MATERIAL FLOW IN AUTOMATED PRODUCTION SYSTEMS

Peter KOŠŤÁL[1], György KOVÁCS[2], Dávid TÓTH[1], Andrea MUDRIKOVÁ[1]

[1]doc. Ing. Peter Košťál, PhD., Ing. Dávid Tóth, Ing. Andrea Mudriková, PhD., Slovak University of Technology, Faculty of Materials Science and Technology, Institute of Manufacturing Technologies, ul. J. Bottu 25, 91724 Trnava, Slovakia,
e-mail: peter.kostal@stuba.sk, david.toth@stuba.sk, andrea.mudrikova@stuba.sk

[2]Ing. György Kovács, PhD., University of Miskolc, Faculty of Mechanical Engineering and Informatics, Institute of Logistics, Miskolc-Egyetemvaros, 3515 Miskolc, Hungary,
e-mail: altkovac@uni-miskolc.hu

Abstract

Today, manufacturing is characterized by a trend in production broadening, innovation cycle shortening, and products with new shape, material and functions. The production strategy focuses on the time needed to change from a traditional functional production structure to production by flexible manufacturing cells and lines. Production by flexible system (FMS) is a most important manufacturing philosophy in recent years.

Key words

material flow, information flow, flexible manufacturing

INTRODUCTION

Today's market is characterized by a strategy of consumer's individualization. This strategy focuses on consumers requests. Consumers want new products and time is a fundamental requirement for satisfaction. As production is broadened, the innovation cycle is shortened, and the products have new shape, material and functions. In this strategy, the traditional understanding of costs is lost in importance. Most important is shortening the time of production.

The flexible manufacturing systems (FMS) for small batch production are characterized by high complexity of material flow. This complexity is caused by a wide range of manufactured parts and so different material flow is needed for each of these parts (1).

A production strategy focused on time requires a change from a traditional functional production structure to production using flexible manufacturing systems. Production by flexible manufacturing systems (FMS) is the most important manufacturing philosophy in recent years.

This philosophy is based on the following similarities:

- Similarity of manufactured parts,
- Similarity of process plans.

Recognition of the similarity of manufactured parts allows them to be sorted into groups by the machine required for manufacturing. By manufacturing of a single group of parts, economic benefits near to mass production can be achieved.

MATERIAL FLOW PLANNING IN FMS

The number of product types required by customers is increasing which has an influence on the capacity demand of finished good storage at manufacturers. Due to a variety of products, minimum stock levels of components should be provided to fulfill the customers' demands (2).

The general procedure of planning of transport, handling and storage system is as follows:

1. Analysis of material flows and calculation of traffic system performance,
2. Processing of workshops disposition (layout of production centers),
3. Analysis of existing devices (transport equipment, auxiliary resources, storage facilities, containers, handling devices),
4. Processing of transport systems variants, handling and storage:
   a) Transport system topology,
   b) Static dimensioning of materials flow elements (calculations of transport devices, speed parameters, loading capacity, loading and unloading times and others),
   c) Interface between transport system and workstation solution and possibilities of pallet and tools relocation.
   d) Processing transport control system, handling and storage.
5. Simulation and dynamic dimensioning of material flow components and optimization of transport, handling and storage systems (analysis of narrow places, system lockouts, container sizes, transport and storage devices capacity utilization, control rules).

The analysis of material flows is one of the main subparagraph of material handling analysis (3).

The rules for effective material handling:

- Creation/selection of the simplest and shortest transport routes,
- Determination of maintenance rhythm, continuity and fluency of material flows,
- Simplification of material handling,
- Design of manufacturing process and layout with regard to the optimal flow of materials,
- Assessment of the possibility to use material movement due to gravity,
- Optimizing quantities, size and weight of transferred units,
- Application of mechanization and automation in handling,
- Design all handling, transport and storage activities as the most effective,
- Analysis of handling from the global aspects of the entire corporation,
- Evaluation of the possibilities to use standard handling devices,
- Achievement of exploitation of transport and handling devices minimally at 60%,
- Accomplishment of ergonomic and safety requirements (6).

