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Development of a Robotic Complex for the Manufacture of Parts Used in Civil Engineering

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Abstract

The article proposes a methodology for the development of a robotic complex for the manufacture of building parts. An analysis was carried out to select the most preferable option for the layout of the robotic complex and the option was selected using the method of the resulting quality indicator, consisting of an industrial floor robot, a mechatronic lathe and a storage device. Requirements for the manufacture of parts using the SolidWorks computer-aided design system (finite element method). The optimal robotic device was selected using the hierarchy analysis method, which could perform tasks related to loading and unloading parts into the machine. Auxiliary equipment was selected for the safe operation of the robotic complex - sensors and protective columns that would meet the standards of modern production of parts. Graphic materials were developed for a ready-made robotic complex consisting of a floor robot, a mechatronic lathe and a storage device, taking into account safety precautions at the workplace.

Keywords

Computer-aided design system, layout of machine equipment, mechatronic machine equipment, robotic complex

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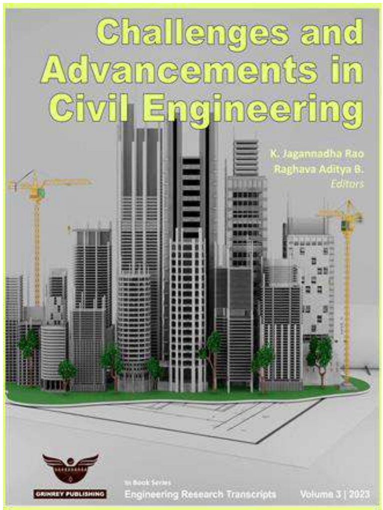


1. Introduction

The modern production of manufacturing parts for construction work must comply with the trends that set the following tasks: increasing productivity [6, 10, 12] [1-3], increasing the accuracy of processing, as well as expanding the functionality of technological equipment [5, 7, 13] [4-6] through the introduction of new technological solutions [4, 9, 14][7-9].

Modern construction cannot be imagined without the use of details [15, 17, 22][10-12]. These simple, at first glance, structural elements are indispensable in the construction of residential buildings, shopping and office centers, sports facilities, public buildings and workshops of industrial enterprises [18, 20, 21][13-15].

For quick and reliable delivery of the required parts used in construction, a modern solution for the manufacture of these parts [16, 19, 23][16-18] is required. That is why a methodology for the development of a robotic complex for the manufacture of building parts is proposed. This solution is the most reliable and efficient [24, 26][19-20].

The purpose of this work is to develop a robotic complex for the manufacture of parts used in the construction of various types of buildings and structures.

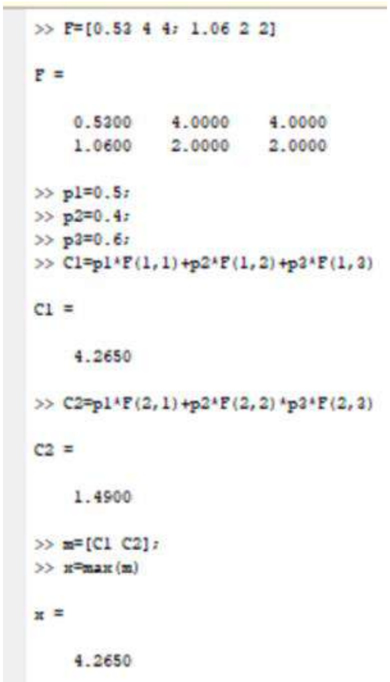
The initial stage in the course of introducing new technological equipment is the technical development of the proposal.

2. The Choice of the Layout of the Robotic Complex

This section describes the information about the structure of the article. The initial part of the manuscript should consist of a concise article title, name of the authors with **affiliation, abstract and keywords**. Further the manuscript text can be divided into different numbered sections such as,

To design a robotic complex, you must first choose its optimal layout using the method of the resulting quality indicator, namely the additive criterion. The essence of this criterion is to obtain the objective function by adding the normative values of particular criteria [3, 11, 25][21-23].

The calculation by this method using the Matlab system is shown in Fig. 1.


```
>> F=[0.53 4 4; 1.06 2 2]

F =

    0.5300    4.0000    4.0000
    1.0600    2.0000    2.0000

>> p1=0.5;
>> p2=0.4;
>> p3=0.6;
>> C1=p1*F(1,1)+p2*F(1,2)+p3*F(1,3)

C1 =

    4.2650

>> C2=p1*F(2,1)+p2*F(2,2)*p3*F(2,3)

C2 =

    1.4900

>> m=[C1 C2];
>> x=max(m)

x =

    4.2650
```

Fig. 1. Calculation of the layout of the robotic complex in Matlab

The program has chosen the value corresponding to the first variant of the layout of the robotic complex - a floor robot + 1 machine.

