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TOPOLOGY OPTIMIZATION FOR HEAT TRANSFER PROBLEMS WITH MULTIPLE MATERIALS

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The main goal of this work is the application of the topological optimization procedure to heat transfer problems considering multiple materials. The topological derivative (TD) is employed for evaluating the domain sensitivity [1] when perturbed by inserting a small inclusion. As the technique is based on the total potential energy, those areas with less heat transfer efficiency will be progressively replaced with inclusions of another material with different conductivity. Despite TD being a new optimization procedure, its mathematical formulation has been well established in the last few years [2,3]. Electronic components such as printed circuit boards (PCBs) are an important branch for applying topological optimization. Generally, geometrical optimization involving heat transfer in PCBs considers only isotropic behaviour and/or a single material [3,4,5]. Multiple domains with anisotropic characteristics take an important role on many industrial products, especially when considering PCBs which are often connected to other components of different materials. In this sense, a methodology for solving topological optimization problems considering anisotropy and multiple regions with embedded heat sources is developed in this paper. A direct boundary element method (BEM) is employed for solving the proposed numerical problem. A mapping procedure coupling BEM and TD is employed in order to allow the use of TD for solving problems with anisotropic behaviour [6]. A previous benchmark test investigated in [7] is revisited here for illustrating the proposed methodology. The present problem refers to a heat conducting field with dimensions 30 x 30 mm. The external boundary is discretized with 80 constant boundary elements and Dirichlet boundary conditions are imposed as 10°C at the middle of the right and left edges. All other external boundaries have a prescribed temperature of 0°C (see Fig. 1).

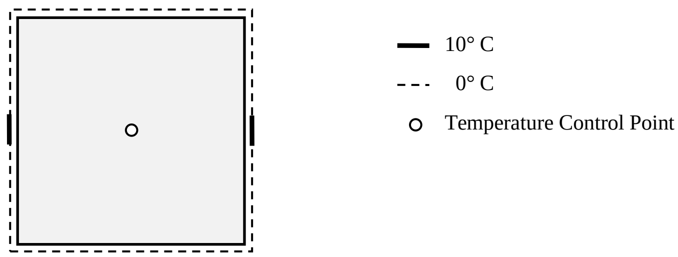
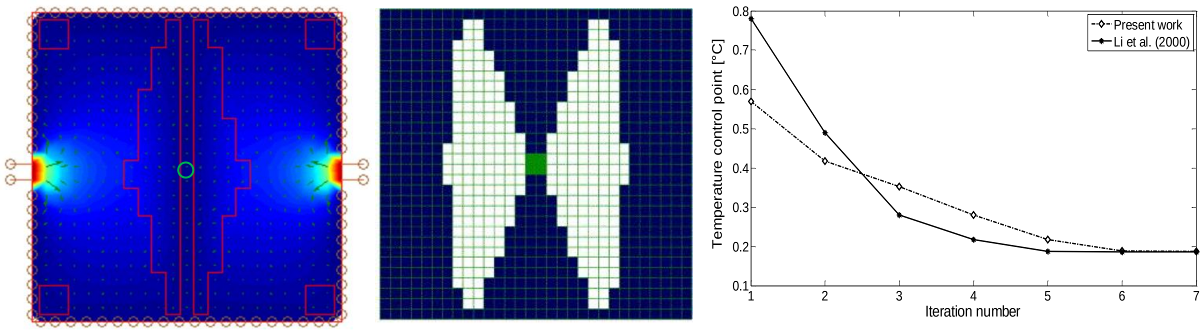


Figure 1. Boundary conditions and control point.

Initially, the design domain is made of a single material with conductivity k = 0.045 W/mm°C. During the optimization process, a new material with lower conductivity (k = 0.001

W/mm°C) is inserted inside the domain. For the purpose of comparing the present solution with that presented in [7], a temperature control point is set at the domain centre. The optimization process is halted when the control point reach a temperature of 0.19°C. The final topology resulted is presented in fig. 2(a). Despite the final topology resulting in a slightly different shape than that presented in [7], the task of insulating the temperature control point was clearly accomplished, as shown in fig.2. The reason for this topology difference is the different objective functions used here and in [7]. An explicit objective is imposed in the ESO method adopted in [7], while in the TD method adopted here the sensitivity formula is deduced by the total potential energy. The final optimized topology presented good results and the insertion of an insulating material aided to reduce the temperature at the control point, as depicted in fig.2(c). Furthermore, the optimization process by employing BEM as the numerical method was successful from the point of view of computational cost, since the BEM presents no internal mesh dependency as one of its main characteristics. The proposed methodology should be useful for designing high performance heat transfer topologies involving the coupling of different materials.



(a) (b) (c)

Figure 2. Final topologies: a) Present result by using BEM/TD, b) Result obtained by Li et al. [7] by the ESO method and c) Evolutionary history for BEM/TD and ESO.

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