Research Article

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Assessment of a robot base production using CAM programming for the FANUC control system

https://doi.org/10.1515/eng-2021-0085
received June 04, 2021; accepted July 26, 2021

Abstract: The subject of the article is the research of the production of a robot base using CAM programming, Autodesk Inventor HSM software, followed by the generation of G code – NC program. The research specifically examined the accuracy of measurement and evaluation of roundness with coaxiality on a 3D measuring device Thome. The surface roughness of the circular holes was measured using a Mitutoyo SJ 400 roughness meter. The maximum deviation of the roundness of the diameter D56H7 measured was 0.011 mm, and the diameter D72H7 measured was 0.013 mm. The coaxiality deviation of the diameters D56H7 and D72H7 measured was 0.017 mm.

Keywords: robot, CAM, coaxiality, roughness, robot base

1 Introduction

Robotics is currently established not only in industry but also in research laboratories. This term can be used even in areas where it is inappropriate, so knowing exactly what the word robot means, how it is controlled and how it can be used in specific applications is very important.

Souza et al. [1] designed a wireless lightweight robotic arm for teaching purposes that serves only to program its path without a gripper. And our robotic arm can be used not only for educational but also for industrial purposes, handling light loads up to 2 kg. Unda et al. [2] introduced the most general case study of the movement of a mobile robot with robotic arm. The four-wheel differential configuration allows greater stability for robotic arm operation. In addition, the design allows the incorporation of sensors such as ultrasonic sensors for interaction with obstacles. The built robotic arm allows the clamping of pieces of less than 20 g, at a maximum distance of 350 mm from the base of the robotic arm. Benitez et al. [3] designed and manufactured a simple robotic arm for online teaching of students. For comparison with our robotic arm, which was produced by the chip milling method, Benitez et al. made arms on a 3D printer with printing arms made of plastic materials. This method of production is commonly available to most students. Sáenz Zamarrón et al. [4] developed Educational Robot Arm, which has four axes of freedom and is also intended for educational purposes, however. Our robotic arm has one less degree of freedom. Similarly, the components of our robotic arm were fabricated by the chip method on a CNC milling machining center. Zamarrón et al. used Robotics Toolbox to simulate the control of the Matlab robotic arm and we are considering the use of LabView software. We also consider the control unit Arduino.

One of the specific applications is the use of robotic workplaces in the handling and transport of various products using trough and hose conveyors, which are currently finding increasing use [6]. The individual components of the robots are also manufactured using CAM programming [7]. The robots are divided according to various criteria. One of them is the division according to kinematics. The first type is the cylindrical coordination system (Figure 1) [13].

This construction performs three primary movements, of which two movements are translational and the third is rotary. The coordination system is not widely represented in the industry and with a construction based on a

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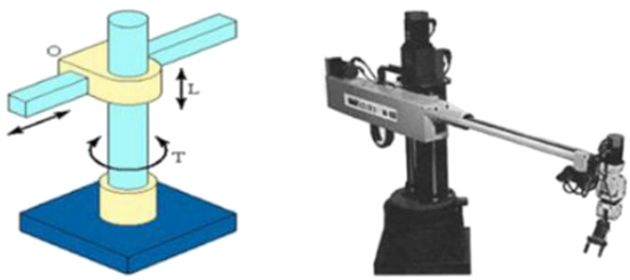

Figure 1: Cylindrical coordination system of a robot [13].

cylindrical system of movements, it is used for primitive tasks, such as spot welding, or as a simple manipulator. The robot nodes are inspected by the finite element method [5] not only for the magnitude of the stress but also for the magnitude of the deformation [8]. Prior to actual production of some robot components, the properties of the materials are also checked [11]. In addition to conventional machining technologies, water jet machining is used to produce some robot components [10], while it is also necessary to control the quality of the machined surface [12]. At the starting point, the control unit is instructed to start the motors in the order specified by the program until the position required to reach the end point position is reached. The whole cycle is repeated either immediately after reaching the starting point or after instructing a timer or a pulse from the sensor – cameras [9].

