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CORRELATION GEOMETRY-PARAMETERS ON THE DESIGN OF CONSTANT PITCH SPIRAL-TURNED ORNAMENTS

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Rezumat. *Ornamentele de tip torsadă, utilizate în decorarea pieselor de mobilier necesită un studiu aparte din punct de vedere al geometriei lor, de corelare a elementelor geometrice în aşa fel încât să asigure o estetică adecvată atât pentru reperul pe care îl decorează, cât şi pentru produsul de mobilier ca ansamblu. Modificarea unui singur parametru geometric, din condiţii impuse de execuţie estetică, poate duce în mod implicit la o recorelare a tuturor celorlalţi parametri, pentru a păstra interdependenţa lor geometrică. Lucrarea îşi propune să prezinte aceste posibilităţi de recorelare a parametrilor geometrici încă din faza de proiectare a torsadelor, proiectare ce trebuie realizată pe baza unui algoritm bine definit. Algoritmul stabilit în lucrarea de faţă, privind proiectarea şi recorelarea parametrial–geometrică la torsadele cu pas constant, asigură condiţiile optime de menţinere a esteticii ornamentului la nivelul concepţiei iniţiale de către proiectantul de produs. Recorelarea parametrial–geometrică are la bază o metodă analitico-grafică aşa cum se prezintă în lucrare.*

Abstract. *Spiral-turned ornaments used in the decoration of furniture requires a special study in terms of their geometry, for correlating the geometrical elements in such a way as to ensure an adequate aesthetic shape, both of the decorated part, as well as of the furniture as a whole. When change a single geometric parameter imposed by the aesthetic execution, a re-correlation of all other parameters occurs, in order to fulfil their geometric dependence. This paper aims to present the possibilities of re-correlating the geometrical parameters from the design phase of the spiral-turned parts, design to be performed based on a well-defined algorithm. The algorithm established in this paper with regard to the design and the re-correlation of the parameters – in case of constant pitch spiral-turned ornaments – ensures the optimal conditions for maintaining the aesthetics of ornament as in the original concept of the product designer. Re-correlation of geometry and parameters is based on an analytical and graphic method, as shown in the paper.*

Keywords: spiral-turned ornament, pitch, tilting angle, dynamism

1. Introduction

Spiral-turned ornaments are helical windings processed on cylindrical, conical, hyperboloid, parabolic or spherical elements. The section of the wounded element

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might be semi-cylindrical shape, elliptical, ogive or complex shapes, as shown in Fig. 1. The spiral-turned ornaments are found in decorative arts from ancient times when they were used to decorate columns of the Egyptian and Roman temples, giving the building a sense of movement itself, exaltation and dynamism. (Fig. 1).

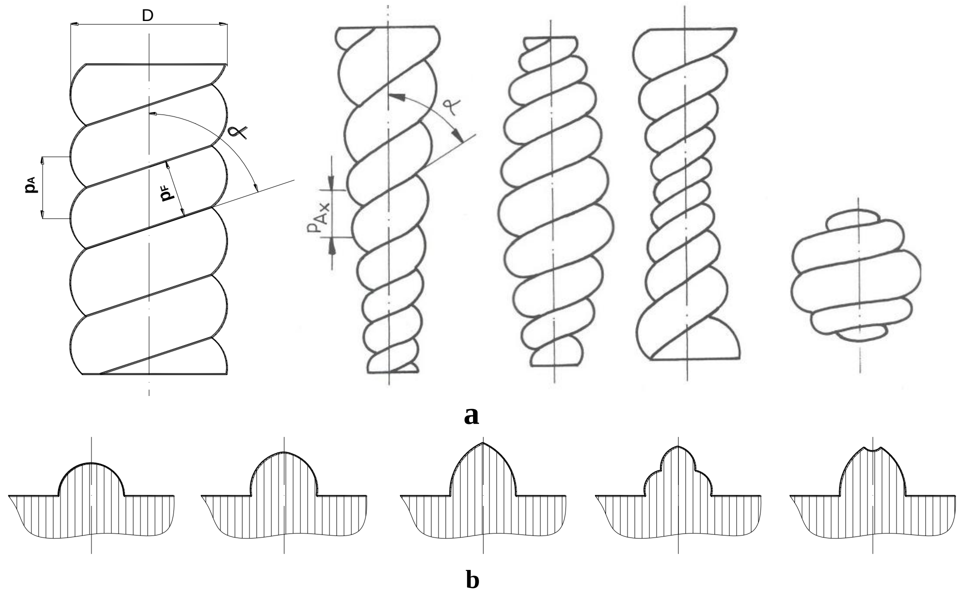


Fig. 1. Spiral-turned ornaments;
a – shapes of winding with constant or variable pitches; b- shape of sections.

