DESIGNING A ROBOTIC COMPLEX FOR EFFICIENT BUILDING PART MANUFACTURING: A METHODOLOGICAL APPROACH

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ABSTRACT

To improve the efficiency of producing building parts, these abstract lays forth a methodology for developing a robotic complex. The suggested approach incorporates several design factors, such as the latest developments in automation, robotics, and material science. Through the coordination of these components, the complex strives to reduce production costs, maximize efficiency in resource usage, and simplify manufacturing processes. Iterative prototyping, collaborative multidisciplinary design teams, and thorough feasibility assessments are key components of the technique. The importance of using sophisticated robots for complex jobs is highlighted in the abstract, as it guarantees industrial processes are precise, fast, and scalable. Also, by using eco-friendly materials and energy-efficient procedures, it stresses the significance of sustainability. By providing a solid foundation for the creation of very efficient and versatile robotic complexes, the suggested method aspires to transform the production of building parts.

Keywords: *Robotic Complex; Layout; Industrial; Automation; Manufacturing.*

INTRODUCTION

The use of robots has become a game-changer in the industrial sector, which places a premium on efficiency, speed, and accuracy. The use of automation and robots is on the rise in many industries throughout the world. This is because these technologies allow businesses to increase output while decreasing expenses and staying competitive in a dynamic market. When it comes to producing building parts, robots has a lot of promise. Building elements, from structural components to complex fittings, need a careful balancing act of technical accuracy, material science, and efficient operations. Due to the need for high-quality components, short production cycles, and design flexibility, traditional manufacturing processes often fall short of satisfying the expectations of contemporary building projects. In light of these difficulties, scientists and engineers are looking into new ways to radically alter the production of building parts; one such way is the development of robotic complexes. From homes to businesses to public works projects, the construction sector designs and constructs a vast diversity of structures that make up our built environment. Manufacturing building parts, which includes the fabrication of components including beams, columns, panels, and fittings, is essential to the construction process. Traditional machining processes and human labor have been the backbone of building component manufacture for a long time, but they have their limitations when it comes to scalability, consistency, and efficiency. Robots have revolutionized production by bringing efficiency, accuracy, and reproducibility to previously unimaginable levels. Robotic systems that include state-of-the-art sensors, actuators, and control algorithms are perfect for automating production processes since they can do a wide variety of jobs quickly and accurately. Robotics integration has been on the rise in several sectors in recent years, with the automotive, aerospace, electronics, and healthcare sectors being among the most prominent. Robots have great promise in the construction industry, but they have not yet reached their full potential in this area. Several obstacles prevent the widespread use of automated solutions in the construction industry's component production process, notwithstanding robots' potential. The wide variety of building components, each with its own unique design and set of requirements for production, is a major challenge. Manufacturing systems in the construction industry must be adaptable in order to satisfy the ever-changing demands of projects, since building components are highly tailored to match the particular needs of each one. The wide variety of building materials, from time-honored staples like wood, steel, and concrete to more modern options like composites and sophisticated alloys, presents still another obstacle. It is difficult to build robotic systems that can function with a broad variety of materials because each material has its own unique qualities, processing needs, and environmental issues. Additionally, there are logistical issues with handling and transporting construction components because of their size and scale. Modular assemblies and prefabricated panels are examples of large-scale components that increase production complexity due to the specialized equipment needed for their assembly and installation.

REVIEW OF LITERATURE

Luo, Dan & Yu, Lei. (2021) One way to save money, time, and materials is to deploy construction robots, which are becoming more common on the job site. Using robots on-site has several benefits, such as accurately transforming digital designs into physical form, making bespoke building components easier to integrate with the construction management process, and most importantly, providing a solution to the worldwide problem of an aging construction workforce. The need for an interdisciplinary approach and site-specific difficulties with space and time limitations are two of the obstacles to deploying these robots on-site. We provide three comprehensive case studies that illustrate the use of on-site robots in three different construction processes: concrete casting, bricklaying, and steel structure assembly. Although there are many benefits to using these robots, humans will still need to be creative and provide input so that the technology can adapt to the wide range of site conditions, such as changing design and material needs and the complex web of social interactions that exists on a construction site.

