ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2012. No. 3(119)
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Research of Finite Element Analysis Software Performance Relation to the type of Operating System

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http://dx.doi.org/10.5755/j01.eee.119.3.1362

Introduction

Finite element method is widely used to analyze, simulate, optimize and design of electronic devices and their systems. Lots of modern CAD, CAM, CAE programs are based on this method. Fig. 1 summarizes the process of finite element analysis.

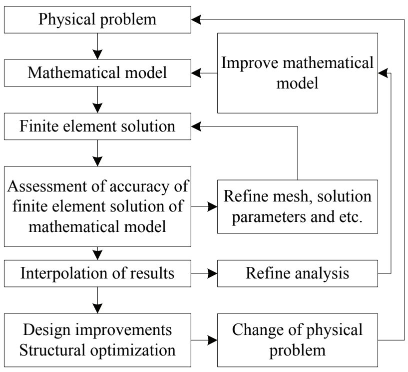

Fig. 1. Process of finite element analysis

Although numerical application of finite element method is easy and straightforward and it produces accurate results, several problems have been identified, e.g. when modeling electronic devices or systems of complex structure. The following important problems should be noted: long computation time and large amount of memory required to store intermediate computational data.

With rapid development of the field of electronics various software packages based on finite element analysis have been created, which are typically used to model and simulate processes taking place in electronic devices and their systems. It should be noted that more and more finite element analysis software brands are being created or ported to operating system “Apple Mac OS X”, especially after company “Apple” started manufacturing personal computers compatible with “Intel” processors. Also more software is being created with capability of supporting two most popular operating systems, i.e. “Microsoft Windows 7” and “Apple Mac OS X”. The following finite element analysis software packages can be noted: COMSOL (COMSOL, Inc.), MATLAB Partial Differential Equation Toolbox (The MathWorks, Inc.), FLexPDE (PDE Solutions, Inc.). These programs differ in peculiarities of geometrical model creation, finite element mesh generation, methods of solution of differential equation systems and result analysis functionality. Also the required computational resources are different. The performance of the mentioned software packages also depends on the amount of computer resources reserved to the operating system and on the efficiency of utilization of available computational resources. This fact is especially relevant during prolonged spatial (3D) modeling which may take up to several hours or even longer.

It is also known that the precision of mathematical description of the simulated geometrical model depends on the size and shape of finite elements. Therefore it is important to select finite elements of most suitable shape and size in the respective areas of the overall model. The number of finite elements and in turn the number of finite element mesh nodes determines how long the formation of differential equation system, its solution and all the modeling will last [1]. There are also other factors influencing the modeling performance, and we accomplished an experiment during which we investigated the performance of the selected finite element software in “Windows 7” and “Mac OS X” operating systems.

The model in the analysis of performance

To analyze the finite element meshing performance the spatial model constructed in the COMSOL software environment [2-4] was used. The model of the simulated device is provided in Fig. 2. The model represents a section of the circuit board consisting of transistor and solder tracks connected to the terminals of the transistor [4].

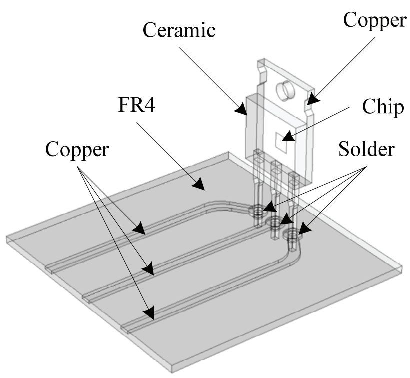

Fig. 2. Geometrical model of the electronic circuit segment [4] used to analyze the modeling performance

