Manufacturing capability of the robotic complex machining edge details

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Abstract – The article presents results of influence the gain factor in the control channel of speed of the robot for a given axis on the technological properties of the robotic complex machining edge details. The proposed method is based on variation of two parameters: the gain factor and feed along the axis Y. The aim is to assess their impact on the character of the force interactions parts and tools, as well as the quality of the processing. As a result of this study the optimum gain factor influencing the operational characteristics of the robotic complex machining edge details is identified. Practical necessary recommendations on setting up the gain factor have been formulated. The results of the measures taken to achieve minimum interference in the channel sensor ForceTorqueControl are provided.

Keywords: robotic system, finishing, deburring, force-torque sensor, gain factor

I. Introduction

In the process of machining work burrs remaining on parts group are to be deleated. Currently, for machining edge aircraft details manual bench work is used. This process has typical number of disadvantages: low productivity, the emergence of gouge and refacing, the human factor, etc. [1].

Automating this process will significantly increase the productivity and improve the quality of the products, as well as get rid of some of the disadvantages of manual work. It is proposed to use the robotic system to solve this problem (automated deburring typical aircraft parts).

An important tuning parameter in the complex is the gain factor (KR), research of the influence of this parameter on the technological properties of the robotic complex machining edge details previously carried out.

This article presents the results of the gain factor (KR) influence in the control channel of speed of the robot for a given axis (X-axis) on the technological properties of the robotic complex machining edge details.

II. Research Method

In this experiment, the tool has been fixed in the spindle «Colombo RC90», the spatial position of which is regulated by software (Fig. 1). Spindle speed has not been changed and compiled - 2000 rpm in this experiment.

The study was conducted on robotic complex machining edge details on the basis robot Kuka KR210 R2700. We used samples (grade material V95-PCHT2 (ISO AlZn5.5MgCu)), mechanical processing carried cylindrical burr «Garant» Ø10.

To eliminate the negative impact of the deviation spatial position processed edges (eg distortion of part) for precision machining, in "wrist" of the robot installed force sensor «ForceTorqueControl 3.0» [2], [4]. Analysis

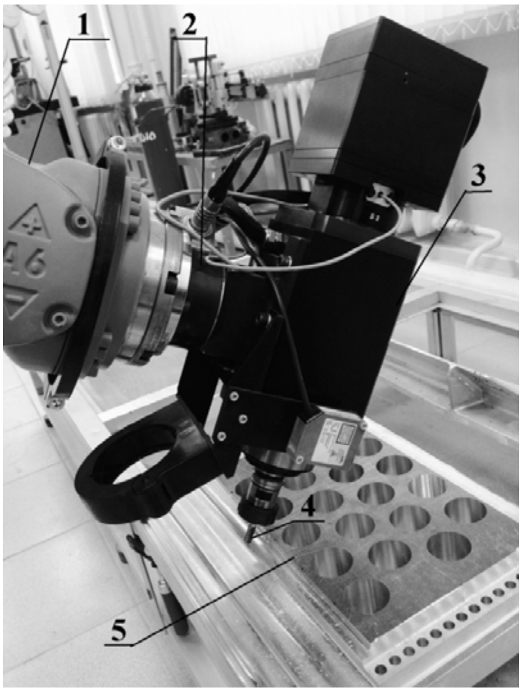


Fig. 1. Location scheme of nodes: 1 - robot “Kuka”, 2 - force-torque sensor “Kuka.ForceTorqueControl 3.0”, 3 - electric spindle “Colombo RC90”, 4 - cylindrical burr, 5 - workpiece

of the impact of the gain factor in the channel automatic correction motion path on the technological properties was carried out at a fixed value for the axis forces - 5 N.

The experiment was conducted with variation of two parameters: the gain factor (KR) and feed along the axis Y (Sy). Informative characterization was made by X-axis force (Fx) [3].

KR coefficient ranged from 0.01 to 1, each successive value will be doubled compared to the previous. Total 8 coefficient values. Feed chosen from the lowest possible 1 mm/sec to the maximum in learning mode - 250 mm/sec. Supply increased by 25% from the previous (total 24 variants).

Tool was moving in a straight line along the edge of the product, on the pre-programmed path through training robot points.

During Application «Make contact», «Tracking motion» the current values of forces and moments on the axes X, Y, Z were recorded, the sensor signals «ForceTorqueControl 3.0».

These graphics are characteristic of force interaction and are mainly determined by the drive parameters control motion axis of the robot. At the same time some increase in the amplitude fluctuations force Fx, compared with the amplitude of oscillation forces Fy and Fz, is explained by sensitivity of the sensor for a given coordinate.

