IOP Conf. Series: Materials Science and Engineering **450** (2018) 032028 doi:10.1088/1757-899X/450/3/032028

Implementation of the design concept of a high-speed processing cycle for CNC machines in the form of a software module CAM-system

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Abstract. In this paper, the authors considered the factors of the technological system that affect the performance of high-speed operation, and formulated recommendations for designing high-speed operations on CNC machines, as well as the directions for automating calculation data based on CAM systems.

1. Introduction

In modern engineering, high-speed processing with abrasive wheels is used to produce products with high-precision dimensions and low roughness. Modern high-tech CNC machines for high-speed machining allow processing as a grinding sequences consisting of several stages. The above sequences for a CNC machine is represented as a consecution of commands in G-codes according to the international standard ISO, recorded in the control program.

When developing the grinding sequences and the control program, it is necessary to take into account the whole complex of requirements for roughness and accuracy of the machine surface, for the absence of burns, for the intensity of tool wear, for the power of the machine. It is also necessary to ensure maximum performance. Manual development of a control program that takes into account all the above factors is very difficult, which forms the problem to be solved. It is proposed to develop a software module based on advanced scientific research and allowing to design a machining cycle which is based on the data entered by the user and output it as a control program file.

For development a software module, it is necessary to build an algorithm for its functioning. In the algorithm, it is necessary to enclose a scientific methodology for designing a high-speed processing cycle for CNC machines. Considering the research on the design of high-speed machining cycles, we note that in this area there are both foreign [1–6] and domestic researches [7–15]. A proprietary method of designing a high-speed machining cycle for a CNC machine is proposed, allowing to calculate process rates with automatic generation of cycle steps.

2. Design technique for high-speed processing cycle

The construction of the grinding sequences is made in the coordinate system “radial feed / stock”. After the formation of the grid, a certain consecution of checking constraints is set when moving along the “radial feed / stock” grid. First, the feed is calculated that meets the requirements for the surface roughness of the part at a given frequency of rotation of the workpiece. Further, this feed is compared with the nameplate data of the machine. When constraint satisfaction on the surface roughness of the part, the following is checked for the limitation on the required drive power for a given value of the radial feed. When the specified conditions are met, the limit force, at which the grinding wheel will intensively wear out, and the main component of the cutting force are calculated. Then, the temperature in the treatment zone and the depth of burn on the workpiece surface are calculated for a given radial feed. The obtained value of the burn's depth is verified by comparison with the residual value of the stock. Next, the specified radial feed is checked by the magnitude of the elastic deformations in the technological system. When the above conditions are met, the grid is moved in the coordinate of the stock at the specified feed and the constraints described above are recalculated.

Consider the order of formation of the high-speed processing cycle on a specific example (Figures 1-6). Figure 1 shows the grid step with the radial feed rate S1 and the stock h1. At point 1, the calculation of the limitations of the radial feed S1 was made on the nameplate data of the machine, the surface roughness, the required drive power, friability of the grinding wheel. This feed has passed this block of limitations, therefore, the burn depth h_{burn} is calculated. It can be seen from the graph that the depth of the burn is limited by the residual stock. Therefore, the actual change of the radial feed is calculated taking into account the actual stiffness of the technological system (curve 1) from the preselected feed S_1 to the feed S_{min}, in which the requirements on the surface roughness of the part are fulfilled. As a result of the calculation, the actual coordinate of the removed stock 2* shows the difference from the specified value in the coordinate of the "stock" (point 2), but at the same time the elastic deformations limit in the technological system is satisfied.

To test the possibility of improving the resulting two-stage grinding sequence, a repeated step is taken along the axis of the "stock" with the feed S_1 (see figure 2). At point 2, the calculation of the radial feed limit S_1 to the depth of burn is also calculated. When limiting the burn depth, the actual change in the radial feed is calculated taking into account the actual rigidity of the technological system (curve 1) from the preselected feed S_1 to the feed S_{min}, in which the surface roughness of the part is fulfilled. As a result of the calculation, the actual coordinate of the removed stock 3 * shows the difference from the specified value in the coordinate of the "stock" (point 3), but the requirement to limit the feed depends on elastic deformations in the technological system is accomplished (curve 1).

