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ROBOTIC SANDING OF FREESTANDING BATHTUBS

ROBOTSKO BRUŠENJE PROSTOSTOJEČIH KADI

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Abstract

Modern production is characterized by great variability, with the possibility of making complex parts. However, as modern technology helps increase the efficiency of factors of production, it can also replace labour to reduce costs. For example, Artificial Intelligence and robotic systems are used in manufacturing, to achieve greater productivity and reduce costly human errors. That is why human resources are being replaced gradually by automated robotic systems. In this paper a novel approach was used to sand and polish freestanding bathtubs, using an industrial manipulator and a standardised procedure of sanding, with automatic detection of force when in contact with a part. This process resulted in over 30% of savings in consumable materials (sand paper, etc.) and an almost 50% increase in productivity. To conclude, using two robotic cells in the process of manufacturing of freestanding bathtubs produced four times greater labor saving in comparison to manual sanding.

Povzetek

Za sodobno proizvodnjo je značilna velika variabilnost z možnostjo izdelave kompleksnih delov. Sodobna tehnologija pomaga povečati učinkovitost proizvodnih dejavnikov, posledično lahko tudi zmanjša stroške. Na primer, umetna inteligenca in robotski sistemi se uporabljajo v proizvodnji za doseganje večje produktivnosti in zmanjšanje dragih človeških napak. Zato človeške vire postopoma nadomeščajo avtomatizirani robotski sistemi. V tem prispevku je bil uporabljen

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nov pristop za brušenje in poliranje samostoječih kadi z uporabo industrijskega manipulatorja in standardiziranega postopka brušenja s samodejnim zaznavanjem sile ob stiku z delom. Rezultat tega postopka je več kot 30-odstotni prihranek pri potrošnem materialu (brusni papir itd.) in skoraj 50-odstotno povečanje produktivnosti. Če sklenemo, z uporabo dveh robotskih celic v procesu izdelave prostostoječih kopalnih kadi smo dosegli štirikrat večji prihranek dela v primerjavi z ročnim brušenjem.

1 INTRODUCTION

The idea of automatic devices that serve man has been around for a long time, like the idea of automatic door opening recorded in historical stories. Around the 9th century, hundreds of preserved texts and ideas were collected and compiled into one book called "The Science of Ingenious Mechanisms". This book and the Renaissance brought together many scientists, including Leonardo da Vinci, to create or design some of the first automated devices. The industrial revolution brought with it an increasing demand for production, and thus the motivation to automate systems. The development of the integrated circuit, the invention of numerically controlled (NC) machines, and the popularity of computers, helped create the first simple industrial robot. They managed to replace people in performing difficult and monotonous jobs. However, they did not have as many sensors as today's robots have, so they were used only for the simplest tasks, such as accepting an object and placing it in a certain position [1].

An industrial robot is a mechanical device that is controlled automatically, and is adaptable enough to be programmed to perform various tasks and be able to use various tools. As electronics, sensors and computing progressed, so did the capabilities of industrial robots, which performed increasingly complex tasks, such as welding, assembly, packaging, all achieved with precision, speed and repeatability [1].

Figure 1 [2]. shows an estimate of the number of industrial robots installed annually in the world. From 2007 to 2009, a drastic drop can be observed in the number of robots, due to the global financial crisis, and stagnation in 2020 due to the impact of COVID-19.. The next decade was characterized by a significant growth of industrial robotics.

