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Novel Design Solutions for Fishing Reel Mechanisms

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Abstract: Currently, there are various reels on the market regarding the type of mechanism, which achieves the winding and unwinding of the line. The designers have the purpose of obtaining a linear transmission function, by means of a simple and small-sized mechanism. However, the present solutions are not satisfactory because of large deviations from linearity of the transmission function and complexity of mechanical schema. A novel solution for the reel spool mechanism is proposed. Its kinematic schema and synthesis method are described. The kinematic schema of the chosen mechanism is based on a noncircular gear in series with a scotch-yoke mechanism. The yoke is driven by a stud fixed on the driving noncircular gear. The drawbacks of other models regarding the effects occurring at the ends of the spool are eliminated through achieving an appropriate transmission function of the spool. The linear function approximation with curved end-arches appropriately computed to ensure mathematical continuity is very good. The experimental results on the mechanism model validate the theoretical approach. The developed mechanism solution is recorded under a reel spool mechanism patent.

Keywords: reel mechanism, noncircular gears, analysis, synthesis, transmission function

1 Introduction

Reels attached to fishing rods should perform the unwinding of the line when the bait, the weight and the hook are cast toward the water and the winding of the line onto the spool, when the line is removed from the water. Ideally, the speed of the axial movement of the spool should be constant, in both directions, so that the line would wind and unwind uniformly by rotating of the line guide with the angle ξ onto the spool.

Large deviations from this requirement cause two effects. When casting the line, the effect of clinging occurs and at removal of line and bulges form at both ends of the spool (Fig. 1). The bigger the spool is the more obvious the effects show. In practice, long lines are desirable for efficient fishing, so that the spool should be long and thick.

From mechanism science point of view, the crank rotated manually drives a mechanism, which must rotate and translate the spool of the reel at constant speed. Also, the movement must be reversible. It is important to mention that the movement of the spool is a long translation. Practically, it is necessary to achieve the transforming of a rotation at constant angular velocity into a reversible translation movement combined with a rotation movement. Along with the linear stroke, the rotation movement should run at constant transmission ratio. This aspect is of great interest especially for the end points of the linear stroke.

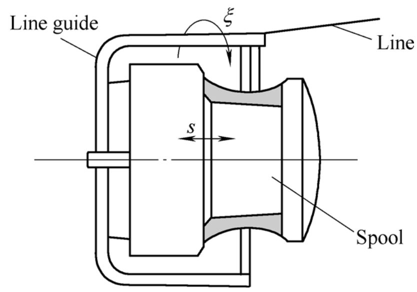

Fig. 1. Forming of bulges at both ends of the spool

The companies which produce reels use different types of simple or complex mechanisms including gears, cams and linkages. There are solutions, which accept the continuous variation of the linear velocity and try to compensate the out coming drawbacks by an asymmetrical design of the spool. The mechanism associated to this concept is quite simple, consisting of two elliptical gears and a bevel gear, as conceived by LEROUX[1].

Most mechanisms used in fishing reel construction include gears(spur, bevel and/or elliptical) and a special

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scotch-yoke mechanism, to which a stud moves along a shaped guiding groove in the yoke. Such a solution was patented by BANCROFT in patent [2]. Most designers provide a shape of the yoke groove roughly resembling with the letter “S”, which is very important for the output transmission function(Fig. 2).

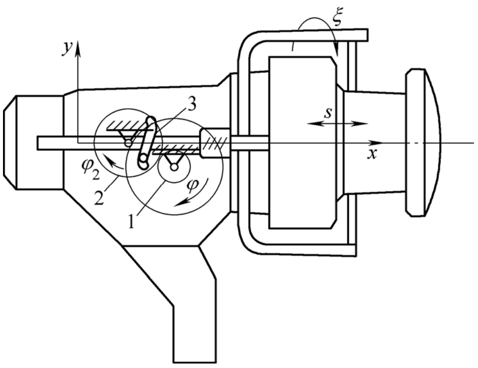


Fig. 2. Mechanism design of the fishing reel with scotch-yoke mechanism and “S” shaped yoke

A quasi-linear transmission function(TF) was obtained by JEONG with the solution described in patent [3].

Beside the irregular deviations from the linear shape of the TF, a major disadvantage of the solution is the abrupt endings of the motion curve, which means there are high acceleration and deceleration around the end points of the strokes.

A slight improvement on TF shape was obtained at Okuma Fishing Tackle by tilting the guide groove[4]. A different original solution featuring specific design of the „S” guide slot were described by BAUMGARTMER[5]. In order to avoid the drawbacks of the solutions above, a solution with fixed spool and additional device to compensate line storage at the margins of the spool was proposed by ZANON[6]. This concept assumes a complex mechanism, involving many parts.

On the market there are also reels with mechanisms based on cylindrical cams, as proposed by SUGAHARA in patent [7]. The long size of the cam and the accompanying extra-set of precise mechanical parts is a disadvantage, which is not compensated by a very good shape of the TF. In order to avoid end effects, NILSEN proposed a double speed fishing reel, producing a high speed operation and a low speed operation, respectively[8]. The construction is very complex, including a very large number of mobile or fixed parts.

Some solutions are based on simple mechanisms of actuation and additional systems to control the dragging of the line. CRAWFORD and RYALL proposed such systems in Refs. [9–10]. MILLER patented a mechanical system based on a finger lever, which guides the line. It is an additional assembly to the actuation system based on a bevel gear[11].

Some reel mechanisms integrate assemblies, which provide supplemental information, such as the estimate weight of the fish[12].

2 Requirements for the Novel Fishing Reel Spool Mechanism

Considering the brief description of the prior state-of-art, the authors decided to start a research based on the following requirements for the fishing reel spool mechanism:

(1) The input link of the reel spool mechanism is a crank, which rotates theoretically with constant angular velocity. The angle is denoted φ;

(2) The output element is the spool, which moves reversibly along a linear direction. The stroke is denoted s;

(3) The line guide is also rotated onto the spool, with correlated angular velocity to the crank’s one;

(4) The desired TF generated by the reel spool mechanism should be a straight line - curve one.

