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THE PARAMETRIC CORRELATION OF THE WOOD CABLE MOULDING AT THE KINEMATICS PROCESS WITH CONSTANT PITCH

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Abstract:*This paper aim is to achieve a relation between the geometric elements of the cable moulding (design) with constant pitch and kinematics parameters, participants in the industrial system for data processing, when using specialized machine tools.*
The kinematics parameters must be "controlled" and adjusted to the values that would ensure the proposed geometric shape and the surface quality resulting from processing, can thus be made both in the roughing stage and in the final stages processing of the surfaces, in correlation with the type of finish that will be applied to surfaces (the type of lacquer, the preparation module of surface, the specific consumption of lacquer or primer, etc.).
The correlation of the kinematics parameters should be performed through *morphology of the machine tools which must include specific structural components (reducers, mechanical variators, frequency converters, etc.).*

Keywords: *cable moulding, normal pitch, front pitch, axial pitch, cutting speed, feed speed*

1. INTRODUCTION IN THE CABLE MOULDINGS GEOMETRY with CONSTANT PICH

The cable mouldings with constant pitch are special ornaments that decorate furniture pieces, being specific , in generally, to Renaissance styles both from the continental (Italy, France, Spain, Germany) and island area (United Kingdom).

The ornament of cable moulding with constant pitch type is performed on cylindrical elements from the furniture structure (table legs, moulding, pillar for canopy beds, support columns for lamps, flower supports, etc.). The ornament is presented as a helical rib wrapped on a cylinder. In the perpendicularly section, the rib has various forms: semicircular, ogive, trapezoidal, complex profiles (Fig. 1)

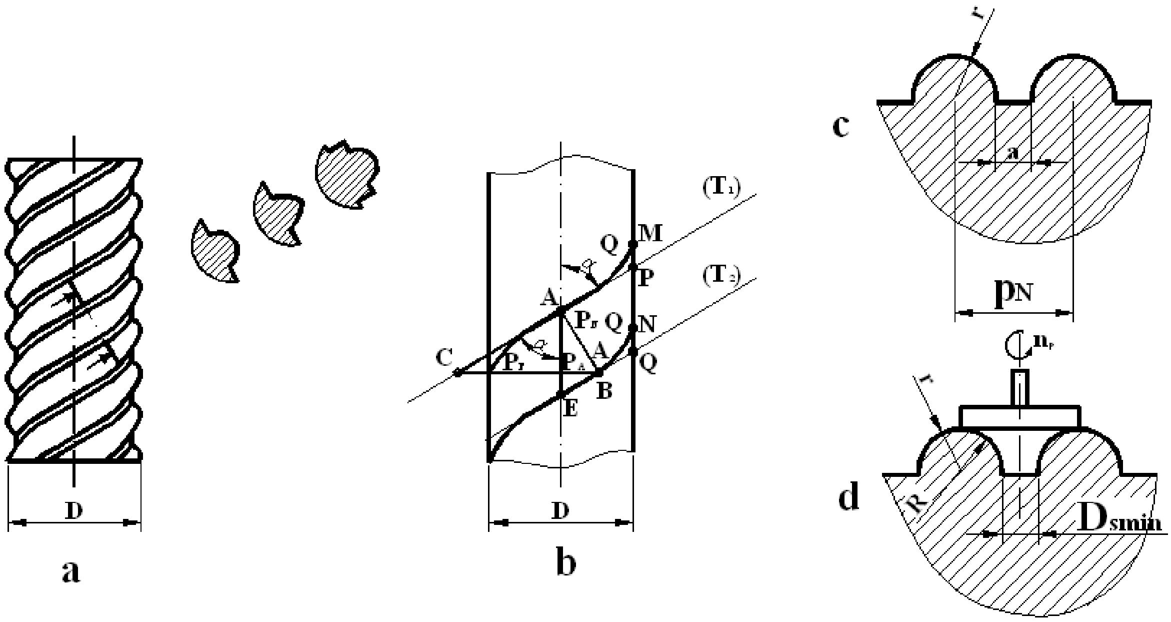

Fig.1.
The cable mouldings geometry elements

The design of the cable mouldings with constant pitch, for operation in industrial systems, on specialized machinery, must ensure the following:

- to respect the proportionality in the product decoration, falling within the mandatory rules of the product aesthetics;
- to ensure resistance in the product structure;
- to can only be processed mechanically.

