Analysis of PMP Module Using Mesh Generation Techniques

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Abstract—**Consumers are generally required the use of high energy density batteries. However, most consumers are often dissatisfied with the battery life from even the most advanced lithium-ion rechargeable batteries in mobile phone. All In recent years, plastic products have become thinner and lighter and proper materials, processing technology and product technology have been developed accordingly. PMP (Protection Module Package) has the potential of providing energy densities that are several times more than that PCM (Protection Circuit Module), making them attractive power source for mobile applications, such as next generation cellular phones that require high energy density power sources to enable extended operation times. In this paper, we explain an element generation method of PMP module using several types. Also, it is performed the several analysis of epoxy molding compound module using this mesh generation method.**

Keywords-component; protection circuit module, protection module package, mesh generation, finite element method

I. INTRODUCTION

The mesh generation process, which influences computational accuracy as efficiency and whose fully automation is very difficult in three-dimensional cases, has become the most critical issue in a whole process of the FE analyses. In this respect, one of the authors has been developed CAE system with mesh generation [1].

Consumers are generally required the use of high energy density batteries. However, most consumers are often dissatisfied with the battery life from even the most advanced lithium-ion rechargeable batteries in mobile phone[2]. In recent years, plastic products have become thinner and lighter and proper materials, processing technology and product technology have been developed accordingly. PMP (Protection Module Package) has the potential of providing energy densities that are several times more than that PCM (Protection Circuit Module),3 making them attractive power source for mobile applications, such as next generation cellular phones that require high energy density power sources to enable extended operation times

In this paper, several mesh generation method which is useful automated analysis system are describe. Also, FE analysis simulation for PMP module was carried out using several mesh generation method.

II. SYSTEM USING BUBBLE PACKING

The developed CAE system allows designers to evaluate detailed physical behaviors of structures through some simple interactive operations to their geometry models. In other words, designers do not have to deal with mesh data when they operate the system. The key element of this system, bubble meshing[4] lies in the first step, that is, the optimization of mesh node locations by close packing bubbles. By this method, bubbles move in a domain until forces between them are stabilized, and Delaunay triangulation is then applied to generate a mesh connecting the nodes defined by the bubble packing. A repulsive or attractive force much like an intermolecular van der Waals force is assumed to exist between two adjacent bubbles.

A globally stable configuration of tightly packed bubbles is determined by solving the equation of motion. The novelty of this method is that the close packing of bubbles forms a pattern of Voronoi polygons, corresponding to well-shaped Delaunay triangles[5]. Figure 1 shows the procedure of the bubble packing method. Bubble meshing generates a two-dimensional triangular mesh by the following two steps: (a) Solving the equation of motion on vertices, edges, and faces (or loops) in that order, (b) Generation of triangular mesh by connecting the center points of bubbles by Delaunay Triangulation. Similar steps are also applied to the generation of three-dimensional tetrahedral meshes.
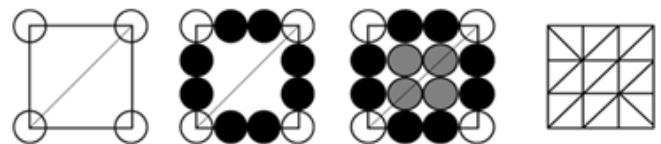

FIGURE I. PROCEDURE OF THE BUBBLE MESH

III. NODE GENERATION

Node generation is one of time consuming processes in automatic mesh generation. The input data required are only the node density of the base node pattern such as unit distance of nodes, the kinds of special node patterns, and the location and node densities at the representative points of the special node patterns.

The procedure of two dimensional node generation of the base node pattern is illustrated in Figure 2. First, either a circumscribed rectangle or box (in the 3D) to the domain is determined, in which nodes are generated regularly. A distance of neighboring nodes of the pattern, which is called "base grid size" here, is inputted by a user.

