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Solution of task related to control of swiss-type automatic lathe to get planes parallel to part axis

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Abstract. The work solves the problem of automation of machining process namely turning to produce parts having the planes parallel to an axis of rotation of part without using special tools. According to the results, the availability of the equipment of a high speed electromechanical drive to control the operative movements of lathe machine will enable one to get the planes parallel to the part axis. The method of getting planes parallel to the part axis is based on the mathematical model, which is presented as functional dependency between the conveying velocity of the driven element and the time. It describes the operative movements of lathe machine all over the tool path. Using the model of movement of the tool, it has been found that the conveying velocity varies from the maximum to zero value. It will allow one to carry out the reverse of the drive. The scheme of tool placement regarding the workpiece has been proposed for unidirectional movement of the driven element at high conveying velocity. The control method of CNC machines can be used for getting geometrically complex parts on the lathe without using special milling tools.

1. Introduction

Swiss-type automatic lathes are widely used in mass production. Their main advantage over other types of equipment is high productivity while ensuring the accuracy of the received parts.

The accuracy control issues have been examined most extensively in literature. For example, the paper [1] deals with the possibility of ensuring the specified accuracy of the part profile in the longitudinal section depending on the geometry of the received elements. CNC systems make it possible to monitor dimensions of parts by the tool wear, the deviations of dimensions of workpiece from the theoretical one, etc. [2].

At present, the planes parallel to the part axis have obtained on swiss-type automatic lathes using special milling attachments [2]. The scheme of such operation is shown in Figure 1. A cutter 1 and a cutter 2 remove material with preliminary tool adjustment while a bar stock gradually moves with the feed force f_L . The rotation of the bar stock stops once it takes the standard position. After that the bar stock is rigidly fixed in the machine. Then the end mill fixed in the special attachment performs the stock removal with cutting force f_M for getting planes parallel to the part axis.

It should be noted that the bar stock has a considerable overhang during this operation (Figure 1), hence the forces arising during the milling operation give the displacement of the received plane.



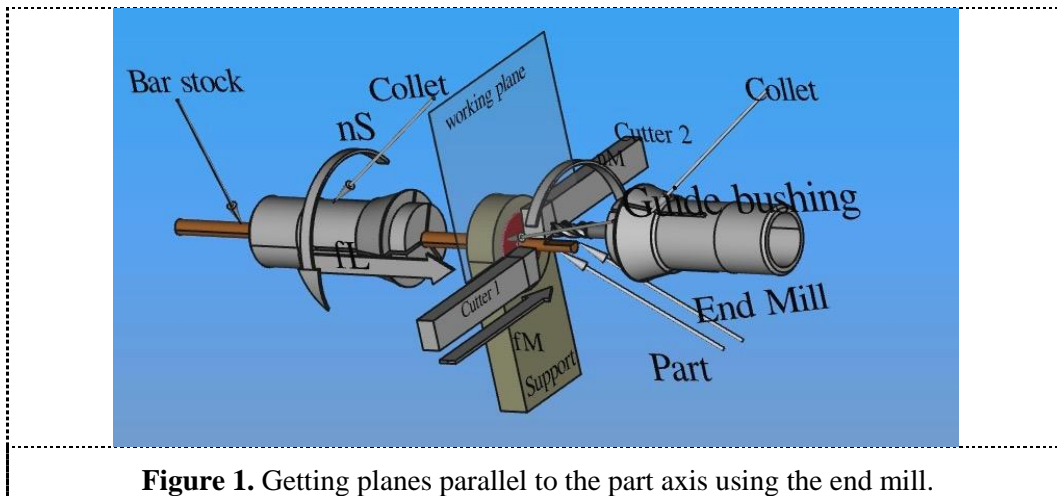


Figure 1. Getting planes parallel to the part axis using the end mill.

