MATHEMATICAL MODELING WORKSPACES IN MEANS OF ASSEMBLY SYSTEMS

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Abstract
In designing of assembly systems have an important role optimization of spatial solutions grouping means of production. An important implement to tackle the problem are approaches based on mathematical modelling. This paper presented approaches to mathematical description of workspace zones and their synthesis.

Key words: assembly system, workspace zone, zone size

Introduction
In designing assembly systems is important task to optimize spatial resolution grouping assembly device. An important tool in the problem solving is based on mathematical modelling. This stage of the project activity results in spatial solutions and for the practical needs is more exact descriptions, using mathematical and other principles.

Industrial rasters are planar or spatial grid formed by parallel perpendicularly intersecting lines (raster lines), which mutual distances (the grid) are the most common standardized dimensions, which are in one direction the same size. (Fig. 1)

Workspace of assembly systems
Industrial rasters allow to create immediate direct dimensional relations between exact area and placing assembly system that realizes the assembly process.

For identification of topological relations in assembly systems it is appropriate to define the grid (place) zone and subzone.

Zone is bounded area within a reference area which involves a certain functional activities respectively the entire assembly process. Subzone is limited space within the zone which takes place only certain elemental component assembly process.

Number of zones and their geometric characteristics were determined and size of area to be placed assembly system and its structure. Subzone within each zone detail the functional and spatial relationships wall solutions elements assembly system.

In terms of functional activities ongoing in the area of the zone is defined by the following zones:

- **technology** - limited space in which ongoing assembly operations,
- **handling** - limited space in which ongoing handling, transport and storage operations,
- **control** - limited space in which ongoing management operations,
- **help** - limited space in which the operation is performed by a manufacturing process,
- **others**.

In addition to functional activities are ongoing in the zone for a zone characterized by the following basic parameters:

- **The shape zone** expressed system of equations, equations of surfaces bounding the zone in the reference space.
- **The size of the zone** depends on the individual dimensions of space.
- **The accessibility zones** defined by a vector passing through the operating point in the direction of the best zone of access to the zone.
- **The position and orientation of the zone** is defined relative to the coordinate system of space respectively element of the building.

In general it is possible to describe the zone throughout its volume (in space) or in the examined section. Using this approach, the whole task is reduced to a description of the areas bounded by curves. After a suitable choice of the position...
coordinate system (depending on the particular case) are determined equation curves bounding zone and zone itself is then expressed as a set of points bounded by these curves. An example of a zone is shown in Fig. 2. General form the described area is as follows:

\[ z = \{(x, y): f(x_1), f(x_2), \ldots, f(x_i)\} \]

where \(x, y\) – coordinates of the points zone of the building element in the chosen coordinate system

\[ f(x_i) \] – function expressing the curve shape boundary zone.

\( i \) – number of curves, boundary zone.

**Mathematical models zone**

In describing the various zones and the calculation of the zone, proceed as follows:

1. We choose a coordinate system - the top coordinate system and the orientation of the axes of the coordinate system (mostly right-handed Cartesian system).

2. Zone divide the elemental area covered by:
   - functions \( f(x_i), f(x_j) \) are continuous on \((a, b)\).
   - to let the \((a, b)\) is \( f(x_i) < f(x_j) \)

3. According to the form of elemental areas (according to the type of functions which determine the elemental area) describe the area in question.

4. The size of the elemental area can be expressed using double:

\[ P = \int \int_{Z} dxdy, \quad Z: a \leq x \leq b, \quad f(x_i) \leq y \leq f(x_j) \]

5. The size of the elemental area is simply the sum of the size of the areas of individual elementary zones.

Example elemental area of the destination zones in Cartesian coordinates is in Fig. 3.

