Adaptive Mesh Generation Method Utilizing Magnetic Flux Lines in Two-Dimensional Finite Element Analysis

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Abstract — In the Finite Element Method for the electromagnetic field problems, it is necessary for a user to make a mesh as preprocess. However, the made mesh is different from that made by the other users, and the mesh strongly affects the accuracy of the analysis result. The adaptive finite element method has been researched to solve this problem. In this paper, we propose a new mesh generation method utilizing magnetic flux lines in two-dimensional electromagnetic field problem. Utilizing the magnetic flux lines, it is possible to distribute elements with different densities suitable for the electromagnetic field distribution.

I. Introduction

In the Finite Element Method (FEM), to obtain a highly accurate result users have to only divide a whole analysis region into small elements uniformly and finely, although the number of elements and the computation time are increased. It is necessary to make the mesh with suitable coarseness and fineness with estimating the distribution of the physical quantity. The mesh generation work, which is time-consuming and requires adequate experiences, is a bottleneck in order to easily and widely use the FEM. Therefore, the adaptive finite element method has been researched as one of the promising numerical analysis techniques [1]-[5] recently. The adaptive finite element method commonly consists of an error estimation method and a mesh generation scheme. In this paper, we propose the adaptive mesh generation method utilizing the magnetic flux lines computed by FEM with rough mesh for the two-dimensional magnetic field problem. In the magnetic field problem, our attention has focused on the equivalent of the magnetic flux lines distribution and the physical quantity distribution, and we propose a new mesh generation scheme. In order to verify its usefulness we have applied the proposed mesh generation method to magnetic field problems.

II. Proposed Adaptive Mesh Generation Scheme

Generally, in the magnetic field problem, the magnetic vector potential is an unknown variable. Therefore, it is necessary to divide into small elements on the region where the magnetic vector potential changes drastically. On the other hand it is necessary to divide into large elements on the region where it gradually changes. The magnetic flux lines represent equipotential lines on 2D magnetic field, thereby the interval of the magnetic flux lines is relative to the potential valuations. In this paper, we propose the mesh generation scheme, which utilizes this feature without an error estimation process. In the proposed method, the nodes constructing triangles are laid out on the magnetic flux lines with distance of the neighboring magnetic flux lines. The main procedure of the computation is as follows:

Step 0: An initial rough mesh is prepared.
Step 1: The analysis of the magnetic field by FEM is carried out.
Step 2: The flux lines are computed from the magnetic vector potential distribution, and then the new nodes are generated on the magnetic flux lines.
Step 3: The triangle elements are made from the generated nodes using the Delaunay algorithm.
Step 4: The quality of the generated mesh is improved using the Laplacian smoothing method.
Step 5: If the number of iterations or elements reaches to the threshold, the computation is finished. Otherwise, return the step1.

Next, the way to generate the new nodes in step 2 is described. Generally, the magnetic flux line starts from a point on the natural boundary and ends on the other boundary. The new nodes on the magnetic flux line are generated in the order of the starting point to the ending point. Fig. 1-(a) shows an example existing three flux lines from the boundary PQ. When the new nodes are generated on the magnetic flux line *#2*, the distance *d1* from the neighboring magnetic flux line *#1* is calculated, and *d3* is calculated in the same way. Then a new node *B* is generated from the distance *d* away from the starting point *A*, where the distance *d* is the same as the shorter among *d1* or *d3* as shown in Fig. 1-(b). After that, a new point *C* is generated in the same way as shown in Fig. 1-(c).

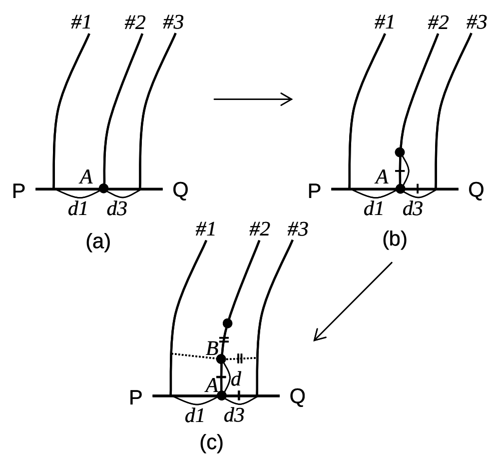

Fig. 1. New nodes are generated on the magnetic flux lines.

III. Applications

A. One Coil Model

At first the proposed mesh generation method was applied to a one coil model shown in Fig. 2. Fig. 3 shows the initial mesh and the magnetic flux lines. Fig. 4 shows the generated mesh and the magnetic flux line distribution that are obtained at 5th iteration. The suitably smooth magnetic flux lines were obtained as the adaptive mesh generation was repeated although the magnetic flux lines were not smooth at the 1st iteration.

