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Analysis of thermomechanical stress on printed circuit board

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Anotace:
Teplotně-mechanické namáhání v oblasti desek plošných spojů může způsobit velké problémy. Rozdílné teplotní koeficienty roztažnosti jednotlivých materiálových složek jsou hlavní potíž. Pokud je deska plošných spojů namáhána díky teplotnímu cyklování, může nastat hned několik závad. Těmto problémům se však můžeme vyhnout již během návrhové fáze díky numerickým simulacím a optimalizaci návrhu. Simulace by měla zahrnovat všechny možné aspekty teplotně-mechanického namáhání. Z hlediska elektrického, přes oteplení až po mechaniku děje. Jen s robustní multifyzikální analýzou můžeme dosáhnout přesných výsledků.

Anotation:
Thermomechanical stress in the field of PCB (Printed Circuit Board) can be a real trouble. Different thermal expansion coefficients of components' materials are the main problem. If the PCB is stressed due to thermal cycling there are several problems that can occur. We can avoid such problem during the design phase with numerical simulation and optimization of our final result. Such simulation should take in account every aspect of this effect. From electrical point of view through heating/cooling to mechanical physics. Only with robust multi-physical analysis we can obtain accurate results.

DESCRIPTION OF THE PROBLEM

High reliability of printed circuit boards and mounted components is one of the key points for high quality electronic asset. Reliability of electrical system on printed circuit board, or power elements can be influenced by thermal stress, that may cause not only the breakthrough of semiconductor junction, but also deformation and possible break of trace due to thermal expansion. The most typical material for one or two layer PCB manufacturing is FR-4. The base material FR-4 is composed from glass fiber and epoxy resin. Therefor the physical parameters are orthotropic. Most of the multi-layer circuit boards are made by lamination of prepreg with Cu foil on existing two-layer circuit board with FR-4 dielectric core. Fig. 1 captures one of the possible four-layer PCB setup. This is resulting in "sandwich structure" of different materials that have different physical properties. Traces and vias are locally changing those material properties, especially thermal properties such as thermal conductivity and thermal expansion coefficient.

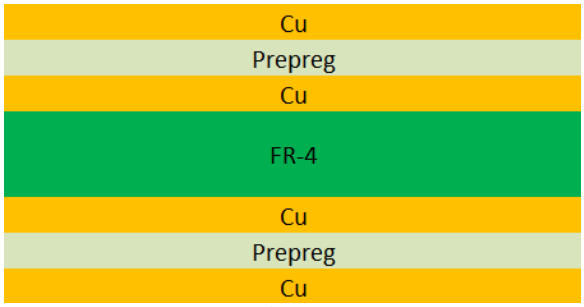

Fig. 1 Possible structure of 4-layer PCB

Problems related to PCB and power components may be generally characterized as electrical, thermal and mechanical. Electrical problems involve signal and power integrity, cross induction, electromagnetic interference or ohmic losses in the system. Ohmic losses may lead to heating up the system and possible dysfunction, due to positive thermal feedback on semiconductor junction or due to thermo-mechanical stress. The most vulnerable to mechanical stress are solder joints, but also the trace or the contact lead can be broken due to this stress.

Electronic components or PCBs are mostly produced in big series. Therefore prevention of mentioned faults during the system design is a must. Appropriate method for elimination of potential faults is numerical simulation during the development of the product. The portfolio of ANSYS tools are providing for calculation of any of these mentioned effects. The product can be simulated during the normal or extreme working conditions. With interdisciplinary simulations ANSYS can cover effects from electrical, thermal and mechanical point of view for the system, so that every aspect is taken into account. Fig. 2 is showing ANSYS possibilities.

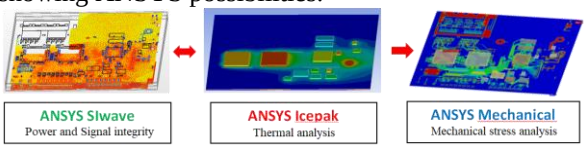

Fig. 2 Interconnection among different physical ANSYS tools during PCB simulation

ANSYS SIWAVE

Specialized simulation software for simulation of CPS (Chip-package-system) is ANSYS SIwave. Allowing simulation from basic DC analysis such as DCIR (Direct Current Internal Resistance), to more complex analysis for power or signal integrity is SIwave suited for high frequency or power

electronics solutions. Tool is able to identify electromagnetic compatibility / interference of printed circuit board due to various simulations providing with emissions and absorptions of electromagnetic waves, cross-talk simulations, optimization of number and placement of DC capacitors for PI and least but not last extraction of RLCG components of traces.
Main advantages are adaptive meshing, import from various ECAD formats and automated iterative loop with ANSYS Icepak for electro-thermal analysis. The setup of thermal analysis is done in the SIwave GUI, where user can choose between natural or forced convection and its parameters, power dissipation of components, apply heatsinks on components and of course set up the convergence criteria for the coupling.