Second, each node is examined whether to be inside the domain by the IN-OUT check criterion, and any nodes outside the domain are removed.
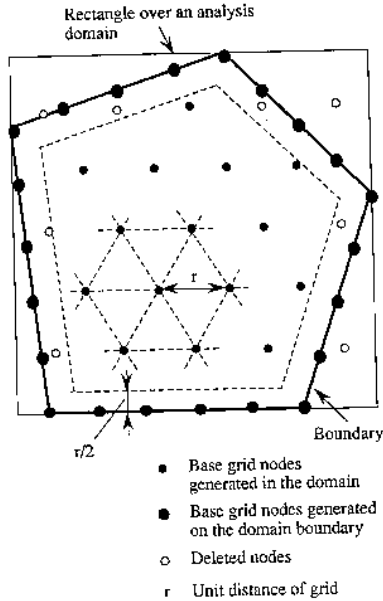

FIGURE II. GENERATION OF BASED NODE PATTERN

Any nodes located very closely to the domain boundary are removed as well to avoid undesirable distortion of mesh shape near the domain boundary. Among algorithms for uniform node generation, the present method may not be the best one as for the uniformity of node locations near the domain boundary, but it is very simple operation. Next, several node patterns are generated through an interactive operation between a user and the system. The input data required here are only the node density and the location of each stress concentration point.

IV. MESHLESS METHOD

Recent advance in computer technology has enabled a number of complicated natural phenomena to be simulated, which were only observed by experiments. Meshless method [6] has the algorithms described in Figure 3. The method commences with the appropriate allocation of nodes in the domain to be analyzed Ω. We first give nodal points $P_i(x, y)$, $\forall i \in \{1, ..., n\}$, in the domain with radius r_i, which represents nodal density, as illustrated in Figure 4.

Meshless method then allows each node P_i to nominate a set of candidate nodes for creating local elements within radius r_i, altogether being C_i, which is given by

$$C_i = \{P_j \mid \overline{P_i\,P_j} < r_i, \forall j \in \{1,...,n\}\},$$
$$\equiv \{P_0^c, P_1^c, ..., P_n^c\} \qquad (1)$$

where $P_0^c = P_i$ is the current central node, n_c is the number of candidate nodes ($n_c < n$) and

$$\overline{P_i\,P_j} = \sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}. \qquad (2)$$

Subscript c indicates that the numbering of each node is on a local basis.

```
Initialize_global_matrix K=0;
Initialize_global_vector q=0;
do i=1, n {
        Nominate_candidates C(i);
        Select_local_elements L(i);
        Initialize_local_matrix kL(i) = 0;
        Initialize_local_vector qL(i) = 0;
        do j = 1, ns {
                Derive_element_matrix ke(j);
                Derive_element_vector qe(j);
                kL(i) = kL(i) + ke(j);
                qL(i) = qL(i) + qe(j);
        }
        K = K + kL(i);
        q = q + qL(i);
}
```
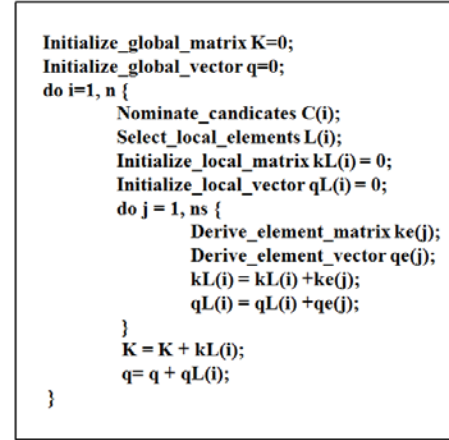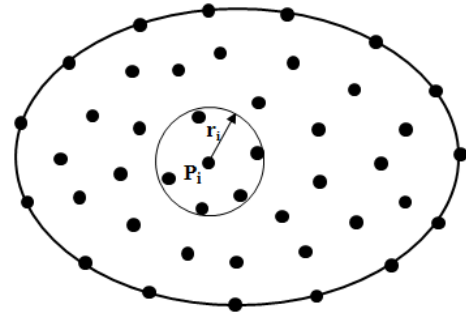
FIGURE III. BASIC ALGORITHM OF MESHLESS METHOD

FIGURE IV. FCENTRAL NODE AND SATELLITE NODE

Local elements are each then selected by connecting two points P_a^c and P_b^c with the center P_0^c.

