Manufacturing Science and Education 2025

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 68, Issue Special II, July, 2025

# ROBOTIC SIMULATION FOR 3D PRINTING: DEVELOPMENT OF AN ADJUSTABLE POSITIONING FIXTURE

**Radovan HOLUBEK, Daynier Rolando DELGADO SOBRINO, Peter KRIŽAN, Mirim MATÚŠOVÁ, Peter KOŠŤÁL,**

***Abstract:*** *This research article aims to develop a robotic simulation of 3D printing for an adjustable positioning fixture, transforming it into a functional, reconfigurable system with a carefully selected component base. Using an ABB IRB 120 robot with 3D print extruder, the study optimizes the additive manufacturing process, focusing on printing parameters, structural integrity, and adaptability. Robotic 3D printing provides flexibility, reduced material waste, and the ability to create complex geometries within an extended workspace. The final fixture will enable reconfigurable part positioning, enhancing students' understanding of industrial robot programming, fixture adjustments, and interactive reprogramming based on workpiece position and robotic program modifications.*

***Keywords:*** *industrial robot, 3D printing, adjustable positioning fixture.*

## 1. INTRODUCTION

Robotic 3D printing is an innovative manufacturing method that utilizes industrial robots for additive manufacturing, providing enhanced flexibility, precision, and scalability. Unlike traditional 3D printers, robotic systems such as the angular industrial robots offer multi-axis movement, enabling complex geometries, reducing material waste, and allowing for larger workspaces. This technology is increasingly used in industries such as automotive, aerospace, and industrial automation, where high adaptability and precision are required [1].

This research focuses on the development of a robotic simulation of 3D printing for an adjustable positioning fixture, which will serve as a functional, reconfigurable system based on a carefully selected component base. The simulation is created in ABB RobotStudio, where an ABB IRB 120 robot equipped with a 3D printing extruder is used to simulate the additive manufacturing process. The primary goals of this study include:

- Optimization of printing parameters, ensuring high precision and structural integrity of the fixture.
- Simulation of robotic motion and tool path planning to explore the flexibility of robot-assisted 3D printing.
- Development of a reconfigurable fixture, allowing for interactive repositioning of the workpiece and adaptation to various robotic programs [2].

The final robotic simulation will serve both as a research tool and an educational aid for students at the bachelor's and engineering levels of study, providing hands-on experience in robot programming, fixture positioning, and interactive reconfiguration [3]. The simulation will demonstrate how the position of the fixture and workpiece can be adapted dynamically based on the requirements of the robotic program, helping students understand key principles of industrial automation and flexible manufacturing.

The expected outcome of this research is a fully simulated process of robotic 3D printing, based on which an adjustable positioning fixture is created into an automated work process [4]. The ability to reconfigure the fixture and adjust robotic programs based on workpiece positioning will be a significant contribution to automated production lines. The findings of this study will be useful for robotic process planning, fixture design, and smart manufacturing applications [5].

## 2. THE PROCESS OF CREATING 3D CAD MODELS AND DATA FOR THE ADJUSTABLE POSITIONING FIXTURE

The process of creating an adjustable positioning fixture involved developing 3D CAD models based on the envisioned final design, leading up to 3D printing or the creation of a robotic simulation [6]. This simulation was used to demonstrate how the entire printing process would be executed using a robotic kinematic structure. Throughout this process, several intermediate objectives had to be met to ensure the authors of this research article achieved the desired outcome.

### 2.1 Modeling of components

The conceptual design of the reconfigurable positioning fixture and its individual components was developed using Siemens NX software. This CAD software was selected due to its advanced modeling capabilities, which allow for precise design and parametric adjustments. The design process began with defining the structural requirements of the 3D CAD data of the adjustable positioning fixture, ensuring that each component was functionally adaptable and mechanically robust.

Each part was modeled with exact geometrical features to ensure compatibility during assembly. Particular attention was given to the joints and adjustable elements, as they are critical for the reconfigurability of the adjustable fixture. Once the design was finalized, the individual components were exported in STL format, which is widely used for additive manufacturing. These STL files served as the input for the next stage of the process G-code generation.

