A modeling technique for loading and scheduling problems in FMS

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2. Literature survey
3. Issues in FMS
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1. Introduction

❖ Background

➢ FMS
  ✓ An FMS can be defined as a computer-controlled configuration of
    • semi-dependent workstations
    • material-handling systems designed

➢ Goal of FMS
  ✓ Flexibility of low volume production
  ✓ Efficiency of high volume mass production

➢ Operational policies in FMS:
  ✓ Tool movement policy
  ✓ Part movement policy

❖ Preview

➢ A modeling technique for loading and scheduling problems in FMS
➢ Objective with minimizing
  ✓ maximum completion time, material handling time, total processing time
## 2. Literature Survey

### Literatures – Loading & Scheduling problem

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarin and Chen</td>
<td>1987</td>
<td>Machine loading and tool allocation problem of an FMS</td>
</tr>
<tr>
<td>Amorko-gyamph et al.</td>
<td>1992</td>
<td>Compared four tool allocation and scheduling procedures for a FMS</td>
</tr>
</tbody>
</table>
3. Issues in FMS

❖ Decisions in FMS

➢ Loading in FMS
  ✓ Assignment of operations and tools to each machine

➢ Routing decisions in FMS
  ✓ Decisions of the route and sequence of each part

➢ Scheduling problems in FMS
  ✓ Decisions of sequence on each machine

➢ System utilization
  ✓ \((\text{Working time}) / (\text{total time})\)

➢ Setup time
  ✓ Minimizing the setup times

➢ Tool management in FMS
4. Proposed model

**Problem description**

- **Problem**
  - Loading and scheduling problems in FMS

- **Objective**
  - Minimizing the sum of
    - maximum completion time
    - material handling time
    - total processing time

- **Decision variables**
  - Tool allocation, operation allocation and operation schedule

- **Constraints**
  - Tool magazine capacity, Tool life and Setup cost

- **Assumptions**
  - The machines are not identical
  - The distance between machines are equal
  - No breakdowns for machines or material handing systems
  - There is limited number of each tool type
  - All tools are new at the initial stage
  - Each tool and each operation are assigned only to one machine
  - The setup costs differ according to the size and shape of the parts
4. Proposed model

**Notations**

>- **Indices**
  - $I$ Machine $I = 1, 2, \ldots, m$
  - $J$ Part $J = 1, 2, \ldots, n$
  - $R(J)$ Operation $R(J) = 1, 2, \ldots, q(J)$
  - $L$ Tool $L = 1, 2, \ldots, w$
  - $A$ Machine stage $A = 1, 2, \ldots, z$
  - $S$ Maximum completion time
  - $T_L$ Tool life for type $L$ tool
  - $P_{R(J), J, L, I}$ Processing time for operation $R(J)$ of part $J$ using tool $L$ on machine $I$
  - $C_{R(J), J, L, I}$ Cost of operation $R(J)$ of part $J$ using tool $L$ on machine $I$
  - $C$ Total target cost for the processing
  - $X_J$ Number of movements of part $J$ between machines
  - $C_J$ Setup cost for part $J$
  - $D_J$ Due date of part $J$
  - $C_{SETUP}$ Limit on setup cost
  - $S_I$ Tool magazine capacity of machine $I$

>- **Decision variables**
  - $X_{L,I}$ = 1 if tool $L$ is assigned to machine $I$; 0 otherwise
  - $Y_{R(J), J, L, I, A}$ = 1 if operation $R(J)$ of part $J$ is assigned to machine $I$ containing tool $L$ in stage $A$; 0 otherwise
4. Proposed model

- Integrated planning model (Loading problem)

  - Objective function

    \[
    \text{Min } T = S + \sum_{j=1}^{n} X_j + \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} P_{R(j),J,L,I} \cdot Y_{R(j),J,L,I,A}.
    \]

