CNC MANUFACTURING TECHNOLOGY OF A STRAIGHT SHAFT PART USING EMCO CONCEPT TURN 55 CNC MACHINE

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Abstract: *In order to support the rapid and efficient acquisition of various industrial products, numerous data archiving and management systems have been created in virtual environments. These digital platforms are complemented by the constant advancement of cutting tools and modern machinery, capable of adjusting and improving dimensional and construction parameters before parts are actually made. A significant contribution to this process is made by Computerized Numerical Control machines - CNC. These optimize the production flow through a high level of precision, a superior work capacity and a reduced execution time. In this paper, a CNC manufacturing technology for a straight shaft part, using EMCO Concept Turn 55 CNC system is presented. The stages of the machining process are described, from model preparation and setting of working parameters, to machine programming and final execution of the part.*

Keywords: *CNC, shaft, EMCO, turning*

1. Introduction

In the context of the rapid development of modern technologies, the automation of manufacturing processes has become an essential element for increasing productivity, ensuring product quality and reducing production costs. In this sense, Computer Numerical Control machines - CNC, occupy a central place in different industrial sectors [Carta,2025], [Moroșanu,2025].

These allow for complex machining and operate on the basis of computer programs that control tool movements and machining operations, largely eliminating direct operator intervention. Commands are entered through numerical codes that describe tool paths, working speeds, cutting depths and other parameters [Mishra,2025].

The implementation of CNC technology in industry has significantly optimized manufacturing processes. Vertical and horizontal machining centers, lathes, milling and drilling machines can be numerically controlled, which allows for automation and increased precision of machining operations [Baroiu,2024].

Computer numerical control machines offer a number of technological advantages, including high dimensional accuracy, reduced cycle time and the ability to produce both large-scale and one-off parts without mechanical modifications to the machine. These machines can be easily integrated into automated production flows and can operate continuously, 24/7 [Petru,2025].

CNC-manufactured parts meet the same tolerances and deviations, ensuring dimensional uniformity throughout production [Baroiu,2020].

The operation of these machines does not necessarily require highly trained personnel and the work interface allows for rapid adjustments and optimizations, which contributes to reducing downtimes [Susac,2019], [Manolache-Rusu,2021].

These systems can process various complex shapes and contours, with high precision, in short time intervals. Dedicated software allows for digital simulation of the part, eliminating the need for physical prototypes and reducing both the duration of the development cycle and the associated costs [Costin,2016].

Operating a CNC involves a reduced number of operators compared to conventional methods, which leads to lower labor costs and increased overall efficiency of the manufacturing process.

The classification of CNC equipment is carried out according to the number of axes on which the cutting tool or part can move, this criterion directly influencing the complexity of the operations that can be performed. Thus, there are CNC machines with 2, 3, 4, 5, 7, 9 or even 12 axes [José,2024].

As for CNC lathes, they are available in multiple configurations, among the most used being models with 2 axes (*X* and *Z*, to which the *Y* axis can be added for tool feed), but there are also variants with 4 or 5 axes, which allow significantly greater flexibility in the processing of parts with complex geometries [Bučányová,2014], [Shuling,2024].

In order to obtain the straight shaft part, the EMCO Concept Turn 55 equipment was used, Figure 1, which represents a CNC lathe with 2 axes (*X* and *Z*), designed for didactic applications [Čuboňová, 2013], [Dspace, 2025].

Figure 1: *EMCO Concept Turn 55 CNC machine* [EMCO,2025].

The machine has an inclined table, a turret with 8 tool positions and a main spindle with a speed between 120 and 4000 rpm, ensuring a positioning accuracy of ±0.008 mm. It can process cylindrical parts - shafts, bushings, rings, discs etc. with a maximum diameter of Ø130 mm and a maximum length of 215 mm [Harja,2023].

The equipment is equipped with 3D simulation software and a user-friendly interface, allowing for checking programs and optimizing machining parameters before the actual execution of the part [Fountas,2025].

2. Determining the shape and dimensions of the blank

Figure 2 shows the execution drawing of the straight shaft part.