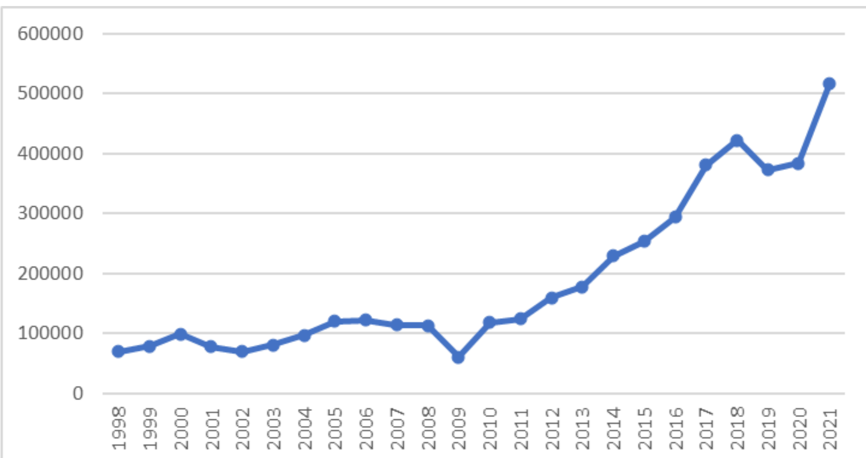

Figure 1: *Estimate of the number of robots installed annually in the world*

1 SANDING PROCES

According to DIN 8580, sanding belongs to the machining processes of particle separation with a cutting tool with a geometrically undefined cutting edge, together with super-finishing, honing and lapping. Sanding is the most common and cost-effective finishing process for flat, cylindrical or profile-shaped hard surfaces. The addition of sanding material is from 0.1 to 0.2 mm and the surface roughness class from N3 to N6 can be achieved [3].

2 MATERIALS AND METHODS USED IN THE PROCESS OF ROBOTIC SANDING

2.1 Sander Mirka AIROS 650CV

A Mirka AIROS is an automatic, integrated, random orbital sander for industrial robots, in any industry with a need to automate surface finishing tasks. It is designed for intensive sanding with heavy loads, where precision and minimal maintenance are critical. Mirka AIROS is an electric and smart sander, built in a strong, but light aluminum housing, with a flange compatible with ISO 9409-1 for mechanical connection of robots. It can be adapted to all mechanical couplings, offering maximum flexibility.

The long-lasting brushless motor is particularly safe for wet sanding, and operates at a constant and adjustable rpm. This model has a 150 mm pad and needs to be connected to a dust extraction system.

The Mirka AIROS is the first main sanding attachment designed for use in automated robotic production for fine sanding. The main motion is eccentric rotation. It can be installed on most industrial manipulators on the market, and is light and compact. The model that was used in this paper is the Mirka airos 650CV, with a disc diameter of 150 mm, an eccentric of 5 mm and a speed of 4000-10000 rpm. Figure 3 shows the sander. [4]

Figure 3: *Mirka AIROS 650DV Sander [4]*

2.2 ABB IRB 4600 robot

The industrial manipulator to which the sander was connected is an ABB IRB 4600, shown in Figure 4. The IRB 4600 is a high productivity general purpose robot optimized for short cycle times, where compact robots can help create high productivity jobs. The IRB 4600 enables more compact production cells with increased production and higher quality – and this means improved productivity [5].

The IRB 4600 is the fastest palletizing robot in the world, capable of reducing cycle times significantly and increasing productivity. With a reach of 2.4 meters and a payload of 110 kg, this compact four-axis robot can achieve up to 2,190 cycles per hour with a load of 60 kg, which is 15 percent faster than its nearest competitor.

A small base area, acthin base radius around axis 1, the high mobility of axis 3, small lower and upper arms and compact wrist contribute to the most compact robot in its class. With the IRB 4600, a production cell with reduced floor space can be created by placing robots closer to the machines being served, which also increases output and productivity [5].

Figure 4: *ABB IRB 4600 robot [5]*

2.3 Force compensator FCU

Two representative force control methods have been proposed. They are impedance control [6] and hybrid position/force control [7]. The ABB robot and the Mirka sander are connected by a force compensator. It is possible to find only pneumatic force compensators on the market, which are, therefore, extremely expensive, both in terms of purchase and regular maintenance. Therefore, for the purpose of this research, in cooperation with the Faculty of Mechanical Engineering and Naval Architecure from Zagreb, we installed a custom made force compensator with an electric servomotor.

The force compensator is extremely important, because each manufactured tub deviates from the ideal model by a few millimeters. The reasons for this can be varied. From the type of acrylic, roving, the connection between the tub and the lining, to the weather conditions and the reaction of the tub during cooling and drying. The FCU device allows deviations from the ideal 3D model +/- 25mm. This is extremely important in production, because, in this way, we can detect a bad bathtub and a deviation from the ideal model. Also, in the case of human error and the wrong selection of the sanding program, with the help of the sensor in the FCU, the robot stops, and no parts of the robot, sander or bathtub are broken.