On the Figure 1 shows a 3D model of the base of the adjustable fixture. Using the same approach, all other 3D CAD models of the individual parts of the adjustable positioning fixture were created to assemble a complete 3D model of the fixture. The design process considered multiple reconfiguration possibilities for each serially connected part of the adjustable fixture. In addition to enabling 3D printing by the robot, the CAD design also focused on programming the industrial robot and ensuring the rapid reconfiguration of the individual axes of the IRB 120 robot which was not the subject of this research and is planned in the next stage of evaluating robotic simulation.

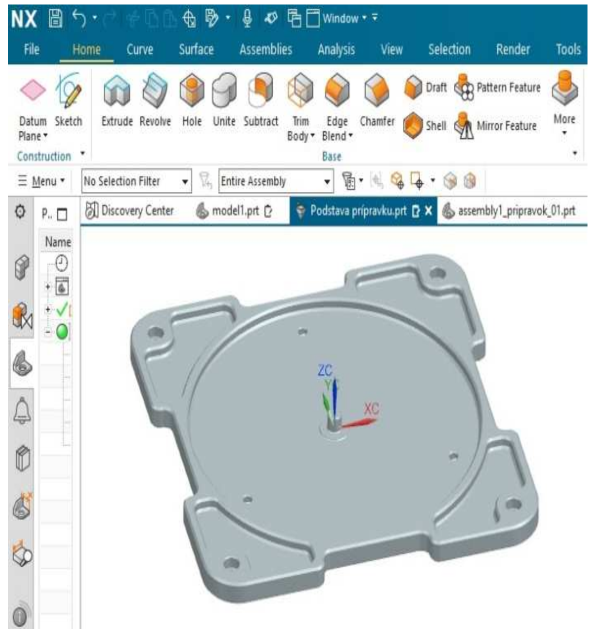


**Fig. 1.** 3D CAD model of the base of the adjustable positioning fixture

The overall 3D model of the adjustable positioning fixture is shown in Figure 2.

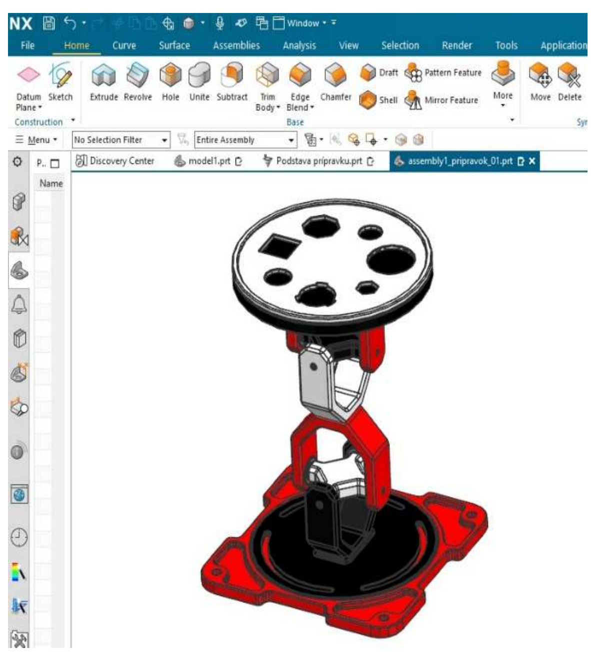


**Fig. 2.** The overall 3D model of the adjustable positioning fixture

## 2.2. G-code generation

Once the individual components of the reconfigurable positioning fixture were modelled in CAD software, the next crucial step was to generate the corresponding G-code necessary for robotic 3D printing. This process involved several key stages to ensure that the generated toolpaths were optimized for execution by the ABB IRB 120 robot equipped with a Hotend extruder.

The first step was to export the designed parts from the CAD environment in a format compatible with slicing software, such as STL (Stereolithography) or OBJ (Object file format). These formats accurately represent the 3D geometry while maintaining the necessary surface detail for slicing.

