A Novel Remesh-Free Method based on Finite Element Method for Electromagnetic Devices with Rotation or Translation

Xiu Zhang[1,2], and Xin Zhang[1,2*]

[1]Tianjin Key Laboratory of Wireless Mobile Communication and Wireless Power Transmission, Tianjin Normal University
[2]College of Electronic and Communication Engineering, Tianjin Normal University, Tianjin, China
Corresponding author: tjnumark@126.com

For the electromagnetic devices with rotation and translation, it is important to analyze their electromagnetic characteristic at each position. When the numerical method is applied to analyze these devices, the solving domain of the devices should be remeshed again when the position changed. The analysis process requires a large amount of computation time especially when the electromagnetic devices have large size. To address this issue, a novel remesh-free method is proposed in this paper. In this method, the mesh data of the moving part and the static part are saves as two independent files. Before analysis, the two mesh data files are merged together. The overlap part should be processed according to its position in the two independent files. After the two mesh data files are merged together, it will be analyzed as a whole mesh data. When the moving part translates a certain distance or rotates a certain angle, the whole computational domain should not be remeshed again. It just needs to merge the two mesh data files. A numerical method is given to showcase the effectiveness of the proposed method.

***Index Terms*—Electromagnetic, finite element method, numerical method, remesh-free method.**

I. Introduction

FOR ELECTROMAGNETIC devices, it is important to obtain their electromagnetic properties using numerical method. In practice, finite element method (FEM) is frequently used to analyze the electromagnetic devices based on Maxwell's electromagnetic field equations [1-4]. The computational precision and the computational speed are determined by the model shape of the devices and the quality of the mesh.

When the devices have rotation or translation, FEM will be solved repeatedly once the position of moving part in the device is changed. In this case, repetitive remeshing process should be applied to analyze the devices. It will cost a lot of computational time. Thus, it is highly desirable to reduce the computational time.

Several methods are proposed to reduce the computational time, such as partially remesh method [5-6], the mesh deformation based on redial basis function interpolation [7], new deformed mesh using a coordinate mapping technique [8-9] and optimization based moving mesh strategy [10]. Among these methods, the partially remesh method need to solve the equations of elasticity or the Laplace equation which is still time consuming; the other methods are suitable to analyze the problems with shape deformations.

For the devices with rotation and translation, in this paper, a novel remesh-free method is proposed to save computational time. In this method, it does not need to solve additional equations except for the finite element equations. A numerical example is simulated to showcase the proposed method.

II. Proposed Remesh-Free Method

In this paper, a novel remesh-free method is proposed to analyze the electromagnetic devices with rotation and translation. The flowchart of the method is shown in Fig. 1.

In this proposed method, as shown in Fig. 2, the geometry of the electromagnetic device is devised into two parts, the moving part and the static part. The two parts are meshed separately to form two sets of mesh data. Then the two sets of mesh data are merged to be one set of mesh data.

During merging, the moving part becomes the overlapping part which can be divided into two types. One type is the element in the static part is fully included in the moving part which can be deleted during merging; the other type is the elements in the static part are partly included in the moving part. For these elements, they are lack of vertices after merging. The missing vertices will be relocated in the nodes in the boundary of the moving part. If the node in the boundary of the moving part locates in the element in the static part which is partly included in the moving part, this node will be chosen to replace the missing vertex.

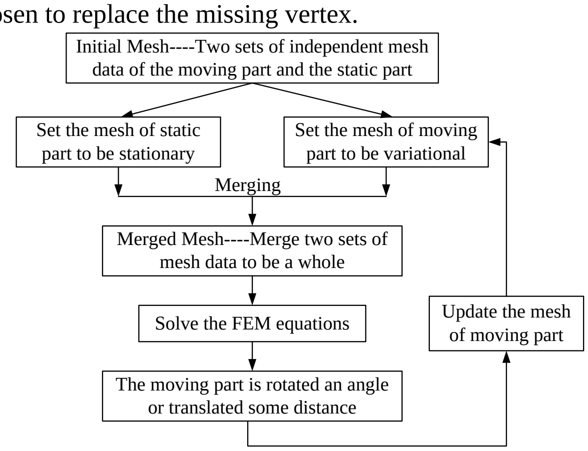
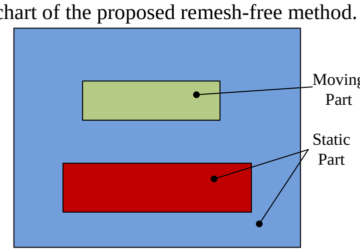


Fig. 1. The flowchart of the proposed remesh-free method.



(a)

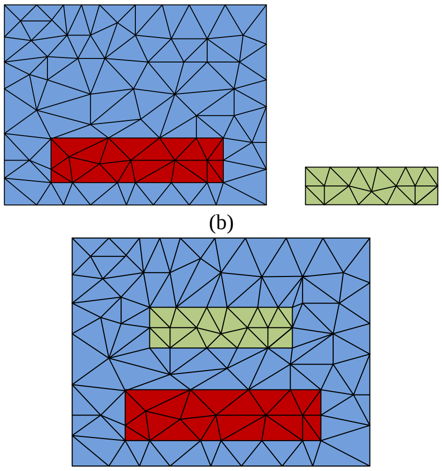


Fig. 2. The simple sketch of the proposed remesh-free method. (a) 2D geometry of the solving domain; (b) Initial mesh: two set of independent mesh data for moving part and static part; (c) Merged mesh.

III. Numerical Example

In order to test and verify the proposed method, the TEAM workshop problem 28 is chosen to be analyzed using the proposed method [11].