3. Choosing an Industrial Robot

To justify the choice of an industrial robot, we will use the Hierarchy Analysis Method (HAI) [27, 30, 33][24-26]. This method consists of building hierarchies, where at the top is the goal (in our case, an industrial robot), in the middle are the criteria for choosing a robot (E21-technical indicators, E22 - maintenance of the robot and E23 - economic indicators) and at the bottom level alternatives are presented to achieve the set targets (A1 – Eidos Robotics (ER) industrial robot, A2 – KUKA industrial robot, A3 – FANUC industrial robot). A notation is also introduced, where E are the evaluation criteria, A are alternatives for solving the set goal.

The hierarchy of industrial robot selection is shown in Fig. 2.

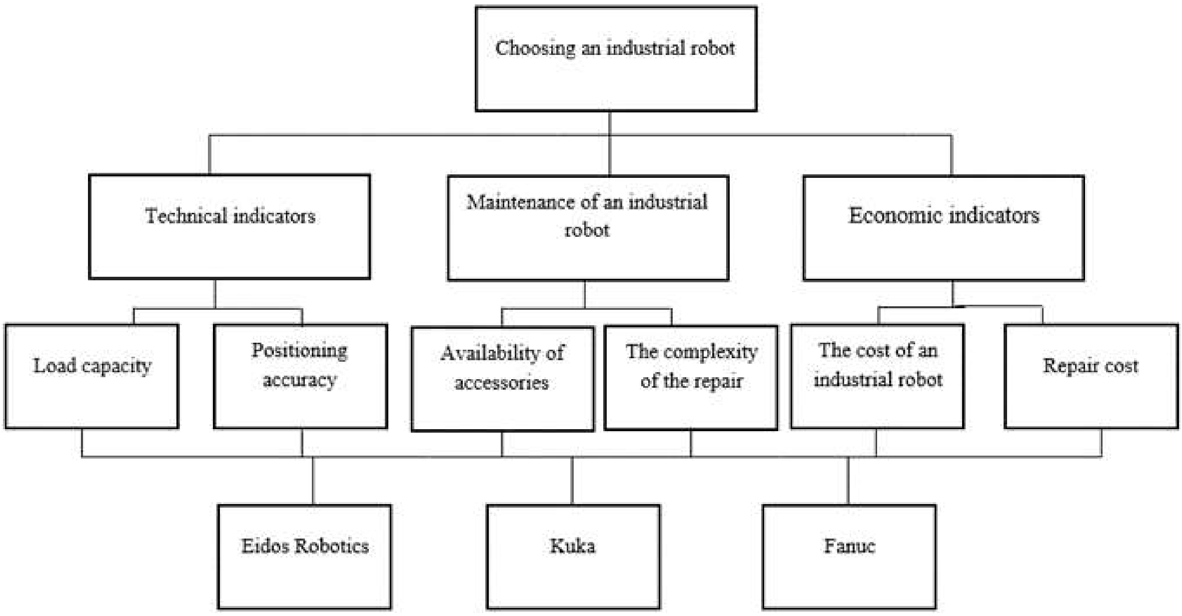


Fig. 2. Hierarchy of industrial robot selection

After the analysis, it can be concluded that the most preferable option is to choose an industrial robot from ER.

4. Choice of Machine Layout

Because for the manufacture of parts for construction, the executive movements of lathes and milling machines are required, then a lathe with the ability to perform milling model 200HTP is selected.

To improve the dynamic characteristics of the machine, it is required to analyze the possible layouts of the designed machine [1, 28, 29][27-29]. Possible layouts of the machine are selected according to the theory of Yu.D. Vragov and highlights possible workable options presented in Table 1.

Table 1. Machine layout options

Considered layout	
cOXZ	cXZO
cOZX	cXOZ
cZOX	cZXO

As you can see from tables 1, the most preferred options for machine layouts from a design point of view and the execution of the required executive movements are the layouts cOXZ and cZOX.

During the analysis, the SolidWorks Simulation program was used to solve problems by the finite element method (FEM). The finite element method is a grid method designed to solve micro-level problems, for which the object model is given by a system of partial differential equations with given boundary conditions [2, 31, 32][30-32].

Comparing the results of studies of layouts according to the graphs (Fig. 3), we see that the rigidity of the second layout is higher than that of the first layout.

