Product Performance

Structural failure analysis of polycarbonate enclosures of electronic devices subjected to multiple ball impacts

Yat Huang Yau\textsuperscript{a},*, Shijie Norman Hua\textsuperscript{a, b},**, Chee Kuang Kok\textsuperscript{c}

\textsuperscript{a} Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
\textsuperscript{b} Motorola Solutions (M) Sdn. Bhd., 11990 Bayan Lepas, Penang, Malaysia
\textsuperscript{c} Faculty of Engineering and Technology, Multimedia University, 75450 Bukit Beruang, Melaka, Malaysia

A R T I C L E   I N F O

Keywords:
Ball impact
Finite element analysis
Structural failures
Multiple impacts
Polycarbonate
Crack

A B S T R A C T

The present study predicts the structural damage on polycarbonate enclosures of electronic devices in multiple ball impact tests, achieved through numerical simulation and experiments. A novel methodology in modelling repeated ball impacts was established and proven. It was found that the finite element model must be allowed to achieve static equilibrium at the end of each impact before the next impact. The ball impact was performed on the polycarbonate enclosures at different heights ranging from 20 to 70 cm. The results suggested that the maximum penetration depth from both finite element analysis (FEA) and experiment were in good agreement. The failure sites were also predicted with reasonable consistency.

1. Introduction

Industries are constantly finding ways to develop electronic devices that have higher drop survivability, which translates to brand trustworthiness. To achieve this, numerical analysis such as drop impact simulation has been employed, and its advantages over trial-and-error prototyping highlighted in the literature [1]. However, the impact performance has been characterized based on the analysis of a single drop impact, usually performed at the most critical impact orientation. Lim et al. [2–4] and Low et al. [5] investigated the drop impact response of a wide range of electronic devices at different drop orientation and height but only for a single impact. This information is not sufficient to predict the reliability of these devices under consecutive impacts in field usage. Often, mechanical failures are only induced after multiple impacts and could not be accurately predicted via a single drop event. Therefore, there is a need to conduct multiple impact simulations on electronic devices to predict their robustness.

A comprehensive literature survey [6] indicated that, over the years, publications on numerical analysis of drop analysis under consecutive drop conditions have been limited. This could be due to the fact that running subsequent drop impacts in numerical simulation will increase the computational costs [7]. The study of consecutive impacts on electronic devices has been acknowledged as an emerging area of interest and one with considerable technical challenges [8–10]. The ability to capture the cumulative effects of consecutive impacts through numerical analysis is believed to be of great value in the design of a product.

The ball drop test is a form of ‘drop impact’ test performed on electronic devices as a measure of robustness at localized areas such as display, speaker grill and keypad interfaces. These areas are highly susceptible to permanent damage from ball impact. The ball impact test involves dropping a steel ball of a certain weight directed at a marked location on the test device from varying drop height. The test is customized based on field conditions, and the requirements could vary among manufacturers. Although not a part of the MIL-STD testing, the ball impact test is customarily conducted to ensure robustness of a device, and is usually a part of its technical specifications.

Several challenges have been identified by numerical analysis involving consecutive drop impacts, namely: 1. Accumulation of plastic strains: Plastic strains incurred during the first impact need to be accounted for in the subsequent drop analyses. This requires the tracking of plastic strains from one analysis to another. 2. Release of elastic strains: The state of the dynamic model at the end of each drop impact simulation must be approximate that of a static model, containing only residual strains. All recoverable elastic strains must be released. This can be accomplished by running the dynamic model indefinitely, which is both costly and impractical in terms of computational work. Therefore, the determination of a suitable time frame to end the drop impact analysis at a state of near static equilibrium is required. 3. Re-initialization: The drop impact model must be re-aligned to reflect the desired drop angle, and the

* Corresponding author.
** Corresponding author. Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.
Email address: ybyau@um.edu.my (Y.H. Yau)

Received 30 October 2017; Accepted 11 December 2017
Available online xxx
0142-9418/ © 2017.
1) A novel approach to model multiple-ball impacts on polycarbonate enclosures in electronic devices has been comprehensively presented. The modelling approach requires that a state of static equilibrium to be achieved in the model on dynamic impact. This is to ensure that the model contains only residual strain to be accumulated in the next impact.

2) The model proves to be accurate in predicting the penetration depth on both the representative enclosure and the speaker cover.

3) The experimental crack sites and the locations of peak equivalent plastic strains in the simulation were in excellent agreement at higher strain rates. The predictions at low strain rates were less good.

Acknowledgement

The authors would like to acknowledge the sponsorship of equipment and materials by Motorola Solutions (M) Sdn. Bhd for the completion of this study.

The technical advices of Motorola employees, Mr. Tee Boon Hoo and Ms. Ooi Chin Chin, are greatly appreciated. Thanks are also extended to University of Malaya UMRG Grant RG030/15AET for the partial financial assistance to the first-author for conducting the research work at the HVAC&R Lab at the Department of Mechanical Engineering, University of Malaya.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.polymertesting.2017.12.013.
Fig. 19. The deformed surface is reconstructed and the penetration depth is measured in CAD software.

Fig. 20. Penetration depths on the representative front enclosure as predicted in the FEA and measured in the experiments.

Fig. 21. Penetration depths on the speaker cover as predicted in the FEA and measured in the experiments.
**Fig. 22.** Distributions of equivalent plastic strain on the representative enclosure after the 5th impact at 40 cm.

Table 4  
Comparisons between the predicted locations with peak equivalent plastic strain and observed crack locations on the representative enclosure.

<table>
<thead>
<tr>
<th>Drop Height</th>
<th>FEA</th>
<th>Experiment</th>
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<tbody>
<tr>
<td></td>
<td>Locations of Peak Equivalent Plastic Strain</td>
<td>Crack sites on Representative Enclosure</td>
</tr>
<tr>
<td>70 cm</td>
<td>Rib 4-4'</td>
<td>Rib 4-4'</td>
</tr>
<tr>
<td>60 cm</td>
<td>Rib 4-4'</td>
<td>Rib 3-4'</td>
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<tr>
<td>50 cm</td>
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<td>Rib 4-4'</td>
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<td></td>
<td>Rib 4-4'</td>
<td>Rib 4-5'</td>
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<tr>
<td>40 cm</td>
<td>Rib 5-5'</td>
<td>Rib 4-4'</td>
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<tr>
<td>30 cm</td>
<td>Rib 5-5'</td>
<td>Rib 4-4'</td>
</tr>
<tr>
<td>20 cm</td>
<td>Rib 5-5'</td>
<td>Rib 4-4'</td>
</tr>
</tbody>
</table>

Table 5  
Comparisons between the predicted locations with peak equivalent peak plastic strain and observed crack locations on the speaker cover.

<table>
<thead>
<tr>
<th>Drop Height</th>
<th>FEA</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location of Peak Equivalent Plastic Strain</td>
<td>Crack sites on Speaker Cover</td>
</tr>
<tr>
<td>70 cm</td>
<td>Rib 3-3'</td>
<td>Rib 3-3'</td>
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<td>Rib 3-3'</td>
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<tr>
<td>20 cm</td>
<td>Rib 2-2'</td>
<td>Rib 3-3'</td>
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</table>
Fig. 23. Equivalent plastic strain versus impact number for the representative enclosure.

Fig. 24. Equivalent plastic strain versus impact number for the speaker cover.

Fig. 25. Estimated peak equivalent plastic strain at failure versus impact number for the representative enclosure.
References