The important note in the selection is that local elements created at each node must be consistent in a global manner. Figure 5 illustrates and example of violation in the selection, where element $\triangle P_a P_b P_d$, created with central node P_a does not coincide with the equivalent $\triangle P_d P_a P_c$ having P_d as its center. This inconsistency can be eliminated by setting up rules that select local elements irrespective of what the current central node is. To begin with, all $\triangle P_i^c P_j^c P_k^c$ are considered to be local elements. $P_j^c P_k^c$ is then sorted in its length and, from the shortest, eliminative rules described in Figure 6 are carried out. Here we will describe the set of nodes in Figure 7, which finally construct the local elements, for further convenience as follows:

$$L_i = \{P_0^s, P_1^s, \ldots, P_n^s\} \qquad (3)$$

where the subscript s indicates that each node is numbered with the selected local elements.
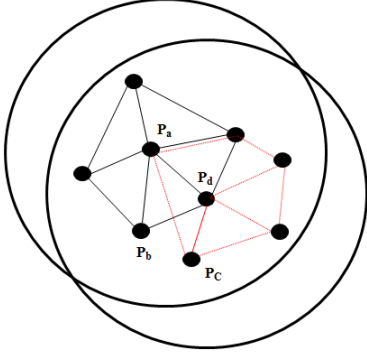

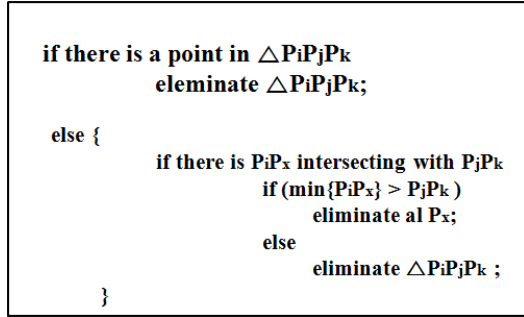FIGURE V. EXAMPLE OF VIOLATION IN LOCAL ELEMENTS SELECTION

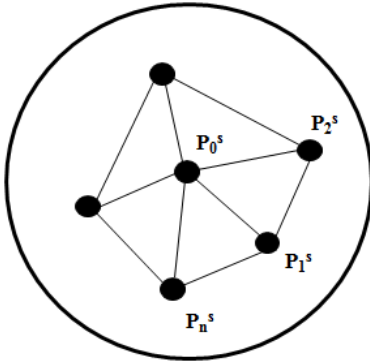
FIGURE VI. SELECTION OF LOCAL ELEMENTS

FIGURE VII. A SET OF LOCAL ELEMENTS

V. PMP MODULE

PMP module is introduced to reduce the thickness and internal resistance of the mobile phone battery. Figure 8 shows the shape of PMP module. Figures 9 and 10 is a configuration model and modeling for heat transfer analysis of PMP module respectively. In this study, a protection module of mobile battery was chosen because it is the flat plate of small thin wall which is expected to have great short shot and flexing. The size of module 3mm × 12mm × 1mm was used in this evaluation. Table 1 shows the property of different epoxy molding.
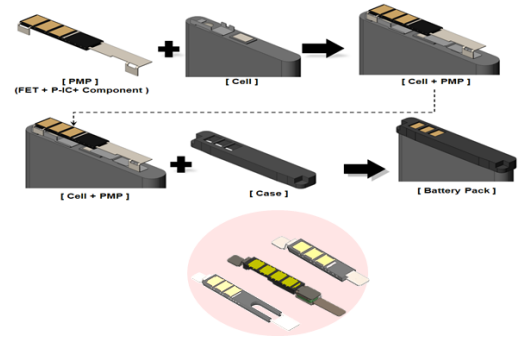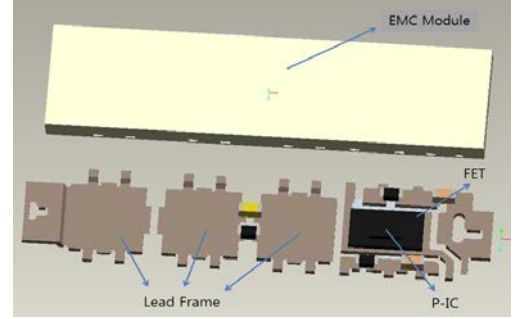

