

Robotic edge machining using elastic abrasive tool

A V Sidorova, E N Semyonov, A S Belomestnykh

Irkutsk National Research Technical University, 83, Lermontov St., 664074, Irkutsk, Russia

E-mail: berkut1@mail.ru

Abstract. The article describes a robotic center designed for automation of finishing operations, and analyzes technological aspects of an elastic abrasive tool applied for edge machining. Based on the experimental studies, practical recommendations on the application of the robotic center for finishing operations were developed.

1. Introduction

In modern machine building, most parts are finished. At Irkutsk Aviation Plant, these operations are manual. As a result, they are labor intensive and have low performance (edge machining speed is 0.5 mm/sec) and cause different defects: undergrinding and gouging [1]. To improve edge machining, a robotic center was developed. It consists of the KUKA KR210 R2700 extra with a KR C4 control system [7], a KUKA KL 1000-2 linear axis, a worktable, an extractor plant, a RC90/22 spindle, a Delta IP60 330-30 force-torque sensor (Figure 1).



Figure 1. Robotic center for edge machining



The robotic center is designed for deburring, flash removal, and root face automation.

Earlier, for edge machining, rigid cutting tools (mills) were used [6]. However at increased feed rates, machining ($S > 5$ mm/sec) caused self-oscillations in the system and decreased stability and accuracy [2]. To eliminate those problems, a special elastic abrasive tool was developed [5]. The present work describes the research results for edge machining using a synthesized robotic center with an elastic abrasive tool.

2. Materials and methods

Rectangular samples made from aluminum V95pchT2 150x50x2 mm in size were used. Three types of an abrasive tool were used (Figure 2):

1. 3M Scotch-Brite Roloc Bristle P50,
2. SCM siafix t3875 P36,
3. SCM siafix t3875 P100.



Figure 2. 3M Scotch-Brite Roloc Bristle P50 tool adjustment for edge machining

With regard to customer's performance and quality requirements, grinding conditions were as follows: spindle rotation frequency was 5000 rev/min, feed varied from 5 to 20 mm/sec, force/torque contour transition factor was $KR=0.2$, tool pressing force was reduced to 0.5 N. The number of repetitions at each mode was 3.

Two machining methods were used: by the whole tool surface (to ensure uniform tool wear) and by its side.

Surface roughness and edge chamfer dimensions were monitored. Output parameters were determined using a Taylor Hobson Form Talysurf profilometer. The chamfer was measured at eight equally spaced points (distance between them is 20 mm), and roughness – in sectors between these points.

3. Results and discussion

When the adjustment scheme for 3M Scotch-Brite Roloc Bristle P50 was symmetrical (Figure 3 trend "Center"), roughness and chamfer dimensions fell outside the tolerable limits. When the adjustment scheme was asymmetrical (trend "Sides"), machining quality requirements were met (Figure 3). It should be noted that at increased feed rates of 10, 15, 20 mm/sec, machining with this tool was impossible due to cutting instability and significant vibrations [3, 4].

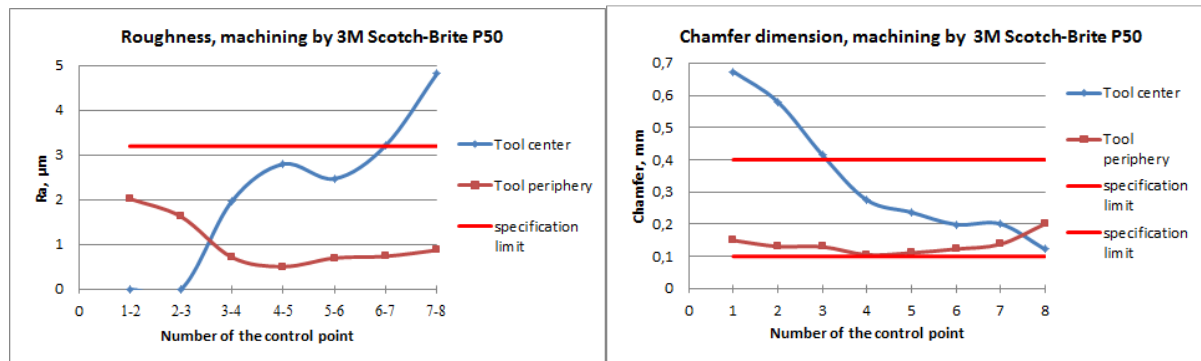


Figure 3. Comparison of roughness and chamfer dimensions after machining with a 3M tool at different tool adjustment schemes

