Mechanics
Transport
Communications
Academic journal

ISSN 1312-3823
volume 12, issue 3/3, 2014
article № 1072
http://www.mtc-aj.com

UNINTERRUPTED AND CONSISTENT PROCESSING OF GEOMETRIC DATA OF A ROTATIONALLY-SYMMETRIC PART

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Key words: *CAM, CAPP, machining.*

Abstract: *The term section used here is defined as well as the way to division of exemplary rotationally-symmetric part surfaces to sections. The way to fill in the input data form with data describing part surfaces of each section according to the accepted rules is explained. Data are grouped together according to section type: cylindrical, conical, circular and threaded. Dimensions and tolerances of each section surface written on the drawing and sufficient for full description of section geometry are written into the input data form. Data as accuracy grade roughness tolerances of form orientation location and run-out in relation to datum surface also can be filled in the corresponding section of the input data form. Tolerances (tolerance grade 12 or higher) are added to each size without tolerance indication. Software for uninterrupted and consistent processing of part geometric data is developed for avoiding of its intermediate input. Longitudinal dimensions are recalculated to a common datum – coordinate system origin which is fixed at the right hand side part face. If there is need to turn the part positioning for its full processing longitudinal dimensions are recalculated again to a common datum – coordinate system origin which is fixed at the right end of the turned part. Tolerances of the initial longitudinal dimensions to the left end of each section remain unchanged that is just the same values that are written on the drawing. Tolerances of longitudinal, diametrical and radial dimensions written on the drawing together with tolerances added to sizes without tolerance indication form continuous tolerance zone along part contour.*

INTRODUCTION

Yet the big bottleneck in the automated generation of process plans is the issue of geometric recognition of shapes and mapping of the shapes into functions that can trigger machining operation. To resolve this complex task an attempt is made for a new approach based on uninterrupted and consistent processing of geometric data of an exemplary rotationally-symmetric part.

The object of this paper is to define the tool nose trajectory during the final pass based on part geometric data. The following tasks must be solved to define the trajectory:

- Uniquely define in explicit mode all part and workpiece geometry according to the coordinate system connected with the part, fig. 1. The origin “*O*” is at the intersection point of spindle rotational axis and the most right hand side part face. *Oz* axis coincide with the lathe spindle axis and +z direction shows the motion of the tool away from the spindle. *Ox* axis is perpendicular to *Oz* axis and is collinear with direction of cross slide motion of some lathes.

- Tool nose trajectory at the final pass can be defined by calculating the middle line of dimension tolerance zone of each section.

Tasks are geometrical and to solve them analytic geometry and numerical methods must be used as well as data from various standards.

Input of part and workpiece data

First of all the surface of a rotationally-symmetric part has to be divided into sections and marked with consecutive section numbers (enclosed in circle), fig. 1. A section is a portion of a part surface which has line or circular arc for generant and can be machined with only one tool moving along the generant or has complex generant which is made up by coping the tool cutting edge when it moves rectilinear towards the part (cross feed) during machining.