The desired TF should contain four curved arches with imposed linear section and boundary conditions. Fig. 3 illustrates the desired TF of the spool for a complete input rotation of the crank. The drawing emphasizes the four arches denoted φ_a, $\varphi_c - \varphi_b$ and $\pi+\varphi_a$, $\pi+\varphi_c - \varphi_b$ respectively, corresponding to the beginning of (un)winding along the stroke h_1 and the ending of (un)winding along the stroke h_3 of the spool. The TF of the spool is symmetrically shaped. The first half corresponds to the rise-stroke and half of the input rotation(φ_c=180°) and contains a middle linear segment and two curved arches.

The mathematical form of the TF of the spool movement is given in the following relationships[13]:

$$s(\phi)=\begin{cases} h_1\left\{1-\cos\dfrac{\pi\varphi}{2\varphi_a}\right\}, & 0\leqslant\varphi<\varphi_a; \\ h_1+\dfrac{h-2h_1}{\pi-2\varphi_a}(\varphi-\varphi_a), & \varphi_a\leqslant\varphi<\varphi_b; \\ h-h_1\left\{1-\cos\dfrac{\pi(\varphi-\pi)}{2\varphi_a}\right\}, & \varphi_b\leqslant\varphi<\varphi_c; \\ h-h_1\left\{1-\cos\dfrac{\pi(\varphi-\pi)}{2\varphi_a}\right\}, & \pi\leqslant\varphi<\pi+\varphi_a; \\ h-h_1+\dfrac{2h_1-h}{\pi-2\varphi_a}(\phi-\pi-\varphi_a), & \pi+\varphi_a\leqslant\varphi<\pi+\varphi_b; \\ h_1\left\{1-\cos\dfrac{\pi(\varphi-2\pi)}{2\varphi_a}\right\}, & \pi+\varphi_b\leqslant\varphi\leqslant\pi+\varphi_c; \end{cases} \tag{1}$$

with

$$h_1=h_3=h\frac{2\varphi_a}{\pi^2-2(\pi-2)\varphi_a}, \tag{2}$$

$$\varphi_a=\varphi_c-\varphi_b. \tag{3}$$

The return points refer to changing of sliding sense, which takes place twice during a complete input rotation.

The criteria for selecting an optimal novel design solution for the fishing reel spool mechanism must contain the following analytical conditions[10]:

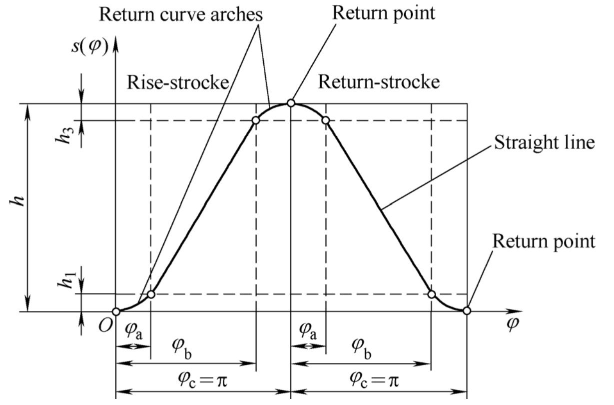


Fig. 3. Transmission function of the spool

(1) The TF should have a minimal average deviation from the desired TF along the whole rotation of the crank:

$$\Delta s_a = \frac{\int_0^{2\pi} \left| s_a(\varphi) - s(\varphi) \right| \mathrm{d}\varphi}{2\pi}, \tag{4}$$

where $s_a(\varphi)$ is the achieved TF of the spool mechanism and $\Delta s(\varphi) = s_a(\varphi) - s(\varphi)$ is the current deviation of TF.

(2) The curved arches of the TF $s(\varphi)$ must be designed so that the jerk at the return points should be avoided:

$$s'(0) = 0, \quad s'(\pi) = 0, \quad s'(2\pi) = 0. \tag{5}$$

(3) The mechanism is supposed to contain a minimum number of parts n:

$$n \to \min; \tag{6}$$

(4) The required workspace of the mechanism along the translation direction is limited. A compact construction is desirable, which is characterized by the relationships:

$$\begin{aligned} c_x &= \dim x(workspace)_{s \in [0,h]}, \\ c_y &= \dim y(workspace)_{s \in [0,h]}. \end{aligned} \tag{7}$$

3 Mechanism Solutions for the Spool Movement

The structure studies have provided a lot of solutions of mechanisms, which transform the rotation motion of the driving element into reciprocating motion of the driven element with a straight line – return curve arches function (given in Fig. 3)[14].

Fig. 4 and Fig. 5 present a systematic overview of the mechanism structures, which are grouped into two large categories: basic and combined mechanisms[14].

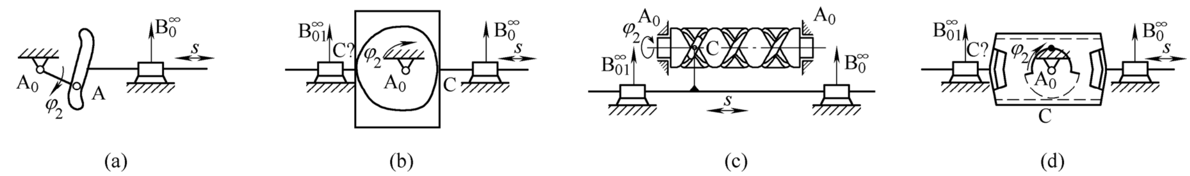


Fig. 4. Basic mechanism structures suitable for the spool mechanism

(a) Scotch-yoke mechanism with "S" profiled yoke; (b) Cam mechanism with constant width and double flat faced follower; (c) Cylindrical cam mechanism with translating follower; (d) Gear mechanism with geared sector and double symmetrical rack.