When using SCM siafix t3875 P36 with a symmetrical tool adjustment scheme at feed rates of 5 and 10 mm/sec, chamfer dimensions were within the tolerable limits, however the roughness rate was unsuitable (Figure 5). At feed rates of 15 and 20 mm/sec, self-oscillations occurred which caused significant increase in cutting forces (up to 50 N) and, as a result, an emergency stop of the center. In case of the asymmetrical tool adjustment, the operation performance increased. Roughness values met the requirements at all feed rates, except for some sectors in the tolerance band. Chamfer dimensions also met the requirements, except for the base sector where some insignificant gouges developed (Figure 4). At the same time, these defects can be eliminated unless a perpendicular tool penetration scheme is applied.

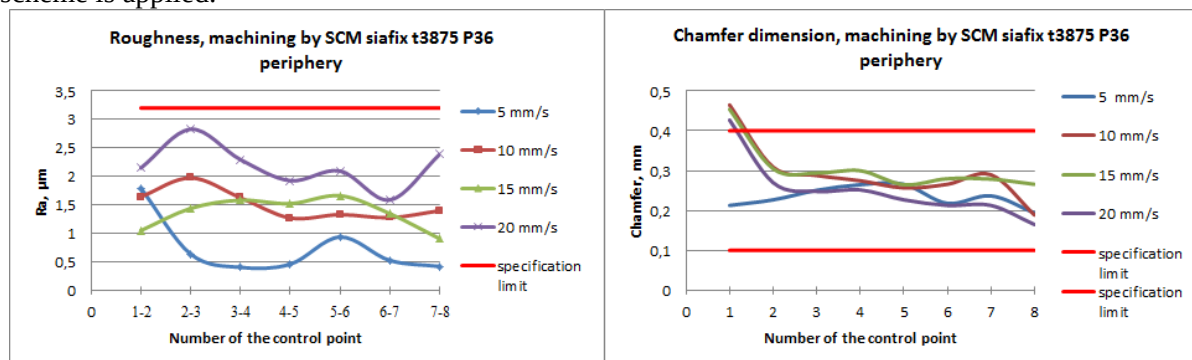


Figure 4. Roughness and chamfer dimension, machining by SCM siafix t3875 P36 sides

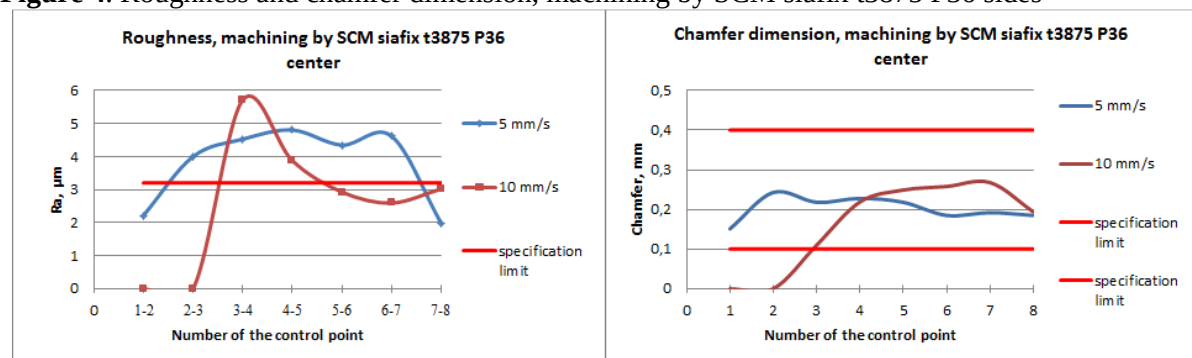


Figure 5. Roughness and chamfer dimension, machining by SCM siafix t3875 P36 center with the symmetrical tool adjustment

When machining with SCM siafix t3875 P100, the results were the best, chamfer dimensions and roughness values were within the tolerable limits at different tool adjustment schemes (Figure 6 and Figure 7). An exception to it was the machining operation at a feed rate of 20 mm/sec after which the

chamfer dimension was intolerably small (Figure 5). However, it does not eliminate the possibility to work under these highly efficient conditions. To this end, a force set-up parameter should be increased.