The questions concerning compensation of geometrical errors have been repeatedly discussed in various works, both in turning [4] and other types of machining [5]. However, if the overhang of the part far exceeds its diameter, as shown in Figure 1, the elimination of these geometrical errors is very problematic. For this reason, the authors have suggested that the obtaining of planes parallel to the part axis is possible using only turning tools [6]. It will eliminate geometrical errors occur during turning.

2. The method of getting planes parallel to the part axis

The method offered by the authors consists in the application of the turning tool for stock removal not around circumference of the bar stock, but by the movement of the tool in the cross-machine direction with cutting force f_c (Figure 2) according to geometrical parameters of the desired plane.

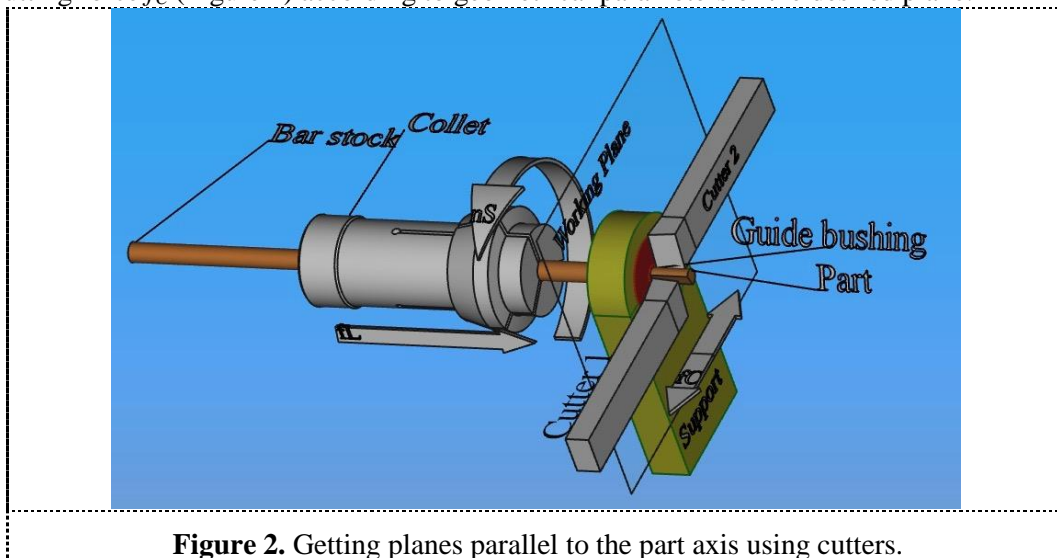


Figure 2. Getting planes parallel to the part axis using cutters.

The scheme of stock removal in the working plane is presented in Figure 3. Let us consider the movement of the cutter during one rotation of the bar stock. This linear movement of driven element will be presented as a function of time.

The time of movement of the tool is equal to T :

$$T = \frac{60}{nS} \quad (1)$$

where nS is the rotation speed of the tool calculated in accordance with the desired cutting velocity, *RPM* [7].

The coordinate system of the part is set in accordance with the position of axis during the turning. Thus, during one rotation of the bar stock, the cutter has reciprocating movement along axis X to remove the material by the maximum value of Δx . Therefore, in the process of getting the plane with an angle φ , the position of the tool corner changes from R to $(R - \Delta x_{max})$ and from $(R - \Delta x_{max})$ to R during one rotation.

