Definition of Output Parameters for Sensitivity Studies of Drop Tests with Randomly Varying Orientation

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Abstract

To ensure the mechanical quality of mobile devices, their behaviour is verified by drop tests in which they are dropped onto a hard surface. FEM simulations of these tests are carried out to predict failures and to provide a basis for decisions on design improvements. The results are not only varying due to material, assembly and geometric tolerances – they depend strongly on the drop orientation.
Drop tests are carried out as random free fall tests with randomly varying drop orientation. Being part of boundary and initial conditions, the varying drop orientation has a much stronger influence on the results than the scattering of geometric dimensions and material parameters. Therefore a two-step approach is proposed for the sensitivity analysis. In the first step the design is investigated by simulation-based sensitivity studies with the drop orientation angles as input parameters. In the second step, sensitivity to material and geometry variation is analysed with fixed orientation angles. These angles are selected based on the results of step 1. Those orientations which produce the highest stress - the „worst case orientations" are analysed.
By application of the Metamodel of Optimal Prognosis (MOP) in optiSLang, Coefficients of Prognosis (CoP) are calculated, which can be used as a quality measure for the model. It was found that the CoP value depends strongly on the method of results extraction. In particular, CoP is sensitive to the location of stress evaluation. Typically, stress or strain maxima over a certain area and time are calculated and applied as output parameters for sensitivity studies in mechanics. Search of maxima over too large areas or over long time durations can mean that physically different events are used as the basis for the Metamodel. The proposed Local Maximum Method aims to take into account the physical background of the results and leads to significantly increased CoP values.

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1 Introduction

A standard requirement for mobile devices is their robustness against drops on hard surfaces. The performance of devices with regard to this requirement is investigated in physical tests and numerical simulations. The target is to cover all load cases for drop events which are occuring in the daily use of the device. For this purpose, random free fall tests are carried out, where many subsequential drop tests are made, with randomly varying drop orientation, reflecting the random nature of this event when a user drops the phone accidentially. The simulation of this test is limited to a smaller number of drop orientations than in physical tests. This selection of simulated orientations should contain the worst cases which produce the highest loads on components. These cases can be used to verify the effect of modifications to improve the design.
A sensitivity study with the orientation angles as input parameters is an appropriate means to discover the worst case drop orientations. Mobile devices consist of many different components and materials, all of which are subject to different loading histories after the impact and thus the orientation of the worst case drop is different for each component or in each finite element involved in the output for the sensitivity analysis.
Additionally it is of interest if high loads which are found for one „worst case“ orientation disappear after small changes of the drop angles or if they are „robust“ against variations of the orientation in a bigger range. If the latter is the case, these orientations can be used to investigate the effect of design modifications for improvement. If high stresses occur only if the device is dropped at a specific angle and they decrease if the orientation slightly changes, then this load case is less probable to occur in real life.
Generally, the drop orientation which produces the highest loads is different for each component of the device.

2 Sensitivity Analysis of Drop Test Simulations

In a drop test FEA model, a complete evaluation of the stress history for each finite element is not feasible given current hardware capability. Therefore, efficient methods of summarizing and condensing results are required to deliver a reliable basis for decisions on design modifications. The need for such methods is driven as well by the relatively short development cycles in mobile phone development.
The location of maximum stress over time in each component varies for different drop orientations. Additionally, the maxima occur for different orientations at different times after impact.
Since it is part of boundary and initial conditions, drop orientation has a much stronger influence on the results than other scattering input parameters like material properties or geometry. For this reason, the sensitivity analysis is split up into two steps:

1. Analyse sensitivity to drop orientation (cf. Figure 1) and identify "worst case orientations".
2. Verify sensitivity to other scattering input parameters for worst case orientations.

Advanced Latin Hypercube Sampling is applied in both steps to reduce the number of designs.

After worst case orientations are defined based on step 1 results, further sensitivity analyses with fixed orientations are made to investigate the influence of all other input parameters. It is assumed that all drop orientations are equally probable; a uniform distribution of the drop angles is the basis for sampling.

Output regions are e.g. electronic component solder joints, display glass or specific locations on covers. Each output region has multiple finite elements.

To identify the design sensitivity to these tests as a basis for robust design optimization, output parameters have to be selected in a way to include all potential failure locations.

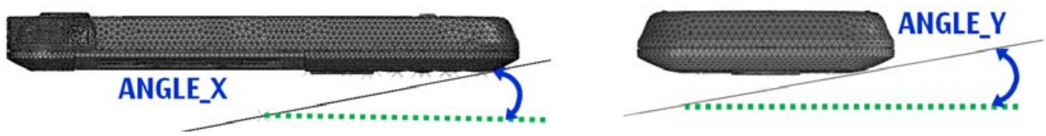

Figure 1: Boundary conditions (drop orientation angles) as input parameters in step 1 of sensitivity analyses