FIGURE VIII. SHAPE OF PMP MODULE

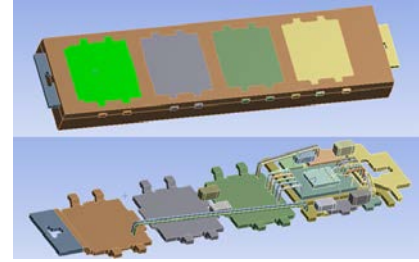

FIGURE IX. CONFIGURATION OF MODEL

FIGURE X. MODELING FOR ANALYSIS

TABLE I. PROPERTY OF SEVERAL MATERIAL

Type	A	B	C
Density[g/cc]	1.82	1.88	1.79
Flexural Modulus[GPa]	12	16	17
Poisson' ratio	0.43	0.36	0.34

VI. EXAMPLES AND DISCUSSIONS

The performance of the mesh generator is demonstrated through the mesh generation of several geometries. In case of a complex geometry as shown in Figure 11, a uniform mesh and a nonuniform mesh were connected very smoothly. Bubble and elements are generated in about 2 minutes and in about 3 minutes, respectively. The mesh consists of 6.896 tetrahedral elements.
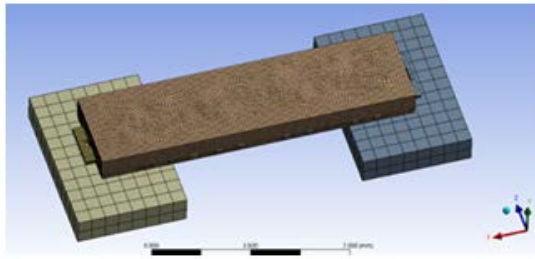

FIGURE XI. BUBBLE MESH
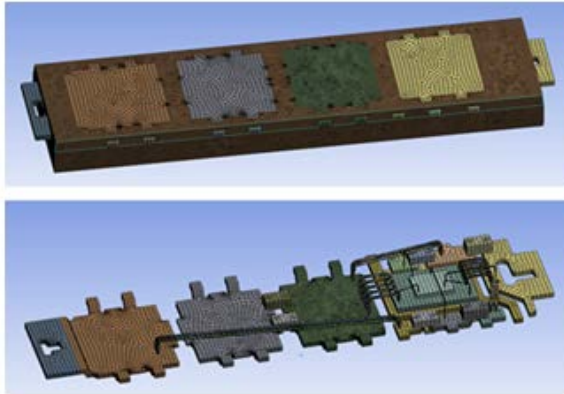
FIGURE XII. DELAUNAY MESH OF PMP

FIGURE XIII. MESH FOR HEAT TRANSFER ANALYSIS

Figure 12 and Figure 13 is a mesh for strength analysis and thermal analysis of PMP module respectively.

The several mesh generation method was applied to static heat conduction problem of three type's battery to show the performance and accuracy. Table 2 shows the comparisons of temperature values obtained at four points a, b, c and d along the top edge of the domain between the several mesh generation method.

The nodal patterns are equally applied. This means that a mesh for this domain is created implicitly by this method and that the small difference between the present solution and that of the Delaunay mesh attributes to the difference of the mesh topology seen at a few parts of the domain between the three methods.

TABLE II. ANALYSIS RESULT FOR TEMPERATURE

Material	Location	Bubble Mesh	Delaunay Mesh	Meshless Method
A	a	20.451	20.452	20.456
	b	22.463	22.463	22.464
	c	30.525	30.527	30.529
	d	49.884	49.884	49.887
B	a	19.251	19.251	19.254
	b	21.243	21.244	21.246
	c	29.219	29.220	29.223
	d	48.638	48.639	48.640
C	a	17.360	17.360	17.362
	b	20.822	20.823	20.826
	c	28.407	28.408	28.409
	d	47.647	47.648	47.650

VII. CONCLUSION

The In this paper, practical performance of battery using several mesh generation methods such as bubble meshing, Delaunay triangulation method and meshless method is demonstrated through heat conduction analysis. It is shown that nearly the same solution as the conventional finite element method using the Delaunay mesh is obtained under the condition of distribution pattern of nodes. Also, a technique, incorporating patch elements to achieve in meshless method, has been proposed. The use of patch elements can reduce the size of the global stiffness matrix in comparison to that by quadrilateral elements, as the quantity of the central node at each patch element is dependent on those at its vertices. It is shown that the meshless technique was used to solve a steady state thermal conductivity problem and the same problem was solved with the normal finite element method for comparison.

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