cell scheduling using a comparative approach between the fuzzy set approach and dispatching rules like SPT and WEED (weighted earliest due date) with the fuzzy strategy of the fuzzy machine and fuzzy job [12]. Mouzon et al. minimized energy consumption by proposing dispatching rules and utilizing a mathematical programming model [13-14]. Mokhtari et al. developed a multi-objective flexible job shop scheduling model for minimizing total completion time, total availability of the system, and total energy consumption using an evolutionary algorithm [15]. Atan et al. solved the single CNC machine scheduling problem to maximize the overall profit using the heuristic algorithm [16]. Wang Y et al. analyzed the performance of priority rules considering stochastic variables using a full factorial experiment [17]. Chiang TC et al. solved the due date-based job shop-scheduling problem using eighteen dispatching rules [18]. Dispatching rules have an advantage over other methods and rules because it requires minimum information and computational effort [20,21]. Kianfar et al. formulated a mixed-integer programming model for minimizing rejection and tardiness cost of jobs in the dynamic flow shop scheduling system by comparing four dispatching rules from literature to the new proposed four dispatching rules [22]. If a part or job is manufactured before the due date, then it incurs earliness cost and if it manufactures after the due date, it incurs a penalty. So, most of the researchers follow the objective to manufacture part or job as close as the due date [23]. From the above-reviewed literature, we found out that the common objectives in scheduling problems are to minimize the makespan, energy consumption, machine utilization, finishing time, overtime, setup time, rejection cost, and tardiness cost [8,10,22].

3. Manufacturing Process of Crankcase Cover

Generally, 60% fresh aluminum brick and 40% rejected pieces are used for melting in a furnace. Each aluminum brick (raw material) is 5 kg. A ladle is used to carry out the molten aluminum from the furnace to PDC (pressure die casting) machine. Crankcase covers were obtained through the PDC machine. Generally, the production rate of this crankcase covers is 50 parts per hour. But it varies according to the variation in the parts. The target production per hour for cover Lk 38 is 60. CNC usually vertical milling center (VMC) is used for machining of these crankcase covers after fettling and drilling operation The cycle time of cover LK 38 is 5 min 24 seconds which includes a cutting time of 3 min 28 seconds and a non-cutting time of 1 min 28 seconds. The cutting time to cycle time ratio for cover LK 38 is 84%. After machining and buffing operation, pre-treatment or surface treatment processes are done. This pretreatment process is done almost for 12 to 15 min for removing surface defects. Almost 150 crankcase covers can be pretreated simultaneously in one lot. After the pretreatment process, the masking operation is done for covering those parts where there is no need for paint like in the threads of the crankcase covers. This operation is done before the painting operation. The second last stage of crankcase covers manufacturing is the painting shop. The product remains in the painting shop for almost 2 hours. The painting stage includes loading, primer, base coat, top coat, honda monogram PU red paint, and baking in the oven. Baking time is 10 min and baking temperature is 90 degrees. The last stage is the inspection and packaging.

4. Methodology

We have taken four types of crankcases covers in our study. Our main aim is to do single machine scheduling of this crankcase cover on the vertical milling center. These parts are cover left side crankcase KWPG, cover left crankcase K38, cover crankcase 206 G, and cover right crankcase KTE as shown in Figure 2.

Cover left side crankcase KWPG

Cover left crankcase K38

Cover crankcase 206 G

Cover right crankcase KTE

Figure 2. Types of crankcases covers

Nomenclature used in this study are as follows. All parameters are taken in hours. P_j is total processing time of job j including setup time, T_j is time duration of job j since order arrived, S is part lot sequence, T_b is begin work time, T_{fi} is finish time for lot, T_{fl} is flow time for lot, T_d is time duration until the due date, T_s is slack time remaining, T_{sp} is scheduled customer pickup time, T_{ap} is actual customer pickup time, T_{he} is hours early, and T_{hpd} is hours past due. Some data is collected from industry, and some are taken from the literature review and industry experts. Table 1 shows the data of different parts.

For 'n' jobs on a single machine, we have different priority rules FCFS, SPT, EDD, slack time remaining (STR), and CR. EDD priority rule sequences the jobs by their due dates. This rule also minimizes the maximum lateness and maximum tardiness [23]. SPT rule helps in minimizing the mean flow time, total waiting time, maximum waiting time, and total completion time, etc. It also maximizes shop floor utilization. This rule also provides the lowest mean finish time for a single workstation problem. But it increases total inventory because it finishes all work very fast compared to other rules. CR is calculated by the ratio of time remaining before the due date and remaining processing time. The smallest CR goes first. For conditional mean tardiness (CMT) which is a ratio of mean tardiness and proportion of jobs tardy, CR priorities are effective. These approaches are used in computer software [9].

