

ALGORITHM AND PARAMETRIC PROGRAM FOR PROCESSING CHAIN WHEELS

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Abstract: The article deals with developing a parametric (macro) program for processing a chain wheel for bush-roller chains. The parametric program is developed for CNC Fanuc and implemented in the production process for the chain wheel family. To develop the parametric program, the dependences for constructing the tooth profile are used: chain pitch and a dividing diameter of the chain wheel, etc. The basic geometrical parameters for processing the chain wheel are set as input data at the beginning of the control program. Based on this information the automatic determination of the coordinates from the trajectory of the tool is performed. The trajectory coordinates are determined for one interdental, where for processing the next ones are used commands, characteristic of the parametric programming, with which the processing algorithm is organised. The machining algorithm can be organised using two approaches: recalculating the initial machining angle and the command to rotate the working coordinate system G68. The first approach is universal because the CNC generation does not influence it, i.e., it applies to both modern and traditional- CNCs, while the second applies to modern CNCs or those supporting the G68 command. The parametric program was tested virtually using the Vericut software, where the basic geometric parameters of the sprocket were tested with its dimensional measurement capabilities.

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Keywords: parametric program, macro program, chain wheels, machining, CNC.

Introduction

The CNC machines process the details according to a pre-created control program. Programming can be done manually or by using workshop-oriented programming or CAM systems. While using CAM systems, it is necessary to have a 3D model of the part on which the instrumental transitions for its processing are created with the subsequent generation of the control program for direct control of the machine. When processing similar parts geometrically, it is necessary to create a 3D model of the part for each one of them, after which the programming phase is repeated. It increases the time required to generate the control programs. This drawback can be avoided by using a parametric program instead of a CAM system for generating control programs, where the dimensions (parameters) for the part of the family are set in variables. The present study examines the possibility of machining sprockets using a parametric program.

The parametric programs for processing details on lathes, milling machines, etc. significantly expand the technological capabilities in processing geometrically similar details, processing surfaces other than a circle or other than those set in the main language having an analytical description (Kaldashev T. , 2019). These programs make it possible to use variables, arithmetic operations, trigonometric and other functions, construction of algorithmic structures, etc. (Hadjiiski, 2010) (Groves) (Smid, 2005) (Dimitrov, 2016). Depending on the CNC, variables are set with the symbol # (for CNC Fanuc, Mazak), address R (for CNC Siemens) (Golebski, 2017), address Q (for CNC Heidenhain), followed by a numeric part, for example, # 10, # 25, R101, Q1, Q20. While developing algorithmic structures, the operators for unconditional transition GOTO, conditional transition IF-Then, and the operator for cycle WHILE are used. Depending on the CNC, the development of algorithmic structures is different but essentially with the same meaning. This result in the automatic calculation of the nodal points' coordinates of the instrument's trajectory depending on the variable's numerical value.

Development of algorithm and parametric program for processing of chain wheels

The parametric program is being developed for CNC Fanuc 0i. In the development of the parametric program, the basic data related to the tooth profile, like pitch P , the diameter of the roller d , the number of teeth Z , and the angle of the tooth α (fig. 1), are used as input data. This information is used for further calculations required for the trajectory of the instrument. Figure 2 shows the trajectory of the tool for machining an interdental.