2 Robot base

Robot base in Figure 2 shows that 3D model is one of the parts of the robot assembly, it forms the base of the robot, therefore its design paid attention to its rigidity and load-bearing capacity and its dimensions were chosen on the basis of these requirements. The base of the robot houses a gearbox with a servomotor, which performs a rotary movement of the arm installed on the base. High emphasis is placed on mounting the gearbox in the robot base. Its mounting must be as precise as possible in order to prevent or minimize deviations of the arm rotational movement. The gearbox is housed in tolerated holes D56H7 and D72H7. The placement of H7 at a given dimension represents a hole tolerance of 0.015 mm. To produce these tolerated dimensions, a reaming operation with a boring bar was chosen.

2.1 Procedure of robot base programming and production

For programming the production of tolerated dimensions of the robot base, the drawing documentation in Figure 3 with a roughness R_z of 12.5 µm, made of Al4.5MgMn material, was documented. The tools used to produce tolerated holes were as follows:

- Face drill 880-D4100C6-03,

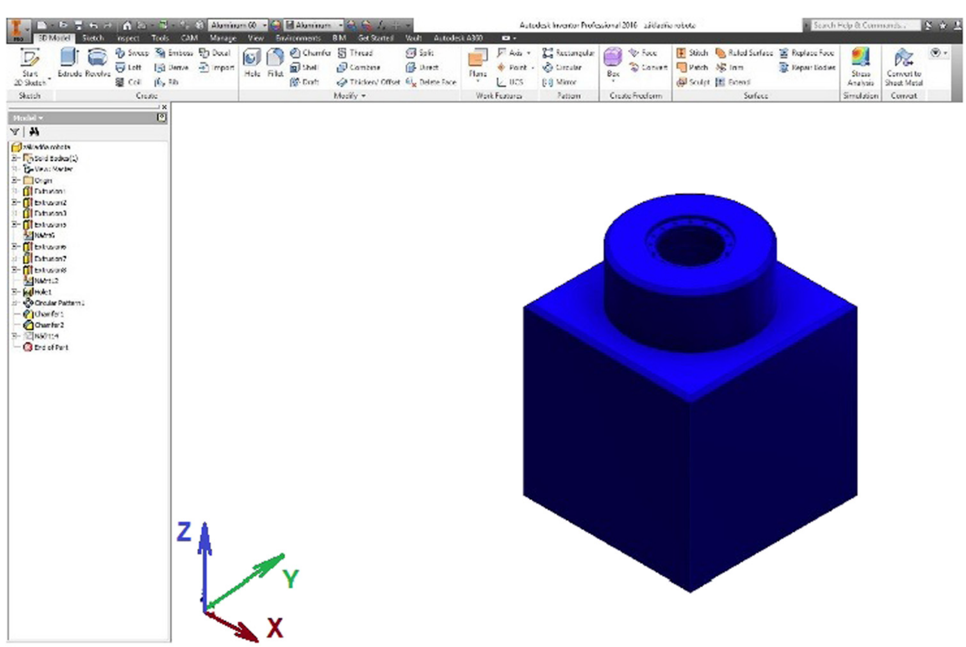

Figure 2: 3D model of a robot base.

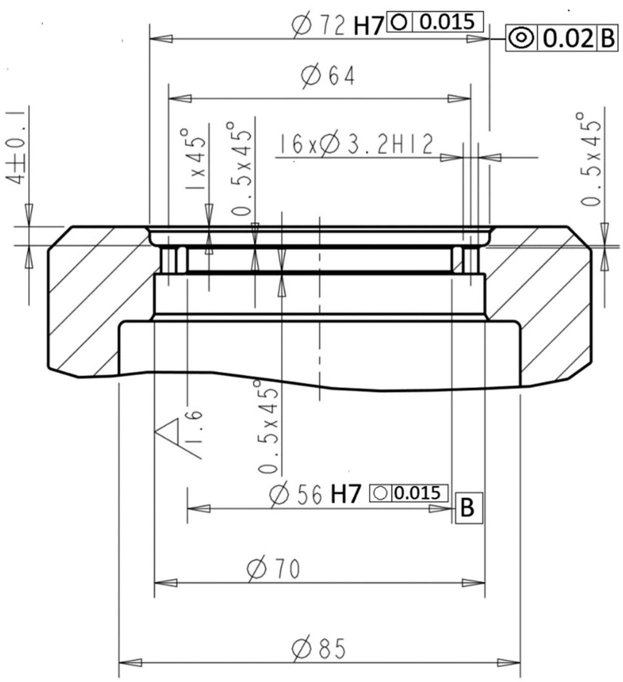

Figure 3: Production drawing of a robot base.