After importing the models into Repetier-Host, a slicing software commonly used for generating G-code, several parameters needed to be defined to ensure proper printing:

- Layer Height & Resolution – Determining the layer thickness to balance surface finish quality and printing time. A finer resolution (e.g., 0.2mm) produces smoother parts but increases print duration.
- Extrusion Settings – Configuring parameters such as extrusion temperature, material flow rate, and retraction settings to prevent defects like stringing or under-extrusion.
- Print Speed & Movement – Adjusting feed rates and movement speeds to ensure smooth transitions between layers while maintaining structural integrity.
- Infill Density & Pattern – Setting the internal structure of the components to optimize strength-to-weight ratio. Higher infill densities enhance rigidity, while patterns like honeycomb or grid structures improve material efficiency.
- Support Structures – If the part contained overhangs or complex geometries, support generation was necessary to prevent sagging during the printing process.
- Print Orientation – Ensuring that each part was oriented optimally for layer adhesion and minimal warping.

Once all these parameters were fine-tuned, Repetier-Host Figure 3 generated the G-code, which translates the sliced model into machine-readable commands specifying the robot's motion and extrusion control. The generated G-code was subsequently verified through simulation to ensure there were no errors in toolpath generation, such as abrupt movements or excessive extrusion that could compromise print quality.

Finally, the validated G-code files were imported into RobotStudio, where they were adapted for robotic execution. Since the ABB IRB 120 robot follows a different kinematic model compared to traditional Cartesian 3D printers, it was necessary to convert the linear G-code instructions into robotic motion commands that accounted for the robot's degrees of freedom, ensuring smooth and accurate deposition of material.

This thorough process of G-code generation and validation laid the foundation for successful robotic 3D printing, allowing for precise manufacturing of the individual parts that would later be assembled into the complete reconfigurable positioning fixture.

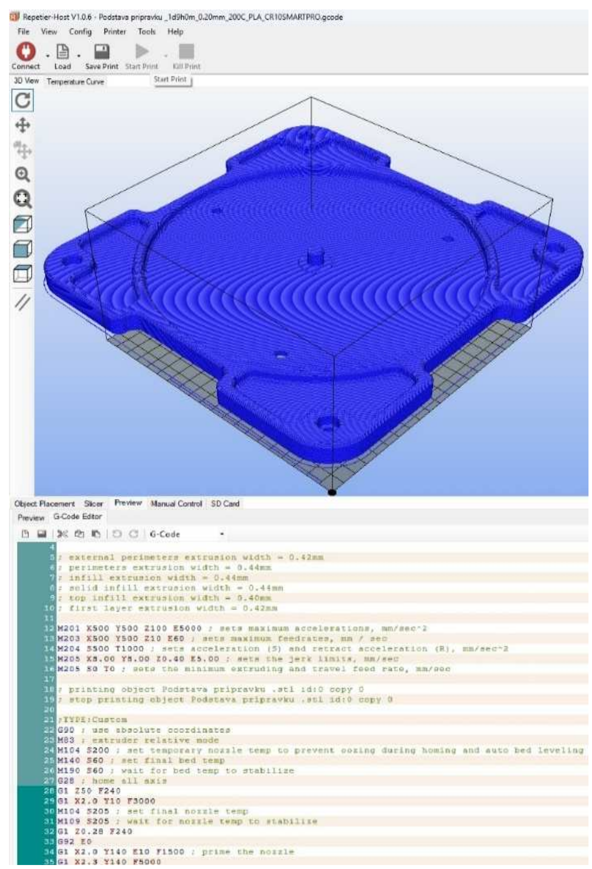


**Fig. 3.** G-code generation based on a 3D part model with additionally defined parameters

## 3. THE PROCESS OF CREATING A ROBOTIC 3D PRINT SIMULATION

### 3.1 First setup of the robotic workstation

To begin the process and setup of the robotic workstation is necessary to create a new study in RobotStudio software, defining the virtual environment where the simulation will take place. The workstation design and layouting consists of an aluminum-profiled framework of the worktable, ensuring a stable and structured working environment. Since precision and rigidity are crucial in 3D printing, the robot is mounted onto a steel plate to minimize vibrations that could compromise printing accuracy Figure 4. At this stage, all essential 3D CAD models, including the workstation, fixtures, and peripheral devices, are imported to ensure that the virtual setup mirrors the real-world robotized workstation for 3D printing.

