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TEZĂ DE DOCTORAT

Abstract

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DOCTORAL THESIS

TITLU (română): Studii și cercetări inovative privind cinematica generării suprafețelor cilindrice

TITLE (engleză): Innovative studies and research regarding the kinematics of generating cylindrical surfaces

Doctoral field: Industrial Engineering

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Chapter I – The genesis of the theme and the objectives of the thesis

1.1. The genesis of the theme

The present doctoral thesis has as its theme - *Innovative studies and research on the kinematics of cylindrical surface generation* - one of those proposed by the scientific supervisor, consistent with the developments and discoveries in the field of processing technologies with a rapid rise in recent decades.

1.2. The objectives of the thesis

In accordance with ... the very title of the work, the main scientific objective of this doctoral thesis is **the detailed analysis and expansion of the possibilities for processing external cylindrical surfaces**, through innovation-invention.

Two directions of action are estimated for which success was foreseen even from the preliminary analysis phase of the thesis:

1) - **revealing (by at least one example) the multitude of possibilities for machining external cylindrical surfaces** characterized by straight directrix and circle generatrix, and

2) - **detailed study of the machining of (external) cylindrical surfaces by turning with a lathe tool with an inclined tangential cutting edge**.

The thesis will include an introductory chapter, a table of contents, a bibliography and, possibly, a number of annexes.

Chapter II – Brief history of the evolution of manufacturing processes

People began to make pieces by carving, that is, by removing material.

A second way of making pieces that has emerged and developed over time is through the redistribution of a material.

The third method, used since ancient human history, is by adding material. Adding material can be combined with redistributing material; ….

"*The concept of machine tool directly refers to and is based on two … essential concepts, which refer to goods without which the modern world cannot be imagined: **machine** and **tool***". A machine tool generates surfaces by machining a semi-finished product with the help of a tool, thus obtaining a part. Surface generation involves relative desmodromic movements between the part and the tool, at least one of which is moving. The part is characterized by a certain geometry, therefore by one or more surfaces that define it, by the precision and quality of these surfaces and by the material used.

Machine tools can perform machining by cutting, plastic deformation or using "unconventional" processes.

The definitions of the concept of machine tool given over time reflect the historical moment and the development of knowledge in the field. … the pertinent definitions highlight, explicitly or implicitly, that a machine tool uses appropriate tools to modify, during a machining process, the shape and dimensions of bodies (solid, metallic or non-metallic).

Whatever the definition (and regardless of it), it is obvious that the role of a machine tool is to achieve one or more new surfaces on the desired piece (as a result of changing the shape and dimensions of a semi-finished product), through a machining process and using appropriate tools.

Chapter III - About generating surfaces on machine tools

3.1. The concept of surface

The notion of surface is of great importance in relation to the shape of a part. Most often a part is characterized by several surfaces, two by two immediately adjacent and in continuity. In many technical bodies, an edge is often identified at the boundary between such two adjacent surfaces.

3.2. On the theoretical generation of surfaces

Using machine tools, real surfaces are generated, but designing or choosing a machine tool capable of generating the desired surface involves developing a virtual image of the respective process, therefore a theoretical generation of the respective surface. As a result, the study of the theoretical generation of surfaces precedes and is reflected in their practical generation.

For the present thesis, the priority is the theoretical generation of surfaces, this being the basis for the innovative study of the kinematics of machine tools capable of generating cylindrical surfaces.

Within the theory, the notions of directrix (curve) and generatrix (curve) are of particular importance.

3.3. Directrix and generatrix: forms and classifications

A "*unitary surface*" of a body can be called a surface characterized by a single generatrix & directrix pair.

Using <u>the criterion of the mode of generation</u>, a contemporary point of view proposes the consideration of six types of generatrix and directrix curves, …. In this sense, both the directrix (D) and the generatrix (G) can be: (M; m) materialized; (Co; co) generated by copying; (Citp; citp) generated kinematically as a trajectory of a point; (Cifc; cifc) generated kinematically as an envelope of a family of curves; (R; r) generated (kinematically) by rolling; (P; p) programmed.

Table 3.1. Possible combinations of surface generation,
depending on the generation modes of the directrix and generatrix curves

		Directrix					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix	m	M&m	Co&m	Ci_{tp}&m	Ci_{fc}&m	R&m	P&m
	co	M&co	Co&co	Ci_{tp}&co	Ci_{fc}&co	R&co	P&co
	ci_{tp}	M&ci_{tp}	Co&ci_{tp}	Ci_{tp}&ci_{tp}	Ci_{fc}&ci_{tp}	R&ci_{tp}	P&ci_{tp}
	ci_{fc}	M&ci_{fc}	Co&ci_{fc}	Ci_{tp}&ci_{fc}	Ci_{fc}&ci_{fc}	R&ci_{fc}	P&ci_{fc}
	r	M&r	Co&r	Ci_{tp}&r	Ci_{fc}&r	R&r	P&r
	p	M&p	Co&p	Ci_{tp}&p	Ci_{fc}&p	R&p	P&p

The meanings in the previous table are sufficiently explicit: for example, by Ci_{tp}&m we will understand D(Ci_{tp})&G(m), that is, a way of generating a surface in which the directrix D is obtained kinematically as the trajectory of a point (Ci_{tp}), and the generatrix G is materialized (m) on the tool, usually as the profile of the cutting edge of its active part.

Chapter IV – Analysis of machining processes and machine tools intended for generating cylindrical surfaces

In this doctoral thesis, "*Studies and innovative research on the kinematics of generating cylindrical surfaces*", the analysis of machining processes and associated machine tools addresses exclusively those intended for the processing of cylindrical surfaces, characterized by straight directrix and circle generatrix.

4.2. Machining processes and machine tools that generate (also) cylindrical surfaces (with straight directrix and circle generatrix)

It is necessary to explore the various known processes for generating cylindrical surfaces, regardless of whether these processes are conventional or unconventional and regardless of whether they operate by removing material, adding material, or redistributing material.

4.2.1. Drilling and drilling machine tools

Table 4.1. Common ways to obtain directrix (D) when drilling

M	Co	Ci_{tp}	Ci_{fc}	R	P
● circle; cylindrical propeller	×	×	×	×	×

Table 4.2. Common ways to obtain generatrix (G) when drilling

m	co	ci_{tp}	ci_{fc}	r	p
■ circle; cylindrical propeller	×	● straight	×	×	×

In conclusion, since drilling cannot obtain straight lines and implicitly cannot generate a cylindrical surface characterized simultaneously by straight directrix and circle generatrix, the drilling processing process on drilling machines is not of interest for this doctoral thesis.

4.2.2. Turning and turning machine tools

Turning is one of the most widespread machining processes, with approximately 30% of all machining operations being performed by turning.

Table 4.3. Common ways to obtain directrix (D) when turning

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	×	●	❖	×	×	●
Circle	■	●	●	×	×	●
Another curve	×	●	●	×	×	●

Note. The symbols used have the following meanings: × not possible; ● typical case; ◆ possible case, not very productive, not recommended; ■ specific case of another process; ❖ approximate curve

Table 4.4. Common ways to obtain generatrix (G) when turning

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	●	●	●	◆	●	●
Circle	●	●	●	◆	●	●
Another curve	●	●	×	◆	●	●

Table 4.5. Common combinations for generating a surface on machine tools for turning, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	●	❖	×	×	●
	co	×	●	❖	×	×	●
	ci_{tp}	×	●	❖	×	×	●
	ci_{fc}	×	◆	❖	×	×	◆
	r	×	●	❖	×	×	●
	p	×	●	❖	×	×	●

4.2.3. Milling and milling machine tools

Through milling, very diverse surfaces can be obtained, characterized by directrix curves of various shapes and methods of obtaining.

Table 4.6. Common ways to obtain directrix (D) when milling

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	×	■	×	●	■	●
Circle	■	■	×	●	■	●
Another curve	×	■	×	●	■	●

Table 4.7. Common ways to obtain generatrix (G) when milling

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	●	■	×	●	■	●
Circle	●	■	×	●	■	●
Another curve	●	■	×	●	■	●

Table 4.8. Common combinations for generating a surface on machine tools for milling, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	■	×	●	■	●
	co	×	■	×	●	■	●
	ci_{tp}	×	×	×	×	×	×
	ci_{fc}	×	■	×	●	■	●
	r	×	■	×	●	■	●
	p	×	■	×	●	■	●

Through milling, neither the directrix nor the generatrix can be obtained kinematically as the trajectory of a point.

4.2.4. Grinding and grinding machine tools

Essentially, the machining schemes corresponding to grinding machines are similar to those corresponding to milling machines.

4.2.5. Planing / slotting and planing / slotting machine tools

Through planing / slotting, a materialized directrix cannot be obtained, and the generatrix cannot be obtained kinematically as the trajectory of a point.

Table 4.9. Common ways to obtain directrix (D) when planing / slotting

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	×	■	●	×	×	■
Circle	×	■	■	■	×	■
Another curve	×	■	×	×	×	■

Table 4.10. Common ways to obtain generatrix (G) when planing / slotting

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	●	■	×	●	■	●
Circle	●	■	×	●	■	●
Another curve	●	■	×	●	■	●

Table 4.11. Common combinations for generating a surface on planing / slotting machine tools, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	■	●	×	×	●
	co	×	■	●	×	×	●
	ci_{tp}	×	×	×	×	×	×
	ci_{fc}	×	■	●	×	×	●
	r	×	■	●	×	×	●
	p	×	■	●	×	×	●

4.2.6. Broaching and broaching machine tools

In broaching, the tools used are broaches, some very specific, with exclusively materialized generatrix.

Table 4.12. Common ways to obtain directrix (D) when broaching

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	×	×	●	■	×	×
Circle	×	×	×	■	×	×
Another curve	×	×	×	×	■	×

Table 4.13. Common ways to obtain generatrix (G) when broaching

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	●	×	×	×	■	×
Circle	●	×	×	×	■	×
Another curve	●	×	×	×	■	×

Table 4.14. Common combinations for generating a surface on broaching machine tools, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	×	●	■	×	×
	co	×	×	×	×	×	×
	ci_{tp}	×	×	×	×	×	×
	ci_{fc}	×	×	×	×	×	×
	r	×	×	■	■	×	×
	p	×	×	×	×	×	×

4.2.7. Sawing and sawing machines

When cutting with a saw, the directrix is a straight line obtained kinematically as the trajectory of a point, or a materialized circle. The generatrix is a straight line, obtained kinematically as the trajectory of a point.

Table 4.15. Common ways to obtain directrix (D) when cutting with a saw

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	×	×	●	×	×	×
Circle	■	×	×	×	×	×
Another curve	×	×	×	×	×	×

Table 4.16. Common ways to obtain generatrix (G) when cutting with a saw

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	×	×	●	×	×	×
Circle	×	×	❖	■	×	■
Another curve	×	×	×	❖	×	❖

Table 4.17. Common combinations for generating a surface on using saws, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	×	×	×	×	×
	co	×	×	×	×	×	×
	ci_{tp}	×	×	❖	×	×	×
	ci_{fc}	×	×	■	×	×	×
	r	×	×	×	×	×	×
	p	×	×	■	×	×	×

4.2.8. Generation by chipping of the straight directrix and the circle generatrix

Considering the above, the sets $\mathcal{M}_{D\text{-}dr(M)}$, $\mathcal{M}_{D\text{-}dr(Co)}$, $\mathcal{M}_{D\text{-}dr(Citp)}$, $\mathcal{M}_{D\text{-}dr(Cifc)}$, $\mathcal{M}_{D\text{-}dr(R)}$ and $\mathcal{M}_{D\text{-}dr(P)}$ can be expressed (where, for example, $\mathcal{M}_{D\text{-}dr(M)}$ is understood as *the set of processing processes* (by chipping, in this case) *that allow obtaining surfaces with directrix* (D) *straight* (dr) *materialized* (M), $\mathcal{M}_{D\text{-}dr(Co)}$ is understood as *the set of processing processes that allow obtaining surfaces with directrix* (D) *straight* (dr) *resulting from copying* (Co), and so on):

$$M_{D-dr(M)}^{Aşc} = \emptyset \quad (4.1)$$

$$M_{D-dr(Co)}^{Aşc} = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.2)$$

$$M_{D-dr(Citp)}^{Aşc} = \{strunjire, rabotare, mortezare, broşare, tăiere\ cu\ fierăstrău\} \quad (4.3)$$

$$M_{D-dr(Cifc)}^{Aşc} = \{frezare, rectificare, broşare\} \quad (4.4)$$

$$M_{D-dr(R)}^{Aşc} = \{frezare, rectificare\} \quad (4.5)$$

$$M_{D-dr(P)}^{Aşc} = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.6)$$

The sets $\mathcal{M}_{G\text{-}cerc(m)}$, $\mathcal{M}_{G\text{-}cerc(co)}$, $\mathcal{M}_{G\text{-}cerc(citp)}$, $\mathcal{M}_{G\text{-}cerc(cifc)}$, $\mathcal{M}_{G\text{-}cerc(r)}$ and $\mathcal{M}_{G\text{-}cerc(p)}$ reflecting machining processes that allow obtaining surfaces with generatrix circle by any of the six modes considered (m, co, citp, cifc, r and p) are:

$$M_{G-cerc(m)}^{Aşc} = \{strunjire, frezare, rectificare, rabotare, mortezare, broşare\} \quad (4.7)$$

$$M_{G-cerc(co)}^{Aşc} = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.8)$$

$$M_{G-cerc(citp)}^{Aşc} = \{strunjire, tăiere\ cu\ fierăstrău\} \quad (4.9)$$

$$M_{G-cerc(cifc)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare, tăiere\ cu\ fierăstrău\} \quad (4.10)$$

$$M_{G-cerc(r)}^{Aşc} = \{strunjire, frezare, rectificare, rabotare, mortezare, broşare\} \quad (4.11)$$

$$M_{G-cerc(p)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare, tăiere\ cu\ fierăstrău\} \quad (4.12)$$

The 36 cases of possible combinations are explained by sets that are obtained as the intersection of two sets of procedures that allow obtaining the directrix curve, on the one hand, and the generatrix curve, on the other. The sets in question are:

$$M_{dr(M)\&cerc(m)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \emptyset \quad (4.13)$$

$$M_{dr(M)\&cerc(co)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(co)}^{Aşc} = \emptyset \quad (4.14)$$

$$M_{dr(M)\&cerc(citp)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(citp)}^{Aşc} = \emptyset \quad (4.15)$$

$$M_{dr(M)\&cerc(cifc)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(cifc)}^{Aşc} = \emptyset \quad (4.16)$$

$$M_{dr(M)\&cerc(r)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(r)}^{Aşc} = \emptyset \quad (4.17)$$

$$M_{dr(M)\&cerc(p)}^{Aşc} = M_{D-dr(M)}^{Aşc} \cap M_{G-cerc(p)}^{Aşc} = \emptyset \quad (4.18)$$

$$M_{dr(Co)\&cerc(m)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \tag{4.19}$$

$$M_{dr(Co)\&cerc(co)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(co)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \tag{4.20}$$

$$M_{dr(Co)\&cerc(citp)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(citp)}^{Aşc} = \{strunjire\} \tag{4.21}$$

$$M_{dr(Co)\&cerc(cifc)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(cifc)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\}\emptyset \tag{4.22}$$

$$M_{dr(Co)\&cerc(r)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(r)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\}\emptyset \tag{4.23}$$

$$M_{dr(Co)\&cerc(p)}^{Aşc} = M_{D-dr(Co)}^{Aşc} \cap M_{G-cerc(p)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \tag{4.24}$$

$$M_{dr(Citp)\&cerc(m)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \\ = \{strunjire, rabotare, mortezare, broşare\} \tag{4.25}$$

$$M_{dr(Citp)\&cerc(co)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(co)}^{Aşc} = \\ = \{strunjire, rabotare, mortezare, broşare\} \tag{4.26}$$

$$M_{dr(Citp)\&cerc(citp)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(citp)}^{Aşc} = \{strunjire, tăiere\ cu\ fierăstrău\} \tag{4.27}$$

$$M_{dr(Citp)\&cerc(cifc)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(cifc)}^{Aşc} = \\ = \{strunjire, rabotare, mortezare, broşare, tăiere\ cu\ fierăstrău\} \tag{4.28}$$

$$M_{dr(Citp)\&cerc(r)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(r)}^{Aşc} = \{frezare, rectificare, broşare\} \tag{4.29}$$

$$M_{dr(Citp)\&cerc(p)}^{Aşc} = M_{D-dr(Citp)}^{Aşc} \cap M_{G-cerc(p)}^{Aşc} = \\ = \{strunjire, rabotare, mortezare, broşare, tăiere\ cu\ fierăstrău\} \tag{4.30}$$

$$M_{dr(Cifc)\&cerc(m)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \{frezare, rectificare, broşare\} \tag{4.31}$$

$$M_{dr(Cifc)\&cerc(co)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(co)}^{Aşc} = \{frezare, rectificare\} \tag{4.32}$$

$$M_{dr(Cifc)\&cerc(citp)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(citp)}^{Aşc} = \emptyset \tag{4.33}$$

