CHAPTER 4

4.0 STABILISED SEQUENCE PLANNING SYSTEM

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4.1 INTRODUCTION

Managers of batch manufacturing industries often complain of fluctuating manufacturing lead times for different batches, many bottlenecks in manufacturing, high WIP, difficulty in tracking the progress of orders and inaccuracies in forecasts. Priorities assigned to the various components of different batches change dynamically when the work is being processed. This necessitates such work being processed to be kept aside before it is completed to meet the changes in priorities. It increases queue-lengths, quick piling-up of WIP, frequent bottlenecks and hampers space utilisation and introduces fluctuations in the times of completion of different products. High manufacturing lead times imply that the forecasts have to be made to a more distant point in the future.

4.2 MATERIALS MANAGEMENT

The earliest attempts to counter these problems referred above in section 4.1 were based on simply monitoring the inventories of the finished products. As competition and interest rates increased, Materials Requirements Planning (MRP I) and Manufacturing Resource Planning (MRP II) systems emerged. Though the operations in shop floor are streamlined to a great extent, WIP problem still remains unsolved in batch manufacturing industries.

4.3 NEW APPROACHES FOR WIP REDUCTION

To solve this problem of high WIP in shop floor, a number of methods has been proposed and applied, notable among them are Just-In-Time (JIT) Group Technology (GT). The JIT technique applied to manufacturing systems greatly reduces WIP. But it demands effective co-ordination among various external factors apart from harmonious interaction between all internal factors. At present a few automobile industries are using JIT technique. But any attempt to integrate the supply of raw material to the industry and finished goods to the market into JIT system will prove futile.
since one of the key requirements for successful implementation of JIT is the guarantee of undisturbed supply unaffected by the external factors like transportation problems or internal factors like machine breakdown, operator absenteeism etc. If the complete manufacturing system is not designed to counteract such eventualities, it would lead to losses, as a result of flow imbalance [29]. Another approach to reduce WIP build-up is GT which leads to integration of handling system and workcells. Good amount of research is going on in this field to exploit benefits of both process layout (flexibility) and flow layout (efficiency) using cell formation.

There is one more option to tackle the problem of WIP, i.e., Sequence Planning as this system does not involve effective co-ordination and harmonious integration of external factors, high capital, any new handling system etc. The simple and logical strategy of loading in sequence planning ensures that it can be a best approach to reduce manufacturing lead times with low WIP ratio. A new Sequence Planning System, designed to monitor WIP and stabilise manufacturing lead times is discussed here. The details of the computer software developed for this sequence planning are also explained.

4.4 LOADING STRATEGY

The loading strategy followed in this system is that it will not load an order unless all workstations, materials and other necessary resources are available for processing the complete order. Hence SSPS is an order-oriented system as against the conventional operations-oriented system. Three finishing times are mainly used in this algorithm, namely,

1. Earliest Finish Time (EFT) = Start time + Processing time.
2. Latest Finish Time (LFT) = EFT + Queue length.*
3. Average Finish Time (AFT) = (LFT + EFT) / 2.

* Queue length here is the maximum permissible waiting time for a component.
4.5 MATHEMATICAL MODEL

\[
MLT = \sum_{i=1}^{m} (T_{si} + Q \cdot T_{ei} + T_{neo}) \\
BT = T_s + \frac{Q/(1-q)}{T_o} \\
T_p = \frac{BT}{Q} \\
R_p = \frac{1}{T_p} \\
C = m \cdot S \cdot H \cdot R_p \\
U = \frac{O}{C} \\
WIP = \left(\frac{C \cdot U}{S \cdot H}\right) \cdot MLT \\
WIPR = \frac{WIP}{m} \\
TIPR = \frac{MLT}{\sum_{i=1}^{m} T_o} \\
\]

Where

- **MLT**: Manufacturing lead time.
- **m**: Number of machines engaged in production.
- **T_{si}**: Set up time of \(i^{th}\) machine.
- **Q**: (Average) Batch quantity.
- **T_{o}**: Operation time of \(i^{th}\) machine.
- **T_{neo}**: Non productive time associated with \(i^{th}\) machine.
- **BT**: Batch time / machine.
- **q**: Scrap rate.
- **T_p**: Average production rate per unit of product for given machine.
- **R_p**: Average production rate for machine.
4.6 SCHEDULING PROCEDURE

The scheduling procedure is depicted in Fig. 4.1. If a workstation K has to be loaded now, its status is checked. If it is preoccupied with another component, the present one will be loaded at a later time. The interval between current time and next loading attempt is defined as 'block time'. Shorter block time implies more computation and larger block time may miss the free capacity available between blocks. Hence the selection of block time directly affects the search efficiency. So, an event-based approach will be followed to select the block time. According to this, the next look-up point will be the beginning of first free capacity in the next block. The search will go on until the free capacity available on workstation K is sufficient to complete the operation on component. If the component has to be processed by the subsequent workstation L, the same procedure will be followed except that the search commences from average finish time on previous workstation. Mathematically, this could be expressed as

Start time on i\textsuperscript{th} workstation = Average Finish Time on (i-1)\textsuperscript{th} workstation.

