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ScienceDirect

Procedia Engineering 173 (2017) 424 – 431

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Comparison of Explicit and Implicit finite element methods and its effectiveness for drop test of Electronic control unit

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Abstract

Engine control unit consists of many electronic components like capacitors, inductor coils, Ball Grid Array (BGA) and Ceramic chips which are prone to fail during drop. As per ISO 16750-3 standard electronic components are dropped from one meter height on rigid wall in six different dimensional axis to check the reliability of the system [4]. Unless the ECU mechanical structure fails or components inside housing separates from PCB drop failures cannot be noticed. Designing drop reliable electronic components are critical to improve the quality of ECU and vehicle.

This paper discusses the effectiveness of four simulation methods used to simulate electronic control unit (ECU) drop test. Explicit and Implicit simulation methods are considered in this study. Under implicit simulation technique full transient, steady state static and mode super position methods are studied and they are compared with explicit method. Explicit simulation method is conditionally stable whereas implicit methods are un-conditionally stable, this makes the explicit method computationally costlier and time consuming. Convergence and absence to capture the dynamic response are the major challenges in implicit method. For this study the electronic control unit is simplified with bare printed circuit board (PCB) and frame for drop simulation. PCB in-plane strains and displacements are evaluated for one meter height drop on rigid floor and all corresponding results are compared to find the effectiveness of each method.

Peer-review under responsibility of the organizing committee of Implast 2016

Keywords: ECU; BGA; drop; explicit analysis; sub-modelling; board level drop test

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Peer-review under responsibility of the organizing committee of Implast 2016
doi:10.1016/j.proeng.2016.12.042

1. Introduction

Electronic control units (ECU) are excessively used in automobile and aerospace industries. In automotive vehicle assembly, ECU may subject to free fall, in such cases the electrical and mechanical functionality of ECU is questionable. Drop test is a destructive test and this is helpful to ensure the mechanical reliability of electronic components in drop, generally ECU development cycle is shorter in nature and does not have any room for error in designing reliable ECU's. Finite element simulation helps to reduce this ECU drop reliability risk in design phase and various drop simulation methods are used to predict the ECU components failure in drop.

A study of free drop for portable IC package is done by Irving and Lui [3] using fully non-linear, transient implicit dynamic algorithm for three different package design. Stress and strain for these cases were compared and its relation with solder joint height, stress propagation and package weight are compared. This analysis is useful to find out the effect of surface mounted components on PCB and the variation of stress and strain with different components height and weight during free fall.

Drop dynamic responses and modal analysis for board level TFBGA is proposed by Kai-lin et al. [2]. Modal superposition harmonic responses are compared with different number of screw fixations on PCB. The weakest components location and criticality of outermost solder joint for ball grid array are investigated using mode super position method.

Yiyi Ma [1] introduced board level drop test simulation using explicit and implicit solver and a correlation between experimental and simulation result for PCB dynamic behavior and solder joint reliability is mainly focused. An acceleration of 1500g +/-10% was applied during testing and solved with explicit and implicit solver using Input-G and DSI method respectively.

This manuscript presents a comparative study of explicit, implicit static, mode superposition and implicit full transient methods for simulating drop test using ANSYS/LS-DYNA solver. Explicit methods are meant for simulating short transient dynamic events and implicit methods are generally used to simulate static and problems which are less transient using mode super position and also time step integration in full transient methods are used to solve dynamic events as in explicit method.

2. Drop test modeling and simulation:

Dynamic simulation of electronic control unit (ECU) drop test can be carried out using Explicit, Implicit simulation methods. In Implicit method, input – G, mode super position and full transient methods are used to simulate the drop test. Implicit input-G method require a measurement data, where the acceleration load profile measured over ECU in drop test is applied as static load. If the measurement data is not available an iterative approach is followed to find the acceleration which can generate a strain energy equivalent to potential energy of the system. But this method does not capture the secondary events like bouncing of ECU during drop and the steady state approach does not capture the actual PCB bending behavior.

Implicit mode super position is a linear approach to capture the dynamic behavior of the system which is missing in steady state approach. With sufficient knowledge of system modes the result from this method could be accurate. But mode super position method cannot capture the material and contact non linearity and the results can be inaccurate in such cases. Mode super position method calls for attention towards the load profile derivation, the load profile is dependent on geometry of the component, strike surface and drop height. In this paper JEDEC standard [5] load profile of high sine pulse with peak amplitude of 1500G for a period of 0.5 ms is used to simulate the drop of a test board of size 135 x 100 x1.7 mm.

Implicit full transient analysis method can capture the dynamic impact load and secondary events, but this method is computationally costlier and it is not robust as explicit solver in handling non-linearity and numerical convergence