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AN INTEGRATED EIGHT DISCIPLINE APPROACH (IEDA) FOR TIME MANAGEMENT IN CRANKSHAFT MANUFACTURING ENVIRONMENT

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ABSTRACT

This article addresses the problem of time management for scheduling the system to reach the delivery date on or before the due date. An Integrated Eight Discipline Approach (IEDA) is proposed to manage the time schedule by minimizing the process time of the system. This method includes a heuristic approach, re-allocation of resource, grouping technique and hybrid simulation technique; to reach the above objectives with cost-effective and risk-less criteria. This proposed IEDA is implemented in a crankshaft manufacturing environment to evaluate the robustness and effectiveness and it is analyzed with simulation models. As a result, it promises that the delivery date is below the due date is achievable with a practically feasible solution.

Key words: Due Date, Time Management, Case Study, Simulation, Eight Disciplines.

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1. INTRODUCTION

Challenge in manufacturing various products for the real world makes a new dimension for time management in terms of scheduling. The allocation of resources and in a manufacturing under various constraints makes the difficulty in decision making and time scheduling [1]. The decisions regarding delivery date are taken based on the job sequence, allocation of critical resources, etc. Generally, the manufacturing environment is described as hybrid flowshop, flexible hybrid flowshop, etc [2]. The major aim in any manufacturing environment is to provide the earlier delivery with effective utilization of resources and capitalization [3]. The demanded product in the market requires best manufacturing method and production schedule. Scheduling is a vital task, which involves organizing, choosing, and timing the resource to carry out all the activities necessary to produce the desired output at the desired time, while satisfying more number of time and relationship constraints among the activities and the resource [4]. Since the manufacturing method remains fixed and good, the production schedule is to be optimized to meet the market demand [5].

The best sequence for manufacturing is proposed by many authors [6, 7] and many authors changed the manufacturing route to reach the delivery date is below the due date [8]. But only a few articles focused on optimizing both the delivery date and resource utilization for the manufacturing environment [9]. The optimization of both the delivery date and resource utilization for multi-stage manufacturing environment remains a tedious task and it makes a vision for the new researchers.

2. PROBLEM STATEMENT

Though the survey has brought out an extensive analysis of problem-related to manufacturing scheduling but not focused with the objective of both delivery date and resource utilization. As such the survey has set in a starting point for new research efforts. In practice, the objective may vary for a different organization and therefore, the different schematics of the system are possible. This information and opportunity have given way for the selection of real-world motivated problem for developing a solution to a manufacturing scheduling problem. It is important to consider that the real world is the unpredictable and dynamic system. The algorithms must be able to find solutions, which are robust. The problem posed for the development of a solution to solve the manufacturing scheduling problem with the primary objective of minimizing the delivery date by time management and effective resource utilization.

3. PROPOSED METHODOLOGY

The eight disciplines model is incorporated into the standard approach to developing the Integrated Eight Discipline Approach (IEDA). The steps involved in IEDA are,

Step 1: Determine the prerequisites and basic study of the problem.

Step 2: Determine the root line of the problem to study the product/process.

Step 3: Analyze the existing solution methodology and frame its drawbacks.

Step 4: Define a failure cause analysis with the existing models.

Step 5: Define and describe the problem by identifying in quantifiable terms for the problem.

Step 6: Develop interim containment plan and estimate the possible hypothesis.

Step 7: Implement and verify interim actions with considering the real-time factors.

Step 8: Evaluate the performance of the system, if any error or indefinite efficiency perform the corrective actions through preproduction programs and quantitatively confirm that the selected correction will resolve the issue.

Step 9: Frame the preventive measures for the management systems, and operation systems, to prevent recurrence of similar problems.

4. EVALUATION OF IEDA – CASE STUDY

A case study has been carried out in a small firm, which produces the crankshaft through forging method. The IEDA is evaluated by solving the problem in the selected firm. The crankshafts are manufactured in various specifications and considerations. The consideration includes unidirectional flow, all jobs at a stage have the same priority as FIFO logic, and all jobs must process all the stages in the same order, such that no jobs will skip any stage.

4.1. Basic Study

For this study, the crankshafts manufactured in a particular firm with the same specification are considered but the cylinder count is varied as 3, 4 and 6 cylinders i.e. HY14C3, HY23C4 and HY27C6. The steps involved in crankshafts manufacturing through various machines after forging was shown in Fig. 1. The processing time of the above-described crankshaft models under each process is tabulated in Table 1.