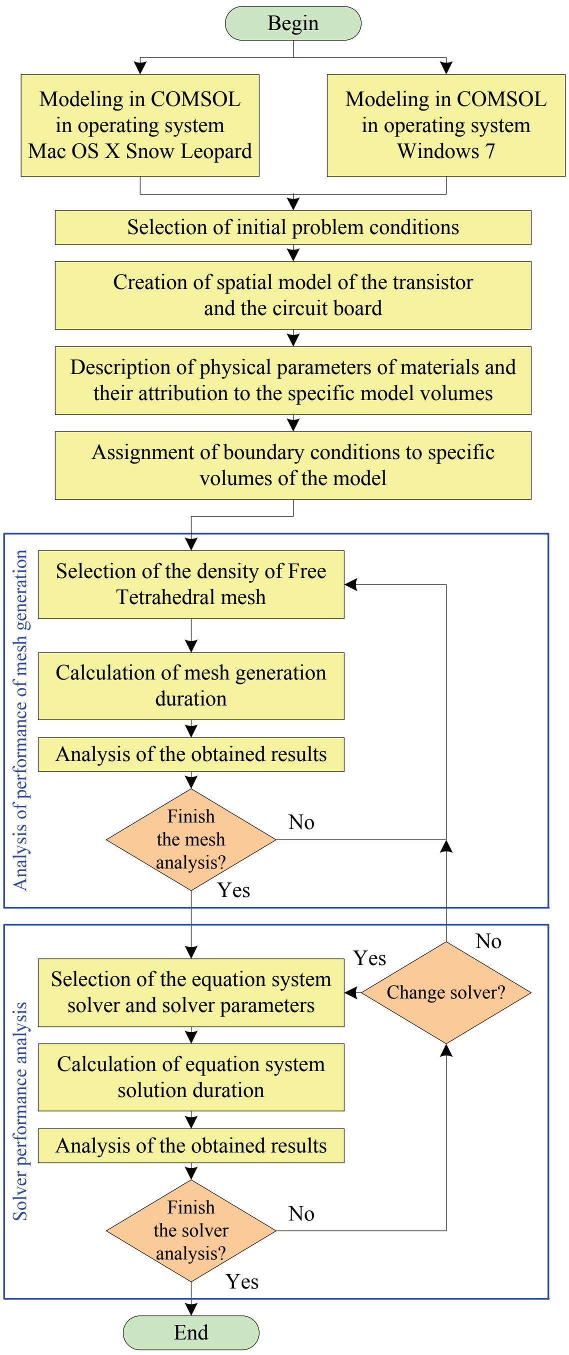

Fig. 3. The algorithm for the analysis of modeling performance

Through-hole technology is used to attach the the transistor to the PCB. All the mentioned parts form an integral electrical system. Since our aim is to analyze only the finite element mesh creation and solver performances, we do not provide the detailed discussion regarding the rest parameters of the model. The modeling algorithm is given in Fig. 3.

The performance of the finite element mesh creation was analyzed using two computers of different configuration. The specification of the first computer system: mainboard Apple 661-5038 Logic Board, processor Intel Core 2 Duo T9550 (2,66 GHz), hard disk drive Seagate ST9320421ASG; the second specification: mainboard Apple 661-4960 Logic Board, processor Intel Core 2 Duo P8600 (2,4 GHz), hard disk drive Seagate ST3250620AS. Both computer systems used the random access memory of type 2 x 2 GB PC3-8500 DDR3 SDRAM (1066 MHz). In this experiment the operating systems "Mac OS X Snow Leopard" and "Microsoft Windows 7" were used.

Research of the finite element mesh creation performance

The most typical problem which has to be solved or at least answered approximately is related to the density of the finite element mesh. This parameter is directly related to the modeling precision and duration. Usually we seek a balance between these characteristics and, since there are no universal recommendations every modeling situation is more or less unique. In some cases a denser mesh is more preferable, since smaller size of finite elements generally leads to smaller errors of modeling results. However decrease in size of finite elements leads to increase of modeling duration, therefore excess time resources or increased amount of computational power may be required in such case. Therefore a question regarding a balance between the size of finite elements used to mesh the geometrical model and available resources (amount of computational power and/or time) has to be clarified, especially in cases of large and elaborate models.