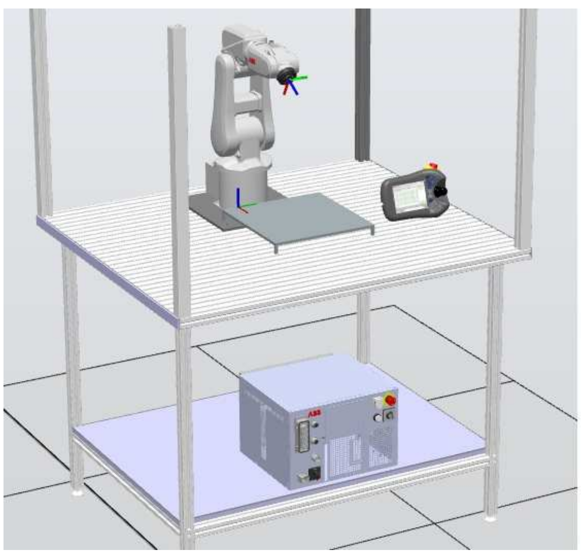

**Fig. 4.** Initial setup and positioning of the IRB 120 robot in the desired position in RS

### 3.2 Setup of the virtual controller for the 3D printing

For proper functionality, a virtual controller must be installed through Installation Manager 6 Figure 5. This controller replicates the real robotic system, allowing users to simulate movements and interactions accurately. It is necessary to select the correct firmware version compatible with the ABB IRB 120, followed by uploading a predefined or custom system configuration that includes drive parameters, kinematics, and additional settings. Once the controller is successfully installed, it is activated to verify its operational status before proceeding with further configurations.

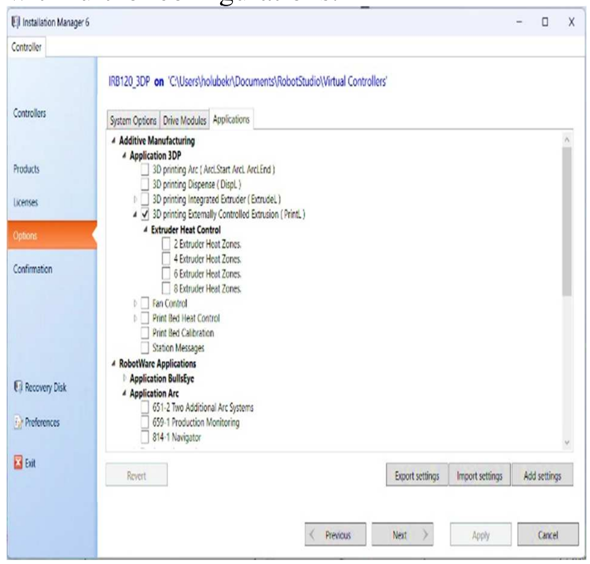


**Fig. 5.** Setup of the virtual controller of the IRB 120 robot for the 3D printing

### 3.3 Setup of the 3D printing tool

The next step involves integrating the 3D printing tool, specifically a Hotend extruder, which serves as the material deposition system. The extruder's CAD model is imported into RobotStudio from formats such as STEP or ACIS file Figure 6. Once imported, the extruder is assigned as a tool (3D printing tool) and configured with physical properties, including mass, inertia, and positioning relative to the robot flange. This setup ensures that the robot recognizes the extruder as an active tool in its motion planning.

