

OPTIMIZATION DIMENSIONAL-STRENGTHAL PARAMETERS OF SPATIAL CHAIN DRIVE FOR NOT PARALLEL SHAFTS

ОПТИМИЗАЦИЯ РАЗМЕРНО-ПРОЧНОСТНЫХ ПАРАМЕТРОВ ПРОСТРАНСТВЕННОЙ ЦЕПНОЙ ПЕРЕДАЧИ ДЛЯ НЕПАРАЛЛЕЛЬНЫХ ВАЛОВ

Prof. Dr.Sc. Pilipenko O.
The State Technological University- Chernigiv, Ukraine

Abstract: Design of a spatial chain for transfer of the torque between not parallel shafts out of polymeric composites is presented. The offered method of optimization of a design allows at analysis stages and synthesis to define an optimum design of elements of spatial chain drive, having revealed necessary and sufficient elements for maintenance of its working capacity, and at a stage of the further optimization to receive optimum values of key parameters.

KEY WORDS: SPATIAL CHAIN DRIVE, OPTIMIZATION, KEY PARAMETERS

1. Introduction

For maintenance of transmission of the torque between not parallel shafts it is necessary, that the chain possessed, at least, two degrees of freedom of elements of flexibility, and elements of gearing of a chain and sprockets should possess three degrees of freedom. It will give the chance to a chain to enter freely into gearing with a sprocket under any corner to an average plane of its tooth rim and to transfer movement without infringement of normal contact between gearing elements.

2. Design of spatial chain drive

The spatial chain (fig. 1) consists of the monolithic links 1 which working surfaces are executed in the form of the sphere, connected among themselves cross bonds 2 [1].

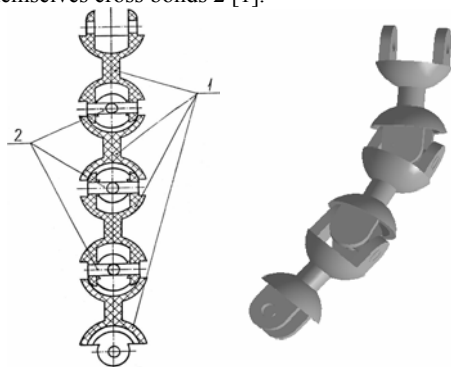


Fig.1. Chain for not parallel shafts

The spatial link (fig. 2) is executed in the form of the monolithic element consisting of two hemispheres of 1 radius R , connected among themselves by a cylindrical crosspiece 2 diameters D_{nep} , four ledges 3 (on two from both sides) by thickness $H_{выст}$ and radius $R_{выст}$ with apertures of 4 diameters $D_{отв}$, hollows 5 (on one from both sides) width L and radius R_l of the spherical surface forming their bottom.

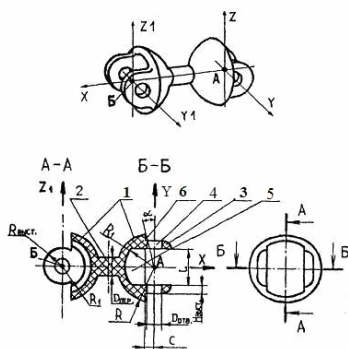


Fig.2. Spatial link of a chain

The centers of spherical surfaces of a link are points A and B , the distance between which is equal to a chain step. The centers of apertures 4 lay on axes Y and Y_l . On the same axes the centers of circles of radius $R_{выст}$ forming ledges 3 lay also. The planes forming internal surfaces of ledges 3 and lateral surfaces of hollows 5 are symmetric concerning an axis X . A bottom of a hollow 5 – a part of a spherical surface of radius R_l .

The sprocket represents a disk (fig. 3), on a cylindrical surface 1 which the hollows 2 consisting of a part of a concave spherical surface 3 and convex part tore 4 are executed. In the middle of a cylindrical surface the groove 5 which profile is formed by arches of circles is executed. On fig. 3 are shown forming spheres 6 – a circle of radius R_u and forming tore 7 – a circle of radius R_l . The centres of circles generatrices lay on pitch circle 8 of radiuses R_p of a sprocket.