The design of the cable mouldings with constant pitch must follow a binding algorithm:

- sizing the element (which is to be decorated) in terms of resistance, depending on which requests will be subject to the product, resulted the base diameter "*D*";
- Establishment from aesthetic conditions point of view of:
  - o the shape and size of ribs (for a semicircular shape resulting size "*r*")
  - o the space between two adjacent ribs (required by the size "*a*");
  - o the angle of inclination of the cable moulding in relation with the geometric axis marker (required by the angle α), an element that "gives the motion" to the ornament, so a big α angle suggests: peace, stability, calmness, while a small α angle suggests dynamism, rigor, and restlessness.

With these elements determined by calculation of resistance or adopted in terms of aesthetics it proceeds to calculate (Fig.1):

- o normal pitch: $p_N = 2r + a$ (Fig.1.c.) (1)
- o frontal pitch: $p_F = \frac{p_N}{\cos\alpha}$ (Fig.1.b din ΔABC) (2)
- o axial pitch: $p_A = \frac{p_N}{\sin\alpha}$ (Fig.1.b din ΔABE) (3)

The pitch values: normal, frontal and axial, can be calculated, analyzed and interpreted by relating with similar elements from the mechanical threads.

- Number Sizing of the parallel windings (see the beginnings number of the mechanical threads):

$$Z_c = \frac{\pi \cdot D}{p_F} = \frac{\pi \cdot D \cdot \cos\alpha}{2r + a} \qquad (4)$$

The Z_c value resulting from the calculation, is not always a rigorously integer number and therefore the number is rounded to the nearest integer value of Z_i. With this rounded value the elements which can ensure the geometric correlation of the cable moulding characteristics are recalculated.

Recalculation can be applied generally upon three elements:

- resulting normal pitch:

$$p_{Nr} = \frac{\pi \cdot D \cdot \cos\alpha}{Z_i} \text{ (mm)} \qquad (5)$$

It should be noted that upon this element it can intervene more difficult because it involves the choice of other tools characterized by an "*r*" and $D_{smin} = a$ (see Fig.1.d.) which if there is not it must be executed. Initially when it started the calculation the choice of the „*r*" and „*a*" values in terms of aesthetics was based on an existing tool.

- angle of the cable moulding:

$$\alpha_r = \arccos\left[\frac{Z_i \cdot (2r + a)}{\pi \cdot \cos\alpha}\right] \text{ (mm)} \qquad (6)$$

- disposition diameter of the cable moulding $D_r = \dfrac{Z_i \cdot (2r + a)}{\pi \cdot \cos\alpha}$ (mm)

$$(7)$$

The recalculation is done only on one of the elements, in most of the cases intervening on the diameter because the angle changing can affects the aesthetics "movement" of the cable moulding.

The final items taken and recalculated are standing at the base of processing definition.

2. CABLE MOULDINGS KINEMATICS PROCESSING WITH CONSTANT PITCH

The Determination of the kinematics parameters required for cable moulding processing with constant pitch and also the interdependence value between them can be achieved according to the scheme presented in Fig. 2.

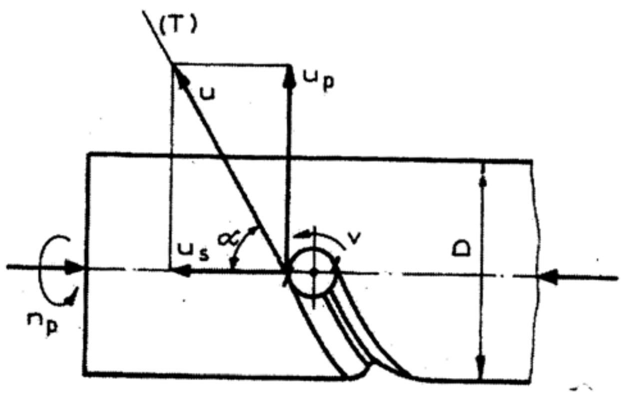

Fig.2.
The scheme for calculating the kinematics parameters required to generate the cable moulding with constant pitch

Generating a certain helical trajectories characterized by a normal pitch, an axial pitch and one front pitch, ordered after the propeller angle *α* and wound on a cylindrical surface with a defined value of the diameter (*D*) is possible by combining movements with values constant defined as:

• cylindrical work piece rotation n_p;

• manufacturing tool rotation for wood cutting, *v*;

• linear feed tool motion along the work piece.