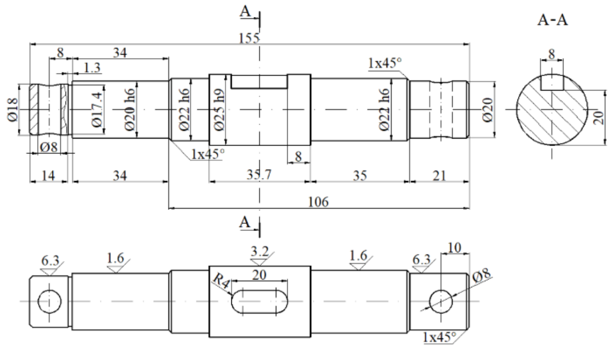

Figure 2: *Straight shaft part - 2D model.*

The machining process of the straight shaft part, which will be performed on the EMCO Concept Turn 55 CNC numerical control lathe, Figure 3, will include all the steps necessary to obtain the main shape and dimensions of the shaft, except for the operations related to the two holes and the channel.

Figure 3: *Straight shaft part on EMCO Concept Turn 55 CNC equipment* [Susac,2017].

In order to obtain the part, it will be decomposed into simple surfaces (plane, cylindrical, conical, etc.). The resulting surfaces and their coding are presented in Figure 4 and Table 1.

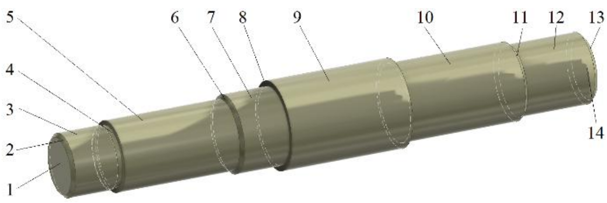

Figure 4: *Part decomposition and surface numbering.*

Table 1: *Surface identification and coding.*

No.	Surface type	Code	Dimensions [mm]	Roughness and tolerances [µm]
1	Frontal plane	SPF – 01	Ø18 – Ø20	6.3
2	Outer conical	SKE – 02	Ø18 / 1x45º	3.2
3	Outer cylindrical	SCE – 03	Ø18x14	6.3
4	Circular channel	CC – 04	Ø17.4 x 2	3.2
5	Outer cylindrical	SCE – 05	Ø20x34	1.6 h6$\begin{pmatrix}0\\-13\end{pmatrix}$
6	Outer conical	SKE – 06	Ø22 / 1x45º	3.2
7	Outer cylindrical	SCE – 07	Ø22x14.3	1.6 h6$\begin{pmatrix}0\\-13\end{pmatrix}$
8	Toroidal	ST – 08	Ø22xR1	3.2
9	Outer cylindrical	SCE – 9	Ø25x35	3.2 h9$\begin{pmatrix}0\\-52\end{pmatrix}$
10	Outer cylindrical	SCE – 10	Ø22x35	1.6 h6$\begin{pmatrix}0\\-13\end{pmatrix}$
11	Outer conical	SKE – 11	Ø22 / 1x45º	3.2
12	Outer cylindrical	SCE – 12	Ø20x21	6.3
13	Outer conical	SKE – 13	Ø20 / 1x45º	3.2
14	Frontal plane	SPF – 14	Ø20 – Ø22	6.3

For shaft-type parts, depending on purpose, importance and dimensions, the blanks are obtained by: casting, in the case of large shafts; rolled, cold or hot drawn, in the case of shafts with dimensions smaller than 150 mm; by free forging; by stamping, in the case of medium and large series production.

Thus, the choice is made for a blank of a round bar type, with a diameter of *Ø28* mm and a length of *l=156.6* mm, the material being an alloy steel - 41MoCr11, Figure 5.

