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GEOMETRIC MODELING OF PARTS OF SHIP EQUIPMENT WITH MATCH SURFACES

Formulation of the problem.

When modeling connected kinematic pairs in mechanical engineering, when designing complex connected surfaces, including ship hardware, it became necessary to develop fundamentally new methods for forming connected conical surfaces that exclude interference during design.

Analysis of achievements and publications.

Background factors for the development of a method of geometric design of a conical surface based on a parametric kinematic screw are the theorem of Dr. A. Podkorytov [1].

Surfaces Σ_A and Σ_B will be connected if each of them is formed by the corresponding relative motion of Φ_A/Σ_A and Φ/Σ_B of congruent mediators $\Phi_A \equiv \Phi_B$. The surface Σ_A and the mediator surface Φ_A are mutually enveloped with the linear contact $l_1(l^1{}_2)$.

Formulation of the objectives of the article.

The aim of the work is to develop an algorithm for the geometric design of a conical surface based on a parametric kinematic screw for practical use in the design of a cutting tool.

Main part.

Let's consider the geometric modeling of a conical surface $\sum$ of a curvilinear generating surface $r(\tau)$, with the m axis and a variable step $h(\alpha,t)$ by a helical transformation about the m axis of each point of the given conical surface $T(s,r)$ [1].

The conical surface T is defined by the vertex S and the curvilinear generatrix $r(\tau)$. When the conical surface T rotates around the m axis, the lines $l^1{}_1, l^2{}_2, ..., l^n{}_n$ form a family of guiding (basic) cones.

The helical conical surface Σ is defined as the locus of points located at the initial moment $t = 0$ on a given generatrix $r(\tau)$ and simultaneously participating in two movements: in rotation - about the axis m and translational - along a straight line passing through the generatrix $r(\tau)$ and the vertex S of the cone so that at the time $\tau = 1$ all points of the generatrix will be at the vertex of the cone S.

Each line $l^1, l^2, \ldots, l^n$ turns into a conical helical line $l^{1*}, l^{2*}, \ldots, l^{n*}$ with a variable pitch by a curvilinear transformation (Fig. 1). A family of conical helical lines $l^{1*}, l^{2*}, \ldots, l^{n*}$ with a common axis m form a conical surface Σ [2].

To form a geometric model of a conical surface, we set the initial conical surface $T(S,\tau)$ with vertex S and curvilinear generating $r(t) c \le t \le b$ (Fig. 1).

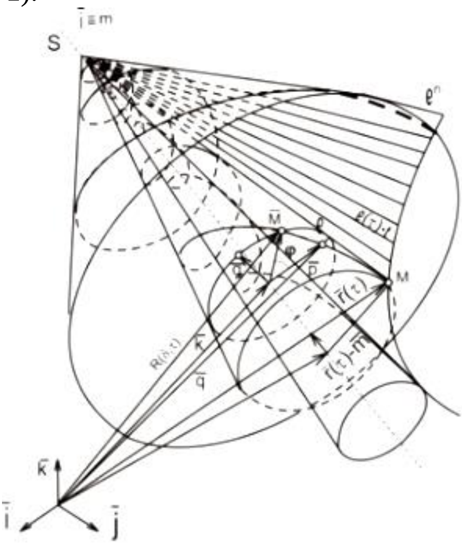

Fig. 1 Family of conical helixes.

The radius vector is: $\overline{l}(\tau)$ equals: $\overline{l}(\tau) = \overline{v} - \overline{r(\tau)}$

Let us define the radius vector $\overline{g}(\tau,t)$;

$$\overline{q}(\tau,t) = \overline{r}(\tau) + \overline{l} \cdot t = \overline{g}(\tau,t) = \overline{r}(\tau) + \overline{l} \cdot t = \overline{r}(\tau)(1-t) + \overline{v} \cdot t$$

$0 \le t \le 1$

The radius vector $\overline{r_0}$ is equal to:

$$\overline{r} = \overline{r_0} = \overline{v} - (\overline{v} \cdot \overline{\rho}) \cdot \overline{\rho}$$

where $(\overline{v} \cdot \overline{\rho}) \cdot \overline{\rho}$ is the projection of the vector $\overline{v}$ onto the *m* axis.