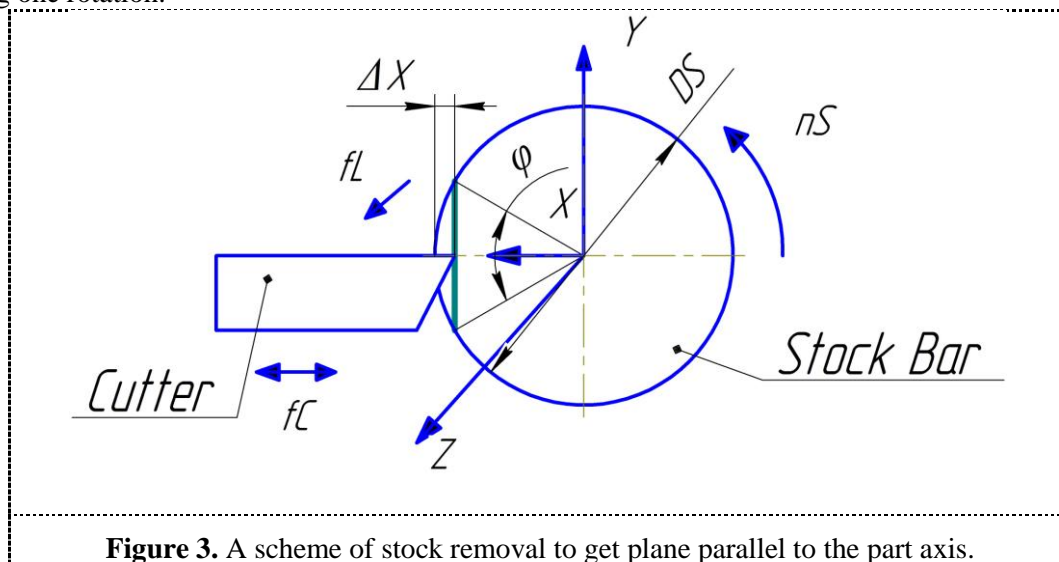


Figure 3. A scheme of stock removal to get plane parallel to the part axis.

The conveying velocity of the tool is a constant. At the same time, it reversed at point $\varphi/2$ (Figure 3) during turning. The simulation and theoretical analysis of such movement of the tool confirms the capability of getting planes parallel to the part axis [8]. However, there is no drive performing an «instantaneous» stop of the actuator. To reverse the direction of movement until the dead stop, it is necessary to displace with time delay (to reduce the conveying velocity) and then accelerate again (to increase the conveying velocity). It causes the formation of convex shape of the machined surface. If the technical requirements allows it, the machining should be performed following the scheme shown in Figure 2. But generally the plane must be «perfect».

Let us consider the construction of the graph that will show a dependence of movement of the tool along axis X on the time. The models of movement of the tool have been previously obtained in works [6], [8]. Having the necessary simplification, the model of movement of the tool of getting planes parallel to the part axis can be written as:

$$f(x) = \frac{Ds}{2} - X(x) - \left(\frac{Y(x)}{\operatorname{tg}\left(\frac{180 - \varphi}{2} + x - 1\right)} \right) \quad (2)$$

where Ds is the diameter of the bar stock, *mm*; X is the current X position; Y is the current Y position; φ is the angle of the plane (according to Figure 3), degree. Using *Smath Studio*, the calculation and the graph of movement of the tool have been made. The fragment of calculation and the graph of movement of the tool are shown in Figure 4.

Because of X changes from 0 to φ (Figure 3), the axis of abscissas represents its value in degrees (Figure 4).