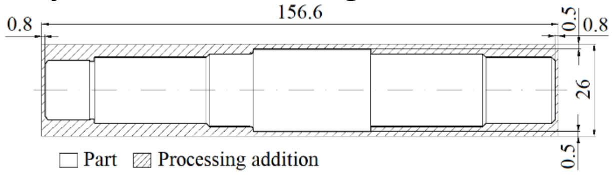

Figure 5: *The shape and dimensions of the blank.*

Considering that the diameter of Ø26 mm is not standardized, a round bar with a diameter of Ø28 mm will be chosen, according to SR 13172-1 [ASRO,2025].

For processing, complex surfaces were created, consisting of groups of simple geometric entities, Figure 6.

Figure 6: *Geometrical structure - surfaces to be processed.*

Notations:
- CC-4 - circular channel 4, containing surface 4;
- SLC-2 - complex longitudinal surface 2, containing surfaces 2 - 3 - 5 - 6 - 7 - 8;
- SCE-9 - outer cylindrical surface 9, containing surface 9;
- SLC-1 - complex longitudinal surface 1, containing surfaces 13 - 12 - 11 - 10.

3. The flow of the processing phases

The adopted blank is in the form of a rolled bar, with a circular section, having the following characteristics:
- blank type: hot-rolled round bar;
- material: 41MoCr11; C=35% – 45%;
- mechanical characteristics: $R_m=93$ daN/mm^2, *HB=223*;
- calculated dimensions: Ø26x156.6 mm;
- adopted dimensions: Ø28x157 mm, according to SR EN 10060 [ASRO,2025].

The ordering of the processing phases was carried out in two clampings of the blank, so that the tools could have access to the processing of surfaces outside the clamping area in the mandrel.

Grip 1 contains the following processing phases, Figure 7:
- F1 - profiled turning on the outer contour (roughing + finishing) SLC-1;
- Machine origin displacement M-A4: G54;
- Part origin displacement A4-W: TRANS Z155.

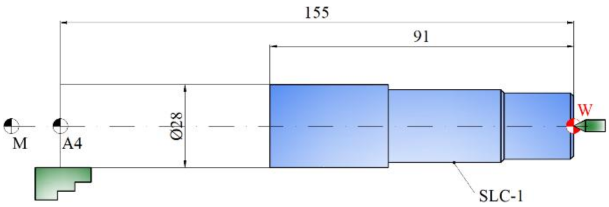

Figure 7: *Processing phases - Grip 1.*

Grip 2 contains the following processing phases, Figure 2:
- F2 - profiled turning on the outer contour (roughing + finishing) SLC-2;
- F3 - channel turning CC-4;
- F4 - cylindrical turning (finishing) SCE-9;
- Machine origin displacement M-A4: G54;
- Part origin displacement A4-W: TRANS Z155.

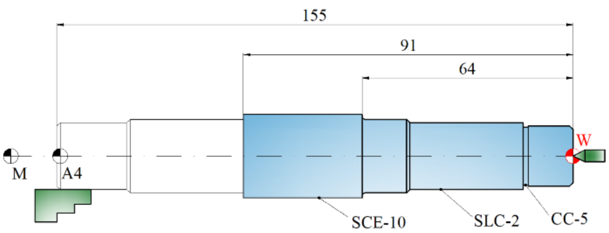

Figure 8: *Processing phases - Grip 2.*

The tools are chosen depending on the type of surface to be processed and the machining method that can be programmed on the machine.

The functional parameters associated with each processing phase are:
- for phase F1:
Processing method: Profile turning CYCLE95
Tool type / code: External turning tool / 510
Turret post: 2
Functional parameters:
- *axb*: 12x10;
- *r:* 0.4;
- ψ: 93;
- *cutting edge*: RT;
- L_x: 4.966;
- L_z: 1.988.

- for phase F2:
Processing method: Profile turning CYCLE95
Tool type / code: External turning tool / 510
Turret post: 2
Functional parameters:
- *axb*: 12x10;
- *r:* 0.4;
- ψ: 93;
- *cutting edge*: DR;
- L_x: 4.966;
- L_z: 1.988.

- for phase F3:
Processing method: Channel turning G1
Tool type / code: Wide channel tool / 530
Turret post: 6
Functional parameters:
- *axb*: 12x29;
- *r:* 0.1;
- ψ: 12;
- *cutting edge*: DR;
- L_x: 9.08;
- L_z: 17.10.