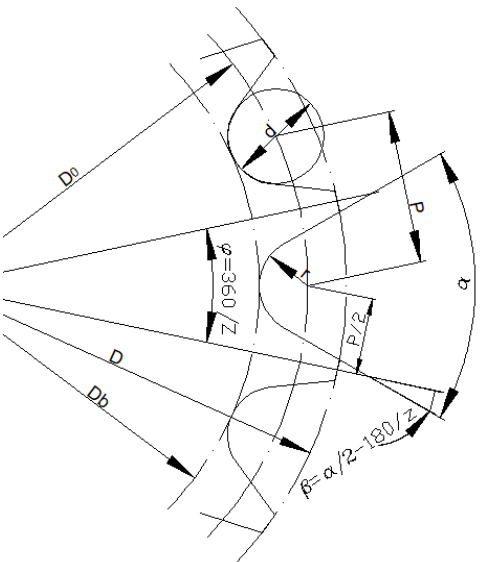
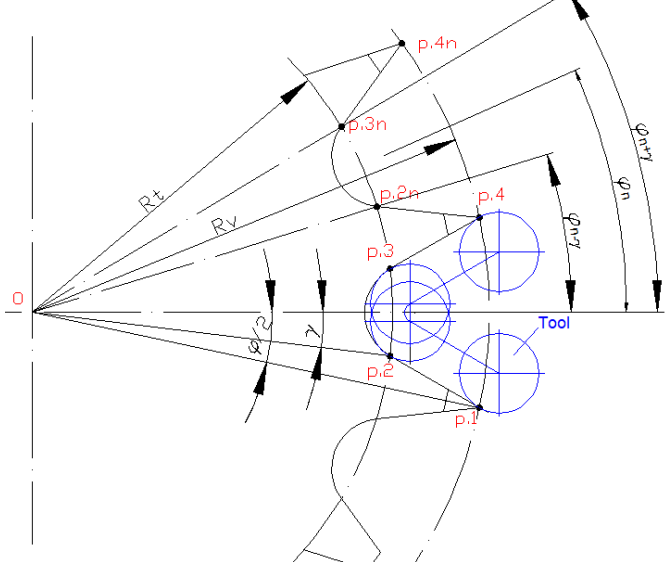
Figure 2 illustrates that four points are required for processing. The coordinates of the points are determined according to fig. 3. The coordinates of points 1 and 4 are determined using the radius of the vertex of the circle R_v , and of points 2 and 3 using the radius R_t (Fig. 2) of the circle passing through the tangent points between the line at an angle α and the radius at the bottom r .

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The radius of the vertex circle R_v is determined by the dependence (1) (fig. 3)

$$R_v = \frac{p}{2 \tan\left(\frac{\phi}{2}\right)} + \frac{a}{\tan \beta} \quad (1)$$

where P is the pitch of the chain wheels (fig. 3), a - the distance between points D and F and is determined by the dependence (2) (fig. 3)

Figure 1: Basic data on the tooth	Figure 2: Trajectory of the tool
	
Source: (Hristov, 1967)	Source: Author

$$a = CF - CD = \frac{p}{2} - c = \frac{p}{2} - \frac{r}{\cos \beta} \quad (2)$$

Where $r=0.505*d$, and the angle $= \frac{\alpha}{2} - \frac{180^\circ}{Z}$, (Hristov, 1967)

To determine R_t , it is necessary to determine the radius of the dividing circle R_0 in advance and the value of the angle γ . R_0 is determined by dependence (3) (Hristov, 1967)

$$R_0 = \frac{p}{2 \sin\left(\frac{180}{Z}\right)} \quad (3)$$

and the angle γ depending on (4)

$$\gamma = \tan^{-1}\left(\frac{b_r}{a_t}\right) \quad (4)$$

Where b_r is determined by dependence (5), and a_t depending on (6) (fig. 3)