Main features in material flows:

- Transported material,
- Transport, handling and storage units,
- Transport equipment, handling devices, storage devices,
- Personnel,
- System of organization and control of transport and storage processes.

In the process of material flow planning, the formula of material flows (Fig. 1) is (4).

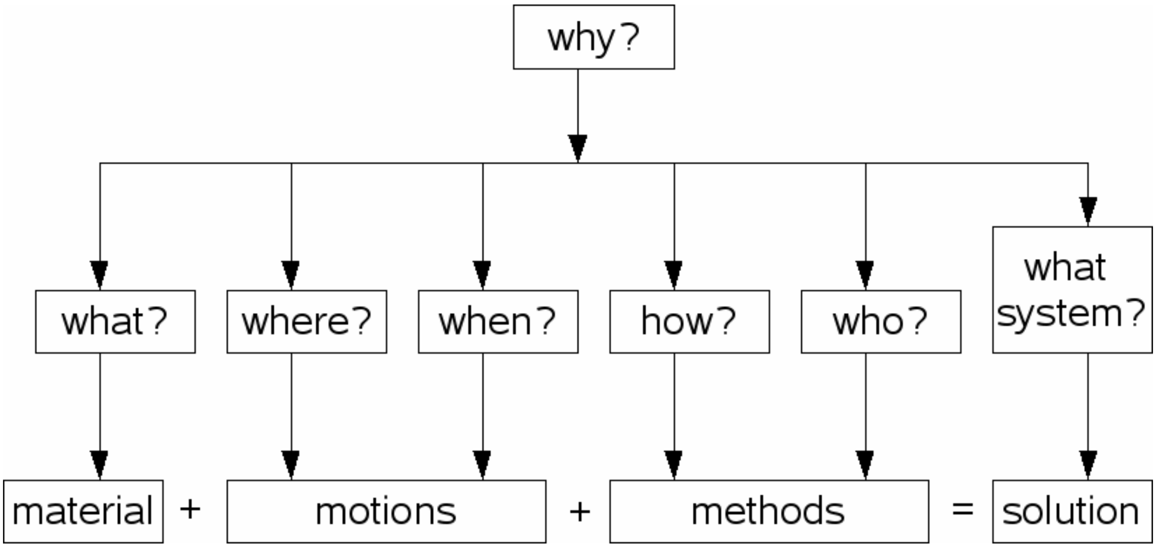

Fig. 1. *Formula of material flow*

WAYS OF MATERIAL FLOW DESCRIPTION IN THE FLEXIBLE PRODUCTION SYSTEM

Material flow directs the movement of passive elements (material, raw materials, semi-finished goods, products) that is secured by means of active elements (transport, handling, storage systems). It also characterizes the dynamics of production flow. It's most important part is the flow of working objects. Material flow is influenced by more factors, e.g.:

- production volume and assortment,
- level of technological complexity and segmentation of assembling units,
- number of operations on individual parts,
- shape of the given space,
- way of interoperation transport,
- placing of auxiliary plants and services (tool issuance, maintenance location, placing of the co-operating production subdivisions etc.).

To illustrate and describe the material flow, the following methods are usually adopted:

1. flow diagrams:
   a) flow chart – contains the sequence of technological and non-technological operations within the individual parts during their transition through the production process with the recording of individual operational time factors;
   b) flow graph – graph that schematically traces the material flow by means of production process or its part. In these graphs, it is possible to draw not only all the data concerning the technological process (figures of operations and their duration), but also other information that may be significant for the material flow analysis, e.g. warehouse location, distance between the work places and so on;
   c) manufacturing process scheme – is a joint visualization of the technologically similar parts group process and it presents the possible differences that arise on certain parts during this process, e.g. skipping of some operations;
2. material flow schemes:
   a) simplified scheme of material flow – calculates the volume of material transported between individual workplaces without reference to its real arrangement. It considers only the sequence of material flow and meeting the conditions of certain

selected scale regarding the transported amount;

b) material flow sequence scheme – with the help of reciprocally different lines, it calculates the flow of individual parts, tools, waste between individual workplaces – these are drawn in ground plans to a certain scale;

c) Sankey's material flow diagram – originates by making a simplified material flow scheme into the ground plan of dislocated workplaces. It is a matter of complex material flow image that shows, by a visual demonstration, its length, direction, intensity, crossing and returning;

