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CAD SYSTEM OF THE BALL SCREWS TYPE END-CAP DESIGNING

Ця стаття присвячена автоматизованому проектуванню кульових гвинтів. Наведена обчислювальна модель bBalls траєкторії, яка дає змогу визначати основні вимірювання як головки, так і поворотних елементів.
Ключові слова – кульовий гвинт, параметрична модель

This paper is devoted to the CAD Designing of the ball screws. Computational model of bBalls trajectory which allows to determine basic dimensions of both nuts and return elements is presented.
Keywords – ball screw, parametrical model

Introduction

Ball screws are used as elements of feed systems in CNC machinery and precision machine tools. The feed rating for innovative ball screws have increased to 160 m/min, it forces designers to comply with these conditions. Based on numerous ball recirculation systems [2], the new type of circulation of so-called end cap (Fig.1) meets these increased requirements allowing application of high helix leads and the fast feed. Main purpose of the work is to describe the conception of the CAD system which enables the return element designing.

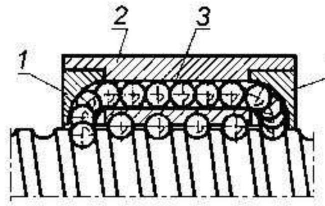

Fig. 1. Ball screw end-cap type ball circulation:
1 - the return element (end cap type), 2 – ball nut, 3 – ball return hole

Other serious problem is a good match of ball thread dimensions (Fig. 2) such as: screw diameter d, lead P, ball diameter d_k, contact angle α, number I_z of loaded turns and the relationship between main radii of the curvature of the screw shaft and the nut. These parameters is a confidential know how. Proper selection of these characteristic determines structural features such as rigidity, load capacity, mass, performance etc.

Calculating Structural Thread Model

Design of ball screws requires making many calculations out. In order to make the work of the designer easier at the Institute of Machine Design Fundamentals of the Warsaw University of Technology a computational model and a computer program which enables to the ball screw designing were made. The first step in developing a numerical model is to define decision variables and basic structural parameters of thread. Basic conditions and design limitations (besides those on Fig.2) were presented in work [2]. The screw diameter is calculated on the basis of strength condition. The contact angle applicable in modern design is α=40°÷45°. Relationships between contact angle α and another dimensions are described by:

$$k_{s,n} = \frac{(2R_{s,n} - d_k)\sin\alpha_{s,n}}{2} \tag{1}$$

$$k_{ps,n} = \frac{(2R_{s,n} - d_k)\cos\alpha_{s,n}}{2} \tag{2}$$

Where

$$\cos\alpha = \frac{R_s + R_n - 0{,}5(D_r - d_r)}{R_s + R} \tag{3}$$

The calculated screw diameter $$d_r = d \; - d_k - 2R \; + \frac{2k_s}{tg\alpha_s} \tag{4}$$

The calculated screw diameter $$D_r = d + d_k + 2R \; - \frac{2k_n}{tg\alpha_n} \tag{5}$$

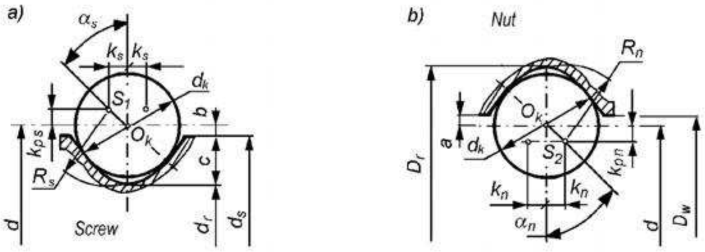

Fig. 2. Basic design thread parameters of screw (a) and nut (b): d - nominal diameter, d_k - ball diameter, $R_{s,n}$ - balltrack radius of the screw and nut, α - contact angle, $k_{s,n}$, $k_{ps,n}$- points of catching $R_{s,n}$ radii

Computational Model of Balls Trajectory

Analysis of the balls trajectory is a base for creating the computational model. Full cycle of the balls circulation in the arrangement screw - nut - return elements is showed on Fig. 3.

