Development of automation assembly systems makes the question of efficiency and optimization, which can be addressed with regard to external conditions and internal conditions. One of the determining factors is the automation of manipulating and flexibility of material flows that are important in adapting assembly systems for large-scale changes in market quality and reducing production costs. The requirements of flexibility and quality production, low implementation costs lead to the creation of expediency handling equipment and structures based on nature of phenomena associated with the implementation of functions and activities.

For this purpose, to accede to the development of manipulating systems perspective as a basis for the creation of flexible material flows. These are being diverted away from graphical, analytical and parametric models and then used to design effective and efficient elements, equipment manipulating and ensembles.

**IMPORTANCE OF INTEGRATED SOLUTIONS**

Addressing integrated handling due to the fact that the function of the material handling time and the number required to provide a process or department material producing mounting devices as well as time to settle differences and inequalities, which have created in integrate technology operations in a coherent process.

For medium-sized enterprises in manufacturing structures for small series as well as large enterprises with a variety of simple tasks in the handling of workpieces is under considerable pressure to reduce production costs by all means and purposeful automation. For these areas it is advisable to develop an integrated material flow solutions. Flexible automated handling the machine and automatic supply of individual production cells are still scarce. Towards an integrated manufacturing system automation modules are still missing. Even in exceptional cases specifically addressing the use of automation of handling general fail and the concatenation of certain types of components and the high costs incurred in individual solutions. Only by developing the production-transmission systems, and in particular concatenation of grouping of workpieces can create cost-effective systems that meet the established requirements.

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Preparatory technologies - Production stage
Preparatory technologies - Stage stock
Preparatory technologies - Stage supply and distribution
Main technologies - Fabrication and components
Main technologies - Integration of product design
Main technologies - Inspection and testing
Expedition technologies - Integration product for the market

**Fig. 1. Production logistics chain**
The strategic objective is to achieve a more comprehensive application of automation engineering and manufacturing into one compact unit production logistics chain – Fig. 1 profiling under the integrated material flow. This trend makes the deployment of advanced concepts of the transport storage and handling systems that ensure a high degree of automation. Handling, transport and storage technology is indispensable for those goals, but far from forming an integrated system. Equally important is a well-organized flow of material. While the system applies the principle of integration objects to avoid unnecessary handling operations, respectively to be easily automated. The rational is needed to automate operations such level of integration to secure the required handling functions and to avoid duplication and thus unorganized production.

Creating an integrated handling system, and hence more real integrated production and assembly is, undoubtedly, the systemic nature of the creative question. This leads to the search for answers on how to create complex technical systems, which currently require only a significant increase in the level of automation, but also the design of appropriate means of forming system.

**MODELING TASKS**

In modeling tasks, automated handling assuming availability of exact methods of system analysis, in methods for the registration system using a formal mathematical apparatus. Mathematical modeling is one tool in addressing the tasks of analysis, design and management of handling systems, which have a material effect on its efficiency. It is an abstraction model that is based on the allocation and modeling of critical information, material and physical communication in circulation [3].

Creating the material flow logistics solutions preceeds the description of communication material – Fig. 2 and registration material communications network, describing the track mounting system. Based on the decomposition of the assembly of an indirect link between the storage node-handling hub-mounting unit with its own handling equipment. Depending on the status and role of the studied functions handling system varies the number of nodes, their state and mutual relations. Therefore, the model must represent the communication material such registration, to determine the starting node \( (U_1) \), the target node \( (U_n) \) and Center knots \( (U_2, ..., U_{n-1}) \). Then material communication network is the sum of flows in all the roads leading from node \( U_1 \) to node \( U_n \). If the communication system of the material in any sub- \( U_1, U_2, ... U_n \), defined as a structure of nodes \( U_1 (u_{11}, u_{12}, ..., u_{1m}) \), \( U_2 (u_{21}, u_{22}, ..., u_{2m}) \), \( U_n (u_{n1}, u_{n2}, ..., u_{nm}) \), then analyze the material flow system for the distinctive level nodes \( u_{ij} \) (operations, buffer), at nodes \( U_1, U_2, ..., U_n \) (central), or \( U \) level (operational, interoperable, central).

Writing a network of communication between the base material, the target node and the center nodes can be transferred using the incident matrix and graph-oriented material flow [3].

---

**Fig. 2. Description of communication material**

- **Central level**
  - \( U_1 \) - input-output store
  - \( U_i, U_j \) - manufacturing/assembly cells
  - \( u_l \) - technology/storage space

- **Operational level**
  - \( U_1 \) - technology/storage space
  - \( IM \) - material flow
  - \( ID \) - input/output
  - \( U_i \) - manufacturing/assembly cells
  - \( u_l \) - technology/storage space
PARAMETRIZATION TASKS

The communication system can be blamed for the material type and position of individual nodes, the number of input and output material flow, the maximum vertical connection with the node creating the material pattern, the presence of loops and the occurrence of isolated node. These methods of modeling material communications are limited to standard types of distribution operations, which characterize the intervals between arrivals and time requirements of handling a relatively simple structure of network communications material and simple rules for the operation. Cover wider ties information, material and physical communication is configurable options in material flow through the so-called the transport matrix – tab.1.