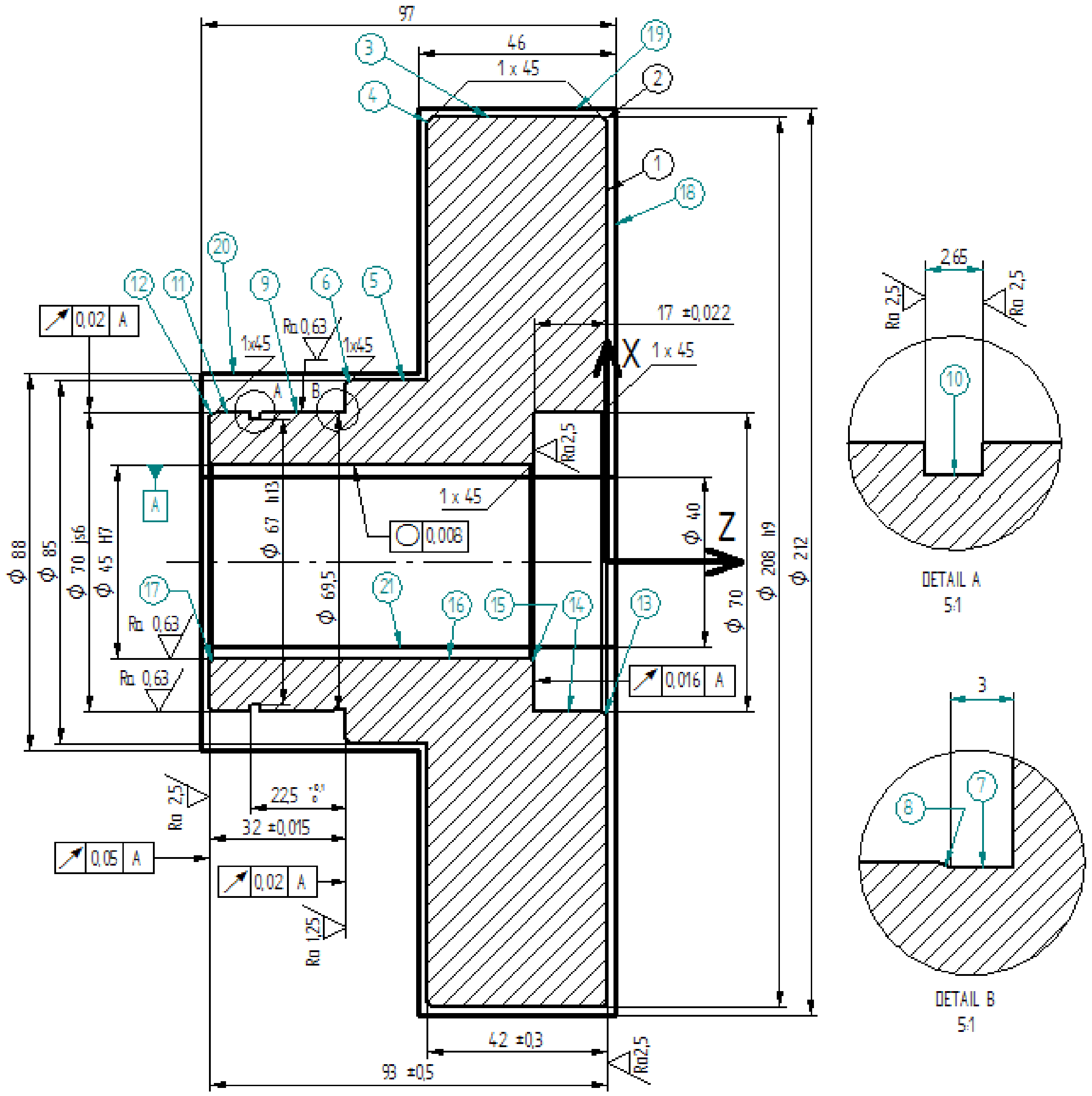

Fig. 1. ***Part drawing with section numbers***

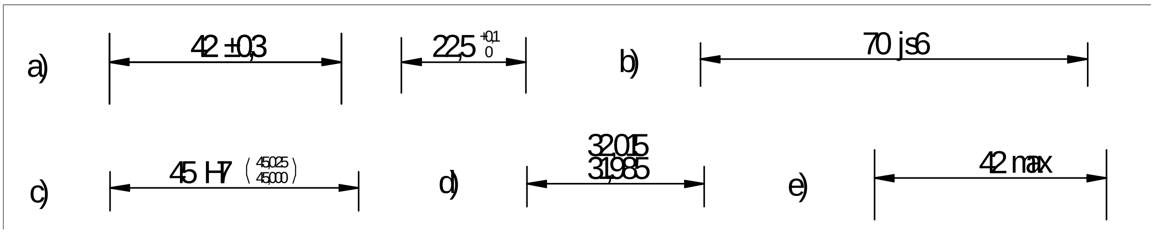

Fig. 2. ***Various way of dimensioning***

To each section must be added adjacent left face (if there is any) for instance sections 4, 6, 9, 12 and 14, fig. 1. Consequently there are cylindrical, conical, contour and threaded section and all of them can be outer or inner. As the most right hand side face of the part and the workpiece cannot be added to any section (it must be left hand side end of the section) it can be considered as left end face of the fictional first section with diameter equal to zero ($d(1)=0$) and length equal to zero ($l(1)=0$), fig. 3.

The input data form is a table. The user can fill in his/her name, part number and machine tool at the header part of the form. The first column identifies the section type (cylindrical, conical, circular, threaded and geometrical tolerancing). The second column is the line number. The next column is "*Symbol*" for data identification. All data from line 1 (*Symbol - d(k)* - diameter data, fig. 3) to line 62 (*Symbol - ζ (k)* – thickness of surface hardened layer, fig. 3) are arrays with maximum element number (*k*) of 99 including both part and workpiece sections. Consecutive section number is the line above the one for input of diameter data - *d(k)*. If a part has many sections (up to 99) more pages can be added, fig. 3.