Gaponenko, E et al., (2020) The paper presents a method for designing six-DOF robotic complexes that can process complex parts. These complexes consist of a base, a module for installing tools, and a module for processing parts placed on top. The complexes are constructed using parallel structure mechanisms and can be controlled by the Teamcenter PLM system using CAD/CAM/CAE of the NX system. A tentative complicated composition for higher level assembly components was constructed using the terms of reference and draft documentation. The steps for creating a digital representation of a robotic complex are laid forth. The foundation for developing different types of robotic complexes was laid with the development of a fully parameterized control framework. Because all modifications are performed to one portion of the product, which includes numerous versions, this technique simplifies the process of making changes and reduces the difficulty of building comparable complexes. Several iterations of robotic systems are shown using the established design process. A method for determining the assembly's strength is introduced. It is shown that the best outcome is only attainable via the integration of design and calculation techniques.

Dritsas, Stylianos & Soh, Gim. (2018) We lay out the factors and design criteria that should be considered while creating construction robotic systems. We have identified three ways for integrating industrial robotics: (a) off-site prefabrication systems; (b) on-site mobility platforms; and (c) embedded designs enabling adaptive integration onsite. The architecture of our mobile platforms is the primary subject of this article. Our goal is to shed light on the difficulties inherent in those systems' designs and provide solutions that could lead to better designs in the future and more widespread use of robots in the building process. Overcoming the present limits of industrial-oriented robotic systems is the first step in addressing applications in building construction. This suggests a greater capacity for adaptability and speed in handling a wide range of jobs, even when faced with unpredictable external factors. Our work is focused on developing new case studies and building pieces, including software and hardware components, for an end-production model that will soon revolutionize architectural design thinking and manufacturing.

Bazhanov, Alexander et al., (2016) Building printing and the evolution of robotic complicated control systems are detailed in this essay. The authors provide a method for the creation of a control system for a 3D printer with a gantry-type architecture that can travel on tracks based on a study of current techniques. The authors completed the control system model and verified its functionality. For studying how the various parts of the system work, it has a Petri net graph. When failure or obstacle sensors are activated, the control system may use this method to avert emergencies in real-time. In addition, the end effector-mounted laser distance sensor allows for consistent printing control and the appropriate positioning error within 10 mm. In order to evaluate the effectiveness of the main movement module's control algorithm, the authors created a Matlab simulation model of the control system and investigated the response to safety sensor triggering and extruder positioning errors. The model verifies that the suggested method might be used in a real-world device.

Manion, Charles et al., (2015) A space-based robotic manufacturing facility that can replicate itself is the subject of this research, which takes a Multiagent Systems-based approach to the design process. Because of their complexity and the need to coordinate several operations, self-replicating systems are notoriously difficult to regulate. This study introduces a novel idea for a space-based robotic manufacturing that makes use of Multiagent Systems. In particular, a method for coordinating a self-replicating system's conceptual model is detailed. The simulation begins with the arrival of a group of agents on a planet that is not yet known; these basic agents will then use the regolith they collect from the planet's surface to grow into a factory that can reproduce itself. The National Aeronautics and Space Administration (NASA) is funding space exploration missions that may one day visit other planets, asteroids, or satellites in search of useful resources. The project's main obstacle is developing a learning algorithm that can improve productivity by allowing several agents to work on tasks simultaneously. By adjusting the settings of the learning algorithm, this study's simulation shows how the agents work together to build the factory. A approach that is pre-programmed uses local and difference incentives to assess the system's performance. The results demonstrate the benefit of including a learning algorithm into the robotic factory construction process.

Bier, Henriette et al., (2014) Research into design-to-production solutions for robotically driven building construction was launched in 2014 within the 3TU Lighthouse framework by the faculties of Civil Engineering and Architecture, TU Delft, and Architecture, TU Eindhoven. The project is known as Robotically Driven Construction of Buildings (RDCB). By bringing together experts in robotics, materials science, structural design, and architecture, we hoped to create new numerically controlled manufacturing techniques and building-design optimization methods that would allow us to creatively enhance buildings while keeping costs down and minimizing environmental impact. This article details the work done by the Hyperbody, Faculty of building, TU Delft Robotic Building team on the RDCB project, which expands on Hyperbody's knowledge of robots in building. This contribution is in keeping with Europe's goal of making buildings more efficient in terms of both energy use and the materials used to create them. The use of tailored building materials and robotically driven construction might make this a reality at a lower cost while also lowering the risk of accidents and health problems for construction workers. For this purpose, RDCB is delivering supplies on an as-needed basis. To do this, one must investigate several approaches, which necessitates the use of tailored materials and procedures, in order to determine the optimal ways to apply materials according to the reasoning behind certain force flows or patterns of heat dissipation. RDCB develops novel building systems for the on-demand creation of customizable building components, advancing multi- and trans-disciplinary expertise in robotically driven construction. The most important thing to keep in mind is that the future of manufacturing in the construction industry will rely on building materials and components that can be processed and assembled robotically on-site.

