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GENERATION FEATURES OF POLYGONAL AREAS ON LATHES

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Abstract. This paper presents generation kinematics and structure of generating kinematic chains for regular polygonal surfaces processing turned by cinematic or numerical generation. The shape for those faces directory is obtained cinematically as a trajectory of a point or trough motions numerically controlled. Generation kinematics on conventional or CNC, mono or multispindles lathes is analyzed. There are established correlations between motion kinematical parameters and tool and machined surface construction parameters.

Keywords: polygonal milling, generation kinematics, kinematic chains, multispindle lathe, numerically controlled lathe

1. Introduction

Surfaces having polygonal and curved directory with linear and curved edges, from different parts have functional role which demands certain accuracy. Significant examples are part surfaces with polygonal directory that can be can be found in shaft – hub assemblies. [1, 5, 9] Such surfaces have to meet dimensional accuracy, shape and quality conditions [8]. Taking this into account and the type of production machine-tool and technological processes are chosen.

For the lathe processing of parts having regular polygons guiding surfaces, are used to generate two variants:

– stopping the part driving shaft, for each polygonal surface component milling. The tool effects the main cutting motion and the longitudinal feed motion, followed by the angular positioning of the spindle and repeat the cycle for each side of the polygon. This alternative is non-productive. The shape of the generated directory meets the accuracy conditions. It is applied on certain specialized or CNC lathes.

– without stopping the rotation motion (circular feed) of the part driving shaft, by cinematic generation of multiple curves by milling with milling head type tools having 1 ... 6 teeth disposed on the peripheral surface. [5, 7] Certain portion of the curve approximates each one a side of the regular polygon.

For this approach, processing accuracy of each side of the polygon is lower, but productivity is high and corresponds to the repetitive manufacturing requirements. Those surfaces have the functional role of manual driving of the piece for fastening.

2. Cinematic generation

The principle of polygonal milling on the lathe is known and applied to multispindle automatic lathes [7] or some specialized machine tools [5]. When machining with specialized lathes, workpiece (*P*) is fixed in each main spindle (*MS*) of the lathe (Figure 1) and driven with speed n_P. Also, tool *T* (side mill) located on the longitudinal slide *LS* is driven through a device in rotary motion with the rotation speed n_{cT} [2]. The slide *LS* stands on the guiding rail from the central tool driving drum (T_T) and it is driven into feed motion along part axis with a certain feed rate (v_f). To generate a regular polygon on the workpiece with z_p sides it is required that part and tool speed ratio to be equal to the ratio between the number of sides of workpiece regular polygon z_P and number of teeth from the tool z_T [5, 6, 7].

$$i = \frac{n_{cT}}{n_P} = \frac{z_P}{z_T} \qquad (1)$$

Both ratio being integers, each cutting edge of the tool describes an elongated epicycloid E1, E2, E3 (three-edged tool) which, in the central portion of the piece, approximates two opposite sides of the polygon generated on the piece (figure 1, *c*).

For generation the geometrical elements, namely: distance *L* between tool axis A_T and the piece axis *MS* is fixed. In figure 2, for the most used regular polygons with an even number of sides (square, hexagon, octagon, decagon, dodecagon), are represented the generation possibilities based on relation (1).

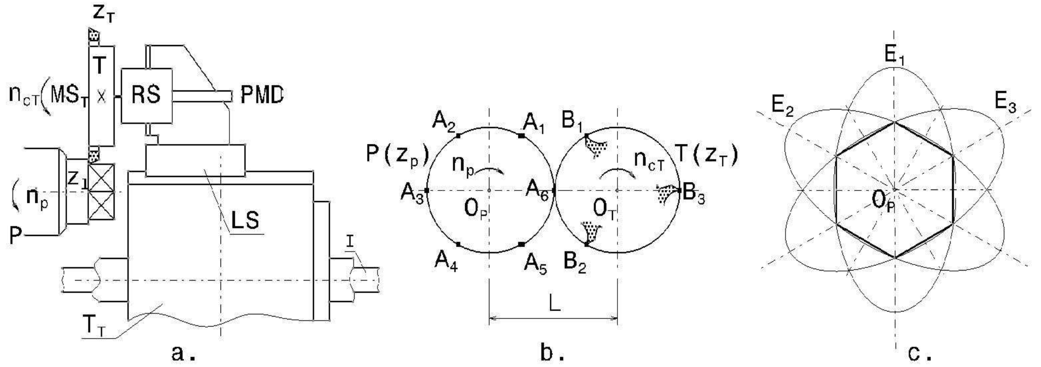

Figure 1. Milling generation of the polygonal directory: a – tool and workpiece positioning; b – correlated motions; c – trajectories that define sides of the directory