ANSYS ICEPAK

ANSYS Icepak is tool for thermal simulation for electronic applications. Key advantage is import of both MCAD and ECAD formats. Another perk is specialization on modeling of electronic components or printed circuit board, from coarse to highly detailed modeling. ANSYS Icepak leverages from ANSYS Fluent solver which is robust CFD finite volume method analyzer. ANSYS Icepak allows import of power maps from various tools, such as SIwave, Apache, Redhawk, Cadence and more. Trace mapping technology of ANSYS is able to perfectly recognize traces from dielectrics for local change in material properties. This technology is as precise as detailed MCAD modeling of traces, but saves the computing time and HW resources.

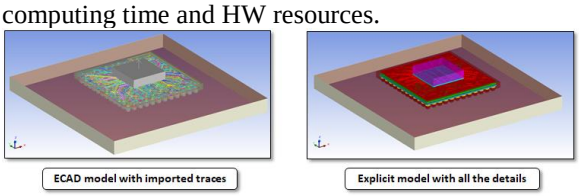

Fig. 3 Trace mapping vs explicit trace modeling

Fig. 3 is showing the difference between detailed explicit modeling and Trace mapping technique. On the left side we have object with ECAD data (Trace mapping). There are 7 objects in the model. On the other hand on the right side we have explicit model with MCAD data. There are 1581 objects. Attitude with ECAD data has mesh with approximately 3.3 million elements against the MCAD design that has 11 million elements. Solve time is approximately more than five time faster in favor of the ECAD model. Tab. 1 is summarizing the advantages of Trace mapping against the explicit object modeling.

Tab. 1: Comparison of modeling methods

	# of objects	Mesh Count	RAM	Solve Time
Trace mapping	7	~3.3 M	0.24 X	0,18 X
Explicit modeling	1581	~11 M	1 X	1 X

ANSYS MECHANICAL

ANSYS Mechanical is worldwide known engineering tool for structural linear and nonlinear problems. ANSYS Mechanical is providing with solution for problems such as fatigue, various stresses, buckling stability, dynamic analysis: modal, harmonic, spectral, random excitation, transient, rotor dynamics, rigid body dynamics. Interaction among bodies is provided via contacts algorithms. As well as ANSYS Icepak, ANSYS Mechanical can leverage from Trace mapping technique. Example of done ECAD import to Mechanical module is in Fig. 4. ANSYS Mechanical can import temperature map from ANSYS Icepak to compute the thermomechanical stress. This stress can lead to deformation of substrate that can be easily visualized. With such results electrical engineer can adjust the whole design to maximize the reliability of the system.

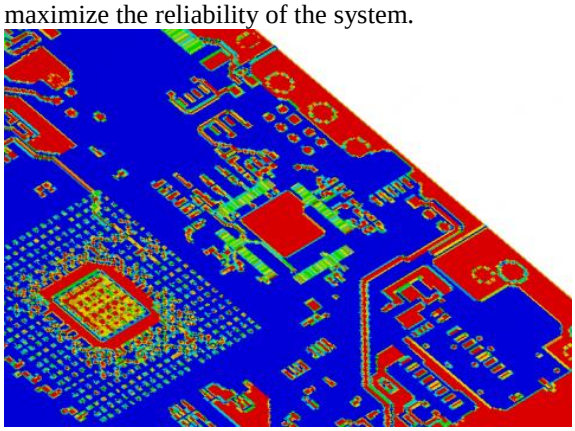

Fig. 4 ECAD import in ANSYS Mechanical

CONCLUSIONS

ANSYS provides with whole portfolio of tools for coupled numerical analysis for electrical engineers. ANSYS Trace mapping can be used in electromagnetic, thermal and as well in mechanical type of simulation. This way engineer can leverage the advantage in whole simulation process. Analysis of thermomechanical stress on PCB is faster and without major problems with convergence or RAM capacity.

LITERATURE

[1] ANSYS Mechanical Technical Notes, ANSYS, Inc., 2018.

[2] ANSYS Electromagnetics Suite Notes, ANSYS, Inc., 2018.