The basic principle could be extended for a production system of 'n' work centers. If a component requiring processing on each of the 'n' work
centers could be completed within the overall latest finish time for that entire component, then the complete processing will be carried out. Otherwise a report is generated giving possible completion time and tardiness, to enable the user to decide upon making alternate arrangements.

4.6.1 Assumptions

1. For every operation, the set-up time is included in the processing time.

2. Processing times are independent of the schedule. This implies two things in particular, firstly, each setup time is sequence independent, that is, the time taken to adjust machine for a component is independent of the component last processed. Secondly, the times to move components between machines are negligible.

Fig. 4.1 SSPS LOADING STRATEGY
3 In-process inventory is allowed, that is, components may wait for their next machine to be free.

4 Machines may be idle

5 Technological constraints are known in advance and are immutable.

4.7 SOFTWARE FEATURES

This software adopts a very simple and logical loading strategy and aims at stabilising manufacturing lead times by keeping a control over WIP. Hence its name - STABILISED SEQUENCE PLANNING SYSTEM (SSPS). As the development continued, it is also referred to, by the name THROUGHPUT ORIENTED PLANNING SYSTEM (TOPS) nowadays. SSPS/TOPS is a throughput oriented and order-based system, where in stabilised sequence plan is evolved using a simple and logical loading strategy. SSPS is designed to take into account, the variability of real life situations and to monitor WIP and also to stabilise production. This is a computerised finite capacity system, specially designed for multistage manufacturing with built-in provision to handle variability in real life manufacturing environment. It is validated by applying to an industry manufacturing pumps.

4.8 SOFTWARE DETAILS

The software for SSPS is developed in 'Turbo C' on an IBM/PC compatible system. The package is menu-driven, main menu consisting of options: INPUT, SAVE, RUN, OUTPUT and EXIT. The option INPUT has two suboptions: KEYBOARD INPUT and FILE INPUT i.e., the user has two choices to input data,
1 In first choice, one can input data in an interactive manner through keyboard, and

2 In the second choice, if minor changes to be incorporated in the data one can retrieve old file and edit it if necessary, again in an interactive manner.

If the option SAVE is selected, it asks the user for a filename in which the data just entered has to be saved. This data may be used for future reference. If the user wants to use this system in another case and if that data is very much similar to that just entered, one can retrieve this file and make modifications as required. The option RUN executes the software and computes the optimum sequence of operation and other details. The option OUTPUT has two suboptions: OPTIMUM SEQUENCE and REPORT. The option OPTIMUM SEQUENCE displays the computed stabilised sequence according to SSPS strategy. If a particular order cannot be loaded, it diverts the user to second option. There it gives the possible completion time of schedule, the tardiness etc., to enable the user to decide upon making alternate arrangements like using other resources and/or increasing number of shifts etc. If the second option is selected, it gives report on machine utilisation, average level of WIP etc. The option EXIT helps to come out of the system and returns to DOS prompt. Figure 4.2 shows the flow chart for SSPS.

4.8.1 DATA INPUT

Generally user will be able to feed input data from the 'works order'. Interactive questions in input module look as follows:
Fig. 4.2 FLOW CHART FOR SSPS
*** CUSTOMER ORDER DETAILS ***

Product ?
Order Number ?
Quantity ?
Number of working days within due date ?
Number of shifts per day ?
Number of hours per shift ?

(The data will be periodically echoed back to user to see if any mistakes were typed. If necessary, the system asks the user to feed the data again. Here, there is one user-friendly option provided - If the user wants to retain old values, one need to press ENTER or RETURN key, thus reducing many keystrokes.)

*** PROCESSING DETAILS ***

Number of components ?

Component 1 :
Name of Component ?
Number of operations for component 1 ?

Operation 1:

Name of machine ?
* Processing Distribution ?
4 Options are provided - 3 distributions and a deterministic case. The three distributions provided are - normal, exponential and uniform. Depending upon user's choice, the user has to feed relevant parameters like mean, standard deviation, etc., according to the distribution selected. Again here, if the user decides that there is no considerable variation in processing time and that particular data is accurate, one can choose the fourth option - deterministic case and proceed. If the operation is being performed newly and if past data is not available to decide on the processing distribution then also the user can choose the fourth option. The process is repeated for all the operations.)

*** RESOURCE DETAILS ***

Number of machines of type 1 present ?
Number of machines of type 2 present ?
Number of machines of type 3 present ?

Generally user types-in his response at '?' prompt. One should not find any difficulty with this interactive and user-friendly software. Illustration shows typical menu appearing when user wants to input the data.