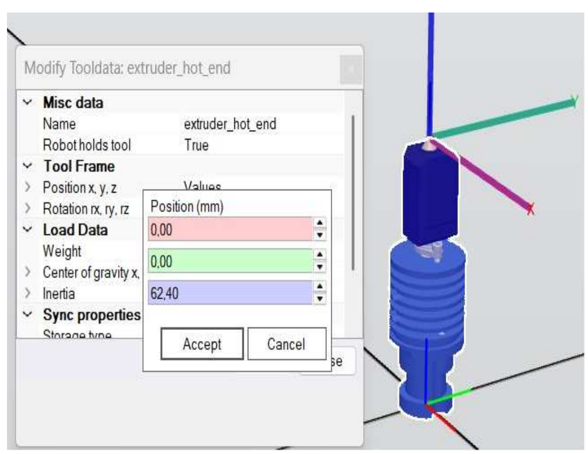


**Fig. 6.** Defining a 3D printing tool with TCP

A critical aspect of this setup is defining the Tool Center Point (TCP), which represents the precise tip of the extruder nozzle Figure 6. Proper TCP calibration is performed by selecting a reference point on the extruder and inputting accurate coordinate values. Adjustments to the tool's orientation are also necessary to ensure that material deposition occurs at the correct angles and positions. Test movements are conducted to validate the TCP configuration before proceeding with the program generation.

### 3.4 Setup of the 3D printing process for IRB120 robot

Once the robotic workstation with 3D printing extruder is set up, we can start generating the robotic program for 3D printing in RobotStudio environment. The first step is importing a pre-prepared G-code file, which contains the toolpath for the 3D part to be printed [7]. This G-code is typically generated using slicing software such as Cura, Slic3r, Prusa or Repetier etc. The imported data Figure 7 is then processed by the PowerPac 3D Printing module, converting the instructions into robotic movement commands for used robot IRB120.

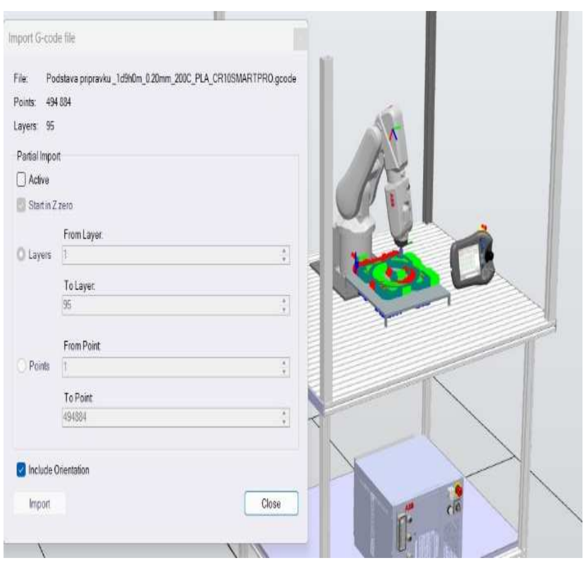


**Fig. 7.** Importing a 3D part in G-code into RobotStudio software

To ensure a smooth and accurate printing process, several key parameters must be configured within the PowerPac 3D Printing module. These include the extrusion speed, which dictates the rate at which material is deposited, and the travel speed, which controls the robot's movement between layers. Additional parameters related to motion control are adjusted to optimize trajectory planning, minimizing unnecessary movements and ensuring a consistent material flow. A preliminary simulation is performed within RobotStudio to verify the extruder path and identify any potential issues before execution. If required, modifications to the printing parameters are made, and the simulation is re-run until an optimal configuration is achieved. Only after these steps are completed can the deployment of the robotic 3D printing process be initiated.

Once the 3D printing simulation with the ABB IRB 120 robot and Hotend extruder is running, several aspects can still be monitored and adjusted to ensure optimal performance. During the process, it is crucial to observe the material deposition accuracy, ensuring that each layer adheres properly to the previous one without gaps or excess extrusion. If inconsistencies in material flow occur, adjustments can be made to the extrusion speed or temperature settings to compensate for variations in material behavior.

Another critical factor is the robot's motion and trajectory execution. If any unexpected jerky movements or deviations from the intended path are detected, modifications in smoothing settings or trajectory interpolation may be required to maintain precision. Additionally, the synchronization between the robot's movement and material extrusion should be closely monitored—any desynchronization could lead to under-extrusion or excess material buildup.

During the simulation Figure 8, it is also important to check for collisions or singularities that might arise as the robot maneuvers around the workspace. If the robot approaches a singularity, adjusting the target orientation or modifying the printing sequence can help avoid unnecessary constraints.