Determining the radius of a vector $\overline{\rho}$ (Fig. 2)

$$\overline{\rho} = \overline{p}(\tau,t) - \left(\overline{g}(\tau,t)\right)\overline{\rho} - \overline{r_0}$$
$$= \overline{r}(\tau)(1-t) + \overline{v}t - \left[\left(\overline{r}(\tau)\overline{\rho}(1-t)\right) + \overline{v}\cdot\overline{\rho}\cdot t\right]\overline{\rho} - \overline{v} + \left(\overline{v\rho}\right)\overline{\rho}$$
$$= \overline{r}(\tau)(1-t) - \overline{v}(1-t) - \left[\overline{r}(\tau)\overline{\rho}(1-t)\right]\overline{\rho}$$
$$= \left(\overline{r}(\tau) - \overline{v}\right)(1-t) - \left[\left(\overline{r}(\tau)\overline{\rho}\right)(1-t)\right]\overline{\rho}$$
$$= \left[\left(\overline{r}(\tau) - \overline{v}\right) - \left(\overline{r}(\tau)\overline{\rho}\right)\overline{\rho}\right](1-t)$$

where $\left(\rho(\tau,\mathrm{t})\overline{\rho}\right)\overline{\rho}$ is the projection of the vector $\overline{\rho}\,(\tau,t)$ on the *m* axis.

The vector is determined from the vector $\overline{\rho}$ by turning it in the positive direction by the angle *ϕ (τ,t)* in the plane perpendicular to the *m* axis.

To do this, you need to vector $\overline{\rho}$ multiply the unit vector of the *m* axis by the vector i.e.

$$\overline{q} = \overline{\rho}\cdot\overline{p} = \left[\left(\overline{\rho}(\tau) - \overline{v}\right)\right]\cdot(1-t) = \left[\left(\overline{\rho}(\tau) - \overline{v}\right)\right]\cdot(1-t)$$

Using radius vectors, a vector is defined:

$$\overline{R} = \mathrm{p}\cdot\cos\varphi + \mathrm{p}\cdot\sin\varphi + \left(\overline{r_0} + \left(\overline{q}(\tau,t)\overline{\rho}\right)\overline{\rho}\right) = \overline{v} - \left(\overline{v} - \overline{\rho}\right)\overline{\rho} +$$
$$+\left(\overline{q}(\tau,t)\overline{\rho}\right)\overline{\rho} + \left[\left(\overline{r}(\tau) - \overline{v}\right) - \left(\overline{r}(\tau)\overline{\rho}\right)\overline{\rho}\right](1-t)\cdot\cos\varphi + \left(\overline{r}(\tau) - \overline{v}\right)\cdot\overline{\rho}(1-t)\cdot\sin\varphi =$$
$$= \overline{v} + \left(\left(\overline{r}(\tau) - \overline{v}\right)\overline{\rho}\right)\overline{\rho}(1-t) + \left[\left(\overline{r}(\tau) - \overline{v}\right) - \left(\overline{r}(\tau)\overline{\rho}\right)\overline{\rho}\right](1-t)\cdot\cos\varphi + \left(\overline{r}(\tau) - \overline{v}\right)\cdot\overline{\rho}(1-t)\cdot\sin\varphi \quad (1.1)$$

Thus, the equation of a conical quasi-helical surface is obtained.

$$R = \cdot\overline{v} + (1-t)\left\{\left(\left(\overline{r}(\tau) - \overline{v}\right)\overline{\rho}\right)\overline{\rho} + \left[\left(\overline{r}(\tau) - \overline{v}\right) - \left(\overline{r}(\tau)\overline{\rho}\right)\overline{\rho}\right]\cdot\cos\varphi + \left[\left(\overline{r}(\tau) - \overline{v}\right)\overline{\rho}\right]\cdot\sin\varphi\right\} \quad (1)$$