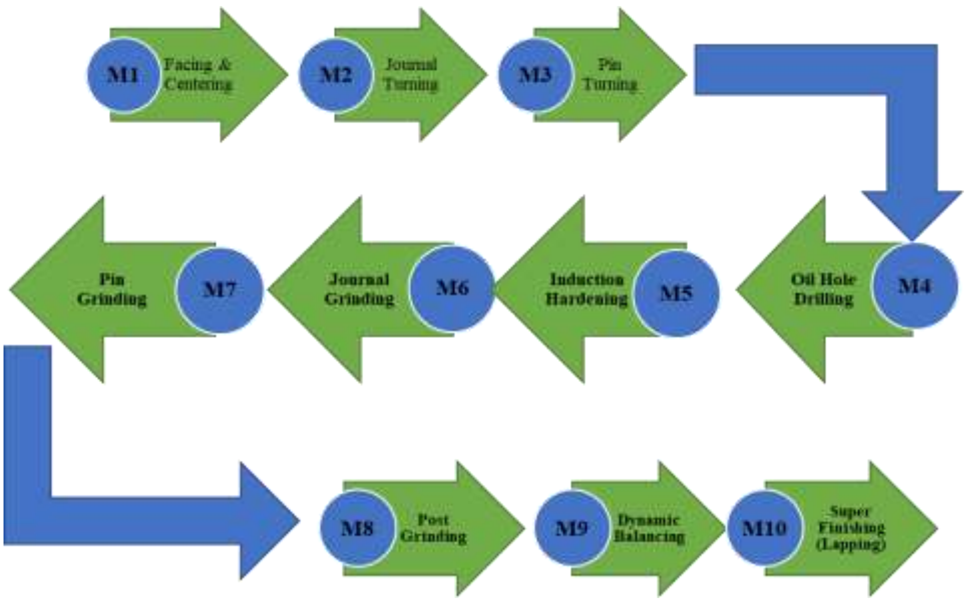

Figure 1 Flowchart of crankshaft manufacturing

Table 1 Processing time of Crankshaft manufacturing

Machine	J1 (HY14C3)	J2 (HY23C4)	J3 (HY27C6)
M1	5	5	5
M2	30	38	45
M3	10	13	15
M4	15	18	22
M5	3	4.5	6
M6	15	16	17
M7	8	10	12
M8	10	15	18
M9	15	15	15
M10	8	11	14

4.2. Root Line of the Problem

The manufacturer produces 150 jobs in each type for a month in a generally followed sequence 1-2-3. The work is completed in 35550 minutes i.e., the workers are working nearly 25 days in 3 shifts with available resources. The manufacturer needs the work to be completed in one week i.e. 21 shifts in time because of the market demand. Since it is a manufacturing environment, the due date is 30300 minutes i.e. around three weeks of time. But the objective is to reach below the due date is a tedious work. This makes the objective to produce the crankshafts before the due date.

4.3. Analyzes of Existing Model

For analyzing the existing model, the existing FIFO sequence is implemented to determine the delivery date. The cycle is executed with non-continuous cycles through simulation and obtained 35550 minutes for delivery date i.e. approximately 74 shifts. Based on this evaluation, it is inferred that the expected delivery date is not feasible by the existing approach.

4.4. Failure Analyze of Existing Solution Approach

The failure analyze is carried by comparing the best or possible models of the system. The time scheduling problem is solved and the possible results are compared in Table 2.

Table 2 Possible Results of Time Scheduling Problem

S.No.	Sequence	Expected Delivery Date		
		Per cycle (minutes)	Non-Continuous Simulation (minutes)	Non-Continuous Simulation (shifts)
1.	1-2-3	237	35550	74
2.	1-3-2	220.5	33075	69
3.	2-1-3	216	32400	67
4.	2-3-1	237	35550	74
5.	3-1-2	220.5	33075	69
6.	3-2-1	202.5	30375	64

The best solution obtained is 30375 minutes (64 shifts) for the time scheduling problem. Even though the best solution is achieved, the due date is not achieved. If this result is utilized then it can save about 10 shifts compared to standard working schedule.

4.5. Define the Cause of Problem

The cause for the failure is analyzed based on the factors identified in the root cause analysis. Based on this analysis, it is identified that the idle time of machine and an excess job waiting are the major reason for the failure of the existing approach. Therefore, the causes of the failure need to be overcome by a set of solution methods.

4.6. Proposed Model

Corollary I: Delivery Date ≤ Due Date

The objective of time scheduling problem requires the delivery date below the due date, then without fail the production environment as to be re-defined by adding inventories or machines. This kind of environment is usually called a flexible manufacturing environment [10]. If the delivery date is reached to the required level then standardize the environment. In this solution method, a critical machine (M_Z) is identified and its work is divided by an identical parallel machine (Fig. 2). The critical machine is identified based on processing time, operation, maintenance requirement, automation, life, breakdown, buffer or delay time, rental cost, and so on. By sub-dividing, the work of a single machine by two or more machines, the delivery date is minimized reasonably [11, 12].