3 Results Extraction: Global and Local Maximum Method

For conventional evaluation of drop test results, it makes sense to extract stress maxima per component over time in order to get an overview on potential failure risks. For sensitivity analysis, however, this „Global Maximum Method" is not the best approach because the global maxima can have different physical causes and their location is changing depending on input parameters. The output parameters of sensitivity studies should be defined in a way that they are based on physically comparable phenomena. This is particularly important in order to generate a valid Metamodel of Optimal Prognosis (MOP) in optiSLang. To evaluate sensitivities for relatively large components of mobile devices like for instance displays, it is not sufficient to define the maximum over the whole component as an output parameter. We propose a „Local Maximum Method" instead, where at first the maximum for one component over all samples is extracted, secondly the location of this maximum is determined and then the values at this location (this node/integration point/section point) are extracted for each sample. In this way, the comparability of physical phenomena is significantly improved. This is a condition to apply results of sensitivity analyses for design decisions or optimisation. The effect of the different methods on the Coefficient of Prognosis is visible in

Figure 2 and Figure 3. For the evaluation of larger components like the display, the method of results extraction has a strong influence on CoP. The prognoses of the metamodel are improved if it is built on results for equal locations within the component. For parts with smaller dimensions like the display IC or the SD card reader, this effect is often not significant.

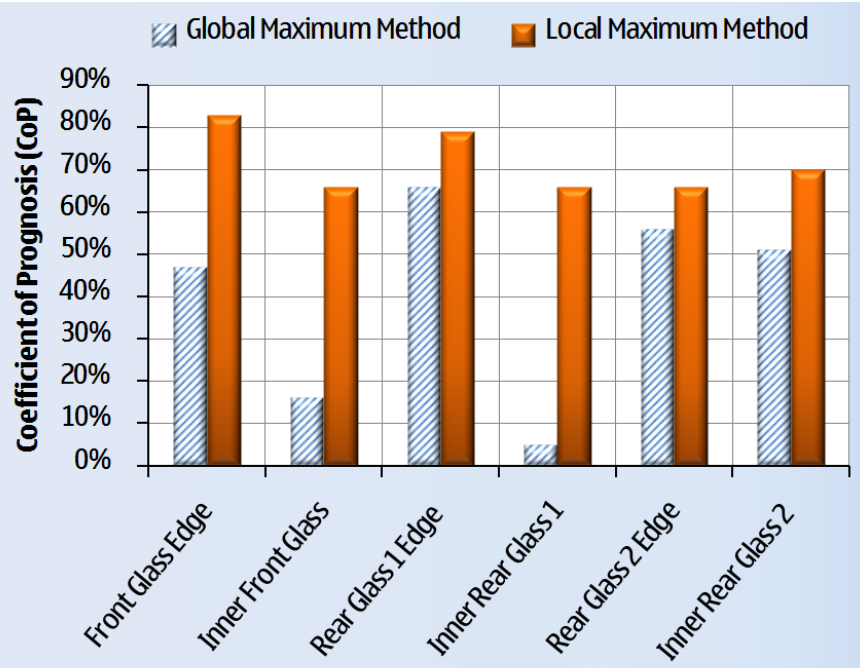

Figure 2: Coefficients of Prognosis for parts of a display. CoP increases strongly with Local Maximum Method.

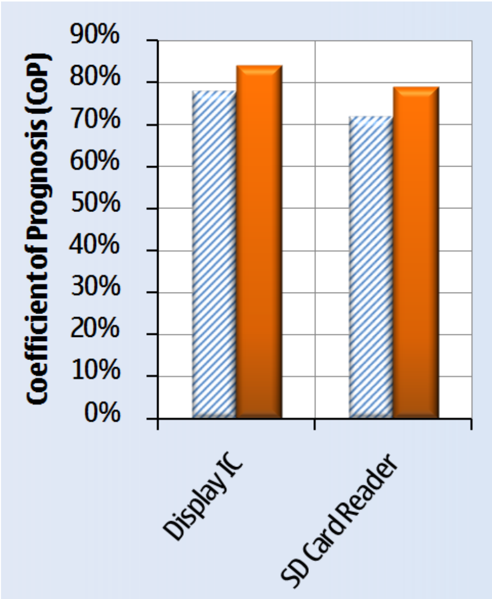

Figure 3: Coefficients of Prognosis for electronic components which are much smaller than the display. CoP increase with Local Maximum Method is not significant.

4 Conclusions

In sensitivity analyses of drop tests for mobile devices, drop orientation has a much stronger influence on the results than other scattering input parameters such as material properties or geometry. Therefore the analysis can be carried out in

two steps. At first the sensitivity to drop orientation is investigated and “worst case orientations” are identified. Then, the sensitivity to other scattering input parameters is analysed for these worst case orientations.
The application of different results extraction methods has significant influence on the resulting drop test sensitivity. The results should be extracted in such a way that they are based on physically comparable phenomena. For some types of output regions the Coefficient of Prognosis can be significantly increased if equal locations are used as a basis for the Metamodel of Optimal Prognosis instead of global maxima over the entire component.
The proposed results extraction approach can be extended by involving more criteria like time duration of peaks. Further research will be done to improve the condensation of sensitivity analysis results to a summary which can efficiently be applied for design decisions. In particular criteria for automated selection of worst case orientations are under investigation.

References

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