- Carbide 4 – plate cutter with a diameter of Ø 20 mm, and
- ISCAR BHF-MB50-80 boring bar.

Machining was designed in the CAD/CAM program Autodesk Inventor HSM. The roughened base of the robot was clamped to the worktable using four clamps.

The first step in programming the machining of the robot base was to select the size of the semi-finished product and set its zero value (Figure 4). The zero point was selected in the middle of the cylindrical part of the robot base with a diameter of D140 mm.

This was followed by drilling and setting the cutting conditions of the defined drilling cycle (Figure 5). A drill bit with a diameter of D41 mm under type designation 880-D4100C6-03 was used for drilling. The drilling depth was 15 mm. After drilling a D41 mm hole, an adaptive milling operation was performed using a carbide four-plate cutter with a diameter of D20 mm. In this machining strategy, the cutter was plunged to a depth of 4 mm and the hole D41 mm was enlarged to a diameter of D72 mm with the addition of 0.3 mm.

The overall dimension of the hole produced was D71.7 mm. An allowance of 0.3 mm was chosen for the last reaming operation when the final dimension of the hole is made to tolerance H7, which means that the hole has a dimension of D72.015 mm (Figure 6).

During programming, a reaming cycle was selected in which a tool was defined – a boring bar, the construction of which allows you to set diameters by one hundredth of a millimeter.

The 3-axis vertical machining center Pinnacle VMC 650S was chosen to produce the robot base. Figure 7 shows hole milling on the Pinnacle VMC 650S. The machining center is controlled by the FANUC control system.

The procedure to produce a hole with the diameter of Ø 56 H7 is the same as for the production of a hole Ø 72 H7.

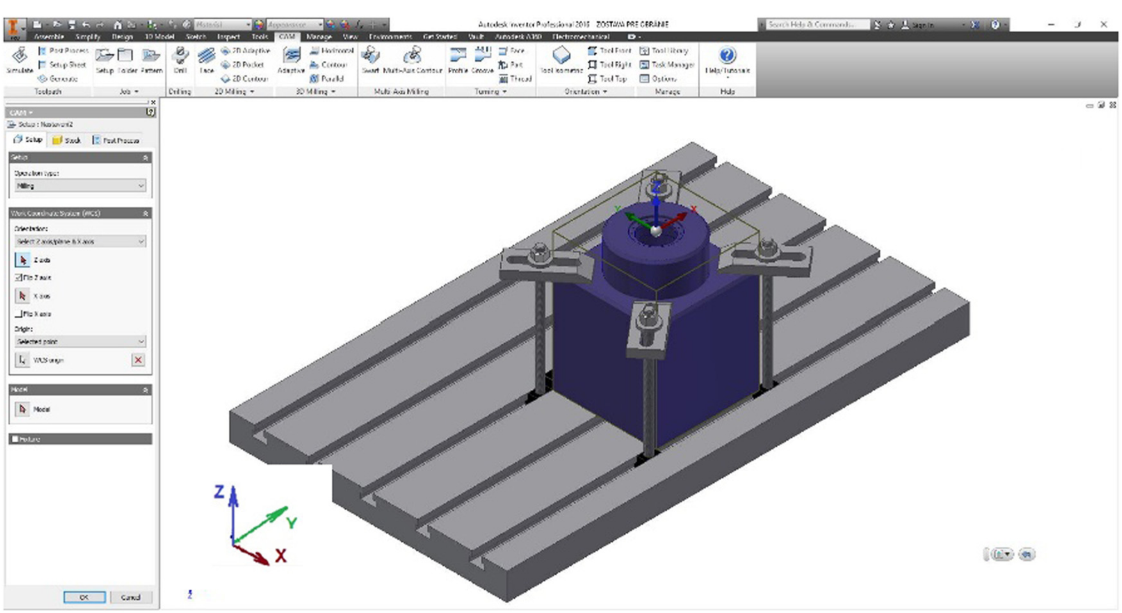

Figure 4: Setting of zero point of the robot base.