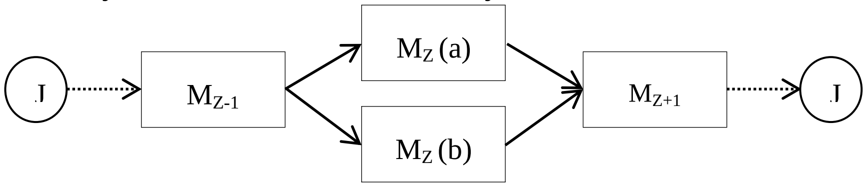

Figure 2 Schematic of the flexible manufacturing environment

Corollary II: Delivery Date ≤ Due Date with practical feasibility

Mostly, the production environment produces the products in the lot. If the job count is high in the huge lot then the separation of job in a sequence is a tedious process. To overcome this demerit, usually skilled labours are used but by using grouping technique (equation 1), the jobs can be grouped while production itself then it can be easily separated [13]. The production environment requires a practically feasible solution to work with a normal human resource, so it can be achieved by this solution method with the reduced delivery date.

$$\mathrm{Min}\{\sum_{m=1}^{M}\sum_{n=1}^{N}(C_{max})_n\} \tag{1}$$

4.7. Implementation of Proposed Model

Corollary I

Since the due date is not achieved by any possible sequence of the job, the manufacturing environment is converted into the flexible manufacturing environment. A single identical parallel machine is added to the flowshop at the stage where the maximum processing time machine is available. The machine 2 (Journal Turning) is identified as the critical machine (M_Z = 2) since working about 113 minutes in a cycle, which is the maximum processing machine in the shopfloor. An identical parallel machine is added at stage 2 and converts it into a critical stage.

Table 3 Possible results of the flexible manufacturing environment.

S.No.	Sequence	Delivery Date		
		Per cycle (minutes)	Continuous Simulation (minutes)	Continuous Simulation (shifts)
1.	1-2-3	199	12450	26
2.	1-3-2	186	10500	22
3.	2-1-3	187	10650	22
4.	2-3-1	204	13200	28
5.	3-1-2	196	12000	25
6.	3-2-1	193	11550	24

In this manufacturing environment, the production is done through simulation software (EXTEND v6) with various possible sequences. The job sequence is continuously engaged without any interval between the cycles. By this, the delivery date is reduced to a greater extent. The delivery date is computed for various possible sequences with continuous engagement is shown in table 3.

The nearer to require delivery date is obtained from the implementation of corollary I. But still, the due date can't be achieved. Among the trails, the job sequence 1-3-2 produced a minimal makespan of 10500 minutes i.e. 22 shifts approximately. For a further decrease in delivery date, the same solution method is introduced in the flexible manufacturing environment. The identical parallel machine is added to other stages along with the critical stage II. This analysis is done for the various possible job sequences and the results are tabulated (Table 4).

Table 4 Delivery Date for further addition of critical machine.

Stages with additional machines	Delivery Date -Continuous Simulation (Minutes)					
	1-2-3	1-3-2	2-3-1	2-1-3	3-1-2	3-2-1
II + III	12450	10500	13200	10650	12000	11550
II + IV	12450	10500	13200	10650	12000	11550
II + V	12450	10500	13200	10200	11400	10950
II + VI	12450	10500	13200	10650	12000	11550
II + VII	12450	10500	13200	10650	12000	11550
II + VIII	12450	10500	13200	10200	11400	10950
II + IX	12450	10500	13200	10650	12000	11550
II + X	12450	10500	13200	10200	11400	10950

From the Table 4, it is noticed that the addition of identical parallel machine with other machines except stage II, doesn't made any valuable change in decreasing delivery date. So it is inferred that the addition of identical parallel machine in multiple stages is not useful in delivery date reduction in this manufacturing environment but it may increase the capital of the manufacturing environment [14].

Corollary II

The implementation of corollary II in manufacturing environment made the possible reduction of delivery date but it raised some demerits. The demerits are queue length, job waiting, idle time, the requirement of skilled labour, reduction in machine life due to continuous engagement and so on. The major demerit is difficulty in distinguishing and collection of same type jobs. The jobs may sequence in 1-2-3 (or) 3-2-1 order, since there is no change in delivery date due to job sequence. But the lot size is 150, makes the difficulty for labour in distinguishing and collection of jobs for packing after completion of each set. If the jobs are manufactured with a single type, it will be easy to collect the same type for the labour. But it will raise the delivery date. Only through the continuous production cycle, the minimizing delivery date objective can be achieved.