THE CHOICE OF THE LAYOUT OF THE ROBOTIC COMPLEX

The article's framework is detailed in this section. In the first section of the document, you should provide a brief title, authors' names and affiliations, abstract, and keywords. It is also possible to split the document into parts with various numbers, for example

Using the additive criteria as a quality indicator, the best arrangement for a robotic complex may be chosen during the design phase. Finding the objective function by summing the normative values of specific criteria is the crux of this criterion.

Figure 1 displays the results of the computation performed using the Matlab system.

```
>> 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 value that corresponds to the first variation of the robotic complex's architecture — a floor robot plus one machine — has been selected by the algorithm.

CHOOSING AN INDUSTRIAL ROBOT

We will use the Hierarchy Analysis Method (HAI) to back up the decision to utilize an industrial robot. Using this method, hierarchies are constructed with the goal (an industrial robot in this case) at the top, criteria (E21-technical indicators, E22-robot maintenance, and E23-economic indicators) for choosing a robot at the middle, and alternatives (A1-Eidos Robotics (ER) industrial robot, A2-KUKA industrial robot, and A3-FANUC industrial robot) presented at the bottom. Also proposed is a notation where E denotes the evaluation criteria and A stands for the alternatives to the goal-solving set.

Figure 2 shows the selection hierarchy for industrial robots.

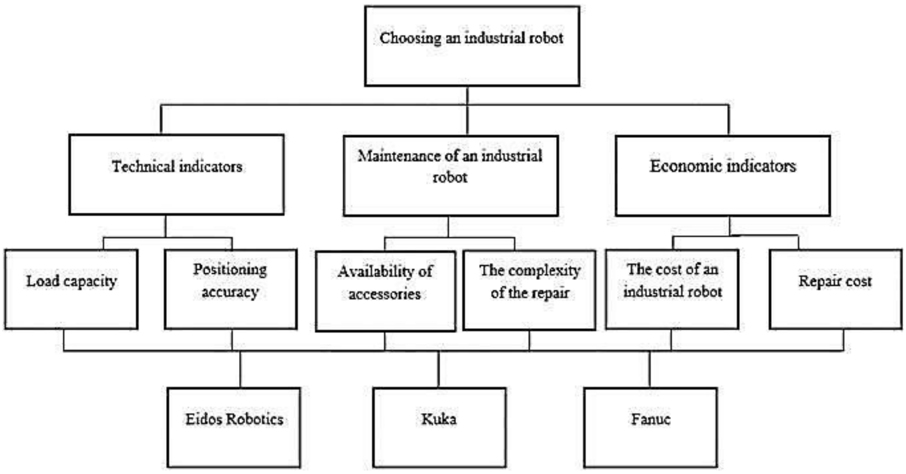

Fig. 2. Hierarchy of industrial robot selection

A conclusion drawn from the study is that an industrial robot from ER is the best choice.

CHOICE OF MACHINE LAYOUT

Manufacturing building components necessitates the use of lathes and milling machines, thus a lathe capable of milling, model 200HTP, is chosen.

The machine's dynamic properties may be enhanced by investigating various machine configurations. Yu.D. Vragov's theory guides the selection of machine configurations, which in turn emphasize feasible alternatives shown in Table 1.

Table 1. Machine layout options

Considered layout	
cOXZ	cXZO
cOZX	cXZO
cZOX	cZXO

From a design perspective and in terms of carrying out the necessary executive motions, the two most recommended machine configurations are cOXZ and cZOX, as shown in tables 1.

