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KINEMATICAL PARTICULARITIES IN PROCESSING THE CONSTANT AND VARIABLE LAY-UP TORSADES

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Rezumat. *Lucrarea de faţă prezintă câteva elemente referitoare la cinematica fabricării torsadelor cu pas constant şi variabil şi diferenţele care există la procesarea lor. Studiile cinematice obligă utilizarea unei anumite structurii morfologice pentru maşinile unelte care prelucrează aceste tipuri de ornamente, demonstrând existenţa în structură a unor elemente prin care să se poată realiza şi regla parametrii necesari prelucrării. Lucrarea a reuşit să prezinte această legătură ce trebuie realizată între geometria elementului (parametrii geometrici), cinematica generării ornamentului (parametrii cinematici) şi structura necesară a lanţurilor cinematice).*

Abstract. *This paper aims at presenting a few elements related to the kinematics of the torsade processing, as well as the differences existing between the processing of the constant lay-up torsades and the one of the variable lay-up torsades. Furthermore, the analysis of the processing kinematics also shows the obligation to include in the kinematical morphology of the machine-tools processing such ornaments, several compulsory structural elements, for which the basic functional parameters are defined. A demonstration is thereby made of the connection between the kinematical parameters of the processing, and the structure of the kinematical chains in the machine-tools by which these parameters are generated, parameters which are necessary to the processing, depending on the conditions in which the actual processing must be conducted.*

Keywords: torsade, axial lay-up, advance speed

1. General elements

The torsades at a constant or variable lay-up are ornamental elements of the furniture, the purpose of which is to decorate furniture pieces. They are helical-shaped windings, placed on revolution surfaces of a cylindrical, tapered, paraboloid, conoid or spherical form (see fig. 1). The “nervures” have different profiles in a normal section, in tune with the ornamentics of the consecrated historical style in which the piece or set of furniture was designed.

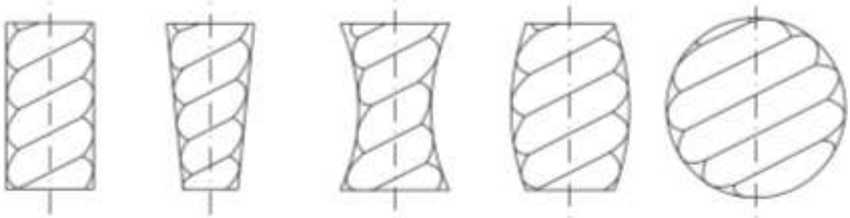

Fig. 1. Ornamental forms of torsade type.

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The axial lay-up of the torsades – the distance between two adjoining windings of the torsades - may be constant (for the cylindrical ones) or variable (for the other forms) and it confers an aesthetic proportionality, together with the diameter of the arrangement [1, 2].

These types of ornaments (created ever since Antiquity) "introduce motion" in the furniture ornamentics, inducing the sensation of restlessness, vigour, ascension, etc. Nowadays, but also formerly, the problem has been raised to simplify by mechanization the processing of these types of ornaments.

By manual processing, much workmanship is being consumed, and the ornaments are not rigorously identical, so as to solve the problem of interchangeability in the case of serial production; therefore, it is necessary to develop the theoretical study on the possibilities of combining the movements of the tool-piece (both as types of movements and as specific values) so that torsades at a constant or variable lay-up might be generated, according to the product designer's proposals. The difficulty in processing these ornaments has always been and still is, even nowadays, a hindrance in manufacturing and appearing on the furniture market with such ornaments.

2. Elements from the kinematics of the constant-lay-up-torsade processing

The torsade at a constant lay-up (see fig. 2) results from combining the translational motion of a cutting tool (of cherry type – which is in rotation).

The translational motion of the tool *U*L combines with the rotary motion of the piece *U*T (transversal motion) so that the processing tool should eventually cover and trace on the processed piece 2, a helix characterized by a constant axial lay-up and a profile introduced by the profile shape of the processing tool.