3 Results

The production of tolerated dimensions was followed by measurements in which the surface roughness of the individual holes, the roundness and the coaxiality of the holes were determined. The surface roughness was measured using a Mitutoyo SJ 400 roughness meter (Figure 8). The measurements were repeated 11 times. The results of measurements for individual holes are shown in the graphs in Figures 9 and 10.

The following values were found by measurement: hole D56H7 highest value of surface roughness R_a =

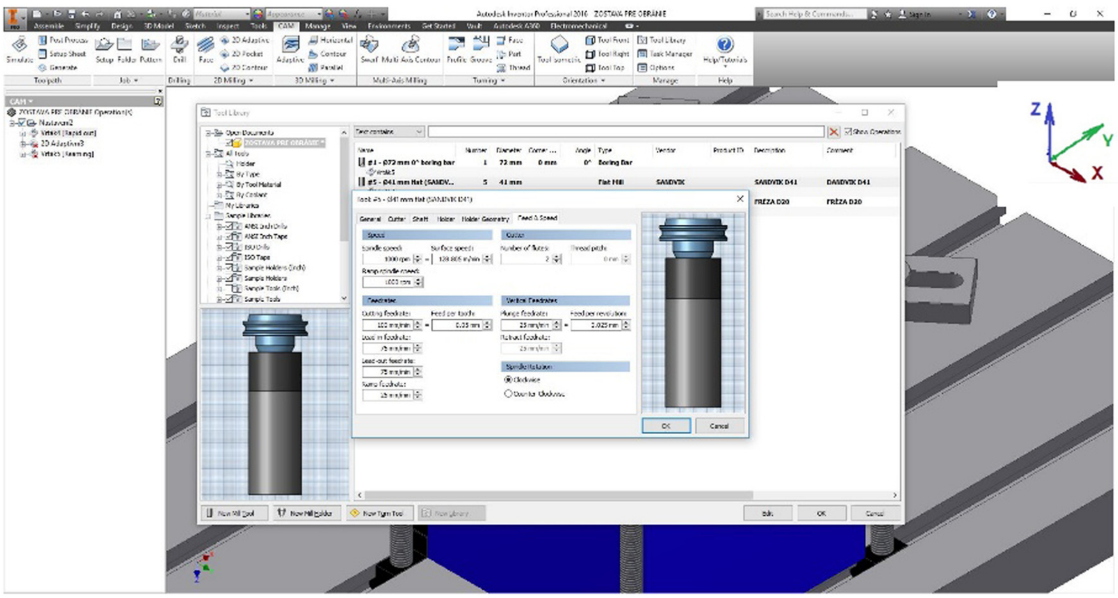

Figure 5: Setting of cutting parameters.

