IMPACT ANALYSIS OF A CELLULAR PHONE

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ABSTRACT –Drop test simulation plays an important role in investigating impact behaviors and identifying weak points of a cellular phone at design stage since actual testing is expensive and time consuming. This paper presents the impact study of a new cell phone design with split steel bands. The finite element model of the assembly was developed by using ANSA, the state-of-the-art pre-processor, and analyzed with LS-DYNA. The unit was dropped on a granite floor from the height of 1 meter with different orientations, such as face drop, edge drop and corner drop. Focus was paid on some key components. The integrity of the split band was investigated carefully; the stresses for cover glass and LCD layers were evaluated numerically; and the shock absorbing performance of different visco-elastic pads attached on camera was compared in details.

1. Introduction

The most common failure of cellular phones is probably the impact due to accidental drop, so the manufacturers aim to develop products that are impact resistant and can survive the drop test from specific height. Both physical test and finite element (FE) simulation are employed in the industry at different stages. At the design stage, FE method plays a more important role since actual drop test can only be conducted at the end of design cycle and provides little feedback to improve the design. The FE simulation will help designers understand how components interact in the assembly and how the failure mode and mechanism is developed under the impact loading [1]. Physical test should be conducted on prototypes since field tests are still the most reliable source of information of the assembly during drop test and the only method of final validation of the FE analysis. High speed cameras are set up to monitor the unit response, and the dropped unit is disassembled carefully to check if cracks develop on some key components such as cover glass, back housing and liquid crystal display (LCD) layers.

This paper discusses the drop test simulation of a new cell phone design whose steel band is split into three segments. Attention was paid on the integrity of the split band, the stresses for the cover glass and LCD layers, and the impact load on the camera module. LS-DYNA, the non-linear explicit FEA code was selected for the analysis due to its robust capability of handling impact phenomenon. The FE model, including around 550,000 elements with more than 130 components, was developed by using ANSA, the state-of-the-art pre-processor in which different engineers' mesh work was incorporated and managed efficiently; high quality meshes were generated quickly, and the model was assembled and modified conveniently. With little modification, the input deck of ABAQUS for static strength analysis was generated with the same model using ANSA. The static analysis will not be discussed in this paper.

2. Development of the FE model

The steel band was divided into three segments which were connected by three plastic inserts as shown in Fig. 1.This feature brought more flexibility to the assembly and consequently had effects on the unit's dynamic response during drop tests.

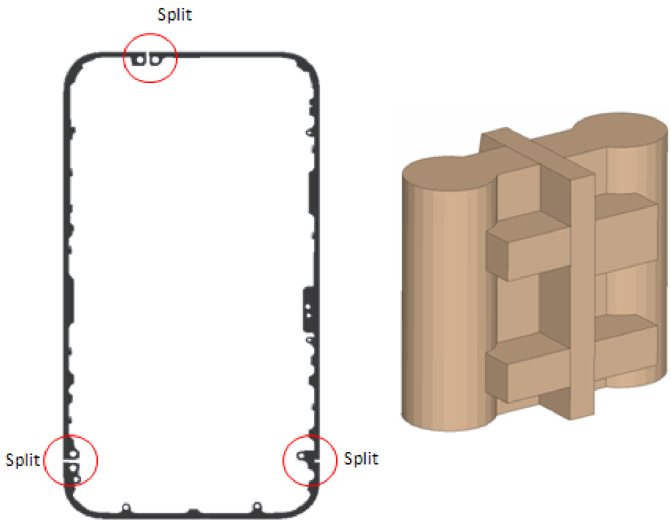

Fig. 1 The split band and plastic insert.

The unit was dropped on granite floor from the height of 1m at different orientations, including face drops, edge drops, corner drops, and tilt face drop as shown in Fig. 2.

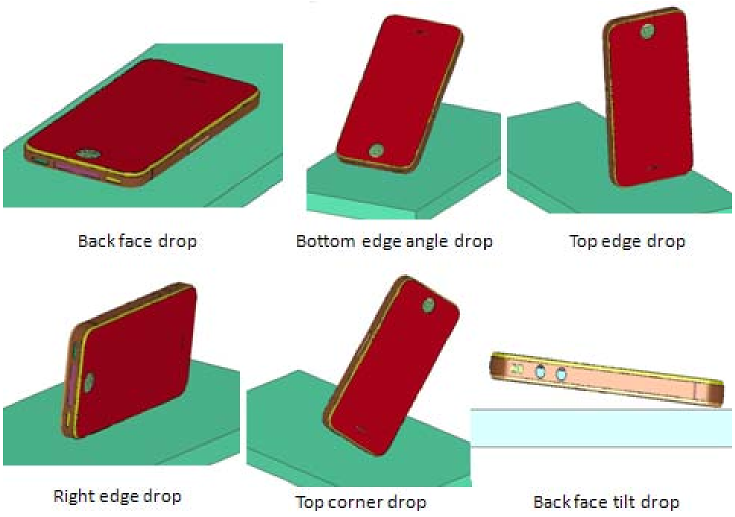

Fig. 2 Drop orientations.