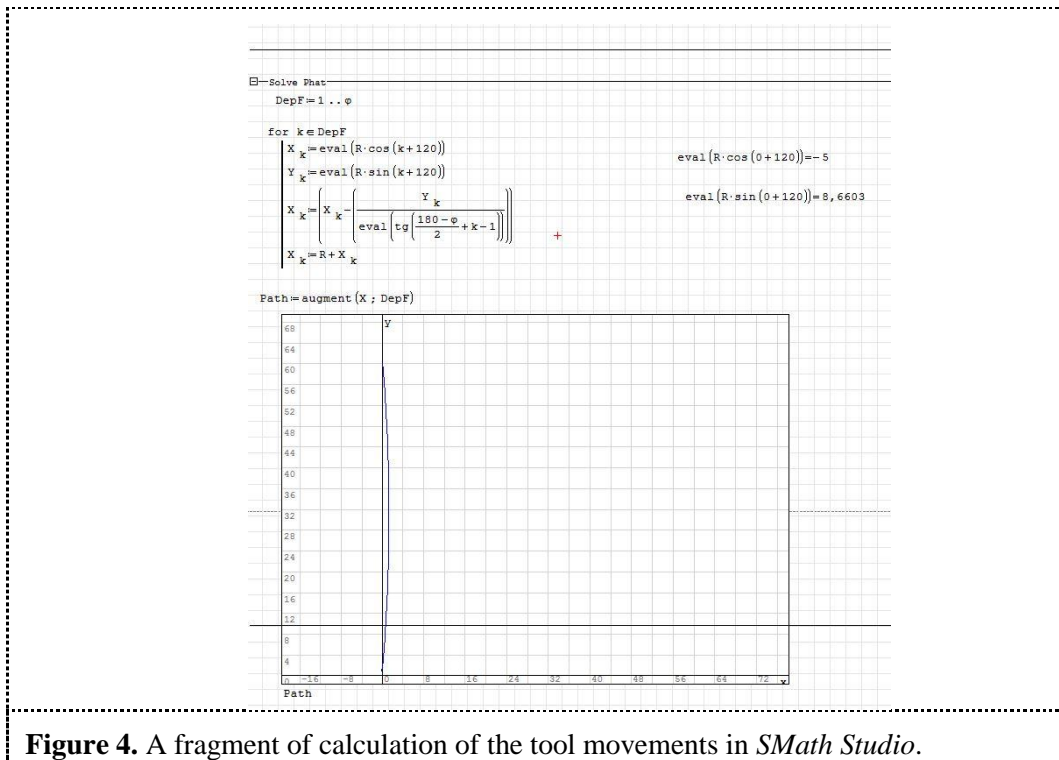


Figure 4. A fragment of calculation of the tool movements in *SMATH Studio*.

In order to calculate the linear movement of the cutter in case of synchronization with rotation of the bar stock, the following equation should be used:

$$\Delta T = \frac{60}{nS \cdot 360} = \frac{1}{6nS} \tag{3}$$

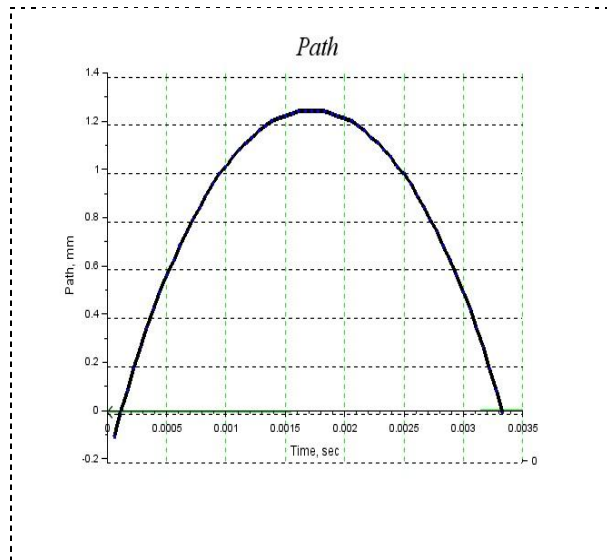


Figure 5. Relation between the movement of the tool along axis *X* and the time *t* during one rotation of the bar stock ($D_s = 20$ mm, $nS = 3000$ RPM, $\varphi = 60^\circ$).

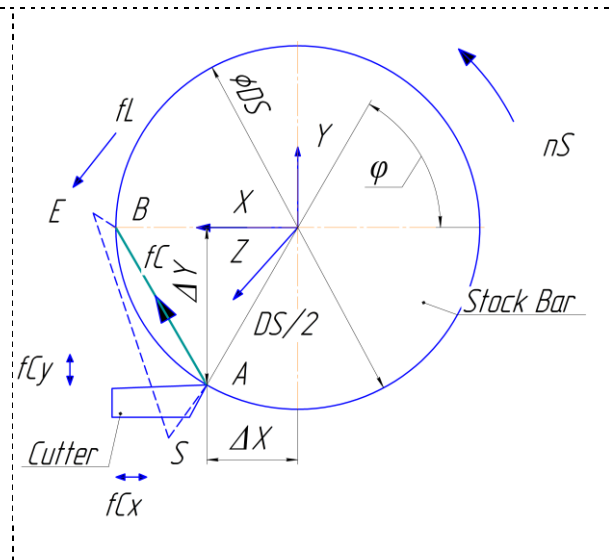


Figure 6. Scheme of getting the plane where it is positioned in quadrant III of the coordinate system.