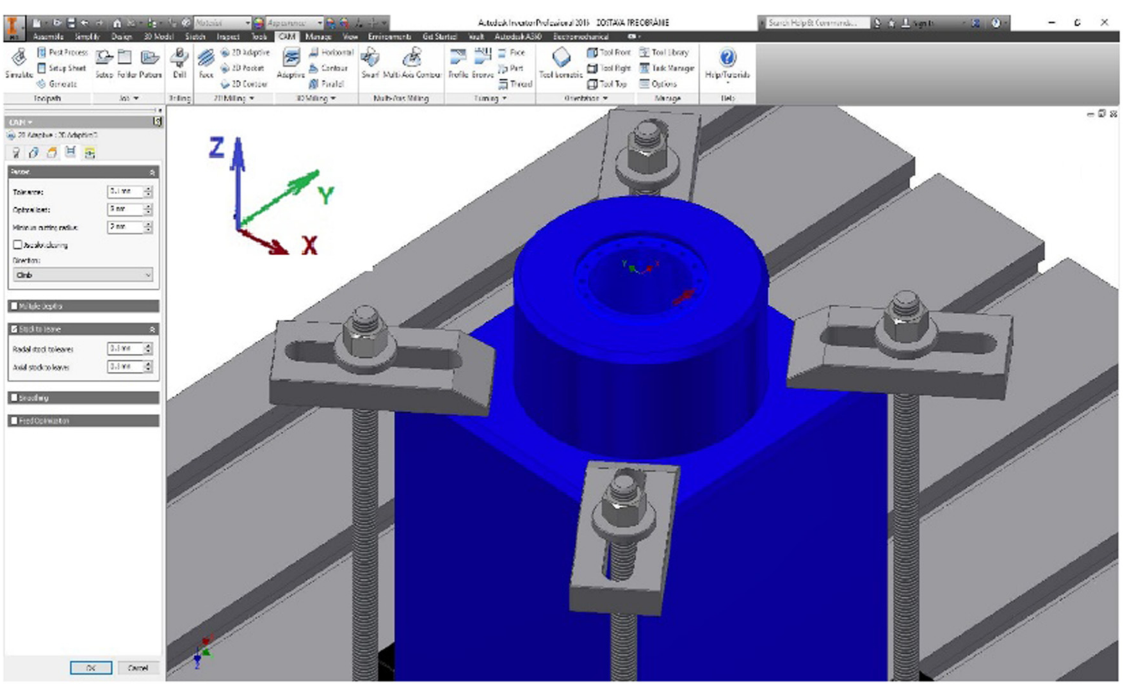

Figure 6: Defining of adaptive milling parameters.

1.01 µm, R_z = 8.4 µm. The lowest surface roughness R_a was 0.58 µm and the lowest R_z value was 3.6 µm. For a hole with dimension D72H7, the highest surface roughness was R_a = 1.08 µm and R_z = 9.2 µm. The lowest surface roughness R_a was 0.57 µm and R_z was 3.8 µm.

Another measured parameter was the roundness and coaxiality of the holes. These parameters were measured on a 3D measuring device of the Thome type. Figure 11 shows the measurement of these parameters.

Figure 12 shows the assembled robot base with robotic arm 1, gearbox and actuator.

The quality of the machining process was evaluated using the process capability index C_P, which is defined by the following relation:

$$C_P = \frac{\text{USL} - \text{LSL}}{6\sigma}, \tag{1}$$

where USL is the upper specification limit, LSL is the lower specification limit and σ is the standard deviation of the process.

For diameter 56H7 the value of C_P = 0.56 and for diameter 72H7 the value of C_P = 0.74.

Figure 7: Hole milling on the Pinnacle VMC 650S.

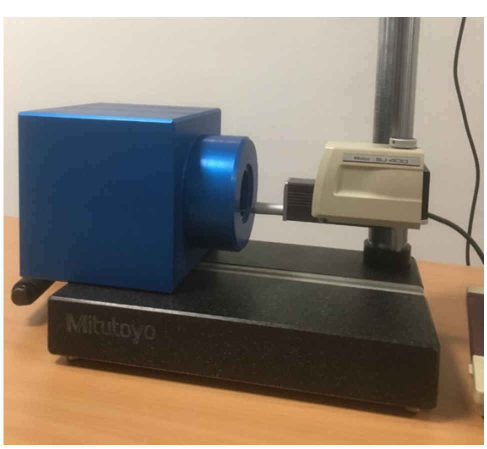

Figure 8: Measurement of the surface roughness of the hole D56H7.

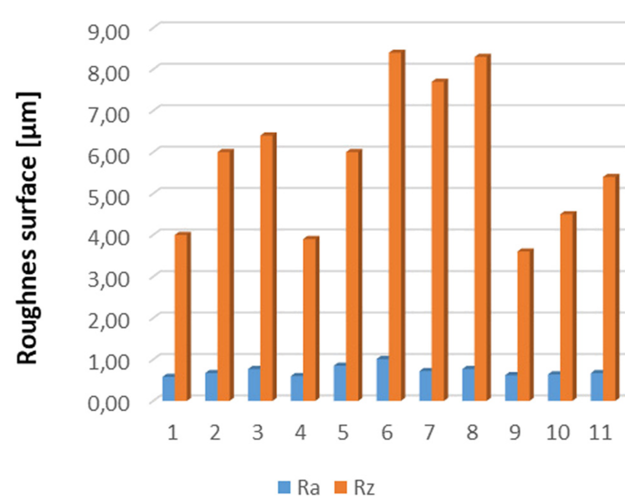

Figure 9: Roughness of the hole surface with diameter D56H7.