In the event of unexpected issues or suboptimal results during the simulation phase, adjustments can be made directly within RobotStudio's PowerPac for 3D Printing. These modifications may include changes to G-code parameters, movement speeds, layer height, or print orientation.

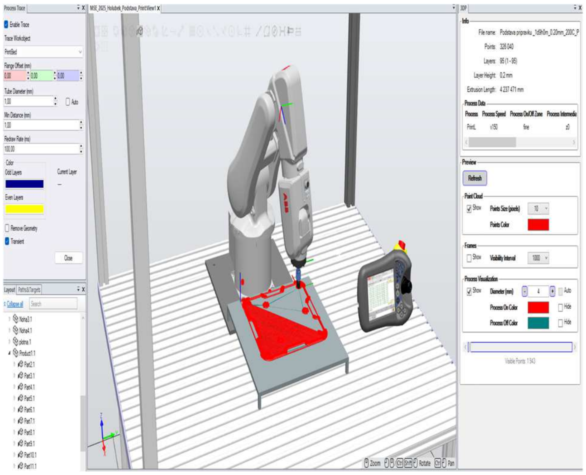

**Fig. 8.** The first of layers process of 3D printing a part using the IRB 120 robot

Such flexibility allows for the refinement of print quality and process reliability before deploying the final program in a real-world robotic environment, thereby minimizing material waste and potential errors during physical execution. Figure 9 shows the printed base of a flexible reconfigurable fixture in its almost final form.

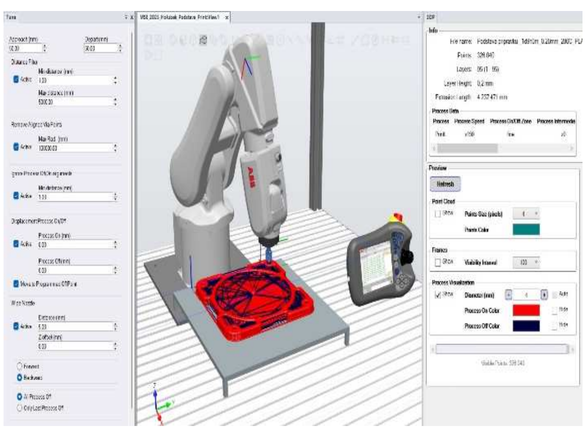

**Fig. 9.** The final process of 3D printing a part using the IRB 120 robot

## 4. CONCLUSION

By following the outlined methodology, it is possible to successfully generate and simulate the 3D printing process for the adjustable positioning fixture using RobotStudio and the ABB IRB 120 robot. The approach ensures precise control over material deposition, robotic motion, and process parameters, which are essential for achieving high-quality printed components. The ability to simulate and fine-tune the printing trajectory, extrusion parameters, and robot kinematics before actual fabrication significantly enhances process reliability and minimizes errors during real-world implementation.

Through this method, all necessary components of the reconfigurable positioning fixture Figure 10 can be successfully modeled, sliced into G-code, simulated, and ultimately 3D printed using the robotic system. The integration of robotic additive manufacturing within an industrial simulation environment not only facilitates precise part fabrication but also paves the way for future advancements in automated 3D printing applications.

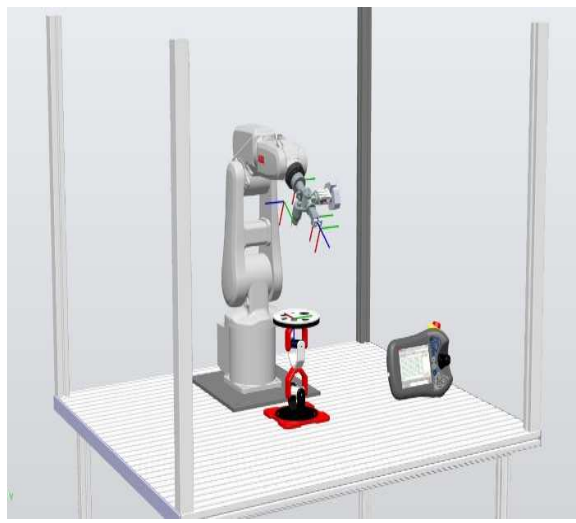

**Fig. 10.** Final simulation of the printed adjustable positioning fixture

The adoption of a two-step approach - initial G-code generation followed by conversion to robot code using ABB RobotStudio - was a deliberate methodological choice based on both practical and technical considerations. As a native development and simulation environment for ABB robots, RobotStudio ensures seamless integration with robot-specific kinematics, joint constraints and motion planning, which is critical for accurate execution on the IRB 120 platform.