These movements must have values well correlated with each other, as follows:

• the n_p work piece rotation should be correlated with the advance movement of the u_s tool so that at a work piece rotation the tool to move with an axial pitch;

• the work piece rotation together with the tool feed speed should provide a "virtual travel" speed of tool on the "*u*" processing path able to ensure the quality desired;

•the tool rotation speed must be related to its advance speed along the "*u*" trajectory so that the processing advance on a knife „u_z" to ensure the desired level of quality of processed surface.

Based on these observations and considering the scheme in Fig. 2 can be written as a kinematics condition:

$$u = \sqrt{\left(u_s^2 + u_p^2\right)} \text{ , (m/min)} \quad (8)$$

From the value correlation condition it can write:

$$u_s = u \cdot \cos\alpha \text{ , (m/min)} \quad (9)$$

and from the quality condition it can write:

$$u = \frac{u_z \cdot Z_s \cdot n_s}{1000} \text{ , (m/min)} \quad (10)$$

Combining relations (9) and (10) it can write:

$$u_s = \frac{u_z \cdot Z_s \cdot n_s}{1000} \cdot \cos\alpha \text{ , (m/min)} \quad (11)$$

Where:

- u_s – is the tool advance feed speed along the work piece (m/min);
- *u* – is the displacement speed of the tool on the processing trajectory as defined in the quality condition (10);
- u_z – is the advance on the blade at processing with the cutting tool, which is chosen according with the quality grade that must result from the flanks milling (mm);
- Z_s –is the cutting tool number of blades (pieces);
- n_s – is the processing tool speed (rot/min).

The feed speed u_s can be ranged between a maximum and a minimum value according to the quality grade and other participant parameters from the relation so that can be defined as:

$$u_{s\,min} = \frac{u_{z\,min} \cdot Z_s \cdot n_s}{1000} \cdot \cos\alpha_{max}$$, for the maximum quality

$$u_{s\,max} = \frac{u_{z\,max} \cdot Z_s \cdot n_s}{1000} \cdot \cos\alpha_{min}$$,

for the roughing

Defined like this the value range takes into consideration that the processing tool has a constant number of knives and a constant rotation speed.

Otherwise in the structure of the machine tools should be an element that can adjust the advance tool u_s values between the minimum and maximum.

If the tool displacement after the u_s direction is achieved by a screw motion characterized by an well defined $p_{Aș}$ axial pitch, then, the range of $n_ș$ speed rotation adjustment screw will be:

$$u_{s\,min} = p_{As} \cdot n_{s\,min} \Rightarrow n_{s\,min} = \frac{u_{s\,min}}{p_{As}}$$,

(rot/min)

$$u_{s\max} = p_{As} \cdot n_{s\max} \Rightarrow n_{s\max} = \frac{u_{s\max}}{p_{As}},$$

(rot/min)

So the element of the machine structure that will adjust feed speed u_s, will actually adjust the screw speed in the range of motion $n_{s\min} \rightarrow n_{s\max}$.

To match the advance of the tool with the work piece speed it starts from the scheme in Fig. 2, where it observes:

$$u_p = u \cdot \sin\alpha \text{ , (m/min)} \quad (14)$$

If it takes into account that „u_p" is actually the peripheral speed at the work piece surface given by:

$$u_p = \frac{\pi \cdot D \cdot n_p}{1000} \text{ , (m/min)} \quad (15)$$

Where:

- D is the diameter of the piece that is cable moulding processed,
- n_p – is the work piece speed rotation

Then, it can write (according to relations 14 and 15):

$$n_p = \frac{1000 \cdot u}{\pi \cdot D} \cdot \sin\alpha \text{ , (rot/min)} \quad (16)$$