$$M_{dr(Cifc)\&cerc(cifc)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(cifc)}^{Aşc} = \{frezare, rectificare\} \tag{4.34}$$

$$M_{dr(Cifc)\&cerc(r)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(r)}^{Aşc} = \{frezare, rectificare, broşare\} \tag{4.35}$$

$$M_{dr(Cifc)\&cerc(p)}^{Aşc} = M_{D-dr(Cifc)}^{Aşc} \cap M_{G-cerc(p)}^{Aşc} = \{frezare, rectificare\} \tag{4.36}$$

$$M_{dr(R)\&cerc(m)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \{frezare, rectificare\} \tag{4.37}$$

$$M_{dr(R)\&cerc(co)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(co)}^{Aşc} = \{frezare, rectificare\} \tag{4.38}$$

$$M_{dr(R)\&cerc(citp)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(citp)}^{Aşc} = \emptyset \tag{4.39}$$

$$M_{dr(R)\&cerc(cifc)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(cifc)}^{Aşc} = \{frezare, rectificare\} \tag{4.40}$$

$$M_{dr(R)\&cerc(r)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(r)}^{Aşc} = \{frezare, rectificare\} \tag{4.41}$$

$$M_{dr(R)\&cerc(p)}^{Aşc} = M_{D-dr(R)}^{Aşc} \cap M_{G-cerc(p)}^{Aşc} = \{frezare, rectificare\} \tag{4.42}$$

$$M_{dr(P)\&cerc(m)}^{Aşc} = M_{D-dr(P)}^{Aşc} \cap M_{G-cerc(m)}^{Aşc} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \tag{4.43}$$

$$M^{Aşc}_{dr(P)\&cerc(co)} = M^{Aşc}_{D-dr(P)} \cap M^{Aşc}_{G-cerc(co)} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.44)$$

$$M^{Aşc}_{dr(P)\&cerc(citp)} = M^{Aşc}_{D-dr(P)} \cap M^{Aşc}_{G-cerc(citp)} = \{strunjire\} \quad (4.45)$$

$$M^{Aşc}_{dr(P)\&cerc(cifc)} = M^{Aşc}_{D-dr(P)} \cap M^{Aşc}_{G-cerc(cifc)} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.46)$$

$$M^{Aşc}_{dr(P)\&cerc(r)} = M^{Aşc}_{D-dr(P)} \cap M^{Aşc}_{G-cerc(r)} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.47)$$

$$M^{Aşc}_{dr(P)\&cerc(p)} = M^{Aşc}_{D-dr(P)} \cap M^{Aşc}_{G-cerc(p)} = \\ = \{strunjire, frezare, rectificare, rabotare, mortezare\} \quad (4.48)$$

Obviously, the sets described by the relations (4.13) ... (4.48) remain open to new analyses and additions.

Table 4.18. Common combinations for generating a surface on chipping, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	×	●	●	●	●	●
	co	×	●	●	●	●	●
	ci_{tp}	×	●	❖	×	×	●
	ci_{fc}	×	●	●	●	●	●
	r	×	●	●	●	●	●
	p	×	●	●	●	●	●

4.2.9. Plastic deformation and machine tools for plastic deformation

Plastic deformation machining represents a large and very diverse group of operations, in which surface generation is achieved either by material removal or by material redistribution.

In various plastic deformation processing operations, the directrix can be:

- materialized – in operations such as die-cutting, stamping, embossing;
- obtained by copying – for example in pin or multipoint stamping;
- obtained kinematically as a trajectory of a point (straight – typical case in cutting / punching operations);
- obtained kinematically as a envelope of a family of curves – for example in the Grob process of machining grooves and cylindrical teeth with straight teeth;
- obtained kinematically by rolling – when rolling the teeth of cylindrical wheels with straight teeth;
- programmed (any plane curve) – for example, when deforming with pins, on CNC machines.

Considering the above, the sets $\mathcal{M}_{D-dr(M)}$, $\mathcal{M}_{D-dr(Co)}$, $\mathcal{M}_{D-dr(Citp)}$, $\mathcal{M}_{D-dr(Cifc)}$, $\mathcal{M}_{D-dr(R)}$ and $\mathcal{M}_{D-dr(P)}$ can be expressed:

$$M^{Def}_{D-dr(M)} = \{refulare, ştampare, reliefare \dots\} \quad (4.49)$$

$$M^{Def}_{D-dr(Co)} = \{ambutisare\ multipunct\} \quad (4.50)$$

$$M^{Def}_{D-dr(Citp)} = \{decupare\ /\ perforare\ cu\ ştanţe; ronţăire\} \quad (4.51)$$

$$M_{D-dr(Cifc)}^{Def} = \{canelare\ /\ danturare\ procedeu\ Grob; profilare\ prin\ forjare\ radială\} \quad (4.52)$$

$$M_{D-dr(R)}^{Def} = \{danturare\ prin\ rulare\ cu\ bacuri\ sau\ role;\ canelare\ cu\ role\ profilate\} \quad (4.53)$$

$$M_{D-dr(P)}^{Def} = \{deformare\ cu\ pini, pe\ mașini\ CNC\} \quad (4.54)$$

Table 4.19. Common ways to obtain directrix (D) when plastic deformation

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	●	●	●	●	●	●
Circle	●	●	●	?	●	●
Another curve	●	●	?	?	?	●

Notă. The notation "?" represents an unknown method, reserve for innovation-invention

In turn, in plastic deformation processing, the generatrix can be:

- materialized (any plane curve) – in operations such as drilling / cutting, stamping, extrusion, die-cutting, stamping, embossing, edging, rolling;
- obtained by copying. An example is rotary stamping;
- obtained kinematically as a trajectory of a point (any plane curve);
- obtained as a envelope of a family of curves (any plane curve) – for example when perforating / cutting on nibbling machines with manual control of the semi-finished product;
- obtained kinematically by rolling (any plane curve obtained as unfolded, including a circle);
- programmed (any plane curve) – for example when punching / cutting on CNC machining centers.

The sets $\mathcal{M}_{G\text{-}cerc(m)}$, $\mathcal{M}_{G\text{-}cerc(co)}$, $\mathcal{M}_{G\text{-}cerc(citp)}$, $\mathcal{M}_{G\text{-}cerc(cifc)}$, $\mathcal{M}_{G\text{-}cerc(r)}$ and $\mathcal{M}_{G\text{-}cerc(p)}$ are:

$$M_{G-cerc(m)}^{Def} = \begin{Bmatrix} decupare/perforare, ambutisare, extrudare, refulare, ștampare, \\ reliefare, bordurare, roluire, lărgire, gâtuire\ ... \end{Bmatrix} \quad (4.55)$$

$$M_{G-cerc(co)}^{Def} = \{ambutisare\ rotativă, extrudare\ rotativă;\ \ ronțăire\} \quad (4.56)$$

$$M_{G-cerc(citp)}^{Def} = \{extrudare\ rotativă\} \quad (4.57)$$

$$M_{G-cerc(cifc)}^{Def} = \{decupare\ /\ perforare\ pe\ mașini\ de\ ronțăit\} \quad (4.58)$$

$$M_{G-cerc(r)}^{Def} = \{danturare\ prin\ rulare\ cu\ bacuri\ sau\ role, canelare\ cu\ role\ profilate\} \quad (4.59)$$

$$M_{G-cerc(p)}^{Def} = \{decupare\ perforare\ pe\ centre\ de\ prelucrare\ prin\ ștanțare\} \quad (4.60)$$

Table 4.20. Common ways to obtain generatrix (G) when plastic deformation

Curve shape		m	co	ci_{tp}	ci_{fc}	r	p
Straight		●	●	●	●	●	●
Circle		●	●	●	●	●	●
Another curve		●	●	●	●	●	●

... deformation processing is often very specific and as a result not every combination of the ways of obtaining the directrix and generatrix is feasible. The 36 cases of possible combinations are explained by sets that are obtained as the intersection of two sets of procedures that allow obtaining the directtix curve, on the one hand, and the generatrix curve, on the other hand:

$$M_{dr(M)\&cerc(m)}^{Def} = M_{D-dr(M)}^{Def} \cap M_{G-cerc(m)}^{Def} = \{refulare, ștampare, reliefare\ ...\} \quad (4.61)$$

$$M^{Def}_{dr(M)\&cerc(co)} = M^{Def}_{D-dr(M)} \cap M^{Def}_{G-cerc(co)} = \emptyset \quad (4.62)$$

$$M^{Def}_{dr(M)\&cerc(citp)} = M^{Def}_{D-dr(M)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.63)$$

$$M^{Def}_{dr(M)\&cerc(cifc)} = M^{Def}_{D-dr(M)} \cap M^{Def}_{G-cerc(cifc)} = \emptyset \quad (4.64)$$

$$M^{Def}_{dr(M)\&cerc(r)} = M^{Def}_{D-dr(M)} \cap M^{Def}_{G-cerc(r)} = \{deformare\ prin\ rulare\ cu\ bacuri\ sau\ role\} \quad (4.65)$$

$$M^{Def}_{dr(M)\&cerc(p)} = M^{Def}_{D-dr(M)} \cap M^{Def}_{G-cerc(p)} = \emptyset \quad (4.66)$$

$$M^{Def}_{dr(Co)\&cerc(m)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(m)} = \emptyset \quad (4.67)$$

$$M^{Def}_{dr(Co)\&cerc(co)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(co)} = \emptyset \quad (4.68)$$

$$M^{Def}_{dr(Co)\&cerc(citp)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.69)$$

$$M^{Def}_{dr(Co)\&cerc(cifc)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(cifc)} = \emptyset \quad (4.70)$$

$$M^{Def}_{dr(Co)\&cerc(r)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(r)} = \emptyset \quad (4.71)$$

$$M^{Def}_{dr(Co)\&cerc(p)} = M^{Def}_{D-dr(Co)} \cap M^{Def}_{G-cerc(p)} = \emptyset \quad (4.72)$$

$$M^{Def}_{dr(Citp)\&cerc(m)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(m)} = \{decupare\ /\ perforare\ cu\ ștanțe\} \quad (4.73)$$

$$M^{Def}_{dr(Citp)\&cerc(co)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(co)} = \{ronțăire\} \quad (4.74)$$

$$M^{Def}_{dr(Citp)\&cerc(citp)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.75)$$

$$M^{Def}_{dr(Citp)\&cerc(cifc)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(cifc)} = \{decupare\ /\ perforare\ pe\ mașini\ de\ ronțăit\} \quad (4.76)$$

$$M^{Def}_{dr(Citp)\&cerc(r)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(r)} = \emptyset \quad (4.77)$$

$$M^{Def}_{dr(Citp)\&cerc(p)} = M^{Def}_{D-dr(Citp)} \cap M^{Def}_{G-cerc(p)} = \{decupare\ /\ perforare\ pe\ centre\ de\ prelucrare\ prin\ ștanțare\} \quad (4.78)$$

$$M^{Def}_{dr(Cifc)\&cerc(m)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(m)} = \{profilare\ prin\ procedeu\ Grob; profilare\ prin\ forjare\ radială\} \quad (4.79)$$

$$M^{Def}_{dr(Cifc)\&cerc(co)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(co)} = \emptyset \quad (4.80)$$

$$M^{Def}_{dr(Cifc)\&cerc(citp)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.81)$$

$$M^{Def}_{dr(Cifc)\&cerc(cifc)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(cifc)} = \emptyset \quad (4.82)$$

$$M^{Def}_{dr(Cifc)\&cerc(r)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(r)} = \{danturare\ cu\ procedeu\ Grob\} \quad (4.83)$$

$$M^{Def}_{dr(Cifc)\&cerc(p)} = M^{Def}_{D-dr(Cifc)} \cap M^{Def}_{G-cerc(p)} = \emptyset \quad (4.84)$$

$$M^{Def}_{dr(R)\&cerc(m)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(m)} = \{canelare\ cu\ role\ profilate\} \quad (4.85)$$

$$M^{Def}_{dr(R)\&cerc(co)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(co)} = \emptyset \quad (4.86)$$

$$M^{Def}_{dr(R)\&cerc(citp)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.87)$$

$$M^{Def}_{dr(R)\&cerc(cifc)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(cifc)} = \emptyset \quad (4.88)$$

$$M^{Def}_{dr(R)\&cerc(r)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(r)} = \{danturare\ prin\ rulare\ cu\ bacuri\ sau\ role\} \quad (4.89)$$

$$M^{Def}_{dr(R)\&cerc(p)} = M^{Def}_{D-dr(R)} \cap M^{Def}_{G-cerc(p)} = \emptyset \quad (4.90)$$

$$M^{Def}_{dr(P)\&cerc(m)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(m)} = \emptyset \quad (4.91)$$

$$M^{Def}_{dr(P)\&cerc(co)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(co)} = \emptyset \quad (4.92)$$

$$M^{Def}_{dr(P)\&cerc(citp)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(citp)} = \emptyset \quad (4.93)$$

$$M^{Def}_{dr(P)\&cerc(cifc)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(cifc)} = \emptyset \quad (4.94)$$

$$M^{Def}_{dr(P)\&cerc(r)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(r)} = \emptyset \quad (4.95)$$

$$M^{Def}_{dr(P)\&cerc(p)} = M^{Def}_{D-dr(P)} \cap M^{Def}_{G-cerc(p)} = \emptyset \quad (4.96)$$

Given the large number of plastic deformation processing processes, the sets described by relations (4.61) … (4.96) remain open for further analysis and development. A synthetic representation of the sets described by relations (4.61) … (4.96) is given in Table 4.21.

Table 4.21. Common combinations for generating a surface on plastic deformation, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	●	×	●	●	×	×
	co	×	×	×	×	×	×
	ci_{tp}	×	×	×	×	×	×
	ci_{fc}	×	×	●	×	×	×
	r	×	×	×	◆	●	×
	p	×	×	●	×	×	×

4.2.10. Unconventional machining processes and machine tools for unconventional processes

It is worth mentioning … that machines in the class under consideration generate parts using various processes, by removing material (e.g. electrical or electrochemical erosion), by cutting (e.g. plasma, laser or abrasive jet cutting), by redistributing material (e.g. plastic deformation by explosion or in an electromagnetic field) or by adding material (by plastic injection or by rapid prototyping using 3D printers).

Also by adding material, parts produced by plastic injection molding are obtained.

4.2.9.8. Diversity of directrices and generatrices curves in unconventional processing

In various machining operations using unconventional processes, the guide can be:

- materialized (any plane curve) – in operations such as erosion with a solid electrode, plastic injection, or explosive or field stamping;
- obtained by copying (any plane curve);

- obtained kinematically as a trajectory of a point (straight) – typical case in cutting operations (cutting / drilling) with laser, plasma or abrasive jet;
- obtained kinematically as a envelope of a family of curves (straight);
- obtained kinematically by rolling (any plane curve);
- programmed – for example, when obtaining bodies by 3D printing.

... the sets $\mathcal{M}_{D\text{-}dr(M)}$, $\mathcal{M}_{D\text{-}dr(Co)}$, $\mathcal{M}_{D\text{-}dr(Citp)}$, $\mathcal{M}_{D\text{-}dr(Cifc)}$, $\mathcal{M}_{D\text{-}dr(R)}$ and $\mathcal{M}_{D\text{-}dr(P)}$ which specify the unconventional processing procedures that allow obtaining a surface with straight directrix ... resulting from the six obtaining modes considered (M, Co, Ci_{tp}, Ci_{fc}, R and P) are:

$$M_{D-dr(M)}^{PrN} = \begin{Bmatrix} electroeroziune\ cu\ electrod\ masiv, tăiere\ electroerozivă\ cu\ fir, \\ injecție\ mase\ plastice, ambutisare\ prin\ explozie, \\ ambutisare\ în\ câmp\ electromagnetic \end{Bmatrix} \quad (4.97)$$

$$M_{D-dr(Co)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.98)$$

$$M_{D-dr(Citp)}^{PrN} = \begin{Bmatrix} tăiere\ cu\ laser, tăiere\ cu\ plasmă, tăiere\ cu\ jet\ de\ apă\ abraziv, \\ electroeroziune\ cu\ electrod\ masiv \end{Bmatrix} \quad (4.99)$$

$$M_{D-dr(Cifc)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.100)$$

$$M_{D-dr(R)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.101)$$

$$M_{D-dr(P)}^{PrN} = \begin{Bmatrix} imprimare\ 3D, electroeroziune\ cu\ electrod\ masiv; \\ tăiere\ cu\ jet\ de\ apă\ abraziv \end{Bmatrix} \quad (4.102$$

Table 4.22. Common ways to obtain directrix (D) when unconventional processes

Curve shape	M	Co	Ci_{tp}	Ci_{fc}	R	P
Straight	●	■	●	❖	■	●
Circle	●	■	×	❖	■	●
Another curve	●	■	×	❖	■	●

In turn, the generatrix can be:

- materialized (any plane curve, including a circle);
- obtained by copying (any plane curve, including a circle) the profile of a stencil;
- obtained kinematically as a trajectory of a point (any plane curve) – such as in cutting with a laser, plasma or abrasive water jet;
- obtained as an envelope of a family of curves (any plane curve);
- obtained kinematically by rolling (any plane curve obtained as unfolded, including a circle);
- programmed (any plane curve) – for example in wire, laser, plasma or abrasive water jet cutting, or bodies obtained by 3D printing.