Longitudinal dimensions *l(k)* (line 4, fig. 3) are assumed to be given to the left end of the section. The other section from which any longitudinal dimension is given is assumed as datum and is marked on line 7 with symbol *Б(k)*, fig. 3. The user fill in the cells of lines 2 and 5 (fig. 3) with upper limit deviation of dimension (fig. 2, a) or tolerance class identifier (fig. 2, b, c) or upper limit of size (fig. 2, c, d) or ***min*** or ***max*** (fig. 2, e). The cells of lines 3 and 6 (fig. 3) ought to be filled in with lower limit deviation of linear size (fig. 2, a) or tolerance class identifier (fig. 2, b, c) or lower limit of size (fig. 2, c, d) or ***min*** or ***max*** (fig. 2, e). Some sections have coded elements data. For instance some conical sections can be coded as chamfer *f(k)* with its dimension which relates to generating or not tool path and does not relate to geometrical data processing. The same logic relates to fillet radius *r(k)* (line 10, fig.3) at the bound between two sections made up by coping of tool radius. Coding the conical section with number greater than 9000 means larger left or smaller right or smaller left or larger right diameter assigns the diameter of the adjacent section. The code *9611* means cylindrical (digit 6) section 11 diameter to be assigned. The line named *KAN* shows coded data for grooves. When cut-off tool cuts the part perpendicular to the rotation axis to make a groove for cylindrical grinding the code is 2 (sections 7 and 8, fig. 1 and fig. 3). The code for rectangular groove made up with cut-off tool is 5 (section 10). Geometrical tolerancing area of the input data form comprises accuracy grade which is also coded data and roughness requirements. The symbols T^d - accuracy grade and $R_a{}^d$ - roughness refer to cylindrical or conical or contour surface. The symbols T^l - accuracy grade and $R_a{}^l$ - roughness refer to face surface. Lines from 49 to 60 refer to geometrical tolerancing, fig. 3. One surface can have up to two type geometrical tolerance requirements ($\varepsilon_1{}^d(\kappa)$, $\varepsilon_2{}^d(\kappa)$, $\varepsilon_1{}^l(\kappa)$, $\varepsilon_2{}^l(\kappa)$) which are given coded for cylindrical, conical or contour surface, superscript *d*, as well as faces, superscript *l*. The datum surface ($Б^d_{\varepsilon_1}(\kappa)$, $Б^d_{\varepsilon_2}(\kappa)$, $Б^l_{\varepsilon_1}(\kappa)$, $Б^l_{\varepsilon_2}(\kappa)$) of the requirement is specified by part's section number and the tolerance ($\delta_1{}^d(\kappa)$, $\delta_2{}^d(\kappa)$, $\delta_1{}^l(\kappa)$, $\delta_2{}^l(\kappa)$) is specified by value.

Section 1 (column 1, fig.3) is only the right hand side end face of the part as it is explained above. That face has accuracy grade requirement coded as $T^{l}(1)=4$ (line47) and roughness requirement coded as $R_a^{l}(1)=2,5\ \mu m$ (line 48).

Section 2 (column 2, fig. 3) has longitudinal dimension $l(2)=1\ mm$ to its left end which is set from section 1 – $Б(2)=1$ (line 7, fig.3). The section from which the dimension is set is referred to as base. $f(2)=1\ mm$ at line 9 means the section is chamfer and $\alpha(2)=45°$ is the chamfer slope angle to the rotational axis of the part (line 21). "*9603*" at line 12 is conditional assigning of the larger-left diameter ($Д^{ГЛ}(2)$) from the next cylindrical section 3. Section 2 has accuracy grade requirement $T^{d}(2)=5$, (line 45, fig. 3) and roughness requirement $R_a^{d}(2)=10\ \mu m$. These requirements are on the conical surface of the section 2.

Section 3 is a cylindrical surface with nominal size $d(3)=208\ mm$ (line 1), lower deviation $O^{ПД}= -0.09\ mm$ and longitudinal dimension $l(3)=1\ mm$ to the left end of the section given from section 4 – $Б(3)=4$ (line 7). Accuracy grade requirement $T^{d}(3)=5$, (line45, fig. 3) and roughness requirement $R_a^{d}(3)=10\ \mu m$ (line 46, fig. 3) are on the cylindrical surface of the section.

Section 4 has dimension $l(4)=42\ mm$ set from section 1 with symmetric deviation $O^{lГ}=0.03\ mm$ and $O^{lД}=-0.03\ mm$. The section 4 is a chamfer ($f(4)=1$) with conditional assigned larger-right diameter from section 3, $D^{ГД}(4)=9603$. $\alpha(4)=45°$ is the chamfer angle to the part rotational axis. Accuracy grade and roughness requirements are as well as the previous section.

Section 5 is a cylindrical surface with diameter $d(5)=85\ mm$ and dimension $l(5)=1\ mm$ from the left end of the section 6. Accuracy grade requirement $T^{d}(5)=5$, (line45) and $R_a^{d}(5)=10\ \mu m$ (line46) are as well as the previous section.

The dimension to the section 6 left end $l(6)=32\ mm$ is given from the section 12, $Б(6)=12$ (line 7). This section is set as a chamfer, $f(6)=1\ mm$ (line 9) with chamfer slope angle $\alpha(6)=45°$. The larger right diameter is assigned from the section 5 diameter, $D^{ГД}(6)=9605$ (line 11). The accuracy grade requirement of chamfer surface is $T^{d}(6)=5$, (line45) and roughness requirement is $R_a^{d}(6)=10\ \mu m$ (line46). There are also requirements for the adjacent left face of this section as accuracy grade, $T^{l}(6)=2$ and roughness $R_a^{l}(6)=1,25\ \mu m$. There is a requirement for camming action to this end face coded as $\varepsilon^{l}_{1}(6)=2$ (line 55) in relation to datum surface (section 16) marked with *A* letter on figure 1 and line 56 - $Б^{l}_{\varepsilon_1}(к)=16$ (figure 3) and camming action tolerance $\delta^{l}_{1}(6)=0.02\ mm$ (line57).

Section 7 is a groove coded as $KAN(7)=2$ (line 8). It is a portion of the groove surface which includes section 7 and section 8. Section 7 has diameter $d(7)=69.5\ mm$ and dimension $l(7)=3\ mm$ from section 6. $r(7)=0.1\ mm$ (line 10) is the tool radius copied at the end of the section. The accuracy grade and roughness requirements are as well as in previous sections.

