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MEMS 工艺模拟与有限元软件接口的实现

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摘要: 微机电系统工艺模拟可在实际加工前预测 MEMS 器件的实际结构, 有利于理解工艺机理, 缩短设计周期, 减少生产费用。针对目前用于 MEMS 器件分析的模拟软件尚不能很好地与有限元软件对接的问题, 设计了工艺模拟软件与有限元分析软件的接口。通过这个接口, 将 MEMS 工艺模拟所得到的数据经过数据格式的转换导入有限元分析软件 (ANSYS) 中并建模, 使之可以进行诸如机械、热、电等物理参量的分析。在分析了目前关于(曲线)边界轮廓提取的各种方法后, 引进了最大圆算法, 解决了工艺模拟结果在有限元软件中的模型重构问题, 实现了从工艺模拟到有限元分析的无缝对接。提出的接口设计对实现 MEMS CAD 体系化具有重要的促进作用。

关键词: 微机电系统; 工艺模拟; 有限元分析; 接口

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Realization of interface between MEMS process simulation and finite element software

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Abstract: The process simulation for Micro-electric-mechanic Systems(MEMS) can be used in predicting the actual structure of a MEMS before processing, which contributes to understand processing properties, shorten design periods and to reduce production costs. Because the current simulation software for MEMS analysis can not be combined with a finite element software, this paper presents a interface named as ANDYD Parametric Design Language(APDL) to link the process simulation software and the finite element software. By proposed APDL, the results from MEMS process simulation are imported into the finite element software to establish a model, then it is used to analyze on mechanical, electrical and thermal parameters. Moreover, the largest circle algorithm is introduced the software to implement the model reconstruction for the process simulation in the finite element software after analysis on several kinds of boundary contour extraction methods, which completes an seamless linking from the process simulation to the finite element analysis(FEA). Experimental results prove that proposed interface design is conducive to the systematization of MEMS CAD technologies.

Key words: MEMS; process simulation; Finite Element Analysis(FEA); interface

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1 Introduction

MEMS process simulation aids in understanding the accurate structures before actual fabrication, especially nonideal outlines, such as contacts, corners, islands, and defects^[1]. The results of process simulation can show the actual figures of MEMS devices accurately, which have been processed. MEMS process simulation includes lithograph, doping, heat treatment, deposition and etching simulation and so on^[2-3].

Finite Element Method (FEA) is always used to disperse the object to a finite element, and solve the model under some boundaries and load conditions then show the figure of the object and plot the stress ideal structure of the MEMS device. It still can't analyze the actual MEMS process simulation demonstration.

If the results MEMS process simulation can be imported to FEA software, such as ANSYS, it will be useful to improve the performance of MEMS devices. However, it is difficult to analyze the figure in process simulation by ANSYS directly.

Therefore, it is necessary to think about how to import process simulation data with engineering formats such as APDL to integrate with FEM analysis. This work is also valuable to MEMS CAD.

This paper briefly discusses the steps to realize the interface, details a method to convert MEMS process simulation data to APDL format, and gives an example of this interface.

2 General frameworks from MEMS process simulation to finite element analysis

The most important result of MEMS

process simulation is that we can get the process parameters and layout information, and then we understand the accurate and visual three-dimensional geometrical structures. Finally, we use FEM, such as ANSYS, to analyze the three-dimensional structures. MEMS process simulation shows the effect of parameters, so that the actual fabrication can be optimized and the accuracy of critical structures and the reliability of devices can therefore be improved.

The CAD architecture of process simulation of MEMS^[4] is shown as Fig. 1.