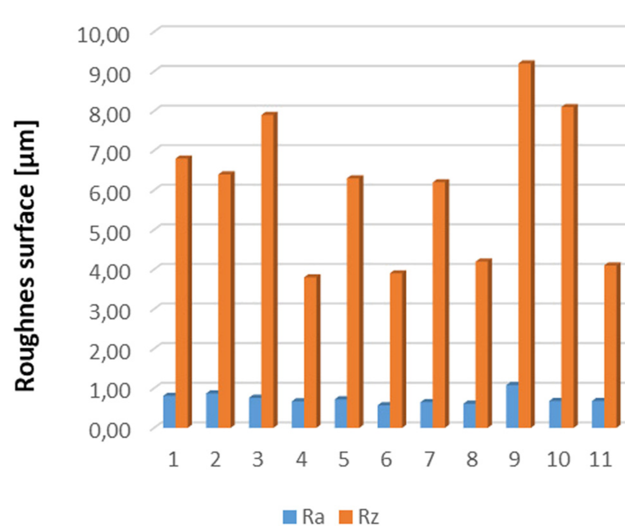

Figure 10: Roughness of the hole surface with diameter D72H7.

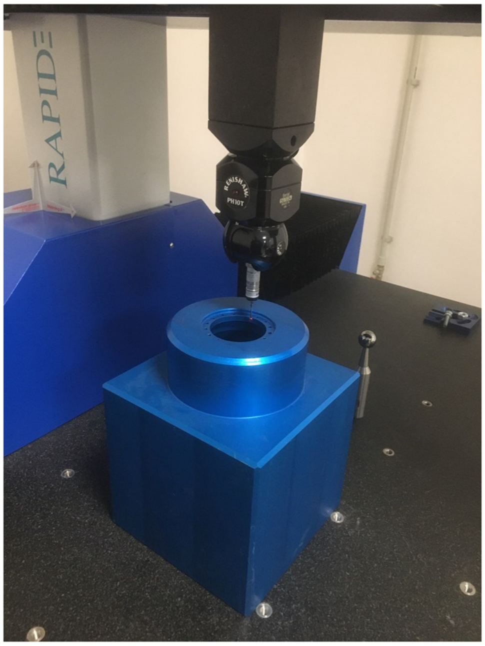

Figure 11: Measurement of 3D parameters with the Thome device.

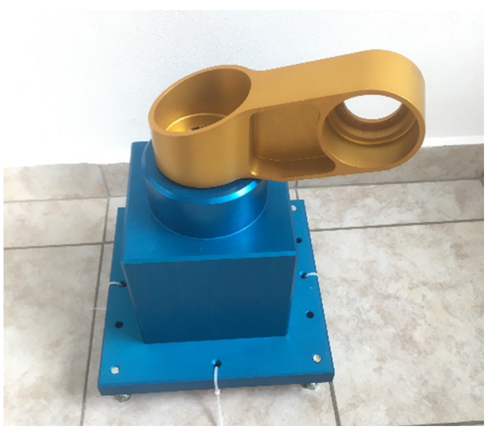

Figure 12: Assembled robot base with robotic arm 1.

4 Conclusion

The proposed method of production of the robot base was realised on a three-axis machining center Pinnacle VMC 650S. The quality of machining was verified using the process capability index C_P. The CAD/CAM program Autodesk Inventor HSM was used for CAM programming. Cylindrical holes with diameters D56H7 and D72H7 were made in three operations: drilling, adaptive milling–punching and reaming. The result of measuring the roundness of the hole D56H7 was 0.011 mm, and for the hole D72H7 it was 0.013 mm. The coaxially deviation between holes D56H7 and D72H7 was 0.017, which meets the required tolerance for given dimensional range. After evaluating these results, we can conclude that the chosen method of production and measurement of the robot base allows you to create the required assembly along with a recommendation for production of other robot components.

Acknowledgments: This work is a part of research project VEGA 1/0045/18 and SK-SRB-18-0053.

Conflict of interest: Authors state no conflict of interest.

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