Section 8 is the second portion of the groove surface coded as $KAN(8)=2$. The left and right diameters are assigned from the adjacent sections: the diameter value of the conical portion left end of the groove is coded as $D^{ГЛ}(8)=9609$ and is assigned from section 9. Its smaller right diameter value is coded as $d^{МД}(8)=9607$ and is assigned from section 7. The accuracy grade and roughness requirements are just like in previous sections.

Section 9 diameter $d(9)=70\ mm$ has upper deviation $O^{ГД}(9)=0.01\ mm$ (line 2) and lower deviation $O^{ПД}(9)=-0.01$ (line 3). The dimension $l(9)=2.65\ mm$ is set from 10th section $Б(9)=10$ and has upper deviation $O^{lГ}(9)=0.3$ mm. The accuracy grade $T^{d}(9)=2$ and roughness $R_a^{d}(9)=0,63\ \mu m$ of the round surface are high requirements. The left end face of the section 9 has no accuracy grade requirement and has roughness requirement coded as $R_a^{l}(9)=2,5\ \mu m$. There is a radial run-out requirement coded as $\varepsilon^{d}_{1}(9)=2$ (line 49) in relation to the hole which is datum surface (section 16) marked with *A* letter (figure 1) and line 50 (figure 3), and run-out tolerance $\delta^{d}_{1}(9)=0.02\ mm$ (line51).

Section 10 is a groove coded as $KAN(10)=5$. The diameter $d(10)=67$ *mm* has lower deviation $O^{ДД}(10)=-0.4$ *mm*. The dimension $l(10)=22.5$ *mm* is set from section 6 ($Б(10)=6$) and has upper deviation $O^{lГ}(10)=0.1$ *mm*. The accuracy grade requirement is coded as $T^d(10)=5$ and roughness requirement is coded as $R_a^d(10)=2,5$ *μm*. The left end face of the section has roughness requirement $R_a^l(10)=2,5$ *μm*.

Section 11 differs from section 9 with the dimension $l(11)=1$ *mm* which is set from section 12 and there is not section's left end face . The other values are as for the section 9.

Section 12 diameter $d(12)$ will be assigned the value of the section 11 diameter $d(11)$ due to the coding $D^{ГД}(12)=9611$. This section is a chamfer with dimension $f(12)=1$ *mm* and slope angle $\alpha(12)=45°$. The dimension $l(12)=93$ *mm* to the left end face of the section is set from section 1 with

symmetric deviations (0.5 and -0.5). There are requirements about accuracy grade and roughness on the chamfer surface and the left end face as well as a requirement about camming action tolerance $\varepsilon^l_1(12)=2$ in relation to section 16 which is the datum surface marked with *A* letter (fig. 1) $Б^l_{\varepsilon_1}(к)=16$ with value $\delta^l_1(12)=0.05$ *mm*, fig. 3.

Section 13 is the first inner section. Its dimension is $l(13)=1$ *mm* set from section 1, $Б(13)=1$. The section is a chamfer with $f(13)=1$ *mm* and slope $\alpha(13)=45°$. The left end diameter is assigned the value of the section 14 diameter, $d^{МЛ}(13)=9614$. The requirements on the chamfer surface are accuracy grade coded $T^d(13)=5$ and roughness coded as $R_a^d(13)=10$ *μm*.

LTS			**INPUT DATA FORM**													Page 1 Total pages 2	
User:			**Part: 120201-0050-08**									**Machine tool: CE 062.10**					
Type	**№**	**Symbol**	**Section number – "k"**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Cylindrical	1	$d(k)$			208		85		69.5		70	67	70			70	
	2	$O^{ГД}(k)$									0.01		0.01				
	3	$O^{ДД}(k)$			-0.09						-0.01	-0.4	-0.01				
	4	$l(k)$		1	1	42	1	32	3		2.65	22.5	1	93	1	17	1
	5	$O^{lГ}(k)$				0.3					0.3	0.1		0.5			
	6	$O^{lД}(k)$				-0.3								-0.5			
	7	$Б(k)$	1	1	4	1	6	12	6		10	6	12	1	1	1	14
	8	$KAN(k)$							2	2		5					
	9	$f(k)$		1		1		1						1	1		1
	10	$r(k)$							0.1								
Conical	11	$D^{ГД}(к)$				9603		9605						9611			
	12	$D^{ГЛ}(к)$		9603						9609							
	13	$O^{ГК}(к)$															
	14	$O^{ДК}(к)$															
	15	$d^{МД}(к)$								9607							
	16	$d^{МЛ}(к)$													9614		9616
	17	$O^{ГК}(к)$															
	18	$O^{ДК}(к)$															
	19	$ЧС(к)$															
	20	$ЗН(к)$															
	21	$\alpha(к)$		45		45		45		45				45	45		45
	22	$\beta(к)$															
	23	$N^{МЕТР}(к)$															
	24	$N^{МОРЗ}(к)$															
	25	$O^{П}(к)$															
	26	$l^{ОБР}(к)$															
	27	$O^{ОГ}(к)$															
	28	$O^{ОД}(к)$															
Contour	29	$\pm R^{C}(к)$															
	30	$a(k)$															
	31	$\pm Б^{C}(к)$															
	32	$b(k)$															
	33	$x_{M'}(к)$															
	34	$Б^{M'}(к)$															
	35	$y_{M'}(к)$															
	36	$x_{M''}(к)$															