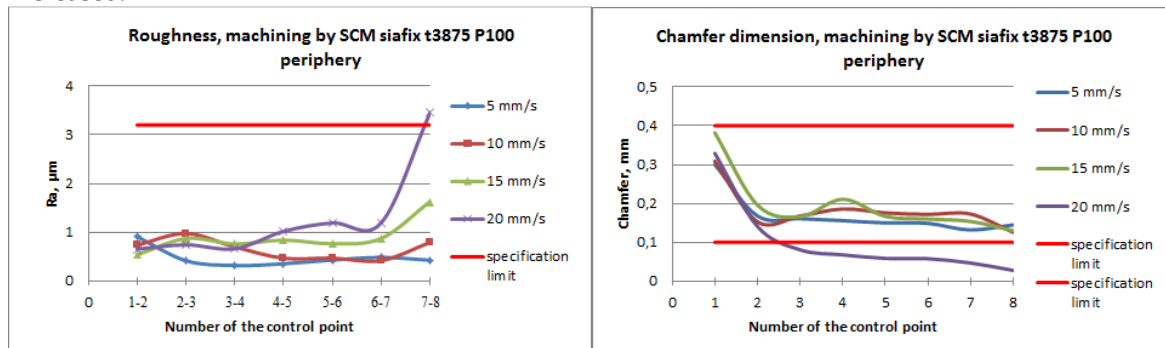


Figure 6. Roughness and chamfer dimension, machining by SCM siafix t3875 P100 sides

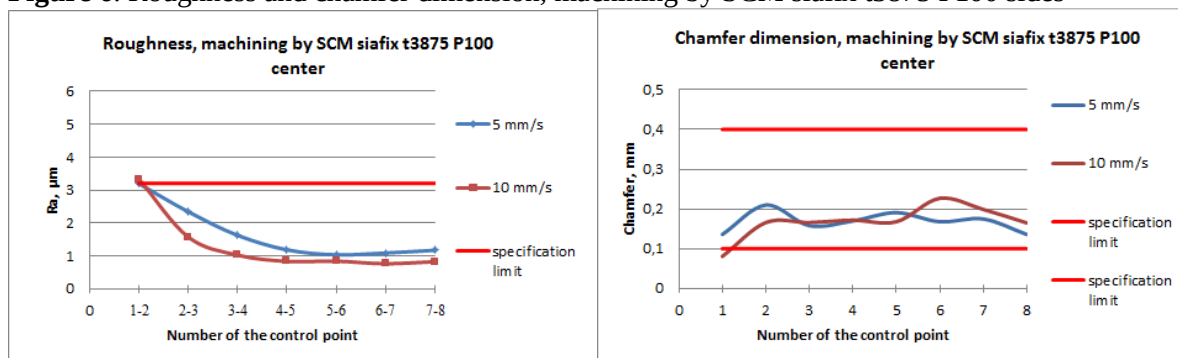


Figure 7. Roughness and circle chamfer dimension with the symmetrical tool adjustment

The research results show that edge machining using all types of elastic tools with an asymmetrical adjustment scheme is more efficient than machining with a symmetrical adjustment scheme.

This effect is conditioned by a decreased tool contact line with a part surface when machining by sides and increased tool compliance.

Analysis of the profile of the edge machined with an elastic tool identified sharp edge roundness (Figure 8).