In addition, the intermediate G-code layer provides increased transparency and flexibility, allowing manual inspection, adjustment, or optimization of print paths prior to conversion. This level of control is particularly valuable in experimental or research environments, where iterative refinement and process analysis are often required. RobotStudio's high-fidelity simulation capabilities also allow for detailed validation of robot motion, collision checking, and time estimation - features that are essential when working within constrained or custom workcells. While integrated solutions such as RoboDK or ENCY Robot streamline the workflow, our approach provides deeper access to individual process steps, allowing for greater customization, enhanced control, and alignment with existing academic software environments.

In comparison with conventional 3D printing methodologies employing gantry-based FDM systems, robotic 3D printing offers a substantially higher degree of flexibility in terms of workspace, orientation, and scalability. The IRB 120's six degrees of freedom enable non-planar printing, deposition on complex geometries, and potential integration with multi-material or hybrid manufacturing processes. While conventional printers are constrained to layer-by-layer deposition on a fixed plane, the robotic system allows for more adaptive strategies. This increased flexibility, however, necessitates more complex motion planning and validation. Future research should focus on comparing the printed outcomes with those produced by conventional 3D printers. In addition, mechanical testing of the realized support structure will be carried out to validate its structural integrity.

## 5. ACKNOWLEDGMENTS

The paper is a part of the research done within the project APVV-23-0084 „Robotic-Based Hybrid Manufacturing of Workpiece for the Concept of Smart Production“ funded by the Slovak Research and Development Agency.

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**Simulare robotică pentru imprimarea 3d: dezvoltarea unui dispozitiv de poziționare reglabil**

Acest articol de cercetare își propune să dezvolte o simulare robotică a imprimării 3D pentru un dispozitiv de poziționare reglabil, transformându-l într-un sistem funcțional și reconfigurabil, cu o bază de componente atent selectată. Folosind un robot ABB IRB 120 echipat cu un extruder pentru imprimare 3D, studiul optimizează procesul de fabricație aditivă, concentrându-se pe parametrii de imprimare, integritatea structurală și adaptabilitate. Imprimarea 3D robotică oferă flexibilitate, reducerea risipei de material și capacitatea de a crea geometrie complexă într-un spațiu de lucru extins. Dispozitivul final va permite poziționarea reconfigurabilă a pieselor, îmbunătățind înțelegerea studenților asupra programării roboților industriali, ajustărilor dispozitivelor și reprogramării interactive în funcție de poziția piesei și modificările programului robotic.

**Radovan HOLUBEK,** assoc. prof. Eng. PhD., teacher, Slovak University of Technology in Bratislava, Faculty of Material Science and Technology in Trnava, Institute of the production technologies, radovan.holubek@stuba.sk, +421908674132.

**Daynier Rolando DELGADO SOBRINO,** assoc. prof. Eng. PhD., teacher, Slovak University of Technology in Bratislava, Faculty of Material Science and Technology in Trnava, Institute of the production technologies, daynier_sobrino@stuba.sk, +421908674132.

**Peter KRIŽAN,** assoc. prof. Eng. PhD., teacher, Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering in Bratislava, Institute of Production Engineering and Quality, peter.krizan@stuba.sk, +421257296 539.

**Miriam MATÚŠOVÁ,** Eng. PhD., teacher, Slovak University of Technology in Bratislava, Faculty of Material Science and Technology in Trnava, Institute of the production technologies, miriam.matusova@stuba.sk, +421 908674142.

**Peter KOŠŤÁL,** prof. Eng. PhD., teacher, Slovak University of Technology in Bratislava, Faculty of Material Science and Technology in Trnava, Institute of the production technologies, peter.kostal@stuba.sk, +421 908674143.