	37	$\text{Б}^{M''}(\text{к})$															
	38	$y_{M''}(\text{к})$															
	39	$\Omega(\text{к})$															
Thread	40	$\rho(\text{к})$															
	41	$d^{\rho}(\text{к})$															
	42	$\pm S^{\rho}(\text{к})$															
	43	$T^{\rho}(\text{к})$															
	44	$R_a^{\rho}(\text{к})$															
Geometrical tolerancing	45	$T^{d}(\text{к})$		5	5	5	5	5	5	5	2	5	2	4	5	5	5
	46	$R_a^{d}(\text{к})$		10	10	10	10	10	10	10	0,63	2,5	0,63	10	10	10	10
	47	$T^{l}(\text{к})$	4					2						3		3	
	48	$R_a^{l}(\text{к})$	2,5					1,25			2,5	2,5		2,5		2,5	
	49	$\varepsilon_1^{d}(\text{к})$									2		2				
	50	$\text{Б}_{\varepsilon_1}^{d}(\text{к})$									16		16				
	51	$\delta_1^{d}(\text{к})$									0.02		0.02				
	52	$\varepsilon_2^{d}(\text{к})$															
	53	$\text{Б}_{\varepsilon_2}^{d}(\text{к})$															
	54	$\delta_2^{d}(\text{к})$															
	55	$\varepsilon_1^{l}(\text{к})$						2						2		2	
	56	$\text{Б}_{\varepsilon_1}^{l}(\text{к})$						16						16		16	
	57	$\delta_1^{l}(\text{к})$						0.02						0.05		0.05	
	58	$\varepsilon_2^{l}(\text{к})$															
	59	$\text{Б}_{\varepsilon_2}^{l}(\text{к})$															
	60	$\delta_2^{l}(\text{к})$															
	61	$\tau(\text{к})$															
	62	$\zeta(\text{к})$															
№			63	64	65	66	67	68	69	70	71	72	73	74	75	76	
Symbol			MAT	HB	HRC	σ_B	$n^{\text{Д}}$	$r^{\text{Д}}$	$n^{\text{З}}$	$r^{\text{З}}$	$L^{\text{Д}}$	$L^{\text{З}}$	C	B	O	Machine Tool	
Value			CT45				12	17	3	4	93	97	2			CE062.10	

Type	**№**	**Symbol**	**Section number – “k” (continuation)**														
			16	**17**	**18**	**19**	**20**	**21**									
Cylindrical	1	$d(k)$	45			212	88	40									
	2	$O^{\text{ГД}}(k)$	0.027														
	3	$O^{\text{ДД}}(k)$															
	4	$l(k)$	1	93		46	97	97									
	5	$O^{l\text{Г}}(k)$		0.5													
	6	$O^{l\text{Д}}(k)$		-0.5													
	7	$\text{Б}(k)$	17	1	18	18	18	18									
	8	$KAN(k)$															
	9	$f(k)$		1													
	10	$r(k)$															
Conical	11	$D^{\text{ГД}}(\text{к})$															
	12	$D^{\text{ГЛ}}(\text{к})$															
	13	$O^{\text{ГК}}(\text{к})$															
	14	$O^{\text{ДК}}(\text{к})$															
	15	$d^{\text{МД}}(\text{к})$		9616													
	16	$d^{\text{МЛ}}(\text{к})$															
	17	$O^{\text{ГК}}(\text{к})$															
	18	$O^{\text{ДК}}(\text{к})$															
	19	$\text{ЧС}(\text{к})$															
	20	$\text{ЗН}(\text{к})$															
	21	$\alpha(\text{к})$		45													
	22	$\beta(\text{к})$															
	23	$N^{\text{МЕТР}}(\text{к})$															
	24	$N^{\text{МОРЗ}}(\text{к})$															
	25	$O^{\text{П}}(\text{к})$															
	26	$l^{\text{ОБР}}(\text{к})$															
	27	$O^{\text{ОГ}}(\text{к})$															
	28	$O^{\text{ОД}}(\text{к})$															
Contour	29	$\pm R^{C}(\text{к})$															
	30	$a(k)$															
	31	$\pm \text{Б}^{C}(\text{к})$															
	32	$b(k)$															
	33	$x_{M'}(\text{к})$															
	34	$\text{Б}^{M'}(\text{к})$															
	35	$y_{M'}(\text{к})$															