$$b_r = AB = r \cos\left(\frac{\alpha}{2}\right) \quad (5)$$

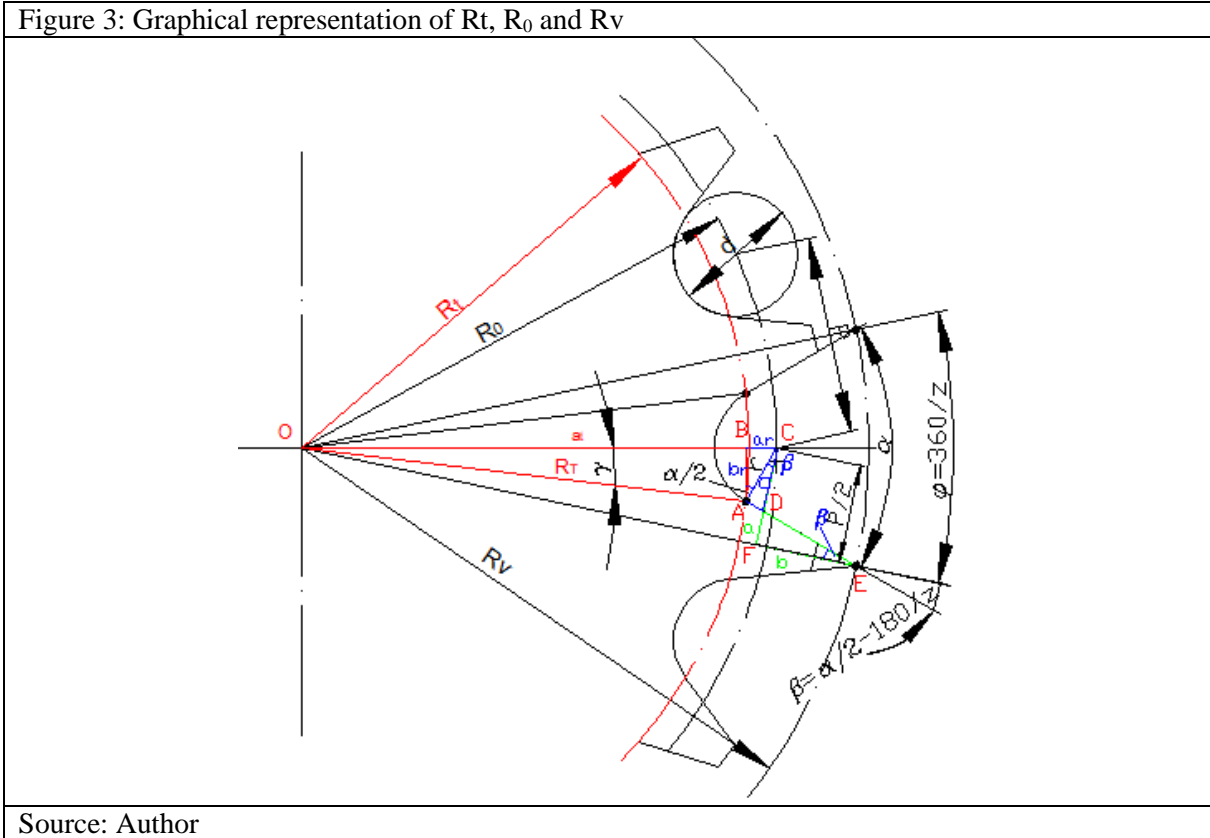
$$a_t = OC - BC = R_0 - a_r = \frac{p}{2 \sin\left(\frac{180}{Z}\right)} - r \sin\left(\frac{\alpha}{2}\right) \quad (6)$$

This is how R_t is obtained (7)

$$R_t = \frac{a_t}{\cos \gamma} \quad (7)$$

The analytical dependences (1) to (7) are used to calculate the coordinates of the trajectory of the tool for processing one interdental of the chain wheels. Table 1 shows the dependences by which the coordinates of points p.1 to p.4 are determined (fig. 2).

