Cover Glass Behavior in Handheld Device Drop: Modeling; Validation and Design Evaluation

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Handheld device

✓ Smartphones
  • 2D, 2.5D and 3D cover glass
✓ Other portable electronic devices
  • tablet; iPod; watch etc.
✓ Test vehicles
  • puck; dummy device

Drop test

✓ Consumer device drop test
✓ Puck drop test / lab test
✓ Mechanical testing
  • Hammer / ball impact
  • flexure; modulus; mech. props.
  • glass characterization
Background & Problem Statement

**Approach**
- Study handheld devices drop test through testing and FEA modeling. Integrate the methods to supplement each other and, therefore, reduce, optimize, and accelerate the tests.

**Objectives**
- Combining testing and numerical modeling, develop a method for optimization of consumer electronic devices development and testing.
- Through modeling, get mechanical and physical parameters, which cannot be measured in a test in cover glass and other device components.
Drop test features

- Number of the test parameters vary from run to run
  - Device rotation at the moment of impact
  - Impact velocity
  - Environmental parameters
- Limited capabilities to measure stresses and strains during the test
- Flaw population in glass vary for each of the cover glass resulting in scattered glass failure test data.

- Typically, drop test requires significant number of runs to get statistically meaningful data. Due to a device cost and the significant number of the drops, the expenses associated with the test are high
Handheld device description

Schematic of a developed handheld device

(1) Cover glass (GG)
(2) Optically clear adhesive (OCA)
(3) Display module
(4) Electronic components/modules
(5) Battery
(6) Foam/adhesive
(7) Back cover / Bezel
(8) Screws/connectors

This device was designed, machined tested and simulated to study a drop test of an averaged commercial handheld device.
Accelerated Stress Testing and Reliability Conference

Device drop test

Test outputs:

- Process animations
  - Device deformations
  - Contact and rebound times
  - Rebound heights
- Fractography data

Drop test setup:
- Drop tower with pneumatic acceleration and clamps
- 2 high speed video cameras for front and side views
- 2-axis digital inclinometer
Handheld device drop mechanics

1. First contact: Localized impact load
2. Second corner/edge contact: Flexure
3. Third corner contact
4. Fourth corner contact: Twist, Accelerated impact
5. Fifth contact
6. Six contact
7. Rebound
8. Max. rebound height
9. Secondary impacts: Free flight - deceleration
**Model description**

**Device Model**
- Finite element based
- Explicit (LS-DYNA)
- Device level (full 3D)
- Include all the device components
- Include the ground/target

**The model accounts for:**
- Materials non-linearity
- Frictional contacts
  - between components
  - with a target - granite plate
- Earth gravity
- Drop velocity

Mid-plane cut

Target
Device Drop Modeling details

Deformations in time
(cross section view)

Trajectory features

Initial contact
Device mid-section contact
Glass-target contacts

Contact force [kN]

Time [10^-3 s]

Contact force spikes location
Contact history
Model validation

The model validated for:
- Device deformations (at specific times)
- Contact with ground and rebound times
- Rebound heights
Stress induced in a cover glass during a drop test

- Glass bending due to global deformation
- Local stress due to second impact
- Scattered stress due to battery impact

- First impacts on the corner
- Bending affected by display module

Force [kN]

- ~220MPa (front surface)
- ~100MPa (front & back surface)
- ~100 to 160MPa (back surface)
- ~170 to 250 MPa (front surface & edge)
- ~200 to 600 MPa (front surface & edges)

Time [ms]

September 28- 30 2016, Pensacola Beach, Florida
In addition to the test data, the modeling gives:

- Stress distribution in glass (as function of time)
- Contact pressure (and forces) from the glass-ground contact interface and the other glass contact surfaces when appears
- Details on interaction between a cover glass and inner parts of a device such as display module, battery, tapes, printed circuit boards etc.
Goal

Estimate a contact force (as surrogate of glass and device performance) on the cover glass surface as a function of adhesive thickness and softness.

Key learning

- Identified the range of thick and soft adhesive to reduce the localized load in glass during the device drop.
- Design for the glass adhesion that minimizes impact effect in the cover glass.
Goal
Estimate effects of the device global stiffness and an adhesive compliance on the cover glass

Key learning
Estimate effects of the device global stiffness and an adhesive compliance on the cover glass

Failure modes indicators:
• High contact pressure + localization area factor – failure due to sharp indentation
• High principal stress + stress gradient effect – flexure related failure mode
Conclusions

Key results

- Developed the approach which utilizes a synergy of testing and numerical modeling for better understanding for a handheld device drop performance. Once validated, it allowed us to parametrically study the drop test sensitivity to the test and the device parameters. This can be used to better set up the test and minimize the cost associated with the test.

- A handheld device drop test was designed and performed for a developed test vehicle.

- A full-scale handheld device model was developed using explicit finite element analysis (FEA).

- The model was validated against the experiment for set of parameters.
Key findings

• Series of numerical simulations have been conducted to study the cover glass performance with respect to:
  – glass adhesion to device
  – overall and & local device stiffness.

• The work showed that significant cover glass reliability improvement in the device resistance against sharp indentation can be achieved if
  – the glass is supported from the back side with a soft adhesive material;
  – a device is designed to minimize glass overstressing for an initial contacts (as in slide 12)
  – device is designed to compensate or control interaction of the internal device components with respect to the overall device flexure
Questions / Comments
Abstract

Cover glass reliability performance in a drop test is critical for handheld electronic devices. Handheld device drop test has limitations in measuring dynamic response on the device components which complicates the test control and data analysis. To supplement, design and improve the drop test we developed a full-scale modeling approach of a representative handheld device drop test. The device model includes all the major components such as: display, cover glass, rear cover, battery, printed circuit board/bracket, screws, adhesives, etc. The developed model explicitly simulates the device drop test, allowing us to measure mechanical parameters as function of process time for each of the device components. The numerical model was validated with the device drop test. In the current report we are focused on cover glass reliability. The cover glass performance was studied with respect to effects of adhesive materials on the rear side of the cover glass and the overall device rigidity. Using the model, we evaluated effects of each device component for the cover glass during drop. It was shown that significant cover glass reliability improvement in the device resistance against sharp indentation can be achieved if the glass is supported from the back side with a soft adhesive material. Key observations from these extensive modeling efforts have been discussed and the conclusions from the current study can serve as a general guideline to improve cover glass’s reliability of a handheld device.