If it is envisaged that for a certain quality "u" should be constant then it can say that work piece speed rotation should modify in the minimum-maximum range according to the values resulted by using the relations:

$$n_{p\min} = \frac{1000 \cdot u}{\pi \cdot D_{\max}} \cdot \sin\alpha_{\min} \text{ , (rot/min)}$$

$$n_{p\max} = \frac{1000 \cdot u}{\pi \cdot D_{\min}} \cdot \sin\alpha_{\max} \text{ , (rot/min)}$$

So the drive system of the piece must be provided with an element able to change the work piece speed rotation in the range $n_{p\min} \rightarrow n_{p\max}$, an element that must be reflected in the morphology of the tool-machine

To achieve the correlation between the work piece n_p speed rotation and u_s the linear advance of the tool is required as between the two rotation axes of the screw motion - piece to be a direct link through an element which takes into account the correlation between the screw motion speed and work piece speed rotation, so that at one work piece rotation, the tool moves with one axial pitch along the piece part of the cable moulding.

The functional link of parameters correlation is made through the relation

$$n_s \cdot p_{As} = n_p \cdot p_A \quad (18)$$

where:

n_s – is the screw speed rotation;

p_{As} – is the axial pitch of the screw motion

n_p – is the work piece speed rotation

p_A – is the axial pitch of the cable moulding

If the equation (18) is differently organized, results:

$$\frac{n_s}{n_p} = \frac{p_A}{p_{As}} = i \quad (19)$$

Where:

i - is the gear ratio that must be achieved between the two axes - the rotation of the screw motion and rotation of the work piece. (17) If it is envisaged that prior it said that tool and work piece speeds rotation may change in the minimum - maximum range then results:

$$i_{\max} = \frac{n_{s\max}}{n_{p\min}}$$

$$i_{\min} = \frac{n_{s\min}}{n_{p\max}}$$

(20)

So the element of machine tool structure located between the two axes of rotation (screw motion - work piece) should have an adjustable gear ratio in the minimum - maximum range, so an adjusting report:

$$R = \frac{i_{\max}}{i_{\min}} \quad (21)$$

Based on the presented issues it can conceive a general morphology of a cable moudling processing tool machine with the form given in Fig.3. from which it can be devise a scheme for a machine tool kinematics as that shown in Fig.4.

3. TOOLS MACHINE MORPHOLOGY

Morphology of tools- machinery that can provide the necessary processing kinematic parameters should include both moving sources and elements capable to transfer and modify the motion parameters of the required performance level.

A block diagram with the needed morphology of a tools- machine that could provide the cable moulding processing with constant pitch is presented in Fig.3

From the analysis of the structural elements of the general scheme shown in Fig.3, results the functional role of each one in the kinematic parameters insurance necessary for the cable moulding processing with constant pitch as follows:

1. is the motion source for the tool advance generation of the movement and rotation of the work piece subjected processing;
2. is what makes the characteristics of motion between the motion source and the axis of rotation of the motion screw (4), such as a mechanical variator;
3. is the transfer element of the movement with or without transformation between the structure elements (taking into account that the source of movement and variator generally are attached to the foundation and the screw motion around processing level);
4. motion screw that ensures „u_s” the advance movement of the manufacturing tool;
5. processing tool profile cutters type, with tail;
6. mobile table (support tool) of the machine;
7. motion source for the tool driving and to ensure the cutting speed in correlation with the tool diameter for wood milling cutting (may have a fixed or adjustable speed);
8. wood work piece subjected of processing;
9. transformation element of motion characteristics at the level of the screw axis n_s at the work piece level n_p based on a well established transmission ratio $\left(i = \frac{p_A}{p_{As}} \right)$
10. Inverting element - to change the direction of rotation of the work piece when it comes to processing cable mouldings with angle of inclination to the right or left.
11. index element – for cable mouldings working with multiple windings