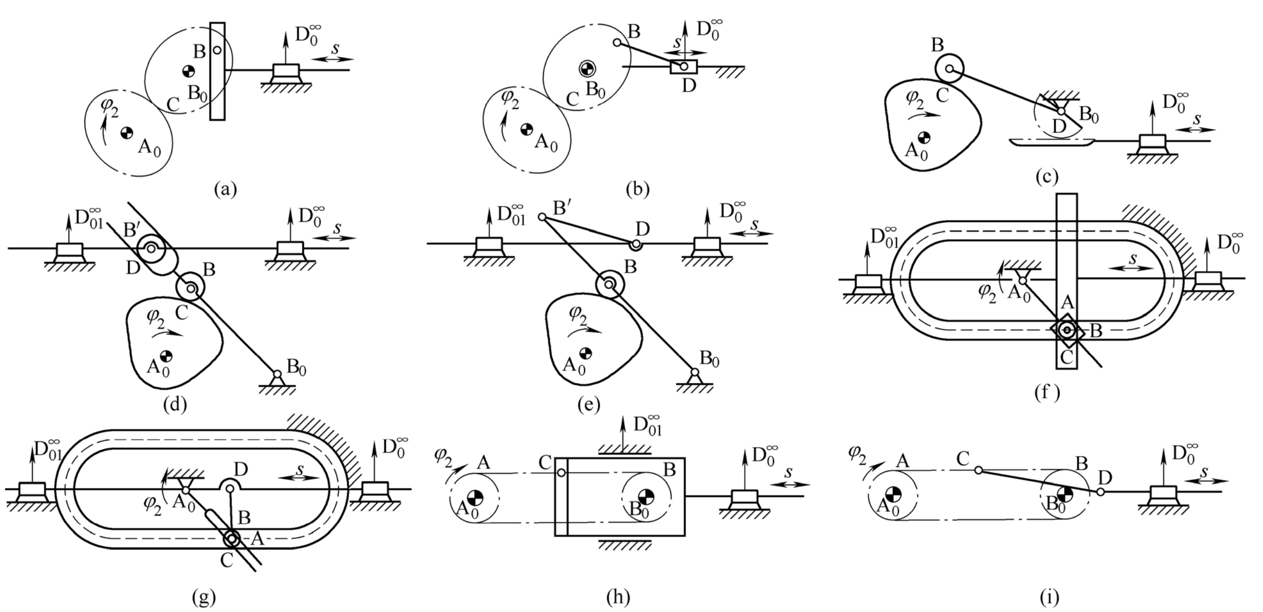


Fig. 5. Combined mechanism structures suitable for the spool mechanism

(a) Noncircular gear mechanism in series with a scotch-yoke mechanism; (b) Noncircular gears mechanism in series with a slider-crank mechanism; (c) Cam mechanism with oscillating roller follower in series with a gear and rack sector pair; (d) Cam mechanism with oscillating roller follower in series with an inverted slider-crank mechanism; (e) Cam mechanism with oscillating roller follower in series with a slider-crank mechanism; (f) Scotch-yoke mechanism with variable crank length; (g) Slider-crank mechanism with variable crank length; (h) Scotch-yoke mechanism driven by a belt mechanism; (i) Slider-crank mechanism driven by a belt mechanism.

The category of basic mechanisms contains:

(1) Scotch-yoke mechanism with “S” profiled yoke(Fig. 4(a));

(2) Cam mechanism with constant width and double flat faced follower(Fig. 4(b));

(3) Cylindrical cam mechanism with translating follower(Fig. 4(c));

(4) Gear mechanism with geared sector and double symmetrical rack(Fig. 4(d)).

The category of combined mechanisms contains:

(1) Noncircular gear mechanism in series with a scotch-yoke mechanism(Fig. 5(a));

(2) Noncircular gears mechanism in series with a slider - crank mechanism(Fig. 5(b));

(3) Cam mechanism with oscillating roller follower in series with a gear and rack sector pair (Fig. 5(c));

(4) Cam mechanism with oscillating roller follower in series with an inverted slider – crank mechanism (Fig. 5(d));

(5) Cam mechanism with oscillating roller follower in series with a slider – crank mechanism (Fig. 5(e));

(6) Scotch-yoke mechanism with variable crank length (Fig. 5(f));

(7) Slider-crank mechanism with variable crank length (Fig. 5(g));

(8) Scotch-yoke mechanism driven by a belt mechanism (Fig. 5(h));

(9) Slider-crank mechanism driven by a belt mechanism (Fig. 5(i)).

4 Synthesis of Some Spool Mechanism Solutions

In order to find an optimal solution for the spool mechanism with the above described requirements the mechanisms’ synthesis was achieved.

The numerical input data for the synthesis of several mechanisms is given in Table 1.

Table 1. Input numerical data for the reel spool mechanism

Mechanism parameter	Value
Stroke h/mm	17
Reference center distance a/mm	20
Stud mounting radius r_{SB}/mm	8.5
Gear transmission ratio i_{01}/	3
Up-stroke angle φ_c/(°)	180
Return-stroke angle φ_c/(°)	180
Curved arches angle φ_a=$\varphi_c-\varphi_b$/(°)	45

Between the fishing reel crank and the input gear of the spool mechanism, which transforms the rotation motion in a rectilinear translation, a gear train with the ratio i_{01} is connected:

$$i_{01} = \mathrm{d}\varphi / \mathrm{d}\varphi_2. \tag{8}$$

Because the gear ratio has a constant value, the shape of the TF is identical with relationship given in Eq. (1), where the rotation angle is φ_2 and it belongs within the range $\phi_2 \in [0, 2\pi]$.

4.1 Scotch-yoke mechanism with “S” shaped yoke

The scotch-yoke mechanism with “S” shaped yoke (modified) is a usual solution for the spool mechanism[3], which allows the achievement of the TF approximately, over some ranges of the angle φ_2.

The synthesis equation of the mechanism based on the kinematic schema in Fig. 6 allows the determination of the profile coordinate(u, v) of the “S” shaped yoke:

$$\begin{aligned} u(\varphi_2) &= r_{SB} \bullet \cos\varphi_2 + s\varphi_2, \\ v(\varphi_2) &= r_{SB} \bullet \sin\varphi_2. \end{aligned} \tag{9}$$

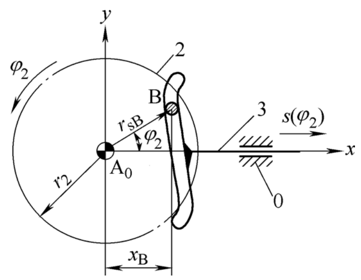


Fig. 6. Kinematic schema of the scotch-yoke mechanism with “S” shaped yoke

The full profile of the shaped yoke has a vertical elongate “∞” form, which contains crossed profiles with guiding problems for the stud. So, it is used only a half of the resulted yoke shape profile. Fig. 7 shows the pitch curve of the theoretical “S” profile of the yoke over the ranges $\varphi_2 \in [\pi/2, \pi] \cup [3\pi/2, 2\pi]$ with r_2=11[mm] and stud radius r=2[mm].