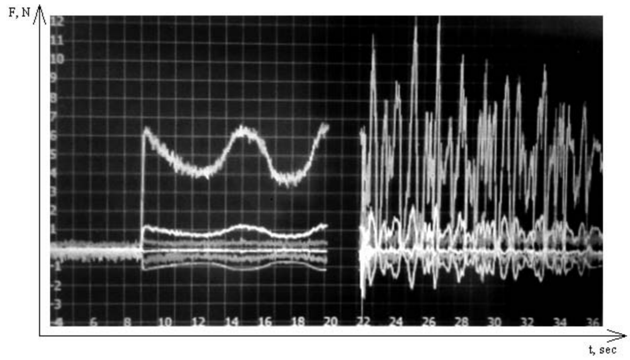
The automatic program «Tracking motion» takes force jump associated with the tool plunging into the material details. Constantly monitor the cutting forces and the automatic correction of the tool position along the axis X is carried later in the process of moving the cutter on a given path. The values of forces and moments vary during processing. This is due, primarily, with a rough original profile detail, the work driven the robot, as well as the functional advanced of algorithm of motion correction for the X-axis robot. In addition, it is found that the work of automatic systems has noise induced in the sensor channel. These may be visually detected on the scan mode signal «Make contact», and in the final part of the force diagram. Preliminary tests have shown that the impact of this noise will occur the greater, the greater the value KR is.

The main feature of the correction system of tool position is coefficient KR. Study of the impact of one on the type and properties of force diagrams is a technological basis for the development of effective modes of cutting - modes, providing the required quality of processing (roughness, waviness, size scallops) for the implementation of the required (the highest possible) performance.

III. Research results

As a result, a series of natural tests (automatic machining of parts on the robotic system with various combinations of operating parameters) working masses of 104 of temporal trends of forces and moments is obtained. According to the results of this experiment there is more than one variation with promising settings of complex and an unstable area of the system.

When coefficients KR is 0.01; 0.02; 0.05; 0.1 milling happening consistently, all varying feed value was developed, significant differences amplitudes were observed, gouge has been insignificant, but the amplitude of the graph force Fx had different values, as shown in Figure 2, which leads to variations in surface quality and depth of cut. With increasing forces was observed an increase in allowance, increasing the size of the chamfer part.



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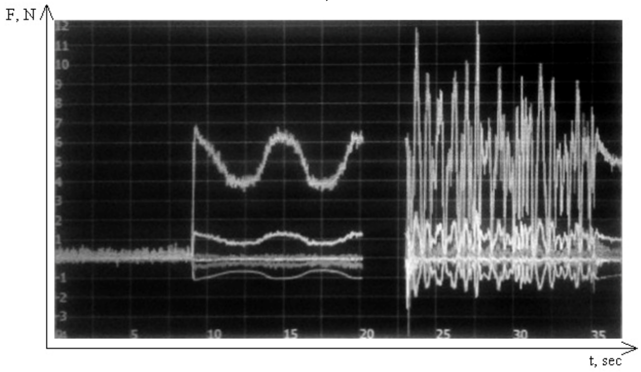

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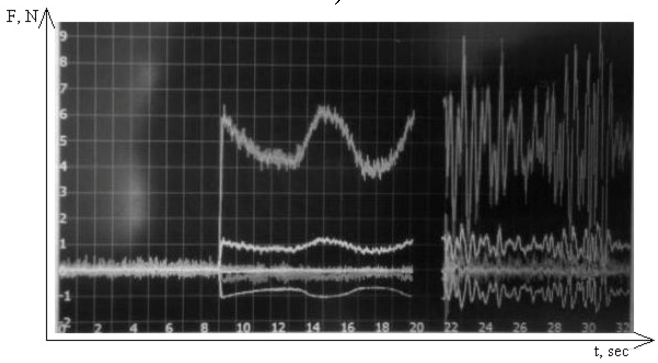

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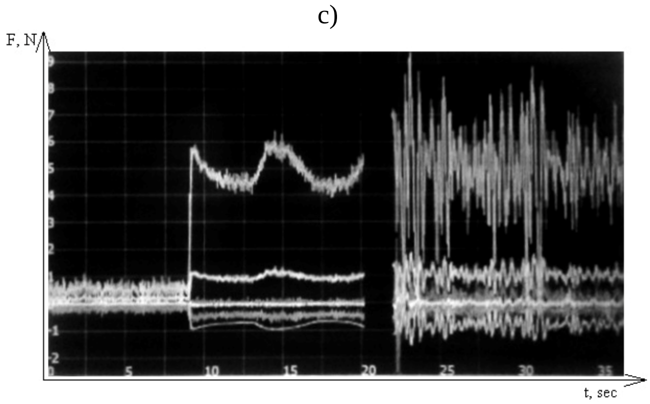


d)