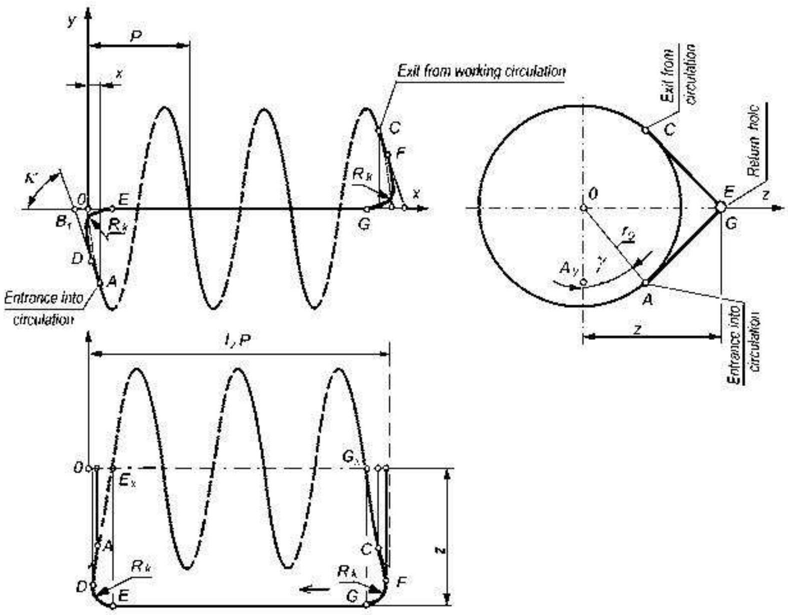

Fig. 3. Geometry of the ball trajectory in the end- cap type of circulation:
P – lead of tread, I_z - number of turns,
z - distance of the axis of the return hole,
R_k – radius of the path of the ball in the return element [1]

Main dimensions that influence the calculating of the structural parameters are: nominal diameter d=2ro, on which there are the centers of balls, the balls diameter dk and the lead P. Calculation is done on the basis of the work [1].

Geometrical calculations were made with the assumption, that axes of return opening were tangent to the helix on which there are the centres of the balls (points A and C). Mathematical equation of the projection of the helix onto the axial plain is as follows [1].

$$y = -r_o \sin \frac{2\pi x}{P} \tag{6}$$

where: $r_o = 0{,}5d$ – radius of the helix cylinder.

Differentiating equation (1) we are finding the tangent of the lead angle of the axis of the return hole:

$$|tg\kappa| = \frac{2\pi r_o}{P} \cdot \cos \frac{2\pi x}{P} = ctg\lambda \cdot \cos \frac{2\pi x}{P} \tag{7}$$

where:

$\lambda = arctg \dfrac{P}{\pi d}$ – lead angle.

After transformations, except for signs of absolute value:

$$tg\kappa = ctg\lambda \sin\gamma \tag{8}$$

It is possible to connect the angle g with dimensions z and d with the following relation:

$$\sin\gamma = d / 2z .$$

Angle κ determines the position of the axis of the return hole plain with regard to the axis "x" of the nut. Minimal dimension z is calculated as follows (Fig. 4)

$$z_{min} = 0{,}5(D_r + d_o) + t_r \tag{9}$$

where: D_r – diameter of the core of the nut, t_r – minimal reserve of material, e.g. distance between the core of the nut and the wall of the return hole, $d_o = d_k + l_k$ - diameter of the ball return hole, l_k – assumed backlash between the diameter of the ball and the return hole.

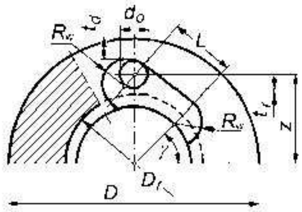

Fig. 4. Relation between dimensions of the return element and nuts: D - external diameter of the nut, D_r - diameter of the nut core, d_o – diameter of the return hole, L - length of the tool feed, R - radius of the tool.

When we accept then the dimension $z \geq z_{\min}$ we can calculate external diameter of the nut

$$D = 2(z + 0{,}5d_o + t_r) \tag{10}$$

We suppose, that in order to guarantee the fluid ball path - radius of the channel in – the return element at the DE segment

$$R_{kan} \geq d_k .$$

Additional calculations, enabling to ball screw design (e.g. number of balls in the circulation, dimensions of the ball thread, etc.) were omitted.

Dimensions of the return element are shown on Fig. 4.