3. transfer relations matrix (matrix table) – shows the volume of material that was supplied or purchased by individual workplaces within a certain production subdivision over a certain time period. It is necessary to differ between the workplaces that supply exclusively, purchase exclusively and the workplaces that supply and purchase at the same time;
4. triangular table of mutual relations – it presents a method that is used to design the spatial arrangement of workplaces (or more precisely machines, devices). Its subject matter presents the carrying-out of material flow intensity analysis in the individual workplaces. Those which have the highest intensity of material flow are placed as close to each other as possible. Another workplace which has the highest intensity in connection with them is placed in the triangular position opposite to them.

The triangular table of mutual relations, also called the triangular method, is the most exact and most effective from all mentioned methods. Therefore, we will use it during the material flow planning in the laboratory of flexible production system and the next chapter will be dedicated to it in more detail (5).

Nowadays, more software for material flow graphic visualization and simulation are being utilized. One of the most popular is Witness, which is used in our workplace too. An example of material flow graphic visualization and simulation using this software can be seen in the Fig. 2.

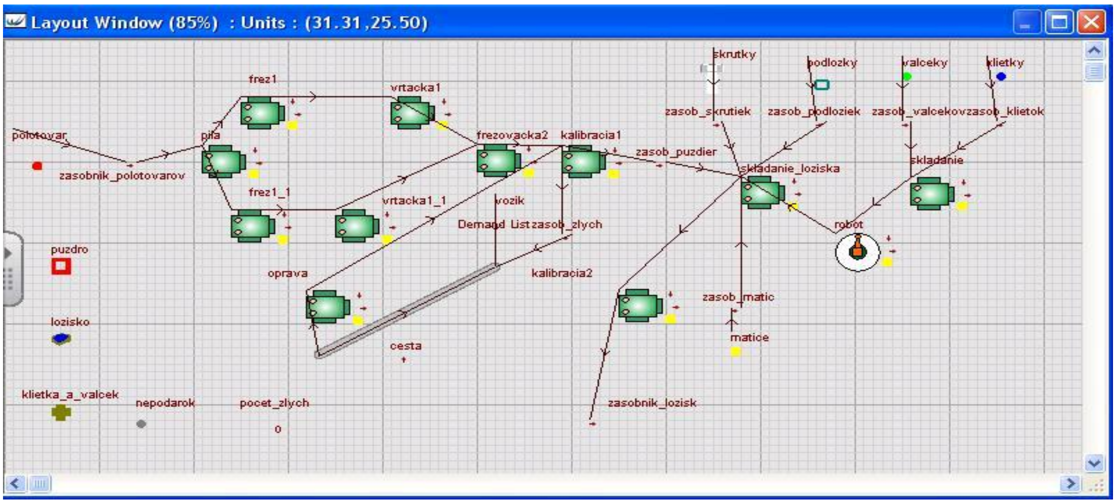

Fig. 2. Example of material flow description by Witness

MATERIAL FLOW REALIZING

During material flow analysis, the transport stream is analyzed first. The transport stream is the organized moving of handling and transport devices. The data obtained from this analysis characterizes the transport roads loading, material flow and transport rails crossing, transit seed requirements and other important facts about a material flow layout. We also obtain information about transport devices capacity utilization and an overview of transport handling devices. From this analysis we obtain information about the required number of operators and their required qualifications. Completion of this analysis is the starting point to effective design of logistics activities (6).