Figure 3: Graphical representation of R_t , R_0 and R_v



Source: Author

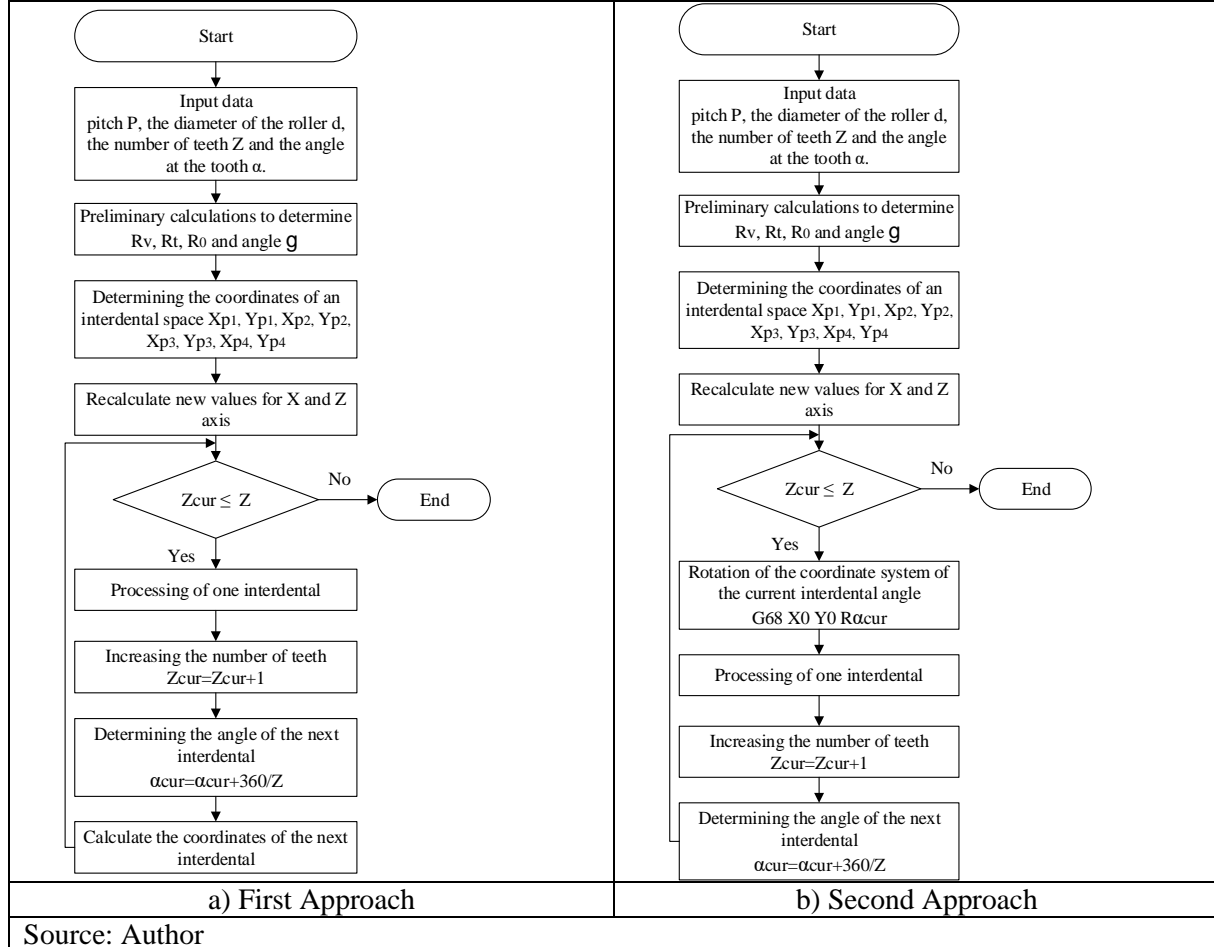
While processing all teeth (interdental), two approaches, depending on the capabilities of the CNC, are possible. Figure 4 displays the algorithms by which the processing of the chain wheel is carried out, fig. 4a displays the first approach and, fig. 4b demonstrate the second approach. In the first approach, the coordinates of each subsequent interdental tooth are analytically determined depending on the current angular pitch between the teeth φ_n (fig. 2). Figure 5a shows a part of the control parametric program, where an algorithm of the first approach is used for processing by accumulating the value of the angle in # 6, where to its current value is added the value of the angle between teeth predetermined and stored in # 8. The current angle for determining the coordinates of points $X_{2n}, Y_{2n}, X_{3n}, Y_{3n}$, is determined relative to the current value of # 6 and angle g calculated and stored in # 15 depending on (4). These values are calculated and stored in # 26 (for X_{2n}, Y_{2n}) and # 27 (for X_{3n}, Y_{3n}) (fig. 2).

Table 1: Coordinates of points on the trajectory

	Point	Coordinate	Variable	Equations
1	X		#18	$X_{p1} = R_v \cos(\varphi/2)$
	Y		#19	$Y_{p1} = R_v \sin(360 - \varphi/2)$
2	X		#20	$X_{p2} = R_t \cos(\gamma)$
	Y		#21	$Y_{p2} = R_t \sin(360 - \gamma)$
3	X		#22	$X_{p3} = R_t \cos(\gamma)$
	Y		#23	$Y_{p3} = R_t \sin(\gamma)$
4	X		#24	$X_{p4} = R_v \cos(\varphi/2)$
	Y		#25	$Y_{p4} = R_v \sin(\varphi/2)$