Notably geometrical features of the model can also have a critical importance regarding the end results of the modeling. For example, the geometrical model may consist of the volumes of regular geometrical shapes or contrarily. This aspect is important when selecting free (unstructured) mesh or mapped (structured) mesh types. Mapped meshing requires that the modeling area or a part of it would consist of regularly shaped volumes. In general free meshing is compatible with different types of finite elements, as opposed to the mapped meshing, however, in many cases it can be associated with more intense computational load.

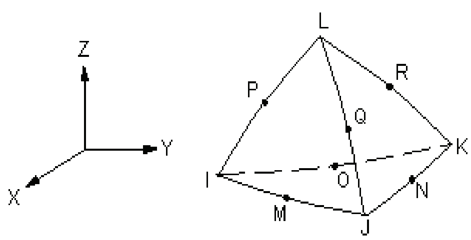

Fig. 4. Tetrahedral finite element. Letters indicate nodes

In our research we used a Free Tetrahedral feature to create an unstructured mesh consisting of tetrahedral finite elements [2, 3]. This software feature provides us with the possibility to control the number, size, and distribution of elements by using Size and Distribution features. In order to generate the finite element mesh the tetrahedral finite elements were used (Fig. 4.).

In general case the shape functions for tetrahedron element are defined as [5]:

$$u=u_I(2L_1-1)L_1+u_J(2L_2-1)L_2+u_K(2L_3-1)L_3+u_L(2L_4-1)L_4+ +4(u_M L_1 L_2+u_N L_2 L_3+u_O L_1 L_3+u_P L_1 L_4+u_Q L_2 L_4+u_R L_3 L_4), \quad (1)$$

$$v=v_I(2L_1-1)L_1+v_J(2L_2-1)L_2+v_K(2L_3-1)L_3+v_L(2L_4-1)L_4+ +4(v_M L_1 L_2+v_N L_2 L_3+v_O L_1 L_3+v_P L_1 L_4+v_Q L_2 L_4+v_R L_3 L_4), \quad (2)$$

$$w=w_I(2L_1-1)L_1+w_J(2L_2-1)L_2+w_K(2L_3-1)L_3+w_L(2L_4-1)L_4+ +4(w_M L_1 L_2+w_N L_2 L_3+w_O L_1 L_3+w_P L_1 L_4+w_Q L_2 L_4+w_R L_3 L_4), \quad (3)$$

$$\varphi=\varphi_I(2L_1-1)L_1+\varphi_J(2L_2-1)L_2+\varphi_K(2L_3-1)L_3+\varphi_L(2L_4-1)L_4+ +4(\varphi_M L_1 L_2+\varphi_N L_2 L_3+\varphi_O L_1 L_3+\varphi_P L_1 L_4+\varphi_Q L_2 L_4+\varphi_R L_3 L_4), \quad (4)$$

here u_i, v_i, w_i – the displacement of the finite element nodes *I*, *J*, *K*, *L*, *M*, *N*, *O*, *P*, *Q*, *R* (Fig. 4) along directions of axes *x*, *y*, *z*; φ_i – scalar field parameter (e.g. electrical potential) at the nodes of the finite element, where *i* denotes the node index; L_1, L_2, L_3 and L_4 – normalized coordinates, the magnitude of which ranges from 0 at the top of the element and 1 at the opposite wall of the tetrahedral finite element.