At $\alpha = \infty, t = \varphi/\alpha$, we obtain from equation (1) a cylindrical surface:

The helical line of the helicoid is given by the system of equations (2)

$$\begin{cases} \mathrm{X} = \sqrt{\mathrm{b}^2 + \dfrac{\omega_A^2\cdot\sin^2\beta}{\cos^2\alpha}}\cdot\cos\phi - e \\ Y = \sqrt{\mathrm{b}^2 + \dfrac{\omega_A^2\cdot\sin^2\beta}{\cos^2\alpha}}\cdot\sin\phi\cdot\cos\theta + \left[\rho\cdot\phi + \dfrac{\omega_A\cdot\cos\ \beta}{\cos\ \alpha}\right]\cdot\sin\theta \\ Z = \sqrt{\mathrm{b}^2 + \dfrac{\omega_A^2\cdot\sin^2\beta}{\cos^2\alpha}}\cdot\sin\phi\cdot\cos\theta + \left[\rho\cdot\phi + \dfrac{\omega_A\cdot\cos\ \beta}{\cos\ \alpha}\right]\cdot\cos\theta \end{cases}$$

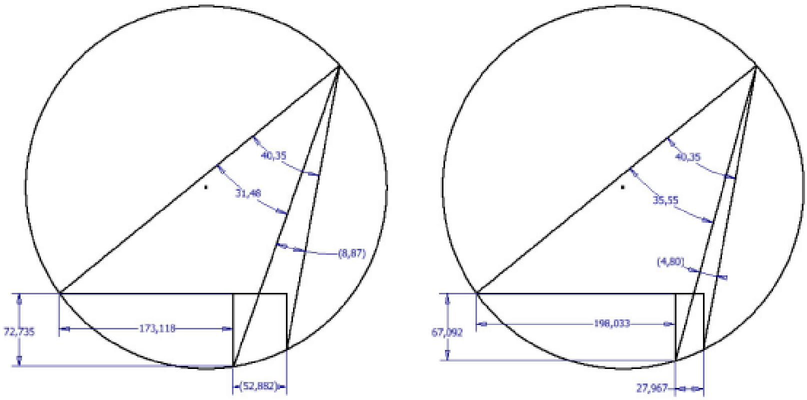

Fig.2 Diagram family of parametric kinematic propeller

From formula (2) we determine the value: $\xi = arctg\dfrac{\omega_A \cdot \sin\beta}{b \cdot \cos\alpha}$

The results obtained are presented in Fig.3.

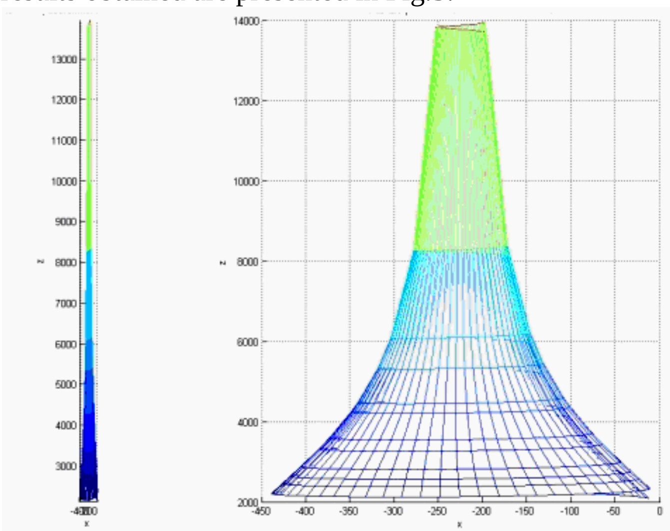

Fig. 3 Tapered surface

Conclusions.

On the basis of a parametric kinematic screw, families of conical helical lines are defined. It allows to determine the cross section of points of the conical axis creating with a horizontal plane, which makes it possible to determine interference, due to which it is possible to correct the curvilinear conical surface of the future product.

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