	36	$x_{M''}(к)$															
	37	$Б^{M''}(к)$															
	38	$y_{M''}(к)$															
	39	$\Omega(к)$															
Thread	40	$\rho(к)$															
	41	$d^{\rho}(к)$															
	42	$\pm S^{\rho}(к)$															
	43	$T^{\rho}(к)$															
	44	$R_a^{\rho}(к)$															
Geometrical tolerancing	45	$T^{d}(к)$	2	5													
	46	$R_a^{d}(к)$	8	4													
	47	$T^{l}(к)$															
	48	$R_a^{l}(к)$															
	49	$\varepsilon_1^{d}(к)$															
	50	$Б^{d}_{\varepsilon_1}(к)$															
	51	$\delta_1^{d}(к)$															
	52	$\varepsilon_2^{d}(к)$															
	53	$Б^{d}_{\varepsilon_2}(к)$															
	54	$\delta_2^{d}(к)$															
	55	$\varepsilon_1^{l}(к)$															
	56	$Б^{l}_{\varepsilon_1}(к)$															
	57	$\delta_1^{l}(к)$															
	58	$\varepsilon_2^{l}(к)$															
	59	$Б^{l}_{\varepsilon_2}(к)$															
	60	$\delta_2^{l}(к)$															
	61	$\tau(к)$															
	62	$\zeta(к)$															

Fig. 3. ***Input data form***

Section 14 is also inner section with diameter $d(14)=70\ mm$ and dimension $l(14)=17\ mm$ set from section 1 ($Б(14)=1$).There are requirements on the round surface as accuracy grade $T^d(14)=5$ and roughness $R_a^d(14)=10\ \mu m$ and on the left end face – accuracy grade $T^l(14)=3$, roughness $R_a^l(14)=2{,}5\ \mu m$ as well as camming action requirement $\varepsilon^l{}_1(14)=2$ in relation to section 16 which is the datum surface marked with A letter $Б^l_{\varepsilon_1}(к)=16$, with value $\delta^l{}_1(14)=0.05\ mm$.

Section 15 is analogues to section 13.

Section 16 has diameter $d(16)=45\ mm$ with upper deviation $O^{ГД}(16)=0.027\ mm$, dimension $l(16)=1\ mm$ which is set from next section 17 ($Б(16)=17$) and high requirement about accuracy grade $T^d(16)=2$ and roughness $R_a^d(16)=0{,}63\ \mu m$.

Section 17 is the last part section with nominal size $l(17)=93\ mm$ set from section 1 and symmetric deviations of 0.5 mm. This section is a chamfer, $f(17)=1\ mm$. The right hand side larger diameter is assigned the diameter of section 16 which is *45 mm* and a half of the upper deviation added. Thus the difference between the diameter $d(16)$ after processing and the small chamfer diameter $d^{МД}(17)$ can be avoided.

Sections 18 to Section 21 are workpiece surfaces which are described by diameters and longitudinal dimensions set from the section 18.

There are not thread and contour sections on the part.

The area of the input data form named “Geometrical tolerancing” contains data for processing by the programmes for calculation of the cutting conditions so that the part with required quality to be manufactured.

All data from line 1 to line 62 (fig.3) are arrays with maximum element number of 99 inclusive both part and workpiece sections. The part and workpiece section number (fig. 1 and fig. 3) corresponds to array element number. Data with numbers greater than 62 are not arrays: material (63), hardness of material (64-HB, 65-HRC), ultimate stress - $\sigma_В$ (66), maximum number of part outer section - $n^Д$ (67), maximum number of part inner section - $r^Д$ (68), maximum number of workpiece outer section - n^3 (69), maximum number of workpiece inner section - r^3 (70), total length of part - $L^Д$ (71), total length of workpiece - L^3 (72) and displacement in *mm* of the workpiece left end face in relation to the part left end face - C (73).

Input data processing

Column named “k” (fig. 4) is the consecutive section number. Basic sizes with given tolerances on the drawing have been filled in the corresponding cells of the input data form. The programme system find appropriate tolerances of 12th accuracy grade in database and add them to the basic sizes without tolerance indication, for instance section 2, 3, 5 etc. so that all basic sizes have tolerances excluding section 1 which is the most right hand side end face of the part. The programme calculates dimension *l(k)* of each part section from the section 1 as datum surface (*Б(k)=1*) and the workpiece sections dimension *l(k)* from the section 18 (*Б(k)=18*) as datum surface. Calculation of *l(k)* from section 1 takes into account deviations so that the new value of *l(k)* to be at the middle of tolerance zone. The programme does not change original deviations. The program also calculates diameter *d(k)* of each cylindrical section taking into account given deviations so that the diameter coincides with the middle of tolerance zone. There are exclusions e.g. section 2 – the chamfer larger left diameter ($D^{ГЛ}(2)=9603$, fig. 3) is assigned the section 3 already calculated diameter *d(3)* without assignment of deviations. Analogous assignments are made for sections 4, 6, 8, 12, 13, 15 and 17. Assignments of cone diameters coded with number greater than 9000 are made after calculation of nominal sizes of the cylindrical surfaces. Each conical section has left and right diameter. To a conical section coded with number greater than *9000* is assigned diameter of the adjacent cylindrical surface (last two digits of the number greater then *9000*), column *d(k),* fig. 4, without deviations as the cylindrical surface diameter is already calculated.