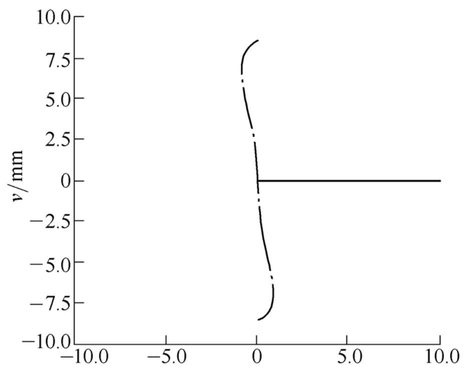
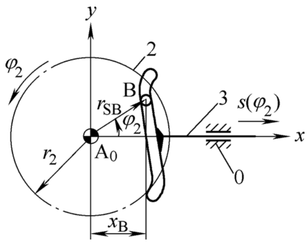
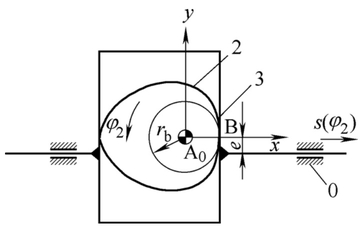
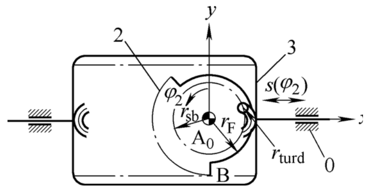
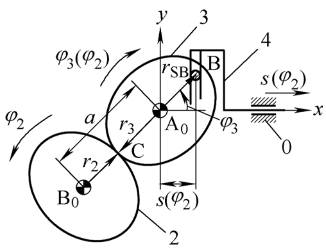
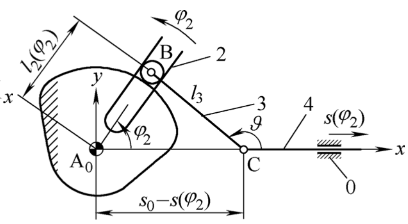
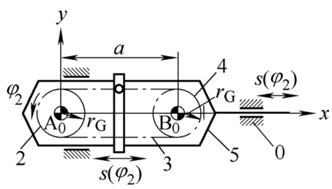


Fig. 7. Pitch curve of the scotch-yoke mechanism with “S” profiled yoke

The computed TF achieved with the spool mechanism with “S” shaped yoke, considering only a half of the resulted pitch curve reproduces approximately the desired TF. The desired TF, the computed TF and the deviation Δs to the desired TF are shown in Fig. 8.

The considered criteria for selecting of the optimal design solutions are presented in Table 2.

Table 2. Summarized values of the selection criteria for the reel spool mechanism

Selection criteria			
Δs_a / mm	0.464	0	0
$s'(0), s'(\pi), s'(2\pi)$ / mm	1.88, –2, 1.88	0, 0, 0	0, 0, 0
n / elements	3	3	3
c_x / mm	24	44	41
c_y / mm	24	45	17
Selection criteria			
Δs_a / mm	0	0	2.75 10^{-3}
$s'(0), s'(\pi), s'(2\pi)$ / mm	0, 0, 0	0, 0, 0	0, 0, 0
n / elements	4	4	5
c_x / mm	24	41	38
c_y / mm	24	20	12

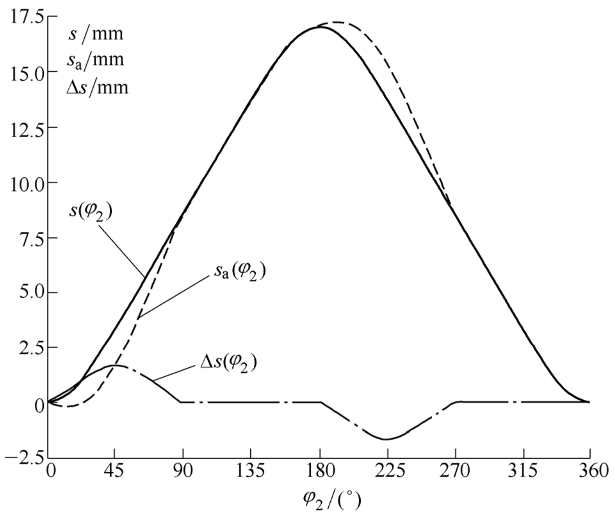


Fig. 8. Deviation of the transmission function of the scotch-yoke mechanism with "S" profiled yoke

The scotch-yoke mechanism with "S" shaped yoke is a simple and compact mechanism, but fulfils the imposed TF only approximately.

4.2 Cam mechanism with constant width and double flat faced follower

The cam mechanism with constant width and double flat faced follower is shown in the kinematic schema in Fig. 9. This mechanism achieves the TF (1) through a proper synthesis of the cam profile.

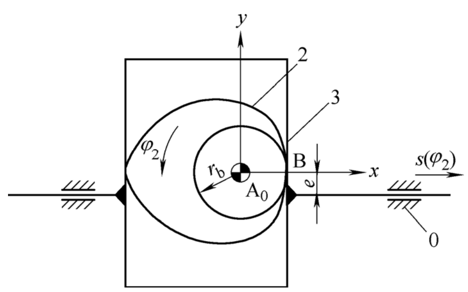


Fig. 9. Kinematic schema of the cam mechanism with constant width and double flat faced follower

Synthesis data for the schema(Fig. 9) is e=0[mm], r_b=3[mm]. The cam profile of the cam mechanism with constant width and double flat faced follower is computed with the relationships[15–16]:

$$\begin{aligned} x_B(\varphi_2) &= [r_b + s(\varphi_2)]\sin\varphi_2 + s'(\varphi_2)\cos\varphi_2, \\ y_B(\varphi_2) &= [r_b + s(\varphi_2)]\cos\varphi_2 + s'(\varphi_2)\sin\varphi_2, \end{aligned} \tag{10}$$

$$s'(\varphi_2) = \partial s(\varphi_2) / \partial\varphi_2. \tag{11}$$

The resulting profile is shown in Fig. 10.

