COUPLING THE AUTOCADE AND DELPHI ENVIRONMENTS FOR GENERATING 3D FINITE ELEMENT MESH IN THE ELECTROMAGNETIC DEVICES DESIGN

Abstract: A computer - aided design system for electromagnetic device is presented. The system has been adopted for the design of the middle-power three-phase transformers. The elaborated system consists of (1) computer application aiding the design and discretization process and (2) a module for presentation of the results of calculation and design process. The results of calculations may be presented in a textual or graphic form. The AutoCAD program is used for the graphic presentation.

1. Introduction

The design process of different types of electromagnetic devices is a complicated task that requires a broad knowledge of the designer. The intensive development of computer engineering made possible the creation of many tools helping constructor works. The basic works realized computer applications aiding design are as follows: calculations, data base systems (e.g. those of ready solutions or material parameters) and visual presentation of calculation results. There are also programs making possible to simulate the operation of any designed object. The extension of the design system by the simulation program enables in many cases to rough test and in case of need to improve the obtained solution without the necessity to build any prototype. However, such procedure needs the precise model of the physical phenomena of different nature, e.g. electromagnetic or thermal phenomena. Recently, the field models and final element method is commonly used. The first step in such modelling is so called preprocessing, which includes discretization of the analyzed object. This is most time consuming stage for the designer. On the other hand, the Autodesk AutoCAD application is one of the most spread graphic programs, applied for technical design problems. In this paper, a combination of the AutoCAD system for the design of electromagnetic circuit of the middle-power transformer with the code generating a three-dimensional discretization mesh for the initially designed object is presented.

2. Principle of optimal meshes generation

2.1. Introduction

A discretization is a division of the continuum (continuous medium) to the finite number of finite elements [1, 2]. The object with the complicated shape is here replaced by the series of elements with the simple structure. In the two-dimensional space triangles are the simplest geometrical objects, however in the three-dimensional space the tetrahedral elements are most often used.

For generating the discretization mesh most often a Delaunay triangulation is applied [1, 2]. This method consists in the division of area into not overlapping triangles. The Delaunay mesh is an optimal mesh. The optimization of the mesh can be realized out with the aid of criterion of the circle [1, 2] or with the help of the angle criterion [1, 2]. Applying the criterion of the circle (Fig. 1) one should check whether on another points still belong to the circle circumscribed on vertexes of the single triangle of the mesh; if so (Fig. 1a) it means that the criterion is not fulfilled. Then a change of connections between the nodes of the mesh is taking place, that is reorganization of the mesh (Fig. 1b). New-created triangles fulfill the criterion of the circle (Fig. 1c).

Fig. 1. The Circle Criterion

Many algorithms of triangulations have been worked out; these algorithms differ in
computational complexity. It is possible to divide algorithms of the Delaunay triangulation in two kinds: static and dynamic. In static methods in the first step a mesh containing all nodes of the input set is being generated. In next steps it is being made optimization (legalization) of triangulation. However in dynamic algorithms legalization of the mesh is realized every time after putting the point [2]. In the group of static algorithms it is possible to make mention of the following algorithms: radial sweep, recursive split, divide and conquer [1, 2, 7], however in the group of dynamic algorithms: step by step, incremental and incremental delete and build [1, 2].

2.2 Radial sweep algorithm

Radial sweep algorithm is an essential static algorithm of the Delaunay triangulation. It was presented by A. Mirante [7]. The first step of the algorithm consists in the choice of one point belonging to the set of input data. This point should be nearest the centre of discretized area (2D) or space (3D); within the first step the connection of this specific point with all remaining set points are realized (Fig. 2a). Next not-crossing segments (2D) or faces (3D) linking the adjacent points are being created (Fig. 2b, c). The formed mesh contains elements that don’t overlap. In the consecutive step a legalization of the mesh is being made with the aid of the criterion of the circle (Fig. 2d).