- for phase F4:
Processing method: Cylindrical turning G1
Tool type / code: External turning tool / 510
Turret post: 2
Functional parameters:
- *axb*: 12x10;
- *r:* 0.4;
- ψ: 93;
- *cutting edge*: RT;
- L_x: 4.966;
- L_z: 1.988.

Notations:
- *axb* – shank section of the square shank tools (turning tools);
- *r* – radius at the tip of the plate;
- ψ – main attack angle;
- *cutting edge* - *RT* - right; *LT* - left;
- L_x – compensation length on the *X* axis;

- L_z – compensation length on the *Z* axis.

4. CNC technological sketches and the coordinates of the characteristic points

The CNC technological sketches are presented in Figures 9÷12, and the coordinates of the characteristic points (*PC*) are centralized in Tables 2÷5.

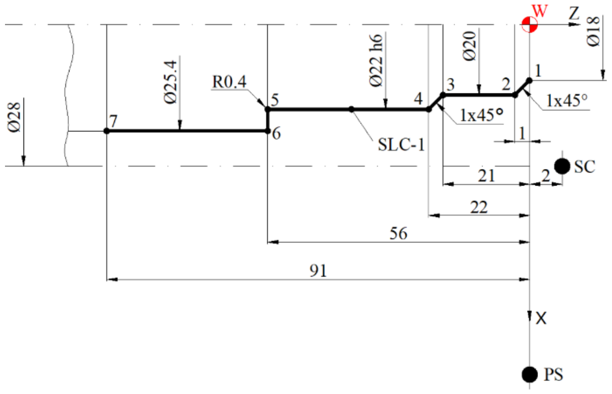

Figure 9: *Phase 1 - Profile turning on external contour (roughing and finishing) - SLC-1.*

Table 2: *Coordinates of characteristic points at profile turning on external contour SLC-1.*

W	1	2	3	4	5	6	7	SC	PS
X	18	20	20	22	22	25.4	25.4	28	40
Z	0	-1	-21	-22	-56	-56	-91	2	0

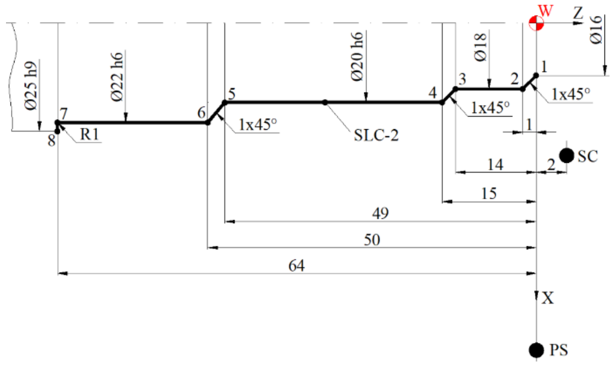

Figure 10: *Phase 2 - Profile turning on external contour (roughing and finishing) - SLC-2.*

Table 3: *Coordinates of characteristic points at profile turning on external contour SLC-2.*

W	1	2	3	4	5	6	7	8	SC	PS
X	16	18	18	20	20	22	22	25	28	40
Z	0	-1	-14	-15	-49	-50	-64	-64	2	0

Table 4: *Coordinates of characteristic points at the turning of the CC-5 channel.*