The TF and its deviation Δs achieved with the spool mechanism using a cam mechanism with constant width and double flat faced follower is drawn in Fig. 11.

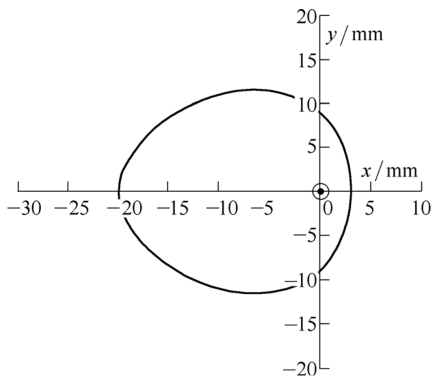


Fig. 10. Cam profile of the cam mechanism with constant width and double flat faced follower

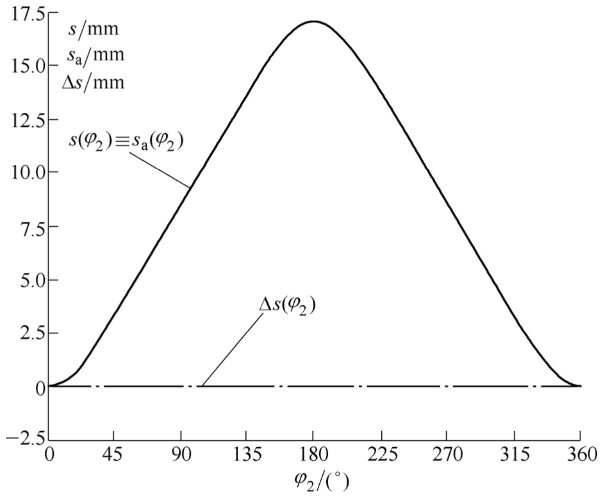


Fig. 11. Deviation of the transmission function of the cam mechanism with constant width and double flat faced follower

Table 2 shows the considered criteria for selecting of the optimal design solutions.

In order to obtain a cam profile without singularities, the cam mechanism size is larger with the double of base circle radius r_b than the double stud mounting radius r_{SB} and thus the cam mechanism(Fig. 9) workspace is more than twice larger than the scotch-yoke mechanism(Fig. 6). It is possible to use also a cam mechanism with translating roller follower, but in this case the cam profile has a concave interval and the size of the cam needs to be slightly increased.

4.3 Gear mechanism with geared sector and double symmetrical rack

This mechanism structure uses a geared sector and double symmetrical racks. For the smooth return of the driven element a yoke is used. The stud is fixed with the driving geared sector 2 and moves along an open grooved cam profile at both return points of the driven element 3, on which the grooved cam profile is fixed(Fig. 12).

To achieve the imposed stroke of the driven element the mounting radius of the stud should be r_{SB} and the stud radius r_{Stud}=0.5[mm].

The angular position of the stud is symmetrically opposite to the gear sector, as shown in Fig. 13.

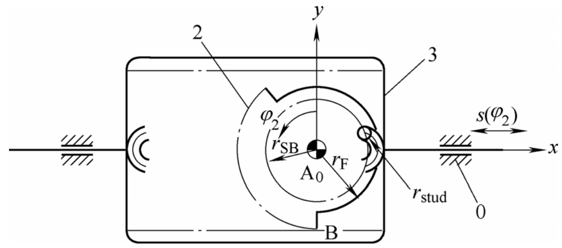


Fig. 12. Kinematic schema of the gear mechanism with geared sector and double symmetrical rack

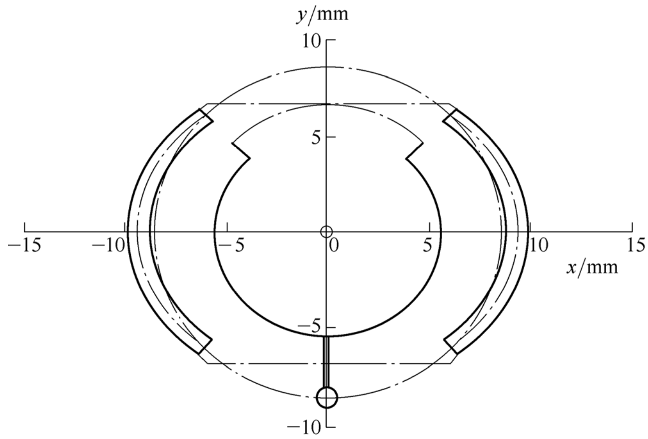


Fig. 13. Grooved cam profiles and geared sector with double simmetrically rack

For synthesis of the return curve arches one uses the TF relationship (1) over the return intervals.

The TF of the gear mechanism with geared sector and double symmetrical rack looks identical with the previous mechanism (Fig. 11). The criteria for selecting the optimal design solutions are given in Table 2.

The gear mechanism with geared sector and double symmetrical rack is a compact mechanism solution, but uses grooved cam profiles at the beginning and the end of the return movement of the driven element to avoid the jerk [17–18]. The manufacturing of the yoke with the double symmetrical rack and the open grooved cam profiles is complicated.

4.4 Noncircular gear mechanism in series with a scotch-yoke mechanism

The mechanism with noncircular gears in series with a classical scotch-yoke mechanism transmits the nonlinear motion provided by the noncircular gear by means of a stud, which is fixed into the output noncircular gear. The motion is transmitted to the stud, which displaces along a linear grooved yoke. Thus, the uniform rotation of the driving element 2 turns into a translation of the slider, obeying a TF $s(\varphi_2)$. The stud fixed on the noncircular gear 3 performs the nonlinear motion $\varphi_3(\varphi_2)$, depending on the variable transmission ratio of the noncircular gears[19–20].