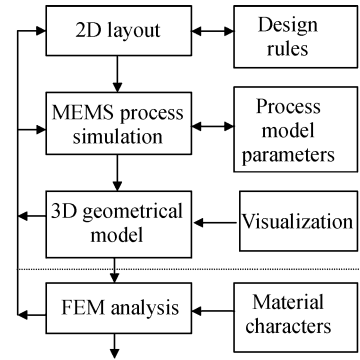


Fig. 1 CAD frameworks of process simulation of MEMS

It indicates two key points from process simulations to FEA. One is that how to put the process simulation results into ANSYS via data exchange method. The other is that how to build a finite element model in ANSYS. According to the analysis mentioned above, we present the

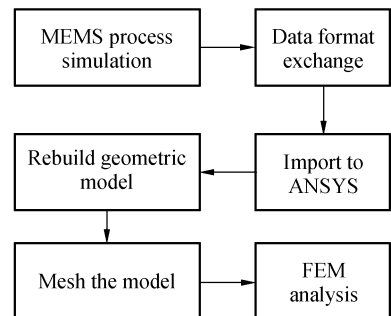


Fig. 2 General frameworks from MEMS process simulation to FEA

general framework from MEMS process simulation to FEA. The procedure described consists of six steps, which is shown in Fig. 2.

Data format exchange and rebuilding geometric model are the main work in this paper.

3 Method

APDL stands for ANSYS Parametric Design Language, a scripting language that you can use to automate common tasks or even build your model in terms of parameters (variables). APDL also encompasses a wide range of other features such as repeating a command, macros, if-then-else branching, do-loops, and scalar, vector and matrix operations. While APDL is the foundation for sophisticated features such as design optimization and adaptive meshing, it also offers many conveniences that you can use in your day-to-day analysis.

The finite element model can be built in two ways; one is the method that the meshed elements are directly defined through nodes, which also is defined at first; the other is the method that the element will be created by a sequence of operation like the creating geometry, meshing the geometry, etc. For the whole structure FEA, the first method will be convenient and easy. In this paper, we adopt the first method to rebuild the finite element model.

To facilitate programming and upgrading, we adopt file stream method to exchange data format in VC++. In other words, we finish the data format exchange via a program. The output of process simulation is a text, which includes coordinates of points and flags of states. To integrate with FEA, all the coordinates must be written into APDL file to obtain keypoints via ANSYS orders K , NPT , X , Y , Z , while K defines a keypoint, NPT means reference number for keypoint, X , Y , and Z means keypoint location in the active coordinate system. To rebuild geometric model, we pick up boundary key-

points. And then we use the order LSTR, P_1 , P_2 to define a straight line irrespective of the coordinate system, where P_1 means keypoint at the beginning of line and P_2 is the ending keypoint. We can create volumes by areas, which can be created by lines. Finishing these steps, the geometric model is built. To mesh the model, we define element type, real constants, and material attributes. Finally, we load boundary conditions to solve the model^[5-8].

The procedure to realize the interface between MEMS process simulation and ANSYS is shown in Fig. 3.

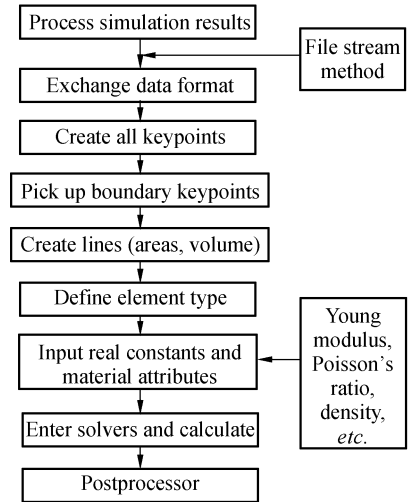


Fig. 3 Procedure to realize APDL interface

4 Example

Now we choose a common beam as an example to show APDL, in which all the geometry and topology information is kept well. First of all, the result of the MEMS process simulation is given, which is shown in visual software developed by our lab.

The main steps to realize the interface between MEMS process simulation and FEA is shown as followings:

(1) All the data are imported to ANSYS as keypoints after the data format exchange (file stream method).