<table>
<thead>
<tr>
<th>OD/DO</th>
<th>U₁</th>
<th>U₂</th>
<th>U₃</th>
<th>U₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>U₁</td>
<td>𝑋₁₂</td>
<td>𝑌₁₂</td>
<td>𝑋₁₃</td>
<td>𝑌₁₃</td>
</tr>
<tr>
<td>U₂</td>
<td>𝑋₂₁</td>
<td>𝑌₂₁</td>
<td>𝑋₂₃</td>
<td>𝑌₂₃</td>
</tr>
<tr>
<td>U₃</td>
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<td>𝑌₃₁</td>
<td>𝑋₃₂</td>
<td>𝑌₃₂</td>
</tr>
<tr>
<td>U₄</td>
<td>𝑋₄₁</td>
<td>𝑌₄₁</td>
<td>𝑋₄₂</td>
<td>𝑌₄₂</td>
</tr>
</tbody>
</table>

Legend:
𝑋_{ij} - the number of objects (handling units),
𝑌_{ij} - distance respectively transit time between nodes,
𝑎_{ij} - continuity operations and activities between the production and storage sites.

Rows respectively columns represent different points of the network once communication material, and the transition from one point to the second point is represented by the matrix element, whose index is the line end point (where), and a member of itself contains a value which is given by elements x, y, a. Parametrization problem can be further used to determine the number of transport and handling units and the organization handling the arrangements.

In determining the number of vehicles (ID) and manipulation (IM) units of the production system based on:
• the relationship (1) if it is the flow of materials between storage nodes and production units in direct custody or between nodes and storage nodes handling of individual production cells with indirect link (central level).

\[ ID = \frac{X_{ij} \cdot Y_{ij}}{60 \cdot p \cdot s \cdot \eta} \]  \hspace{1cm} (1)

where:
𝑋_{ij} - the number of objects (handling units) transported per hour,
𝑌_{ij} - transit time between nodes [min],
p - the number of pallets in the transport dose,
s - the number of components in the palette,
𝜂 - access to η transport units in the system,

• the relationship (2) if it is the flow of material handling between the nodes and production

\[ IM = \frac{X_{ij} \cdot Z_{ij}}{60 \cdot \xi} \]  \hspace{1cm} (2)

units (operational and buffer level).

where:
𝑋_{ij} - the number of objects (handling units) transported per hour,
𝑍_{ij} - time handling operation [min],
ξ - operating attainability (time, dimensions) in the robot cell.

These relationships are representative of some approaching the importance of parametrization, which remains open and accessible to address other tasks to optimize the production system.

ALGORITHMS TASKS

The basis for attributing the work of algorithm – Fig. 3 profiling integrated service system is set the following parameters:
• a description of the track mounting system,
• a description of material flow in the system,
• database handling equipment and systems,
• specify additional parameters.

Description tracks manufacturing / assembly system based on the decomposition, such as a storage node, service node, a manufacturing and assembly unit with its own handling equipment. System components are selected from the database component, which is freely editable and contains the description of the handling functions.

Description of material flow is realized in the system parameter. The program tracks entered the production system will determine whether it is a direct or indirect link between storage nodes and assembly units. The decisive factor is the presence of node handling the manufacturing / assembly systems and storage nodes.

Database handling equipment and systems based on the handling, transport and storage facilities for the operational, intermediate and central level. The database can be modified and supplemented by editing the form. Specifying additional parameters of the system is used for calculating the optimal number of transport units in the system, the number of potential manufacturing cells and integrating handling units.
Select can not reach to an optimal solution but we can achieve a combination of concepts and innovative handling.

GENERATION AND SIMULATIONS OF MANIPULATION SYSTEMS

Generating solutions were made using the simulation program ShowFlow. The main application area of this program is the modeling and analysis of material flow in the system, determine its capacity respectively handling the design parameters to ensure some of its capacity. The system can process simulation during and after their statistical analysis of monitoring and determine its weak points, the possibility of conflict states. Simulation can be observed in animated form, graphic statistical form, or a combination of these methods display.

For reasons of limitations demonstration version of a simulation program ShowFlow to a maximum of 20 objects (the objects are: machinery, tanks, transport equipment, transport path segments defined by the system) was also simulated production system is limited in terms of size and complexity.

The parameters of the model solutions

The system under consideration the following parameters were selected (focused on the parameters required for its calculation program OptiMan / 5/):

• The specified structure of manufacturing / assembly system for model solution consists of storage nodes, a transport system and three manufacturing / assembly cells.
• String handling functions in the system consists of those functions PO12 - F32 - Tr32 - Pr32 - Pr21 - PO11 - F11 / 3/.