The sets $\mathcal{M}_{G\text{-}cerc(m)}$, $\mathcal{M}_{G\text{-}cerc(co)}$, $\mathcal{M}_{G\text{-}cerc(citp)}$, $\mathcal{M}_{G\text{-}cerc(cifc)}$, $\mathcal{M}_{G\text{-}cerc(r)}$ and $\mathcal{M}_{G\text{-}cerc(p)}$ which specify the processing procedures that allow obtaining a surface with generatrix circle resulting from the six obtaining modes considered (m, co, ci_{tp}, ci_{fc}, r and p) are:

$$M_{G-cerc(m)}^{PrN} = \begin{Bmatrix} electroeroziune\ cu\ electrod\ masiv; injecție\ mase\ plastice; \\ ambutisare\ prin\ explozie; ambutisare\ în\ câmp\ electromagnetic \end{Bmatrix} \quad (4.103)$$

$$M_{G-cerc(co)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.104)$$

$$M_{G-cerc(citp)}^{PrN} = \left\{ \begin{matrix} tăiere\ cu\ laser;\ tăiere\ cu\ plasmă;\ tăiere\ cu\ jet\ de\ apă\ abraziv; \\ tăiere\ electroerozivă\ cu\ fir \end{matrix} \right\} \quad (4.105)$$

$$M_{G-cerc(cifc)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.106)$$

$$M_{G-cerc(r)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.107)$$

$$M_{G-cerc(p)}^{PrN} = \\ = \left\{ \begin{matrix} tăiere\ electroerozivă\ cu\ fir;\ tăiere\ cu\ laser;\ tăiere\ cu\ plasmă; \\ tăiere\ cu\ jet\ de\ apă\ abraziv;\ imprimare\ 3D;\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (4.108)$$

Table 4.23. Common ways to obtain generatrix (G) when unconventional processes

Curve shape	m	co	ci_{tp}	ci_{fc}	r	p
Straight	●	■	●	×	×	●
Circle	●	■	●	×	×	●
Another curve	●	■	●	×	×	●

$$M_{dr(M)\&cerc(m)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(m)}^{PrN} = \\ = \left\{ \begin{matrix} injecție\ mase\ plastice;\ electroeroziune\ cu\ electrod\ masiv; \\ ambutisare\ prin\ explozie;\ ambutisare\ în\ câmp\ electromagnetic \end{matrix} \right\} \quad (4.109)$$

$$M_{dr(M)\&cerc(co)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(co)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.110)$$

$$M_{dr(M)\&cerc(citp)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(citp)}^{PrN} = \{tăiere\ electroerozivă\ cu\ fir\} \quad (4.111)$$

$$M_{dr(M)\&cerc(cifc)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(cifc)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.112)$$

$$M_{dr(M)\&cerc(r)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(r)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.113)$$

$$M_{dr(M)\&cerc(p)}^{PrN} = M_{D-dr(M)}^{PrN} \cap M_{G-cerc(p)}^{PrN} = \\ = \{electroeroziune\ cu\ electrod\ masiv;\ electroeroziune\ cu\ fir\} \quad (4.114)$$

$$M_{dr(Co)\&cerc(m)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(m)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.115)$$

$$M_{dr(Co)\&cerc(co)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(co)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.116)$$

$$M_{dr(Co)\&cerc(citp)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(citp)}^{PrN} = \emptyset \quad (4.117)$$

$$M_{dr(Co)\&cerc(cifc)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(cifc)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.118)$$

$$M_{dr(Co)\&cerc(r)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(r)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.119)$$

$$M_{dr(Co)\&cerc(p)}^{PrN} = M_{D-dr(Co)}^{PrN} \cap M_{G-cerc(p)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.120)$$

$$M_{dr(Citp)\&cerc(m)}^{PrN} = M_{D-dr(Citp)}^{PrN} \cap M_{G-cerc(m)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.121)$$

$$M_{dr(Citp)\&cerc(co)}^{PrN} = M_{D-dr(Citp)}^{PrN} \cap M_{G-cerc(co)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.122)$$

$$M_{dr(Citp)\&cerc(citp)}^{PrN} = M_{D-dr(Citp)}^{PrN} \cap M_{G-cerc(citp)}^{PrN} = \\ = \{tăiere\ cu\ laser;\ tăiere\ cu\ plasmă;\ tăiere\ cu\ jet\ de\ apă\ abraziv\} \quad (4.123)$$

$$M_{dr(Citp)\&cerc(cifc)}^{PrN} = M_{D-dr(Citp)}^{PrN} \cap M_{G-cerc(cifc)}^{PrN} = \\ = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.124)$$

$$M_{dr(Citp)\&cerc(r)}^{PrN} = M_{D-dr(Citp)}^{PrN} \cap M_{G-cerc(r)}^{PrN} = \{electroeroziune\ cu\ electrod\ masiv\} \quad (4.125)$$

$$M^{PrN}_{dr(Citp)\&cerc(p)} = M^{PrN}_{D-dr(Citp)} \cap M^{PrN}_{G-cerc(p)} = \\ = \left\{\begin{matrix} tăiere\ cu\ laser; tăiere\ cu\ plasmă; tăiere\ cu\ jet\ de\ apă\ abraziv; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix}\right\} \tag{4.126}$$

$$M^{PrN}_{dr(Cifc)\&cerc(m)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(m)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.127}$$

$$M^{PrN}_{dr(Cifc)\&cerc(co)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(co)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.128}$$

$$M^{PrN}_{dr(Cifc)\&cerc(citp)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(citp)} = \emptyset \tag{4.129}$$

$$M^{PrN}_{dr(Cifc)\&cerc(cifc)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(cifc)} = \\ = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.130}$$

$$M^{PrN}_{dr(Cifc)\&cerc(r)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(r)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.131}$$

$$M^{PrN}_{dr(Cifc)\&cerc(p)} = M^{PrN}_{D-dr(Cifc)} \cap M^{PrN}_{G-cerc(p)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.132}$$

$$M^{PrN}_{dr(R)\&cerc(m)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(m)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.133}$$

$$M^{PrN}_{dr(R)\&cerc(co)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(co)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.134}$$

$$M^{PrN}_{dr(R)\&cerc(citp)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(citp)} = \emptyset \tag{4.135}$$

$$M^{PrN}_{dr(R)\&cerc(cifc)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(cifc)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.136}$$

$$M^{PrN}_{dr(R)\&cerc(r)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(r)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.137}$$

$$M^{PrN}_{dr(R)\&cerc(p)} = M^{PrN}_{D-dr(R)} \cap M^{PrN}_{G-cerc(p)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.138}$$

$$M^{PrN}_{dr(P)\&cerc(m)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(m)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.139}$$

$$M^{PrN}_{dr(P)\&cerc(co)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(co)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.140}$$

$$M^{PrN}_{dr(P)\&cerc(citp)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(citp)} = \emptyset \tag{4.141}$$

$$M^{PrN}_{dr(P)\&cerc(cifc)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(cifc)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.142}$$

$$M^{PrN}_{dr(P)\&cerc(r)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(r)} = \{electroeroziune\ cu\ electrod\ masiv\} \tag{4.143}$$

$$M^{PrN}_{dr(P)\&cerc(p)} = M^{PrN}_{D-dr(P)} \cap M^{PrN}_{G-cerc(p)} = \\ = \left\{\begin{matrix} imprimare\ 3D; electroeroziune\ cu\ electrod\ masiv; \\ tăiere\ cu\ jet\ de\ apă \end{matrix}\right\} \tag{4.144}$$

Table 4.24. Common combinations for generating a surface on unconventional processes, having directrix straight and generatrix circle

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	●	◆	●	◆	◆	◆
	co	◆	◆	◆	◆	◆	◆
	ci_{tp}	×	×	●	×	×	×
	ci_{fc}	◆	◆	◆	◆	◆	◆
	r	◆	◆	◆	◆	◆	◆
	p	●	◆	●	◆	◆	●

4.3. Conclusions

For any situation, the generation of a surface involves relative movements between the workpiece and the tool used, movements that occur during the actual machining process and involve direct contact between the tool and the workpiece, as well as some auxiliary movements, which are usually performed outside the machining process and without direct contact between the tool and the workpiece.

… any movement of a machine tool must be precisely defined in nature and characteristics and be the result of a final executing element. The theory of typical kinematic chains is a modern development, oriented towards the kinematic synthesis of machine tools, and favors an explicit and logical connection between the theory of surface generation on machine tools and the kinematics of machine tools as a whole.

The study conducted on the current state of knowledge of machine tools focuses on the analysis of machine tools intended for the generation of cylindrical surfaces with straight directrix guides and circle generatrix, taking into account the various known and currently used machining processes in practice. The machining processes by cutting, various plastic deformation machining processes and various unconventional machining processes are analyzed. For each process, the multitude of possibilities for achieving the straight directrix and the circle generatrix are revealed.

... the sets of processes that allow the simultaneous obtaining of the straight directrix and the circle generatrix are explained, taking into account the known ways of generating the two mentioned curves. It is found that for each group of processing processes there are cases that do not allow the creation of a cylindrical surface where the directrix is straight and the generatrix is a circle, because either only the directrix, or only the generatrix, or both simultaneously cannot be obtained in the considered way.

At the overall level, without differentiation by processing groups, three empty sets are identified: $M_{dr(M)\&cerc(citp)}$, $M_{dr(Cifc)\&cerc(citp)}$ and $M_{dr(R)\&cerc(citp)}$. Coincidentally, all of them have in common the set of procedures for kinematic obtaining of the circle generatrix as a trajectory of a point.

Chapter V - Innovative theoretical contributions regarding the kinematics of machine tools intended for the processing of cylindrical surfaces. Kinematic synthesis of machine tools

Kinematic synthesis is a decisive stage in the process of designing a new machine tool. The design theme imposes the nature of the surface or surfaces that can be generated by the new machine, as well as various specific technical and economic conditions. The nature of the surface required to be created is equivalent to a certain combination between the directrix curve and the generatrix curve that describe the respective surface. The analysis of known processing procedures provides relevant information about the possibilities of generating the directrix and generatrix curves and implicitly indicates which processing procedures can be adopted to satisfy the project theme. At the limit, the analysis may indicate as possible, based on the current state of knowledge, a single processing procedure or even not indicate any possibility of solving the imposed theme. In such cases, but not only, an explicit innovation-invention effort is necessary.

The kinematic synthesis process starts with the design of machining schemes in accordance with the various possible machining processes and the adoption of the most efficient one. It continues with the logical design of the kinematic scheme using the theory of type kinematic chains, a theory that explicitly links the theory of surface generation and the general theory of kinematic chains. The initial kinematic scheme, without links between the kinematic chains, is developed successively until the detailed kinematic scheme is obtained, indicating the necessary or useful links between the kinematic chains and clearly indicating the component mechanisms in each kinematic chain, including their sequence.

5.1. Kinematic synthesis of machine tools intended for processing cylindrical surfaces with straight directrix and circle generatrix

Specializing the general case... table 5.1 is obtained.

Table 5.1. Possible combinations for generating a cylindrical surface, depending on the generation modes of the straight directrix and circle generatrix curves

		Directrix straight					
		M	Co	Ci_{tp}	Ci_{fc}	R	P
Generatrix circle	m	M&m	Co&m	Ci_{tp}&m	Ci_{fc}&m	R&m	P&m
	co	M&co	Co&co	Ci_{tp}&co	Ci_{fc}&co	R&co	P&co
	ci_{tp}	M&ci_{tp}	Co&ci_{tp}	Ci_{tp}&ci_{tp}	Ci_{fc}&ci_{tp}	R&ci_{tp}	P&ci_{tp}
	ci_{fc}	M&ci_{fc}	Co&ci_{fc}	Ci_{tp}&ci_{fc}	Ci_{fc}&ci_{fc}	R&ci_{fc}	P&ci_{fc}
	r	M&r	Co&r	Ci_{tp}&r	Ci_{fc}&r	R&r	P&r
	p	M&p	Co&p	Ci_{tp}&p	Ci_{fc}&p	R&p	P&p

5.1.1. Cases with materialized straight directrix

Regardless of the method of obtaining the directrix curve, at least one movement, the main one, is required to translate it onto the surface of the machined part. Often, one or more additional movements, the generation feed, are also required. The main movement, as well as the generating feed movements (if any) that participate in the description of the directrix curve, also express the need for a relative movement between the tool used and the workpiece. One or more auxiliary movements are also necessary for relative positioning between the tool and the workpiece.

A1. Generation with straight directrix and circle generatrix, both materialized (M&m case)

For the considered case, the set of possible processing procedures resulting from the synthesis of known cases is highlighted by the union of the sets given by relations (4.13), (4.61) and (4.109), that is

$$M_{dr(M)\&cerc(m)} = \\ = M^{Aşc}_{dr(M)\&cerc(m)} \bigcup M^{Def}_{dr(M)\&cerc(m)} \bigcup M^{PrN}_{dr(M)\&cerc(m)} = \\ = \left\{ \begin{matrix} refulare, ştampare, reliefare \dots, injecţie\ mase\ plastice, \\ electroeroziune\ cu\ electrod\ masiv, ambutisare\ prin\ explozie, \\ ambutisare\ în\ câmp\ electromagnetic \end{matrix} \right\} \tag{5.1}$$

Figure 5.1 shows a machining scheme suitable for the M&m case, which can be achieved both by plastic deformation and by solid electrode electric discharge machining.

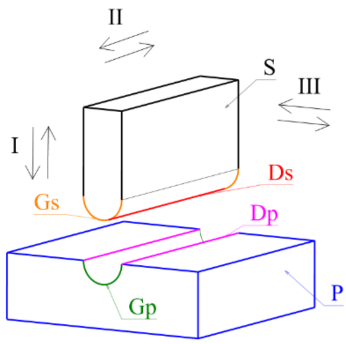


Fig. 5.1. Processing scheme corresponding to the M&m case

A2. Generation with materialized straight directrix and circle generatrix obtained by copying (M&co case)

The set of possible machining processes resulting from the synthesis of known cases is reduced to one, solid electrode electroerosion, the union of the sets described by relations (4.14), (4.62) and (4.110) expressed by relation (5.2) explicitly reflecting this fact:

$$M_{dr(M)\&cerc(co)} = \\ = M^{Aşc}_{dr(M)\&cerc(co)} \bigcup M^{Def}_{dr(M)\&cerc(co)} \bigcup M^{PrN}_{dr(M)\&cerc(co)} = \\ = \{electroeroziune\ cu\ electrod\ masiv\} \tag{5.2}$$

A3. Generation with materialized straight directrix and circle generatrix obtained kinematically as a trajectory of a point (M&ci$_{tp}$ case)

According to the current state of the art, the set of possible processing procedures for this case is given by the union of the sets expressed by relations (4.15), (4.63) and (4.111), i.e.

$$M_{dr(M)\&cerc(citp)} = \\ = M^{Aşc}_{dr(M)\&cerc(citp)} \bigcup M^{Def}_{dr(M)\&cerc(citp)} \bigcup M^{PrN}_{dr(M)\&cerc(citp)} = \\ = \{tăiere\ electroerozivă\ cu\ fir\} \tag{5.3}$$

5.1.2. Cases with a straight directrix obtained by copying

In all cases where the directrix is obtained by copying, the presence of a template that materializes this curve is necessary and, obviously, a kinematic copying chain that allows its transposition onto the piece being processed.

B1. Generation with straight directrix obtained by copying and materialized circle generatrix (Co&m case)

The set of possible processing procedures for this case is given by the union of the sets expressed by relations (4.19), (4.67) and (4.115), i.e.

$$M_{dr(Co)\&cerc(m)} = \\ = M^{Aşc}_{dr(Co)\&cerc(m)} \bigcup M^{Def}_{dr(Co)\&cerc(m)} \bigcup M^{PrN}_{dr(Co)\&cerc(m)} = \\ = \left\{ \begin{matrix} strunjire; frezare; rectificare;\ rabotare;\ mortezare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \tag{5.7}$$

The case addressed is exemplified in figure 5.13 by a solid electrode electroerosion machining scheme. A milling machining scheme (with a spherical milling tool), figure 5.15, or one by planing with a profiled tool would be very similar.