A kinematical structure was designed (in figure 2) with a view to facilitating this combination of movements. The movement is introduced by a motion screw (*n*ş) which moves the table on which the beam 6 with the processing tool 1 is fixed. Also from the motion screw 4, the movement is transferred to the rotation axis of piece 1 by structural elements (still undefined – but as mechanical transmissions).

The dimensional correlation between the motion introduced by the screw *n*ş and the rotation of the piece *n*p constitutes the motivation of the study to be conducted [2, 3].

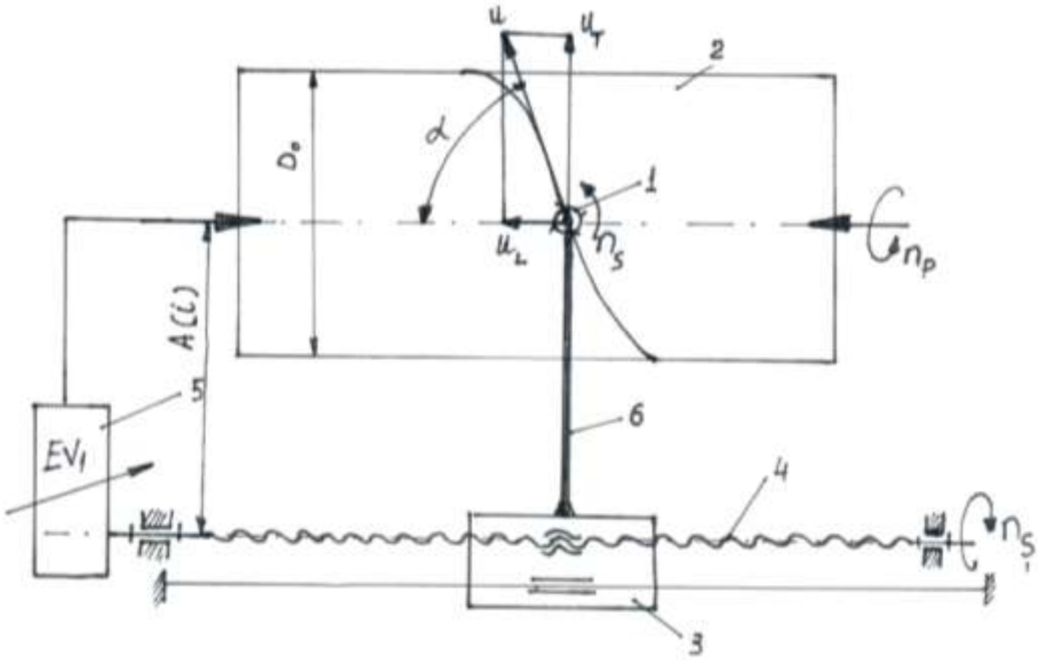

Fig. 2. Scheme for Kinematics parameters calculus of the constant-lay-up-torsade processing.

On the scheme in figure 2, the following elements were considered:

* ***u*** = advance speed along the processed helical trajectory, which is defined from the condition for achieving the quality of the processed surfaces, which should be tangentially oriented to the trajectory:

$$u = \frac{u_z \cdot z_s \cdot n_s}{60 \cdot 1000} \; [m/min] \tag{1}$$

where:

- u_z – is the advance on the cutter plate of the tool – which is chosen from the condition of obtaining a certain quality class of the surface to be processed (implicitly of a rugosity – imposed);
- z_s – number of cutter plates of the cutting tool;
- n_s – rotative speed of the processing tool [rot/min] - in the construction of the machine

* $\mathbf{u_L}$ - is the advance speed of the tool along the processed piece, made by the tool support (driven by the motion screw):

$U_L = u \cdot \cos\alpha$, α being the inclination angle of the torsade:

$$U_L = \frac{u_z \cdot z_s \cdot n_s}{60 \cdot 1000} \cos\alpha \; [m/min] \tag{2}$$

