A BRIEF METHOD FOR MODULAR DESIGN OF RECONFIGURABLE MULTIFUNCTIONAL MACHINE TOOLS

Prof. DSc Guergov, S.
Technical University - Sofia , Bulgaria

Abstract: The paper presents a brief method of structure generation reconfigurable multifunctional machine tools. The design method and the machine concept in the paper have been developed at the Technical University of Sofia. The suggested machines can do different machining operations (e.g. turning, grinding, drilling, milling etc.) can realize a complex technological process for machining rotation and prismatic parts and combining the advantages of different machine tools in a single unit.

KEYWORDS: RECONFIGURABLE MACHINE TOOLS, MULTIFUNCTIONAL MACHINE TOOLS, DESIGN METHOD

1. Introduction

The concept of rapid adjustment to the market requirements is initiated in 1991 [5,10], which reflect on the development of production techniques and the appearance of the idea of reconfiguration in two directions basically:

• combining of maximum number of different machining operations in a single unit [2,3,9];
• developing of reconfigurable machines [4,6].

A new generation of production machines capable of reconfiguration of their structure in order to adjust the machine to the requirements of the production task appears in the last 15-20 years.

Reconfigurable production systems require a new design approach on systems and machine level also. The key core moments by these approaches are connected with:

• development of basic principles and methods for design and analysis of reconfigurable machines and systems;
• design and development of Reconfigurable Machine Tools (PMT) models, responsible of the key characteristics for reconfiguration (modularity, scalability, inerrability, convertibility, diagnostic ability and customization).

The investigations in this area [4,7], determine that the reconfigurable production has the highest priority for future investigations in the field of machine-building, and the reconfigurable machine tools are estimated as a key challenge until 2020.

Drawing a conclusion from the mentioned above, the object of the paper is development of a method for generating of structures for reconfigurable machine tools with possibilities for concentration of more technological operations and machining of different parts (rotation, prismatic and complex work part (CWP) combining prismatic and rotation surfaces) on a single machine. The model of RMT is used as a base of this method, and developed in [1].

2. Prerequisites and ways of solving the problem

Based on the methodology developed for creating the RMT in [1], including technological analysis of the production task and selected modules, a multifunctional machine tool with possibilities for reconfiguration of its structure is synthesized (Fig.1).

Because of the big variety of work parts, operations and modules in multifunctional machines, it is necessary to choose the relevant optimal structure of the machine for the accomplishment of an effective technological process, which permits to:

1) Processing of different type details - rotation parts (RP), prismatic parts (PP) or in combination;

2) Realization of an effective technological process with possibilities of maximal concentration of technological operations;

3) Using the advantages of the relevant machine structure by means automatic reconfiguration, in order to position and set up the work part in optimum.

The machine has the possibility of processing both rotation and prismatic parts or a combination between them, as follow:

• one RP (L/D>5);
• one RP (L/D<5);
• one PP;
• one complex work part combining both prismatic and rotation surfaces;
• two RP (L/D<5);
• two PP;
• one RP (L/D>5) and one PP;
• one RP (L/D<5) and one PP.

The object of the present investigations is connected with the developing of a method for composing of multifunctional reconfigurable machine tools that use the same modules.
Assuming all the necessary cutting motions of RP, PP and CWP (Table 1) and the matrix \( \{ M \} \), as vector is defined and available for the different modules,

Where

- \( d \) is the direction of the respective coordinate axis;
- \( p \) - the contact surface of the modules, corresponding to the contact surfaces on the machine body (Fig.2).