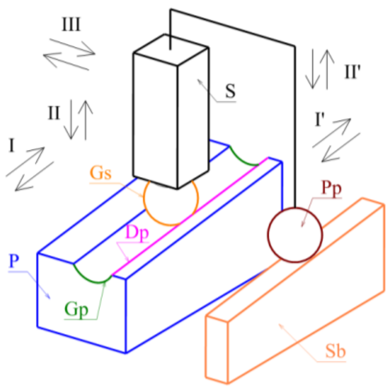


Fig. 5.13. Solid electrode erosion machining scheme corresponding to the Co&m case[1]

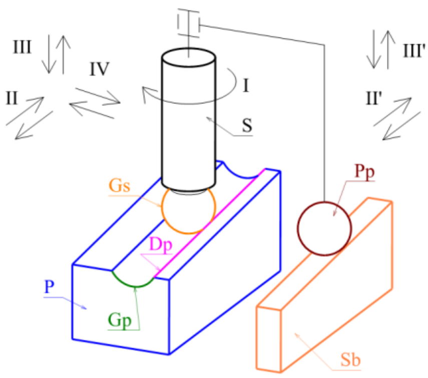


Fig. 5.15. Milling processing scheme, corresponding to the Co&m case

B2. Generation with straight directrix and circle generatrix, both obtained by copying (Co&co case)

The set of possible processing procedures for this case is given by the union of the sets expressed by

[1] **Puriciuc M.V.**: *Kinematic Structures for Surface Processing with Straight-Line Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 23, is. 1(66), pp. 4-12, Brașov, 2022, https://doi.org/10.31926/RECENT.2022.66.004

relations (4.20), (4.68) and (4.116), i.e.

$$M_{dr(Co)\&cerc(co)} = \\ = M^{Aşc}_{dr(Co)\&cerc(co)} \bigcup M^{Def}_{dr(Co)\&cerc(co)} \bigcup M^{PrN}_{dr(Co)\&cerc(co)} = \\ = \left\{ \begin{matrix} strunjire; frezare; rectificare; \ rabotare; \ mortezare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \tag{5.8}$$

The Co&co case is a classic one represented by the milling of complex spatial surfaces where both the directrix and the generatrix are arbitrary kinematically obtained (i.e. without materialized directrix and generatrix).

B3. Generation with straight directrix obtained by copying and circle generatrix obtained kinematically as a trajectory of a point (Co&ci$_{tp}$ case)

The set of possible processing procedures for this case is given by the union of the sets expressed by relations (4.21), (4.69) and (4.117), i.e.

$$M_{dr(Co)\&cerc(citp)} = \\ = M^{Aşc}_{dr(Co)\&cerc(citp)} \bigcup M^{Def}_{dr(Co)\&cerc(citp)} \bigcup M^{PrN}_{dr(Co)\&cerc(citp)} = \\ = \{strunjire\} \tag{5.9}$$

The analysis of the current state of knowledge and practice in the field indicates a single machining process compatible with the Co&ci$_{tp}$ case, turning. The case is suggestively represented by the machining scheme in figure 5.23.

A principle kinematic diagram according to the processing diagram in figure 5.23 is presented in figure 5.24.

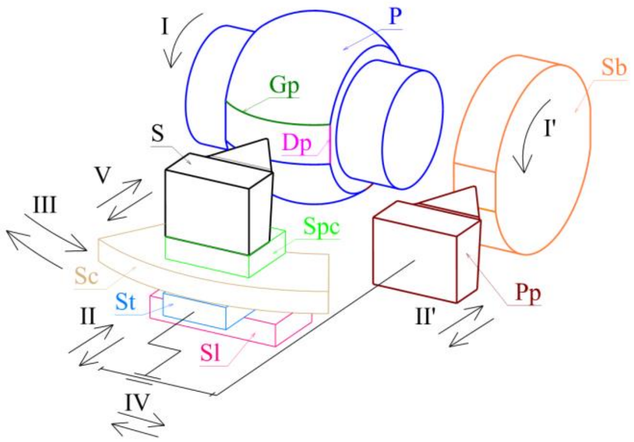


Fig. 5.23. Turning processing scheme appropriate to the Co&ci$_{tp}$ case[1]

[1] **Puriciuc M.V.**: *Kinematic Structures for Surface Processing with Straight-Line Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 23, is. 1(66), pp. 4-12, Brașov, 2022, https://doi.org/10.31926/RECENT.2022.66.004

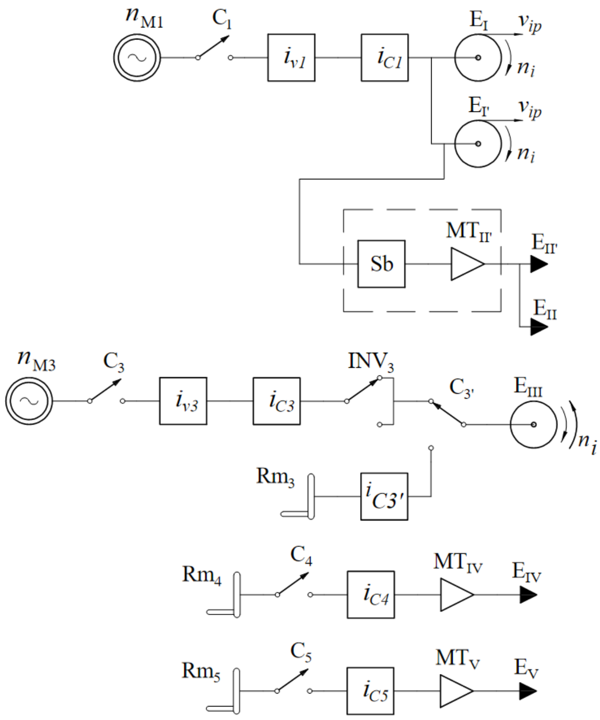


Fig. 5.24. Principle kinematic diagram with connections corresponding to the Co&ci_{tp} case

B4. Generation with straight directrix obtained by copying and circle generatrix obtained kinematically as a envelope of a family of curves (Co&ci_{fc} case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.22), (4.70) and (4.118), i.e.

$$\begin{aligned} &M_{dr(Co)\&cerc(cifc)} = \\ &= M^{Aşc}_{dr(Co)\&cerc(cifc)} \bigcup M^{Def}_{dr(Co)\&cerc(cifc)} \bigcup M^{PrN}_{dr(Co)\&cerc(cifc)} = \\ &= \left\{ \begin{matrix} strunjire; frezare; rectificare;\ rabotare;\ mortezare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \end{aligned} \tag{5.10}$$

B5. Generation with straight directrix obtained by copying and circle generatrix obtained by rolling (Co&r case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.23), (4.71) and (4.119), i.e.

$$\begin{aligned} &M_{dr(Co)\&cerc(r)} = \\ &= M^{Aşc}_{dr(Co)\&cerc(r)} \bigcup M^{Def}_{dr(Co)\&cerc(r)} \bigcup M^{PrN}_{dr(Co)\&cerc(r)} = \\ &= \left\{ \begin{matrix} strunjire; frezare; rectificare;\ rabotare;\ mortezare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \end{aligned} \tag{5.11}$$

B6. Generation with straight directrix obtained by copying and programmed circle generatrix (Co&p case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.24), (4.72) and (4.120), i.e.

$$M_{dr(Co)\&cerc(p)} = = M^{Aşc}_{dr(Co)\&cerc(p)} \bigcup M^{Def}_{dr(Co)\&cerc(p)} \bigcup M^{PrN}_{dr(Co)\&cerc(p)} = = \left\{ \begin{matrix} strunjire; frezare; rectificare;\ rabotare;\ mortezare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.12)$$

Any machining pattern with circle generatrix obtained kinematically can be transformed into a programmed machining pattern with circle generatrix.

5.1.3. Cases with a straight directrix obtained kinematically as a trajectory of a point

In all cases when the directrix is straight, obtained kinematically as the trajectory of a point, the main movement must be of continuous translation at least for that part of the trajectory that corresponds to the transposition of the directrix Dp onto the part.

C1. Generation with straight directrix obtained kinematically as a trajectory of a point and materialized circle generatrix (Ci_{tp}&m case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.25), (4.73) and (4.121), i.e.

$$M_{dr(Citp)\&cerc(m)} = = M^{Aşc}_{dr(Citp)\&cerc(m)} \bigcup M^{Def}_{dr(Citp)\&cerc(m)} \bigcup M^{PrN}_{dr(Citp)\&cerc(m)} = = \left\{ \begin{matrix} strunjire; rabotare;\ mortezare; broşare; decupare\ /\ perforare \\ cu\ ştanţe;\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.13)$$

The broaching and punching processes can be considered representative for the Ci_{tp}&m case.

C2. Generation with straight directrix obtained kinematically as a trajectory of a point and circle generatrix obtained by copying (Ci_{tp}&co case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.26), (4.74) and (4.122), i.e.[1]

$$M_{dr(Citp)\&cerc(co)} = = M^{Aşc}_{dr(Citp)\&cerc(co)} \bigcup M^{Def}_{dr(Citp)\&cerc(co)} \bigcup M^{PrN}_{dr(Citp)\&cerc(co)} = = \left\{ \begin{matrix} strunjire; rabotare;\ mortezare; broşare; ronţăire \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.14)$$

This case can be exemplified by ... a process of processing a sheet by gnawing.

C3. Generation with straight directrix and circle generatrix, both obtained kinematically as trajectories of a point (Ci_{tp}&ci_{tp} case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.27), (4.75) and (4.123), i.e.

$$M_{dr(Citp)\&cerc(citp)} = = M^{Aşc}_{dr(Citp)\&cerc(citp)} \bigcup M^{Def}_{dr(Citp)\&cerc(citp)} \bigcup M^{PrN}_{dr(Citp)\&cerc(citp)} = = \left\{ \begin{matrix} strunjire;\ tăiere\ cu\ fierăstrău;\ \ tăiere\ cu\ laser; \\ tăiere\ cu\ plasmă; tăiere\ cu\ jet\ de\ apă\ abraziv \end{matrix} \right\} \quad (5.15)$$

[1] **Puriciuc M.V.** (2025): *Kinematic Requirements for Machining Cylindrical Surfaces Characterized by Straight Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 26, is. 1(75), pp. 37-46, https://doi.org/10.31926/RECENT.2025.75.037

The case addressed is exemplified by a chainsaw processing scheme, figure 5.35, original, unidentified in the current state of knowledge and practice of surface generation[1].

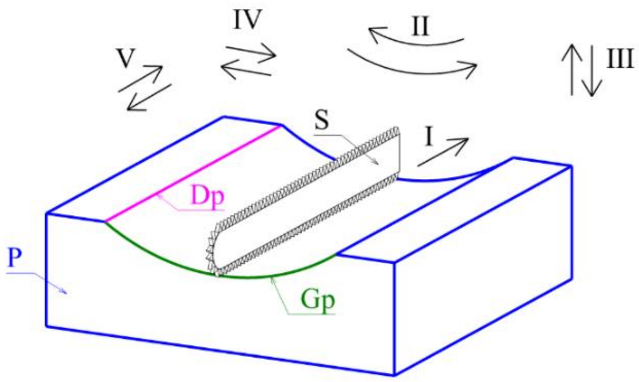


Fig. 5.35. Chainsaw cutting processing scheme, corresponding to the $Ci_{tp}\&ci_{tp}$ case

The main movement I is of guided translation of the chain teeth, obtained by transforming the rotational movement of the drive wheel of the wheel-chain mechanism. In this way, the straight directrix curve Dp is obtained in a kinematic way as a trajectory of a point. The movement II is of continuous circular advance and determines the obtaining of the generatrix Gp also kinematically as a trajectory of a point. Movements III, IV and V are auxiliary for relative positioning of the tool - workpiece, including for adjusting the size of the radius of the generatrix Gp and the position of the axis of rotation of movement II relative to the workpiece. Movement III also has the role of a penetration feed movement, necessary for removing a new layer of material.

A principle kinematic diagram without links suitable for the described $Ci_{tp}\&ci_{tp}$ processing case is presented in figure 5.36.

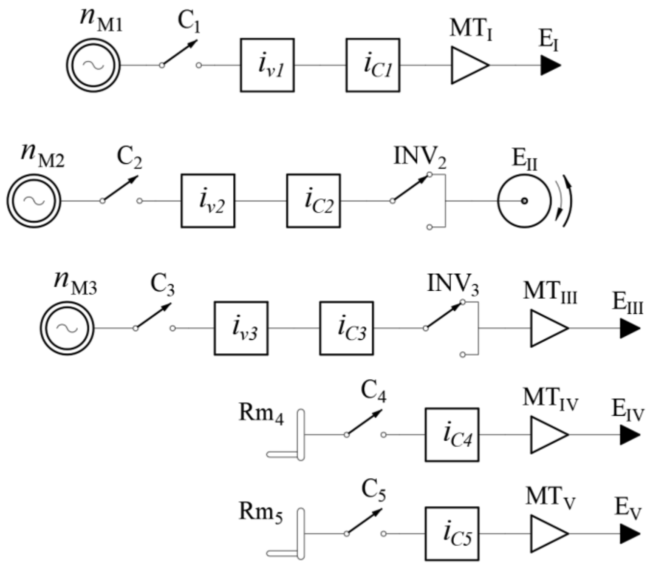


Fig. 5.36. Principle kinematic diagram without connections corresponding to the $Ci_{tp}\&ci_{tp}$ case

C4. <u>Generation with straight directrix obtained kinematically as a trajectory of a point and circle generatrix obtained kinematically as a envelope of a family of curves ($Ci_{tp}\&ci_{fc}$ case)</u>

[1] **Puriciuc M.** (2025): *Kinematic Requirements for Machining Cylindrical Surfaces Characterized by Straight Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 26, is. 1(75), pp. 37-46, https://doi.org/10.31926/RECENT.2025.75.037

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.28), (4.76) and (4.124), i.e.

$$M_{dr(Citp)\&cerc(cifc)} = \\ = M^{Aşc}_{dr(Citp)\&cerc(cifc)} \bigcup M^{Def}_{dr(Citp)\&cerc(cifc)} \bigcup M^{PrN}_{dr(Citp)\&cerc(cifc)} = \\ = \left\{ \begin{matrix} strunjire;\ rabotare;\ mortezare;\ broşare, tăiere\ cu\ fierăstrău; \\ decupare\ /\ perforare\ pe\ maşini\ de\ ronţăit; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.16)$$

The present case is exemplified by a slotting processing scheme, figure 5.37, sometimes encountered in industrial practice[1].

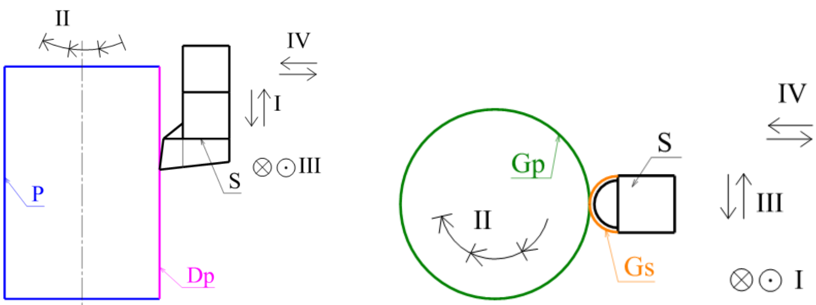


Fig. 5.37. Slotting processing scheme corresponding to the $Ci_{tp}\&ci_{fc}$ case

Obviously, the tool generatrix does not necessarily have to be an arc, as shown in figure 5.37. From a cost perspective, the tool generatrix Gs is preferable to be straight, which determines the generation of the part profile Gp by tangents. In general, Gs can be any convex curve.

C5. Generation with straight directrix obtained kinematically as a trajectory of a point and circle generatrix obtained by rolling ($Ci_{tp}\&r$ case)

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.29), (4.77) and (4.125), i.e.

$$M_{dr(Citp)\&cerc(r)} = \\ = M^{Aşc}_{dr(Citp)\&cerc(r)} \bigcup M^{Def}_{dr(Citp)\&cerc(r)} \bigcup M^{PrN}_{dr(Citp)\&cerc(r)} = \\ = \left\{ \begin{matrix} strunjire; rabotare;\ mortezare; broşare; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.17)$$

The $Ci_{tp}\&r$ case is well-known and relatively common in industrial practice, a relevant example being the machining of straight cylindrical teeth with arc generatrix or chain wheels with a slotting tool-wheel. A schematic representation of the machining process and an image of the tool-part assembly are presented in figure 5.40[2].

The diagram has all the characteristics corresponding to a slotting machine with a cylindrical toothed tool-wheel, such as the MD 250 machine. It does not represent a "technological" movement, of discrete translation and small amplitude, of approach-removal between the tool and the part in order to avoid friction between the tool and the part during the tool idle time.