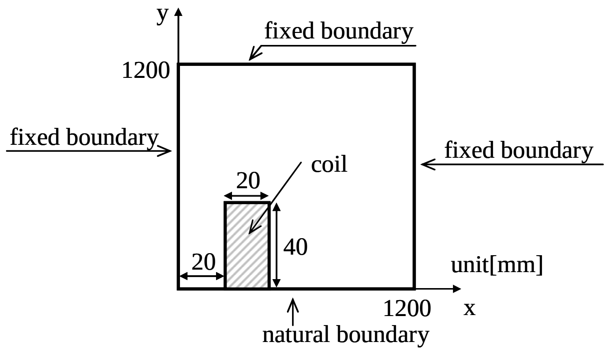

Fig. 2. The one coil model.

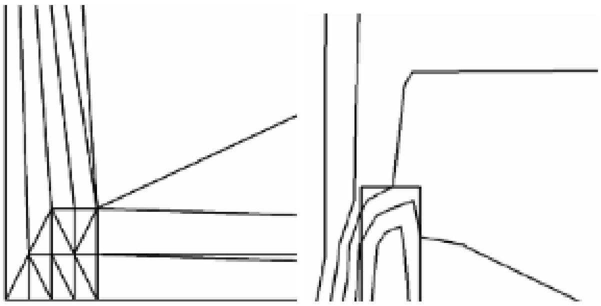

Fig. 3. The initial mesh and the magnetic flux lines for the one coil model.

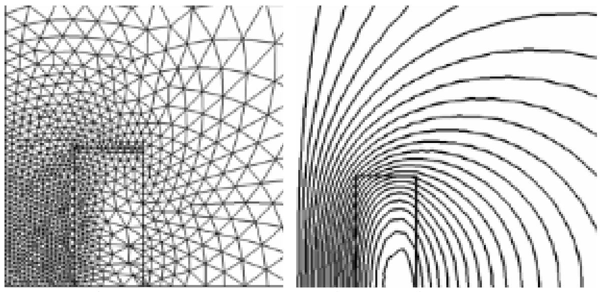

Fig. 4. The final mesh and the magnetic flux lines for the one coil model.

B. Coil and Ferrite Model

Next the proposed method was applied to a coil and ferrite model shown in Fig. 5. Fig. 6 shows the initial mesh and the magnetic flux lines, and Fig. 7 shows the finally obtained mesh. In this case, it is necessary for the ferrite to be divided into small elements since the magnetic flux lines are dense in the ferrite. As a result, it was verified that the proposed method was suitable for generating the mesh of the magnetic field problems since the obtained mesh depended on the change of the physical quantity in the magnetic field.

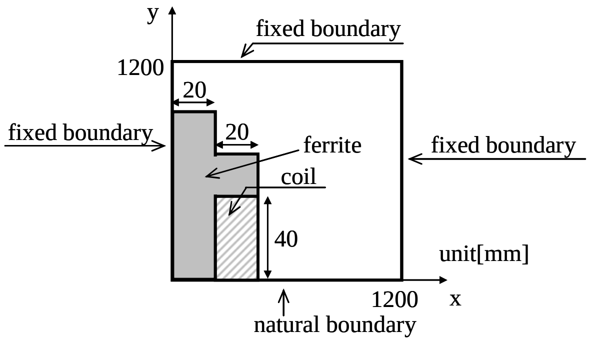

Fig. 5. The one coil and ferrite model.

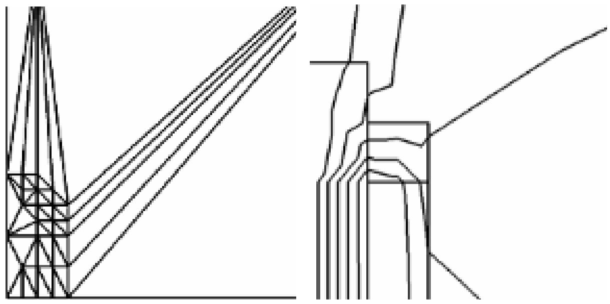

Fig. 6. The initial mesh and the magnetic flux lines for the one coil and ferrite model.

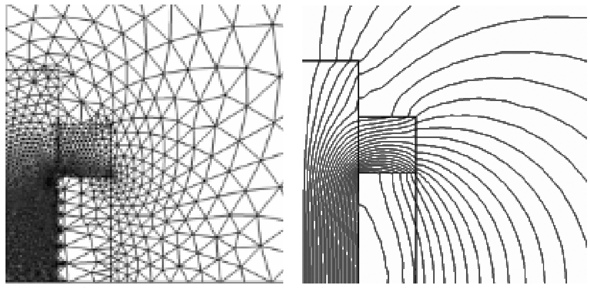

Fig. 7. The final mesh and the magnetic flux lines for the one coil and ferrite model.

IV. References

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