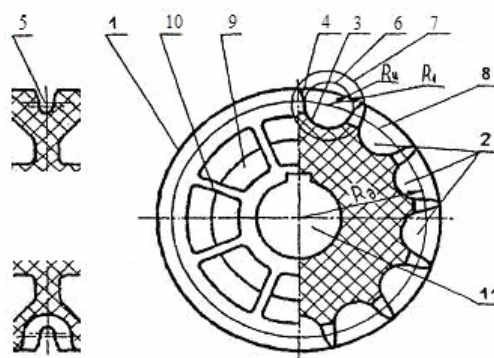


Fig. 3. Sprocket of spatial chain drive

For reduction materials consumption sprocket on its front surface groove 9 can be executed, and rigidity of a sprocket in this case is provided with ribs of rigidity 10. For design simplification casting molds the working variant of a sprocket will consist of two identical half concerning an average plane of the tooth rim, connected among themselves latches or bolts. The sprocket is established on a shaft by an aperture 11.

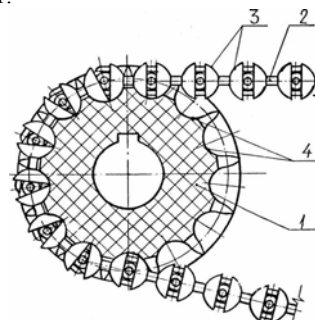


Fig. 4. Spatial chain drive

Spatial chain drive (fig. 4) works as follows. At rotation of a sprocket 1 movement is transferred to a chain 2. Connection cross bond allows a chain to be bent in any direction. Gearing between a chain and a sprocket occurs on spherical surfaces 3 and 4.

By means of spherical surfaces 1 (fig. 2) is transferred the force directed on a longitudinal axis of a chain. The crosspiece 2 interferes with cross-section sliding of links of a chain on a sprocket. The corner of turn of links of a chain is limited and equal 2α , it can be changed, varying distance C (distance from axis Z to a surface 6, fig. 2).

3. Definition and optimization dimensional-strength parameters

Because the created spatial chain drive has no widespread analogues, there is a necessity of definition of its optimum dimensional parameters.

Criterion of quality or criterion function of the given system is the volume occupied with chain drive of the offered design. Key parameters influencing volume: interaxial distance, diameters and width of sprockets, the sizes of cross section of a chain. At designing of chain drive of distance between axes of sprockets are set by an arrangement of elements of the mechanism between which it is necessary to transfer the torque, i.e. interaxial distances depend on a concrete design of a drive and consequently at the given stage this dimensional parameter directly influencing volume, by us is not optimized. The width of a sprocket and its diameter at equal numbers of teeth are directly proportional to width and a chain step. Proceeding from the above-stated, it is possible to draw a conclusion, that occupied chain drive the volume, at other equal parameters, is defined by the sizes of cross section of a chain. We draw model of a link of a chain as most difficult and least durable element (fig. 5).

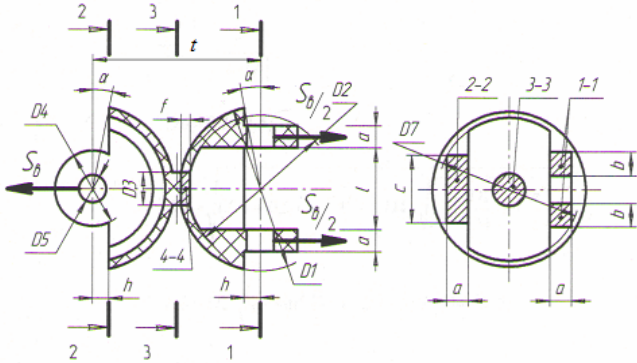


Fig.5. Calculated scheme of optimization of a link of a spatial chain

On fig. 5 it is designated: S_σ – the longitudinal loading operating on a link at a stretching of a chain; $D1$ – diameters of the circles forming a spherical surface of gearing of a chain with a sprocket; $D2$ – diameter of a circle forming a spherical hollow, necessary for unobstructed movement of eyes of diameter $D4$ at chain turn; $D3$ – diameter of a cylindrical crosspiece; $D4$ – external diameter lugs; $D5$ – diameter of apertures under platens cross bond; $D7$ – diameter of an arrangement of the bases of lugs; l – width of a hollow; a – a thickness of a lug in sections 1-1 and 2-2; b – width of a lug in section 1-1; c – width of a lug in section 2-2; f – conditional width of section 4-4; h – distance from an end face of a hemisphere to an axis of apertures of diameter $D5$; t – a chain step; α – a corner of turn of a chain.

Dangerous sections: 1-1 – a tension, the total area of two cross sections $A_1=4ab$; 2-2 – a tension, $A_2=2ac$; 3-3 – a tension, $A_3=\pi D3^2/4$; 4-4 – a cut, $A_4=\pi D3 f$.