[1] **Puriciuc M.** (2025): *Kinematic Requirements for Machining Cylindrical Surfaces Characterized by Straight Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 26, is. 1(75), pp. 37-46, https://doi.org/10.31926/RECENT.2025.75.037
[2] idem

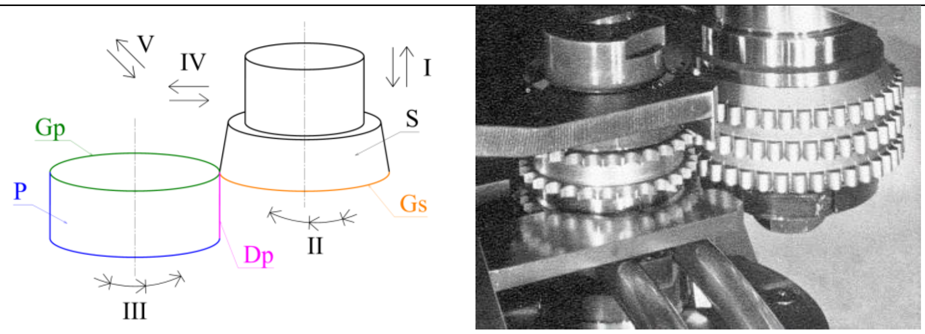


Fig. 5.40. Processing scheme corresponding to the Ci_{tp}&r case and practical example

C6. <u>Generation with straight directrix obtained kinematically as a trajectory of a point and programmed circle generatrix (Ci_{tp}&p case)</u>

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.30), (4.78) and (4.126), i.e.[1]

$$M_{dr(Citp)\&cerc(p)} = \\ = M^{Aşc}_{dr(Citp)\&cerc(p)} \bigcup M^{Def}_{dr(Citp)\&cerc(p)} \bigcup M^{PrN}_{dr(Citp)\&cerc(p)} = \\ = \begin{Bmatrix} strunjire; rabotare;\ mortezare; broșare;\ \ tăiere\ cu\ fierăstrău; \\ decupare\ /\ perforare\ pe\ centre\ de\ prelucrare\ prin\ ștanțare; \\ tăiere\ cu\ laser; tăiere\ cu\ plasmă; tăiere\ cu\ jet\ de\ apă\ abraziv; \\ electroeroziune\ cu\ electrod\ masiv \end{Bmatrix} \tag{5.18}$$

5.1.4. Cases with a straight directrix obtained kinematically as a envelope of a family of curves

It is specified that most often the kinematically obtained guide curve as a winding corresponds to milling processing, rarely otherwise, review relations (4.4), (4.52) and (4.100).

D1. <u>Generation with straight directrix obtained kinematically as a envelope of a family of curves and materialized circle generatrix (Ci_{fc}&m case)</u>

The set of processing procedures identified at the current stage as possible for this case is given by the union of the sets expressed by relations (4.31), (4.79) and (4.127), i.e.

$$M_{dr(Cifc)\&cerc(m)} = \\ = M^{Aşc}_{dr(Cifc)\&cerc(m)} \bigcup M^{Def}_{dr(Cifc)\&cerc(m)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(m)} = \\ = \begin{Bmatrix} frezare; rectificare; broșare; profilare\ prin\ procedeu\ Grob; \\ profilare\ prin\ forjare\ radială; \\ electroeroziune\ cu\ electrod\ masiv \end{Bmatrix} \tag{5.19}$$

The Ci_{fc}&m case is exemplified by the processing scheme ... of milling a rectilinear channel (oriented in the longitudinal direction) with a profile (generatrix) in a circular arc.

D2. <u>Generation with straight directrix obtained kinematically as a envelope of a family of curves and circle generatrix obtained by copying (Ci_{fc}&co case)</u>

[1] **Puriciuc M.** (2025): *Kinematic Requirements for Machining Cylindrical Surfaces Characterized by Straight Directrix and Circle Generatrix.* **RECENT**, eISSN 2065-4529, Vol. 26, is. 1(75), pp. 37-46, https://doi.org/10.31926/RECENT.2025.75.037

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.32), (4.80) and (4.128), i.e.

$$M_{dr(Cifc)\&cerc(m)} = \\ = M^{Aşc}_{dr(Cifc)\&cerc(m)} \bigcup M^{Def}_{dr(Cifc)\&cerc(m)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(m)} = \\ = \{frezare; rectificare;\ electroeroziune\ cu\ electrod\ masiv\} \tag{5.20}$$

D3. <u>Generation with straight directrix obtained kinematically as a envelope of a family of curves and circle generatrix obtained kinematically as a trajectory of a point (Ci_{fc}&ci_{tp} case)</u>

Relations (4.33), (4.81) and (4.129) indicate that none of the processing procedures known and applied at the current stage corresponds to the Ci_{fc}&ci_{tp} case, i.e.

$$M_{dr(Cifc)\&cerc(citp)} = \\ = M^{Aşc}_{dr(Cifc)\&cerc(citp)} \bigcup M^{Def}_{dr(Cifc)\&cerc(citp)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(citp)} = \emptyset \tag{5.21}$$

This result ... urges the researcher to seek and/or design new processing schemes or even, why not, new processing procedures. It is in fact an invitation to innovation and invention.

D4. <u>Generation with straight directrix and circle generatrix, both obtained kinematically as envelopes of families of curves (Ci_{fc}&ci_{fc} case)</u>

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.34), (4.82) and (4.130), i.e.

$$M_{dr(Cifc)\&cerc(cifc)} = \\ = M^{Aşc}_{dr(Cifc)\&cerc(cifc)} \bigcup M^{Def}_{dr(Cifc)\&cerc(cifc)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(cifc)} = \\ = \{frezare; rectificare;\ electroeroziune\ cu\ electrod\ masiv\} \tag{5.22}$$

An example of a processing scheme that corresponds to the analyzed case is presented in figure 5.48.

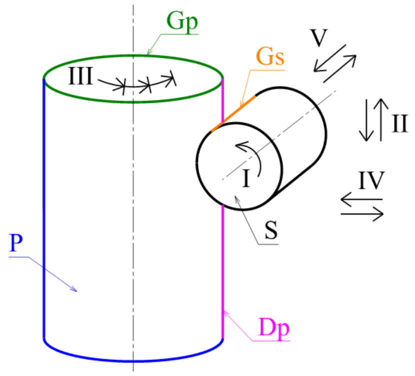


Fig. 5.48. Processing scheme corresponding to the Ci_{fc}&ci_{fc} case

Tool S is a cylindrical milling cutter with straight materialized generatrix Gs. The tool is placed tangentially to the workpiece surface and executes the main rotational movement I. To obtain the directrix Dp, movement II, the vertical generating feed, is also needed, executed either by tool S or by workpiece P. The directrix Dp results as the envelope of a family of orthocycloid arcs. Obviously, at each extremity of movement II, the piece P performs a discrete rotation movement III, of small amplitude, necessary in the present case to obtain the generatrix curve Gp. This is obtained as the envelope of a family of curves, as the envelope of a family of tangents (generatrix Gs successively repositioned with respect to the piece P) to the circle Gp.

Movements IV and V are auxiliary, for relative positioning between the part and the tool. Movement II also performs the same function when needed, but exclusively outside the machining process.

D5. Generation with straight directrix obtained kinematically as a envelope of a family of curves and circle generatrix obtained by rolling (Ci_{fc}&r case)

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.35), (4.83) and (4.131), i.e.

$$M_{dr(Cifc)\&cerc(r)} = \\ = M^{Așc}_{dr(Cifc)\&cerc(r)} \bigcup M^{Def}_{dr(Cifc)\&cerc(r)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(r)} = \\ = \left\{ \begin{matrix} frezare; rectificare; broșare;\ danturare\ cu\ procedeu\ Grob; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.23)$$

A good example of a machining scheme for the analyzed case is the one that corresponds to the processing by worm milling of straight Novikov teeth.

D6. Generation with straight directrix obtained kinematically as a envelope of a family of curves and programmed circle generatrix (Ci_{fc}&p case)

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.36), (4.84) and (4.132), i.e.

$$M_{dr(Cifc)\&cerc(p)} = \\ = M^{Așc}_{dr(Cifc)\&cerc(p)} \bigcup M^{Def}_{dr(Cifc)\&cerc(p)} \bigcup M^{PrN}_{dr(Cifc)\&cerc(p)} = \\ = \{frezare; rectificare; electroeroziune\ cu\ electrod\ masiv\} \quad (5.24)$$

All machining schemes with a straight directrix obtained kinematically as a envelope of a family of curves and kinematically realized circle generatrix can be converted into machining schemes with a programmed circle generatrix.

5.1.5. Cases with straight directrix obtained by rolling

E1. Generation with straight directrix obtained by rolling and materialized circle generatrix (R&m case)

The set of processing procedures identified at the current stage as possible to obtain surfaces characterized by straight directrix obtained by rolling and materialized circle generatrix results as a union of the sets expressed by relations (4.37), (4.85) and (4.133), that is

$$M_{dr(R)\&cerc(m)} = \\ = M^{Așc}_{dr(R)\&cerc(m)} \bigcup M^{Def}_{dr(R)\&cerc(m)} \bigcup M^{PrN}_{dr(R)\&cerc(m)} = \\ = \left\{ \begin{matrix} frezare; rectificare; canelare\ cu\ role\ profilate; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.25)$$

The case addressed is exemplified in figure 5.54 by a special machining scheme, original concept, of electroerosion with massive electrode. The tool S simultaneously executes the main movements I, of rotation, and II, of translation in the longitudinal direction and in the horizontal plane. Between the two movements there is imperatively a rigid kinematic connection specific to rolling kinematic chains. As a result of movements I and II, the tool's Ds directrix describes the part's Dp directrix as an unfolding of the Ds directrix. For the Dp directrix to be inclined to the direction of movement II, the Ds directrix must be an Archimedean spiral.

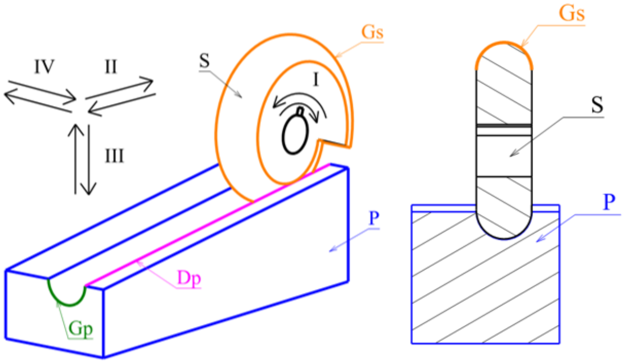


Fig. 5.54. Processing scheme corresponding to the R&m case

Note. It is equally possible to consider translational movement II as main movement I, and tool rotational movement I as "circular feed" movement II.

The generatrix Gp being materialized is obtained as a direct transposition onto the part of the generatrix Gs of the tool, without the need for any specific dedicated movement.

Movements III (vertical feed) and IV (transverse feed) are auxiliary movements. Movement II, as well as the tool rotation movement I, have a similar role outside the machining process, and the angular orientation of the tool relative to the workpiece at the start of the work process is not indifferent.

A very suggestive example of a practical R&m case is shown in figure 5.55: the generation of grooves by longitudinal rolling using profiled disc rollers as tools. The straight directrix is obtained by longitudinal rolling, and the generatrix is materialized as the generator of the tool.

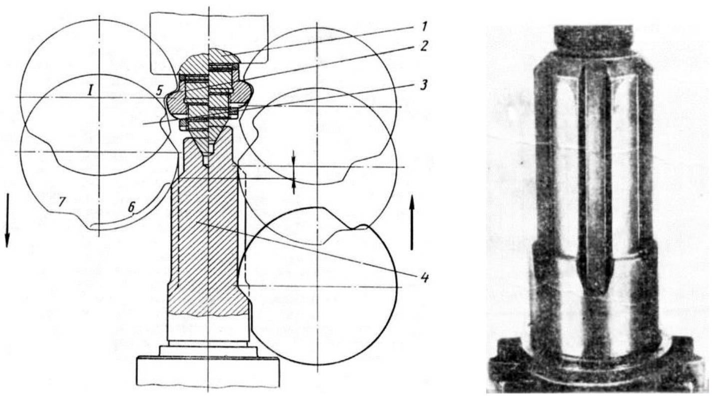


Fig. 5.55. Work scheme and example of a part with grooves obtained by longitudinal rolling[1]

E2. <u>Generation with straight directrix obtained by rolling and circle generatrix obtained by copying (R&co case)</u>

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.38), (4.86) and (4.134), i.e.

[1] Esterzon M.A., Strunin B.I.: *Особенности накатывания шлицев, оканчивающиеся на ступени вала большого диаметра* (*Caracteristici ale canelurilor de rulare care se termină pe o treaptă de arbore cu diametru mare*). Stanki i instrument, nr. 7, pp. 6-8, 1970

$$M_{dr(R)\&cerc(co)} = \\ = M_{dr(R)\&cerc(co)}^{Aşc} \bigcup M_{dr(R)\&cerc(co)}^{Def} \bigcup M_{dr(R)\&cerc(co)}^{PrN} = \\ = \{frezare; rectificare; electroeroziune\ cu\ electrod\ masiv\} \quad (5.26)$$

E3. Generation with straight directrix obtained by rolling and circle generatrix obtained kinematically as a trajectory of a point (R&ci$_{tp}$ case)

Relations (4.39), (4.87) and (4.135) indicate that none of the processing procedures known and applied at the current stage corresponds to the Ci$_{fc}$&ci$_{tp}$ case, i.e.

$$M_{dr(R)\&cerc(citp)} = M_{dr(R)\&cerc(citp)}^{Aşc} \bigcup M_{dr(R)\&cerc(citp)}^{Def} \bigcup M_{dr(R)\&cerc(citp)}^{PrN} = \emptyset \quad (5.27)$$

It is the second case of the 36 theoretically possible ways to obtain surfaces with straight directrix and circle generatrix that does not indicate any way to solve.

E4. Generation with straight directrix obtained by rolling and circle generatrix obtained kinematically as a envelope of a family of curves (R&ci$_{fc}$ case)

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.40), (4.88) and (4.136), i.e.

$$M_{dr(R)\&cerc(cifc)} = \\ = M_{dr(R)\&cerc(cifc)}^{Aşc} \bigcup M_{dr(R)\&cerc(cifc)}^{Def} \bigcup M_{dr(R)\&cerc(cifc)}^{PrN} = \\ = \{frezare; rectificare; electroeroziune\ cu\ electrod\ masiv\} \quad (5.28)$$

This case is exemplified by an original machining scheme by milling with a profiled cylindrical tool, with generatrix Gs in a circular arc, figure 5.58.

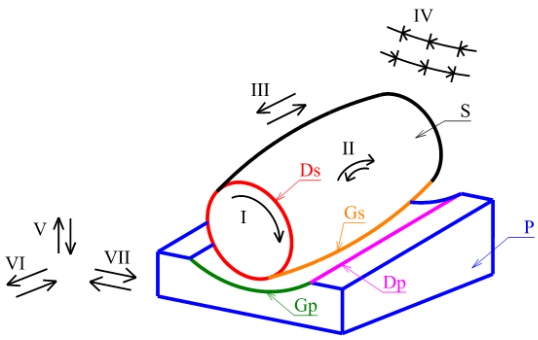


Fig. 5.58. Processing scheme appropriate to the R&ci$_{fc}$ case

E5. Generation with straight directrix and circle generatrix, both obtained by rolling (R&r case)

The set of processing procedures identified at the current stage as possible for this case results as a union of the sets expressed by relations (4.41), (4.89) and (4.137), i.e.

$$M_{dr(R)\&cerc(r)} = \\ = M_{dr(R)\&cerc(r)}^{Aşc} \bigcup M_{dr(R)\&cerc(r)}^{Def} \bigcup M_{dr(R)\&cerc(r)}^{PrN} = \\ = \left\{ \begin{matrix} frezare; rectificare; danturare\ prin\ rulare\ cu\ bacuri\ sau\ role; \\ electroeroziune\ cu\ electrod\ masiv \end{matrix} \right\} \quad (5.29)$$

E6. Generation with straight directrix obtained by rolling and programmed circle generatrix (R&p case)

The set of processing procedures identified at the current stage as possible for the R&p case results as a union of the sets expressed by relations (4.42), (4.90) and (4.138), i.e.

$$\begin{aligned} & M_{dr(R)\&cerc(r)} = \\ & = M_{dr(R)\&cerc(r)}^{Așc} \bigcup M_{dr(R)\&cerc(r)}^{Def} \bigcup M_{dr(R)\&cerc(r)}^{PrN} = \\ & = \{frezare; rectificare; electroeroziune\ cu\ electrod\ masiv\} \end{aligned} \quad (5.30)$$

This case can result from the conversion of any of the machining schemes with straight directrix obtained by rolling and circle generatrix obtained kinematically.

5.1.6. Cases with programmed straight directrix

Any of the machining schemes with straight directrix, whether materialized or kinematically obtained, can be transformed into a programmed straight directrix machining scheme. The examples given below are relevant in this regard.

F3. Generation with programmed straight directrix and circle generatrix obtained kinematically as a trajectory of a point (P&ci$_{tp}$ case)

From the analysis of the current state, it results that for the P&ci$_{tp}$ case the processing procedures expressed as a union of the sets given by the relations (4.45), (4.93) and (4.141) are possible, i.e.

$$\begin{aligned} & M_{dr(P)\&cerc(citp)} = \\ & = M_{dr(P)\&cerc(citp)}^{Așc} \bigcup M_{dr(P)\&cerc(citp)}^{Def} \bigcup M_{dr(P)\&cerc(citp)}^{PrN} = \\ & = \{strunjire\} \end{aligned} \quad (5.33)$$

The analysis of the current state indicates that turning is the only usable machining process for the P&ci$_{tp}$ case. Figure 5.68 shows a scheme that satisfies the generation requirements imposed by this case. It is in fact a conversion of the Co&ci$_{tp}$ case, in which copying has been removed and replaced with numerically controlled movements to obtain the Dp directrix curve.

