A transfer function package-modeling approach for speeding up multi-scale MEMS sensor drop simulations

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Abstract

Drop robustness of MEMS (micro-electromechanical system) sensors becomes increasingly important. More and more devices utilize sensors, while at the same time, the industrial trend requires even smaller, and thus weaker, sensing structures. To evaluate the impact resistance of these devices, long and computationally demanding finite element simulations are conducted. In this contribution, a more efficient way of modeling MEMS sensor drop is proposed. Significant speedup can be achieved by using a discrete transfer function of the package, while the MEMS sensor structure and the carrier device are still simulated with an explicit finite element method (FEM).

The typical way of simulating drop tests or accidental drop of MEMS devices is following a multi-scale finite element approach (1)(2), where the typical length scales (or simulation levels) are that of the package, the MEMS sensor structure, and the microstructure of the polysilicon. These levels can be simulated separately because of the order of magnitude difference in the masses corresponding to each scale. Similar approaches are also common for MEMS gyroscopes, and microphones, even including carrier device level (e.g., a printed circuit board) (3)(4). However, to map the robustness characteristics of the MEMS sensor in a package drop event, many simulations need to be run. To speed up this process a novel transfer-function-based package model is proposed.

A computationally efficient package model can provide a large number of input load curves for structure robustness simulations. The ability to evaluate many drop situations may reveal previously unknown weaknesses in the structure, which can then be adequately addressed. Another strength of the discrete transfer function approach is its relative simplicity compared to e.g., a reduced-order model of the package. The latter is a more complex representation and can only support linear elastic materials, whereas e.g., polymer materials of the package would need a viscoelastic representation. With the transfer function, taking the average velocity of the package as input, the velocity of the anchor is output. This, in turn, can be used in the FEM simulation of the structure as a kinematic constraint.

To obtain an adequate transfer function of the package, the drop of a small number of representative carrier devices should be simulated with a fully modeled package in an explicit FEM model. In the next step, these simulations are used for fitting the package transfer

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function. Then, for further carrier devices only a homogenous package needs to be included, that is, a single solid brick with averaged material model. From this, the necessary input can be extracted, and via the transfer function, the anchor velocity is obtained which is the constraint of the sensor structure simulation. Similarly, for a package drop without a carrier device, a transfer function can be used together with a discrete package impact model to obtain the anchor movement.

The transfer function is shown to be able to approximate the anchor velocity in case of drops with different simplified carrier devices. Moreover, drop of the package onto a smooth floor can also be adequately modeled with the proposed transfer function method even for different drop heights and floor materials.

References

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