* $\mathbf{u_T}$ - is the transversal (advance) speed, introduced by the piece to be driven in rotation (n_p) from the motion screw, through the kinematical structure which will be introduced between the rotation axis of the motion screw and the rotation axis of the processed piece, the piece having the diameter D_0, on which the processing is made:

$$U_T = u \cdot sin\,\alpha = \frac{\pi \cdot D_0 \cdot n_p}{60 \cdot 1000}\,[m/min] \tag{3}$$

$$U_T = \frac{u_z . z_s . n_s}{60 \cdot 1000} \sin\alpha$$

From the analysis of the two equations defining the same parameter, it follows

$$\frac{u_z . z_s . n_s}{60 \cdot 1000} \sin\alpha = \frac{\pi \cdot D_0 \cdot n_p}{60 \cdot 1000} \ ,$$

which, by another arrangement, leads to:

$$n_p = \frac{u_z . z_s . n_s}{\pi \cdot D_0} \sin\alpha \tag{4}$$

It results thereby the mathematical law of defining a basic kinematical feature of the processing system, namely the rotative speed to be provided for the processed piece, so that the resulted surface of the torsades should meet the qualitative conditions imposed by „u_z" and with the angle α (constant angle on the entire length of the respective piece – which is processed). Depending on the "necessary rotative speed" of the piece n_p, resulted by calculation, the rotative speed of the motion screw can be determined, defining a basic characteristic of the kinematic structure situated between the axis of the motion screw and the axis of the piece, to wit the defining the gear reduction rate:

$$i = \frac{n_ș}{n_p} \text{ respectively, } n_ș = i \cdot n_p \tag{5}$$

The gear reduction rate i of the kinematical structure has a constant value throughout the processing of a piece with D_0 = ct and α = ct, yet it depends (by means of the rotative speed of the piece n_p) on the angle α, this imposing on the kinematical structure, the obligation of an adjustable gear reduction rate, $i = f(\alpha)$, which must be made by the structural element EV_1 of variators type [2,3].

If the geometrical elements of the motion screw ($p_{Aș}$) – and the axial lay-up of the screw – and the axial lay-up of the torsade p_{AT} are considered, then as it follows:

$u_L = n_p \cdot p_{AT} = n_s \cdot p_{As}$, wherefrom

$$\frac{n_s}{n_p} = i = \frac{p_{AT}}{p_{As}}, \quad (6)$$

which means the gear reduction rate „i" to be achieved by the kinematical structure must be equal to the ratio between the axial lay-ups of the torsade and of the motion screw. Defining the gear reduction rate must also consider the maximal variation range imposed by the values of the angle α, which may be used in design, between α_{min} and α_{max}.

$$i = \frac{n_s}{n_p} = \frac{n_s}{\frac{u_Z \cdot z_S \cdot n_S}{\pi \cdot D_0} \sin \alpha} = \frac{\pi \cdot D_0 \cdot n_s}{u_Z \cdot z_S \cdot n_S \cdot \sin \alpha} \quad (7)$$

From the analysis of the relation (7) of dependence of the gear reduction rate and the angle α, it follows:

$$i_{min} = \frac{\pi \cdot D_0 \cdot n_s}{u_Z \cdot z_S \cdot n_S \cdot \sin \alpha_{max}} \text{ and } i_{max} = \frac{\pi \cdot D_0 \cdot n_s}{u_Z \cdot z_S \cdot n_S \cdot \sin \alpha_{min}}$$

for $\alpha \neq 0$. The variation range of the gear reduction rate of the kinematical structure i_{min} and i_{max} is the functional characteristic of the element EV_2 which must be integrated in the kinematical structure of the machine-tool.

3. Elements from the kinematics of the variable-lay-up-torsade processing

Processing variable lay-up torsades entails a higher level of difficulty, due to the aesthetical correlation to be achieved, to wit the axial lay-up of the torsade will be variable along the length of the processed piece and proportional with the diameter on which it is measured (and achieved), given that variable lay-up torsades have spatial forms with a variable diameter along their length. In this case, the kinematical structure analysed in processing constant lay-up torsades is not usable; likewise, a thorough study by the kinematics of the variable-lay-up-torsade processing being required, using a scheme shown in fig. 3.

The starting point was the scheme specific to the constant lay-up-torsade processing (see fig. 2.) to which, in anticipation, two elements (EV_2 and ECP) were added, by which an intervention could be made on the gear reduction rate between the rotation axis of the motion screw and the rotation axis of the piece, which can no longer be constant, because the processing diameter D_x is no longer constant.

