THE IDEA OF EVALUATION SYSTEM OF WORK-PLACE LAYOUT PLANNING ESLP FOR CONCURRENT PRODUCTION

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Abstract: The paper deals with the evaluation system of work-place layout planning. It is assumed that manufacturing processes are simultaneously accomplished. Moreover some operations from different processes precede through shared manufacturing system resources. Data describing manufacturing system are stored in the information system ESLP (its database), which has been developed in client/server technique, and the client application was implemented as well. It is brought up the layout optimization issue for a productivity improvement and production cycle shortening, by simulation modelling using ESLP system. An assessment of a layout configuration is obtained by comparing the indices (e.g. number of produced products, machine tools duty), generated by ESLP system. Those indices are solved based on main production schedule. The ESLP system allows: manufacturing system layout definition, customer orders recording, structure of product storing, manufacturing process plans definition, main production schedule editing etc. The architecture of ESLP and examples of use will be presented in the paper.

Keywords: Manufacturing system, Layout planning, database

1. INTRODUCTION

Nowadays, every enterprise tends to become the best one among its competitors in their area (products and processes). It requires to increase parameters, which have influence on a growth in quality, reliability etc., in order to satisfy potential customers. On the other hand it is aspired to decrease manufacturing costs. Production costs are generated at any stage of manufacturing process, so each department of enterprise requires continuous improvement. Modifications which should be made during the manufacturing process are very expensive and often unprofitable. Therefore it is desired to use dedicated tools with computer data analysis. The ability of many software environments gives the chance of creating dedicated programs for each aspect of production issues.

One of the most significant production aspects is layout planning and its analysis. Frequently, wrong design of resources layout has influence on decrease of productivity, because of e.g. long ways between those resources. Layout analysis allows informing about potential changes which should be accomplished.

Before we start design layout of production system, we should know the range of manufactured products. Based on that range of product, manufacturing (machining, assembly etc.) processes are also known. Now it is possible to develop initial main production schedule. That schedule is a base for specific layout design. Schedule development requires information about product and its structure, process plans, and batch production [1].

The ESLP system is created for evaluating work-place layout planning based on the factors generated by that program. It is dedicated for discrete production systems (particularly assembly and machining systems). Production flow planning considers the following constraints [5]:
- Manufacturing system structure (layout) constraints (work stations, machine tools, stores, transport devices etc.)
- Production control (the urgency of works etc.)
- Order constraints (deadline and batch size)
- Accomplishment of way of scheduling tasks (production routes)

It is assumed that manufacturing processes are simultaneously accomplished and they might cross each other. Some work stations are divided between processes concerning different products. Manufacturing resources can be allocated to process in given time, what means, that a resource can’t be released when an operation is in progress. Moreover manufacturing resources are “renewable”, so when an operation is finished, a resource is ready to “take” next operation even from different process.

Production orders are given by their manufacturing processes and a batch size. They are represented as an operations sequence, which are executed at definite time, along manufacturing route. Manufacturing process can access to the common resources in order of urgency level of tasks. Beginning of a next operation comes after ending a previous operation, provided at the resource, which is assigned for the next operation, is not engaged at the particular moment. Operations time is given in seconds. Setup time is included in operation time, but transport time is considered between operations, which are made on different work-stands, and before the first operation, when a semi-finished product is taken from a store.

It was assumed that each manufacturing route may run several times through the same work stations (it may occur recurrently). Production objects are waiting in work-in-progress stores (between operations) until the station has been released. Moreover finished products are moved to the finished-product store (maximum capacity isn’t taken into consideration).

Concurrent processes occur in a production system. It means that at least two processes overlap each other within time interval. They might be in interaction by using the same resources. It is required to synchronize it in time up to the manufacturing route and to obtain rhythmical production through the most regular resources duty possible. But there may appear a conflict. Two or more processes may simultaneously declare readiness to the same resource. Making a decision about process priority we should take into consideration the urgency of tasks.