Table 1. Data table of different parts

Part lot	T_j	P_j	T_d
K38	2	3.5	7
206 G	1	2	9
KTE	7	4	20
KWPG	9	6	28

Table 2. Scheduling using CR rule

S	P_j	T_{sp}	T_s	CR
K38	3.5	7	3.5	2
206 G	2	9	7	4.5
KTE	4	20	16	5
KWPG	6	28	22	4.67
CR values after part K38 completed				
206 G	2	9	-	3.5
KTE	4	20	-	4.5
KWPG	6	28	-	4.33
CR values after part K38 and 206 G completed				
KTE	4	20	-	4
KWPG	6	28	-	4

Table 3. Process time to weights ratio calculation

Part name	P_j	W_j	P_j/W_j
K38	3.5	0.13	26.92
206 G	2	0.17	11.76
KTE	4	0.3	13.33
KWPG	6	0.4	15

Since KTE & KWPG both have the same CR as shown in Table 2, so comparison of processing time is done for scheduling then KTE has less processing time. So, at time 9.5 min, KTE completed, and at time 15.5 min KWPG will be completed. So, scheduling order will be K38 → 206G → KTE → KWPG. LPT approach is developed by Graham in 1969. Croce F Della et al. solved the identical parallel machine scheduling problem using the LPT rule. In the LPT rule, jobs are sequenced in descending order of processing times [24]. In WSPT approach, the processing time to weight ratio is calculated and jobs are arranged according to the increasing order of these ratios. In this study, weights are assigned according to scheduled customer pickup time. Table 3 shows the calculation of these ratios. The part sequence obtained using the WSPT approach (206G → KTE → KWPG → K38). In the COVERT approach, the tardiness to processing time ratio is calculated and based on the largest ratio first, a part sequence is selected as shown in Table 4. This rule is very effective in minimizing average conditional tardiness. The lateness of job j is defined by Eq. (1). Positive lateness is known as tardiness.

$$L_j = T_{fi} - T_d \tag{1}$$

Table 4. Calculation of the COVERT ratio

Part lot	T_j	P_j	T_d	T_{fi}	L_j	COVERT Ratio
K38	2	3.5	7	3.5	-3.5	-1
206 G	1	2	9	5.5	-3.5	-1.75
KTE	7	4	20	9.5	-10.5	-2.62
KWPG	9	6	28	15.5	-12.5	-2.08

Based on this ratio, the part sequence selected is (K38 → 206G → KWPG → KTE). Sequence of operations using various dispatching rules is shown in Table 5.

HODGSON'S algorithm provides the best result in minimizing no. of tardy jobs and it is applicable for only those cases in which no. of tardy jobs are more than one. This algorithm sequences the job with the EDD sequence. In our study, we get no. of tardy jobs is zero according to the EDD sequence which shows optimal sequence [25]. Table 6 shows the part sequence obtained from various dispatching rules. This table also describes the parameters optimized by different dispatching rules. Table 7 describes the dispatching rule-based priority rule summary for crankcase cover prioritization. Figure 3 shows the variations of parameters with dispatching rules. Based on Table 6 & Table 7 and Figure 3, different results can be concluded.

Table 5. Sequence of operations using various dispatching rules

S	T_j	T_b	P_j	T_{fi}	T_{fl}	T_{sp}	T_{ap}	T_{he}	T_{hpd}
Sequence of operations using EDD Approach									
K38	2	0	3.5	3.5	5.5	7	10	6.5	3
206 G	1	3.5	2	5.5	6.5	9	12	6.5	3
KTE	7	5.5	4	9.5	16.5	20	23	13.5	3
KWPG	9	9.5	6	15.5	24.5	28	30	14.5	2
Sequence of operations using SPT Approach									
206 G	1	0	2	2	3	9	10	8	1
K 38	2	2	3.5	5.5	7.5	7	12	6.5	5
KTE	7	5.5	4	9.5	16.5	20	25	15.5	5
KWPG	9	9.5	6	15.5	24.5	28	30	14.5	2
Sequence of operations using CR Approach									
K38	2	0	3.5	3.5	5.5	7	10	6.5	3
206 G	1	3.5	2	5.5	6.5	9	12	6.5	3
KTE	7	5.5	4	9.5	16.5	28	30	20.5	2
KWPG	9	11.5	6	17.5	23.5	20	23	5.5	3
Sequence of operations using LPT Approach									
KWPG	9	0	6	6	15	28	30	24	2
KTE	7	6	4	10	17	20	25	15	5
K 38	2	10	3.5	13.5	15.5	7	12	-1.5	5
206 G	1	13.5	2	15.5	16.5	9	10	-5.5	1
Sequence of operations using the WSPT Approach									
206 G	1	0	2	2	3	9	10	8	1
KTE	7	2	4	6	13	20	25	19	5
KWPG	9	6	6	12	21	28	30	18	2
K38	2	12	3.5	15.5	17.5	7	12	-3.5	5
Sequence of operations using COVERT Approach									
K38	2	0	3.5	3.5	5.5	7	12	8.5	5
206G	1	3.5	2	5.5	6.5	9	10	4.5	1
KWPG	9	5.5	6	11.5	20.5	28	30	18.5	2
KTE	7	11.5	4	15.5	22.5	20	25	9.5	5

