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New Concept for Design and Control of 4 Axis Robot Using the Additive Manufacturing Technology

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Abstract

This work introduces a new concept for designing and manufacturing an industrial robot by using modern production techniques and a 3D modelling software. The most important requirements of this project were to build a customized, lightweight and low cost robot, capable to fulfil many industrial working tasks such as palletizing mobile telephone covers. For designing and optimizing the mechanical structure of the palletizing robot a SolidWorks- software was used. Integrating motion simulation tools in SolidWorks intensely reduces the engineering time for finding the optimal mechanical structure of the robot according to the industrial task. The robot parts are produced by using the additive manufacturing technology- powder material PA 2200. For solving the forward and inverse kinematics of the robot, the Software tool SimMechanics from MathWorks was used. This environment provided by the software enables building a human machine interface in order to store and program the robot targets. This project additionally shows the new benefited experience about mechanical structure of robots using the powder material PA 2200. Furthermore the advantages and disadvantages of this concept will be comprehensively explained.

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Keywords: Robotics; Additive Manufacturing; 3D Modelling; Simulation; Motion Control

1. Introduction

The aspiration of high degreed automation and the need of economically reproducible concepts, require the use of industrial robots. These robots experienced an enormous progress in the development recently; starting off with the

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first simply engineered robot and moving on to the intelligent robot performing a variety of kinematic designs.

In addition to the technological development which undertakes the domain robotics, new technologies such as additive manufacturing are gradually maturing leading to an enrichment of their field of application. This technology, which generate parts in a layered way, has a history of more than 25 years. These processes are not exclusively used for prototyping any longer. New opportunities and applications in appropriate manufacturing tasks opened up, even though the commercial impact is still modest [1]. By building three-dimensional parts in a layer-by-layer additive manner, the Rapid Techniques allow freeform fabrication of parts of complex geometry directly from their CAD models automatically, without having to use special fixtures as in the material removal processes. The rapid prototyping technology has helped product developers to develop their products more rapidly at lower costs in the ever changing and more competitive global market [2].

In order to fully exploit these advantages and to combine them with robotics, the idea was to build a 4 axis palletizing robot, which would be solid enough to fulfill industrial working tasks such as pick & place using the additive manufacturing technology. The first step in order to implement this concept, was to build a mini model with low cost components to test out this theory. Therefore an Arduino microcontroller, Servo motors (radio control servo motors) and a 6V vacuum suction as Endeffector were used.

2. Design and construction

Traditional engineering taught the manufacturability of the product while constructing models. This manufacturability differs according to the used production processes. Manufacturing costs and assembly are other factors that have to be taken into consideration. In addition to these factors, there are defined instructions for a product development process which has to be followed: starting off with devising the idea, up to mass production. Using the additive manufacturing process leads to a shortened lap time between the phases of the development process. Some phases may be even eliminated leading to a new redefinition of these factors. This changes caused a complete change of the product development process [3]. After drawing some sketches the next step was to start with the 3D design and modelling of links and joints of the robot (as shown in Figure 1). During the construction of the 4 axis palletizing robot, the focus was placed directly on the function, not on the way the axis would be manufactured. Furthermore, it has been taken into account to reduce the weight of the robot axis and to adjust the axis and joints on the built engines. Using modern CAD modelling and simulation software, it has made it possible to simulate the mechanical behavior of the used axis material during the motion study of the robot. The purpose was to achieve an optimum on the configured design through which we can obtain a maximum of motor torque utilization.

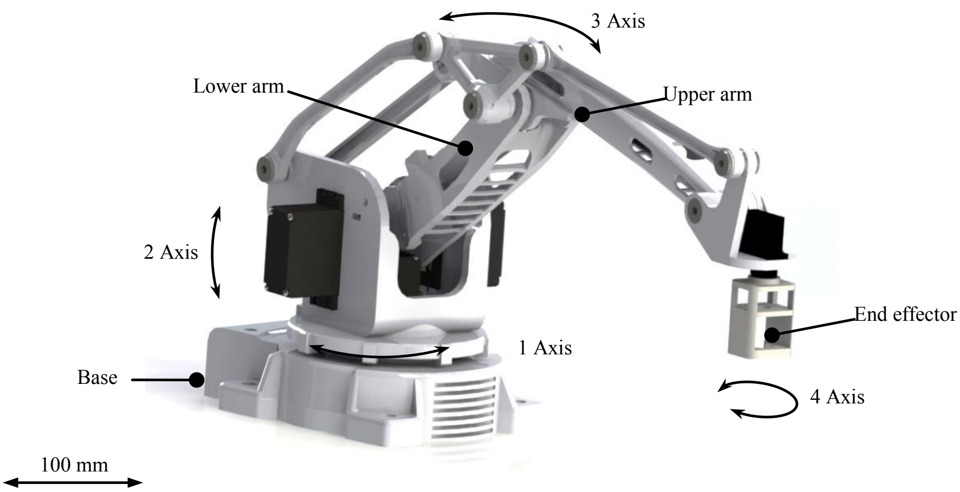

Fig. 1. Robot 3D-Model rendered in SolidWorks.