The sizes $D1$, $D3$, $D4$, a are independent dimensional parameters as it is possible to express other sizes through them.

Criterion function: $f(x) = t \frac{\pi D1^2}{4} (1 - \sin^2 \frac{\pi}{z})$, (1)

where z – number of teeth of a sprocket.

Parameters on which optimization is spent, – $D1$, $D3$, $D4$, a . We express all other dimensional parameters of a chain through these parameters:

$$D2 = \sqrt{(D4 + 0,5 + 2a)^2 + D4^2}. \quad (2)$$

From a condition of contact strength of the hinge of a chain

$$D5 = \frac{F}{2a \cdot [p]}, \quad (3)$$

where F – force of rupture of a chain; $[p]$ – admissible pressure in hinges.

From geometrical reasons

$$D7 = \sqrt{(D4 + 0,5 + 2a)^2 + \left(D4 \cdot \sqrt{1 - \left(\frac{D1}{D4} \cdot \sin \frac{\pi}{z} \right)^2} \right)^2}; \quad (4)$$

$t = D0 \sin \frac{\pi}{z}$, where $D0$ – diameter of an arrangement of hinges of a chain on a sprocket;

$$l = D4 + 0,5; \alpha = \arcsin \frac{h}{D1}; b = \frac{D4}{2} - \frac{F}{4a \cdot [p]}; h = \frac{D1}{2} \sin \frac{\pi}{z}; \quad (5)$$

$$c = \sqrt{D4^2 - \left(D1 \sin \frac{\pi}{z} \right)^2}; f = \frac{1}{2} \left(D1 - \sqrt{(D4 + 0,5 + 2a)^2 + D4^2} \right). \quad (6)$$

Parametrical restrictions: $D1 > 0$, $D3 > 0$, $D4 > 0$, $a > 0$.

Further we enter functional restrictions of two kinds: restrictions on the dimensional parameters caused by necessity of giving of a chain of set strength, and the restrictions defined by a relative arrangement of elements of a link of a chain.

Functional restrictions from strength reasons:

- in cross section 1-1 $\varphi_1 = [\sigma]_p - \frac{F}{4ab} \geq 0$, where $[\sigma]_p$ – admissible stress at a tension.

Substituting value b from (5),

$$\varphi_1 = [\sigma]_p - \frac{F}{2aD4 - \frac{F}{[p]}}; \quad (7)$$

- in cross section 2-2 $\varphi_2 = [\sigma]_p - \frac{F}{4ac} \geq 0$ or, substituting value c

$$\text{from (6), } \varphi_2 = [\sigma]_p - \frac{F}{4a \sqrt{D4^2 - \left(D1 \sin \frac{\pi}{z} \right)^2}} \geq 0; \quad (8)$$

- in cross section 3-3 $\varphi_3 = [\sigma]_p - \frac{4F}{\pi D3^2} \geq 0$; (9)

- in cross section 4-4 $\varphi_4 = [\tau]_{cp} - \frac{F}{\pi D3 \cdot f} \geq 0$, where $[\tau]_{cp}$ – admissible stress of a cut. Substituting f from (6),

$$\varphi_4 = [\tau]_{cp} - \frac{2F}{\pi D3 (D1 - \sqrt{(D4 + 0,5 + 2a)^2 + D4^2})} \geq 0; \quad (10)$$

- cross section of the roller cross bond $\varphi_5 = [\sigma]_{ni} - \frac{4F}{\pi D5^2/4} \geq 0$,

where $[\sigma]_{cm}$ – admissible bearing stress. Substituting $D5$ from (3),

$$\varphi_5 = [\sigma]_{cm} - \frac{64a^2 [p]^2}{\pi F} \geq 0. \quad (11)$$

Functional restrictions from constructive reasons:

$$\varphi_6 = D1 - \frac{\sqrt{(D4 + 0,5 + 2a)^2 + \left(D4 \cdot \sqrt{1 - \left(\frac{D1}{D4} \sin \frac{\pi}{z} \right)^2} \right)^2}}{\sqrt{1 - \sin^2 \frac{\pi}{z}}} \geq 0 \quad (12)$$

$$\text{and } \varphi_7 = 1 - \left(\frac{D1}{D4} \sin \frac{\pi}{z} \right)^2 > 0; \quad (13)$$

$$\varphi_8 = h - \frac{D5}{2} > 0 \text{ or, substituting } h \text{ from (5),}$$