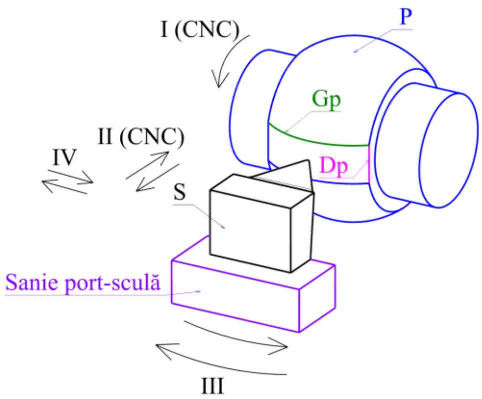


Fig. 5.68. Processing scheme appropriate to the P&ci$_{tp}$ case

The movements I, main, of rotation, and II, of radial feed, of generation, both numerically controlled, contribute to obtaining the directrix curve Dp. The movement III, of circular feed, is the movement that ensures obtaining the generatrix curve Gp. The movement IV is an auxiliary movement, of translation of positioning. Outside the machining process, the movement II also fulfills the role of auxiliary movement, with the role of positioning in the radial direction. A kinematic scheme of principle appropriate to the case is presented in figure 5.69.

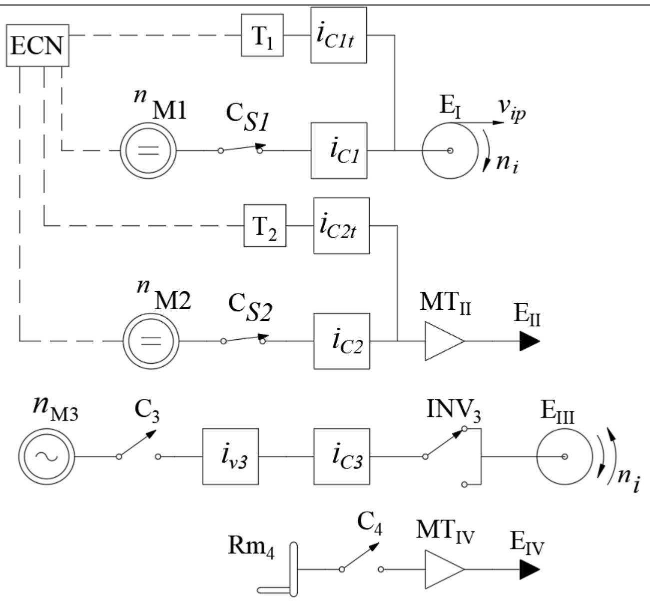


Fig. 5.69. Principle kinematic diagram, corresponding to the P&ci$_{tp}$ case

F6. Generation with straight directrix and circle generatrix, both programmed (P&p case)

The P&p case is a practically general purpose one, in the sense that it is suitable for describing any type of directrix and generatrix. Machining by end milling with a (semi)spherical head using CNC machine tools and generating bodies by 3D printing are typical examples of the P&p case, including the particular case of surfaces characterized by straight directrix and circle generatrix.

The set of processing procedures identified at the current stage as possible for the P&p case (with straight directrix and circle generatrix) results as a union of the sets expressed by relations (4.48), (4.96) and (4.144), i.e.

$$M_{dr(P)\&cerc(p)} = \\ = M^{Aşc}_{dr(P)\&cerc(p)} \bigcup M^{Def}_{dr(P)\&cerc(p)} \bigcup M^{PrN}_{dr(P)\&cerc(p)} = \\ = \left\{ \begin{matrix} strunjire;\ frezare; rectificare;\ rabotare, mortezare \\ electroeroziune\ cu\ electrod\ masiv;\ imprimare\ 3D; \\ tăiere\ cu\ jet\ de\ apă\ abraziv \end{matrix} \right\} \quad (5.36)$$

5.2. Original contributions and conclusions

This chapter has a significant original theoretical contribution, based on the current state of the possibilities of generating surfaces where the directrix is straight line and the generatrix curve is a circle. All three major groups of machining processes – by cutting, by plastic deformation and by unconventional processes – have been considered and relevant examples and the sets of possible processes to be used to machine parts whose surfaces are characterized by various possible combinations of straight directrix and generatrix circles have been identified.

The study also highlighted ... a significant number of "straight directrix + circle generatrix" combinations that are not approachable from the perspective of the various known and currently used processing processes.

Each case was exemplified with adequate processing schemes and kinematic schemes of principle, as suggestive as possible, both identifiable in current practice and original, innovative. The priority was to exemplify possibility, not efficiency. At least one of the processing schemes, original, is potentially efficient (see the case of ... Ci_{tp}&ci_{tp} and figure 5.35), even if it is more applicable to the processing of non-metallic materials. Moreover, it has ... potential to be exploited in the sense of obtaining a patent with multiple claims.

For two of the cases studied, the number of known processing procedures that would allow the generation of surfaces with the respective characteristics is zero. The author sees this not as a failure, but as an invitation to creativity, to innovation-invention activity.

Chapter VI – Roughness in oblique tangential turning

6.1. Introduction

Surface quality is an important characteristic sought when machining parts used in machine construction. New, original machining schemes and tools are also sought that lead to the most efficient results.

6.3. Particular schemes of turning processing

The author of this thesis is also interested in other machining schemes for turning that would favor the obtaining of very good quality surfaces of revolution. In this regard, he identified the possibility of turning with tools with a linear active edge arranged tangential to the (cylindrical) surface to be machined and highly inclined in relation to the axis of rotation of the part to be machined, called "turning with an inclined tangential (linear) edge"[1, 2].

6.4. Theoretical roughness of surfaces obtained by oblique tangential turning

In oblique tangential turning the instantaneous surface generated is given by the cutting edge of the tool in effective contact with the layer of material being removed from the workpiece. The distance from the workpiece axis to the various points of the linear edge of the tool is variable, dependent on the angle λs of inclination of the cutting edge and the radius rp, representing a hyperbola.

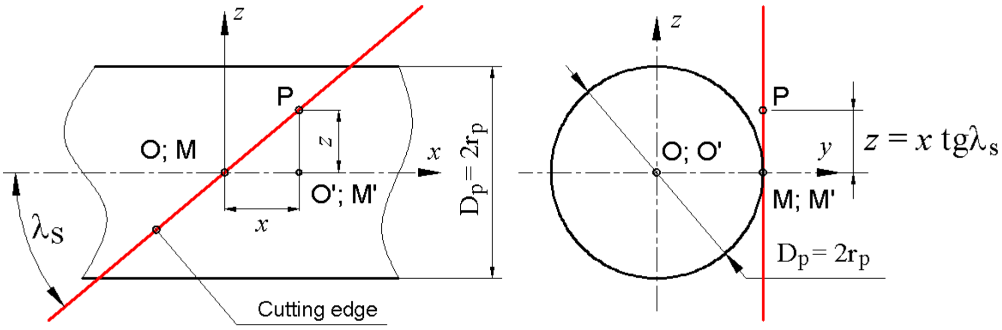


Fig. 6.3. Cutting edge position in oblique tangential turning[3]

Every two such neighboring hyperbolas intersect at a point located relative to the surface of the cylinder of radius r_p at a distance $h = R_t$, which represents the distance between the largest peak and the deepest hollow, figure 6.4, i.e. the theoretical total height of the surface profile.

[1] Cioară R., **Puriciuc M.V.**,Țîțu A.M., Oprean C., Pisarciuc C. (2021): *Procedeu de strunjire cu tăiș tangențial înclinat, cuțit de strung și plăcuță amovibilă pentru acesta* . Cerere de brevet de invenție RO 134952, https://worldwide.espacenet.com/patent/search/family/076070089/publication/RO134952A0?q=RO%20134952

[2] **Puriciuc M.V.**, Cioară R., Pisarciuc C.: *Turning tool with tangential cutting line. Concept and constructive solution.* IOP Conf. Ser.: Mater. Sci. Eng. **1235** 012066, IManEE 2021, https://iopscience.iop.org/article/10.1088/1757-899X/1235/1/012066

[3] **Puriciuc M.V.**, Cioară R., Pisarciuc C.: *Roughness in External Cylindrical Tangential Oblique Turning.* **RECENT**®, ISSN 1582-0246, vol. 25(2024), nr. 1(72), pp. 64-75, Brașov, , https://doi.org/10.31926/RECENT.2024.72.064

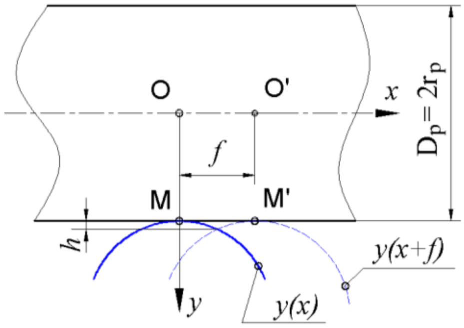


Fig. 6.4. Theoretical profile for oblique tangential turning
(equidistant succession of hyperbolic arcs)

… the analytical expression R_{a0} of the roughness for the studied case is:

$$R_{a0} = \frac{\mathrm{tg}(\lambda_s)}{2} \cdot \sqrt{\frac{f^2}{4} + \frac{r_p^2}{\mathrm{tg}^2(\lambda_s)}} + \frac{r_p^2}{f \cdot \mathrm{tg}(\lambda_s)} \cdot \ln\left(\frac{\mathrm{tg}(\lambda_s)}{r_p} \cdot \frac{f}{2} + \sqrt{\left(\frac{\mathrm{tg}(\lambda_s)}{r_p} \cdot \frac{f}{2}\right)^2 + 1}\right) - r_p. \qquad (6.28)$$

The relationship (6.28) differs significantly from the one determined "*empirically*" by Zamfirache[1].

6.6. Conclusions

… the author of this thesis has developed … a rigorously demonstrated model … (for) … the theoretical prediction of the quality of external cylindrical surfaces using tangentially inclined cutting edges. The original expression obtained by the author of this thesis differs significantly from the "*empirically*" determined one mentioned in the literature.

Our own exploratory research was conducted using a specially made lathe cutter, with the cutting edge inclined to the horizontal plane at an angle of $\lambda_s \approx 70°$, without the possibility of adjusting the cutting edge inclination, with the active part made of P30 carbide. For all combinations of test parameters, surfaces obtained by turning with a tangentially inclined cutting edge tool show lower roughness, most often spectacularly lower, than surfaces obtained by turning with a conventional ISO 2 type tool.

[1] Zamfirache M.: *Prelucrabilitatea prin strunjire a aliajelor de titan*. Editura Universitaria Craiova, 1996, p. 148

Chapter VII – Research and experimental contributions on the quality of external cylindrical surfaces generated by the oblique tangential turning process

7.1. Introduction

The need to design a lathe cutter specifically dedicated to this research became evident, a cutter in which the angle of inclination of the tangential cutting edge could be adjusted to different values with respect to the horizontal plane containing the axis of the workpiece.

7.2. Design and manufacture of a tool with an inclined cutting edge

7.2.2. CAD of the turning tool with inclined tangential cutting edge

The design of the tool with an inclined tangential cutting edge was done in the ProEngineer.

Figure 7.1 shows the assembled lathe tool, in axonometric view.

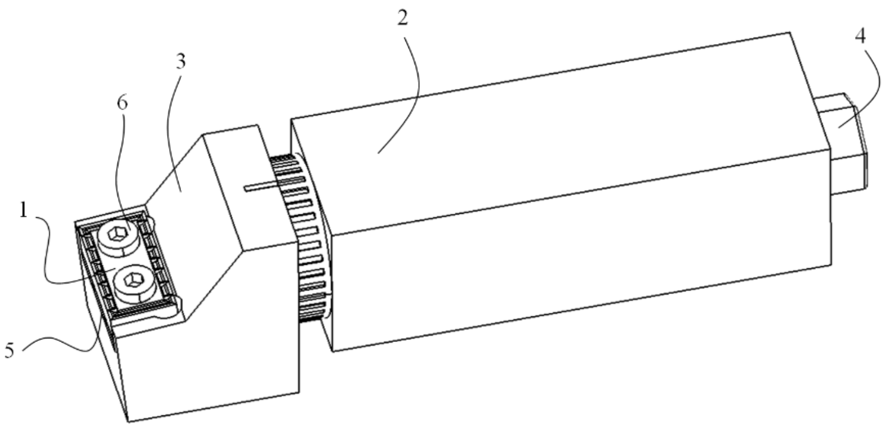


Fig. 7.1. Tangential turning tool with linear tiltable cutting edge, assembled[1]
1 – insert; 2 – fixed tool body; 3 – insert body; 4 – clamping screw;
5 – insert support plate; 6 – insert fixing screws

The lathe cutter described above was considered to have a degree of appreciable originality such as to justify … requesting patent protection[2].

7.2.3. Manufactured a turning tool with a tangentially inclined cutting edge

The knife body and the pill holder body, with the pill assembled, are shown in figure 7.6.

[1] **Puriciuc M.V.**, Cioară R., Pisarciuc C.: *Turning tool with tangential cutting line. Concept and constructive solution*. IOP Conf. Ser.: Mater. Sci. Eng. **1235** 012066, IManEE 2021, https://iopscience.iop.org/article/10.1088/1757-899X/1235/1/012066/pdf

[2] Cioară R., **Puriciuc M.V.**, Țîțu A.M., Oprean C., Pisarciuc C. (2021): *Procedeu de strunjire cu tăiș tangențial înclinat, cuțit de strung și plăcuță amovibilă pentru acesta* . Cerere de brevet de invenție RO 134952, https://worldwide.espacenet.com/patent/search/family/076070089/publication/RO134952A0?q=RO%20134952

Fig. 7.6. The two bodies of the tool with a tangentially inclined edge

7.3. Design and conduct of experiments

All experiments were conducted at Transilvania University of Brașov, Faculty of Technological Engineering and Industrial Management, within the "Mechanical Processing" laboratory of the Department of Industrial Engineering and Management. The available material base – universal lathe SN 250, numerically controlled lathe Poly Gim PLG-42, TESA-rugosurf 10-G roughness meter, ISO1 lathe tool for ISO SNMG 190616 insert and tangentially inclined cutting edge tool specially designed and made by the author for the purpose of conducting the experiments – oriented the research towards adopting those combinations of parameters compatible with the assumed objective of the research, the study of the quality of external cylindrical surfaces obtained by turning with a tangentially inclined cutting edge, possible under the given conditions.

For comparative results, a classic ISO1 tool was used, equipped with an ISO SNMG 190616 insert identical to that used in the inclined tangential cutting edge.

7.3.2. Conduct of experiments

Specifically, the experimental research took into account the following parameters:

- three values for the angle of inclination of the cutting edge of the tool: $\lambda_s \in \{45°, 60°, 70°\}$;
- three materials for the specimens: (polyamide,) duralumin 6061, rolled steel of quality OLC45, alloy steel for heat treatment 42CrMo4QT;
- five speeds for specimens: $n \in \{160, 250, 400, 630, 1000\}$ rpm, which directly determines the cutting speed;
- three values for the longitudinal feed: $f \in \{0{,}12;\ 0{,}2;\ 0{,}28\}$ mm/rot;
- three types of turning tools: the tool with a tangential tiltable cutting edge, the normal ISO1 tool, the rotary insert tool with a tiltable clearance plane;
- a single value for the cutting depth: a_p = 0.5 mm;
- machining without cooling, for all tests.

With the experimental tool, with a tangential linear tiltable cutting edge, 3 x 3 x 5 x 3 = 135 tests were performed, i.e. a complete research plan in relation to the four variable parameters considered. The machining with the normal ISO1 knife was provided for comparison values. 3 x 5 x 3 = 45 tests were performed with this tool.

The initial geometric characteristics of the specimens are shown in figure 7.10, and an image of the specimens in their initial form is shown in figure 7.11. Each specimen has five sectors, so that in one pass, machining can be done with each of the five speeds considered for the tests. A single specimen was used from each material. Three passes were made for each material, one for each feed rate. The successive machining of the specimens determined a gradual reduction in their diameter.

The roughness measurement was performed with a professional electronic roughness meter, TESA-rugosurf 10-G. For each machined surface, the roughness measurement was made along three equiangularly arranged generators (0°, 120° and 240°) and the average value was calculated.