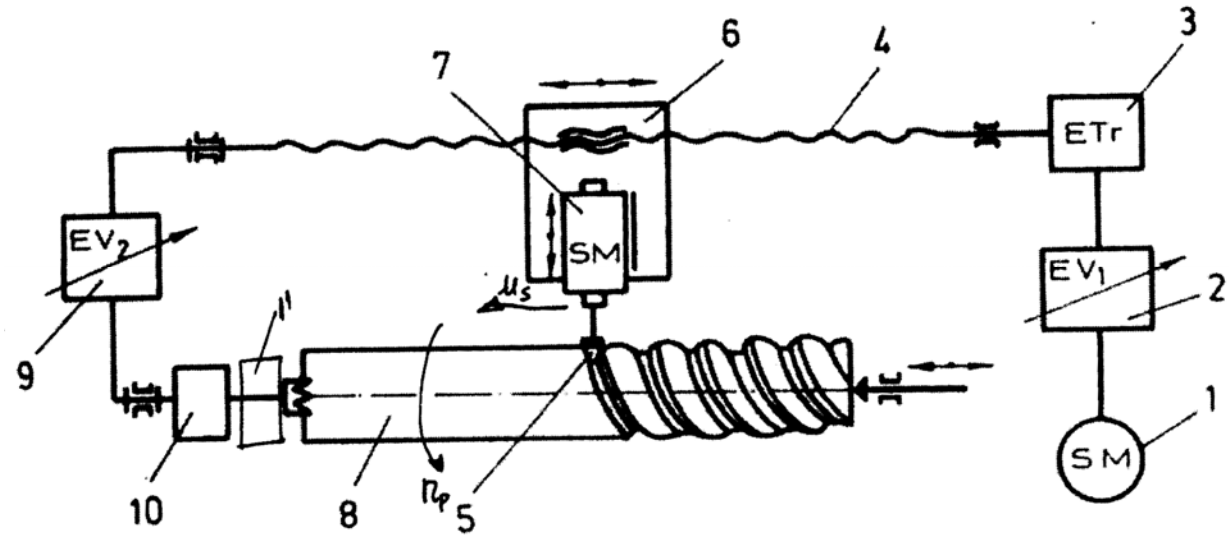

Fig.3.
The block scheme of the cable moulding processing machine with constant pitch