Coordinates	Characteristic points		
	1	2	PS
X	24	17.4	30
Z	-15	-15	-15

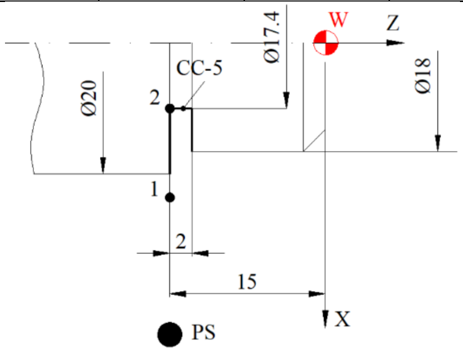

Figure 11: *Phase 3 - Channel turning - CC5.*

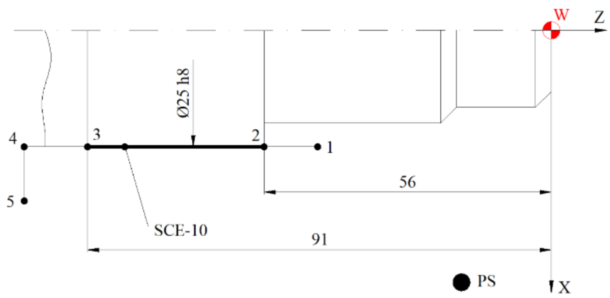

Figure 12: *Phase 4 - Cylindrical turning (finishing) - SCE-10.*

Table 5: *Coordinates of characteristic points at cylindrical turning SCE-10.*

W	1	2	3	4	5	PS
X	25	25	25	25	29	40
Z	-54	-56	-91	-93	-93	-10

5. Technological parameters

The technological parameters will be adopted or calculated from [Susac,2018], depending on the tool type, the processing phase, respectively the turning method.

Phases 1 and 2. Profiled turning on the outer contour, SLC-1: Ø25 - Ø20 şi SLC-2 - Ø25 - Ø18 (Roughing + Finishing)

a. Roughing (R_a=6.3 μm)

- *t=0.6* mm;
- *s=0.08÷0.1* mm/rot.

Checking the feed, s_v:

$$s_v = \sqrt[y]{\frac{14.8}{C_d \cdot t^x \cdot HB^n}} \left[\text{mm/rot.}\right], \qquad (1)$$

where [Susac,2018]:
- C_d - coefficient, $C_d=30.7$;
- *y*, *x*, *n* - exponents, whose values are: $y=0.85$, $x=1$, $n=0.35$;
- *t* - depth of cut, at one pass, in [mm];
- *HB* - hardness of the material to be processed; at 41MoCr11, the hardness is $HB=223$.

$$s_v = \sqrt[0.85]{\frac{14.8}{30.7 \cdot 0.6^1 \cdot 223^{0.35}}} = 0.08 \text{ mm/rot.}$$

Cutting speed, v:

$$v = \frac{C_v \cdot k_v}{T^m \cdot t^x \cdot s^y \cdot \left(\frac{HB}{200}\right)^n} \left[\text{m/min.}\right], \qquad (2)$$

where [Susac,2018]:
- C_v – coefficient, $C_v=146$;
- *m*, *x*, *y*, *n* – exponents, whose values are: $m=0.15$, $x=0.18$, $y=0.2$, $n=1.75$;
- *T* – tool durability, $T=45$ min.;
- $k_v=0.41$, for the ratio $d/D=18/25=0.72$ mm, $D_{med}=21.5$ mm.

$$v = \frac{146 \cdot 0.41}{45^{0.15} \cdot 0.6^{0.18} \cdot 0.08^{0.2} \cdot \left(\frac{223}{200}\right)^{1.75}} = $$
$$= 50.43 \text{ m/min.}$$

Main spindle speed, n:

$$n = \frac{1000 \cdot v}{\pi \cdot D_{med}} \left[\text{rot./min.}\right], \qquad (3)$$

$$n = \frac{1000 \cdot 50.43}{\pi \cdot 21.5} = 747 \text{ rot./min.}$$

b. Finishing (R_a=1.6 µm)
- $t=0.2$ mm;
- $s=0.1$ mm/rot., for $r=0.4$ mm.

Checking the feed, v_s:

$$s_v = 0.07 \text{ mm/rot.}, \quad R_a^p = 0.06 \text{ mm/rot.},$$

where $p=0.07$, for the external turning tool with $\psi = 93^o$.

