METHODS AND HARDWARE ORIENTED ALGORITHMS FOR MAKING STELLARATOR MAGNETIC SYSTEM SCREW-TYPE WINDING IMAGES

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The base methods, algorithms and standard programming tools which using for 3D images and for visualization by projection of the toroidal stellarator magnetic system screw-type winding were represented in this article. Work of the computer program for screw-type winding images manipulation and for necessary geometry information about given object receiving was represented.

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1. INTRODUCTION

Considerable technical problems are appearing under toroidal stellarator magnetic system designing. These problems connected with construction geometry description and with creation images of the complicated construction elements with difficult shape and big overall size [1]. Such kind of working requires a high level accuracy and enlists a lots of specialists and it is also spends a lot of time. Modern computer techniques make available to find solution onto qualitative new high level. For this is necessary to develop mathematical models [2] and algorithms [3] in goal to create interactive systems for receiving geometry and computer images of screw-type winding.

The goal of given work is development such kind of program with possibility to create 2D and 3D images of screw-type winding.

2. MATHEMATICAL MODELS FOR GEOMETRY DESCRIPTION

Mathematical modes for geometry description of the screw-type winding surfaces are describes as solution of the systems of transcendental and non-lineal first order differential equations. Such kind equations provide receiving of the coordinates of the characteristic elements of screw-type winding as data array.

Under development models it is necessary to taking into account following features of the stellarator magnetic systems:

- Complex space shape;
- Periodical configuration of screw-type winding pole;
- Huge overall size;
- Screw-type winding surface do not have evolvent;
- Screw-type winding surfaces formation as result of fixed plate figure movement along winding line;

$$\varphi = \frac{1}{m_h}(\vartheta - \alpha \sin\vartheta - \beta \sin 2\vartheta) + \frac{2\pi}{l}k, \qquad (1)$$

where φ – meridian cross section angle of winding line; α, β – modulation coefficients; m_h – numbers of winding conductor steps; l – numbers of the winding conductor entrance; $k = 0,1,\ldots,m-1$ – numbers of poles. Coordinates of this point is possible to formulate by angles $\overline{\vartheta}$ and $\overline{\varphi}$:

$$\begin{aligned} x_M &= \varsigma_1^0 l_{1x}(\overline{\vartheta},\overline{\varphi}) + \varsigma_2^0 l_{2x}(\overline{\vartheta},\overline{\varphi}); \\ y_M &= \varsigma_1^0 l_{1y}(\overline{\vartheta},\overline{\varphi}) + \varsigma_2^0 l_{2y}(\overline{\vartheta},\overline{\varphi}); \\ x_z &= \varsigma_1^0 l_{1z}(\overline{\vartheta},\overline{\varphi}) + \varsigma_2^0 l_{2z}(\overline{\vartheta},\overline{\varphi}); \end{aligned} \qquad (2)$$

where $\overline{\vartheta}$, $\overline{\varphi}$ – coordinates of the point of intersection of normal plane and winding line; $\varsigma_1^0, \varsigma_2^0$ – coordinates of one of normal cross section pole edges. Impart consequentially $\overline{\vartheta}$, values $\overline{\vartheta}_1, \overline{\vartheta}_2, \ldots, \overline{\vartheta}_N$ it is possible to give coordinates corresponding line points. Such line is described by one of the vertex of normal cross section. Array formed by this way is a data about line formed by pole edge. Similar way it is possible to take arrays, which was characterized other poles. Length of the normal cross section middle line by their angle width is main element, which was defining the shape of pole.

Shaft-bow length of middle line determine from following formula:

$$\begin{aligned} dS^2 &= dx^2 + dy^2 + dz^2 = (a + h/2)^2 d\vartheta^2 + \\ &+ [R_0 + (a + h/2)\cos\vartheta]^2 d\varphi^2, \end{aligned} \qquad (3)$$

therefore

$$\frac{dS}{d\vartheta} = \sqrt{(a + h/2)^2 + [R_0 + (a + h/2)\cos\vartheta]^2 \left(\frac{d\varphi}{d\vartheta}\right)^2}, \qquad (4)$$

here h is pole high R_0, a is longer and shorter tore radius respectively.

