Comparative study of smartphone screens using numerical analysis

I A Magomedov
Faculty of information technology, Chechen State University, 32 Sheripov Street, Grozny, 364024, Russia

E-mail: ismwork@mail.ru

Abstract. This work is focused on investigating smartphone screens using numerical analysis. Two smartphone screens are presented in this work for comparison. Apple and Samsung products will be analyzed, which are Sapphire and Gorilla Glass respectively. Extended finite element method and cohesive zone model for numerical analysis will be used. Software packages of Ansys, Code-aster and Salome Meca were used in this work for analysis to initiate and propagate crack in chosen structure. Brief introduction and literature review of the problem also presented in this work. To gather results for numerical analysis two different structure was build in software Ansys. Wedge shaped structure was built and analyzed to gather results of deformation. First analysis was done by using material properties of Gorilla Glass and second applying material properties of Sapphire. The results illustrated that Samsung product Gorilla Glass is more deformed if to be compared with Sapphire. Then a square shaped structure was created and was tested on fracture. Two different values were used to fracture the structure. The results showed that it is harder to fracture Sapphire than Gorilla Glass. Lastly crack propagation was analyzed. It was found that Gorilla Glass has less propagation than Sapphire.

1. Introduction

In the modern time it is impossible to imagine our society without smartphones. They integrated every aspect of our life. Popularity in the marked is due to its ability to output (input) information through screen. Therefore, it is the main reason for customers to look up, when considering of purchasing smartphone. It is well known that screens of smartphones are prone to fracture. Thus, companies spend a lot of money to improve them. The size of screen is significant when fracture occurs. It is known that larger the size the more chance of it to fracture and verse vise. In the market there are two big companies Apple and Samsung that competes at the moment. Both of them created their own screens of smartphones with different material properties. Apple uses Sapphire and Samsung Gorilla Glass. Both of the screens have advantages and disadvantages. However, this work does not consider of analyzing and stating which one is best, but rather will illustrate what happens under some condition.

2. Literature review

Dynamic fracture can be defined as a branch of fracture mechanics. Dynamic fracture is concerned with fracture phenomena on a time scale. In this case inertial resistance of material to motion is important. Initial consideration is focused to onset of extension of a crack or its arrest, this is due to the imperfection in the material, which leads to stress concentration in the region of defect. Therefore, under dynamic analysis reflected strain waves, inertia of material and rate dependent material behaviour becomes rely
significant with a structure subjected to a time dependent load. Hence fracture arises rapidly, with no time to deform plastically, but causing the structure to fracture [1].

Many experimental, analytical and numerical studies have been done to better understand dynamic fracture. Yet there are some mechanisms and aspects of dynamic fracture that are not fully covered or analysed well. There are some number of numerical studies performed to model dynamic fracture. It is clear that well developed numerical analysis can be utilised to look into dynamic fracture [2].

For analysis of fracture in the structure the following methods can be used: wave equation, extended finite element method (XFEM), cohesive zone model (CZM), cracking node method (CNM) and others. Primarily focus of this work is to utilize extended finite element method with cohesive zone model to investigate crack propagation in structures with material properties of Gorilla Glass and Sapphire.

Finite element method (FEM) is a powerful tool to look into variety of analysis. Finite element method is able to work with huge numbers of degrees of freedom. Finite element method can analyze and represent output data quite correctly [3]. It advantages lays on its ability to precisely analyse the structure under applied boundary conditions and thus saving time and money avoiding doing actual analysis. The difference between extended finite element method and Finite element method is that last mentioned has a significant level of mesh dependency. Extended finite element method or in other words the partition of unity method, which is, simply extend of the finite element method approach to deal with discontinuity surfaces. The extended finite element method was created to solve the problems that arise from localised features, which cannot be solved by finite element method as it requires update of the mesh as crack propagates [4].

Barenblatt’s [5] introduction of cohesive zone method describes dynamic fracture using cohesive law or model. Combination of two approaches were introduced to solve various fracture problems. Materials and material interfaces are modelled through a traction-separation law for which the tractions are zero when the opening displacement (separation) reaches a critical value. It was stated that the area under the curve characterises fracture process, other way the work of separation and the peak stress is the fracture strength. Similarly, studies of Chandra [6] illustrated that the shape of the traction-separation law is also critical to accurately simulate material interface and capture macroscopic mechanical behaviour.