Thus the rotation of the bar stock by one degree is caused by the linear movement of the cutter ΔT .

Figure 5 shows the relation between the movement of the tool along the axis X and the time t during one rotation of the bar stock under the following condition: $D_s = 20 \text{ mm}$, $nS = 3000 \text{ RPM}$, $\varphi = 60^\circ$. Conveying velocity V represents the derivative of Eq. 2, which is the model of movement of the tool:

$$V = \frac{d}{dt} \left(\frac{D_s}{2} - X(t) - \frac{Y(t)}{\operatorname{tg} \left(\frac{180 - \varphi}{2} + \alpha(x) - 1 \right)} \right) \quad (4)$$

where $\alpha(x)$ is the change of the angle of the plane during the time of machining. As can be seen from Figure 5, the driven element of equipment moves to the point at which the conveying velocity is equal the value of zero, and then begins to move in the opposite direction. The movement of driven element only in one direction will solve the problem of reverse or rather will exclude it.

For unidirectional movement, the scheme presented in Figure 3 was positioned in quadrant III of the coordinate system (Figure 6).

The authors have proposed locating the starting point of machining at a distance of ΔX and ΔY from the center of rotation of the bar stock. The coordinates of the starting point are calculated from conditions that all planes are positioned in quadrant III of the coordinate system; the starting point of the angle φ is located in point A ; the point B has coordinate $Y=0$. That is, the coordinate system of the part is shifted by the angle φ . The value of ΔY during the stock removal is estimated from Eq.6:

$$\Delta Y = -\frac{D_s}{2} \sin(90 - j) \quad (6)$$

Let us consider the tool path presented in Figure 6. The cutter moves from point S to the starting point of machining A at the rapid feed. The section AB is the tool path of stock removal, on which the cutter moves with the cutting force fC according to the geometrical parameters of the desired plane.

In this case, the vector sum of fC_x and fC_y can be defined as:

$$fC = fC_x + fC_y \quad (7)$$

After the section AB has been formed, the cutter moves to the end point E and then to the point S on the rapid feed.

Thus, the time of movements shall be subject to the following condition:

$$t_{SA} + t_{BE} + t_{ES} < \frac{360}{6nS \cdot j} \quad (8)$$

where τ_{SA} is the movement from S to A on the rapid feed; τ_{BE} is the movement from B to E on the rapid feed; τ_{ES} is the movement from E to S on the rapid feed. Thus, it has been established (Eq. 8) that the time of movements without cutting should be less than the time of rotation of the bar stock, in which there is no stock removal.

The generation of tool path makes it possible to automate the development of control program for modern equipment [9]. In addition to the coordinates of the reference points, it is required to assign the cutting modes (or the conveying velocity of driven elements) [10].

3. Discussion

Modern control systems based on the electromechanical drives [11] have enabled to realize the offered method with the following parameters: vibration frequency of tool of about 1 kHz, displacement amplitude of 1 mm.

The higher vibration frequency of tool requires the higher-speed drives. This situation arises in the manufacture of parts with small diameters (less than 6 mm). In this case the faster actuators are required, for example using in special equipment [12] and having electro-hydraulic actuator [13]. It will ensure required kinematic and dynamic characteristics of the equipment [14].