Similarly, to assess the possibility of improving the grinding sequence, a displacement along the axis of the "stock" is performed with S_1 fed to point 3 (see figure 3). However, the preselected feed passes only the first four limits. When calculating the burn limit, the figure shows that the residual stock is less than the burn depth and when calculating the decrease of feed S_1 to feed S_{min}, the radial feed is not limited by elastic deformations in the technological system, that is, the actual feed decreases at 4 * limits of residual stock at point P_0 (curve 1). Thus, this option is not accepted and the return along the allowance to point 2 is made and the feed rate S_1 is reduced to feed S_2 (see figure 4). With a new feedrate value S_2, the displacement along the coordinate of the stock from point 3 to point 4 is performed, followed by the calculation of the limitation on the depth of burn and elastic deformations in the technological system. In this case, the feed S2 passes the power limit and the burn depth. After, decrease of feed S_2 to feed S_{min} (curve 1) is simulated. The feed reduction is made at the 5 * point, which shows the implementation of the limit on elastic deformations in the technological system.

To test the possibility of improving the three-stage grinding sequence, the coordinate is moved along the "stock" at feed point S_2 to point 5 (see figure 5). It can be seen from the figure that the feed S2 does not pass the limitation on the burn depth of at point 6 and the magnitude of elastic deformations in the technological system while feed reduction at point 6 *, since there is a departure from the coordinate at point P_0 (curve 1). Therefore, this move on the grid is discarded and returns to point 4, followed by a decrease the feed S_2 to the feed S_3 at point 5 (see figure 6.). This feed goes through force and restrictions on the burn depth when moving to point 6. Next, decreasing of the feed rate S_3 to the feed S_{min} at point 7 is simulated. From the figure, the feed S_3 passes the limits of elastic deformations in the technological system and a four-step grinding sequence with removal residual stock at point P_0 is formed.

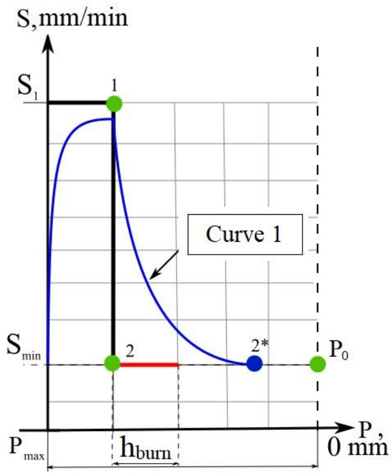

Figure 1. An example of the cycle steps formation in coordinates1–2.

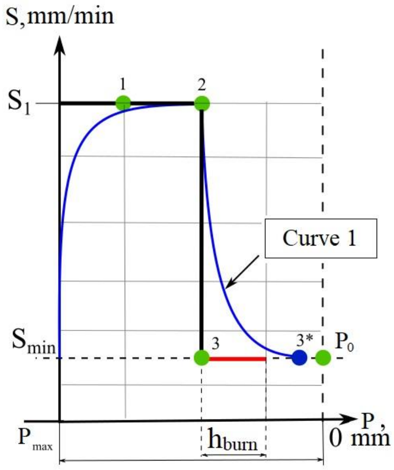

Figure 2. An example of the cycle steps formation in coordinates11–3.

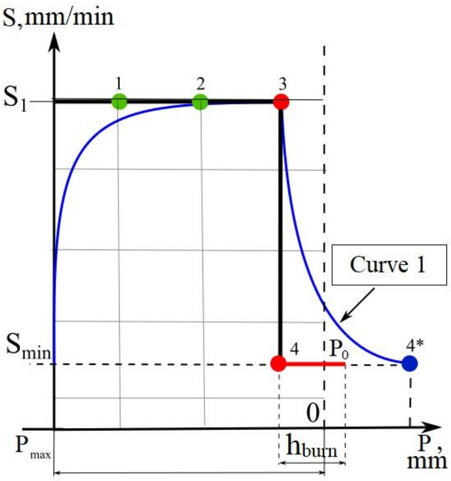

Figure 3. An example of the cycle steps formation in coordinates11–4.

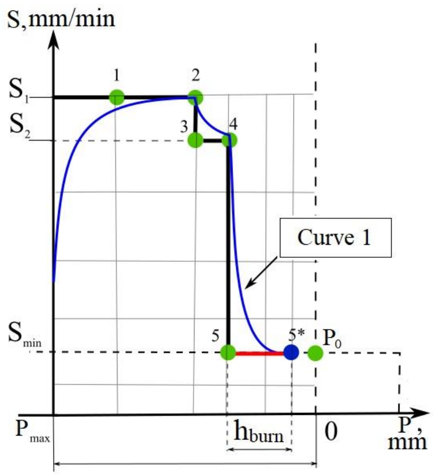

Figure 4. An example of the cycle steps formation in coordinates11–5.