Differential dependences between angle ϑ and shaft-bow of middle line S are:

$$\frac{d\vartheta}{dS} = \frac{1}{a + h/2} \times$$
$$\times \frac{\nu_y \cos\varphi + \nu_x \sin\varphi}{\sqrt{(\nu_y\cos\varphi - \nu_x \sin\varphi)^2 + \{\sin\vartheta[\nu_x\cos\varphi - \nu_y \sin\varphi] + \nu_z\cos\vartheta\}^2}}, \qquad (5)$$

$$\frac{d\varphi}{dS} = \frac{1}{R_0 + (a + h/2)\cos\vartheta} \times$$
$$\times \frac{\sin\vartheta(\nu_x\cos\varphi + \nu_y\sin\varphi) + \nu_z\cos\vartheta}{\sqrt{(\nu_x\cos\varphi - \nu_x\sin\varphi)^2 + \{\sin\vartheta[\nu_x\cos\varphi + \nu_y\sin\varphi] + \nu_z\cos\vartheta\}^2}}, \qquad (6)$$

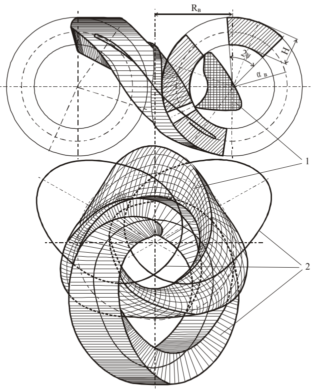
here v_x, v_y, v_z – components of the velocity of point with coordinates $\overline{\vartheta}$, $\overline{\varphi}$.

Equations (5) and (6) are possible to consider as system of two non-linear first order differential equations. By solving this system taking into account initial conditions $\vartheta = \overline{\vartheta}$, $\varphi = \overline{\varphi}$ at $S = 0$ it is possible to determine dependence $\vartheta = \vartheta(S)$ and $\varphi = \varphi(S)$. From this dependences determine desired value S^*.

3. REALIZATION OF ALGORITHM

Realizations of screw-type winding surface model algorithms are following:

- Kinematics designing method with possibility surface modeling by fixed cross section (pole shape) moved along winding line. Verge of such kind of cross section is surface of the pole[3];
- Raster representation of modeled surface. Modeled surface is mesh lay onto given surface. Mesh elements are screw-type winding median pole set and guides. Coordinates of angles of such kind mesh is calculated and kept as array in computer memory;
- Usage of Bezier spline determining of points coordinates when points are located arbitrary at modulated surface [3].



Screw-type winding with trapezoid pole (2) and magnetic surfaces (1)

Computer program for obtaining images screw-type winding poles realized by C code and used existing program libraries MCF 6.0 and Stingray Objective ToolKit 6.0. For 3D images was using TGS Open Inventor V2.62 and TGS 3D Mastersuite V3.62.

Results of realizations following algorithms are represented on figure1. On this figure is shown raster representation of screw-type winding with trapezoid shape of pole. Front and horizontal projections of given of screw-type winding is shown.

4. CONCLUSIONS

Given interactive graphic system make possible appreciably increase developers labour productivity at all level of the stellarator system designing. Using modern computers libraries and standard graphical systems make possibility to modeling stellarator systems on computers and after that developing all necessary technical documentations.

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МЕТОДЫ И АППАРАТНО-ОРИЕНТИРОВАННЫЕ АЛГОРИТМЫ СИНТЕЗА ИЗОБРАЖЕНИЯ ВИНТОВЫХ ОБМОТОК СТЕЛЛАРАТОРНЫХ СИСТЕМ

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В статье изложены основные методы, алгоритмы и стандартные программные средства, используемые для получения 3D-изображения и изображения по проекциям винтовых обмоток тороидальных магнитных систем стеллараторного типа. Описана работа компьютерной программы, позволяющей манипулировать изображением винтовых обмоток и получать необходимую информацию о геометрии моделируемого объекта.

МЕТОДИ ТА АПАРАТНО-ОРІЄНТОВАНІ АЛГОРИТМИ СИНТЕЗУ ЗОБРАЖЕННЯ ГВИНТОВИХ ОБМОТОК СТЕЛАРАТОРНИХ СИСТЕМ

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В статті наведено основні методи, алгоритми та стандартні програмні засоби, що використовуються для отримання 3D-зображення та зображення по проекціям гвинтових обмоток тороїдальних магнітних систем стелараторного типу. Описано роботу комп’ютерної програми, що дозволяє маніпулювати зображенням гвинтових обмоток й отримувати необхідну інформацію про геометрію об’єкту моделювання.