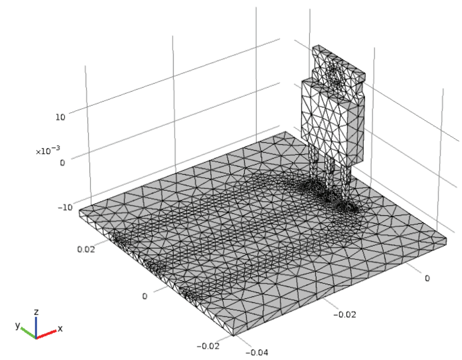

Fig. 5. Mesh containing 12425 tetrahedral finite elements

The generated finite element mesh is shown in Fig. 5. After performing the analysis of finite element mesh creation duration it can be seen that COMSOL software meshes the volume of the model faster when using “Mac OS X Snow Leopard”, compared to “Windows 7”.

The absolute difference between meshing durations increases with the increase of the number of finite elements in the analyzed mesh (Fig. 6).

Analysis of solution performance of differential equation system

For the analysis of the solution performance of differential equation system in each iteration the same spatial geometrical model (Fig. 2) and algorithm (Fig. 3) was used. To perform the analysis the stationary solver [2, 3] was used. This solver is typically used when modeling steady-state problems which do not include any time-based calculations (e.g. transient processes, etc.). This solver is also suitable to perform a steady-state optimizations of the finite element model parameters.

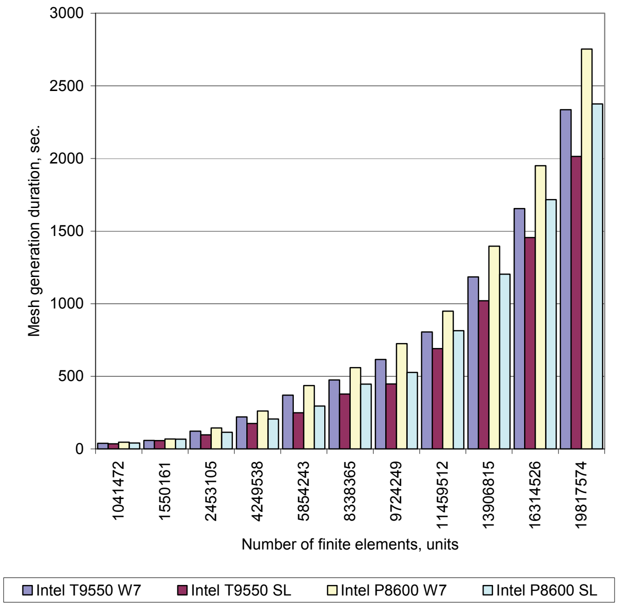

Fig. 6. Durations of finite element mesh generation using microprocessors T9550 and P8600

The obtained distribution of the simulated thermal field is provided in Fig. 7. After performing the analysis of solution duration of differential equation system it can be seen that when using COMSOL the problem is solved faster in “Mac OS X Snow Leopard” environment than in “Windows 7”. The absolute difference between meshing durations increases with the increase of the number of finite elements in the analyzed mesh (Fig. 8).