Table 1: Necessary movements and coordinates for the processing

<table>
<thead>
<tr>
<th>Rotation parts (L/D&gt;5)</th>
<th>Rotation parts (L/D&lt;5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Rotation parts" /></td>
<td><img src="image2" alt="Rotation parts" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prismatic parts</th>
<th>Complex work parts</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Prismatic parts" /></td>
<td><img src="image4" alt="Complex work parts" /></td>
</tr>
</tbody>
</table>

In order to define the optimal machine version it must be considered:

- the type of work part (Table 1);
- the type of composing machine according the position of the main spindle unit – horizontal, vertical or at a random angle \( \phi_z \);
- the number of simultaneously machined sides of the work part \( \{ \phi_x, \phi_z \} \);
- the number of necessary tools and their position of placement – in turrets or in the spindle unit chuck \( \{ \phi_x, \phi_z \} \);
- the number of simultaneously machined work parts \( n \).

Based on the above mentioned prerequisites, moving directions and analysis of the generated variants in [1] the Table 2 is composed.

The table includes the modules for the different machine variants depending on the machined work part/s.

The composing modules for the different machine variants are divided in three groups:

- \( S \) includes constant modules (machine body 1, sector 4 with linear and circular slideways for extending the circular \( a \) and linear \( b \) slideways, instrumental drum-magazine 4, robot for services the turrets with tools from magazine 5, tool and gripper change magazine 13 for robot 15, industrial robot for loading the rotational work pieces and tools) connected with the ability of working in a fully automated environment for all subsidiary operations.

The structure of the machine \( S_i \) for different variants can be represented with the following formula:

\[
S_i = m_c + m_j + m_i, \quad \text{where } i = 1, \ldots, 9; \quad j = 1, \ldots, 3 \quad \text{ or } \quad 4, \ldots, 9.
\]  

(1)

Example: Composing of a RMT for simultaneous machining of two PP.

In this case dependence (1) becomes:

\[
S_{1-6} = m_c + m_{j-6} + m_{i-6}.
\]

(2)

As the composed modules according to Table 2 are as follows:

a) for modules \( m_1 = m_2, m_3, m_7, m_k, m_16 \);

b) for modules \( m_j = m_9 \);

a) for modules \( m_c = m_{1}, m_4, m_5, m_6, m_{13}, m_{15} \).

The general appearance of the machine for the variant \( S_6 \) is like the one shown on Fig.3.
<table>
<thead>
<tr>
<th>i</th>
<th>Work part/s to be machined</th>
<th>MODULES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Options for the variant</td>
<td>Obligatory for the variant RP/PP</td>
</tr>
<tr>
<td></td>
<td>$m_i$</td>
<td>$m_j$</td>
</tr>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image10.png" alt="Image 10" /></td>
<td><img src="image11.png" alt="Image 11" /></td>
</tr>
<tr>
<td>5</td>
<td><img src="image13.png" alt="Image 13" /></td>
<td><img src="image14.png" alt="Image 14" /></td>
</tr>
<tr>
<td>6</td>
<td><img src="image16.png" alt="Image 16" /></td>
<td><img src="image17.png" alt="Image 17" /></td>
</tr>
<tr>
<td>7</td>
<td><img src="image19.png" alt="Image 19" /></td>
<td><img src="image20.png" alt="Image 20" /></td>
</tr>
<tr>
<td>8</td>
<td><img src="image22.png" alt="Image 22" /></td>
<td><img src="image23.png" alt="Image 23" /></td>
</tr>
<tr>
<td>9</td>
<td><img src="image25.png" alt="Image 25" /></td>
<td><img src="image26.png" alt="Image 26" /></td>
</tr>
</tbody>
</table>
3. Conclusion

1. A brief method for structure generation of reconfigurable multifunctional machine tools for machining, separately (one by one) or in simultaneously, of rotation, prismatic and complex work parts, or on a single machine is being suggested.

2. The composed structures of the machine can do different machining operations (e.g. turning, grinding, drilling, milling etc.).

3. The composed structures of the machine have possibilities for working in the field of fully automated environment.

4. References

1. Гергов, С. Методология за изграждане на реконфигуриращи се многооперационни системи за механично обработване, Дисертация за присъждане на научната степен „д.т.н.”, ТУ – София, 2007, стр.263