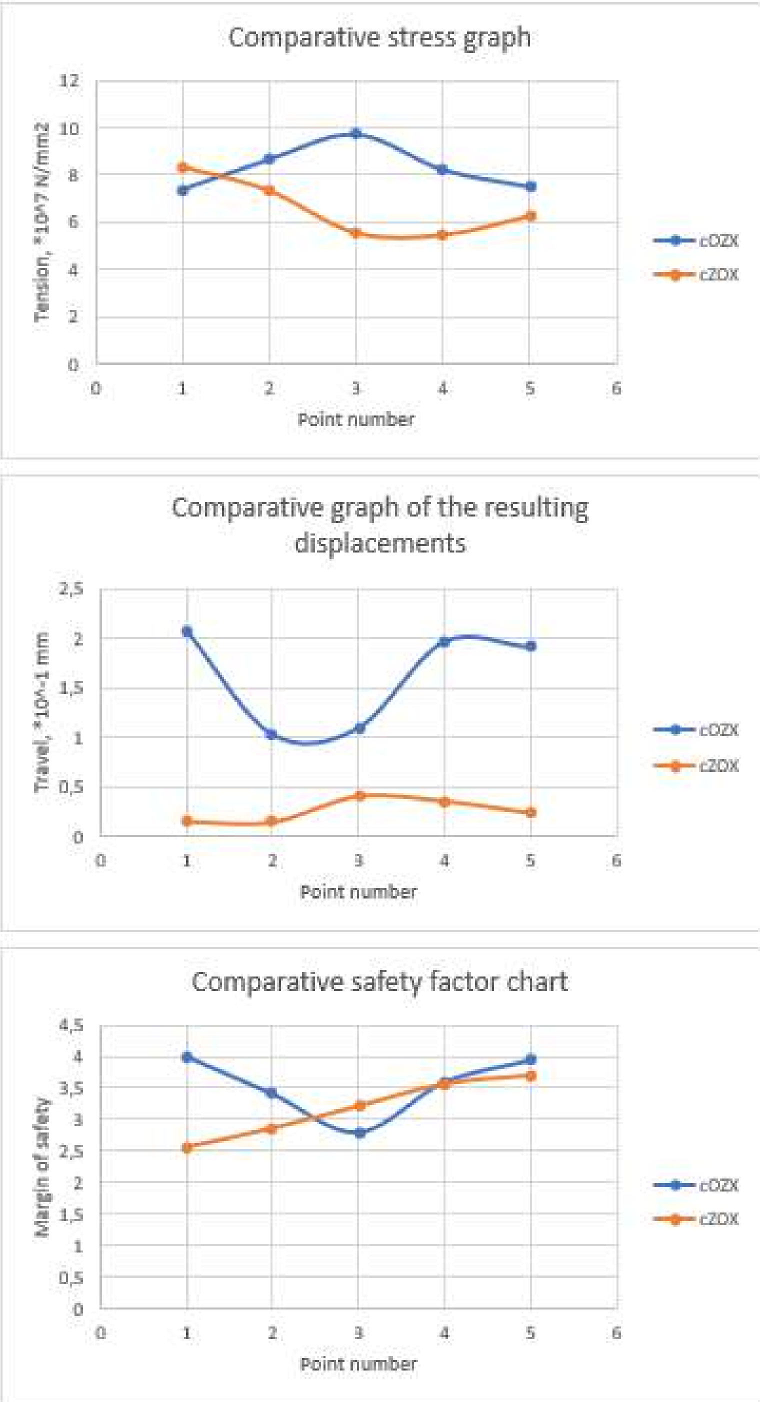


Fig. 3. Plots comparing cOZX and cZOX

We choose cZOX layout, since it is better in terms of static stiffness criteria and simpler from a constructive point of view.

5. The Choice of Sensors for the Safe Operation of the Robotic Complex

Instead of using protective barriers, the security of the robotic complex can be achieved with a simple combination of a pair of light curtains and mirror columns. The mirror columns reflect the beams of the light curtains in such a way that one pair of light curtains is enough to control all three sides for access. This allows not only to provide access control to the hazardous area, but also to rationalize the use of space, reduce costs and installation time [8, 34, 35][33-35].

For the developed robotic complex, columns were chosen, located on 4 sides around the complex for positive protection and uninterrupted operation of the machine and robot.

6. Development of Design Documentation

The development of design documentation includes taking into account all the requirements for the operation of the robot and the machine, as well as taking into account safety requirements, because people are working nearby.

The developed documentation for the robotic complex, consisting of a machine tool, a floor robot and a storage device, is shown in Fig. 4.