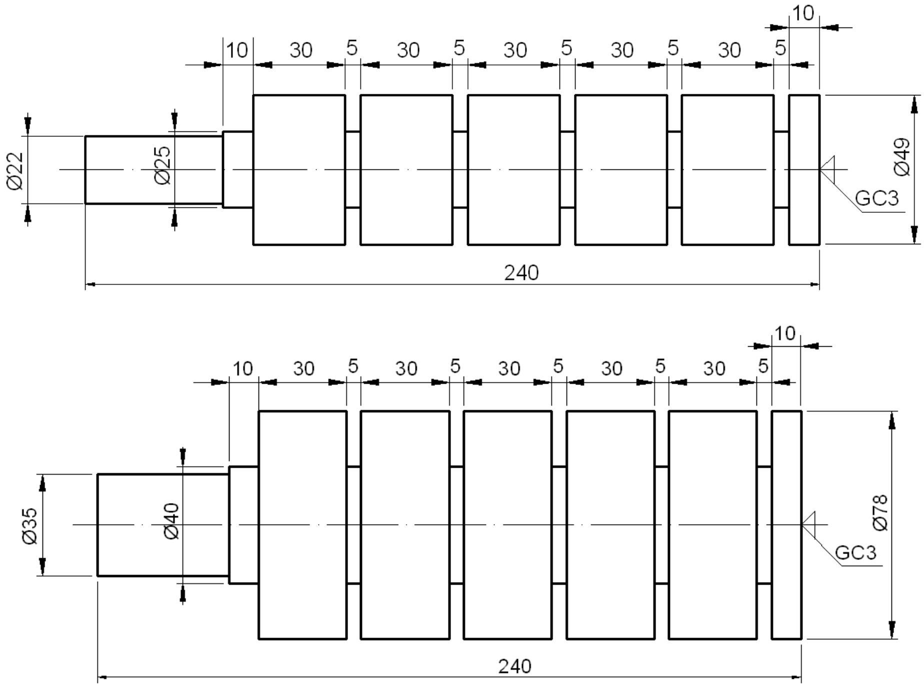


Fig. 7.10. Initial geometric characteristics of the specimens

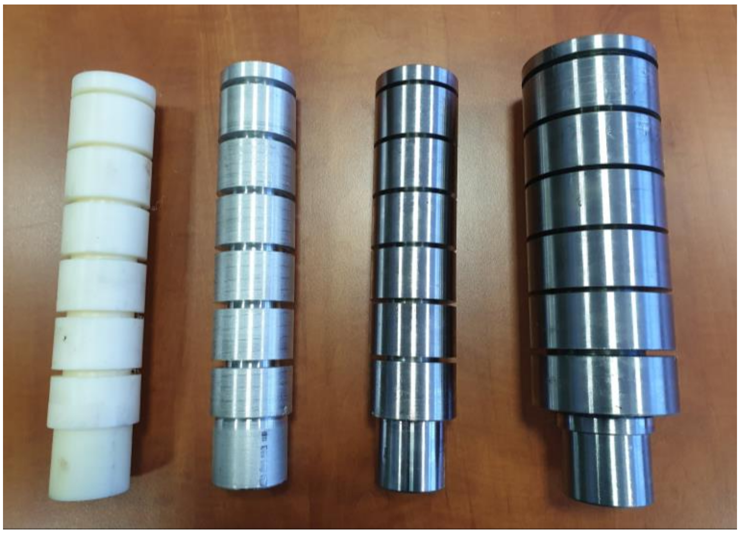


Fig. 7.11. The four specimens, in their original form

7.4. Experimental results and their analysis

The TESA-rugosurf 10-G roughness meter displays both the measured values for the roughnesses R_a, R_q, R_t and R_p, as well as a graphical representation. For the presentation of the results and for the analysis, only the values for the roughness R_a were retained.

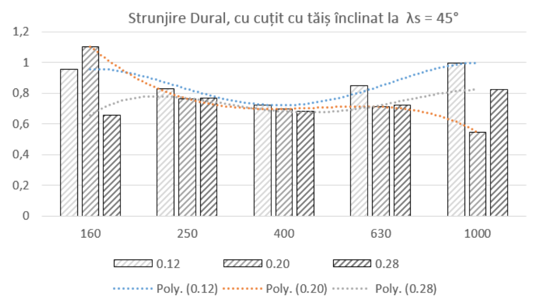
7.4.1. Results obtained when machining with a normal ISO1 turning tool

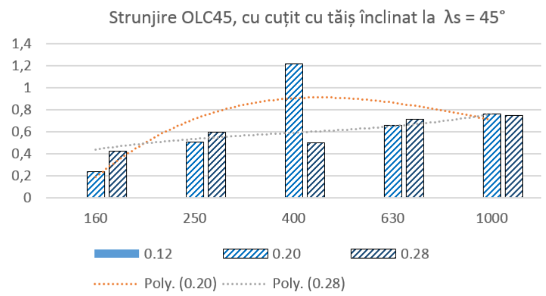
The machining with a normal ISO1 tool, equipped with an ISO SNMG 190616 removable insert, generated reference values for the analysis of the surface quality obtained by turning the tested specimens.

7.4.2. Results obtained when machining with a turning tool with an inclined tangential cutting edge

The roughness values R_a obtained in the research using the specially designed tool, with inclined tangential cutting edge, are presented in the tables.

A graphical representation of the influence of feed and cutting speed when machining Dural, OLC45 and 42CrMo4 with a 45° tangential cutting edge is shown in figure 7.16.





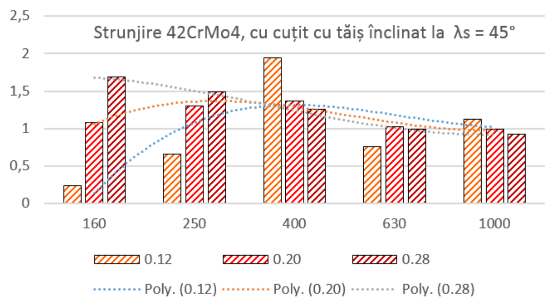


Fig. 7.16. Variation of roughness R_a when turning Dural, OLC45 and 42CrMo4, using the special tool with tangential cutting edge inclined at 45°, depending on feed and cutting speed

For all three processed materials, the roughnesses obtained when turning with a 45° inclined cutting edge are considerably lower than those obtained when turning with an ISO1 cutting edge, 2 ... 5 times better.

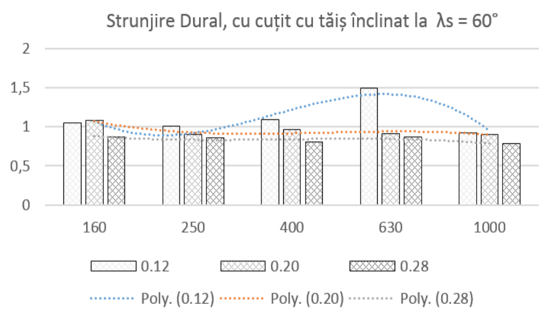
A graphical representation of the influence of feed and cutting speed when machining Dural, OLC45 and 42CrMo4 with a 60° inclined tangential cutting edge is shown in figure 7.20. Turning with a 60° tangential cutting edge tool generated, for low machining speeds, significantly superior results compared to those performed with an ISO1 tool.

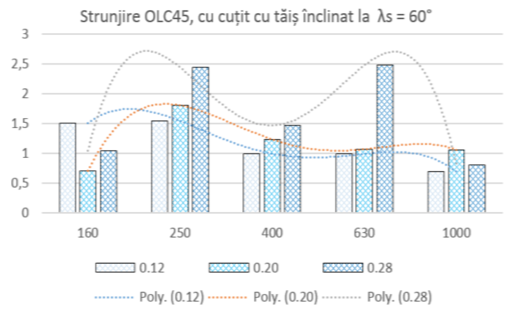
A graphical representation of the influence of feed and cutting speed when machining Dural, OLC45 and 42CrMo4 with a 70° inclined tangential cutting edge is shown in figure 7.21.

The roughness values R_a recorded during the experiments, arranged according to table 7.7, allow the graphical representation of the variation in roughness as a function of the angle of inclination of the tangential edge and speed for each of the materials of the specimens used and for each of the feed values selected for the experimental research, including in comparison with the roughness obtained in ISO1 tool machining.

When machining Dural... with low and medium speeds and feed s = 0.2 ... 0.28 mm/rev, the superiority of machining with a tangentially inclined cutting edge over that with an ISO1 tool is undeniable.

When turning OLC45, figure 7.23, in all machining operations – regardless of feed, speed and cutting edge inclination angle – the superiority of using the tangentially inclined cutting edge over using the ISO1 tool is evident. The superiority is strongly manifested at low speeds (n = 160 rpm and n = 250 rpm), for all feed values.





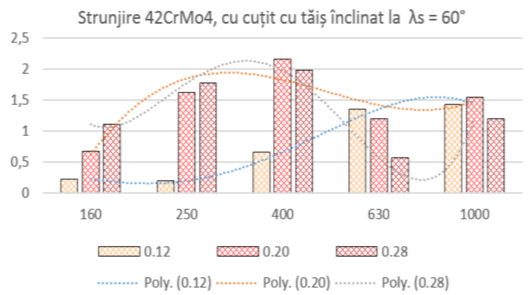
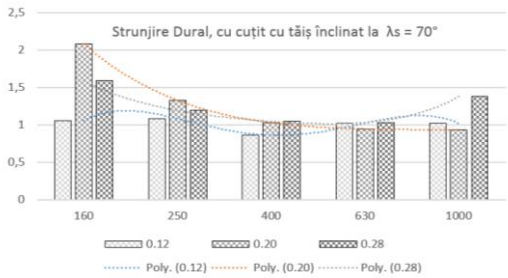
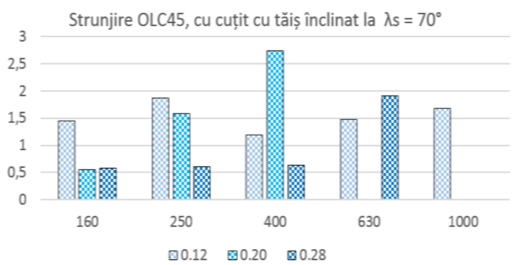


Fig. 7.20. Variation of roughness R_a when turning Dural, OLC45 and 42CrMo4, using the special tool with tangential cutting edge inclined at 60°, depending on feed and cutting speed





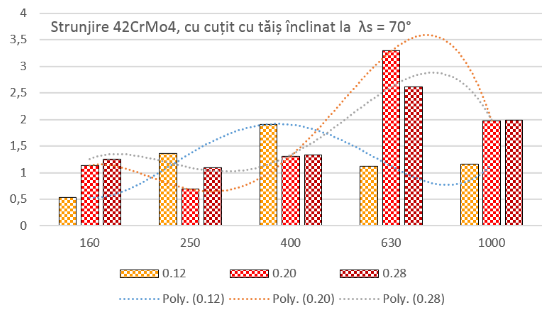
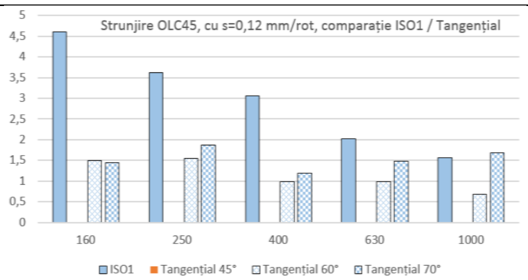


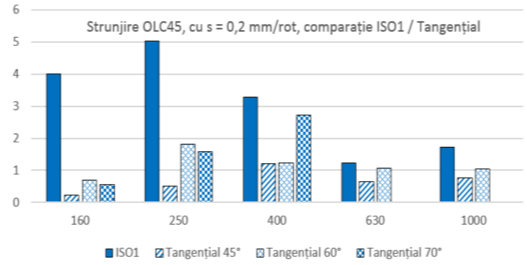
Fig. 7.21. Variation of roughness R_a when turning Dural, OLC45 and 42CrMo4, using the special tool with tangential cutting edge inclined at 70°, depending on feed and cutting speed

When turning 42CrMo4, figure 7.24, obvious superiority of using the tangentially inclined cutting edge tool over using the ISO1 tool is identified for all three feeds adopted only at low speed, n = 160 rpm, but also in the case of low feed machining, s = 0.12 mm/rot and speed n = 250 rpm. In medium or high speed machining, the roughness R_a shows small differences for all considered feed values, often resulting in better results for machining with the ISO1 tool than with the tangentially inclined cutting edge tool.

Table 7.7. All experimental results obtained,
ordered to highlight the comparison with ISO1 tool turning

Feed	Material	Tool	Speed, in rpm				
			160	250	400	630	1000
0,12 mm/rev	Dural 6061	ISO1	1,667	1,382	1,035	1,232	1,091
		Tangențial 45°	0,956	0,826	0,721	0,847	0,995
		Tangențial 60°	1,052	1,004	1,094	1,499	0,925
		Tangențial 70°	1,061	1,086	0,865	1,026	1,021
	OLC45	ISO1	4,598	3,613	3,052	2,019	1,565
		Tangențial 45°	x	x	x	x	x
		Tangențial 60°	1,503	1,539	0,993	0,989	0,686
		Tangențial 70°	1,453	1,870	1,193	1,476	1,678
	42CrMo4	ISO1	4,482	4,502	0,634	0,823	0,979
		Tangențial 45°	0,238	0,656	1,947	0,759	1,127
		Tangențial 60°	0,224	0,195	0,660	1,351	1,421
		Tangențial 70°	0,536	1,360	1,903	1,119	1,155
0,2 mm/rev	Dural 6061	ISO1	5,472	5,367	4,238	2,761	1,268
		Tangențial 45°	1,103	0,763	0,697	0,710	0,545
		Tangențial 60°	1,078	0,898	0,960	0,911	0,903
		Tangențial 70°	2,081	1,330	1,030	0,948	0,936
	OLC45	ISO1	4,01	5,029	3,277	1,238	1,715
		Tangențial 45°	0,238	0,506	1,216	0,654	0,758
		Tangențial 60°	0,703	1,804	1,232	1,068	1,053
		Tangențial 70°	0,554	1,586	2,733	x	x
	42CrMo4	ISO1	6,116	3,269	1,131	1,176	1,398
		Tangențial 45°	1,074	1,306	1,367	1,025	0,989
		Tangențial 60°	0,671	1,619	2,161	1,193	1,540
		Tangențial 70°	1,139	0,687	1,313	3,291	1,971
0,28 mm/rev	Dural 6061	ISO1	6,043	4,026	4,422	4,352	2,015
		Tangențial 45°	0,656	0,767	0,680	0,722	0,822
		Tangențial 60°	0,875	0,857	0,805	0,868	0,780
		Tangențial 70°	1,590	1,195	1,048	1,035	1,379
	OLC45	ISO1	6,674	5,281	2,622	2,191	1,761
		Tangențial 45°	0,422	0,596	0,497	0,711	0,744
		Tangențial 60°	1,044	2,440	1,469	2,478	0,803
		Tangențial 70°	0,577	0,609	0,634	1,915	x
	42CrMo4	ISO1	7,122	2,055	1,984	1,901	1,855
		Tangențial 45°	1,683	1,493	1,256	0,995	0,922
		Tangențial 60°	1,107	1,772	1,972	0,569	1,197
		Tangențial 70°	1,258	1,096	1,331	2,615	1,984





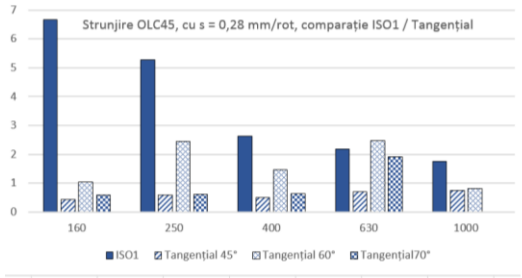
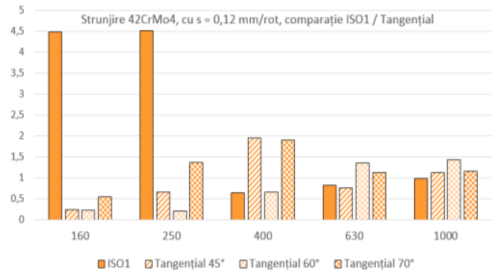
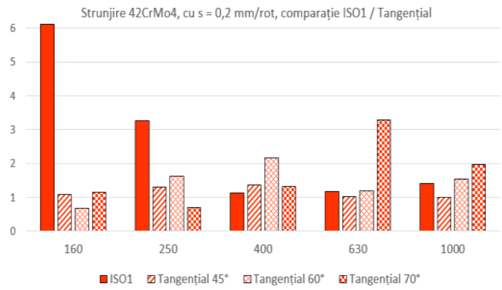


Fig. 7.23. Variation of roughness R_a when turning OLC45, for each of the feeds s = 0.12; 0.2; 0.28 mm/min, depending on the angle λs of inclination of the tangential edge and the cutting speed





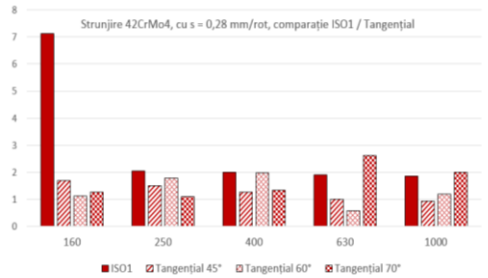


Fig. 7.24. Variation of roughness Ra when turning 42CrMo4, for each of the feeds s = 0.12; 0.2; 0.28 mm/min, depending on the angle λs of inclination of the tangential cutting edge and the cutting speed

The conclusion that must be drawn is that machining with a tangentially inclined cutting edge, regardless of the value of the cutting edge inclination angle λs, is clearly superior to turning with an ISO1 cutting edge when using the low speed n = 160 rpm, regardless of the material processed and the feed rate adopted, except for Dural turning with feed rate s = 0.12 mm/rotation. On the other hand, the use of high speed n = 1000 rpm gives the advantage to machining with ISO1 tool for all studied materials, for all adopted feeds and for all tangential edge inclination angles λs.

7.5. Directions for further research

The objective of the experimental research was "*the study of the quality of the outer cylindrical surface obtained by turning with a tool with a linear cutting edge arranged tangentially inclined*". The study of the cutting forces and the instantaneous and average energy consumption that characterize the processing with the mentioned type of tool was also taken into account, but ... this study remains a future, exciting and very useful objective not only regarding turning processing, in particular using a tool with a tangentially inclined cutting edge.