Cutting speed, v:

$$v = \frac{146 \cdot 0.41}{45^{0.15} \cdot 0.6^{0.18} \cdot 0.07^{0.2} \cdot \left(\frac{223}{200}\right)^{1.75}} =$$
$$= 50.26 \text{ m/min.}$$

Main spindle speed, n:

$$n = \frac{1000 \cdot 59.26}{\pi \cdot 21.5} = 877.78 \text{ rot./min.}$$

Phase 3. Channel turning, CC-4: Ø20 - Ø17.4

The channel length is equal to the width of the cutting edge, so it will be processed in a single radial pass $b_c=b=2$ mm / 1 pass, the average diameter being, $D_{med}=18.7$ mm.

$$s_p = C_s \cdot k_s \cdot D_p^z \cdot b^x \cdot \left(\frac{d}{D}\right)^q \cdot \left(\frac{D_s}{D_p}\right)^p \left[\text{mm/rot.}\right], \quad (4)$$

where [Susac,2018]: $C_s=0.014$; $D_p=55$ mm; $D_s=28$ mm; $D=20$ mm; $d=17.4$ mm; $x=0.85$; $q=0.25$; $p=0.25$; $z=0.12$.

$$k_s = C_m \cdot \frac{1}{HB^n}, \qquad (5)$$

where: $C_m=16.3$; $n=0.631$; $HB=223$.

$$k_s = 16.3 \cdot \frac{1}{223^{0.631}} = 0.537.$$

$$s_p = 0.014 \cdot 0.537 \cdot 55^{0.12} \cdot 2^{0.85} \cdot 2^{0.85} \cdot$$
$$\cdot \left(\frac{17.4}{20}\right)^{0.25} \cdot \left(\frac{28}{55}\right)^{0.25} = 0.02 \text{ mm/rot.}$$

Cutting speed, v:

$$v = \frac{C_v \cdot K_v}{b^x \cdot s^y \cdot \left(\frac{d}{D}\right)^q} \left[\text{m/min.}\right], \qquad (6)$$

where [Susac,2018]: $C_v=17.9$; $x=0.1$; $y=0.4$; $q=0.1$; $k_v=k_s=0.41$ ($C_m=287.56$; $n=1.213$; $HB=223$).

$$v=\frac{17.9\cdot 0.41}{2^{0.1}\cdot 0.07^{0.4}\cdot\left(\frac{17.4}{20}\right)^{0.1}}=35.19\text{ m/min.}$$

Main spindle speed, n:

$$n=\frac{1000\cdot 35.19}{\pi\cdot 18.7}=1881.98\text{ rot./min.}$$

Phase 4. Cylindrical turning, SCE-9: Ø25 h9 **Finishing**

- processing addition, $A_p=0.2$ *mm*;
- $t=0.2$ mm / 1 pass;
- $s=0.1$ mm/rot., for $r=0.4$ mm.

Checking the feed, s_v:

$$s_v=0.065\text{ mm/rot.},\quad R_a^p=0.07\text{ mm/rot.},$$

where $p=0.07$, for the external turning tool with $\psi=93^{\circ}$ [Susac,2018].

The cutting speed, v, is calculated using Equation (2), where $k_v=0.9$, for $D=16$ mm.

$$v=\frac{146\cdot 0.9}{45^{0.15}\cdot 0.6^{0.18}\cdot 0.065^{0.2}\cdot\left(\frac{223}{200}\right)^{1.75}}=$$

$$=116.21\text{ m/min.}$$

Main spindle speed, n:

$$n=\frac{1000\cdot 116.21}{\pi\cdot 25}=1480.38\text{ rot./min.}$$

The basic and programmable parameters have been centralized in Tables 6 and 7.

Tabelul 6: *Basic technological parameters.*

Phase	Tool	Basic parameters			
		t [mm]	s [mm/rot]	V [m/min]	n [rot/min]
F1	External turning tool 510	0.6	0.08	50.43	747
F2	External turning tool 510	0.2	0.06	59.26	877.78
F3	Wide channel tool 530	–	0.02	35.19	1881.98
F4	External turning tool 510	0.2	0.07	116.21	1480.38

Tabelul 7: *Programmable technological parameters.*

Phase	Tool	Programmable parameters		
		t [mm]	F [mm/rot]	S [rot/min]
F1	External turning tool 510	0.6	0.083	50.43
F2	External turning tool 510	0.2	0.06	59.26
F3	Wide channel tool 530	–	0.017	35.19
F4	External turning tool 510	0.2	0.07	116.21

6. Editing the part program

The structure of the part program will contain the program blocks (*BP*), associated with each phase and machining tool, ordered according to Table 8.