In this case, the element EV_2 should complementarily interfere in the modification of the total reduction rate, depending on the position „*X*" of processing, read and signalled by ECP – the element for reading the operating position.

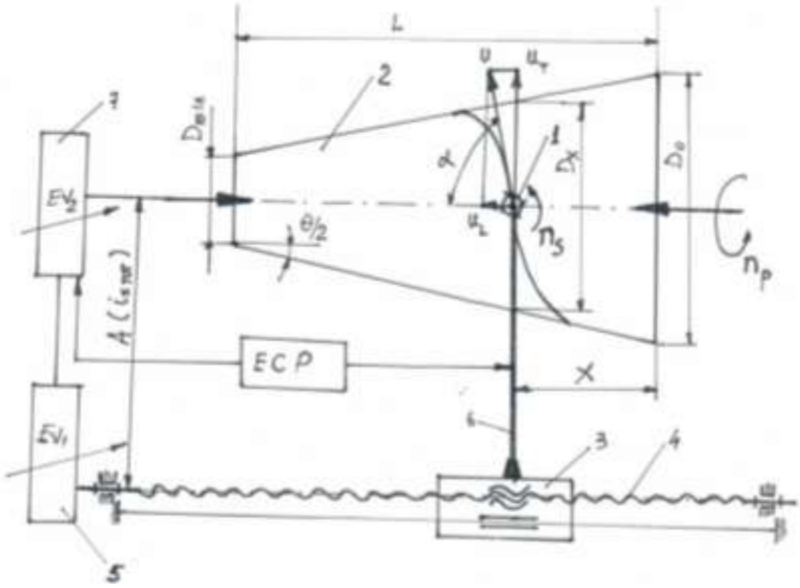

Fig. 3. Scheme for Kinematics parameters calculus of the variable-lay-up-torsade processing

On the scheme in figure 3, the following were considered:

$$* u = \frac{u_z . z_s . n_s}{60 \cdot 1000} [m/min] = ct$$

as being the advance speed for providing the processing along the trajectory (tapered helical):

$$*U_L = u \cdot \cos\alpha = \frac{u_z . z_s . n_s}{60 \cdot 1000} \cos\alpha \ [m/min] = ct \text{ for } \alpha = ct$$

is the advance speed of the processing tool, along the processed piece;

$$* U_T = u \cdot sin\,\alpha = \frac{\pi \cdot D_x \cdot n_{px}}{60 \cdot 1000} = \frac{u_z . z_s . n_s}{60 \cdot 1000} \sin\alpha,$$

where the terms have the same significations as for the constant lay-up torsades;

D_x is the "instantaneous" processing diameter, situated at „*x*" distance against D_0.

By rearranging both of them in equations specific to U_L it follows:

$$n_{px} = \frac{u_z . z_s . n_s}{\pi \cdot D_x} \sin\alpha, \quad (8)$$

If it is considered (from figure 3) that $D_x = D_0 - 2xtg\frac{\theta}{2}$, then it follows:

$$n_{px} = \frac{u_Z . z_S . n_S}{\pi \ (D_0 - 2xtg\frac{\theta}{2})} \sin\alpha, \tag{8'}$$

where it is apparent that the rotative speed of the piece is no longer a constant, but a variable, throughout the processing, depending on the position "*x*" of processing

$$n_{px} = f(x) \tag{9}$$

The relation (9) proves that throughout the processing, the gear reduction rate between the rotation axis of the motion screw and the rotation axis of the piece is no longer a constant, but it is a variable, along the piece, depending on the operating position „*x*".

If a constant lay-up torsade (at the diameter D_0) were processed, then the gear reduction rate would be a constant "*i*". In this case, the total gear reduction rate may be written as:

$$i_{x_{TOT}} = i \cdot i_x \tag{10}$$

where "i"- is the "initial processing ratio", as if a constant lay-up torsade, with the diameter D_0, introduced by EV_1 were processed;
i_x- is the complementary gear reduction rate, due to the modification of the working diameter ($D_x \neq D_0$), introduced by EV_2, by reading the value $D_x \neq ct.$, specific to the position „*x*" of processing.