The material which is subject to the transporting and handling operation, is modified in terms of orientation and positioned towards its surroundings in sequence. These changes are defined by sets of movement elements which are completed in the manipulation device work space. The movement of material is passive because these movements are completed by handling devices. The movement of handling or transport devices are characterized as active movements. On the basis of this premise we can divide the material flow elements into active and passive.

The active elements of logistics systems are elements which complete the logistical functions – this means those which complete sequences of non-technological operations by passive elements. Logistical functions are handling and transport operations. Operations such as packing, unpacking, loading, unloading, storage, identification, acquiring, transferring, processing, storing of data and others are logistical operations. Operators and other decision making subjects are active elements of logistics systems too. The movement of all passive elements are completed by active elements of the system (active devices, information, human operators).

From a material flow point of view, it is possible to divide the technological processes into discreet processes and continuous processes. This classification influences the global conception of material flow in the manufacturing system.

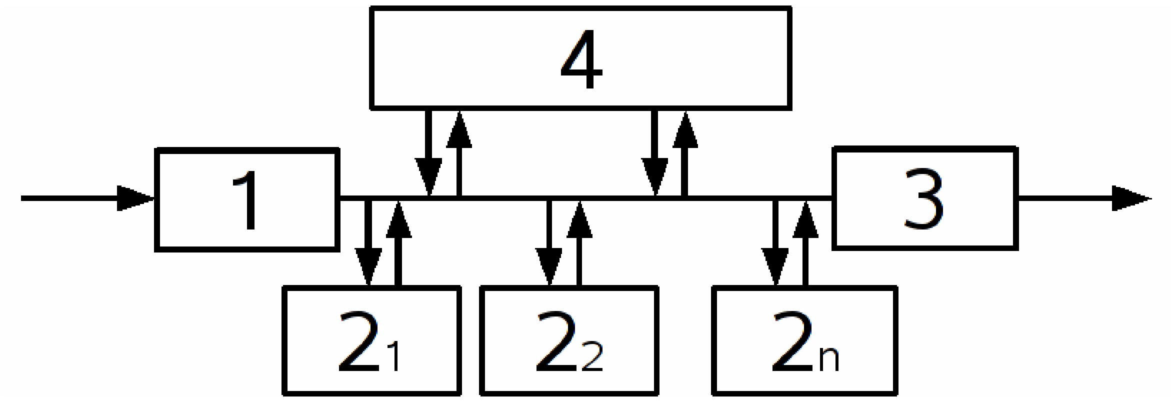

Fig. 3. *Material flow inside of technological process*
1 – input storage, 2 – technological devices, 3 – output storage, 4 – inter deck

Fig. 3 shows the usual model of material flow in discreet technological processes.

The technological processes are completed sequentially by material moving between discreet technological devices. The processing time for technological devices are different. The raw materials are moved to the first technological device from input storage [1]. On this device is completed the required technological process (or sequence of technological processes). After the first technological process, the raw material is moved to the next technological device for processing. In the case when this technological device is occupied, the raw materials are moved to the inter deck [4]. The material will wait in the inter deck until the next technological device for its processing is available. After completion of all technological processes, the finished products (finished from the viewpoint of this given manufacturing system) are moved to output storage [3].

The inter deck can be one central inter deck for the whole system, or a decentralized set of inter decks for all technological operations. The material flow between input storage, output storage, inter decks and technological devices form continuously working devices (conveyors) or discreetly working devices (crane, carriages ...). Some devices enable completion of the loading and unloading operations at the same time.

A contiguous technological process is the material flow scheme shown in Fig. 3. The manufacturing system for contiguous completion of material processing obtains the raw material from input storage [1]. The processing time for each technological device must be similar. Depending on the technological processes, it is possible to achieve the fluent raw material ongoing and finished products outgoing, or batch type of ongoing and outgoing. At the end of the technological order (manufacturing system) are outgoing products moved to output storage [3].

