Statistical Analysis Method for Assessing Drop-shock Reliability of OLED module for Portable Devices

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Nowadays, mobile electronic devices with a large multi-function display, such as smartphones and tablet computers, are widely used and have become an essential and ubiquitous part of our lives. Meanwhile, the average display size of mobile devices has been steadily in-creased while the thickness has been reduced. This makes the display module more vulnerable to drop impact which is inevitable during use of the mobile device. Drop impact is known as one of the most frequent causes of failure of mobile devices. Since the multifunction display is the main way users interacted with the mobile devices, the reliability of the display module by drop impact is one of the most important concerns for both manufacturers and customers.

In recent decades, there have been extensive studies on drop impact. Most existing approaches can be categorized into two groups [1]: numerical method and experimental method. The experimental method can be again divided into two types: the free fall method and shock method (or constrained drop method). As the names suggest, both methods have their own pros and cons.

The free fall method can mimic a realistic drop impact, while it is difficult to control the exact direction of impact and has less repeatability. Conversely, the shock method can precisely control the amplitude and duration of shock, while it is difficult to replicate its real drop impact dynamics. In general, the shock method is the most common and favorable for drop testing at component level such as mobile display modules while the free fall method is more suitable for product level [1, 2]. Therefore, in this study, we focus on the shock method.

For the shock method, there are several international standards for the drop impact test. Based on the dam-age boundary curve [3], a drop test standard for a general purpose was established by ASTM [4]. The drop test standards for electronic devices at component level are established by JEDEC [5, 6], ETSI [7] and IEC [8, 9].

Lim and Low [10] examined the drop impact response of a cellular phone by the free fall method at difference impact orientations and heights. The high-speed camera photographs, the impact force, the shock level, and the dynamic strains measured on the PCB board were obtained and analyzed. Yu et al. [11] proposed a shock-based drop test method at PCB board level and per-formed comparisons with the finite element analysis results. Chung et al. [12] investigated drop reliability of glass panel for LCD. In the study, three-point bending and free fall drop test of LCD panel with test jig were performed. The finite element analysis was performed to verify the drop test method. Mattila et al. [13] investigated the shock method at board level to better represent the user loading conditions of mobile devices. To do so, eight smartphones from different companies were evaluated by free-fall drop test and the drop response of mobile devices were characterized. Wong et al. [14] presented a review of the drop impact reliability that focus-es on lead-free solder joints of PCB for mobile devices. Yau and Hua [2] presented a comprehensive review of the drop impact test methods for mobile devices. They summarized the progress and development of drop impact test and analysis methods on mobile electronic de-vices.

To date, most existing research focuses on the investigation of the underlying failure mechanism of drop impact and the development of the test method that can mimic actual drop impact. It has, however, paid less attention to the application to reliability assessment from a statistical modeling perspective.

In practice, a prediction of failure of drop impact is important to assess the reliability of mobile devices at both the development and production stage. There are two major sources of uncertainty in the drop test: inherent variation in test item and limitation of the drop impact test method.

The former issue has been addressed in some works [12, 15, 16] by employing the Weibull distribution and Inverse-Gaussian distribution to modeling the drop impact failure data. Using the estimated statistical model, prediction of the p-th quantiles and MTTF was presented. To the best of our knowledge, however, the later issue is not sufficiently addressed yet. Since drop test is conducted by gradually increasing drop height until the failure is observed, we can only know the interval of the failure height, but not the exact value.

This is called “interval-censored”. It can lead to significant bias in prediction unless an appropriate modeling method is employed to address this problem.

In addition, there are three decision variables to be determined in advance of a drop impact test: the initial drop height, the increasing interval, and the number of test items. When conducting a drop impact test, practitioners need to balance a trade-off between the total cost of the test and the accuracy of the analysis. However, there is a lack of literature that specifically focuses on the planning of the drop impact test procedure.

In this paper, we propose a drop-impact reliability assessment method for display module of mobile devices using a statistical modeling approach. First, we introduce a statistical reliability model for drop impact failure having left-, right- and intervall-censored data. Then, we propose a drop impact test planning method that minimizes the estimation error while meeting the total cost constraints. The proposed method is demonstrated by simulation studies. Drop impact datasets of the OLED module for portable devices are used to illustrate the proposed method.

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