ALTERNATE PROCESS PLANNING AND SCHEDULING OF FMS SYSTEM

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In recent years, due to highly competitive market conditions, it has become necessary for manufacturing systems to have quick response times and high flexibility. Flexible manufacturing systems can produce multiple types of products using various resources. FMS requires the development of efficient and effective methods for integrated production planning and control.

We have done computational experiments of individual production of each parts and mix production of all parts (x, y, and z) according to their multiple process plans such as BPP, SBPP, TBPP and FBPP and found values of parameters such as average flow time in the system, average resource utilization and blockage and while comparing these parameters values in both productions we have found increment in the average flow time (up-to 60%), blockage (up-to 34%) and average resource utilization (up-to 12%) and these parameters will decide the increment and decrement of make-span or total production time. These parameters will decide which production (mixed or individual) is best for current system production.

I. INTRODUCTION

Process planning and scheduling are two of the most important sub-systems in manufacturing systems. A process plan specifies what raw materials or components are needed to produce a product, and what processes and operations are necessary to transform those raw materials into the final product. The outcome of process planning is the information required for manufacturing processes, including the identification of the machines, tools, and fixtures. Typically, most jobs may have a large number of alternative process plans. Process planning is the bridge of the product design and manufacturing. Scheduling plans receive process plans as their input and their task is to schedule the operations on the machines while satisfying the precedence relations given in the process plans. It is the link of the two production steps which are the preparing processes and putting them into action [1]. Although there is a strong relationship between process planning and scheduling, the integration of them is still a challenge in both research and applications. In traditional approach, process planning and scheduling were carried out sequentially, where scheduling was done separately after the process plan had been generated. This approach has become an obstacle to enhance the productivity and responsiveness of manufacturing systems, and it may cause the following problems [2,3]:

[1] In a manufacturing organization, process planning function works in static. It considers the resources on the shop floor in an ideal way. Process planners assume unlimited resources on the shop floor and plan for the most recommended alternative process [4]. This may lead to the process planners favoring to select the desirable machines repeatedly. Therefore, the generated process plans are somewhat unrealistic and cannot be readily executed on the shop floor [5]. Accordingly, the resulting optimum process plans often be-come infeasible when they are carried out in practice at the latter stage.

[2] Even if, in the planning phase, process planners consider the current resources on the shop floor, the constraints considered in the process planning phase may have already changed greatly because of the time delay between planning phase and execution phase. This may lead to the optimized process plan infeasibility. Investigations have shown that 20–30% of the total production plans in a given period have to be modified to adapt to the dynamic changing of a production environment [3].

[3] Scheduling plans are often determined after process plans. In the scheduling phase, scheduling planners have to consider the determined process plans. Fixed process plans may drive scheduling plans to end up with severely unbalanced resource load and create superfluous bottlenecks.

In most cases, both for process planning and scheduling, a single criterion optimization technique is used for determining the best solution. However, the real production environment is best represented by considering more than one criterion simultaneously [3]. Furthermore, the process planning and scheduling may have conflicting objectives. Process planning
emphasizes the technological requirements of a task, while scheduling involves the timing aspects of it. If there is no appropriate coordination, it may create conflicting problems. To overcome these problems, there is thus a major need for an integrated process planning and scheduling system. The integration of the two functions may introduce significant improvements to the efficiency of the manufacturing facilities through elimination or reduction in scheduling conflicts, reduction of flow-time and work-in-process, improvement of production resources utilization and adaptation to irregular shop floor disturbances [5]. Without the integration of process planning and scheduling (IPPS), a true computer integrated manufacturing system (CIMS), which strives to integrate the various phases of manufacturing in a single comprehensive system, may not be effectively realized.

II. LITERATURE SURVAY

Maccarthy and Liu [6] introduced approach to the definition and classification of flexible manufacturing systems. The approach emphasizes the number and characteristics of the material handling devices as well as the configuration of the processing elements. Liu and Maccarthy proposed a classification scheme for FMS scheduling problems based on the analysis and discussion of the scheduling decisions in FMS and the factors related to these decisions. They provided a systematic framework for description and analysis of FMS scheduling problems and for development, evaluation and comparison of FMS scheduling approach. Fischer [6] presented a framework for the design of the planning and controlling components in a flexible manufacturing system. Chen and Chung [1996] addressed the importance of examining the FMS planning problem in conjunction with the scheduling scheme. They formulated makespan minimization as the objective of the integrated planning model. They designed model to calculate job makespan in each batch so that the sum of the makespan of each batch and the tool changeover times between batches can be minimized. Dessouky, Moray and Kijowski presented a conceptual framework and task taxonomy that permit human factors researchers to make use of the extensive and sophisticated methods that exist in scheduling theory for the study of strategic behavior.