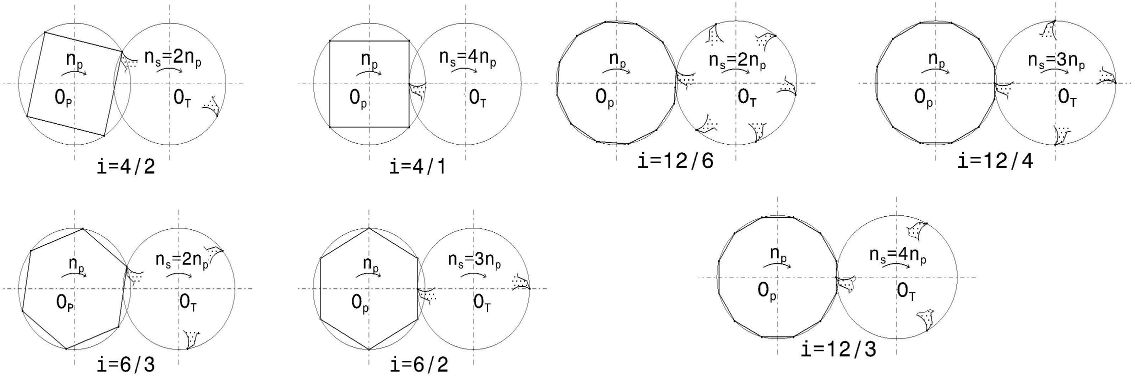

Figure 2. Manufacturing possibilities

For a specific number of sides of the piece there are two or even three solutions possible (in the case of the dodecagon). It is necessary to choose a tool with the number of cutting edges in order to have the lowest speed of the tool. Thus, the main milling spindle bearing wearing MS_T is diminished. Correlation of tool speed and piece speed, according to relation (1) is assured using change gears or numerical controlled axes.

3. Polygonal surface milling on lathes

3.1. Cinematic structure of a multispindle lathe

Multispindle automatic lathes with automatic control systems through control shaft and cams have one electric motor M_E (Fig. 3) which drives [4, 10]:

- main spindles *MS* (a number of 6 or 8) fixed in rotating drum *TMS*, very important assembly of lathe;
- control shafts *AC*, on which are located cylindrical cams *KC*, disc cams *KD* and coupling *MCC* of Maltese cross mechanism *MC*, for periodic rotation and indexing of the main spindles drum;
- rotary tools, among them the tool located in the polygonal milling device *PMD* (figure 1, *a*) mounted on one of the longitudinal slides *LS*, with independent feed, of the polygonal drum *TP*. This one has 6 respectively 8 flat surfaces, parallel to the rotation axes of main spindle.

Adjustment of main spindles speed is attained with change gears type mechanism (A_v/B_v).

In order to increase machining productivity for the multispindle automatic lathe, the speed of the control shaft *AC* is low during the working strokes and is high in auxiliary strokes. Low speed of the command shaft is also adjusted using the change gears (*As/Bs*). The feed rate is determined by the angle of working sector of the cam [6]. A complete rotation of control shaft corresponds to a fully processed part.

KC cylindrical cams and disc cams *KD* ensure radial motion of the lathe longitudinal slides *LS* and radial slides *RS*. (figure 1, *a*).

In figure 5, tool and part position in the case of four side polygonal surface manufacturing is presented. The director and generator curves are rectilinear and have high precision conditions. Such machining can be made on the lathe whose structure is presented in figure 4. The tool is placed into a seat of the turret RH_1 on his radial direction. Necessary motions for the generation are supplied by the cinematic couples (R_3) – main cutting motion, (T_{T1}) – transversal feed/positioning motion, (T_{L1}) – longitudinal feed/positioning motion and (R_1) – C_1 axis (positioning motion).

