Research Article

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Intelligent programming of robotic flange production by means of CAM programming

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Abstract: The article deals with the description of the production programming of a robotic flange, which consists of outer conical, cylindrical surface, face area and internal threaded surfaces. For the modelling of a 3D model and the generation of production design, the Autodesk Inventor Professional 2018 software was used. To enter the semi-finished piece, select individual tools, cutting conditions, simulation and the NC program generation for RS FANUC, the HSM PRO 2018 software extension was used. The circularity deviation was measured using the Roundtest RA 120 measuring device. The mean arithmetic values of roughness for the hole were: $D = 126$, $R_z = 11.43 \mu\text{m}$, $R_a = 1.92 \mu\text{m}$. The circularity deviation was $22.3 \mu\text{m}$.

Keywords: CAM programming, CNC program, robotic flange

1 Introduction

Numerically controlled NC or CNC machines, unlike conventional machine tools, via manual control, copying, mechanically automated by cams, stopper, are characterized by the control of all machine functions being performed using abstractly programmed commands in the program recorded in the storage medium of the control system / CS /. The driving force for the development and emergence of NC machine tools was the demand for the production of shaped surfaces with repeatable adherence to the shape and dimension tolerance of the components. Only conventional operators could produce them on conventional machine tools. The term numerically controlled machine tool

means a machine on which the necessary geometric, technological and auxiliary information for the production of a part is entered as numbers, in the form of a program that reads and processes the machine tool control system - Figure 1.

The use of computer technology has greatly simplified and accelerated the programming of a numerically controlled machine and data storage for re-use. Increasing the performance of computers, improving software, and using new automation features leads to the expansion of possibilities of the control systems of numerically controlled machine tools. The changes in the kinematics of numerically controlled machine tools are also connected to this. Thanks to labour productivity, there is also an economic effect, saving workers and production areas.

Today, we are most likely to encounter CNC machines in connection with drilling and machining, or with drills and machine tools. In fact, their use is much wider. They can be used anywhere where it is possible to produce more parts with the same technology, because in the case of CNC it is sufficient to change the program [2, 3]. Thus, the most used technological operations are grinding, drilling, cutting and machining of various materials [4]. In production, we can come across CNC woodworking, engraving machines, bending machines for bending sheet metal and pipes, etc., which are also used in the manufacturing of hose conveyor components [5–7]. However, CNC machines can also be distinguished by their kinematics. With serial (single axis positioning provides one actuator), parallel (multiple servo drives for positioning as the number of axes) and mixed kinematics [8, 9]. The most important criterion for choosing a programming method for numerically controlled machines is the complexity of the shape of the produced component [10]. Other criteria are the number of parts produced, the level of programmer's programming knowledge, and last but not least, the level of hardware [8, 11] available cutting tools [12, 13] and software that can be used [14]. The following methods of programming numerically controlled machines are currently in use:

- Manual programming.
- Workshop programming,
- Automatic programming using CAD / CAM system,

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Figure 1: Block diagram of the CNC machine tool [1].

- Step NC programming [15, 16].

Automatic programming can be classified among modern programming methods.

- Examples of some applications:
- Pro Engineer, Catia, SolidWorks,
- Work NC, Unigraphics,
- Kovoprog /Czech software/,
- Alpha CAD/CAM /The British LCOM Company/
- EdgeCAM, MasterCAM,
- Esprit [17].

Wan *et al.* precisely calculated the dwell time of a polishing robotic tool and developed a proprietary algorithm of de-convolution with a spatial variation thereby reducing the error deflection thereof [18]. Otsukki *et al.* [19] reduced the error resulting from circular interpolation of the tool during CAM programming. This helps to achieve higher machining accuracy, reduces production times and maintains the processing time of program blocks. Klancik *et al.* [20] have developed a CAD / CAM program that uses NSGA-II optimization and swarm intelligence. The evaluation module estimates the proposed solutions taking into account the geometric, technological and time criteria and the criterion of work efficiency. A simulation model was developed to find the optimal tool paths. The test results confirmed that machine tools can be automatically programmed with this artificial intelligence method.

2 Manufactured robotic flange

The robotic flange in Figure 2 is composed of an outer conical, cylindrical surface, end faces and internal threaded surface.

Figure 2: The machining diagram of the robotic flange.

Figure 3: Location of the coordinate system on the semi-finished piece.

Figure 4: Choice of cutting tool and cutting conditions.

The flange material is Polyamide PA6. It is used to cover the end arm of the robot while supporting the end and reference position sensors. The spherical surface serves to guide and centre the sensor holder during the positioning of the robot arms. For the production of a diameter of 126 mm, a tolerance of ± 0.04 mm and a deviation of circularity of 0.05 mm should be observed. Required surface roughness is $R_a = 3.2\mu\text{m}$.

3 CAM program creation procedure

The Autodesk Inventor Professional 2018 software was used to create a 3D robotic flange model and then generate a production drawing. The 3D model was also used in the HSM PRO 2018 application to simulate and generate an NC program for the FANUC control system. In the first step,

Figure 5: Simulation of the face processing of the semi-finished piece.