Although it is so difficult and hard for skilled workers to keep the polishing force, tool position and orientation in the desired situation simultaneously, even for a few minutes, the robot sander can perform the task more uniformly and continuously. [8]

Figure 5: *Force compensator FCU*

3 RESULTS OF A ROBOTIC SANDING IMPLEMENTATION

From Table 1/Figure 4, we can see clearly that, with the introduction of robotic sanding, the consumption of sanding paper has almost halved. That may not seem like much when it comes to a freestanding bathtub, but the factory produces 1,000 freestanding bathtubs per week. That's about 50,000 tubs per year. Let's take into account the average price of sandpaper of 0,33 euros/piece + VAT. The annual consumption before the introduction of robotic sanding was about 500,000 pieces of sandpaper of all grain sizes, which is about 166,000 € + VAT. After the introduction of robotic sanding, the consumption of sanding paper decreased to about 350,000 pieces, which is about 116,000 € + VAT. This is a reduction of 30% per year. The savings on sandpaper were around 50,000 € + VAT. Paper consumption also varied greatly from worker to worker in manual sanding. The consumption of sandpaper was not the same between a worker who worked for several years and a worker who worked for a few days. Equally, it is easier for a worker to learn to manipulate a robot than to learn to sand, because the sanding of acrylic is very specific. The sanding robots have a barcode scanner that scans each tub. With this technique, the operator scans the barcode, the robot connects the barcode with the sanding program automatically and loads the program. Each tub has a sticker on the back that contains a bar code and the name of the tub. It is up to the operator to start the sanding cycle.

***Table 1**: Comparison of sandpaper consumption per bathtub*

No.	Bathtub type	Manual sanding	Robotic sanding
1	Wall 1a37 SLOT	5 pcs	3 pcs
2	Wall Corner L 1a37 SLOT	5 pcs	3 pcs
3	Form 1a37 SLOT	12 pcs	8 pcs
4	Cool 1a37 SLOT	10 pcs	8 pcs
5	Ideal Standard 180 1a28 SLOT	8 pcs	6 pcs