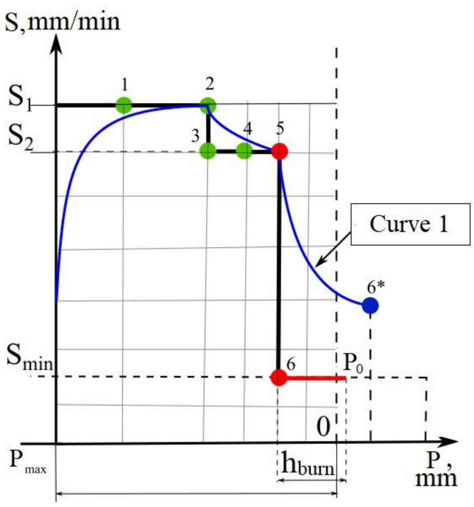

Figure 5. An example of the cycle steps formation in coordinates11–6.

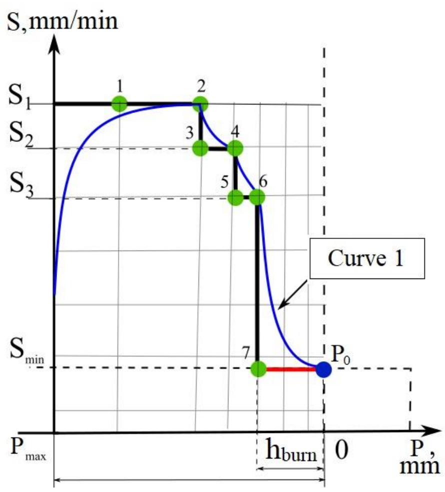

Figure 6. An example of the cycle steps formation in coordinates11–7.

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Thus, according to the developed design methodology, the first version of the permissible grinding sequence is formed, which is written into an array of cycles at a given frequency. Then the initial feed in the grid S_1 is reduced by a given step h_s and the limits are recalculated to assess the admissibility of this move.

After calculating the limits, the same as in the first variant of the cycle, the remaining stages of the grinding sequence are calculated. As a result of the n-th number of limits in the initial feed of the cycle and repeated calculations, a second permissible grinding sequence is formed, which is written into the cycle array at a given frequency of rotation of the workpiece. Thus, the initial feed rate is reduced in the next version of the cycle until the initial radial feed rate S_1 is not equal to S_{min}, that is, a single-stage grinding sequence is formed. As a result, the cycle array will contain the n-th set of permissible grinding sequences with different number of cycle steps. From this array of cycles, the option with the shortest processing time is selected. If the requirements for limits are met, then this cycle is recorded optimally at a given frequency of rotation of the workpiece. If the requirements are not met, this cycle is removed from the array of cycles and the verification calculation of the next cycle in performance. This consecution is repeated until the tested cycle satisfies the requirements for the specified accuracy of the part. The most productive grinding cycle that fulfills technological limitations is recorded as optimal at a given frequency of rotation of the workpiece.

3. Development of software module for CAM-system

Based on the described methodology, a software module for calculating the cycle of high-speed processing was developed. In this software module, the user sets the source data for the following groups of parameters: equipment parameters, tool parameters, workpiece parameters, coefficients to take into account the temperature in the processing area and the wear of the grinding wheel. The interface of the program module is presented in figure 7.