A. Strategic roles of part loading and scheduling in FMS:

Sarin and Chen [7] discussed the machine loading and tool allocation problem of an FMS. They developed mathematical model to determine part routings through the machines and to allocate appropriate cutting tools to each machine to achieve minimum machining cost. They assumed that a new tool is assigned each time a batch is assigned to a machine even though that tool has already been loaded on that machine, this increase the number of tools assigned to a machine which reduces the machine capability.

An optimal selection and operation allocation to minimize the processing and setup costs. considered part allocation, part loading, and tool loading problems under tool movement policy. They suggested three heuristic approaches to minimize the total tardiness form a given set of parts. H. Co and J. Zhu [8] developed the expression for the optimal run length and delivery frequency of each part family, assuming that the sequence of production of the part-families has been determined. They examined two control strategies of processing the part types within each part family. They showed that loading the part types in the family simultaneously results in a lower annual cost, however, when loading the part types sequentially. The FMS is dedicated to processing one part types at a time in cyclic order. Date based approach to part type selection in FMS. Blazewicz and Finke (1994) studied scheduling with resource management.

ZavaneTella et al.(1992) illustrated an analytical procedure based on the markov chain theory, able to forecast the composition of buffers, a few combinatorial optimization models, which explicitly reflect some of the characteristic features of flexible manufacturing systems. Mukhopadhyay and Maitii (1991) presented heuristic approach to determine an optimal schedule of part integrating the scheduling criteria. Li et al. [8] applied neural network learning techniques and a decisions tree methods to obtain scheduling for flexible manufacturing systems.

 Characteristics of setup activities and discussed models for sequencing setup activities. They presented two linear programming models for scheduling setup activities. The models minimized the set up time and make a tradeoff between the time and cost of set up activities with limited machining resources and budget. Bard and Feo [1989] studied the problem of minimizing the total set up, tool replacement and machining times for individual batches subject to tool magazine and metal volume removal constraints. This approach requires that all feasible tool paths be generated manually before being considered by the optimum algorithm.

Mittal and Lewis [10] presented a mixed integer programming formulation to minimize the sum of the machining time, the tool change times, and the tool travel times. They used a special set of constraints to handle tool life economics and tool changes due to accumulated wear. Their model considered various tooling aspects, but it did not include the option of loading duplicate tools in the magazine. Walas and Askin [1984] addressed the problem of sequencing operations within part programs and assigning tools to slots for punch press to minimize the part cycle time, including both table move times and tool change times.
investigated machine grouping and loading decisions under several different loading objectives, including balancing machine processing times, maximizing the number of consecutive operations on a machine, balancing the workload per machine for a system containing groups of pooled machines of equal sizes, and unbalancing the workload per machine for a system containing groups of pooled machines of equal sizes. The major problem constraints are tooling requirements and tool magazine capacities. Gyampah et al. [11] compared four tool allocation and scheduling procedures for a flexible manufacturing system [bulk exchange, tool migration, resident tooling, and tool sharing] in the presence of three part scheduling rules [largest number of tools, smallest number of tools, and earliest due date] through simulation study of five machine FMS with an automated tool handling system. They reported the comparison between these methods using the mean flow time, mean tardiness, percent of job tardy, and machine utilization. Tetzlaff [12] presented analytical model, considers the influence of specific design variables like tool transportation time and the number of transportation vehicles for tools. He showed analytical methods for performance evaluation by incorporating the performance of the tool management system in the evaluation procedure.