$$\varphi_8 = D l \sin \frac{\pi}{z} - \frac{F}{2a \cdot [p]} > 0; \quad (14)$$

$$\varphi_9 = D1 - \sqrt{D4^2 + (D4 + 0,5 + 2a)^2} > 0; \quad (15)$$

$$\varphi_{10} = D4 - \frac{F}{2a \cdot [p]} > 0; \quad (16)$$

$$\varphi_{11} = D4 - D1 \sin \frac{\pi}{z} > 0 ; \quad (17)$$

$$\varphi_{12} = D1\sqrt{1 - \sin^2 \frac{\pi}{z}} - 3D3 > 0. \quad (18)$$

Search of optimum parameters is spent to two stages [2]. At the first stage search of a base point by step-by-step trial run of parameters of optimization is conducted. At the second stage there is a minimum of criterion function by a method of direct search, using for this purpose modified method Huk-Dzhivis [3].

As a result of realisation of the program of the optimization written in programming language Pascal the following (approximated to millimeters) values of independent dimensional parameters is received: $D1 = 30$ mm, $D3 = 6$ mm, $D4 = 15$ mm, $a = 4$ mm. On these parameters from dependences (2) – (6) other sizes of a link of a chain and a sprocket are defined. Knowing optimum values of the sizes, we draw link and sprocket working drawings (fig. 6, 7).

4. Conclusion

The presented design of a spatial chain for transfer of the torque between not parallel shafts out of polymeric composites shows, that the ideology of its designing differs first of all that instead of several metal elements of which consist usually standard driven chains, the polymeric chain can be made by means of one monolithic link out of the polymeric composite representing the integrated element.

The offered method of optimization of a design allows at analysis stages and synthesis to define an optimum design of elements of spatial chain drive, having revealed necessary and sufficient elements for maintenance of its working capacity, and at a stage of the further optimization to receive optimum values of key parameters.

In summary we will notice, that links of a chain of an offered design and a sprocket are made by molding under pressure on thermoplast automatic machines out of polymeric composites for one technological operation.

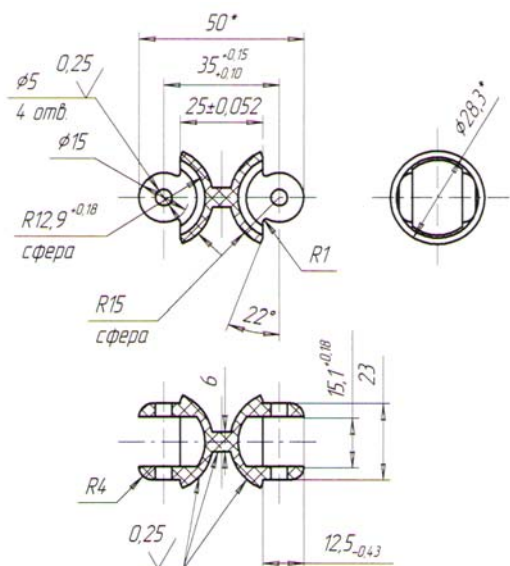


Fig.6. Drawing of a link of a spatial chain

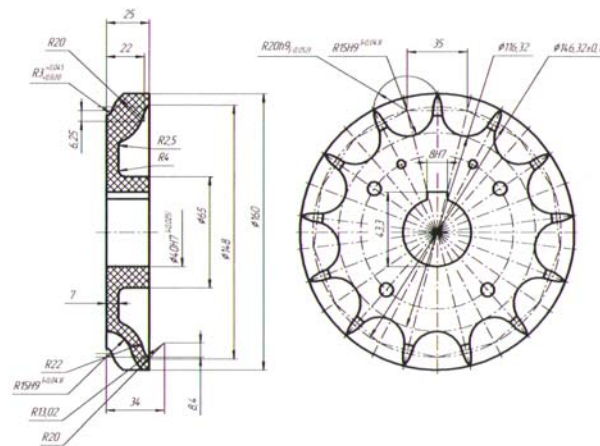


Fig.7. Drawing of half of sprocket of chain drive

In summary we will notice, that links of a chain of an offered design and a sprocket are made by molding under pressure on thermoplast automatic machines out of polymeric composites for one technological operation.

5. Literature

1. Пилипенко О.І., Козар І.Ф., Степенко А.П. Просторова ланцюгова передача для непаралельних валів. Патент України 25748 А. Бюл. № 6, 25.12.98.
2. Соболь І.М., Статников Р.Б. Выбор оптимальных параметров в задачах со многими критериями. М.: Наука, 1981. – 108с.
3. Банди Б. Методы оптимизации. Пер. с англ. – М.: Радио и связь, 1988. – 128с.