Spiral-turned ornaments were taken from decorative aesthetics of the building and transferred to the furniture, in order to decorate it.

Over time, architects and designers have included this ornament into the furniture decorative art, using it to decorate furniture of high aesthetic value, given the technical difficulty of obtaining ornament and especially its reproducibility for identical components of furniture or sets of furniture. Spiral-turned ornament can be found in the decoration of the furniture designed and made in English and Renaissance styles (France, Italy).

Generally, this ornaments decorates the vertical parts of furniture (feet, moldings, pillars, balusters, columns canopy etc.), thus giving the furniture a special value through the sensation of movement and dynamism. Spiral-turned ornaments are characterized by two important geometric elements: pitch (*p*) and the angle of inclination (α).

The pitch is the geometric element measured between two adjacent windings. Depending on the basic shape of the spiral-turned parts of the furniture, the pitch can have a constant value (in the case of cylindrical shape) or variable value (in the case of conical elements, parabolic, bi-parabolic or spherical ones).

Aesthetics of ornament requires a dimensional proportion between the pitch and the diameter (D) of the part, so to like it. There are no rigorous studies to define this proportionality.

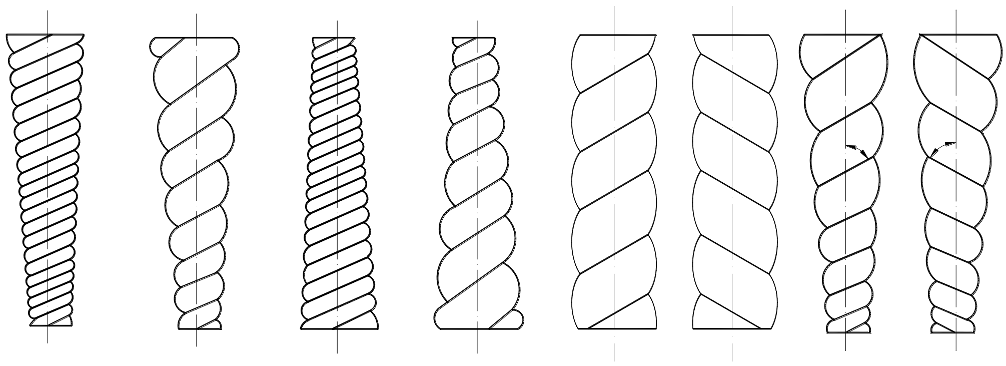
It should be mentioned, however, that small values of the pitch give a finesse appearance of the object, whilst the high value of the pitch gives the image of solidity, robustness, etc.

Proportionality between the pitch and the diameter of the decorated furniture part must be considered as an integrated ornament in the general aesthetics of the product (not just of the decorated part), ensuring the dynamism and the constructive robustness of the general functional assembly.

When the winding is made on non-cylindrical elements, the variable pitch (p_x) must be proportional to the variable diameter (D_x) all along the piece, to provide aesthetic value of ornament in conjunction with the proportion rules, as widely used in furniture decoration as symmetry rules are.

The variable pitch correlated with the diameter of the part, accentuates the sensation of movement (from one end to the other of the furniture part).

Winding angle is the one that creates the dynamism of the ornament. Small winding angles (30° to 40°) creates the sensation of speed, restlessness, rapid ascent, while larger winding angles (45° to 60°) provides stability, calm and peace (Fig. 2a).



a. **b.**

Fig. 2. Influence of the inclination angle upon the "dynamism" of the ornament and "stability" of the product.

a. ornaments with variable and constant pitch. **b.** symmetrical ornaments.