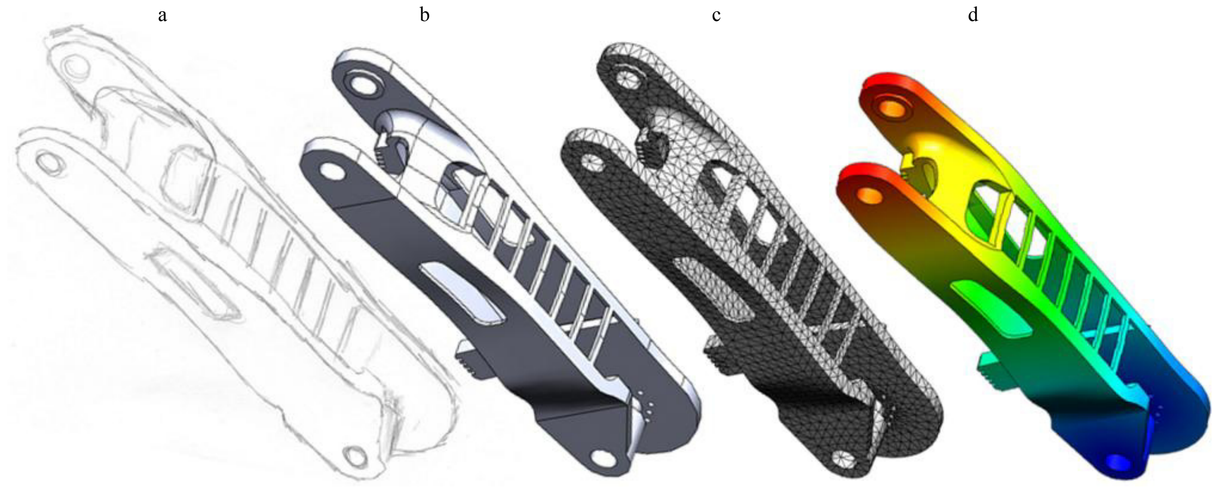

Fig. 2. (a) Sketch of a robot axis; (b) 3D-Modell; (c) Meshed-Model (for static study); (d) result of a Static Analysis.

Hence it was examined if the robot axis are over-designed or if the axis would break while performing common operations. By using static and dynamic studies for the stress analysis of parts and assemblies loaded by static and/or dynamic loads, it has been determined how safe, efficient, and economical is our design. Additionally this study presents the answers to the manipulator stability during the motion operations.

3. Manufacturing and assembling of the robot axis

3.1. Manufacturing of robot joints

The additive manufacturing methods are generally similar to each other in the way that they add and bond materials in layerwise-fashion to form objects [2]. The employed method called Laser Sintering uses laser to sinter powdered material, bonding it together to create a solid structure. The machines consist of a build chamber to be filled with powder with a grain size of up to 50 µm and a laser scanner unit on top that generates the x-y contour. The bottom of the build chamber is designed as a movable piston that can be adjusted at any z-level. The top of the powder bed defines the build area in which the actual layer is built. The laser beam contours each layer. Where the beam touches the surface, the powder particles are locally molten [3].

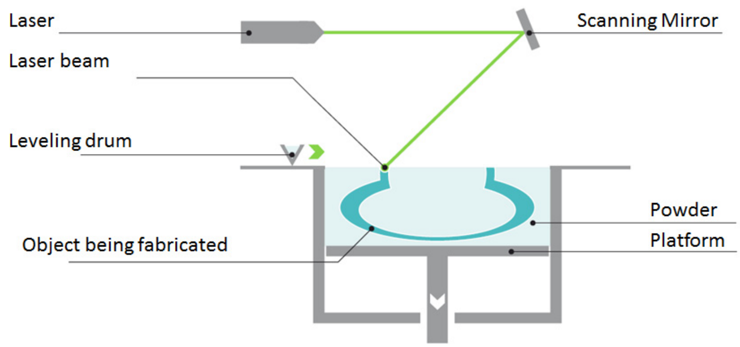

Fig. 3. Laser Sintering System [6].

When a layer is finished, the build platform moves 0.1 mm (layer thicknesses) down and an automated roller adds a new layer of material which is sintered to form the next cross section of the object. While non-sintered material is used as supporting material. The robot axis were produced by the plastic laser sintering system EOS FORMIGA P 110. With a build envelope of 200 mm x 250 mm x 330 mm the machine produces plastic products from polyamide or polystyrene within a few hours directly from CAD data without requiring tools [4]. The used powder material is PA 2200 which is a non-filled powder on basis of PA 12 with the following characteristics:

- high strength and stiffness
- good chemical resistance
- excellent long-term constant behaviour
- high selectivity and detail resolution
- various finishing possibilities (e.g. metallisation, stove enamelling, vibratory grinding, tub colouring, bonding, powder coating, flocking)

To start static and dynamic studies before manufacturing the robot axis it is required to define the material properties that will be used in the additive manufacturing process.

Table 1. PA2200 Properties [5].