  - Constraints

    \[
    \begin{align*}
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} Y_{R(j),L,I,A} &= 1, & \forall R(j), I. & \text{Tool assignment and available machine} \\
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} P_{R(j),J,L,I} \cdot Y_{R(j),J,L,I,A} & \leq TL, & \forall L. & \text{Tool life} \\
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} P_{R(j),J,L,I} \cdot Y_{R(j),J,L,I,A} & \leq S, & \forall I. & \text{Processing time} \\
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} P_{R(j),J,L,I} \cdot Y_{R(j),J,L,I,A} & \leq DJ, & \forall J. & \text{Due date} \\
    A(Y_{R(j)} + 1, J, L, I, A) - Y_{R(j),J,L,I,A} & \geq 0, & \forall R(j), J, L, I. & \text{Precedence relationship} \\
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} Y_{R(j),J,L,I,A} & \leq 1, & \forall A, J. & \text{Operation assignment} \\
    \sum_{L=1}^{w} X_{L,J} & \leq 1, & \forall I. & \text{Tool assignment} \\
    \sum_{L=1}^{w} X_{L,J} & \leq S_I, & \forall I. & \text{Tool magazine capacity} \\
    \sum_{A=1}^{m} \sum_{I=1}^{n} \sum_{L=1}^{w} \sum_{R(j)=1}^{q(j)} C_{R(j),J,L,I} \cdot Y_{R(j),J,L,I,A} & \leq C, & \forall R(j), I. & \text{Target cost} \\
    X_{J} = \sum_{I=1}^{m} \left| Y_{R(j),J,L,I,A} - Y_{R(j)+1, J, L, I, A} \right| / 2, & \forall R(j), J, L, A & \text{Part movements} \\
    \sum_{j=1}^{n} X_j \cdot C_j C_{\text{SETUP}}. & \forall R(j), J, L, A & \text{Setup cost}
    \end{align*}
    \]

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4. Proposed model

❖ Heuristic method for detailed parts scheduling

➢ Scheduling the operations on machines to minimize the completion time
  (Dispatching with minimum start time → FIFO)

✓ Step 0: Obtain the results of assignment of operations and tool from the IP model.

✓ Step 1: Start with the first operation on each part, and with first stage for each machine.
  \( R(J) = 1, A = 1. \)

✓ Step 2: \( EF_R(J) = ES_R(J)_{M,A} + P_R(J)_{M} \) (the completion time of operation \( R(J) \)).
  Increase \( R(J) \) and \( A \) by one. \( R(J) = R(J) + 1, A = A + 1. \)

✓ Step 3: Check the machine availability for the operation \( R(J) \);
  The start time of operation \( R(J) \) as: \( ES_{R(J)}_{M,A} = \max (EF_{R(J)−1}, EF_{M,K−1}) \)

✓ Step 4: Check if all operations are scheduled; calculate the completion time and stop, otherwise, go to step 2.
5. Illustrates examples and analysis of results

- **Example 1**
  - 4 parts with 4 operation
  - 4 machines with 40 tool slots/20 types of tool

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**Assignment of tools and operations to machines and the utilization of machines**

<table>
<thead>
<tr>
<th>Machines</th>
<th>Operations assigned</th>
<th>Tools assigned</th>
<th>Processing time</th>
<th>Completion time</th>
<th>Processing cost</th>
<th>Setup cost</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>11, 12, 22, 14</td>
<td>1, 7, 10, 16</td>
<td>281</td>
<td>374</td>
<td>1130</td>
<td>160</td>
<td>0.70</td>
</tr>
<tr>
<td>M2</td>
<td>21, 42, 33, 34, 44</td>
<td>3, 5, 14, 19, 20</td>
<td>346</td>
<td>384</td>
<td>1140</td>
<td>360</td>
<td>0.86</td>
</tr>
<tr>
<td>M3</td>
<td>41, 13, 23, 24</td>
<td>2, 6, 12, 17</td>
<td>280</td>
<td>403</td>
<td>1380</td>
<td>160</td>
<td>0.69</td>
</tr>
<tr>
<td>M4</td>
<td>31, 32, 43</td>
<td>13, 15, 18</td>
<td>294</td>
<td>294</td>
<td>890</td>
<td>110</td>
<td>0.73</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td>1201</td>
<td>1612</td>
<td>4540</td>
<td>790</td>
<td>0.75</td>
</tr>
</tbody>
</table>