The synthesis of the mechanism is developed on the basis of the kinematic schema in Fig. 14. The ratio between the sliding $s(\varphi_2)$ and the current position radius of the stud, r_{SB}, is given by the cosine of the angle $\varphi_3(\varphi_2)$, with the relationship:

$$\varphi_3(\varphi_2) = \arccos\left(\frac{s(\varphi_2)}{r_{SB}}\right). \quad (12)$$

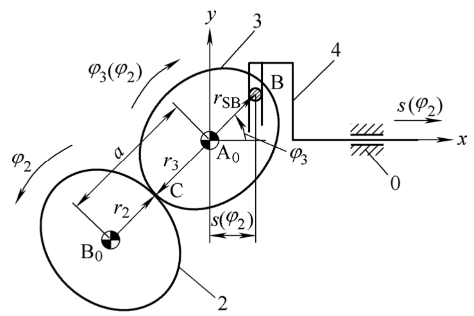


Fig. 14. Kinematic schema of the noncircular gears mechanism in series with a scotch-yoke mechanism

The rotation angle $\varphi_3(\varphi_2)$ depends on the transmission ratio of the noncircular gear. So, it is necessary to perform the geometric calculus of this gear. The reference center distance a, is imposed on constructive basis. Its value is the sum of current radii r_2 and r_3, both depending on φ_2:

$$a = r_2(\varphi_2) + r_3(\varphi_2). \quad (13)$$

The first derivative of the angle $\varphi_3(\varphi_2)$ in respect with the angle φ_2 is equal to the inverse of the instantaneous transmission ratio of the noncircular gear:

$$(i_{23})^{-1} = \varphi_3'(\varphi_2) = \frac{\mathrm{d}}{d\varphi_2}\varphi_3(\varphi_2). \quad (14)$$

The reference pitch curves radii of the noncircular gears result from Eq. (13) and Eq. (14):

$$r_3(\varphi_2) = \frac{a}{1+\varphi_3'(\varphi_2)}, \qquad r_2(\varphi_2) = a - r_3(\varphi_2). \quad (15)$$

The additional synthesis data used for the mechanism in Fig. 14 is $A_0(0,\ 0)$; $B_0(0,\ -20)$. The resulting profiles of the noncircular gears are shown in Fig. 15.

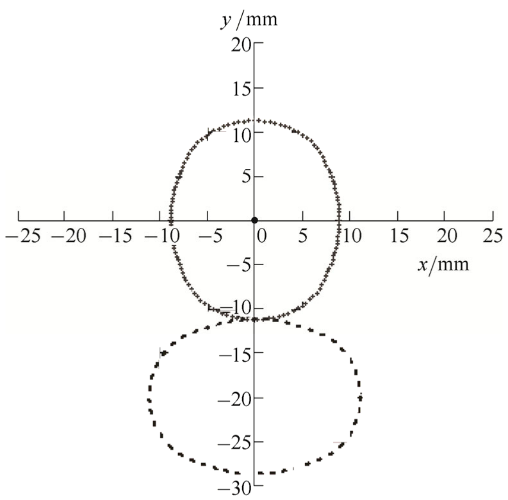


Fig. 15. Pitch curves of the noncircular gear mechanism in series with a scotch-yoke mechanism

To verify the synthesis results, the noncircular gears pair was analyzed. For the analysis of the mechanism one should notice that the ratio of gears radii is according to Eq. (14) the first derivative of the nonlinear angle $\varphi_3(\varphi_2)$. Integration of Eq. (14) provides the nonlinear expression of gear movement angle:

$$\varphi_3(\varphi_2) = \int_0^{\varphi_2} \varphi_3'(\varphi_2)\,\mathrm{d}\varphi_2 = \int_0^{\varphi_2} \frac{r_2(\varphi_2)}{r_3(\varphi_2)}\mathrm{d}\varphi_2. \quad (16)$$

The achieved TF results from Eq. (12), with the angle $\varphi_3(\varphi_2)$ given by Eq. 16:

$$s_a(\varphi_2) = r_{SB} \bullet \cos[\varphi_3(\varphi_2)]. \quad (17)$$

The achieved TF upon a full cycle is identical with the desired TF and is identical with the function represented in Fig. 11.

The criteria for selecting the optimal design solutions are analogue to the ones given in Table 2 §5.

This mechanism solution allows the achievement of the imposed TF, but increases the transversal dimension of the workspace of the mechanism(A_0y) and slightly dimension of the workspace along the translation direction(A_0x). Also a disadvantage is the use of an additional element.

4.5 Slider-crank mechanism with variable crank length

This mechanism uses as crank a slider which guides a double roller along the slider straight line and a fixed cam profile. The design allows getting a variable crank length. The variable crank is the driving element[21]. Usually a grooved cam is recommended. Its profile allows obtaining of the imposed TF(Eq. (1).

In order to compute the cam profile it is necessary to establish the synthesis equation. According to Fig. 16 the following vector equation written in complex numbers is available:

$$l_2(\varphi_2)\exp(i \bullet \varphi_2) = [s_0 - s(\varphi_2)] + l_3\exp(i \bullet \vartheta). \quad (18)$$

From Eq. (18) the variable crank length will results as

$$l_2(\varphi_2) = [s_0 - s(\varphi_2)]\cos\varphi_2 - \sqrt{l_3^2 - [s_0 - s(\varphi_2)]^2\sin^2\varphi_2}. \quad (19)$$

The pitch curve coordinates of the cam are

$$x(\varphi_2) = l_2(\varphi_2)\cos\varphi_2, \quad y(\varphi_2) = l_2(\varphi_2)\sin\varphi_2. \quad (20)$$

For the numerical example shown in Fig. 17 were chosen the initial stroke s_0=8.5 mm, the coupler length l_3=6 mm and the roller radius r_R=2 mm.