In this case, as shown in Fig.3, there are two cylindrical coils which are aligned coaxially. The inner coil and the outer coil have 960 turns and 576 turns respectively. A cylindrical aluminium plate is located above the coils. Its mass is about 0.107 kg. The plate will shake up and down when the two coils are added different direction of sinusoidal current. The dimensions of the device are shown in Fig. 4.

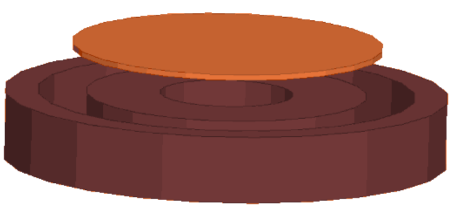


Fig. 3. TEAM Workshop Problem 28: An electrodynamic levitation device [11].

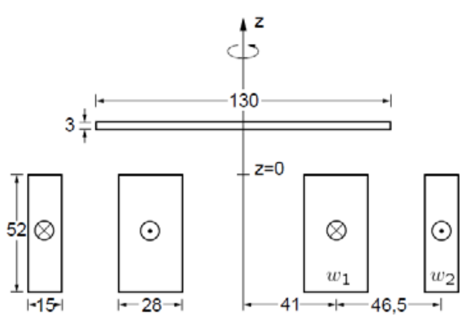


Fig. 4. Dimension of the electrodynamic levitation device (in mm) [11].

In this device, the two coils are static part and the aluminium plate is the moving part. The proposed method is applied to analyzed the model. When the aluminium plate has up and down shaking, remeshing process will be omitted which will save computational time. The force in the aluminium plate under electromeanetic field is shown in Fig. 5. Thus, the position of the aluminium plate will be calculated in the next step which will be given in the full paper.

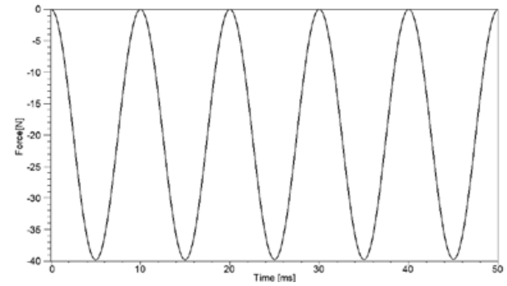


Fig. 5. The force in aluminium plate under electromeanetic field.

IV. Conclusion

In this paper, a novel remesh-free method is proposed which is suitable to analyze the electromagnetic devices with rotation or translation. In this method, there are no supplementary equations to be added in the process of solving. The procedure of the proposed method indicates that it can save much computational time. The TEAM workshop problem 28 is chosen to showcase this method which is effective and efficient.

Acknowledgment

This research was supported by the National Natural Science Foundation of China (61601329) and Applied Basic Research Program of Tianjin (15JCYBJC52300).

References

[1] X. Zhang, Xiu Zhang, Shiu Yin Yuen, S. L. Ho, and W. N. Fu, "An improved artificial bee colony algorithm for optimal design of electromagnetic devices,"*IEEE Trans. Magn.*, vol. 49, no. 8, pp. 4811-4816, August 2013.

[2] W. N. Fu, and S. L. Ho, "Extension of the concept of windings in magnetic field electric circuit coupled finite element method," *IEEE Trans. Magn.*, vol. 46, no. 6, pp. 2119-2123, June 2010.

[3] Xiu Zhang, Y. Zhao, S. L. Ho, and W. N. Fu, "Analysis of wireless power transfer system based on 3-D finite element method including displacement current," *IEEE Trans. Magn.*, vol. 48, no. 11, pp. 3692-3695, Nov. 2012.

[4] Xiu Zhang, H. L. Li, S. L. Ho, and W. N. Fu, "A multi-slice finite element model including distributive capacitances for wireless magnetic resonant energy transfer systems with circular coils," *IEEE Trans. Magn.*, vol. 49, no. 5, pp.1857-1860, May 2013.

[5] Y. Yao, J. S. Ryu, C. S. Koh, and D. Xie, "A novel mesh regeneration using structural deformation analysis for 3-D shape optimization of electromagnetic devices," *IEEE Trans. Magn.*, vol. 40, no. 2, pp. 1009-1012, Mar. 2004.

[6] K. Yamazaki, H. Ishigami, and A. Abe, "An adaptive finite element method for minor shape modification in optimization algorithms," *IEEE Trans. Magn.*, vol. 44, no. 6, pp. 1202–1205, Jun. 2008.

[7] A. de Boer, M. S. van der Schoot, and H. Bijl, "Mesh deformation based on radial basis function interpolation," *Comput. Struct.*, vol. 85, nos. 11-14, pp. 784-795, 2007.

[8] S. L. Ho, Y. Zhao, W. N. Fu, and X. Zhang, "A novel mesh morphing technique for large shape deformation and its application to optimal design problems," *IEEE Trans. Magn.*, vol. 49, no. 5, pp. 2165–2168, May 2013.

[9] Yanpu Zhao, S. L. Ho, and W. N. Fu, "A novel fast remesh-free mesh deformation method and its application to optimal design of electromagnetic devices," *IEEE Trans. Magn.*, vol. 50, no. 11, pp. 1–4, Nov. 2014.

[10] E. J. López, N. M. Nigro, M. A. Storti, and J. A. Toth, "A minimal element distortion strategy for computational mesh dynamics," *Int. J. Numer. Methods Eng.*, vol. 69, no. 9, pp. 1898–1929, Feb. 2007.

[11] H. Karl, J. Fetzer, S. Kurz, G. Lehner, and W. M. Rucker, "Description of team workshop problem 28: An electrodynamic levitation device," 1997.