Figure 6: Simulation of the 144 mm diameter machining of the semi-finished piece.

the coordinate system in the centre of the part rotation and its machined face was chosen. see Figure 3.

This was followed by the choice of the tool, a right side turning cutting blade. Adjusting its shift extent, 0.1 mm. 0.1 feed and 850 rev.min⁻¹ speed required for external face area and cylindrical area machining - Figure 4.

In the next step, the simulation of the face processing was performed - Figure 5 and the machining of the outer cylindrical surface to a diameter of 144 mm - Figure 6.

The last turning operation is the production of a diameter of 126 mm to a depth of 6 mm with a tolerance of ± 0.04 mm and a deviation of roundness of 0.05 mm - Figure 7. After turning the semi-finished piece, a cone will be made.

Figure 7: Simulation production of 126 mm diameter to 6 mm depth.

Figure 8: Selection of drill and cutting conditions for 5 mm hole production.

This is followed by drilling eight holes with a diameter $D = 5\text{ mm}$. As in the previous operation, it is necessary to select a tool, define a feed rate of $250\text{ mm}\cdot\text{min}^{-1}$ and a drill speed of 1200 RPM , see Figure 8.

After simulating the drilling of the holes with a diameter of $D = 5\text{ mm}$ - Figure 9, follows the internal thread $8\times M6$ cutting. Sintered carbide drill was used for drilling on a CNC machine, thus avoiding the use of a centring drill, en-

suring by that the alignment of the drilling tool and the prescribed hole axis position.

Tool Selection - $M6\text{ Tap}$, $350\text{ mm}\cdot\text{min}^{-1}$ feed, 350 RPM - 1 in the Autodesk Inventor HSM environment is shown in Figure 10.

When defining the thread cutting depth, it is necessary to take into account the length of the tapping cone of the thread and add a margin of $3 - 5\text{ mm}$ so that the threaded

Figure 9: Simulation of drilling holes for threaded surfaces.

Figure 10: Selection of taps and cutting conditions for the M6 hole.

surface on the real component is properly made. The tap angle can also be checked during thread cutting simulation, see Figure 11.

When machining on CNC machine tools - Figure 12, the operator makes sure that the semi-finished piece and tools are properly clamped and the size of the cutting conditions was adapted to the size of the clamping surfaces of the semi-finished piece and its rigid.

4 Measurement and evaluation of the robotic flange accuracy

The surface roughness measurement on a manufactured 126 mm diameter with a tolerance of $\pm 0.04\text{mm}$ performed on a Mitutoyo SJ 400 device. The completed robotic flange was fixed in a hand vice with shaped jaws, see Figure 13.

Figure 11: 8 × M6 thread cutting simulation.

Figure 12: Manufacturing of the conical surface on CNC lathe.

The roughness measurements performed in four quadrants.

For the evaluation of the roundness of the cylindrical surface with the diameter of 126 mm the Roundtest RA device was used Figure 14. The robotic flange has been sta-

Figure 13: The measurement of roughness in the four quadrants performed on the measuring device Mitutoyo SJ 400.

bilized and centred by means of an elastic non-hardening material.

The average arithmetic mean of Ra was $1.92\mu\text{m}$ - Figure 15.

The circularity value $22.3\mu\text{m}$, see Figure 16.

Figure 14: Measuring of the roundness by device Roundtest RA 120.

Figure 15: Display of values of the Ra dimension in individual quadrants.

5 Discussion

The CAM software product type was selected by the shape of the model component itself, based on the shortest program creation time and using the least number of mouse clicks. Furthermore, the work environment of the software in question has, in comparison with more transparent working windows and overall program commands. The CAM Autodesk Inventor 2018 software product is a programmer who has perfect control.

6 Conclusion

The reason for the creation of automatic programming was the increase in the production of complex shaped parts, for mass production using NC machines and devices on automatic principle. The components thus drafted and designed, require proper skill in the use of the mathematical

Figure 16: Display of circularity deviation for diameter 126mm.

apparatus in order to be able to cope with the manual, respectively workshop programming. For this reason, Computer Aided Manufacturing (CAM) programs have been developed. This abbreviation means that the NC program will be created by a programmer on the PC with the aid of CAM support programs. This is how fast and high-quality NC programs can be created. CAM includes elements such as machining simulation, collision indication, etc. Nowadays, it is possible to purchase a CAM extension for all CAD systems, a wide range of which offered on the market, but not every application is suitable for any form part, respectively technology. The so-called internal core of the processor - the para-solid of the application - that designed by the CAM application manufacturer and which are constantly undergoing an innovative process gives it.

The following values were achieved in the production of the respective robotic flange. Mean arithmetic value for individual quadrants $R_a = 1.92\mu\text{m}$. Circularity deviation $22.3\mu\text{m}$. By comparing the desired and achieved deviations, it can be stated that the manufactured component is suitable for assembly and the prescribed function.

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