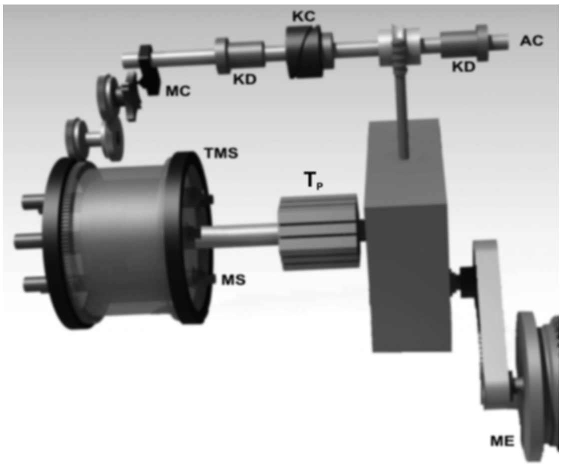

Figure 3. Mechanisms from an automated multispindle lathe

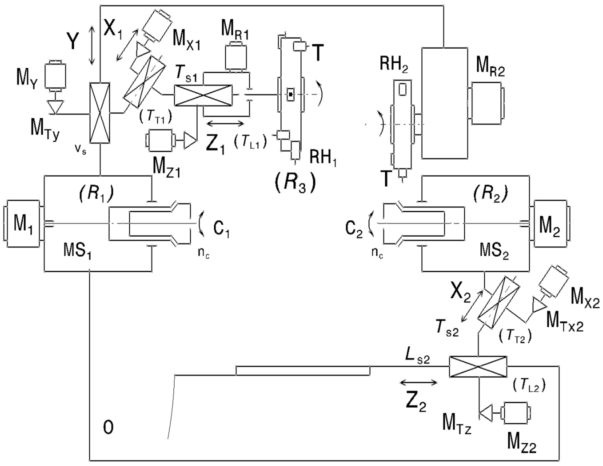

Figure 4. Turret lathe with two coaxial symmetrical main spindles

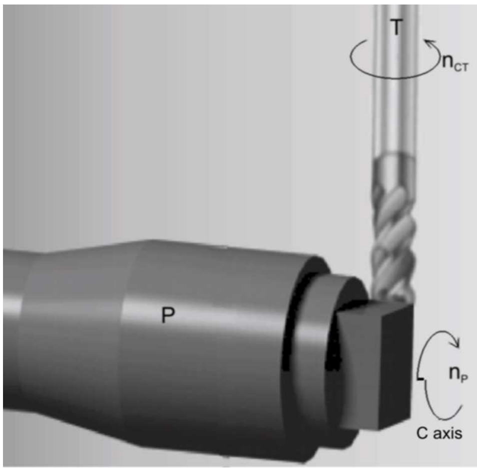

Figure 5. Polygonal milling

Polygonal milling device takes over the rotating motion of the shaft *I*, which motion is strictly correlated with main spindles motion, trough the reducer R_{d1}, and transfers it to the main spindle which drives the tool.

The tool used for polygonal milling has milled teeth. The number of teeth of the tool is chosen based on the number of sides of polygon from the piece. Edges constructive geometry (angle of clearance and angle of departure) is established depending on piece and tool material, but there are checked the active entrance/exit angles of the tool to/from the contact with the part.

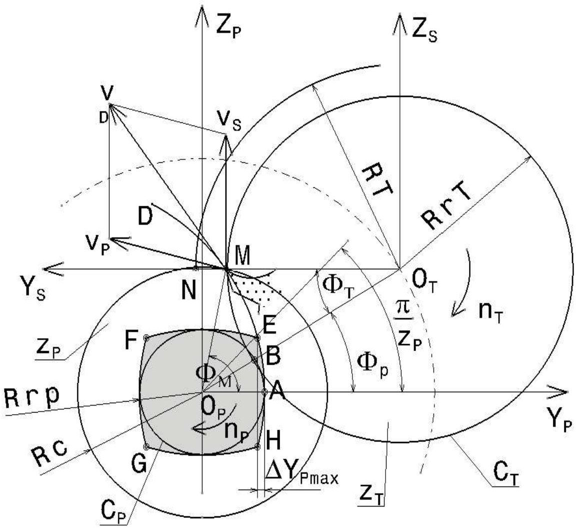

Figure 6. Parameters of milling generation for a polygonal directory

Point M of each tool tooth edge describes a closed trajectory (D). We consider the piece fixed and machining made by cut-up milling (to increase the angle Φ_P). Circle C_T belonging to the tool, rolls on circle C_P belonging to the piece, so that:

$$\phi_P = \frac{R_{rP}}{R_{rT}}\phi_T, \qquad (2)$$

which brings us to respecting the equality of frequencies expressed in equation (1).