III. FRAMEWORK FOR INTEGRATED PROCESS PLANNING AND SCHEDULING SYSTEM

Figure 1 is a graphical representation of the integrated production scheduling system envisioned in this study. The system is composed of two basic modules: process plans selection module (PPSM) and scheduling module (SM). Interfacing the PPSM is the production order details, i.e., number of part types, production quantity of each part type, MPP for each part type and number of pallets available. Another source of information needed for integration is the shop status information. The shop status database provides information on the status of machines and other resources (material handling systems) as well as the parts currently on shop floor. This information includes in-process parts currently assigned to each machine, workload on each machine and the functional status (i.e., up or down) of each machine. This information is necessary for selecting the right process plan [13].

A. Process plans selection module

After a production order is received, PPSM is invoked to rank the available MPP for each part type using minimum total production time (sum of total machining time and total transportation time) as the criterion. Total production time is taken as a criterion, as the literature review suggests that the optimal process plan which might have the shortest processing time or the least number of operations may not guarantee the best system performance [14]. Also, in a FMS, shop time of each part is composed of machining time, transportation time, and waiting time in the input and output queues of machines. While waiting times in the input and output queues are influenced by scheduling of parts, the other two categories of shop time, i.e., machining time and transportation time are influenced by the process plans selected for producing the parts. During ranking, if a tie occurs between two process plans, then one of them is selected randomly. From the ranked process plans, best four process plans for each part type are selected and arranged in decreasing order of their priority and stored in the ‘selected process plans’ database for further use. These four process plans are named as the best process plan (BPP), second best process plan (SBPP), third best process plan (TBPP), and fourth best process plan (FBPP), respectively. PPSM selects the best four process plans for each part type of the production order and these best four process plans for each part type will remain available during scheduling. Availability of MPP for each part type ensures that, as far as possible, a feasible alternative is available to take care of workshop disturbances such as non-availability of machine tool. Number of MPP available for each part type are restricted to four as by allowing availability of a large number of MPP per part type may create chaos on the shop floor. Also, literature review suggests that only limited amount of flexibility should be present in the process plans [15]. However, the number and type of process plans selected for each part type may vary depending on the level of flexibility desired.

B. Scheduling module

![Fig 1 Integration methodology for Process Planning and Scheduling](image)
This module is invoked after the execution of PPSM. Initially, from the ‘selected process plans’ database, the best process plan for each part type is passed to SM. Once a process plan for each part type and the current shop floor status is available, scheduling is carried out by following the event-driven simulation approach. Current shop floor status is the backbone of the scheduling module. This module receives the current status of various resources such as machines, robots, input and output buffers, and parts. During scheduling, part selection may be performed using a dispatching rule such as shortest processing time (SPT) and initially, machine selection for the selected part is performed according to the currently followed process plan. However, it may happen that the next destination machine according to the currently followed process plan for the selected part may not be available due to non-availability of space in the input buffer of the machine. In such situation, the scheduler searches the ‘selected process plans’ database again to identify the next suitable process plan for the selected part depending on the current processing stage of the part and already followed route. It is important to mention that at this stage of the proposed approach, the integration between process planning and scheduling occurs, in order to achieve a realistic production schedule. In general, by allowing MPP for each part type to be available on the shop floor, a scheduler can react fast to unforeseen workshop disturbances such as non-availability of a machine tool. The scheduler is capable enough to select an alternative path, if possible, at any time and at any processing stage of a part to overcome the disturbances occurring on the shop floor. As MPP are allowed, it may happen; that various parts of the same part type may follow different process plans owing to shop floor disturbances at different stages of their completion. The final outcome will be a process plan that a part will follow in the shop[15].

Table 3.1 Parameters and their range considered in the present work

<table>
<thead>
<tr>
<th>S. No</th>
<th>Parameter</th>
<th>Range/value employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Production quantity of each part type in a production order</td>
<td>20–50</td>
</tr>
<tr>
<td>2.</td>
<td>Number of part types in a production order</td>
<td>3</td>
</tr>
<tr>
<td>3.</td>
<td>Number of operations per job</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Operation time</td>
<td>20–100 units</td>
</tr>
<tr>
<td>5.</td>
<td>Number of pallets released</td>
<td>16</td>
</tr>
<tr>
<td>6.</td>
<td>Dispatching rule</td>
<td>Shortest processing time</td>
</tr>
</tbody>
</table>

IV. IMPLEMENTATION OF PROPOSED SCHEME OF INTEGRATION

An example FMS consisting of four CNC machines (M1, M2, M3, M4, M5andM6), each with common input and output buffer of capacity infinite is considered for implementation of the proposed integration scheme [23]. A giant robot R-2 is available to serve all four machines. There is a load and unload (L/UL) station of infinite capacity to load/unload the parts on/from the pallets. The system input (B-IN) and output buffer (B-OUT) have a capacity infinite. There is another robot R-1 in the system, which operates between L/UL station and B-IN/B-OUT for part transfer.