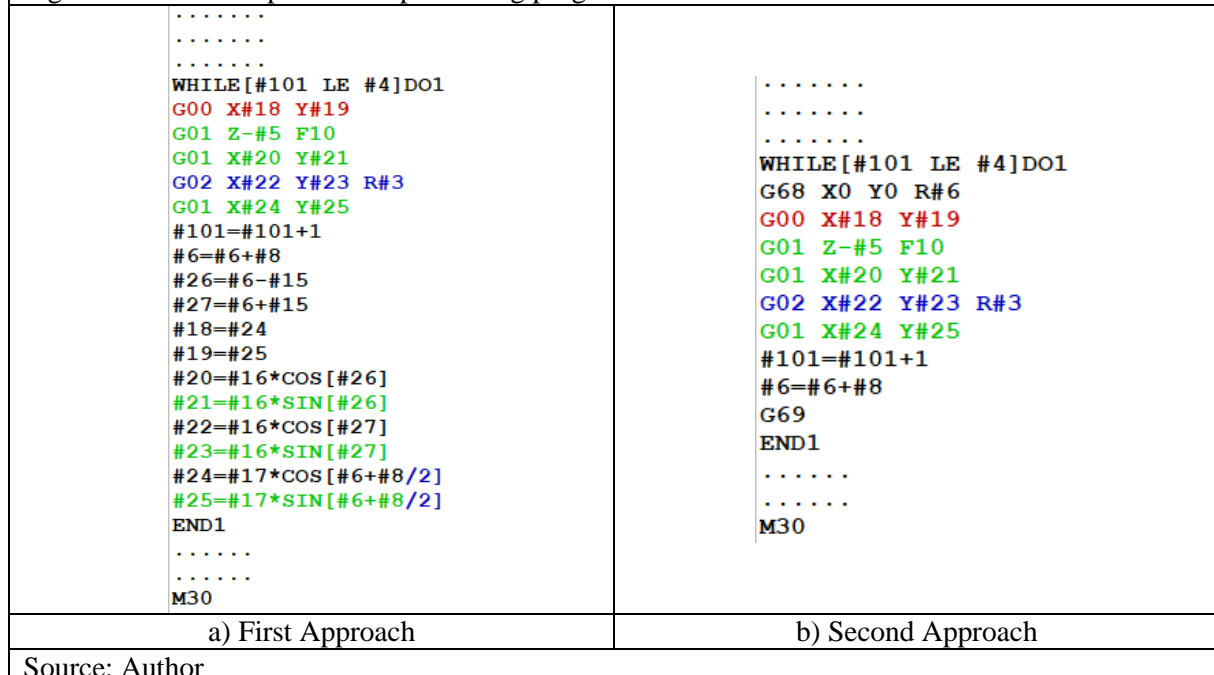
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Figure 4: Macro program algorithm



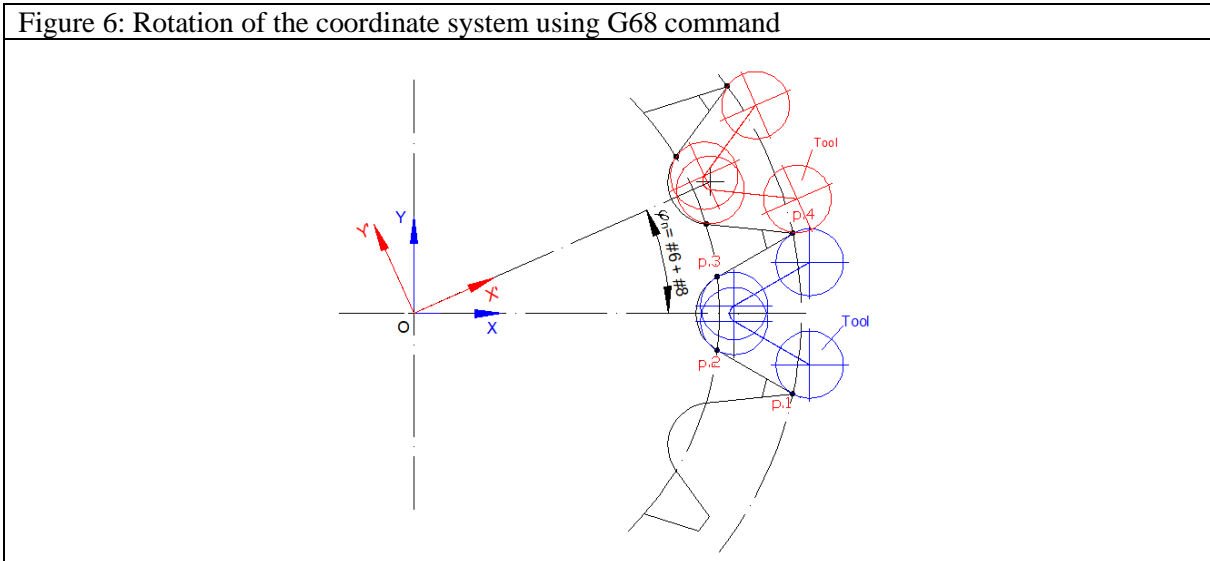
A WHILE / DO loop operator is used to process all sprocket teeth. In the cycle condition, the machining is controlled depending on the number of teeth on the sprocket. Thus, in # 101 the current number of processed teeth from the part is stored, and in # 4 the total number of teeth is set. When treating one tooth, the number of teeth increases (# 101 = # 101 + 1) (fig. 5a).