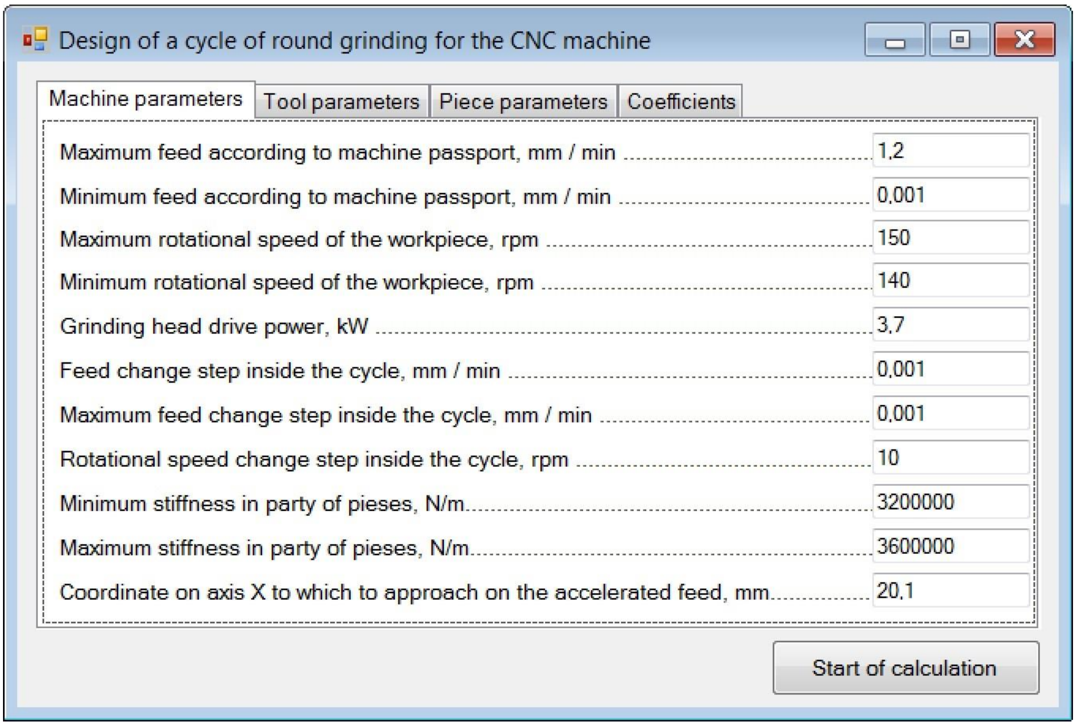

Figure 7. High Speed Processing Cycle Calculation Interface.

After entering all the necessary data in the form presented in figure 7, the user needs to press the "Start Cycle Calculation" button, thereby launching the execution of the internal algorithm of the program. After completing the design by the program module of the cycle, a file with a control program is generated in the folder (see figure 8). This file can be transferred to the machine in any way possible and run without prior adjustment.

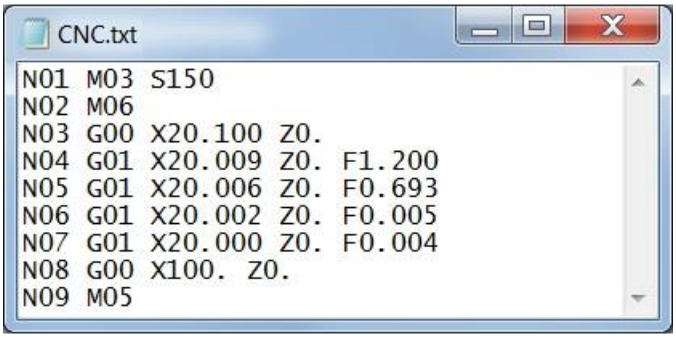

Figure 8. The file with the control program in the form of a cycle.

4. Conclusion

Thus, a software module was developed based on the high-speed processing cycle design method for CNC machines. The cycle allows to develop an effective and most productive cycle of high-speed processing on CNC machines based on the data entered by the designer. The developed module is intended for software engineers at machine-building enterprises, and can also be integrated into the CAM system for its further use.

Acknowledgments
The work was supported by the grant of the President of the Russian Federation MD932.2017.8.

References

[1] Malkin S and Guo C 2008 *Grinding Technology: Theory and Applications of Machining with Abrasives* (2nd Edn. Industrial New York)
[2] Chen X 2016 *Advances in Quality and Productivity in Precision Grinding: A Review of Selected Research* (Virginia: ASME 2016 11th International Manufacturing Science and Engineering Conference, V. 1: Processing Blacksburg, USA)
[3] Li B, Luo B, Mao X, Peng F and Liu H 2013 *International Journal of Machine Tools and Manufacture* 73–84
[4] Chen D and Tian Y 2010 *Jixie Gongcheng Xuebao/Journal of Mechanical Engineering* **46(13)** 186-91
[5] Kumar N, Tripathi H and Gandotra S 2015 *Int. Journal of Engineering Research and Applications www.ijera.com* **5** 100-4
[6] Li H L, Cao H Y and Jiang C 2013 *Advanced Materials Research* **690 693** 2442-5
[7] Shipulin L V, Dyakonov A A and Al-Aqeeli M M 2017 *Procedia Engineering* **206** 1211-4
[8] Shipulin L V and D'Yakonov A A 2016 *Procedia Engineering* **50** 936-41
[9] Ardashev D V and Shipulin L V 2017 *Russian Engineering Research* **37(2)** 150-3
[10] Ardashev D V and Guzeev V I 2017 *Russian Engineering Research* **37(5)** 459-61
[11] D'yakonov A A 2014 *Russian Engineering Research* **34(12)** 778-80
[12] Ardashev D V 2007 *Cutting Conditions in Manual and Semiautomatic Grinding and Finishing Machines: A Handbook* (Chelyabinsk: ATOKSO)
[13] Guzeev V I and Nurkenov A Kh 2016 *Procedia Engineering* **150** 815-20
[14] Guzeev V I and Nurkenov A Kh 2017 *Procedia Engineering* **206** 1221-6
[15] Guzeev V I and Nurkenov A Kh 2015 *Russian Engineering Research* **35(2)** 150-3