The method of getting planes parallel to the part axis in turning described in this work allows one to solve the problem of achievement of various qualitative characteristics of the product. For example, unidirectional movement of the tool on the horizontal axis, directed normally to the surface, will not allow achieving flat surface. Since there is insignificant stop time of the tool between zero velocity and rapid feed. It causes the formation of convex shape of the machined surface. If the received product has the hole directed on the axes, according to the authors, the application of the similar scheme of getting planes by machining is admissible. But the scheme of obtaining the plane by machining without change the direction of movement is preferable.

4. Conclusion

The method of getting planes parallel to the part axis using only turning tools is realized on the basis of the received mathematical model, which describes the operative movements of lathe machine. This method aims at addressing the problem of control the machining equipment. The mathematical description of tool path provides the position control of the tool to the reference axis. At the same time the derivative of this function describes the procedure of control of the drive using programmable logic controller (for example drives having interface Step-Dir-Enable [15]).

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References

- [1] Polini W, Prisco U 2003 The estimation of the diameter error in bar turning: a comparison among three cutting force models *The International Journal of Advanced Manufacturing Technology* **22** 465-474
- [2] Manos N P, Bedi S, Miller D et al 2007 Single controlled axis lathe mill *The International Journal of Advanced Manufacturing Technology* **32** 55-65
- [3] Zhu L, Jiang Z, Shi J et al 2015 An overview of turn-milling technology *The International Journal of Advanced Manufacturing Technology* **81** 493-505
- [4] Lian R J, Lin B F and Huang J H 2004 Self-organizing fuzzy control of constant cutting force in turning *The International Journal of Advanced Manufacturing Technology* **29** 436-445
- [5] Ahn K G, Min B K and Pasek Z 2006 Modeling and compensation of geometric errors in simultaneous cutting using a multi-spindle machine tool *The International Journal of Advanced Manufacturing Technology* **29** 929-939
- [6] Chepchurov M S, Tyurin A V and Zhukov E M 2014 Getting flat surfaces in turning *World Applied Sciences Journal* **30(10)** 1208-1213
- [7] Wu D, Chen K and Wang X 2009 An investigation of practical application of variable spindle speed machining to noncircular turning process *The International Journal of Advanced Manufacturing Technology* **44** 1094-1105
- [8] Chepchurov M S, Tabekina N A and Tyurin A V 2016 Application of mechatronic modules for process equipment updating *International Journal of Pharmacy and Technology* **8(4)** 22619-22631
- [9] Wang X, Fu X, Li C et al 2015 Tool path generation for slow tool servo turning of complex optical surfaces *The International Journal of Advanced Manufacturing Technology* **79** 437-448
- [10] Irving P G, Jaspreet S D 2015 *Machine tools for machining*. In: Nee AYC (ed) *Handbook of Manufacturing Engineering and Technology* (London: Springer)
- [11] Martins Crichigno Filho J 2012 Prediction of cutting forces in mill turning through process simulation using a five-axis machining center *The International Journal of Advanced Manufacturing Technology* **58** 71-80
- [12] Habeeb S and Xu X 2008 A novel CNC system for turning operations based on a high-level

- data model *The International Journal of Advanced Manufacturing Technology* **43** 323
- [13] Moyzes B B, Zhang X, Gavrilin A N, Mel'kov K V and Fayngerts A V 2015 Actuators of the seismic vibrations sources *Proceedings of 2015 International Conference on Mechanical Engineering, Automation and Control Systems, MEACS 2015. Institute of Electrical and Electronics Engineers Inc* (Tomsk: IEEE) Retrieved from: <http://ieeexplore.ieee.org/document/7414967/>
- [14] Gavrilin A, Moyzes B and Zharkevich O 2015 Constructive and processing methods of reducing vibration level of the metalworking machinery elements *Journal of vibroengineering* **17(7)** 3495-3504
- [15] SongYong 2017 *Hybrid Stepping Motor. General Specification for High Torque Hybrid Stepping Motor*. Retrieved from: <http://www.kosmodrom.com.ua/pdf/SongyangPdf.pdf>