The components were meshed by different engineers and were assembled in ANSA. Based on the geometric characteristics of each part, different element types in LS-DYNA were used. Hexahedral elements were used for the parts which could be meshed with brick elements within reasonable time even though additional efforts were needed, since hexahedral elements have better performance than tetrahedral elements in explicit codes. Some parts with hex meshes are shown in Fig.3.

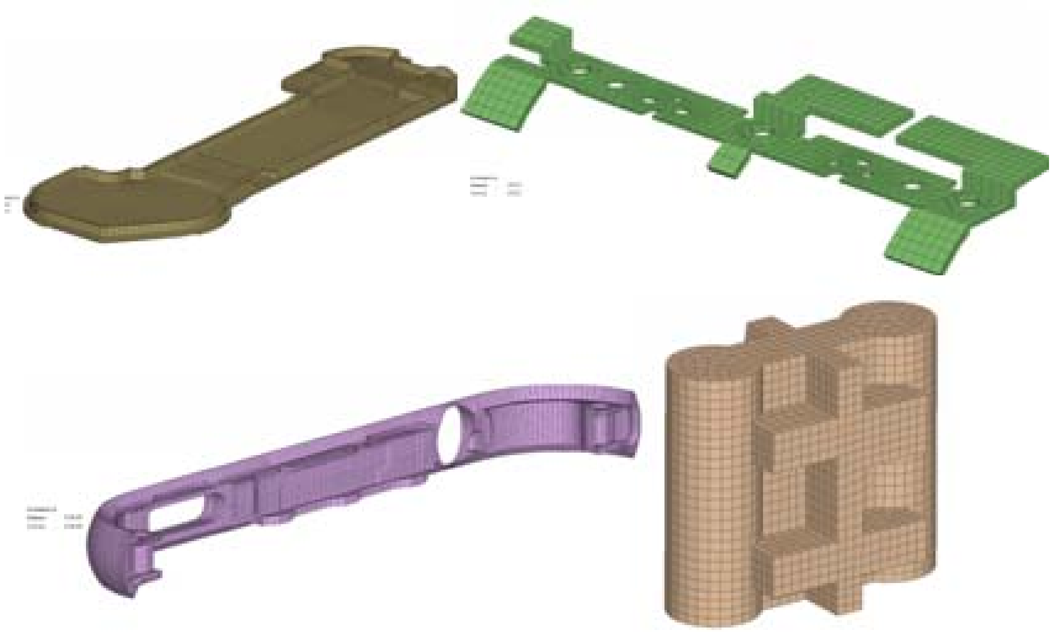

Fig. 3 Hex mesh for some components.

It was very difficult, if not impossible, to hex-mesh some parts with complicated geometry, so they were represented by second order tetrahedral elements. Shell elements were used by many engineers to model cover glass and LCD glass layers, but they were not employed in this model. The reason lay in the fact that shell elements performed satisfactorily to represent bending modes of layers during face drops, but caused numerical problem in the edge and corner drops in which shell edges and corners contacted with other components. Four layers of hex elements were designed along the thickness of each glass layer to correctly represent its bending stiffness. Beam elements were used for simplified joints, which was the only choice to include tiny structures like screws and clips into a system level model [2]. The representation was proven effective and accurate enough.

All meshes were verified for consistencies and refined to improve their quality. Decisions regarding material models, contact algorithms, multipoint constraints (MPC), loading and boundary conditions, and solution parameters were determined to complete the whole model of the phone. Time increment was set to 1E-8s with mass scaling. It was found that the added mass was less than 2% of the total weight of the unit.
The FE model was completely managed in ANSA. Some components had several versions of design. It was convenient and efficient to change the model by replacing some parts with their modified versions. It significantly reduced the period of run-model, modify-model and rerun-model process, and helped the designers quickly figure out the appropriate design. Fig. 4 presents the FE model of the assembly.