By performing analysis on crack propagation, there occurs a narrow layer or in other words cohesive zone. In that zone voids initiate and join with crack formation. With the applied force, cohesive surface will be separated, but still connected by cohesive traction. The relation between cohesive traction and displacement jump of cohesive surfaces is usually called traction-separation law [7].

3. Methodology
Software Ansys was used to build two different structure. At the beginning the wedge-shaped structure was modelled. Afterwards square shaped structure, which is similar to smartphone screen. Boundary conditions were applied to the structures and then structures were analysed. At the one end the structure was constrained by the fixture tool. Forces were added to other sides of the structure’s end, to the faces, which are perpendicular to the fixed faces. Material properties were added to the structure from table 1 bellow. Table 1 represents available material properties of Saphhire and Garilla Glass. Material properties of Garilla Glass are in open access and can be downloaded from official webpage. However material properties of Apple (Saphpire) are not in open access. Thus material properties of Sapphires are represented as in table 1.

In addition, the following software packages were used: Solom Meca, Code Aster. Code Aster is EDF’s software package that can be integrated to investigate numerical analysis with the usage of python language. Therefore, the following software will be utilized to analyse crack opening displacement. In addition, Code Aster can cover such fields as: thermal, mechanical and acoustical. Also the package is able to model damage, fatigue and fracture. Solome Meca is used to visualise the output results. All the results of crack opening displacement are visualised through Solome Meca and the following figures are taken out from the software.
Table 1. Material properties of two materials.

| Material properties          | Sapphire  | Gorilla Glass |
|-----------------------------|-----------|---------------|
| Young’s modulus (GPa)       | 345.0     | 71.100        |
| Passion’s ratio             | 0.250     | 0.2100        |
| Density (kg/mm$^3$)         | 3.97*10^{-6} | 2.42*10^{-6} |
| Vickers hardness (kg/mm$^2$)| 2200      | 649.00        |
| Fracture toughness (MPa$\sqrt{m}$) | 2.300 | 0.6800        |
| Tensile yield strength (MPa)| 7333.30   | 2163.3        |
| Strain energy release rate  | 14.3750   | 6.2160        |

4. Results

At the beginning wedge formed structure with initial crack was used to gather results (figure 1 and 2). For both structure the same force with the magnitude of 9 N was applied. Analysis was performed to collect results of structure deformation with different material properties (tab. 1). It can be seen that material with properties of Gorilla Glass (figure 1) is deformed more if to be compared with Sapphire. Thus by observing structure of Sapphire (figure 2) it’s clear, that it is more robust to deform under the same applied force. Then material properties of both Gorilla Glass and Sapphire were applied to one structure (square shaped structure) to get maximum force required to brake the structure. It was found that fracture in Gorilla Glass will occur with applied force approximately higher than 5 N. Similarly fracture in Sapphire will occur around 7.5 N. By examining table 2 it is obvious that crack propagation in sapphire is more than in Gorilla Glass by increasing applied force.

Figure 1. Structure deformation of Gorilla Glass.

Figure 2. Structure deformation of Sapphire.
Table 2. Crack opening length.

| Material properties | Force (N) | Crack length (mm) |
|---------------------|-----------|-------------------|
| Sapphire            | 9.0       | 26.80             |
|                     | 5.0       | 16.40             |
| Gorilla Glass       | 9.0       | 25.90             |
|                     | 5.0       | 16.60             |

5. Conclusion
To conclude, this work looked into dynamic fracture of two smartphone screens. Two smartphone screens of Apple and Samsung were analysed. The method used tends to illustrated tendency of experimental results. It is obvious that Sapphire is stronger than Gorilla Glass. It seems that Gorilla Glass is more ductile and hence deforms more. Therefore, by observing results from table 2 one can say that sapphire is hard to fracture but ones fractured its crack opening distance tents to be more. In conclusion both of the structure/materials has their own advantages and disadvantages under different condition.

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