Both in the case of constant and variable pitch of the spiral-turned parts, the "stability" sensation given by the piece of furniture requires that the symmetric parts (in the front of the product) to have oriented reverse winding angles ($\propto$) (Fig. 2b).

Given these restrictions imposed in the decoration of furniture parts, these ornaments require a design able to meet the mentioned rules. The geometry of the spiral-turned ornaments with constant and variable pitch should take account of:

- The size of the decorated parts of the furniture, the dimensions that must result from the calculations of the strength or of the volume proportions to be achieved in the product assembly furniture;
- General forms of the decorated parts of the furniture (cylindrical, conical) and elements that define the geometry (diameter, taper, length);
- The dynamism the product has to have (which will be materialized by the angle of inclination) and its stability, solidity and smoothness (which will be materialized by the winding pitch size);
- Compliance with the artistic style of furniture addressed in the design and manufacture - which will be achieved by the used profile.

All these elements must be taken into account by the architect or design engineer to define the correct geometry of ornamental elements, strictly necessary for mechanical processing.

2. The geometry of constant pitch spiral-turned ornaments

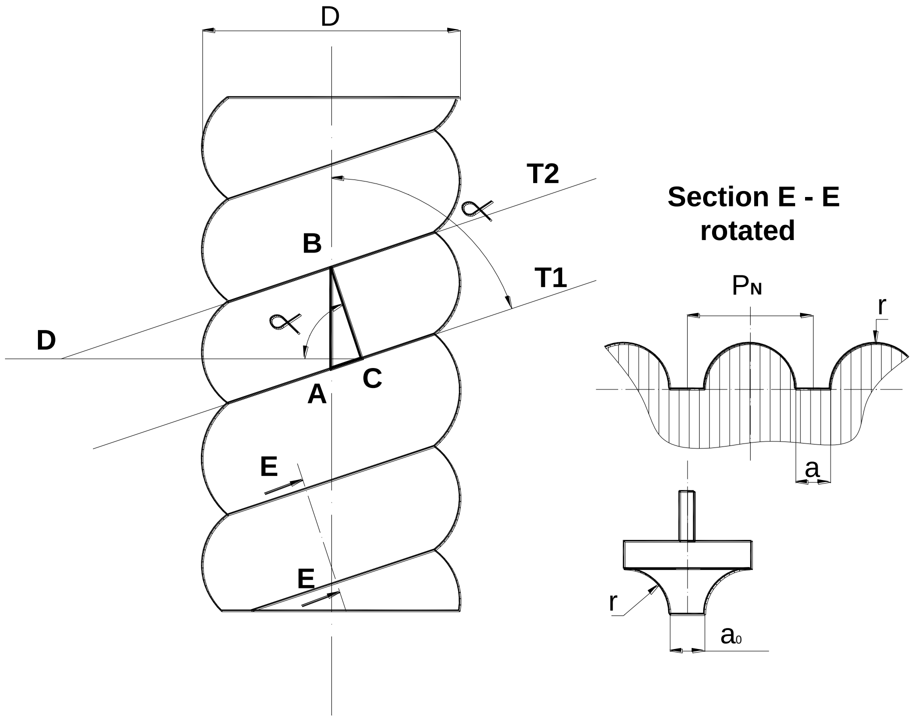


Fig. 3. The geometrical elements of the spiral-turned ornament with constant pitch.

Design of the spiral-turned parts with constant pitch, requires the compliance with rules and the correlation between the geometric elements of these ornaments:

- The existence of the proportionality between the dimensions of the cylindrical parts (*D*) and the pitch, thereby ensuring the proportionality of the decoration;
- Correct choice of winding angle ($\propto$), which impose the dynamism of the ornament used to decorate the pieces of furniture;
- Correlation between the front pitch, normal pitch and axial one, in order to establish the kinematic parameters that describe the helical trajectory during processing.