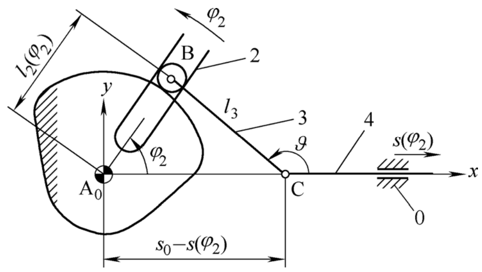


Fig. 16. Kinematic schema of the slider-crank mechanism with variable crank length

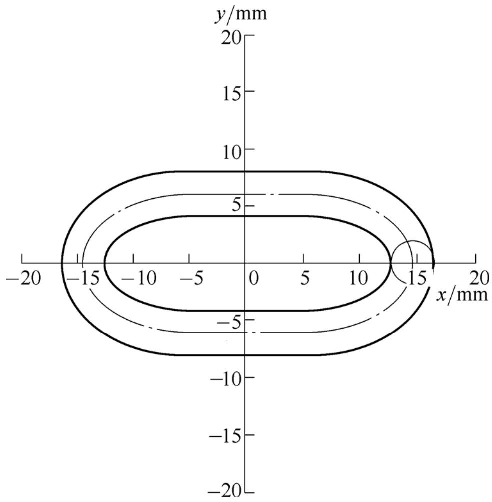


Fig. 17. Grooved cam profile of the slider-crank mechanism with variable crank length

For analysis of the slider-crank mechanism with variable crank length the relationship developed from the closed loop Eq. (18) is used in the form:

$$s(\varphi_2)=s_0+\sqrt{x(\varphi_2)^2+y(\varphi_2)^2}\bullet\cos\varphi_2\pm\sqrt{l_3^2-[x(\varphi_2)^2+y(\varphi_2)^2]\sin^2\varphi_2}\,. \tag{21}$$

The TF of the mechanism fulfils the desired TF and shows identical with the function depicted in Fig. 11. The criteria for selecting the optimal design solutions are given in Table 2.

The mechanism solution with variable crank length achieves the imposed TF, but the size of the mechanism is large and uses an additional element. It must be mentioned that the coupler and the slider must be largely tolerated in order to avoid the self-locking in the movement interval with constant transmission ratio, because they move together on overlapped direction.

4.6 Scotch-yoke mechanism driven by a belt mechanism

The combined mechanism uses a toothed belt mechanism to drive the scotch-yoke mechanism. A stud is fixed in the toothed belt and slides in the yoke. This mechanism achieves partially the requested TF, only within the interval with constant transmission ratio. The return curve arches are generated by the rotation movement of the stud around the belt gears. The kinematic schema of the mechanism is given in Fig. 18.

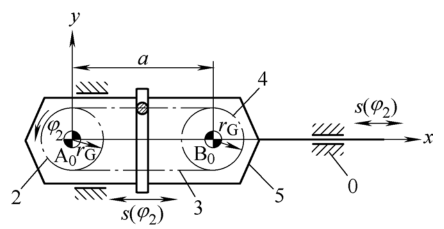


Fig. 18. Kinematic schema of the scotch-yoke mechanism driven by a belt mechanism

The synthesis of the mechanism for the imposed stroke and TF yields the belt gear radius r_G and the reference center distance a using the relationships:

$$r_G=h_1,\ a=h-2r_G. \tag{22}$$

For the numerical example, the driving belt mechanism is shown in Fig. 19, with the gear radius r_G=3.3 mm and the reference center distance a=10.4 mm.

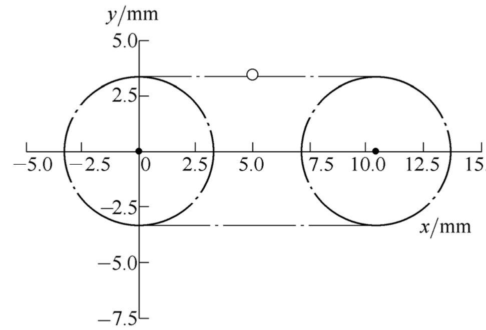


Fig. 19 Toothed belt mechanism of the scotch-yoke mechanism driven by a belt mechanism

For the analysis of the scotch-yoke mechanism driven by a belt mechanism the archived TF is given by the relationships:

$$s(\varphi)=\begin{cases} r_G(1-\cos(2\varphi), & 0\leqslant\varphi<\dfrac{\pi}{4}; \\ r_G+\dfrac{2(h-2r_G)}{\pi}\left(\varphi-\dfrac{\pi}{4}\right), & \dfrac{\pi}{4}\leqslant\varphi<\dfrac{3\pi}{4}; \\ h-r_G\left[1-\cos(2\varphi)\right], & \dfrac{3\pi}{4}\leqslant\varphi<\dfrac{5\pi}{4}; \\ h-r_G-\dfrac{2(h-2r_G)}{\pi}\left(\varphi-5\dfrac{\pi}{4}\right), & \dfrac{5\pi}{4}\leqslant\varphi<\dfrac{7\pi}{4}; \\ r_G(1-\cos(2\varphi), & \dfrac{7\pi}{4}\leqslant\varphi<2\pi. \end{cases} \tag{23}$$

This mechanism achieves a TF alike the desired TF (1) and has a compact size, but uses additional elements. The deviation of the archived TF is shown in the Fig. 20. Similarly the criteria for selecting the optimal design solutions are given in Table 2.

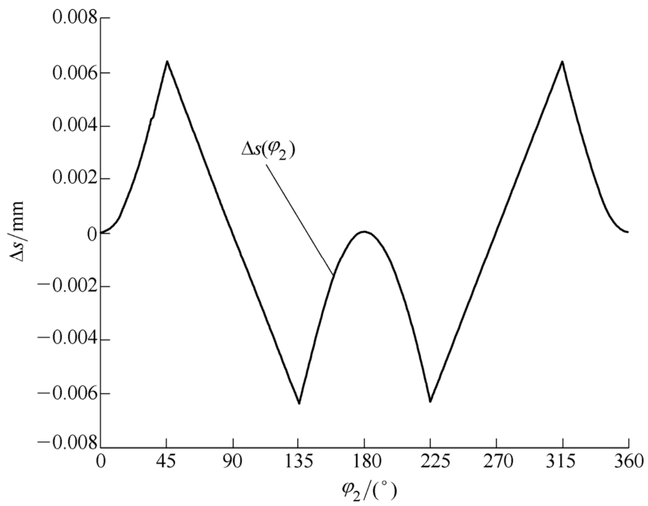


Fig. 20. Deviation of the transmission function of the cam mechanism with constant width and double flat faced follower

5 Choice of the Optimal Design Solution for the Reel Spool Mechanism

In order to find the optimal design solution the selecting criteria were computed and they are summarized in Table 2.