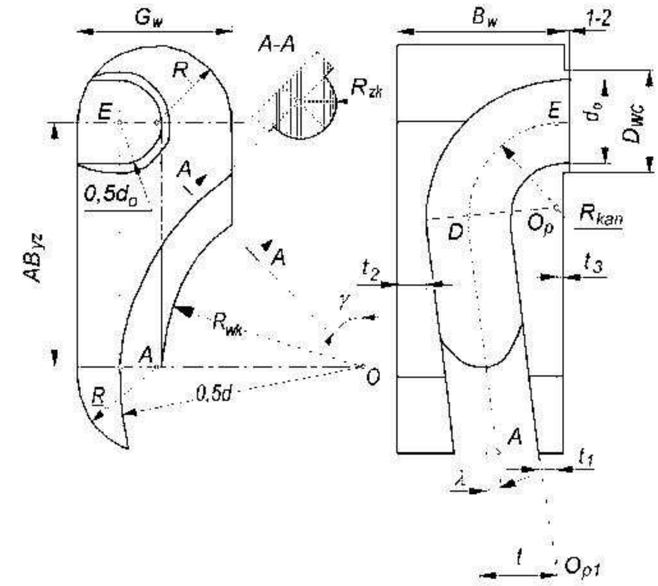

Fig. 5. Geometrical parameters of the return element [1]

Computational Example

On the basis of the computational model an integrated computer system was built.

This system can:

a) calculate dimensions,

b) make a specification sheet (2D) of return element ,

c) make 3D pictures.

We suggest the following conception of system:

1. Input data are entered into application, written in Visual Basic language. This application calculates geometrical dimensions ball screw elements:

Contact angle …………………………… □ = 40.0°

Nominal diameter ………………………. d = 40 [mm]

Screw diameter ....………………………d_s = 38.1 [mm]

Ball diameters………………………….. d_k = 6.35 [mm]

Balltrack radius of the screw and nut … $R_{s,n}$ = 3.365

Number of loaded turns …………………I_z = 6

Lead ....P = 16 [mm]

Ad a) Calculates geometrical thread dimensions (Fig. 2, Fig. 3) are shown in table 1, geometrical insert dimensions (Fig. 4, Fig. 5) are shown in table 2.

TABLE 1

Calculates geometrical thread dimensions

z	γ	κ	λ	c	Dr	dr	ksr	kp	EG
29	43.6°	79.54°	7.26°	3.36	33.27	46.7	0.122	0.145	82.46

TABLE 2

Calculates of return element

do	D	Rkan	AByz (L)	BW (max)	Bw (min)	t1 (min)	Gw	T	Rwk	Rzk	Dwc
6.5	70.0	6.5	21.0	22.1	13.5	1.43	10.0	6.2	17.0	3.07	7.9

2. This program which calculates geometrical parameters also puts the results into text files too and passes them into worksheets of MS Excel (Fig. 5).

3. In SOLIDWORKS application, which is integrated with MS Excell worksheets, there is built a parametrical 3D model of return element and nut (Fig. 6), set „nut –return element - screw" (Fig. 7). This allows to check on correctness of design process and assembly of the return element. The application can be used for the correction of putting the return element with account of the running track of the thread.

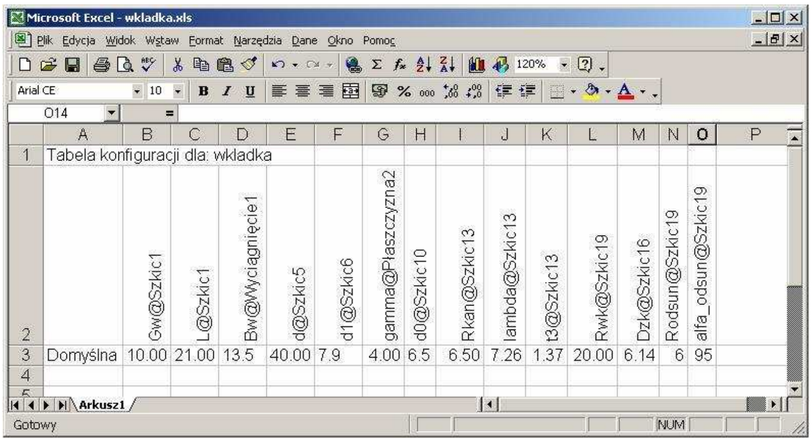

Tabela konfiguracji dla: wkladka

	Gw@Szkic1	L@Szkic1	Bw@Wyciągnięcie1	d@Szkic5	d1@Szkic6	gamma@Płaszczyzna2	d0@Szkic10	Rkan@Szkic13	lambda@Szkic13	t3@Szkic13	Rwk@Szkic19	Dzk@Szkic16	Rodsun@Szkic19	alfa_odsun@Szkic19
Domyślna	10.00	21.00	13.5	40.00	7.9	4.00	6.5	6.50	7.26	1.37	20.00	6.14	6	95