Fig. 2. Graph of force from time at various gain factors: a) KR=0,01(mm/sec)/N; b) KR=0,02(mm/sec)/N; c) KR=0,05(mm/sec)/N; d) KR=0,1(mm/sec)/N

It was established experimentally that for small values of KR in the initial stage of the mining cycle «Tracking motion» linear trends decrease in the average values of the amplitudes of the forces Fx observed after plunging, they lead to the formation of areas with characteristic changes in the profile (short sections with unstable cutting depth - gouge). The size of these areas decreases with increasing KR.

In addition, it should be noted the presence of extensive areas with a gradual increase in the mean amplitude of oscillation Fx (Fig. 3), resulting in a slow monotone change (increase) the size of the chamfer parts throughout the processing (Fig. 4). As seen from the figure the gradual increase of the force is result in the formation of the product shape error value of 0.9 mm.

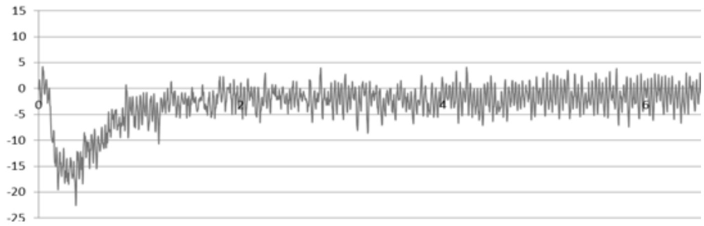


Fig. 3. Force diagram for KR = 0.01

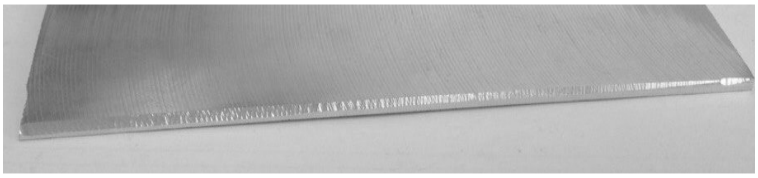
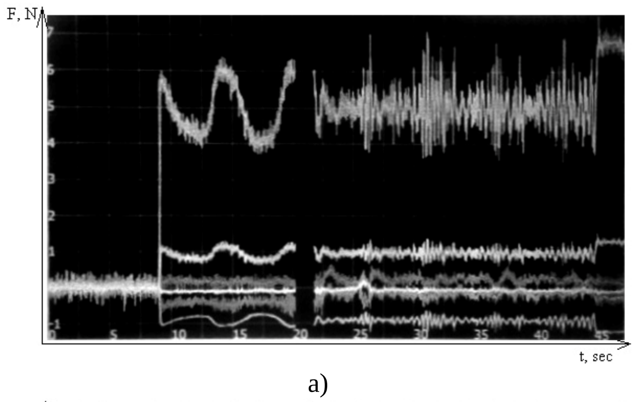


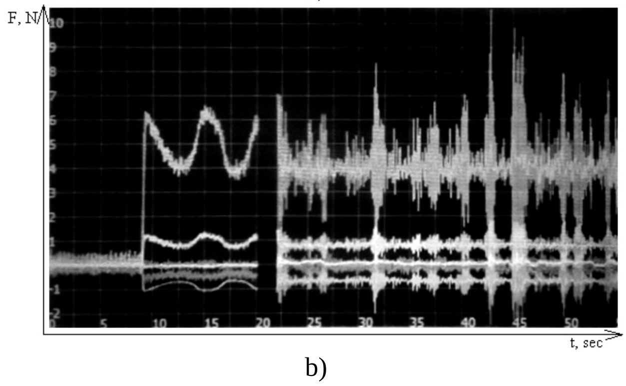
Fig. 4. The processed surface chamfer at KR = 0.01

In such a way, higher values of KR should be recommended in order to improve the quality of processing, which should ensure a reduction waviness, reducing gouge, the stability of geometry.