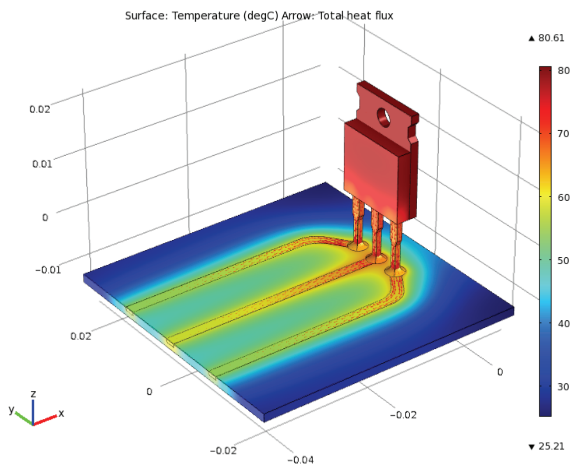

Fig. 7. Representation of the modeling results

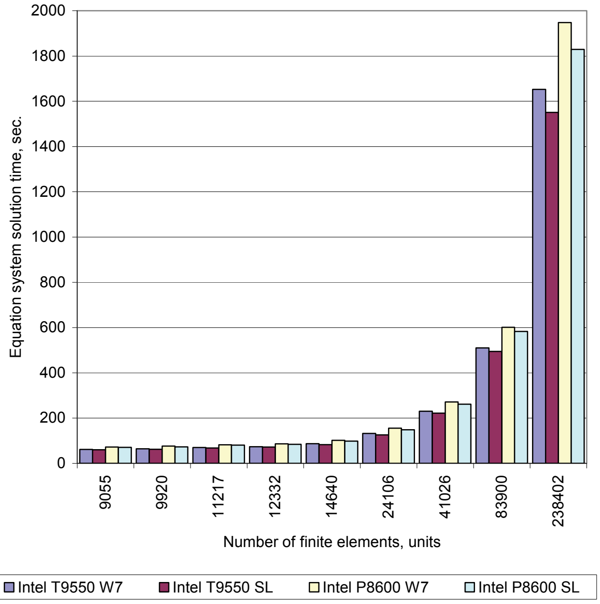

Fig. 8. The solution duration of the differential equation system using microprocessors T9550 and P8600

Conclusions

After generalization of results of the performed analysis, related to the performance of finite element modeling software it was determined that when using the operating system "Mac OS X Snow Leopard" the finite element mesh is generated up to 14 % faster compared to "Windows 7". With the increase of the number of finite elements forming the mesh, the steady increase of differences of meshing durations in these two systems was observed. After the number of finite elements reached approximately 20 mln., the difference of meshing duration was 322 seconds for processor T9550 and 379 seconds for processor P8600.

After completing the analysis of solution of differential equation system it was determined that the problem is solved up to 5 % faster in operating system "Mac OS X Snow Leopard" compared to "Windows 7". The increasing trend of computation duration differences also remain similar.

A conclusion can be made that the operating system in which the finite element analysis software performs the computations during the modeling of electronic devices and their systems does not have the substantial impact on the modeling performance. It is significantly more practical to select and create an optimal geometrical model and to select and optimal density of finite element mesh, which has a substantive influence on the solution duration of differential equation system and basically determines the duration of entire modeling.

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Received 2011 10 12
Accepted after revision 2011 11 14

P. Tarvydas, A. Noreika. Research of Finite Element Analysis Software Performance Relation to the type of Operating System // Electronics and Electrical Engineering. – Kaunas: Technologija, 2012. – No. 3(119). – P. 49–52.

When modeling electronic devices of complex geometry and their systems using finite element analysis software packages, several problems related to the modeling duration emerge. With the increase of the variety of modeling software packages dedicated both to "Microsoft Windows" and "Apple Mac OS X" operating systems, it is important to determine the dependency of modeling performance in respect of operating system which is used to control the modeling environment. The modeling performance investigation was accomplished using COMSOL software. The algorithm used to analyse the finite element mesh generation and differential equation system solution duration was created and it was implemented during the computational experiment during which the modeling performance was analysed. The obtained analysis results are provided. Ill. 8, bibl. 5 (in English; abstracts in English and Lithuanian).

P. Tarvydas, A. Noreika. Baigtinių elementų analizės programų spartos operacinėse sistemose tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 3(119). – P. 49–52.

Sudėtingus elektroninius įtaisus ir sistemas modeliuojant baigtinių elementų analizės programomis susiduriama su modeliavimo trukmės problemomis. Daugėjant programų, galinčių veikti „Microsoft Windows" ir „Apple Mac OS X" operacinėse sistemose, svarbu nustatyti modeliavimo spartos priklausomybę nuo naudojamos operacinės sistemos. Spartos tyrimas atliekamas programa COMSOL. Sudarytas algoritmas baigtinių elementų tinklelio generavimo ir lygčių sistemos sprendimo spartai tirti, atlikta spartos analizė ir pateikti rezultatai. Il. 8, bibl. 5 (anglų kalba; santraukos anglų ir lietuvių k.).