2. THE IDEA OF ESLP SYSTEM

The main idea is based on client/server architecture. System contains the database and client application. Database is managed by that client application through TCP/IP protocol.

The ESLP system is divided into the following modules: manufacture subsystem, transport subsystem, customer orders recording, product structure, manufacturing processes and schedule planning. The architecture and data flow between those modules is presented in the Fig. 1.

The main part of ESLP system is the module for storing the work-place layout configurations. In that module, first the dimensions of production hall should be defined (the rectangular shape is only possible). User can define stations in the form of stores, work stations and control stations inside the defined hall. Those stations are arranged on surface area, by giving them coordinates of left and bottom stations corner (rectangle) relative to the coordinate of left and bottom hall corner. The coordinate of left and bottom hall corner is the origin of coordinates. The coordinates data definition are shown in Fig. 2.

For the manufacturing system, transportation roads and transportation devices can be defined. Transportation roads are composed of transportation paths (e.g. transport road is between point \((X_{C1}, Y_{C1})\) and point \((X_{C2}, Y_{C2})\) see in the Fig. 2). Transportation paths are represented by straight lines between two points (for example a transport path is between
point P1 and P2 in the Fig. 2). Two neighbouring paths, which define a transport road, are perpendicularly arranged each other or the second path can be lengthening of the first one [2].

On the other hand user can also define product and its structure. At that stage it should be decided which part will be bought and which will be machined. For parts which will be machined user can define manufacturing processes in the form of operations (tasks).

Data about manufacturing subsystem, transportation subsystem and manufacturing processes are converted in order to prepare data for scheduling in the form of Gantt chart. It can be designed as a general job-shop schedule, based on an active schedule model. For designed schedule user can set a production rhythm.

Fig. 1 The ESLP system structure with data flow model

Fig. 2 Loading data rules
3. THE EVALUATION FACTORS OF PRODUCTION SYSTEM

A characteristic factor of rhythmical concurrent production is system state repetitiveness achieving at definite period of time. That repetitiveness concerns whole production system involving single resources, stores and manufacturing processes. The repetitiveness can caused steady state and then a value of a calculated ratio for one production cycle is the same for a value of a calculated ratio for all production time.

Manufacturing system is also assessed based on the following factors:

- Coefficient of resources occupancy, which describes the ratio of resources occupancy (cycle times and setup times) to the available standard hours of work in a steady state. This coefficient considers manufacturing processes in T period. Coefficient of resources occupancy is described by following equation [5]:

\[
\eta_z = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} (m_{ij}t_{ij} + t_{p_{ij}})}{\sum_{i=1}^{m} T_i},
\]

where: \( \eta_z \) – coefficient of resources occupancy, \( T_i \) – available standard hours of work of \( i \)-th resource in T period, \( m_{ij} \) – process repetitiveness on \( i \) resource in T period, \( t_{ij} \) – duration of operation of \( j \) process on \( i \) resource, \( t_{p_{ij}} \) – setup time of \( j \) process on \( i \) resource, \( m \) – number of resources, \( n \) – number of processes.

- \( C_j, (C_{max}) \) – completion time of single process (total completion time). It describes moment, when the \( j \) process has been finished (the most delayed process has been finished). Completion times are connected with schedule. It is described as dependence [2][4]:

\[
C_j = r_j + \sum_{k=1}^{p} [(t_{j(k-1);k} + W_{j(k-1);k}) + l_{j}t_{jk}],
\]

where: \( C_j \) – completion time of \( j \) process, \( r_j \) – ready time, \( t_{j(k-1);k} \) – transport time from \( k-l \) previous operation to \( k \) operation, \( W_{j(k-1);k} \) – waiting time between \( k-l \) operation and \( k \) operation, \( l_{j} \) – batch of \( j \) process, \( t_{jk} \) – \( k \) operation time of \( j \) process, \( p \) – number of operations in \( j \) process.