For elemental area in Fig. 3 applies:

\[ Z: \quad x_1 \leq x \leq x_2 \]

\[ f(x_i) \leq y \leq f(x_j) \]

\[ \begin{align*}
  f(x_i) &= \frac{y_2 - y_1}{x_2 - x_1} \cdot x + \frac{x_2 y_1 - x_1 y_2}{x_2 - x_1}, \\
  f(x_j) &= \frac{y_4 - y_3}{x_2 - x_1} \cdot x + \frac{x_2 y_3 - x_1 y_4}{x_2 - x_1}.
\end{align*} \]

The size of elemental surface area applies:

\[ P = \int_{Z} dxdy = \frac{(x_2 - x_1)(y_4 + y_3 - y_2 - y_1)}{2}. \]

The importance of using integrals in describing zones in their suitability for a description of the areas. Of elements working in a different coordinate system than in a rectangular, can be used to transform the polar coordinates (Fig. 4).

For elemental area in Fig. 4 applies:

\[ Z: \quad \rho_1 \leq \rho \leq \rho_2 \]

\[ \varphi_1 \leq \varphi \leq \varphi_2 \]

The size of elemental surface area applies:

\[ P = \int_{\rho_1}^{\rho_2} \int_{\varphi_1}^{\varphi_2} \rho d\rho d\varphi = \frac{\rho_2 - \rho_1}{2} \left( \rho_2^2 - \rho_1^2 \right). \]
When designing the analysis zones from each wall solutions elements mounting system goes on to subsequent synthesis zone. Synthesis and handling technology zones is important for effective functional elements of activity-wall solutions. Between manipulation and technological elements must comply their functional activity. Synthesis of each zone is not only to determine the size of the overlap, but also on the degree of their use. It is necessary to maximize the zones while minimizing depletion of the production system.

The synthesis of each zone is preferably solved graphically, showing the availability and penetration of elementary zones. The results of synthesis are used in processing technology disposition which clearly identifies all the elements and their spatial arrangement.

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An important parameter in the synthesis of single-wall solutions zones elements is the degree of overlap and handling technology zones. Increasing the degree of spatial overlap leads to minimizing the assembly system. To rate coefficient can be used overlay. Is the ratio of the size of the overlap of technology and handling zone to the size of the technology zone: 

$$k_p = \frac{P_P}{P_S},$$

where $k_p$ is the coefficient overlap and values $P_P$ and $P_S$ are calculated using double integrals.

Coefficient maximum overlap is 1. This is where the entire cross-sectional area of technology is located in handling cross-section area. This may in practice occur only rarely, because the size of overlap is dependent on many factors, such as the shape and dimensions of technological and handling areas. Overlap factor can be used in evaluating the synthesis of several variants.

For modeling spatial relationships in production systems are also important geometric characteristics of each wall solutions components manufacturing systems. Determining for addressing spatial relationships these basic geometric characteristics:

- external shape and dimensions of the elements wall solutions,
- maximum dimensions of workspace,
- orientation and position of the coordinate system of the building element with respect to the reference coordinate system,
- geometrical characteristics workspace.

**External shape and dimensions** of the production facilities is a bounded space filled with various structural elements of the device. In terms of stability over time it is possible to distinguish between stable and mobile elements of the production facilities.

**The maximum dimensions** of the system are defined maximum space defined by stationary and portable items of equipment (the maximum extension of mobile elements under consideration in all permissible directions).

**Position and orientation** of the device coordinate system is defined by the position of the start point of the coordinate system of the device in relation to a reference coordinate system.

**Workspace facility** represents the set of all points of the reference area undergoing some functional activity. This space is bounded also referred to the concept of working zone of the machine. Since the working zone is one of the key characteristics for addressing spatial relationships in assembly systems, it is appropriate to distinguish the characteristics of the work area.

**Conclusion**

The proposed models of relationships wall solutions components assembly systems provide the possibility of such deployment optimization problems. Models of topological relations in assembly systems are characterized by considerable versatility in terms of application conditions, as they are suitable for design automation, but also traditional assembly systems.

**References**


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