In Table 2 the best solutions for each considered criterion are depicted with gray color. Two solutions satisfied the most of the considered criteria, namely the noncircular gear mechanism in series with a scotch-yoke mechanism and the gear mechanism with geared sector and double symmetrical rack. Because the workspace along the translation direction is limited, the first design solution is chosen as the optimal design solution for the reel spool mechanism.

Fig. 21 shows the kinematic schema of the reel mechanism using the noncircular gear mechanism in series with a scotch-yoke mechanism.

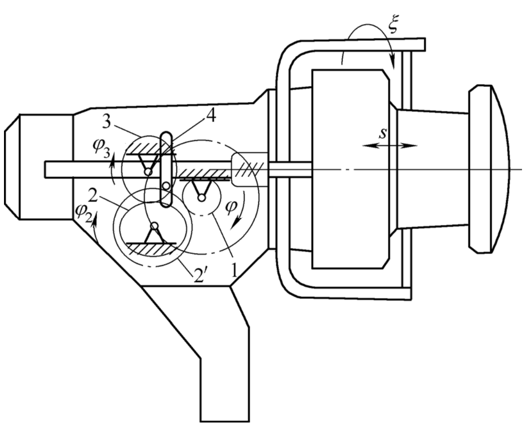


Fig. 21 Kinematic schema of the fishing reel with noncircular gear mechanism in series with a scotch-yoke mechanism

6 Model and Prototype for the Novel Designed Solution of the Reel Spool Mechanisms

For the synthesized mechanism a scaled Plexiglas model shown in Fig. 22 was manufactured.

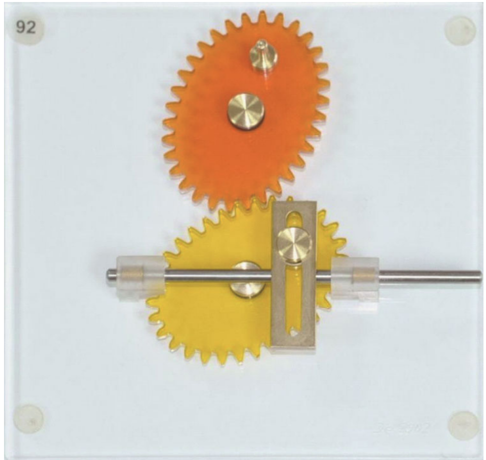


Fig. 22. Model of the noncircular gear mechanism in series with a scotch-yoke mechanism

The experimental TF of the model with the noncircular gear mechanism in series with a scotch-yoke mechanism was determined by using an optical measurement method. The experimental TF validates the theoretical results and it is given in Fig. 23.

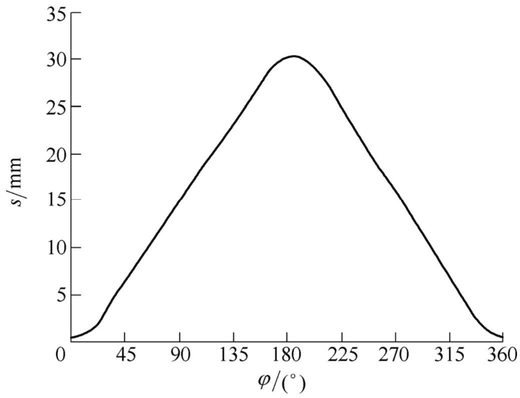


Fig. 23. Experimental TF of the noncircular gear mechanism in series with a scotch-yoke mechanism model

The design schema of the novel reel spool mechanism prototype is shown in Fig. 24.

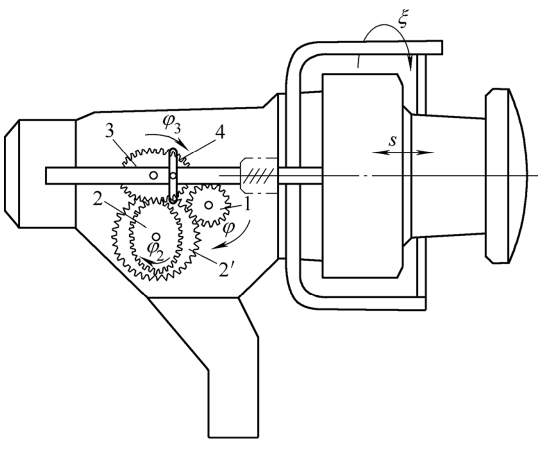


Fig. 24. Design of the novel reel spool mechanism using noncircular gear mechanism in series with a scotch-yoke mechanism

According with the design schema of the novel reel spool mechanism the prototype was manufactured. Fig. 25 presents an overview of the reel and Fig. 26 brings a close view of the mechanism. The noncircular gears were manufactured on a laser cutting CNC machine.

Fig. 25 Overview of the prototype of the reel

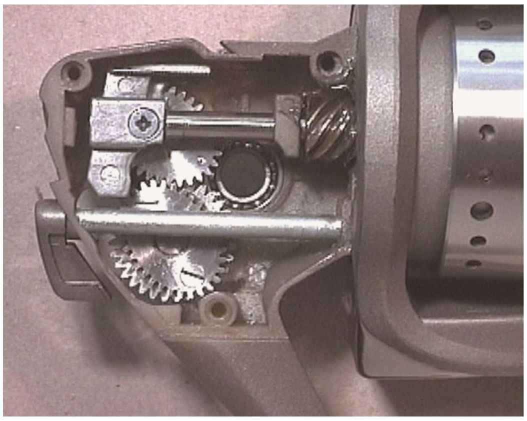


Fig. 26 Detail on reel spool mechanism

7 Conclusions

(1) Several mechanism solutions are considered for converting the unidirectional rotation of the crank into rectilinear alternate motion of the spool.

(2) The novel solution for the reel spool mechanism avoids the jerk at the return points;

(3) The mechanism is simple, needs a reduced number of parts and requires a reduced size as the construction is compact.

(4) In addition, the solution uses the same frame as by the previous reel spool mechanism.

(5) The prototype of the reel with the mechanism described above is manufactured in the workroom of the Mechanisms Department, TU Dresden and the solution for the reel mechanism is patented[22].

(6) The mechanism model with noncircular gear mechanism in series with a scotch-yoke mechanism model is recorded and described in the DMG-Library.

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