When various types of products are manufactured within one manufacturing system, and some of these products do not need all technological operations, it is possible to enter the raw materials, and to finish products at other points on the technological line, not just at the beginning and the end.

On a technological line of manufacturing systems, material flow is usually completed continuously. Sometimes it is necessary to create buffers at midpoints on these technological lines. In this case, the continuous material flow can be changed to discrete material flow.

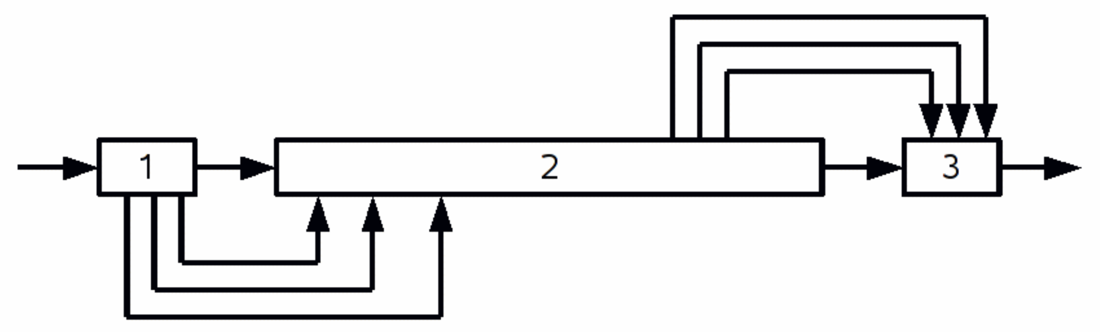

Fig. 4. *Material flow in continuous technological process*
1 – input storage, 2 – continuous technological process, 3 – output storage

CONCLUSION

The aim of material flow optimization in flexible manufacturing systems is to improve the usage of material flow completion devices, improve efficiency of technological devices and transportation time shortening.

A very important property of material flow is its flexibility. This means the possibility for material flow to change depending on technology or production changes.

At times when transport device planning is needed, it is necessary to keep in mind the type of handled materials (pieces, mass, dimensions ...) and type of technological process (discreet or contiguous technological processes).

Acknowledgement

Institutional project MTF 2016/002 – Flexible manufacturing systems in drawingless production.

References:

1. TAMÁS, P., ILLÉS, B., and TOLLÁR, S. 2012. Tárolóterületek méretének meghatározása rugalmas gyártórendszer esetén.
2. TAMÁS, P., KOVÁCS, G. AND ILLÉS, B. 2009. Decision Making Method Relating To Outsourcing of Finished Goods Storage Activities. *Adv. Logist. Syst.*, **3**(1), pp. 120–126.
3. KOŠŤÁL, P., MUDRIKOVÁ, A. 2008. Material flow in flexible manufacturing and assembly. *Acad. J. Manuf. Eng.*, vol. Supplement, no. Issue 1, pp. 185–191.
4. KOŠŤÁL, P., MUDRIKOVÁ, A., SOBRINO, D. D. 2010. Material flow in flexible production systems. *Proc. Manuf. Syst.*, **5**(4), pp. 213–216.
5. KOŠŤÁL, P., KRAJČOVÁ, K., RUŽAROVSKÝ, R. 2010. Material flow description in flexible manufacturing. *ALS*, vol. 4, pp. 104–108.
6. GUBÁN, M., GUBÁN, Á. 2012. Production scheduling with genetic algorithm. Advanced Logistic System: Theory and Practice, **6**(1), pp. 33-44.
7. MUDRIKOVÁ, A., HRUŠKOVÁ, E., VELÍŠEK, K. 2008. Logistics of material flow in flexible manufacturing and assembly cell. In *ANNALS OF DAAAM FOR 2008 & PROCEEDINGS OF THE 19TH INTERNATIONAL DAAAM SYMPOSIUM*. Wien, Vienna univ. Technology, Austria, pp. 919–920.

ORCID:

Peter Koštál 0000-0001-6622-6174