However, significant features were observed with further increase in the gain factor. For example, when KR = 0,5 (mm/sec)/N, feed 1 mm/sec amplitude of oscillations was 2N (Figure 5a) and when KR = 1 (mm/sec)/N, feed 1 mm/sec amplitude increased to 4N (Figure 5b). This effect is associated with an increase in speed of the tool along the axis X and, as a consequence, increases the dynamic loads on the system. In addition, increase KR led to proportional gain noise in an information channel, and hence increases in the instantaneous values of the X-axis feed and increase the cutting forces.



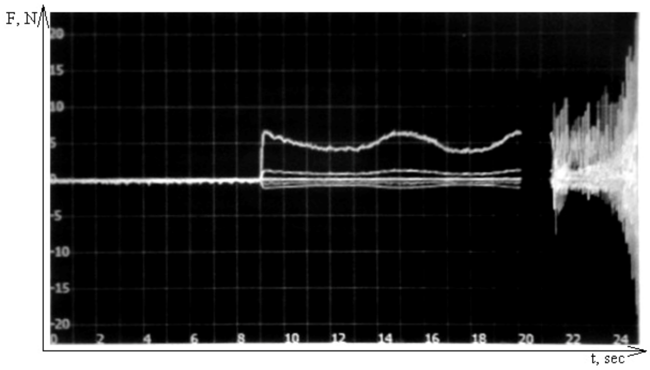
a)



b)

Fig. 5. Graph of force from time at various gain factors: a) - KR = 0,5 (mm/sec)/N; b) - KR = 1 (mm/sec)/N

An increase in feed on the Y axis for large values of KR oscillations occurred with such force that exceeds the maximum force on force and torque. When gain factor was KR = 0,5 (mm/sec)/N and feed was 10 mm/sec overload torque Ty occurred and was more than 15 N·m (Figure 6a), with a coefficient KR = 1 (mm/sec)/N and feed 5 mm/sec as an overload torque Ty (Figure 6b).



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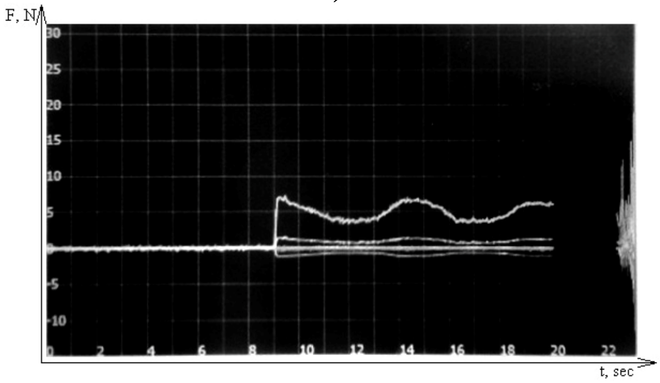
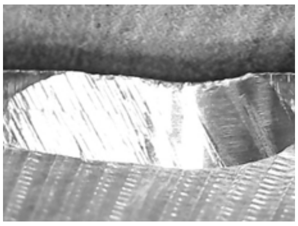
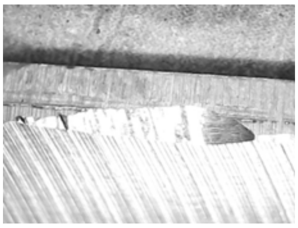


b)

Fig. 6. Graph of force from time at various gain factors: a) - KR = 0,5 (mm/sec)/N; b) - KR = 1 (mm/sec)/N

As a result, at a gain of 0.5 (mm/sec)/N and 1 (mm/sec)/N variation over all feed is failed (milling emergency interrupted due to dynamic loads exceeding the values of maximum permissible levels).

It should be noted at working with coefficients KR = 0,5 (mm/sec)/N and KR = 1 (mm/sec)/N and moving program «Make contact» force overload associated with recessing tools in part material didn't occur. However, at the same time gouge formed outside the tolerance band (Figure 7).

a) b)

Fig. 7. Gouge formed when moving «Tracking motion» a) KR = 0,5 (mm/sec)/N; b) KR = 1 (mm/sec)/N

When the ridges parameters of samples are determined used profilometer “Taylor Hobson Form Talysurf PGI 1240”, there were obtained sweep profile processed chamfers (Fig. 8). In places where there are sharp jumps profile (risks) the manifestation waviness or ridges judged (Fig. 9).