Table 8: *Ordering of program blocks.*

Program block	Tool type	Turret post, T	Processing phases	
			Phase code	Name
Grip 1				
BP1	External turning tool 510	T2	F1	Profiled turning on the outer contour
Grip 2				
BP2	External turning tool 510	T2	F2	Profiled turning on the outer contour
			F4	Cylindrical turning
BP3	Wide channel tool 530	T6	F3	Channel turning

The profile turning cycle is summarized in Table 9, where:

- speed, $s_D=s_F=s_{med}=812$ rot/min.;
- roughing feed rate, $F_D=0.083$ mm/rot.;
- finishing feed rate, $F_F=0.06$ mm/rot.

Table 9: *Profile turning cycle – CYCLE 95.*

Parameter	BP1	BP2
	SCL-1	SCL-2
	D+F	D+F
NPP	SCL1	SCL2

MID	0.6	0.6
FALZ	0	0
FALX	0	0
FAL	0.2	0.2
FF1	0.083	0.083
FF2	0	0
FF3	0.06	0.06
VARI	9	9
DT	0	0
DAM	0	0
VRT	0	0

D – roughing; *F* – finishing.

The subprograms for the profiled contour are presented in Table 10.

The main program contains two program modules, corresponding to the two clampings of the blank (Tables 11 and 12).

Tabelul 10: *Subprograms for profiled contour.*

Subprograms	
SCL1.SPF	**SCL2.SPF**
G1 X18 Z0 X20 Z-1 Z-21 X22 Z-22 Z-56 X25.4 Z-91 M17	G1 X16 Z0 X18 Z-1 Z-14 X20 Z-15 Z-49 X22 Z-50 Z-64 RND=1 X25 M17

Table 11: *Grip 1 – SHAFT1.MPF program.*

Main program		
Program block	**Processing phase**	**Command lines**
BP1	F1 – Profiled turning on the outer contour	G54 TRANS Z155 G0 X70 Z0 T2 D1 M6 G95 S812 M3 G0 X40 Z0 X28 Z2 CYCLE95 (”SCL1”,0.6,0,0,0.2,0.083,0,0.6,9,0,0,0) G0 X40 Z0 M30

Table 12: *Grip 2 – SHAFT2.MPF program.*

Main program		
Program block	**Processing phase**	**Command lines**
BP2	F2 – Profiled turning on the outer contour	G54 TRANS Z155 G0 X70 Z0 T2 D1 M6 G95 S812 M3 G0 X40 Z0 X28 Z2 CYCLE95 (”SCL2”,0.6,0,0,0.2,0.083,0,0.6,9,0,0,0) G0 X40 Z0
	F4 – Cylindrical turning	X 40 Z-10 X25 Z-54 G1 X25 Z-93 F0.065 X29 G0 X52 Z-2
BP3	F3 – Channel turning	T6 D1 M6 G95 S1882 M3 X30 Z-15 X24 G1 X17.4 F0.017 G1 X24 F1 G0 X30 M30

7. Conclusions

The application of CNC technology in the straight shaft part processing, using EMCO Concept Turn 55 equipment, highlighted major advantages of numerical control machining, such as high dimensional accuracy, stability and repeatability of operations, as well as optimization of the technological flow.

The study fully integrated the process stages - from the selection of the blank and the definition of the surfaces to be machined, to the programming of work sequences and the validation of technological parameters through simulation.

Compared to conventional methods, CNC technology led to the reduction of cycle times, improvement of the quality of the obtained surfaces and the risk reduction of the human errors. The structuring of the process provides solid premises for the replication and scaling of production under industrial conditions, while maintaining the constant obtained performances.

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