In general, the diameter of the decorated furniture parts is a result of strength calculations or the results of volumes or dimensional proportions to be achieved in the product design phase, so that the assembly to be liked.
The base of defining the correlation between the geometric elements of the spiral-turned ornaments is presented in Fig. 3, where the following notations have been made:
- T_1 and T_2 – planes perpendicular to winding axis, tangent at the inflection points of the ribs of the points A and B;

- *D* - diameter that corresponds to the initial diameter of the cylindrical part to be processed;

- P_N - *BC* – the normal pitch of the spiral measured between T1 and T2 planes went through homologous points of adjacent windings;

- P_A - *AB* – axial pitch of the spiral, measured in a plane containing the axis and measured between homologous points of adjacent winding;

- P_F - *CD* – front pitch of the spiral measured in a plane perpendicular (transverse) to the axis, measured between homologous points of adjacent windings;

- $\propto$ - inclination angle of the spiral measured between the plane containing the axis and the plane tangent to the winding trajectory;

- *r* - radius of the rib of the spiral profile;

- *a* - distance between two adjacent windings measured at their basis;

- E- E - normal plane to the winding of the ornament.

The proportion used in the ornamentation needs a constant geometry to be fulfilled throughout the entire length of a spiral-turned part. In this case, the equations 1 are valid.

$$\frac{p_F}{D} = ct.; \ \frac{p_A}{D} = ct. \frac{p_N}{D} = ct. \qquad (1)$$

The element that defines the proportionality is the front pitch, calculated with equation 2.

$$p_F = \frac{\pi \cdot D}{Z_i} \tag{2}$$

Where Z_i is the number of parallel windings that are to be achieved in processing and depends on the "effect" the ornament offers (small pitch equal finesse, order and big ones equal robustness, strength, force) together with its proportionality.

Another element that can be defined (or imposed by choosing the tool processing) is p_N, which can be calculated with equation 3:

$$p_N = 2r + a \tag{3}$$

Where:

- r is the radius of the tool reflected on the cutter;

- a is the distance between the flanks of the two windings area (at the basis), which can be defined directly by the processing tool where $a \equiv a_0$ or by design, when $a > a_0$.

Analysing the drawing in Fig. 3, the following remarks are to be made:

In the triangle ΔABC:

$$BC = AB \sin\alpha,\ \text{namely}\ \ p_N = p_A \sin\alpha,\ \text{or}\ \ p_A = \frac{p_N}{\sin\alpha} = \frac{2r+a}{\sin\alpha} \tag{4}$$

In the triangle ΔBCD:

$$BC = CD\cos\alpha,\ \text{namely}\ \ p_N = p_F\cos\alpha,\ \text{or}\ \ p_F = \frac{p_N}{\cos\alpha} = \frac{2r+a}{\cos\alpha} \tag{5}$$

Taking into account the equations 2 and 5, then equation 6 can be written.

$$p_F = \frac{p_N}{\cos\alpha} = \frac{2r+a}{\cos\alpha} = \frac{\pi D}{Z_i},\ or\ \ Z_i = \frac{\pi D\cos\alpha}{p_N} = \frac{\pi D\cos\alpha}{2r+a} \tag{6}$$

So, analysing the relation (6) it is noticed that the number of beginnings (windings) of spiral-turned ornament depend on the manufacturing tool (characterized by r), the aesthetic function (characterized by r and a), the workpiece diameter (D) and the angle of winding and must always be an integer number.

The element of flexibility into the calculation is the distance a between the wings, correlated according to equation 6.

On the basis of the issues presented above, an algorithm of designing the spiral-turned ornaments with constant pitch can be released, based on the following input data:

- Defining the diameter (*D*) of the decorated ornament;
- Defining the winding angle (α) as a solution of *dynamism* in decoration;
- Selection of the manufacturing tool defined by the radius *r* of the profile of the winding;
- Defining the distance (a) between the adjacent winding flanks**:**

  $a = a_0$ - processing is performed by a single phase;

  $a > a_0$ - processing is performed by two or more phases;

  $a_0 < a \le 2a_0$ – processing by two passes,

  $a > 2a_0$ – processing by multiple phases.
- Calculus of the normal pitch (equation 2)**:**

  $$p_N = 2r + a$$
- Calculus of the axial pitch (equation 4)**:**

  $$p_A = \frac{p_N}{\sin\alpha} = \frac{2r + a}{\sin\alpha}$$
- Calculus of the frontal pitch (equation 5):

  $$p_F = \frac{p_N}{\cos\alpha} = \frac{2r + a}{\cos\alpha}$$
- Calculus of the number of parallel windings (equation 6):

  $$Z_i = \frac{\pi D}{p_F} = \frac{\pi D \cos\alpha}{2r + a}$$
- Rounding the number of beginnings to the nearest integer value:

  $$Z_i \rightarrow Z_{i_R}$$
- Correlating geometrical parameters:

  - by adjusting the angle $\propto$;

  $$\propto_R = \arccos\left[\frac{Z_{i_R}\cdot(2r+a)}{\pi D}\right] \qquad (7)$$

  - or by adjusting the normal pitch:

  $$p_{N_R} = \frac{\pi D \cos\alpha}{Z_{i_R}} = 2r + a \qquad (8)$$

- by choosing another manufacturing tool and keeping the distance *a* characterized by $r_R \neq r$, where:

$$r_R = \frac{1}{2}\left(\frac{\pi D \cos\alpha}{Z_{i_R}} - a\right) \qquad (9)$$

- by maintaining the manufacturing tool (radius r) and changing the distance *a* between flanks: $$a_R = \frac{\pi D \cos\alpha}{z_{iR}} - 2r \qquad (10)$$

and the value a_R must be correlated with a_0 specific to the tool, as follows: $a_R < a_0$ in the variants $a_0 < a \le 2a_0$ and $a > 2a_0$.

- or by adjusting the diameter (D) of the decorated part:

$$D_R = \frac{p_N \cdot z_{iR}}{\pi \cdot \cos\alpha} = \frac{(2r+a)\cdot z_{iR}}{\pi \cos\alpha} \qquad (11)$$

Analysing the algorithm of designing the spiral-turned ornaments it was noticed that by rounding the number of beginnings at the nearest integer value Z_{iR}, the re-correlation geometry- parameters is needed to be done, as follows:

-by keeping the tool and the distance between the flanks ($2r + a$) and of the diameter of the decorated part (D) and changing the angle ($\propto \rightarrow \propto_R$), which may lead to changes in the effect of motion created by ornament, obliging in modifying the angle of inclination in the drawing. Comparing the dynamism of the ornament with the original design (the initial one), this measure of re-correlation might be accepted or rejected;

- by keeping the inclination angle $\propto$, the diameter D and the distance between the wings a, and changing the tool radius to r_R, which is a measure that impose the changing of the tool. This measure can be applied rarely, due to the fact that it requires new costs of design and execution, so the measure can be implemented only with additional time and costs;

- by keeping the inclination angle $\propto$, the tool r and the diameter D and modifying the distance between the wings to a_R., Modifying the distance from a to a_R can lead to changes in aesthetics, thus imposing the scale restoration of the ornament drawing, the aesthetic analysis and the acceptance or rejection of the re-correlation measure;

- by keeping the $\propto$ angle, the r tool and the distance a between the flanks, and recalculating the diameter to D_R value. This measure could lead to loss of balance or proportionality between volumes and dimensions, and could result in the acceptance or rejection of the measure re-correlation.

In general, in order to simplify the design and to not affect the aesthetic of the ornament initially imposed by rounding the number of beginnings to the nearest integer value, it is recommended for the re-correlation:

- to recalculate the distance between the flanks to a_R, or
- to recalculate the diameter D_R.

The differences of the values resulted from recalculations do not affect the aesthetic of the ornament, these differences being very small.

Conclusions

The design of the constant pitch spiral-turned ornaments (processed on cylindrical elements) involves the development of dimensional correlations between the geometry and parameters, so to ensure:

- Proportionality between the workpiece diameter and the elements of the ornament;

- Proportionality of the volumes in the furniture structure;

- Aesthetic of ornament by linking the dimensions of the winding with distance between flanks;

- The effect of dynamism created by ornament in furniture product;

- Stability, solidity and finesse that should be induced by the ornament in the structure of part and of the furniture product.

To comply with rigorousness of these solutions, a well-defined algorithm is required since the product and ornament design phase. The algorithm requires a combined analytical and graphical method, through which the results of the calculation of the geometric elements to be checked graphically (by design). If the initial aesthetic conditions imposed by the designer are respected, than the solution is accepted. Finally, the variant of re-correlation which introduces the fewest and insignificant changes compared to the initial image and original aesthetic is selected.

Following this algorithm, the database required for the execution design is also formed, as will be presented in a further paper.

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