The program calculates section 8 length *l(8)=64.425 mm* after section 7 diameter (*d(7)=69.150 mm)* calculation (*70.0-69.150 = 0.850 divided by 2 is 0.425 mm* for the conical part of the groove). The program calculates all dimensions so that they coincide with the middle of the dimension’s tolerance zone in order to use them through the next stage of the programme’s work for generating tool nose trajectory during the final pass.

k	*d*	$O^{ГД}$	$O^{ДД}$	*l*	$O^{lГ}$	$O^{lД}$	*Б*
1	0.000	0.000	0.000	0.000	0.000	0.000	1
2	207.955	0.000	0.000	1.000	0.100	-0.100	1
3	207.955	0.045	-0.045	41.000	0.100	-0.100	1
4	207.955	0.000	0.000	42.000	0.300	-0.300	1
5	84.575	0.425	-0.425	60.000	0.100	-0.100	1
6	84.575	0.000	0.000	61.000	0.300	-0.300	1
7	69.150	0.350	-0.350	64.000	0.150	-0.150	1
8	70.000	0.000	0.000	64.425	0.000	0.000	1
9	70.000	0.010	-0.010	80.750	0.150	-0.150	1
10	66.800	0.200	-0.200	83.550	0.050	-0.050	1
11	70.000	0.010	-0.010	92.000	0.100	-0.100	1
12	70.000	0.000	0.000	93.000	0.500	-0.500	1
13	70.350	0.000	0.000	1.000	0.100	-0.100	1
14	70.350	0.350	-0.350	17.000	0.200	-0.200	1
15	45.014	0.000	0.000	18.000	0.100	-0.100	1
16	45.014	0.014	-0.014	92.000	0.100	-0.100	1
17	45.014	0.000	0.000	93.000	0.500	-0.500	1
18	0.000	0.000	0.000	0.000	0.000	0.000	18
19	212.000	0.000	-1.150	45.300	0.000	-0.600	18
20	88.000	0.000	-0.850	97.400	0.000	-0.800	18
21	40.000	0.600	0.000	97.400	0.000	-0.800	18

Fig. 4. ***Processed geometrical part data – d(k) and l(k)***

The program makes decision to turn the part positioning 180° around *x* axis (fig. 1) when there is need to complete turning operation of the part taking into consideration part section diameters and longitudinal dimensions and their tolerance zone, section surfaces and their roughness, datum surfaces of geometrical tolerances and their tolerance value, shaft shoulders when the part is shaft type as well as appropriate cylindrical surfaces for chucking (Fig. 5).

The left end face of the last outer section 12 before turn of positioning, which is coded as chamfer, fig. 1 and fig. 3, becomes the first section after rotation. The chamfer itself becomes second section with smaller right diameter of the cone equal to 68.0 mm which is computed by the program. The coding $D^{ГД}(12)=9611$ (fig. 3) means the larger right hand side diameter of the section 12 assigns the value of section 11 diameter which is *d(11)=70.0 mm.* This diameter of 70.0 mm the length *l(12)=1* and the angle *α(12)=45*° are enough data for the programme to calculate the other cone diameter of 68.0 mm. The longitudinal dimension of the second section *l(2)* as well as all other sections are recalculated from the new section 1, *Б(k)=1*, as datum surface after turn of part positioning and the workpiece sections longitudinal dimension *l(k)* from the new section 18 (*Б(k)*=18) as datum surface.

k	*d*	$O^{ГД}$	$O^{ДД}$	*l*	$O^{lГ}$	$O^{lД}$	*Б*	*KAN*	*f*	*R*
1	0.000	0.000	0.000	0.000	0.000	0.000	1	0	0.000	0.000
2	68.000	0.000	0.000	1.000	0.100	-0.100	1	0	1.000	0.000
3	70.000	0.010	-0.010	9.450	0.050	-0.050	1	0	0.000	0.000
4	66.800	0.200	-0.200	12.250	0.150	-0.150	1	5	0.000	0.000
5	70.000	0.010	-0.010	28.575	0.000	0.000	1	0	0.000	0.000
6	70.000	0.000	0.000	29.000	0.150	-0.150	1	2	0.000	0.000
7	69.150	0.350	-0.350	32.000	0.300	-0.300	1	2	0.000	0.100
8	82.575	0.000	0.000	33.000	0.100	-0.100	1	0	1.000	0.000
9	84.575	0.425	-0.425	51.000	0.300	-0.300	1	0	0.000	0.000
10	205.955	0.000	0.000	52.000	0.100	-0.100	1	0	1.000	0.000
11	207.955	0.045	-0.045	92.000	0.100	-0.100	1	0	0.000	0.000
12	207.955	0.000	0.000	93.000	0.500	-0.500	1	0	1.000	0.000
13	47.014	0.000	0.000	1.000	0.100	-0.100	1	0	1.000	0.000
14	45.014	0.014	-0.014	75.000	0.100	-0.100	1	0	0.000	0.000
15	45.014	0.000	0.000	76.000	0.200	-0.200	1	0	1.000	0.000
16	70.350	0.350	-0.350	92.000	0.100	-0.100	1	0	0.000	0.000
17	70.350	0.000	0.000	93.000	0.500	-0.500	1	0	1.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	18	0	0.000	0.000
19	88.000	0.000	-0.850	52.100	0.000	-0.600	18	0	0.000	0.000
20	212.000	0.000	-1.150	97.400	0.000	-0.800	18	0	0.000	0.000
21	40.000	0.600	0.000	97.400	0.000	-0.800	18	0	0.000	0.000

Fig. 5 ***Processed geometrical part data – d(k) and l(k) after turn of positioning***

The programme calculates both left and right diameters of each conical section, Fig. 6. Each diameter can be larger or smaller. All their deviations ($O^{ГГ}$, $O^{ГД}$, $O^{МГ}$, $O^{МД}$) have value of *0.001 mm* because at least one diameter of the conical section has been coded with number greater then *9000*. Column named "*ЧС*" means numerator and column named "*ЗН*" means denumerator of the conicity ratio "*ЧС/ЗН*".