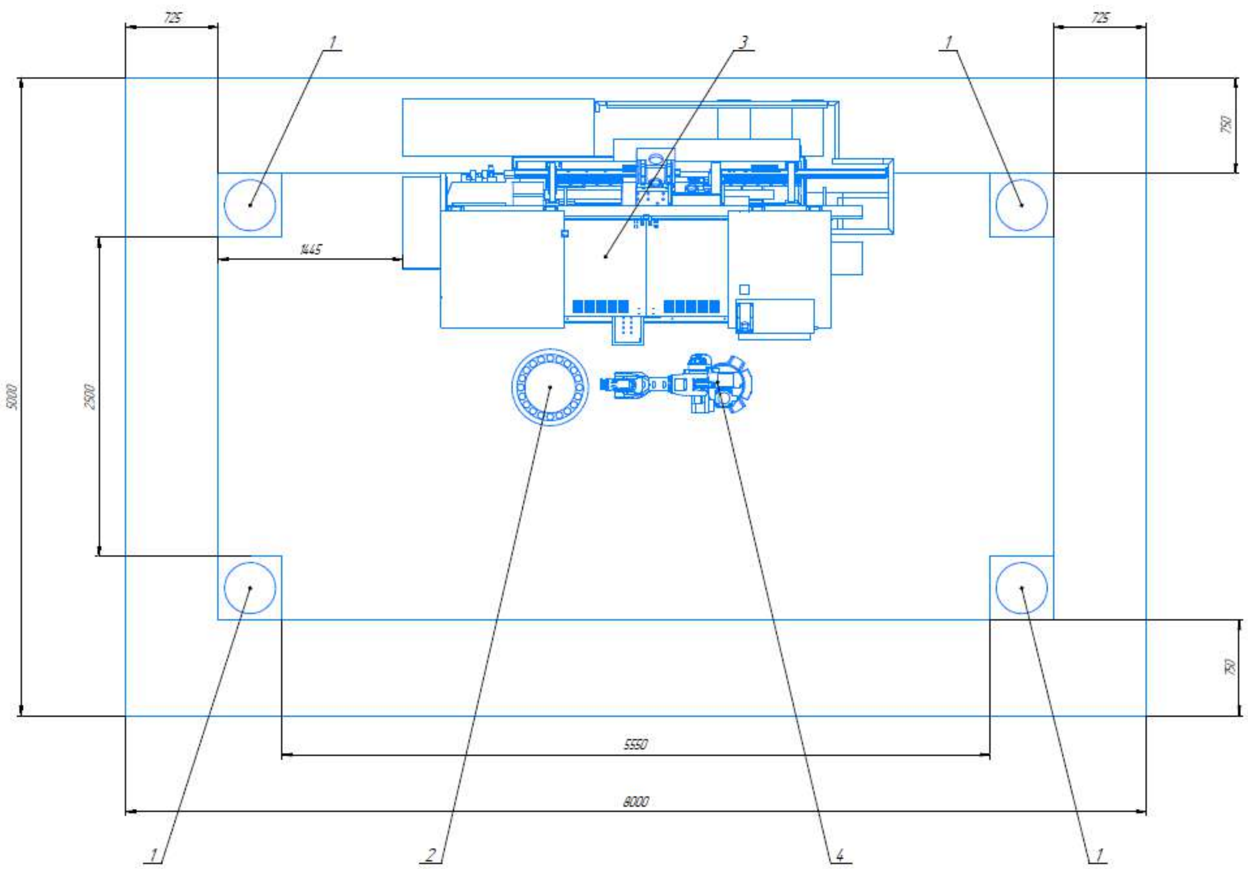


Fig. 4. Sketch of the layout of a robotic complex for the manufacture of parts for construction 1 - columns with sensors; 2 - storage device; 3 - machine; 4 - industrial robot

This design solution reflects all modern trends in the manufacture of parts not only in the construction area, but also in adjacent areas.

7. Conclusion

In the course of this work, a robotic complex was developed for the manufacture of parts for the construction industry.

The optimal robotic device for unloading and loading parts into the machine was selected, which is a floor-standing industrial robot.

A machine was selected from a variety of different layouts that would satisfy the requirements for the manufacture of building parts, and with the help of the CAE system and the finite element method, the optimal layout of mechatronic machine tool equipment was selected - cZOX

The security sensors of the robotic complex were selected, which with 100% probability would allow the complex to work without failures due to the human factor.

Design documentation for the robotic complex was developed, based on the previously selected layout of the robotic complex, consisting of a floor robot, a machine tool and a storage device, which took into account all the operational properties and safety standards of the designed complex.

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