![Figure 1. Scheduling of parts on machines for example 1.](image-url)
5. Illustrates examples and analysis of results

Example 1

Comparison

<table>
<thead>
<tr>
<th></th>
<th>Set up cost</th>
<th>Processing cost</th>
<th>Total time</th>
<th>Max. completion time</th>
<th>Completion cost</th>
<th>Total cost</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarin and Chen</td>
<td>1050</td>
<td>3590</td>
<td>1369</td>
<td>558</td>
<td>5853</td>
<td>6903</td>
<td>61</td>
</tr>
<tr>
<td>Our model</td>
<td>790</td>
<td>4540</td>
<td>1201</td>
<td>403</td>
<td>6094</td>
<td>6884</td>
<td>74.5</td>
</tr>
</tbody>
</table>

Result

✓ Decreasing the total processing time from **1369 to 1201 min**, a decrease of **12.3%**.
✓ Decreasing the maximum completion time from **558 to 403 min**, a decrease of **27.8%**.
✓ Decreasing the set up cost from **$1050 to $790**, a decrease of **24.8%**.
✓ Increasing the utilization from **61% to 74.5%**.
✓ Although the processing cost for the model is higher, the total cost decreased from **$6903 to $6884** as a result of decreasing the maximum completion time, which Increases the production rate and reduces the idle time.
5. Illustrates examples and analysis of results

Example 2

- 5 parts with 5 operation
- 5 machines with 60 tool slots/22 types of tool

<table>
<thead>
<tr>
<th>Machines</th>
<th>Operations assigned</th>
<th>Tools assigned</th>
<th>Processing time</th>
<th>Completion time</th>
<th>Processing cost</th>
<th>Set up cost</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>11, 22, 52, 25</td>
<td>1, 7, 16</td>
<td>314</td>
<td>433</td>
<td>1150</td>
<td>250</td>
<td>0.709</td>
</tr>
<tr>
<td>M2</td>
<td>41, 21, 33, 14, 15</td>
<td>3, 11, 14, 19</td>
<td>324</td>
<td>420</td>
<td>1090</td>
<td>290</td>
<td>0.731</td>
</tr>
<tr>
<td>M3</td>
<td>31, 32, 23, 24, 34, 35</td>
<td>2, 4, 5, 12, 17</td>
<td>413</td>
<td>443</td>
<td>1590</td>
<td>250</td>
<td>0.932</td>
</tr>
<tr>
<td>M4</td>
<td>42, 43, 53, 54, 55</td>
<td>8, 13, 18</td>
<td>356</td>
<td>440</td>
<td>610</td>
<td>180</td>
<td>0.804</td>
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<tr>
<td>M5</td>
<td>51, 12, 13, 44, 45</td>
<td>5, 15, 20, 21, 22</td>
<td>389</td>
<td>413</td>
<td>640</td>
<td>240</td>
<td>0.878</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td>1796</td>
<td>2215</td>
<td>5080</td>
<td>1210</td>
<td>0.811</td>
</tr>
</tbody>
</table>

Fig. 2. Scheduling of parts for example 2.
5. Illustrates examples and analysis of results

Example 2

Result

- The total processing time is 1796 min.
- The target cost is $5200, the actual processing cost is $5080.
- The set up time is 1300 min, the actual set up time is 1210 min.
- The machine utilization is 81.1%.
6. Conclusions

❖ Summary

➢ Problem

✓ Loading and scheduling problems in FMS system
✓ Integrated planning model
  • Solving with IP
✓ Heuristic method
  • Solving with simulation

❖ Adv. & Disadv.
THANK YOU