The resumption of the tests is being considered, using materials other than those already studied. Titanium alloys are particularly targeted. Tests with other cutting depth values compared to the one adopted in the research so far are also being considered.

It is also of great interest to resume experiments with other values of the cutting edge inclination angle. The values of 50°, 55° and 65° are being considered with priority.

The research generated a large volume of original results, but only a few of them were published. It is planned to continue the dissemination of the results obtained.

7.6. Conlusions

To carry out the experimental research, a particular lathe tool was required, with a tangentially arranged linear cutting edge, tiltable at any angle relative to the horizontal plane containing the axis of the workpiece. … its design was carried out in the ProEngineer.

It was considered that the designed lathe tool had a sufficient degree of originality and it was decided to request patent protection.

The designed tool was physically made, by own forces, and was used in all stages of the experimental research. For comparative results, a classic ISO1 tool was used, equipped with an ISO SNMG 190616 insert identical to the one used in the inclined tangential cutting tool.

The experimental research was carried out based on a complete research plan, which took into account three materials for the specimens, three values for the cutting feed, five values of the speed of driving the specimens and three values of the inclination angle of the linear cutting edge arranged tangentially and inclined to the surface of the machined part. All machining was carried out with the same depth of cut and without cooling.

When designing the specimens, five sectors were provided, so that in a single pass all five speeds provided for the experiments could be used.

Machining with a normal ISO1 tool, equipped with an ISO SNMG 190616 removable insert, generated values with which the roughness values obtained with the tool with a tangential tiltable cutting edge were compared.

For all tests, the results were rigorously recorded. The results were appropriately tabulated so that they could be easily graphed and interpreted.

When turning Dural at low and medium speeds and with a feed rate of s = 0.2 … 0.28 mm/rev, the superiority of machining with a tangentially inclined cutting edge over that with an ISO1 cutting edge is undeniable.

When turning OLC45, in all machining operations – regardless of feed, speed and cutting edge inclination angle – the superiority of using the tangentially inclined cutting edge tool over using the ISO1 tool is obvious.

When turning 42CrMo4, the obvious superiority of using the tangentially inclined cutting edge tool over the ISO1 tool is identified for all three feeds adopted only at low speed.

Machining with a tangentially inclined cutting edge, regardless of the value of the cutting edge inclination angle λs, is clearly superior to turning with an ISO1 cutting edge when using low speed, regardless of the material being machined and the feed rate adopted. On the other hand, using a high speed n = 1000 rpm gives the advantage to machining with an ISO1 tool.

Chapter VIII – Original contributions, forms of exploitation, final conclusions, and directions for further research

8.1. Original contributions

❶ Active participation in defining the topic of the doctoral thesis and establishing its objectives.

❷ Conducting an extensive bibliographic research and synthesis of information regarding the current state of knowledge and practice in the field of surface generation on machine tools, without being limited to machining.

❸ It has been revealed that using machine tools, real surfaces are generated, but ... the study of theoretical generation of surfaces precedes and is reflected in their practical generation.

❺ It is justifiably admitted that from the point of view of the generation method, six ways of obtaining both the directrix curve and the generatrix curve are identified, and implicitly 6 x 6 = 36 distinct possibilities of obtaining a surface characterized by a particular directrix and a particular generatrix.

❻ It has been found that for each type of directrix and generatrix only a part of the theoretically possible combinations are found in practice and are described in the specialized literature. The systematic approach must explore the entire set of generation possibilities, applied or not (yet) in practice, and as a result is oriented towards discovery and even inventories.

❼ The use of the theory of kinematic chains-type as a powerful and logical tool for the kinematic construction of any machine tool intended to process surfaces characterized by a certain combination of directrix & generatrix, as a link between the theory of surface generation and the kinematics of machine tools.

❽ By analyzing the current state, identifying the sets of machining processes and types of machine tools intended and/or capable of generating (also) cylindrical surfaces with straight directrix, on the one hand, or with circle generatrix, on the other hand. By intersection, the set of machining processes intended and/or capable of generating (also) cylindrical surfaces with straight directrix and with circle generatrix was also determined.

❾ For each of the groups of processing processes (by cutting, by plastic deformation and by unconventional processes), the sets of processes that allow the simultaneous obtaining of the straight directrix and the circle generatrix are explained, taking into account the known ways of generating the two mentioned curves. It is found that for each group of processing processes there are cases that do not allow the creation of a cylindrical surface where the directrix is a straight line and the generatrix is a circle, because either only the directrix, or only the generatrix, or both simultaneously cannot be obtained in the considered manner.

❶❶ At the overall level, without differentiation by processing groups, three empty sets are identified: $M_{dr(M)\&cerc(citp)}$, $M_{dr(Cifc)\&cerc(citp)}$ and $M_{dr(R)\&cerc(citp)}$. ... all of them have in common the set of procedures for obtaining kinematics as the trajectory of a point of the circle generatrix.

❶❻ At least one of the processing schemes, original, is potentially efficient (the $Ci_{tp}\&ci_{tp}$ case), even if it is more applicable for the processing of non-metallic materials. Moreover, it has the potential to be exploited in the sense of obtaining a patent with multiple claims.

❶❼ For two of the cases studied (the $Ci_{fc}\&ci_{tp}$ case and the $R\&ci_{tp}$ case), the number of known processing procedures that would allow the generation of surfaces with the respective characteristics is zero. The author sees this not as a failure, but as an invitation to creativity, to innovation-invention activity.

❶❽ The actual experimental research was carried out considering a very particular turning processing scheme, rarely mentioned in the literature, "oblique turning", indicated for obtaining very good quality surfaces including parts made of difficult or hard-to-machine materials.

❶❾ A rigorously demonstrated model was developed with the aim of theoretically predicting the quality of external cylindrical surfaces using tangentially inclined cutting edges. The original expression obtained by the author of this paper differs significantly from the "empirically" determined one mentioned in the literature.

❷❶ For all combinations of test parameters, the surfaces obtained by turning with a tangentially inclined cutting edge tool show lower roughness, most often spectacularly lower, than the surfaces obtained by turning with a conventional ISO 2 type tool.

❷❷ A detailed technical design was developed for a tangentially inclined lathe cutter with adjustable inclination of the linear cutting edge, intended for experimental research. The identified solution was appreciated as original and it was decided to protect it by patent. The patent description has been drafted and filed with OSIM, and the substantive examination is in progress. The patent application is being applied for by two universities in Romania: Transilvania University of Braşov and "Lucian Blaga" University of Sibiu.

❷❸ Manufactured and testing of an experimental model of a tool with a tangential inclined cutting edge, physically realized in a constructive variant that allows the use of a removable insert available on the market. The execution of the experimental tool was achieved through own effort. … The success of the experimental research validated through the practical results obtained the concept of oblique turning with a tool with a tangential inclined cutting edge, as well as its superiority under certain conditions over classical orthogonal turning.

❷❺ The publication activity carried out during the preparation and elaboration of the doctoral thesis, aimed at disseminating the results of the research conducted and submitting them to public debate in groups of specialists in the field. This activity will continue, as much of the new knowledge generated within the research has not yet been published.

8.2. Forms of research exploitation

Part of the research results conducted within the framework of this doctoral thesis have been exploited to date through:

- ✓ Design of a lathe tool with a tangentially inclined, orientable cutting edge, with the seating surface oriented in the feed direction.

- ✓ The physical realization of an original, orientable tangential inclined cutting edge lathe tool, in a construction variant adapted to use a removable insert available on the market. The aforementioned tool is specially designed for experimental research, with a view to identifying with priority the influence of the cutting edge inclination angle on the machining performance of external cylindrical surfaces.
- ✓ Elaboration and registration with OSIM of a patent application for invention, with 13 claims (7 independent claims and 6 dependent claims), having as subject matter the oblique turning process, the lathe tool with an orientable inclined tangential cutting edge and a removable plate intended to equip the originally designed tool.
- ✓ Publication in the field of the thesis topic of 1+5 achievements, a patent application registered with OSIM and 5 scientific articles published in specialized journals and in the bulletins of organized international scientific conferences. Of the 5 scientific articles, 2 are ISI indexed, and 3 are included in other international databases. I am the sole author of 2 of the published works (2 BDI works), and I am the first author of the other 3 (2 ISI and 1 BDI). Another work is under evaluation and in the process of publication, in a Q1 ISI indexed journal. I am a co-author on the patent application.

8.3. Final conclusions

The analysis of the topic was done in relation to a possible "roadmap" of the activities necessary to be carried out in order to solve it. The title of the doctoral thesis – „***Studii și cercetări inovative privind cinematica generării suprafețelor cilindrice***" – faithfully reflects its subject - the kinematics of the generation of cylindrical surfaces - and the main mode of action - innovation.

All research activity within the thesis was subordinated to one major objective: **the detailed study of the possibilities of machining external cylindrical surfaces**, reflected in two directions of action for which success was foreseen even from the preliminary analysis phase of the thesis:

1) - **revealing (by at least one example) the multitude of possibilities for machining external cylindrical surfaces** characterized by straight directrix and circle generatrix, and

2) - **detailed study of the machining of (external) cylindrical surfaces by turning with a lathe tool with an inclined tangential cutting edge**.

A special effort was made to identify, by at least one example, as many of the theoretically possible combinations of a cylindrical surface characterized by straight directrix and circle generatrix as possible. This first line of action was crowned with success and also generated evident original theoretical contributions.

The second direction of action was based on a preliminary experimental research whose very encouraging results gave confidence that the extended experimental research in accordance with the requirements of the thesis would also be a success.

... it is unanimously accepted that the kinematic synthesis of machine tools is a subsequent stage to their kinematic analysis, to knowledge of the diversity and possibilities of machining on machine tools. Consistent original theoretical contributions are found in chapter IV, dedicated to the analysis of machining processes and machine tools intended for the generation of cylindrical surfaces.

The research of the specialized literature, including the international databases for patents, revealed that tangential inclined cutting edge turning, expressed by various phrases, has been the subject of study in the last 50 years for a few researchers, very few in number.

A stage with consistent original theoretical contributions was that of kinematic synthesis, one of the two major directions of action envisaged in the thesis. … The processing schemes selected to exemplify the multitude of possible combinations, many of them original, and the corresponding kinematic principles are described in detail in chapter V of the work. This chapter is largely original and contains the main theoretical contributions made to the field studied.

The roughness of cylindrical surfaces obtained by oblique turning is the quality parameter taken into account in experimental research and was also approached from a theoretical perspective. An original theoretical contribution resulted, the exact relationship rigorously demonstrated for determining the value of the theoretical roughness (average and total) of external cylindrical surfaces obtained by oblique turning with a linear cutting edge.

Chapter VII, entirely original, is dedicated to the second major direction of action provided for in the thesis. It is the chapter that synthesizes the practical activity carried out, of original experimental research. This entire activity was carried out using a specially designed, original lathe tool, for which protection by patent was requested, and which was physically realized by own forces. An experimental research plan was designed, which was fully respected. The experimental data were rigorously recorded and analyzed in their complexity. The resulting conclusions are, along with the experimental data themselves, outstanding original practical contributions, similar detailed information being missing from the studied specialized literature. The vast majority of the experimental data indicate the superiority of inclined tangential cutting edge turning over classical turning in terms of the quality of the obtained external cylindrical surfaces, a superiority that is especially evident at low machining speeds achieved with low feed.

The experimental research carried out using an original lathe tool, with a tangential inclined cutting edge that can be tilted at any desired angle, was crowned with success. The original tool itself, the reproducibility at any time and whenever desired of the tests performed, as well as a significant number of video recordings made during the experimental research, bear witness to this.

… the objectives of the thesis are fully met. A main objective was justifiably stated, with two major directions of action, and a number of related objectives. An adequate documentation and bibliographic synthesis was carried out, which formed the basis for identifying the sets of processing procedures capable of generating cylindrical surfaces characterized by the various possible combinations of obtaining the straight directrix curve and the circle generatrix curve, a special theoretical contribution stated in absolute international premiere. An original lathe tool was designed and made, with a tangentially inclined cutting edge, a cutting edge that could be tilted at any desired angle, with which the entire experimental research was carried out. The experimental results were recorded and analyzed, and appropriate and pertinently argued conclusions were expressed. 5 scientific papers in the field of the thesis were written and published and the necessary documentation for a patent application was prepared, registered with OSIM. New directions for further research were identified.

8.4. Directions for further research

During the research, especially in its finalization phase, two important directions for its development and continuation were identified.

A first direction of action is mainly theoretical in nature and aims to expand research on the identification of new machining schemes that can be applied to obtain external cylindrical surfaces characterized by straight directrix and circle generatrix, as well as the critical analysis of the schemes already revealed.

The second direction of action is of an applied nature and aims at the development of experimental research, taking into account more diverse processing regimes. It is envisaged to resume the tests, using other materials than those already studied, especially titanium alloys. Of great interest is also the resumption of experiments with other values of the cutting edge inclination angle, with priority being given to the values of 50°, 55° and 65°.

It is preferable that new experimental research also allows the determination of the instantaneous energy consumption of the entire machine tool used, but also that of the cutting process alone. This information allows highlighting the energy efficiency of turning with a tangentially inclined cutting tool, including in comparison with classic orthogonal turning.

Braşov, October 2018 – October 2025

Innovative studies and research regarding the kinematics of generating cylindrical surfaces

Brief Summary

In the department within Transilvania University of Brașov where the research activity that culminated in this doctoral thesis was carried out, machine tool kinematics and innovation-invention are significant research topics, both of which are reflected in the title and content of this thesis. The research mainly aimed at the analysis and kinematic synthesis of machine tools from an integrative perspective of known machining processes and highlighted, including through an innovation-invention effort, both various machining schemes and a logical methodology for kinematic synthesis of machine tools starting from the basic concepts of surface generation theory.

The initial research objectives were refined, detailed, completed and developed over time. A main objective consisting of two relevant sub-objectives was stated. Some related objectives not initially foreseen were added over time, and some less relevant ones were no longer addressed. The objectives of the thesis are fully met. A bibliographical documentation and an adequate synthesis were carried out, oriented towards identifying the machining possibilities of the various classes of machine tools and especially towards revealing the sets of machining processes capable of simultaneously producing a certain pair of directrix and generatrix. Each of the 36 possibilities of producing a surface described by straight directrix and circle generatrix was exemplified through machining schemes, many originals, and principle kinematic schemes. An original lathe tool with an inclined tangential cutting edge was designed and manufactured, for which patent protection was requested. A tangential cutting model was developed and an original relationship for theoretical roughness when turning with the designed tool was obtained, a relationship that was rigorously demonstrated. Extensive experimental research was conducted using the tool, and the results were interpreted. Five scientific papers in the field of the thesis were written and published, plus a patent application, and directions for further research were highlighted.

Universitatea Transilvania din Brașov

DECLARAȚIE DE ORIGINALITATE | STATEMENT OF ORIGINALITY

Subsemnatul/a | I, the undersigned

___________________________ing. Mitruț PURICIUC______________________________

(nume doctorand | doctoral student's name)

în calitate de student-doctorand la Universitatea Transilvania din Braşov, autor al tezei de doctorat cu titlul:

as doctoral student at Transilvania University of Brasov, author of the doctoral thesis entitled:

___**Studii și cercetări inovative privind cinematica generării suprafețelor cilindrice** ___

___**Innovative studies and research regarding the kinematics of generating cylindrical surfaces** ___

și subsemnatul/a | and I, the undersigned

_________________________prof.dr.ing. Romeo CIOARĂ_________________________

(titlu și nume conducător doctorat | title and name of doctoral supervisor)

în calitate de conducător de doctorat al autorului tezei la Universitatea Transilvania din Braşov,

as doctoral supervisor of the author of the thesis at Transilvania University of Brasov,

declarăm pe proprie răspundere că am luat la cunoştinţă prevederile art. 259 alin. (1)* și art. 174 alin. (1), (3)-(5)** din Legea învățământului superior nr.199/2023, cu modificările și completările ulterioare, ale art. 21, alin. (2), (4)***, art. 13 alin. (9) lit. e), (15)**** și art. 14 alin. (16) lit. g)***** și din Ordinul Ministrului Educației nr. 3020/2024 pentru aprobarea Regulamentului-cadru privind studiile universitare de doctorat şi ne asumăm consecințele nerespectării acestora.

hereby declare, on our own responsibility, that we are aware of the provisions of Art. 259, paragraph (1)* and Art. 174, paragraphs (1), (3)-(5)** of the Higher Education Law no. 199/2023, with subsequent amendments and completions, as well as Art. 21, paragraphs (2), (4)***, Art. 13, paragraphs (9) letter e), (15)****, Art. 14, paragraph (16) letter g)***** of the Ministry of Education Order No. 3020/2024 for the approval of the Framework Regulation for Doctoral Studies, and we take full responsibility for the consequences of non-compliance with these provisions.

Student-doctorand | Doctoral student ______________________________

(semnătură | signature)

Conducător de doctorat | Doctoral supervisor ______________________________

(semnătură | signature)