Mechanical Properties	Column A (*t*)	Column B (*t*)
Tensile Modulus	1700	N/mm^2
Tensile strength	45	N/mm^2
Elongation at break	20	%
Charpy - Impact strength	53	kJ/m^2
Izod – Impact Strength	32,2	kJ/m^2
Flexural Modulus	1240	N/mm^2

3.2. Assembling of Robot Axis

Next step after manufacturing of robot parts was the assembling of robot joints. The physical robot is shown in figure 4.

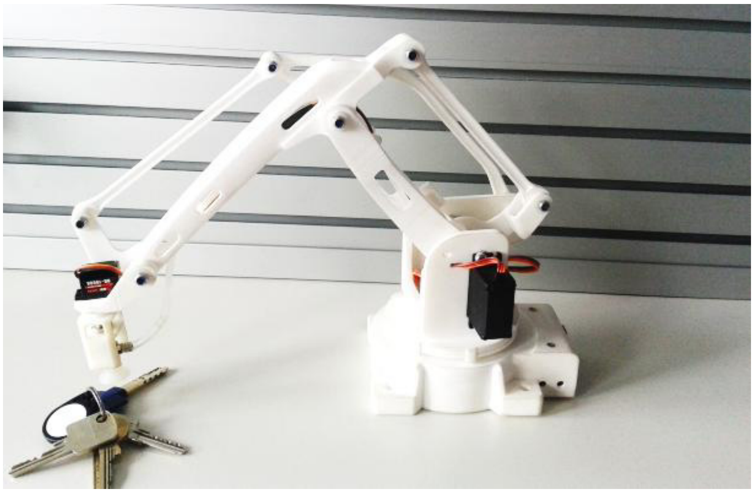

Fig. 4. Physical Model.

4. Design of robot control

After assembling the robot axis and the motors and cabling the system, the programming process began in two stages:

- Microcontroller programming and
- Building a Human Machine Interface

For solving the robot forward and inverse kinematics to achieve a linear motion, the Software tool SimMechanics from MathWorks [7] was used. SimMechanics is a block diagram modeling environment for modeling and simulating mechanical systems which use the standard Newtonian dynamics of forces and torques. The kinematical analyses based on SimMechanics are free from establishing the kinematic model of mechanism. Mechanical systems can be represented in a graphical way by connected block diagrams which saves time and effort to model [8].

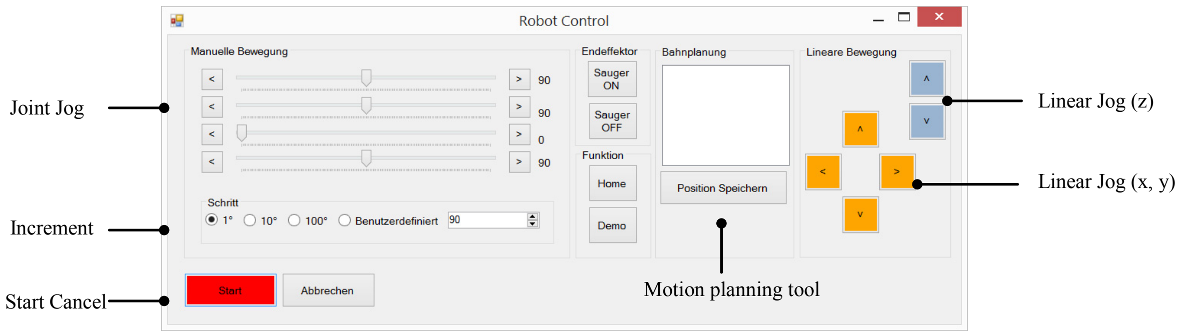

Fig. 5. Human Machine Interface for 4-axis Robot.

5. Results and Future Work

After programming the controlling interface as Windows application, we were able to test the robot conduction. Although the motors and the microcontroller are low cost components, the robot motion was in real time. This robot is optimally suited for pick and place industrial applications, for light workpieces and for learning purposes. Indeed, it was established that the robots axis are almost able to be manufactured by using additive technologies. Also real size axis could be printed. In future, authors will design a real size industrial robot using professional industrially-suited servo motors. Because the main disadvantages of using this low cost servo motors were a poor accuracy and an inability to get a position feedback.

6. Conclusion

In this research, we have shown a new method to manufacture an industrial robot. Using the additive Technology and modern software tools for designing and controlling industrial Robot we were able to shorten the development periods. The first step after creating the main concept was a 3D CAD design of Links and Joints of Robot, which would be stiff enough to pick and place industrial applications. According to the aim of this work, a Polyamide material was used. The simulation software is endowed to simulate the mechanical behavior of the material during the motion study of the robot and consequently the robot axis were optimized. The second step of this study was to design the controller for the robot-plant design. SimMechanics with support of Simulink- Libraries from MathWorks were used to realize this task. The third step of this study was to manufacture and assemble a robot. The fourth and last step was developing a user interface for the operator to program robot motions. The developed robot is suited for pick and place applications and for learning purposes. It was proven that additive manufacturing is an effective production processes for manufacturing high quality robot parts in short time. Also this method helped to save valuable engineering time and the design engineer can focus his work directly on the product functionality.

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