Table 6. Part sequence obtained from various dispatching rules

Dispatching Rule	Part Sequence	Parameters Minimized
EDD	K38 → 206G → KTE → KWPG	Maximum lateness and tardiness
SPT	206G → K38 → KTE → KWPG	Average flow time
CR	K38 → 206G → KTE → KWPG	Conditional mean tardiness
LPT	KWPG → KTE → K38 → 206G	Average hours early
WSPT	206G → KTE → KWPG → K38	Mean flow time and mean finish time
COVERT	K38 → 206G → KWPG → KTE	Average conditional tardiness
Hodgson's Algorithm	K38 → 206G → KTE → KWPG	No. of tardy Jobs

Table 7. Priority Rule Summary

Rule	Mean Flow time	Weighted Mean flow time	Mean Tardi-ness	Mean Lateness	Maximum Lateness	Average hours Early	No. of Tardy Jobs
EDD	13.25	10.87	0.00	-7.50	-12.50	10.25	0.00
SPT	12.87	16.23	0.00	-7.87	-12.50	11.12	0.00
CR	13.00	16.17	0.00	-7.00	-10.50	9.75	0.00
LPT	16.00	15.92	3.25	-4.75	-22.00	8.00	2.00
WSPT	13.625	15.08	2.12	-7.12	-16.00	10.37	1.00
COVERT	13.75	16.77	0.00	-7.00	-16.50	10.25	0.00

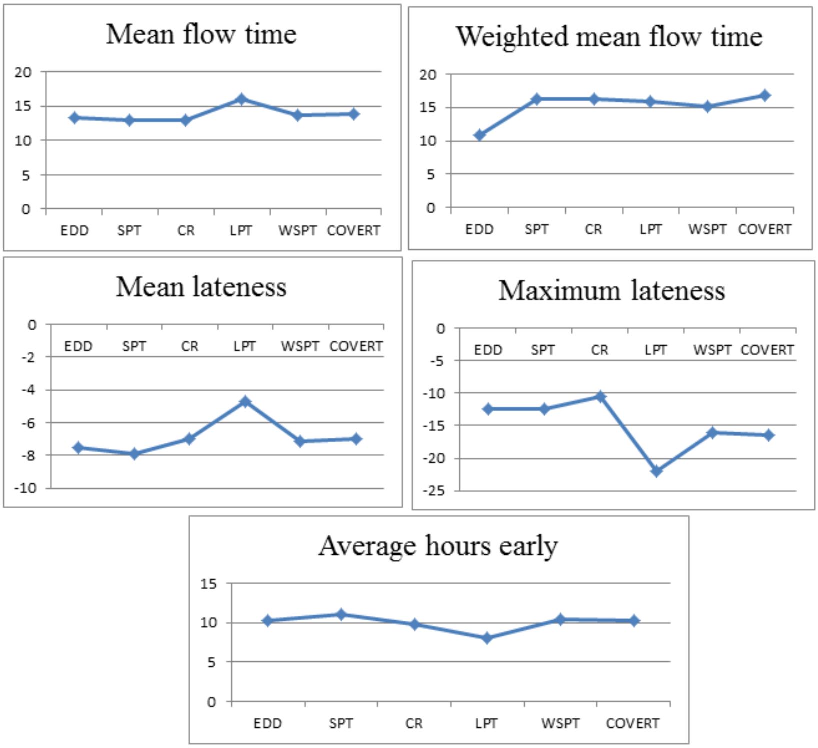

Figure 3. Variations of parameters with dispatching rules

5. Conclusions

Among all priority rules, the SPT approach minimizes average flow time but sometimes it increases the inventory cost also. CR approach provides a balanced schedule having a moderate value of average flow time and due date. CR priorities are effective for conditional mean tardiness. EDD approach provides better customer satisfaction because it delivers the product to the customer on time, and it minimizes the weighted mean flow time also. In our study, we have shifted our production system from the WSPT approach scheduling to the EDD scheduling approach. EDD scheduling approach minimizes the mean flow time by 2.75%, weighted mean flow time by 27.91%, and maximum lateness by 21.87%. Overall, this study, the best part sequence K38 → 206G → KTE → KWPG is obtained from the EDD rule which helps us in achieving on-time delivery and customer satisfaction. The limitation of the research is that these dispatching rules generally provide low-quality solutions because of a lack of flexibility, so it should be used with some mathematical/simulation models to obtain high-quality solutions [19]. This study can be further extended by applying other remaining advanced dispatching rule approaches.

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