If there is considered that, at the beginning of the processing $n_{px} = n_{p0}$ for $x = 0$ it follows:
$i_{TOT} = i$, in this case $i_x = 1$, which means the complementary gear reduction rate (in the beginning of the processing, at x = 0) will have the value "1". If it is written:

$$i_{TOTx} = \frac{n_S}{n_{px}} = i \cdot i_x = \frac{n_S}{n_{po}} \cdot i_x,$$

then it follows:

$$i_x = \frac{n_{po}}{n_{px}}, \tag{11}$$

$$i_x = \frac{\frac{u_Z . z_S . n_S}{\pi \cdot D_0}\sin\alpha}{\frac{u_Z . z_S . n_S}{\pi \cdot D_x}\sin\alpha} = \frac{D_x}{D_0} = \frac{D_0 - 2xtg\frac{\theta}{2}}{D_0},$$

$$i_x = 1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x, \tag{12}$$

which is the variation law of the complementary gear reduction rate to be introduced in the mechanical structure by EV$_2$, depending on the position "*x*" of processing, so that it might follow permanently $i_x = f(x)$ and implicitly.

$$i_{TOTx} = i \cdot i_x = i\left(1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x\right),$$

$$i_{TOTx} = i\left(1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x\right), \qquad (13)$$

which is the variation law of the gear reduction rate (along) the processed piece, depending on the position "*x*" of processing. It is noticeable that for $x = 0$ it follows $i_{TOTx} = i$ namely it would be the necessary ratio if a constant lay-up torsade $D_0 = ct.$ were processed. If there is considered that the complementary gear reduction rate i_x can be written as:

$$i_x = \frac{n_ş}{n_{px}} \text{ it follows } n_{px} = \frac{n_ş}{i_x},$$

or in extenso:

$$n_{px} = \frac{n_ş}{i\left(1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x\right)} \qquad (14)$$

If we consider the defining relation of the ratio „i" from the kinematics of the constant lay-up torsade, as shown in relation (7) then the general relation for the calculation of the total gear reduction rate will be:

$$i_{TOTx} = i \cdot i_x = i\left(1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x\right) = \frac{\pi \cdot D_0 \cdot n_ş}{u_z . z_s . n_s \sin\alpha}\left(1 - \frac{2tg\frac{\theta}{2}}{D_0} \cdot x\right)$$

This proving that: $i_{TOTx} = f(\alpha, x)$.

Hence for a torsade characterized by α = ct $i_{TOTx} = f(x)$.

However, as in the design, torsades with a different α from one case to another can be conceived, this means the kinematical structure should have the possibility:

- to adjust $-i = f(\alpha_{min}, \alpha_{max})$ and
- to adjust $i_x = f(0, L)$ for $0 \leq x \leq L$

This observation proves that between the geometrical axes of the motion screw and of the processed piece, there should be two adjusting elements for the total gear reduction rate, by the independent adjustment of the two partial gear reduction rates $i \rightarrow$ depending on the angle α of the torsade, and i_x depending on the operating position *x*, according to the relations (7) and (12).

Conclusions

The elements from both constant and variable lay-up-torsade processing have led to particularly important conclusions for defining the functional characteristics of “some portions” in the kinematical schemes of the machine-tools, which might be designed for such processing.

Processing these types of ornaments, for use in decorating the pieces of furniture, and also for making interior decorations (floor standard lamps, pendant fittings, support pillars for flowers or statues), raises technical problems due to the kinematical combinations of the required movements. The situation is even more complicated, especially when the problem arises for the kinematical parameters participative in the processing to be variable in time, or variable along the processed pieces.

As a general methodology for defining the kinematical structures of the machine-tools which make complex processing, it is required to perform a very careful kinematical analysis of the issues related to processing, to combining movements, to defining structural elements, to describing trajectories, etc.

The final form of the kinematical structures is obtained by “assembling” the partial structures resulted from differentiated studies, as in the present paper.

R E F E R E N C E S

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