Fig. 4 FE model of the assembly.

3. Discussion of the results

3.1 Stresses for plastic inserts and glass layers

From the simulation results, it was found that the split band did cause higher stresses for the cover glass and other LCD layers compared with the results from the model with a continuous band. However, with a good design of the plastic inserts and the thickness of glass layers, the peak maximum principal stresses for glass layers could be controlled under the material's break stress for all drop orientations. Fig. 5 shows the stress contour of a plastic insert and Fig. 6 shows the stress contour of the cover glass.

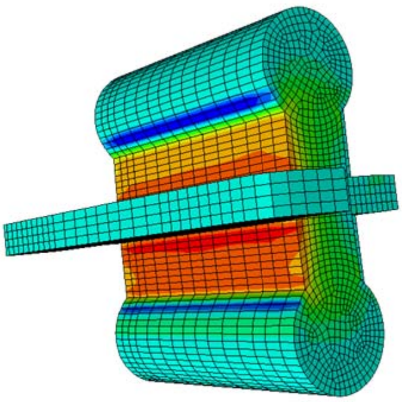

Fig. 5 Stress contour for a plastic insert during back face drop.

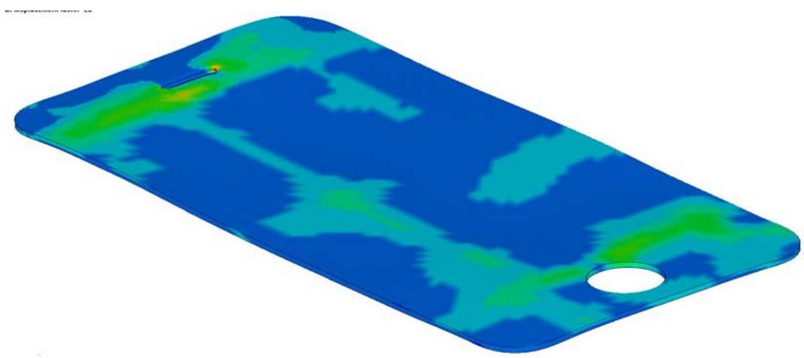

Fig. 6 Stress contour for the cover glass during back face drop.

In drop test simulation, the band splits were typically under a combined loading condition of bending and twisting. These loading conditions are more representative what the assembly will experience during its testing and/or usage. For the split at top as shown in Fig. 1, the typical loading condition is bending along longitudinal and/or vertical axis, and twisting along transverse axis. For the two splits at side, the typical loading condition is bending along transverse axis and twisting along longitudinal axis.

3.2 Impact loading on the camera module

High impact force on camera module was observed in face tilt drop. In order to ensure the camera still functioned properly after the impacting, a pad made of visco-elastic material was attached on the camera module to attenuate the shock. The camera module is shown in Fig. 7.

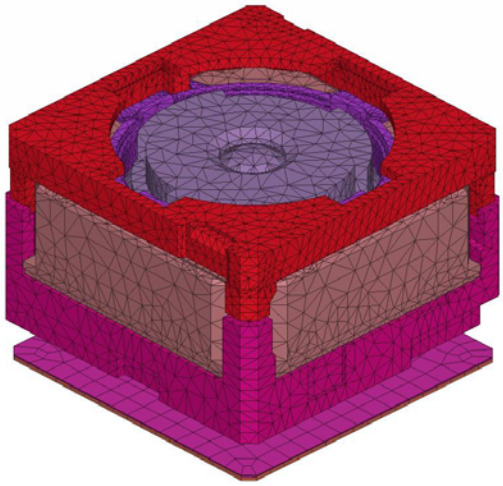

Fig. 7 Camera module.

In LS-DYNA, the key words *MAT_GENERAL_VISCOELASTIC is used to define visco-elastic material by inputting the Prony series [3]:

$$g_R(t) = 1 - \sum_{1}^{N} g_i \left(1 - e^{-t/\tau_i}\right) \qquad (1)$$

Where g_R is dimensionless relaxation modulus, and g_i and τ_i are material parameters.

The visco-elastic behavior of a material is often determined from dynamic vibration experiments. In these experiments the material is exposed to small strain vibrations and the resulting storage modulus G' and loss modulus G'' are determined as a function of the applied frequency ω. The tested storage modulus and loss modulus for the selected material is shown in Fig. 8.