- \( F_j, (F_{max}) \) – flow time of single process (total flow time). It is a time interval when \( j \) process (every process) stays in production. It is taken down as [4]:

\[
F_j = C_j + r_j,
\]

- Number of produced products. That ratio is calculated for one hour, four, eight, sixteen hours and for one day.

4. COMPUTATIONAL EXPERIMENT

A computational experiment is conducted to evaluate the design of given manufacturing system (its work-place layout planning) by using the ESLP. The subject of research is machine tool factory, where pinions and gear wheels are manufactured. It means that manufacturing system consists of work stations accomplishing some operations, which come from different manufacturing processes. Each process involves one product. Manufacturing processes consist of the various amounts of operations and they have various batch size. Manufactured products with number of operations are presented in the Table 1.
The production plant has 44 machines, needed to manufacture products. Production routes proceed through shared manufacturing system resources. It is looked into two variants of the layout configuration [3]. Both layout configurations are shown in the Fig. 3. In the Fig. 3a, there is illustrated layout with initial resources spacing. It means that each resource has been placed in any position on the layout (in this example according to station number); Fig. 3b shows layout with functional resources spacing. Stations have been arranged according to kind of working. Those centres are marked with heavy line rectangles. Transport roads are marked with broken lines.

![Fig. 3 Layout configurations: a) before; b) after functional resources spacing](image)

The evaluation of work-place layout is assessed based on main production schedule. Manufacturing system layout definition with transport subsystem, and manufacturing process plans definition is needed to create production schedule [2]. Manufacturing process, for any product, is stored in database in form of operations. Each operation equals a task, which is placed in the main production schedule. All tasks are illustrated in Gantt chart. Both fragments of Gantt charts of two configurations are shown in Fig. 4.

For each plan of work-place layout factors are calculated. Those factors are the base to evaluate manufacturing system. Moreover making any corrections in production schedule can result to get different values of factors. Besides with the aid of these factors user can compare

### Table 1 List of manufactured products

<table>
<thead>
<tr>
<th>No.</th>
<th>Product name</th>
<th>Colour in schedule</th>
<th>Number of operations</th>
<th>Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bevel pinion 1</td>
<td>Blue</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Bevel gear 1</td>
<td>Red</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Bevel gear 2</td>
<td>Green</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Bevel pinion 2</td>
<td>Yellow</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>Cylindrical gear</td>
<td>Purple</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>Pinion</td>
<td>Grey</td>
<td>18</td>
<td>20</td>
</tr>
</tbody>
</table>
many variants of layout configurations and decide which one should be take into consideration at the potential system implementation.

Fig. 4 Main production schedule definition: a) before b) after resources spacing

Calculated factors for individual products are presented in table 2.

<table>
<thead>
<tr>
<th>Part name</th>
<th>$F_{IB} - F_{IA}$ [min]</th>
<th>$C_{IB} - C_{IA}$ [min]</th>
<th>Difference of parts produced after 24 hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bevel pinion 1</td>
<td>-2</td>
<td>-1</td>
<td>10</td>
</tr>
<tr>
<td>Bevel gear 1</td>
<td>-2</td>
<td>-2</td>
<td>10</td>
</tr>
<tr>
<td>Bevel gear 2</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Bevel pinion 2</td>
<td>-2</td>
<td>-2</td>
<td>8</td>
</tr>
<tr>
<td>Cylindrical gear</td>
<td>13</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Pinion</td>
<td>-7</td>
<td>-7</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2 Differences of factors for individual products

5. CONCLUSION

The computational experiment demonstrates, that the ESLP system allows to evaluate of work-place planning in satisfied way. On the ground of generated factors, it can be compared many configurations of layout, where some resources are shared between different processes. Moreover the above test of two configurations of layout proves that the deterioration of one ratio may not have influence on productivity of whole production system. It should be taken into consideration the group of factors and compared them each other.

The ESLP system allows to develop any kind of manufacturing system. The ESLP system is still improved. It is planned to connect it with automatic manufacturing process planning and automatic main schedule generation. It could be a functional system, which might be used in small and medium companies in order to aid decision making.

6. REFERENCES