One point N, located at R_T radius describes a directory path lengthened (shortened) equations whose parameters are reported in the paper. So that the trajectory passes through point A it is necessary to make proper positioning of O_T and O_P centers, so that radius R_{rT} and R_{rP} respect the condition (1), those radius are expressed by relations:

$$R_{rP} = z_P \frac{R_C + R_T}{z_P + z_T}, \qquad (3)$$

respectively

$$R_{rT} = z_T \frac{R_C + R_T}{z_P + z_T}. \qquad (4)$$

From the technological point of view, it is important to know also the module of speed vector $\bar{v}_D$, which is tangent to directory *D*. In relation (5), the upper signs refer to cut-up milling, and the lower signs to the cut-down milling. $\bar{v}_D$ variation depends also on angle ϕ_P as size and direction. Accordingly, the active geometry of tool cutting edge will be modified. [3] The non-straightness (ΔY_{pmax}) of generated polygonal surface directories, defined by z_P and R_c parameters, depends on ϕ_P, z_T and R_T. The deviation can be positive or negative [5]. For $z_P \leq 2z_T$, the directory of polygon sides results always convex, regardless of R_T/R_c ratio.

$$\left|\bar{v}_D\right| = R_T\sqrt{\left(1+\frac{R_c}{R_T}\right)^2+\left(\frac{z_P}{z_T}\mp 1\right)^2 \pm 2\left(1+\frac{R_c}{R_T}\right)\left(\frac{z_P}{z_T}\mp 1\right)\cdot\cos\left(\frac{z_P}{z_T}\right)\phi_P} \quad (5)$$

3.2. Basic aspects of machining on CNC lathe

Most numerical control lathes allow correlation between rotation motion of the piece mounted in the main spindle (axis C) of the lathe and rotation motion of the tool, mounted on milling main spindle from the turret. On this line, numerical control equipment has the following specialized functions for programming:

– auxiliary M functions for selection/cancellation of polygonal milling;

– preparatory G functions for selection/ cancellation of polygonal milling;

– addresses that allow the introduction of tool and piece speed ratio in integers and direction of relative rotation motion between the two shafts, the piece shaft and, respectively, the cutting tools shaft.

Feed motion and radial and axial positioning are usually programmed on the two CNC axes: Z axis - longitudinal and X axis - radial.

4. Conclusions

The paper presents the generation kinematics, possible variants and cinematic structure of machine-tool, devices and tools used for polygonal milling.

Regular polygonal milling with stopping and repeated positioning of the main shaft is achieved on numerically controlled horizontal lathes. A minimum of 2 axes numerically controlled is required.

Polygonal milling using generation of epicycloid curves that approximate polygon part sides is possible on multispindle automatic lathe for large-scale series production. It is the case of lathes controlled with command shaft and cams systems, or numerically controlled. Also, this alternative is applied on monospindle CNC turret lathe with rotating tool with numerically controled motion and special programming features.

Accuracy for the generation of regular polygon sides that defines the surface of the part processed is lower. It results a maximum error at the middle of each side and a minimum error at its ends. Processing productivity is much higher than in the case when the main spindle stops.

Choosing appropriate constructive parameters for the tool (z_T, R_T/R_c) one can obtain the imposed value for the ΔY_{pmax} deviation. The condition expressed by relation (1) is assured through precise correlation of the two rotation motions, with speeds n_P and n_T, using two horizontal C axes.

The trajectory and the module of speed vector $\bar{v}_D$ allow the definition of components and directory cosine and the active angles of generative cutting edges of the tool. Coordinate systems $Y_PO_PZ_P$ and $Y_TO_TZ_T$ can be assured by axes numerically controlled of the lathe figured in fig. 4; origin points O_P and O_T will be situated on the same line form the plane.

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