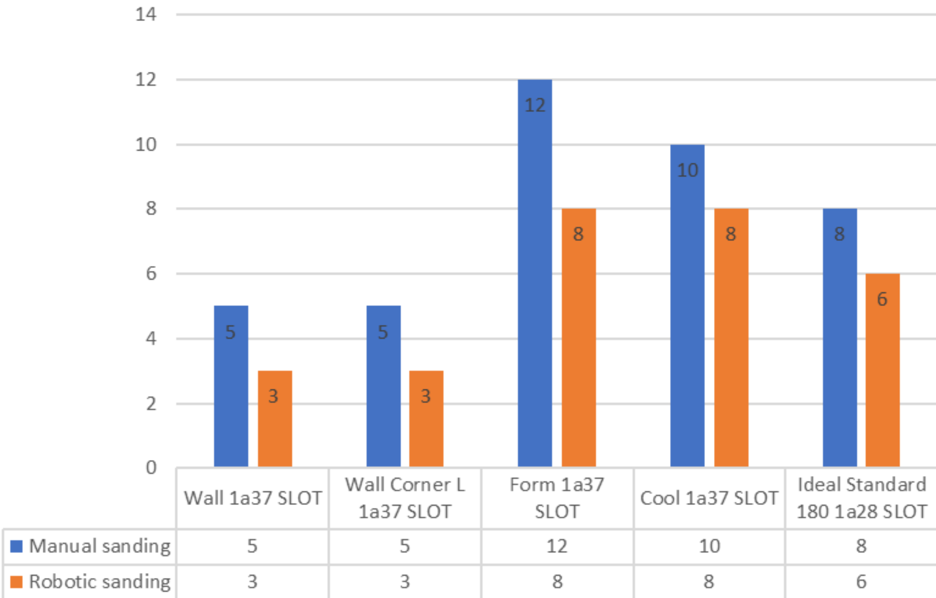

***Figure 4:** Comparison of sandpaper consumption*

Table 2/Figure 5 show the comparison of sanding times between manual and robotic sanding. Wall and Wall Corner bathtubs are the most common bathtubs produced by the Aquaestil factory. The average time for manual bathtub sanding is, depending on the sander, from 12 to 20 minutes, and robotic bathtub sanding takes 7 minutes, which is standardized. The time of robotic sanding is twice as short as the time of manual sanding. In May 2021, the factory increased the production of free-standing bathtubs from 550 bathtubs per week to 1,000 bathtubs per week, based on the purchase of 6 bathtub sanding robots. Of course, several people are also employed in other positions, where, due to the complicated production process, it is impossible to introduce robotization. In addition to speeding up the process and reducing the consumption of sandpaper with robotic sanding, it made it possible to facilitate the procurement of sandpaper, which is now standard, and the exact required amount of sandpaper can be known in advance. On average, one robot sands twice as many tubs as one worker. One operator drives two robots simultaneously. This means that labor saving by robotic sanding is four times greater than by manual sanding.

Table 2: *Comparison of sanding times*

No.	Bathtub type	Manual sanding	Robotic sanding
1	Wall 1a37 SLOT	15 min	7 min
2	Wall Corner L 1a37 SLOT	15 min	7 min
3	Form 1a37 SLOT	75 min	38 min
4	Cool 1a37 SLOT	60 min	33 min
5	Ideal Standard 180 1a28 SLOT	45 min	25 min

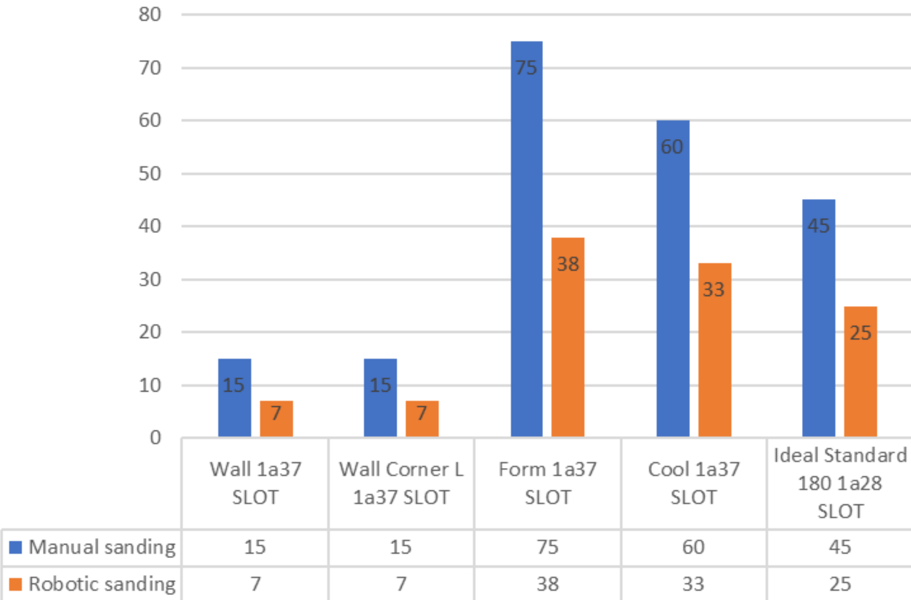

Figure 5: *Comparison of sanding times for different bath types*

4 CONCLUSION

Modern flexible production systems are designed for adaptive production with frequent and rapid changes, additions and improvements. By introducing robots into the production system, the time of product flow through the production process is reduced; product manufacturing time is shortened, i.e. productivity increases; it frees people from monotonous, difficult and dirty work and reduces the required working space. The human factor, which plays a major role in the number of downtimes, errors and, unfortunately, accidents in the production process itself, is being eliminated from production processes slowly by the use of robots. Robots can work 24 hours a day, 365 days a year with the same end result and minimal maintenance costs. With the introduction of robotic sanding in the manufacturing process of bathtubs, the production doubled, and the consumption of sandpaper almost halved, while accomplishing the same quality standards.

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