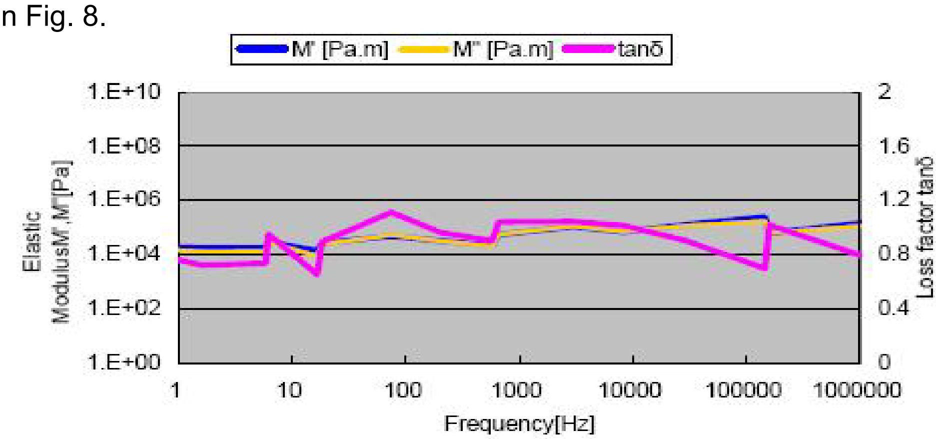

Fig. 8 Tested storage modulus and loss modulus for the material.

The relationship between dynamic frequency data and Prony series data is [4]:

$$G^{'}(\omega) = G_0\left[1-\sum_{i=1}^{N} g_i\right] + G_0\sum_{i=1}^{N}\frac{g_i\tau_i^2\omega^2}{1+\tau_i^2\omega^2}$$
$$G^{''}(\omega) = G_0\sum_{i=1}^{N}\frac{g_i\tau_i\omega}{1+\tau_i^2\omega^2} \tag{2}$$

When the storage and loss modulus are known, the parameters G_0, g_i and τ_i are optimized so that the residual between the calculated modulus and experimental modulus reaches minimum. A more convenient method is to use ABAQUS's material evaluation feature that can quickly perform the data conversion. Fig. 9 shows the acceleration history of the camera lens during face tilt drop. 10,000Hz filter was applied to the data to get rid of noise.

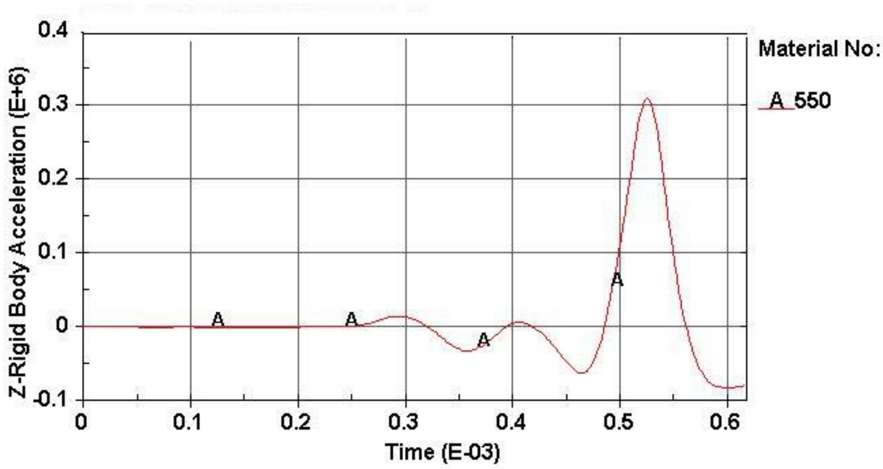

Fig. 9 Acceleration history of the camera lens during face tilt drop.

The peak acceleration is around 30,000g which is 30% lower than the value when non visco-elastic material was used.

4. Summary and Conclusions

In this project, drop test simulations of a new design of cell phone were conducted by using ANSA and LS-DYNA. The FE model was developed and managed in ANSA, an advanced CAE pre-processing tool that provided all the necessary functionality for full-model build up and management, from CAD data to ready-to-run solver input file. It significantly speeded up the design process. Different drop orientations were analyzed.

The introduction of split band did increase the stresses for the cover glass and other glass layers. However, by appropriately designing the splits and plastic inserts and carefully selecting the thickness of glass layers, the peak tensile stresses could be controlled below the material's break stress. Shock absorbing pad was attached on the camera to reduce the impact loading on the lens. The dynamic testing data of the material were converted to Prony series as the input for LS-DYNA. The results showed that the visto-elastic pad significantly reduced the impact loading on the camera lens.

References

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