The investigation relied on the finite element method (FEM) solutions provided by the SolidWorks Simulation application. A system of partial differential equations with stated boundary conditions provides the object model for the grid-based finite element technique, which is used to address micro-level issues.

When we compare the findings of the layout studies using the graphs in Figure 3, we can see that the second pattern is more stiff than the first.

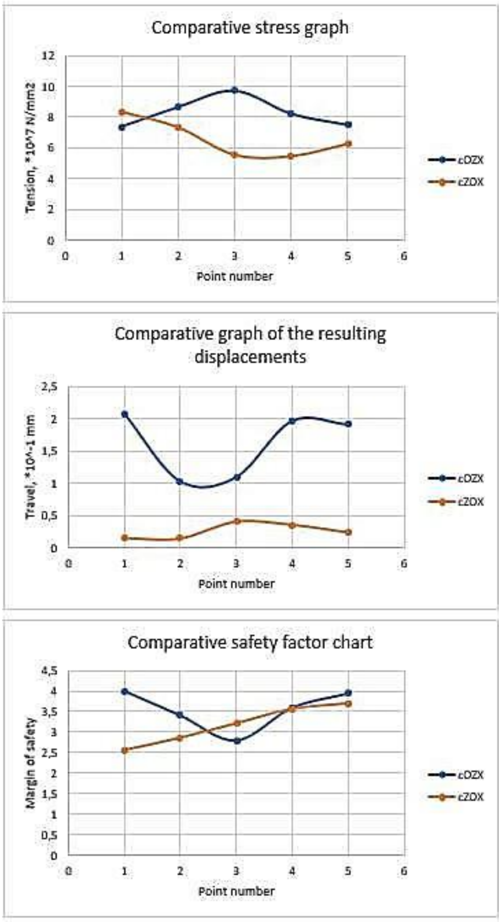

Fig. 3. Plots comparing cOZX and cZOX

Since the cZOX architecture is easier to produce and meets the static stiffness criterion better, we have decided to use it.

DEVELOPMENT OF DESIGN DOCUMENTATION

While creating the design documentation, it is important to think about how the robot and machine will perform, as well as any safety concerns that may arise from having humans working in close proximity.

Figure 4 shows the established paperwork for the robotic complex, which includes a machine tool, a floor robot, and a storage device.

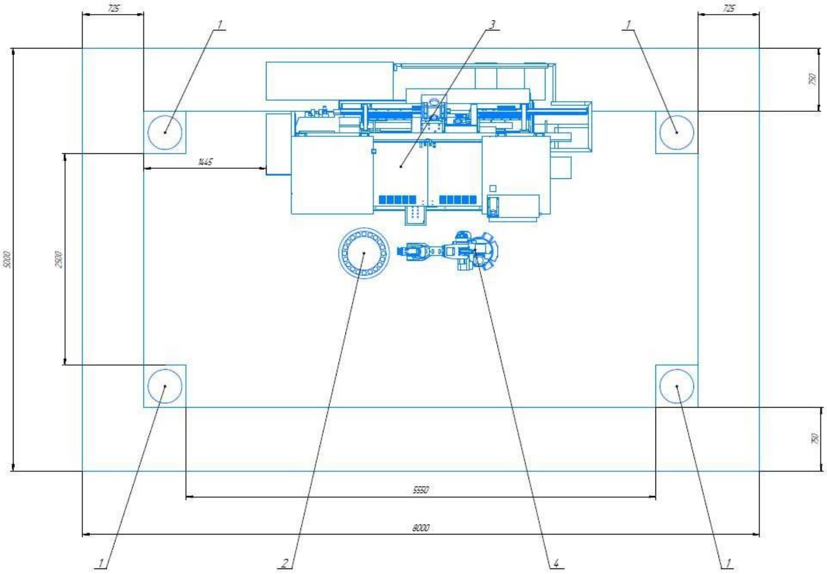

Fig. 4. Sketch of the layout of a robotic complex for the manufacture of parts for construction 1 - columns with sensors; 2 - storage device; 3 - machine; 4 - industrial robot

All the latest developments in construction and nearby regions' component manufacturing are reflected in this design solution.

CONCLUSION

Finally, a potential way to transform the production of building parts is via the development and deployment of robotic complexes. Manufacturing processes may be made more efficient, precise, and adaptable with the use of robotic complexes that combine intelligent control systems with modern robotics and automation. Robotic complexes allow for end-to-end automation by bringing together different manufacturing operations in one place. This streamlines production workflows and reduces lead times. Robotic complexes also make it easier to use data-driven optimization tactics, which make use of machine learning algorithms and big data analytics to boost efficiency and performance in real-time. Robotic complexes can maximize efficiency, reduce waste, and adjust to fluctuating market needs by using real-time feedback and predictive analytics.

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