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Hierarchical Bayesian model for simulating the mechanical behavior of bare printed circuit boards with fixing

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Electronic components of electric vehicles are exposed to demanding load conditions including the excitation of mechanical vibrations. These vibrations are a major factor limiting the lifetime of printed circuit boards (PCB). To study the effects of mechanical excitations and improve the reliability of printed circuit boards, precise simulations of the mechanical behavior of PCB are necessary. The objective of this work is to develop a numerical simulation that accounts for inherent variations in the mechanical behavior of PCBs due to uncertainties in the production process and material composition. The uncertainties in the system behavior are computed by propagating underlying parameter uncertainties through a numerical model.

In the case of complex mechanical systems, it is often difficult or costly to perform measurements on a system level. Instead, experimental studies are performed on different components to save time and costs. Regarding model updating, this divide-and-conquer approach also presents the advantage that the single components depend on a lower number of parameters than the total system. Therefore, the parameter values and uncertainties of the PCB are determined by splitting the system into components and performing model updating on a component level. The parameters of the components and the total system are arranged in a Bayesian network enabling the propagation of parameter distributions from component to system level. The mechanical system examined in this work consists of a bare PCB that is fixed to a casing by bolts. This system is split into two components: the PCB itself and the bolts. The parameters of the two components are separately determined using Bayesian model updating. A hierarchical approach allows to simultaneously estimate the location and the uncertainty of the parameter values. As a result of hierarchical Bayesian model updating, probability distributions representing the inherent variations of parameter values are obtained.
In a first step, distributions of the stiffness parameters of the bare PCB are determined based on modal data of multiple nominally equal PCB. In a second step, further experimental data is generated by fixing one specific PCB with different bolts. This data is then used to update the model parameters of the bolts. The updated parameter distributions of the bare PCB and the bolts are utilized to compute probability distributions for the mechanical behavior of the system consisting of bare PCB and bolts. For validation purpose, the simulation results are compared to additional validation measurements carried out on further bare PCB fixed with bolts.