Figure 5: Part of the parametric processing program



The second possible processing approach is by rotating the working coordinate system using the G68 command. In this case, as can be seen from fig. 5b, it is not necessary to calculate the coordinates of the points of each subsequent interdenal. It is because the CNC automatically calculates them depending on the angle of rotation of the coordinate system set by the sentence G68 X0 Y0 R # 6, where in # 6, the current angular value of rotation is stored.

Figure 6: Rotation of the coordinate system using G68 command



Source: Author

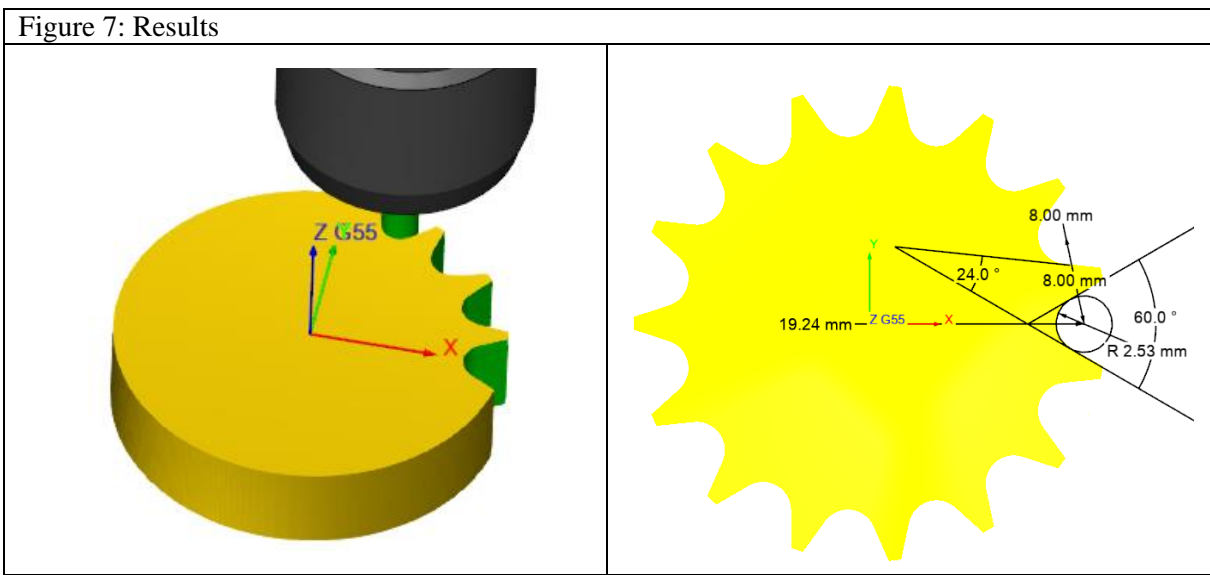
Thus, the processing of the next interdenal is performed according to the coordinate system $X'OY'$ (fig. 6). This approach applies to modern CNCs with a G68 command. The first approach is universal and does not depend on the generation of CNC, i.e., can be applied to both traditional and modern CNCs.

The parametric program is simulated in Vericut, where chain wheels with the following characteristics are processed: pitch P8 mm, angle $\alpha = 60^\circ$, roller diameter d5 mm, and the number of teeth Z15.

After the simulation of removing material from the workpiece, dimensional measurements were made using the X-Caliper tool. Figure 7b demonstrates that the measured values coincide with the input data necessary for determining the coordinates of the nodal points of the trajectory.

Given the capabilities of a CNC, the parametric program thus developed can be converted as part of the basic control commands by using a command for special reference to a macro program (Gainer & Murphy, 2013). Kaldashev (2022) presented this possibility while processing holes whose axes are located at equal angular steps on a circle and along an arc from a circle.

Figure 7: Results



a) Simulation with subtraction of material

b) Virtual Measurement

Source: Author

Conclusion

After conducting a virtual study in the Vericut environment and using its tools to measure the dimensions of the already processed virtual part (Fig. 7 b), it was concluded that the developed parametric program is workable. As the obtained dimensions fully correspond to the dimensions of the chain wheel depending on the set input parameters in the parametric program. It makes it possible to process chain wheels with different characteristics (P , α , d , Z). It reduces the time required to prepare a control program for processing a family of chain wheels. Because the program sets the analytical dependencies characterising the construction of the tooth profile. The developed algorithm can be successfully applied for different CNCs, where the main difference will be in the definition of the variable and the operator used (GOTO, IF-THEN).

Acknowledgements

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