The present mounting system includes handling nodes, which in this case are mounting their own units, thus marking that the indirect link between storage nodes and assembly units / 3/. For this case, is entered in the material flow system at center level.

• Parametrization of material flow

<table>
<thead>
<tr>
<th>Output node</th>
<th>Input node</th>
<th>Number of components /h</th>
<th>Time range transport [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>50</td>
<td>1.2</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>150</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>150</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>150</td>
<td>0.8</td>
</tr>
</tbody>
</table>

• Objects integration of product design mounting systems are machine nodes with weight 5.5 kg, such as roto transported pallets in the system. On 1 pallet of 10 parts, each pallet transport system is transported separately. Accessibility trucks transport buffer in the system is 0.80.
**Profiling handling system**

In profiling of integrated handling system is used the principles of integration /4/ which were algorithmized. Based on the algorithm for generating a variant configuration material flow generates variation and integration in principle, all options for handling a chain of handling functions of the production system. Generated from the variant configuration handling system is also necessary under certain criteria to exclude variants which do not conform to its technical parameters, respectively preferred options, which parameters best match the requirements of material flow in the system. These criteria are based mainly on the load, operational reach and capacity of handling equipment. Taking into account these criteria, a set of handling equipment variation generated by the algorithm reduces to a subset of facilities that meet the terms of their technical characteristics. Of this subset, the selection of an optimal variant of the following criteria:

- implementation costs
- internal and external compatibility elements, modules and ensembles
- openness and modifiable system.

This choice can not reach the optimal solution, but we can achieve a combination of concepts and innovative handling.

In support of variational algorithm for updated data were generated the following results:

| Number of transport equipment in the systems | 1,31 |
| The actual number of transport facilities in the systems | 2 |
| Optimal configuration of a variant MT | Store with rack stackers ESKAY L100 |
| Cart transport system ESKAY MV25 |
| Universal robots KUKA KR-15 |
| Implementation costs of the integrated manipulating system | 1.709.486 EUR |

Before calculation of project expenses had to be even specify the number of individual facilities, such as data system does not. Since it is necessary to serve the 3 machines, which are situated at a distance of 3 m (Assuming the layout of the deployment of production facilities) suggested that 3-robots KR 15th Implementation costs do not include cost of special equipment to ensure functionality Tr12.

**Simulation of material flow**

The present service system was simulated using 2 transport facilities. It was found that despite the high percentage of saturation of the transport system is the percentage of use of assembly machines is very low, about 25%. This was due to inefficient management of driving, when driving an empty chair is very long and trucks rode with only 1 array simultaneously. Another fact is that the material flow is specified in terms of length of time fitting assembly machines designed inefficiently, when driving the trolley is in many cases, longer processing time than the parts. Therefore move to increase the number of trucks to 3, thus the percentage of utilization of machines has grown significantly and there are optimal distribution of activity-figure cars. 4. (Where: icle = idle time inactivity trolley, trFu = driving time with an object, trEm = time driving an empty cart).

![Utilization Pie](chart1.png)

**Fig. 4. Chart No. 3 use handling trolley**

The presentation complements the histogram analysis (Figure 5.), which shows the distribution of times between the products at the outlet assembly machine 2, which are awaiting removal carriage transport system in node 1, storage shelf.

![Waittime Histogram](chart2.png)

**Fig. 5. Histogram of waiting times at the exit node 2 (machine)**

Simulation model of assembly system would not confirm the accuracy of proposal 2 handling trucks OptiMan program, but noted the need to extend the system Op-
Precision assembly systems for medical devices.

Systemy precyzyjnego montażu urządzeń medycznych.

Celem niniejszej pracy jest opisanie metod i technik podejmowanych przez różne firmy produkujące zautomatyzowane wyposażenie do montażu wyrobów medycznych. Została omówiona struktura rynku montażu urządzeń medycznych, a także opisano stan i użyteczność oraz funkcjonowanie małych firm działających na rynku produktów pośrednich. Szczególnie przebadano przystępność modułowych technologii montażu precyzyjnego. Postępy w produkcji i rozwój nowych urządzeń medycznych zalażą od wielu etapów weryfikacji i waliudacji, tworząc niesie rynkowe dla wielu małych, średnich i dużych producentów urządzeń montażowych. Niezawodność i dokładność montażu jest niezbędna dla prawidłowego działania urządzeń w całym okresie ich eksploatacji. W celu zapewnienia wysokiego poziomu bezpieczeństwa i możliwości śledzenia procesu stanowiska badawcze i kontrolne stanowią integralną część wielu linii montażowych. W artykule scharakteryzowano stan rynku urządzeń medycznych i producentów działających w tym sektorze.

LITERATURE


Doc. dr inż. Štefan Valenčík i dr inż. Juraj Kováč są pracownikami Katedry Technologii Produkcji i Robotyki Uniwersytetu Technicznego w Koszycach, Słowacja.

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