To overcome this demerit, the jobs are to be grouped and sequenced [15]. By this grouping of jobs will reduce the queue length, a job waiting, idle time, etc. The possible grouping of jobs are (3,2,1), (3)(2)(1), (3,2)(1), (3)(2,1), and (2)(1,3). Some other possible groupings are left in this case, because the delivery date computed for grouping (a,b)(c) will be equal to (c)(b,a) in the simulation model. The model is generated in the EXTEND software with 3 jobs each of lot 150 is allowed to pass through 10 machines, among that machine 2 is with the identical parallel machine.

Experiment I: As per the present strategy of manufacturing, in this experiment jobs in each group processing group (one group as a batch) by the group. The completion of the batch is the latest finish time of the job in the batch in other words completion time of the last job in the batch. The batch-wise completion time is arrived by simulation and tabulated in Table 5. In this case (manufacturing strategy) work order's completion time or delivery date is the completion of the last job in the last group from the zero starting time. Hence the delivery date computation can be mathematically expressed in equation (2) for a schedule {(1)–(2)–(3)} as,

$$C_j = \sum_{J_1=1}^{150}(C_3)_{J_1} + \sum_{J_2=1}^{150}(C_3)_{J2} + \sum_{J_3=1}^{150}(C_3)_{J3} \tag{2}$$

Table 5 Experiment -1 Batch wise Completion Time and Delivery Date.

S.No.	Batch	Completion Time (minutes)	Completion Time (shifts)
1	(1)	3419	7
2	(2)	3970.5	8
3	(3)	4669	10
Delivery Date		12058.5	25

Experiment -2: In this strategy of manufacturing, two groups (one batch) are taken for processing together then the remaining as a group (batch). In this case batch size is 2 groups or total jobs are 300. The possible groupings (batches) are derived and simulated. The delivery date computation can be mathematically expressed in equation (3) for the possible groups. The batch-wise completion time are tabulated in Table 6.

$$C_j = \max\{\sum_{J_1=1}^{150}(C_3)_{J1}, \sum_{J_2=1}^{150}(C_3)_{J2}\} + \sum_{J_3=1}^{150}(C_3)_{J3} \quad (3)$$

Table 6 Experiment -2 Batch Wise Completion Time and Delivery Date.

S. No	Batch 1	Batch 1 - Completion Time	Batch 2	Batch 2 - Completion Time	Makespan (minutes)	Makespan (shifts)
1	(2 & 1)	5395.5	(3)	4669	10064.5	21
2	(3 & 1)	8424	(2)	3970.5	12394.5	26
3	(3 & 2)	6820.5	(1)	3419	10239.5	21

From the implementation of corollary II, the delivery date is further reduced to 21 shifts and also the difficulty of continuous working is reduced. Now, the due date is achieved by these simple solution methods.

4.8. Evaluation of Proposed Model

As per stated contentions, various manufacturing strategies are derived and simulated. The possible manufacturing environment, schedules and group schedules are identified and their delivery date is computed. The best schedule suggested is based on the objective of minimum delivery date and practically feasible solution. To analyze the effect of various corollary implemented in the manufacturing environment is tabulated in Table 7. This table carries the summary about the delivery date and feasibility of solution in practical cases. The feasibility is determined based on the labour effort requirement and capital.

It is concluded that the corollary I is non-feasible even the delivery date is nearer to the required due date. This is because the production scheduling is practically difficult to work with regular labour force and lag in rest time due to continuous engagement. The corollary II are feasible for practical production schedules, the corollary II is more suitable for minimizing the delivery date and reaches the due date.

Table 7 Effect of Various Corollary Implementations in Manufacturing Environment

Corollary	Sequence	Delivery Date (minutes)	Delivery Date (shifts)	Feasibility
I	1-3-2	10500	22	Not feasible
II	(3), (2 & 1)	10064.5	21	Feasible

4.9. Preventive Measures

The preventive measure is taken to avoid recurrence of similar due date problems and to attain the practically feasible solution. For maintaining the practical feasibility, the corollary II must be adapted but corollary I may be adapted to the requirement. Since, the corollary I may lead to an increase in capital, resource and storage unit.

5. CONCLUSIONS

An Integrated Eight Discipline Approach (IEDA) for time management problem in a real-time production environment of crankshafts is identified with the objective of minimizing the delivery date and effective utilization of resources. A set of solution methods are proposed and it is implemented in the manufacturing environment. The effect of various types of manufacturing environment and time scheduling method are analyzed with simulation models. From this analyze, it is concluded that,

- For practical application, the manufacturing environment is converted into flexible manufacturing environment to achieve the delivery date below due date by dividing the work of critical machine by adding an identical parallel machine.
- The practical demerits also need to be analyzed and a practically feasible solution has to be suggested. In this case, the grouping technique helps in reducing queue length, job waiting, idle time, etc and with the reasonable delivery date.
- The delivery date is achieved below a week time i.e. 21 shifts with practical feasibility. Almost the delivery date is achieved about 1/3 of the standard schedule time.

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