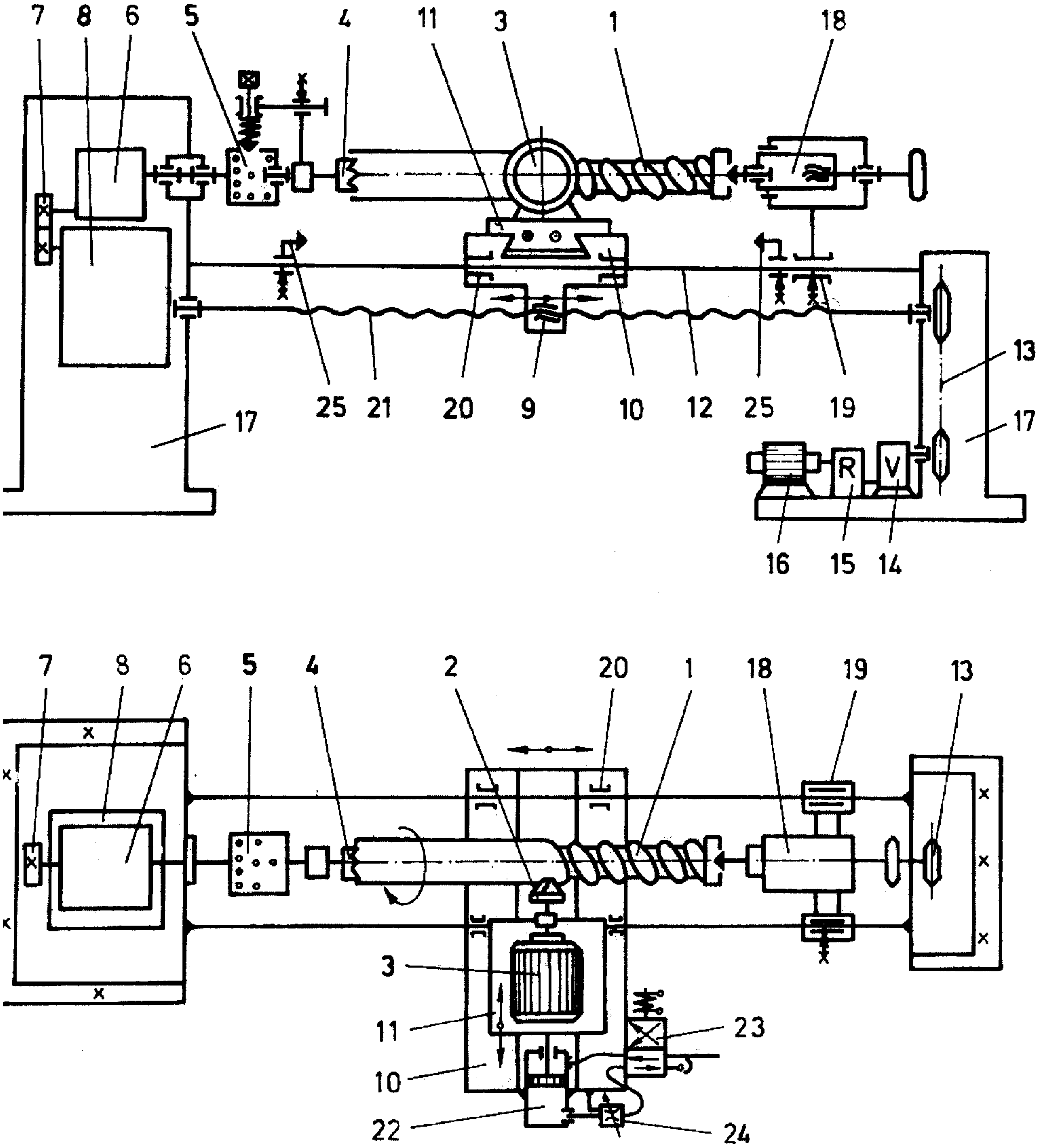

Fig.4.
The block scheme of the cable moulding processing machine with constant pitch (Var.II)

1 - piece that is processed, 2 - tool, 3 - electric motor, 4 - mounting and drive system, 5-division and indexing system, 6-reversing mechanism, 7-gear transmission, 8 - gear mechanism exchange (or gearbox), 9 - nut, 10 - work system support plate, 11 - tool support plate, 12 - cylindrical guide (rods) bar, 13 - chain drive, 14-continuously mechanical variable , 15 - reducer, 16 - electric motor, 17 - frame, 18 - fixing system, 19, 20 - Cylindrical guides; 21 - screw motion, 22 - pneumatic motor, 23 - distributor; 24 - throttle, 25 - end stops, 26 - pneumatic pipelines.

It should be mentioned that the 2 (EV1) elements has the decisive role in establishing the quality of processing. This element provides travel speed change *"u"* of the tool on helical path of the work piece, the element 9 (EV2) controls ($p_A = i \cdot p_{As}$)the size of axial pitch of cable moulding.

The block diagram shown in Fig.3 was translated into a more explicit kinematics scheme, shown in Fig.4. more suggestive and very close to reality, thus justifying the need for structural elements involved in the transfer or change of motion.

4. CONCLUSIONS

Type cable moudling ornaments processing with constant pitch impose a range of technical and technological conditions, namely:

- correlation with the values of geometric design ($D, \alpha, Z_î, p_N, p_A, p_F$);
- ensure kinematics correlation between:
  - tool feed speed u_s, along the work piece and work piece speed rotation n_p;
  - tool feed speed u_s, along the work piece and speed peripheral of work piece „u_p" to get the speed *"u"* on the trajectory that defines the angle α and the surface quality
  - speed rotation screw motion n_s and speed rotation work piece that defines the axial pitch value of the cable moudling winding;
  - speed rotation screw motion n_s and feed speed u_s along the work piece tool;
  - cutting tool speed rotation and its cutting speed through the minimum diameter of tool („*a*").

Ensure of dimensional correlation of geometry elements by referencing kinematics elements requires careful and laborious study and functional and well-defined structures of machine tools in terms of features and control areas of each structural element.

Element 9 (EV2) of general structure (Fig. 3) should be able to control the transmission ratio between the axis of rotation of the screw axis motion and rotation adjustment work piece but the ratio adjustment must remain strictly constant throughout processing of that cable moudling.

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