Fig. 5. Dimensions of geometrical parameters in MS Excel worksheets

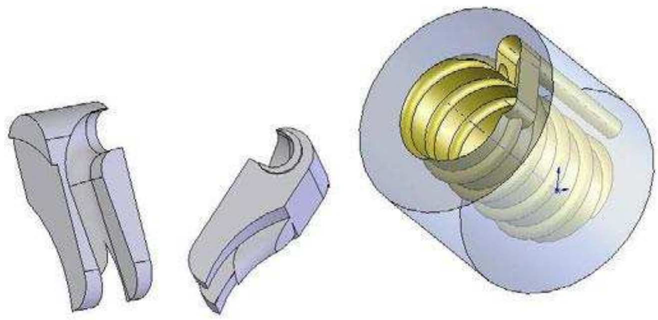

Fig. 6. Parametrical 3D model of the return element and nat

The parametric model of return element can be used for designing an injection mould for making it (return element are made of plastics).

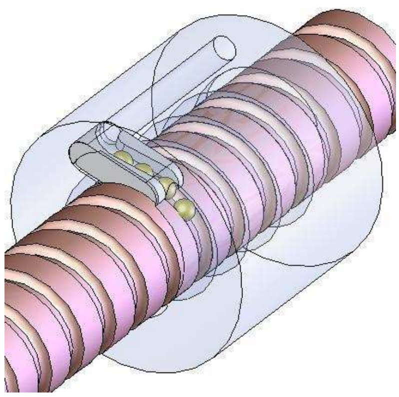

Fig. 7. Parametrical 3D model of set "nut – the return element – screw"

Conclusions

The computational model allows to determine basic dimensions of both nuts and return elements, and also dimensions of the screw thread, with according to determined designing criteria.

Thanks to integrating of the three applications - data are passed to SOLIDWORKS without conversion, and pictures that are received can be immediately verified, edit or – by running the program again with changed entrance parameters – make now.

The above integrated application makes designing and making a specification sheet out of ball screw much faster.

1 J. Z. Sobolewski, J. Bonarowski, „Przekładnie śrubowe z osiowo-czołowym systemem obiegu kulek – projektowanie w CAD", Mechanik Nr 2/2006, pp. 142-143. 2 J. Z. Sobolewski, „Projektowanie przekładni śrubowych tocznych (kulkowych)", Prace Naukowe Mechanika, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2000. 3 J. Bonarowski, S. Skotnicki, and J. Z. Sobolewski, „Zintegrowany system CAD przekładni śrubowych z osiowo-czołowym systemem obiegu kulek", XVI Konf. nt Metody i Środki Projektowania Wspomaganego Komputerowo, Nałęczów 10-12 Oct. 2007, p. 19.

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VIRTUAL MODEL OF 6-AXIS CNC SPIRAL BEVEL AND HYPOID MILLING MACHINE

CNC машина механізму похилої поверхні спіралі, керована в 6-осях, була проаналізована в цій статті. CNC машини дозволяють вирізувати спіраль і гіпоїдні косі механізми незалежно від різальної системи, з індексацією або без індексації. Віртуальну модель 6-осної CNC машини було створено.

Ключові слова – CNC машина, мпіральний механізм, віртуальна модель

The CNC spiral bevel gear machine controlled in 6-axis has been analyzed in this paper. The CNC machines allow to cut spiral and hypoid bevel gears independently of the cutting system, with indexing or without indexing. Virtual model of 6-axis CNC machine was created.

Keywords – CNC machine, spiral gear, virtual model

Introduction

Conventional bevel gears machine include two main components: a cradle, which hold a milling cutter head and carries it along a circular path and work support, which orients the work-piece relative to the cradle and rotates it at a specified ratio to the cradle rotation.

Conventional machine are usually equipped with a series of linear and angular scales which assist the operator in accurately locating the various machine components in their proper position. The eight settings is useful to measure the rotational position of the work about its own axis from some reference. Also, in the case of face-hobbing, the rotary position of the hob about own its axis may be of interest (two settings). Combined together, these ten parameters totally describe the relative positioning between tool and work at any instant. Three of them (cradle angle, work rotation, cutter head rotation) change in the process of generation, while the other seven settings are usually remain fixed.