4.9 SOFTWARE VALIDATION

The developed software has been applied to a medium engineering industry manufacturing pump products. The components selected for this study are as follows: casing, impeller, shaft, bearing bed pedestal and tight/loose pulley. The process sequence were collected as per the shop floor data available. Table.4.1. shows the stabilised sequence of operation according to SSPS strategy.
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>OPERATION No.</th>
<th>MACHINE</th>
<th>TIME (minutes)</th>
<th>EVENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestal</td>
<td>1</td>
<td>DRILLING</td>
<td>00.00</td>
<td>05.23</td>
</tr>
<tr>
<td>Casing</td>
<td>1</td>
<td>C-LATHE</td>
<td>10.00</td>
<td>15.61</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>FP-LATHE</td>
<td>15.61</td>
<td>14.63</td>
</tr>
<tr>
<td>Shaft</td>
<td>1</td>
<td>C-LATHE2</td>
<td>00.00</td>
<td>04.11</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>COPY</td>
<td>17.71</td>
<td>04.11</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>C-LATHE2</td>
<td>17.71</td>
<td>08.41</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>C-LATHE1</td>
<td>17.71</td>
<td>17.71</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>KW MILL</td>
<td>17.71</td>
<td>22.18</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>CY GRIND</td>
<td>17.71</td>
<td>25.19</td>
</tr>
<tr>
<td>Impeller</td>
<td>1</td>
<td>C-LATHE2</td>
<td>23.16</td>
<td>40.87</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C-LATHE1</td>
<td>40.87</td>
<td>52.50</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>C-LATHE1</td>
<td>52.50</td>
<td>52.50</td>
</tr>
<tr>
<td>T/L Pully</td>
<td>1</td>
<td>C-LATHE2</td>
<td>43.01</td>
<td>83.89</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C-LATHE1</td>
<td>12.29</td>
<td>96.18</td>
</tr>
<tr>
<td>Bearing Bed</td>
<td>1</td>
<td>FIXTURE 'D'</td>
<td>0.00</td>
<td>50.89</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>FIXTURE 'D'</td>
<td>50.89</td>
<td>13.83</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>KIRLOSKAR</td>
<td>50.89</td>
<td>71.91</td>
</tr>
</tbody>
</table>
4.10 RESULTS AND ANALYSIS

Table 4.2. Report Generation

<table>
<thead>
<tr>
<th></th>
<th>Completion time of batch</th>
<th>Manufacturing lead time</th>
<th>Batch time</th>
<th>Average production rate of product</th>
<th>Average production rate of machines</th>
<th>Average WIP</th>
<th>WIP ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= 69 days</td>
<td>= 544.771 hrs per batch</td>
<td>= 546.959 hrs</td>
<td>= 5.470 hrs/unit</td>
<td>= 0.183 units/day</td>
<td>= 12.450 units</td>
<td>= 1.383:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine</th>
<th>Time (minutes)</th>
<th>Capacity Utilisation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C LATHE (1)</td>
<td>44.373</td>
<td>51.805 46.11</td>
</tr>
<tr>
<td>C LATHE (2)</td>
<td>79.584</td>
<td>16.593 82.70</td>
</tr>
<tr>
<td>F P LATHE (1)</td>
<td>14.626</td>
<td>81.552 15.20</td>
</tr>
<tr>
<td>COPY ATTACH. LH. LATHE (1)</td>
<td>04.302</td>
<td>91.875 04.50</td>
</tr>
<tr>
<td>K W MILL (1)</td>
<td>03.012</td>
<td>93.166 03.10</td>
</tr>
<tr>
<td>CYLINDRICAL GRINDING MACHINE (1)</td>
<td>07.166</td>
<td>89.012 07.50</td>
</tr>
<tr>
<td>FIXTURED LATHE (1)</td>
<td>64.718</td>
<td>31.459 67.30</td>
</tr>
<tr>
<td>KIRLOSKAR LATHE (1)</td>
<td>07.719</td>
<td>88.981 07.50</td>
</tr>
<tr>
<td>DRILLING MACHINE (1)</td>
<td>05.235</td>
<td>90.943 05.40</td>
</tr>
</tbody>
</table>
The above table shows a WIP ratio of 1.383:1 when comparing to the 15:1 to 20:1 in common batch production industries. The main reason for this low ratio is that only one order is considered for study, in isolation which implies that the machines are assumed to work on this order and be idle for remaining time. The machines are waiting for components and hence there is a minimum waiting time for the components. So this leads to low utilisation of machines as explained below. Drilling machine which is used in an operation for first 5.23 minutes is kept idle for remaining 90.94 minutes with machine utilisation at 5.4%. But it is important to note immediately after first 5.23 minutes, the machine is free to be released for other components. The report reveals another feature of SSPS that is, the software is capable of executing an order with minimum number of machines.

4.11 CONCLUSION

This new Stabilised Sequence Planning System is a powerful tool to monitor the work-in-process inventory level in shop floor. The manufacturing lead time is stabilised to meet the delivery schedule. This user interactive software helps to measure the piled-up WIP in the shop floor. The algorithm developed for this analysis, helps to measure the capacity utilisation of workcenters. The processing pattern r is fitted to standard statistical distributions for smoothening activities. The percentage reduction of non-productive time, increase in resource usefulness and reduction of manufacturing lead time are predicted for the manufacturing system.