The signs "+" and "-" in front of numerator and denumerator (fig.6) and their combination define uniquely which cone diameter to be assigned to *d(k)* column, fig 5. For instance , *d(2)=68,0 mm* is for *ЧС(2)*=2 (>0) and *ЗН(2)*=1 (>0) which means $d^{МД}=68{,}0$ *mm* is assigned to *d(2)*, fig. 5.

When *ЧС(6)*=2 (>0) and *ЗН(6)*=-1 (<0) then $D^{ГД}(6)=70{,}0$ mm (fig. 6) is assigned to *d(6)*, fig. 5. If *ЧС(k)*<0 and *ЗН(k)*>0 then $d^{МЛ}(k)$ is assigned to *d(k)*. If *ЧС(k)*<0 and *ЗН(k)*<0 then $D^{ГЛ}(k)$ is assigned to *d(k)*. Given angles *α(k)* or *β(k)* are calculated in radian. So the conical section data given as various combinations are reduced to a type (diameter, length, angle, numerator, denumerator with “+” or “-“ sign for further processing.

k	$D^{ГД}$	$D^{ГЛ}$	$O^{ГГ}$	$O^{ГД}$	$d^{МД}$	$d^{МЛ}$	$O^{МГ}$	$O^{МД}$	$ЧС$	$ЗН$
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	70.000	0.001	-0.001	68.000	0.000	0.000	0.000	2.000	1.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	70.000	0.000	0.001	-0.001	0.000	69.150	0.001	-0.001	2.000	-1.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	84.575	0.001	-0.001	82.575	0.000	0.000	0.000	2.000	1.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	207.955	0.001	-0.001	205.955	0.000	0.000	0.000	2.000	1.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	207.955	0.000	0.001	-0.001	0.000	205.955	0.000	0.000	2.000	-1.000
13	47.014	0.000	0.000	0.000	0.000	45.014	0.001	-0.001	2.000	-1.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	47.014	0.000	0.000	45.014	0.000	0.001	-0.001	2.000	1.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	72.350	0.000	0.000	70.350	0.000	0.001	-0.001	2.000	1.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Fig. 6 ***Processed part geometrical data of conical sections after turn of positioning***

Conclusions

Rules for input of data from part and workpiece drawing to input data form are created. Only data from the drawing are inputted.

Database of tolerances is created as well as tables for correspondence of some coded data.

The programme system process both part and workpiece geometrical data by uninterrupted and consistent manner without user interaction to the type in figures 3 to 6.

Longitudinal dimensions to the left hand side end of all sections are calculated from the origin of the coordinate system connected with the part. Values of upper deviation and lower deviation of tolerance zones remain unchanged.

Geometrical information of conical sections is reduced to type which is convenient for further processing.

Defined tolerance zones of all sections form continuous zone along part contour where the tool motion can be done through the final pass. There are exclusions for instance when a section must be grinding.

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ОБРАБОТКАТА НА ГЕОМЕТРИЧНИ ДАННИ НА РОТАЦИОННО-СИМЕТРИЧЕН ДЕТАЙЛ

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Ключови думи: *CAM, CAPP, технологичен процес, механична обработка.*

Резюме: *Дефинирано е понятието участък, използвано тук, както и начина за разделяне на примерен ротационно-симетричен детайл на участъци. Обяснени са приетите правила, според които се въвеждат данните, описващи повърхнините на всеки участък във входната бланка. Данните са групирани според вида на участъка: цилиндричен, коничен, контурен и резбови. За всяка повърхнина на участък в бланката се записват размерите и съответните им допуски, нанесени на чертежа, които описват геометрията на повърхнината и стойността на грапавостта, както и допуски на формата, ориентацията, разположението и биенето и съответните базови повърхнини, спрямо които са зададени. Към размерите, които за зададени без допуски се добавят допуски за свободни размери. За да не се налага междинно въвеждане на данни е разработен софтуер за непрекъснатата и последователна обработка на геометричните данни. Надлъжните размери се преизчисляват спрямо обща база - началото на координатната система на детайла, която е в десния му край. Ако е необходимо обръщане на детайла за цялостната му обработка надлъжните размери се преизчисляват отново спрямо десния край на обърнатия детайл. Допуските на надлъжните размерите до левия край на участъците не се променят и остават такива, каквито са зададени на чертежа. Зададените на чертежа допуски на размерите – линейни, диаметрални и радиални и добавени допуските за свободните размери образуват непрекъсната зона от допускови полета по целия контур на детайла.*