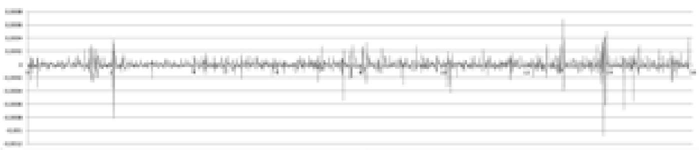


Fig. 8. Graph of profile processed surface

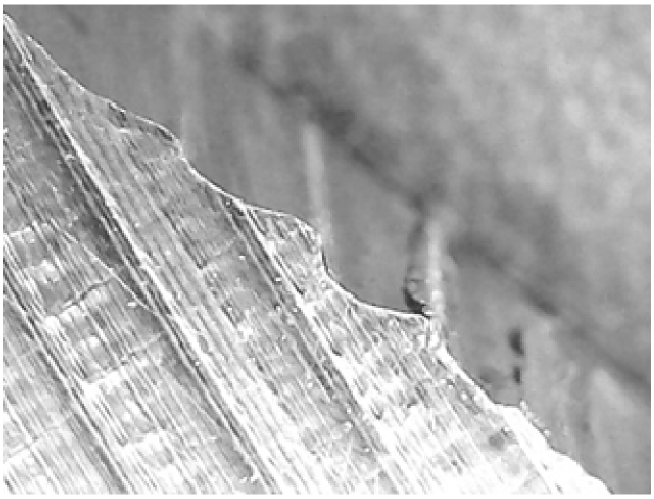


Fig. 9. Education waviness (ridges)

Ridges significantly reduce the quality of processing and technological properties of the finished product. Gain factor KR and Y-axis feed has a significant effect on the height and a step data about waviness. However, founded characteristic curves have nonlinear character, which makes the need for additional research.

To assess the impact of KR on machined surface ridges analysis of high-rise options microrelief was conducted. The experimental data indicate that with an increase in gain factor the improvement of processing quality occurs (reduced Ra and Rz).

Analysis of possibilities of quality control in the automation processing of the edges demonstrated the need to reduce the noise level which does not allow you to use more than 0.5 KR values. The results given of the spectral analysis of the noise is set low-pass filter with a cutoff frequency of 5 Hz.

The results of tests force-torque sensor with low-pass filter identified a number of advantages:

1. The ability to use more than KR=0.5 (mm/sec)/N;

2. To increase the sensitivity of the sensor to 1N;

3. Improving the quality of the processed surface of the product.

The best results of processing were achieved with gain factor KR = 1 (mm/sec)/N and feeding of 20 mm/sec, 1N set force. In these settings there is smallest difference in amplitudes force interactions and, thus, reached the minimum error forming the linear profile of the workpiece and satisfactory performance roughness (Fig. 10).

Fig. 10. The processed surface with low-pass filter

Another promising avenue to improve the quality and performance of finishing on the robotic system should be recognized the increasing spindle speeds up to 20000-25000 rpm. It involves a balancing of special events and the use of high-speed tool spindle with minimal radial run out.

IV. Conclusion

As a result of researchers of influence the gain factor in the control channel of speed of the robot on the technological properties of the robotic complex machining edge details are identified the following effects:

1. Processing edges of aircraft details is automated on the basis of an industrial robot;

2. Surface finish details milling on robotic system (microgeometry, gouge, wavy, size scallops) is caused by the properties of the surface of the workpiece and the parameters of force interaction details with the cutting tool;

3. Gain factor KR has a significant impact on the quality of the non-linear processing;

4. Increase a feed of 0.5 mm/sec at small coefficient KR≤0.2 increases force interactions in the system, increase the allowance, the quality of processing is satisfactory;

5. For large (the most productive) feeds (> 1 mm/s) it is necessary to use a high gain factor (greater than 0.5), but these modes are manifested overload. This is due to the presence of noise in the signal spectrum with the force-torque sensor and an imbalance of the tool and the spindle;

6. The use of low-pass filter in the channel force sensitization with an estimated bandwidth can significantly improve the quality and productivity of processing on robotic system;

7. At low feeds and low value of the coefficient KR effect observed monotonic increase the cutting forces, which leads to errors in shape of the product (unstable cutting depth and size of the chamfer);

8. To reduce the linear dimensions of the gouge should raise KR;

9. Increase KR allows to improve the quality of treatment (decrease Ra and Rz);

10. The study of microprofile the processed surfaces revealed the presence macroroughnesses (scallops), which requires further study in order to minimize their size during milling.

Acknowledgment

The information presented in this article is carried out with the financial support of the Government of the Russian Federation (Russian Ministry of Education) for the integrated project 2012-218-03-120 "Automation and efficiency of manufacturing processes and manufacture of products of new generation aircraft, the Scientific Production Corporation" Irkut "with the scientific support of the Irkutsk State technical University, "according to the decision of the Government of the Russian Federation, April 9, 2010 № 218.

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