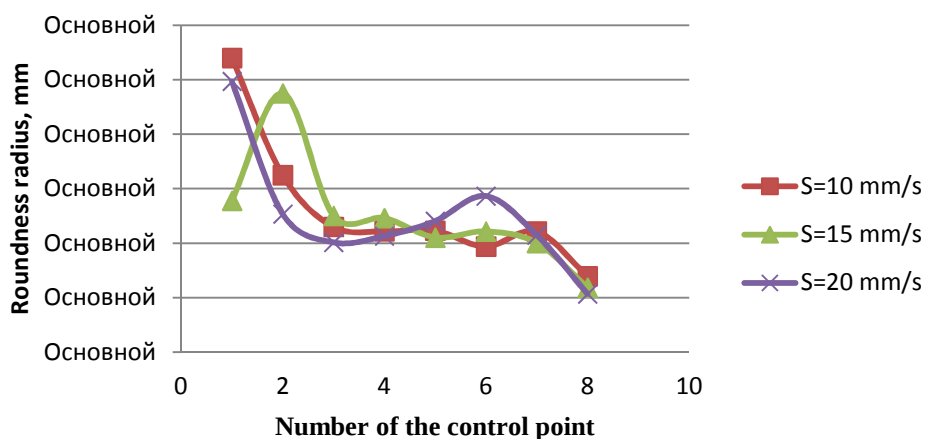


Figure 8. Edge roundness radii at control points after machining with SCM siafix t3875 P100

The significant level of roundness radii in the base sector results from the use of a perpendicular tool penetration scheme. When the tool is penetrated tangentially to the surface, the value can be

stabilized. Practical application of the effect helps reduce the number of edge machining stages by combining two operations – chamfering and rounding sharp edges.

Conclusion

A robotic center with an elastic abrasive tool increases labor efficiency 2-4 times and eliminates possible defects which are typical for manual operations. As compared to rigid tools, the robotic center ensures stable quality values and performs two operations simultaneously: chamfering and rounding sharp edges.

Two machining modes can be applied: symmetrical tool adjustment and asymmetrical tool adjustment. However, machining by sides should be preferred as it ensures increased operation stability and better technological possibilities. At the same time, according to the research results, successful implementation of the developed method requires thorough examination and optimization of the stage of tool penetration.

References

- [1] Ivanova A., Belomestnyh A., Semenov E., Ponomarev B. Manufacturing capability of the robotic complex machining edge details // International Journal of Engineering and Technology (IJET). Vol 7 No 5 Oct-Nov 2015, p.1774-1780.
- [2] Semyonov E.N., Sidorova A.V., Pashkov A.E., Belomestnykh A.S. Accuracy assessment of KUKA KR210 R2700 extra industrial robot // International Journal of Engineering and Technology. 2016. Vol. 16 (1). P. 19-25.
- [3] Aleynikov D.P., Lukyanov A.V. Simulation of the cutting forces and determination of vibrodiagnostics symptoms of end mill defects. Sistemy. Metody. Tekhnologii [Systems. Methods. Technologies]. 2017, no. 1 (33), P. 39–47.
- [4] Lukyanov D.A., Aleynikov D.P., Luk'yanov A.V. Calculation of parameters and visualization of spatial vibrations of machining center spindle by vibration measurement results // Vestnik of ISTU. Irkutsk. 2013. Vol. 12(83). P. 92-99.
- [5] V. Koltsov, D. Starodubtseva. Investigation of Interaction Traces between Flap Wheel and Aluminum Alloy Plain Surface//Procedia Engineering (2017) pp. 473-478 10.1016/j.proeng.2017.10.503
- [6] Sidorova A.V. Model of accuracy control processing in the operation of milling edges on the RTC // In: AIRCRAFT MACHINE BUILDING AND TRANSPORT OF SIBERIA. Collection of articles of the IXth All-Russian Scientific and Practical Conference. Irkutsk National Research Technical University; Ed. by Bobarika I.O.; Lytkina, AA, 2017. P. 246-250.
- [7] Ivanova A V, Ponomarev B B, Savilov A V, Chapyshev A P. Robotic system performing deburring after part milling // Vestnik ISTU. Irkutsk. 2013. Vol. 11(83). P. 49-53.