2.3. Step by step algorithm

Step by step algorithm [1, 2] most often is being applied to the Delaunay triangulation. Drawing the basic line (named base line) between two points is the first step of the algorithm. Basic points are being chosen so that they are on an edge of the set and their reciprocal distance was the nearest (Fig. 3a). Next such neighbouring point is being searched which together with final points of the basic line is defining the circle. A point which is defining the circle with the smallest radius is being selected from among many neighbouring points. The neighbouring point can be determined also by the criterion of the angle. In such case for the triangle with the base created by the base line, a measure of the angle is determined between shoulders of the triangle. A point with the greatest measure of the angle is being chosen. Segments between the new point and two output points will constitute the second and the third side of the triangle (Fig. 3a). Sides of this triangle are being accepted as the base lines for the later triangulation (Fig. 3b). This way the algorithm is creating the Delaunay triangulation in the whole area.

Presented above methods of the generation and optimization of the meshes have been adopted in the elaborated computer application – see section 4.

3. Description of design application

In the Division of Mechatronics and Electrical Machines of the Poznań University of Technology, a program supporting the calculations of the electromagnetic circuits of three-phase middle power transformers has been worked out. The computer code was elaborated by use of the Delphi programming environment and makes possible to realize calculations in an interactive manner. Results of calculations are saved to a text file. A graphic presentation of results is also possible.
The elaborated program helps to design oil power transformers with a power from 20 to 2500 kVA. The voltage of the upper side is comprised in a range from 1 to 30 kV. The program is adapted to the design of transformers with an unsymmetrical core of three columns.

The algorithm [2, 3, 5] implemented in the program makes possible to realize calculations within the following scope:
- selection of main transformer dimensions,
- design of windings for low and high voltage,
- determination of the short-circuit voltage value,
- determination of the no-load current value,
- load and no-load running power losses calculations.

The work with the design program runs in the conversational mode. The main program window (Fig. 4) is divided into several sections.

The individual parts of the form make possible to enter postulated transformer parameters and a current preview and possible corrections of variables used in the design process. In Fig. 5 an exemplary dialogue box helping the design of the low voltage winding is presented.

After the end of design calculations, the results are saved to a text file. The developed program possesses the possibility of visualization of designed electromagnetic circuit in the drawing space of the Autodesk AutoCAD program. The ActiveX Automation [8] technology is used with intent to attain it. The ActiveX Automation technology originates from OLE technology and enables a data exchange between the applications working in the Windows environment. The program aiding the design has been combined with the AutoCAD program. The possibility of program control of AutoCAD drawing objects was created in this way. The elements of designed object are drawn in an automatic manner. Some examples of visualizations are shown in Fig. 6.

4. Discretization application

The geometric dimensions obtained as a result of calculations of the electromagnetic circuit are transmitted to the discretization program by means of text files. Not only the electromagnetic circuit of the transformer is digitalized in the developed computer program, but also the area around the windings and the core, while the transformer components and devices such as tap switches, radiators, oil conservator, cramp beams, etc. are ignored. The transformer vat is reduced to the form of a thin-walled cuboid. The program makes
possible to automatically generate a three-dimensional mesh. The program input data can be also entered in conversational mode.

The electromagnetic circuit of a three-phase transformer is a three-dimensional object. The use of Delaunay tetrahedralization algorithms [2] would substantially complicate the discretization program and extend the machine calculation time. In the program aiding discretization the transformer model is divided into layers with parallel planes along its height. The triangulation on every from those planes is carried out in the same way by use of a step by step algorithm [2, 6] and a two-dimensional mesh results from it. Subsequently, pentahedral elements with trigonal bases (prisms) are created from triangles. The heights of individual layers depend on the adopted partition density. The individual layers superposed one another create one coherent three-dimensional mesh. The use of digitalization being based on the structure of parallel planes considerably shortens the computer calculation time in comparison with the implementation of Delaunay tetrahedralization algorithms.

The three-dimensional discretization net obtained as a result of program calculations can be used in the programs, which analyse the magnetic field by use of the finite element method. In order to validate the digitalization result, the program generating net makes possible to visualize it. Like in the computational program, the AutoCAD system is used for the visualization. The AutoCAD window with an exemplary visualization of the digitalization is presented in Fig. 7.

An additional advantage of such presentation of results is the possibility to edit the drawing-objects in the AutoCAD space. The visualization can also be saved as a dwg type file.

4. Summary

Presented computer programs aiding the design and discretization of the electromagnetic circuit of a three-phase transformer can be used either as independent tools or as computational modules in an expert system. The possibility of graphic presentation of calculation results in the AutoCAD program is the advantage of developed applications.

References


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