A Comprehensive Review of Drop Impact Modeling on Portable Electronic Devices

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This article is dedicated to the review of publications on drop impact analysis performed on consumer electronic devices such as cellular phones and two-way radios in the past decade. Prior to the highlights of this review, the scope and motivation behind this work will be briefly explained. A comprehensive survey on published literature devoted to the methodologies established to analyze the reliability of electronic products exposed to the event of drop impact is presented. The scope of the review is extended beyond product level analysis to also include drop impact study at board level. This type of review is novel and has not been published in the past. The focus will be on the different analytical and numerical modeling approaches and the current status of finite element method in predicting the drop impact performance of electronic devices. Of equal interest is the methodology adopted in past work to establish a correlation between numerical and experimental results. This article serves as a reference to all intended future work which could be an extension from the current known art of drop impact analysis on electronic devices. The time frame of this review is up to year 2010. [DOI: 10.1115/1.4005283]

Keywords: drop impact, electronic devices, board level drop test, product level drop test, numerical simulation

1 Introduction

Consumer electronic devices, which cover a wide range of products such as personal computers, cellular phones, and audio systems, indisputably play a pivotal role in our daily lives. Over the years, manufacturers of consumer-based electronic products have been instrumental in the revolution of new products and technologies to cater to mankind needs. Technology has revolved rapidly, as we witness newly launched devices having enhanced and multiple functions or features. The best example would be the cellular phone. This is a result of research effort put in to develop better products.

The miniaturization of components constitutes one of the key elements of this new age technology revolution. Electronics miniaturization is a driving factor in most consumer products today where increasingly complex functions are confined within a limited space with minimum weight. Long gone are those days where a cellular phone could be as big as a two-way radio! However, this effort is fundamentally constrained by the obstacles in the overall design and manufacturing process. Product designers are constantly challenged to package these devices within a smaller volume which would now be more mobile and thus, susceptible to risk of accidental drop. Today’s modern electronic devices are denser than before with smaller clearances between components. This poses a huge challenge on the structural integrity of the product but at the same time, consumers’ expectations towards the reliability of electronic devices during drop impact have also increased. Thus, drop impact analysis involving electronic devices has garnered a huge interest among academicians and some even funded by industries.

Over the years, the trend of adopting finite element analysis (FEA) as an engineering tool in industries has seen a significant growth based on the number of publications. Finite element analysis has been regarded as an indispensable design tool and has contributed significantly to the design of components and systems in the electronic industries. With the advancement in computer engineering, computer simulation based on finite element method (FEM) precedes over the more common approach of having prototypes built to test first, and later refined through several iterations. There is no longer a need to wait for testing to be completed before a decision can only be made to release the design for tooling fabrication. This has substantially reduced the total design cycle time in products from concept stage to production and also reduced the cost of development. A design released for manufacturing without any data on hand pose a warranted risk; the die/mold will most likely have to go through several iterations of modifications to improve the robustness of the design should it fail to satisfy the required drop impact tolerance. This reduces the lifecycle of the die/mold significantly.

The other advantage that computer simulation holds over physical testing is the ability to retrieve vital information such as localized stress, strain and acceleration response from any location inside the model. Besides, it is also difficult to quantify the mechanical performance of a tested product by solely depending on the results gathered from drop tests. The application of FEM in drop impact analysis is supported by FEA-based software such as ABAQUS, ANSYS, NASTRAN, and LS-DYNA. On the other hand, this does not imply that experimental tests can be entirely dismissed from any product design cycle; test validation is still indispensable because it will always be needed to determine the accuracy of the simulation’s results.

2 Scope and Motivation

A literature search in the field of drop impact analysis involving electronic devices in the past decade has revealed a large number of publications in journals and conference proceedings. Many interesting articles can be found on board level drop impact study after drop test standards had been established by Joint Electron Devices Engineering Council for portable electronic devices. This council is also known as JEDEC. In comparison, drop impact study at board level had outnumbered product level drop analyses as evident by the number of existing publications. It is strongly believed that there are many unpublished work on product level drop study due
is opportunity in this research field involving reliability of system level drop test based on his experience in the electronics industry. Several challenges have been identified with numerical analysis involving consecutive drop impact:

(i) **Accumulation of plastic strain and damage.** Plastic strain and damage on the components have to be brought into the subsequent drop where all recoverable strain energy must be released prior to start of analysis.

(ii) **Dynamic equilibrium.** The dynamic equilibrium obtained at the end of the drop impact simulation must be converted to static equilibrium containing only residual strain inside the components.

(iii) **Drop angle and initial velocity.** The drop impact model must be re-established to reflect the desired drop angle and height in the subsequent drop.

Wang et al. [72] presented some results of a consecutive drop impact analysis performed on an electronic device with aluminum casing. However, the finite element modeling approach was not discussed. A literature survey on available consecutive drop impact analysis on electronic devices proved futile.

Consecutive drop impact at board level had also caught the attention of researchers such as Lai and his co-workers. Lai et al. [99] investigated the dynamic reactions of board level packages subjected to consecutive drop impacts. Results showed that the equivalent plastic strain observed for a single drop condition stopped evolving as flexing of the board gradually dampens, when plasticity no longer develops on the solder joints. Thus, a consecutive drop condition can be simulated by inducing multiple impact acceleration pulses on the test subject, with reasonable separation time in between each pulse to allow plasticity to fully develop. It was observed that for IMC fracturing on solder joints, the maximum shear stress increased with the number of drop count and any drop reliability prediction using the interfacial shear stress in a single drop condition will be inaccurate.

Lai et al. [100] also studied the evolution of damage on solder joints in a package subjected to multiple drop impacts which involved the evolutions of stresses, plastic strains and plastic strain energies. All these were correlated with experimental study. The effects of isotropic hardening and kinematic hardening for solder alloy were investigated and compared. However, experimental verifications were not performed to prove that the two hardening rules represent the true plastic behavior of solder alloy.

### 10 Conclusions

The progress and development of drop impact analysis on electronic devices had been successfully summarized and reviewed in this article. This article attempted to present an overview of all the past attempts accomplished in this research area. The importance of finite element analysis in the study of drop impact had been acknowledged. This does not indicate in any way that experimental work is totally dispensable. Drop impact analysis on electronic devices can be categorized into board and product level. Due to limited literatures on product level drop analysis, this article has considered the work on board level drop impact which depicts similarities in certain areas. Product level drop test is inevitable as board level does not consider the interaction between PCB and enclosure, and also fastening methods during drop impact. Currently, a correlation has yet to be established between board and product level drop testing. Drop test analysis based on finite element method should be dealt effectively to achieve reasonable computational time. Some finite element modeling techniques have been presented which can be adopted by readers interested in pursuing this subject. Literature survey also shows that a gap exists in the study of consecutive drop impacts on electronic devices at the product level.

### Nomenclature

- BGA = ball grid array
- CCD = charge coupled device
- CSP = chip scale package
- ENIG = electroless-nickel immersion
- FEA = finite element analysis
- FEM = finite element method
- FFT = fast Fourier transform
- IC = integrated circuit
- IEEE = Institute of Electrical and Electronics Engineering
- IMC = intermetallic compound
- JEDEC = Joint Electron Devices Engineering Council
- OSP = organic solder preservative
- PCB = printed circuit board
- PDA = personal digital assistant
- QFN = quad flat no-lead
- RSM = response surface methodology
- SHPB = split Hopkinson pressure bar
- TFBGA = thin-profile free-pitch ball grid array
- VAM = video audio module
- VBM = virtual boundary model

### References