The part flow into the FMS is as follows: A piece of raw material is first loaded onto a pallet at load station by manual operation. The palletized part is then transported to B-IN by R-1. R-2 then moves parts from B-IN to various machines according to their process plans. When MPP are available, a part can switch over to an alternate process plan to overcome the non-availability of machine due to limited buffer space. The sequence of part flow at a machine is: machine input buffer ’! machine table ’! machine output buffer. When all the machining operations on a part are completed, R-2 transports it back to B-OUT. R-1 again transports finished parts from B-OUT to unload station, where part is unloaded from the pallet manually. This empty pallet is again loaded with raw part of same part type, if available, and sent into the system.

Table 4.1 Multiple Process Plan For the All the Parts

<table>
<thead>
<tr>
<th>Part name</th>
<th>No of parts</th>
<th>Process plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part X</td>
<td>24</td>
<td>1(30)3(60)4(75)2(78)6(80)1(70)2(70)4(45)5(80)6(78)3(55)2(87)4(70)2(50)1(84)4(73)2(80)5(68)3(90)5(65)6(78)3(73)1(55)4(70)5(82)4(45)3(70)2(78)4(75)3(84)6(65)1(75)2(90)1(60)3(55)6(87)4(70)6(45)5(80)3(85)1(73)2(87)2(70)3(60)6(78)5(72)6(80)4(75)</td>
</tr>
<tr>
<td>Part Y</td>
<td>28</td>
<td>1(45)2(55)4(70)3(84)6(62)5(90)3(35)6(80)2(74)1(54)4(85)3(88)2(60)4(74)5(83)1(54)3(65)2(87)5(73)6(62)2(74)4(58)3(65)5(90)4(60)5(70)1(80)2(90)6(72)1(57)6(55)5(70)3(85)4(75)1(93)6(54)3(35)1(74)3(85)5(64)2(83)4(92)5(70)4(74)3(85)2(90)1(93)6(54)</td>
</tr>
<tr>
<td>Part Z</td>
<td>25</td>
<td>6(25)2(62)1(70)4(85)6(75)5(85)4(53)3(70)2(85)3(61)2(53)1(87)1(56)4(70)5(62)2(85)5(65)4(78)3(46)6(80)4(70)2(85)1(68)4(78)2(60)1(72)6(81)1(77)3(88)6(50)5(72)2(62)3(64)6(84)4(70)2(78)2(60)6(80)2(85)4(85)3(88)5(85)</td>
</tr>
</tbody>
</table>

V. RESULTS

Table 5.1 Analysis of FMS for Part X
Integration process planning and scheduling has been recognized as playing an important role to form of integrated manufacturing. In the traditional approach process planning and scheduling were regarded as two separate tasks and performed sequentially. Integration of process planning and scheduling should be implemented because the selection of optimal process plans for each part has a vital impact on the performance of the manufacturing systems. Therefore the research on the integration of process planning and scheduling is necessary. In the present work, we have done Integration of process planning and scheduling and made the multiple process plans for each part on the basis of shortest process time and old priority rules and analyze different parameter of FMS system.

VI. CONCLUSION

To proceed with a more elaborate analysis of the performance of the proposed methodology, we present the results of simulation experiments to show the impact of the selection of the process plan combination on the scheduling performance.

Tables 5.1, 5.2 and 5.3 present the experimental variables such as Average time in system, Average resource utilization and blockage of each part on the basis of selected process plans such as (BPP, SBPP, TBPP, FBPP).

Experiments are carried out for each combination of levels. The performance was measured based on Shortest processing time (SPT) and Old priority rule of scheduling.

In the presents work we compare the four process plans of each part and we found that on the basis of above tables the makespan can be reduce by using the correct combination of process plan or the sequence of processing time. We also found that in present work for best results some parameters are most important like selection alternate of process plans, dispatching rules, size of batch and sequencing of processing time.

REFERENCES