Fig. 4 A beam structure in process simulation

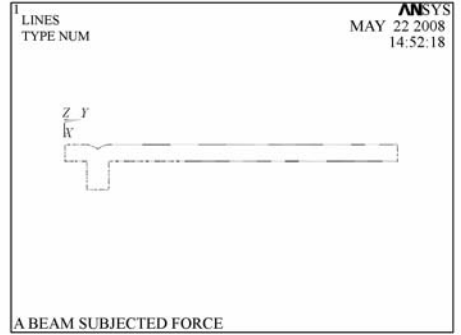


Fig. 7 Create beam outline

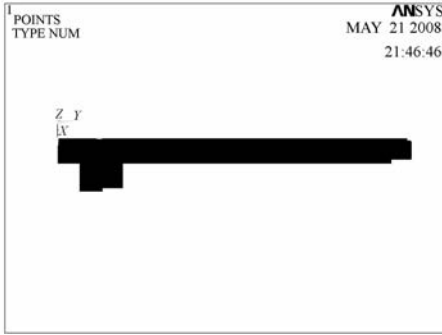


Fig. 5 Create all keypoints

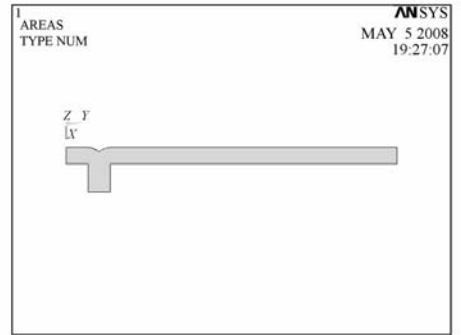


Fig. 8 Rebuild geometric model

(2) Pick up boundary keypoints. If the boundary is a straight line, we just need to pick up the beginning and ending keypoints. If the boundary is a curve, we must pick up all the keypoints.

these, the geometric model has been rebuilt.

(5) Use the geometric model to FEA: mesh the model, and specify force loads at nodes. The result is shown in Fig. 9.

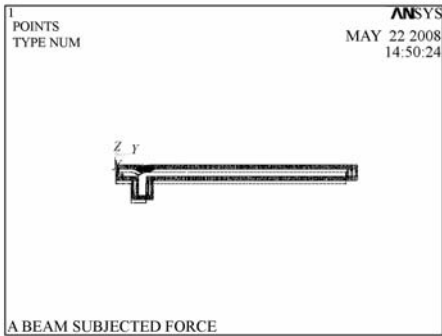


Fig. 6 Pick up boundary keypoints

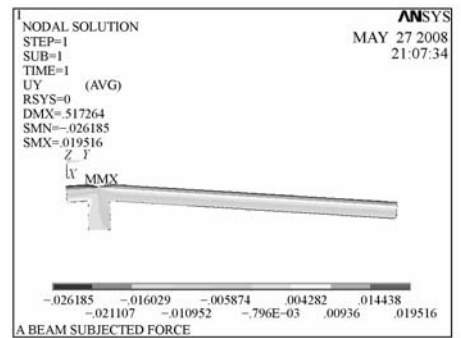


Fig. 9 Specify force loads at nodes

(3) Use the boundary keypoints to create lines. Finishing this step, the outline of the beam is shown in Fig. 7.

(4) Create the area of the beam via lines. As we can see that the beam shown in ANSYS in Fig. 8 agrees well with the simulation result shown in visual software in Fig. 4. After doing

From this example, we know that the AP-DL interface rebuild the geometric model well. Also, the results can be analyzed by FEA accurately. This makes the seamless link of fabrication process simulation and structure performance analysis possible.

5 Conclusions

This paper investigates the interface between MEMS process simulation and FEA, and realized one interface: APDL (ANSYS Parametric Design Language). The FEA results shown

in ANSYS agree well with simulation results shown in visual software, which indicates that the APDL interface is available, accurate and fast. This will be helpful for us to understand the property of the nonideal structure of actual process results, and will be useful to improve the performance of MEMS devices.

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