RESEARCH PAPER

Simulation the Effect of impact on the Mobile Cover Using Solidworks Anal

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ABSTRACT:

Mobile phones are complex and sensitive electronic devices that may be susceptible to fracture if fell down unless shielded securely. Accordingly, Cases are effective means to defend the phones against sudden impact. The performance of these covers relay on many aspects such as design and the potential of the materials. For this reason, it is intended in this project to estimate the effect of the material properties on the impact resistance of the covers using the powerful of Solidworks program. The materials modeled linear elastically and the mobile impacted the ground from a 1 m height under the effect of gravitational force. The results showed that mobile cover made of silicone rubber failed in the impact and polycarbonate shelter was superior to thermoplastic polyurethane rubber cover due to the highest modulus of elasticity. In addition to that, verification of the simulation process was done by comparing the results to the experimental works cited in the literature. It is found that maximum Von Mises stress at the bottom edge and the corners of Gorilla Glass were satisfactory close to the result obtained by Bocko et al.

KEY WORDS: Mobile Cover; Mobile Impact; Solidworks
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INTRODUCTION:

Mobile phones are senior inventions of human beings over the decades as a result of innovated and developed technology involved in. Because of that, the utilities of cell phones exceeded beyond their simple function as a communication mean to include entertainment, education, transportation guidance and many other apps of various purposes (Miron and Opera, 2014). The lacks of these devices are their fragileness hence, they are vulnerable to destruction especially when falls to the ground. For this reason, shielding the device via energy absorbent materials is extremely important, but unfortunately, the literatures review focused on investigating the effect of the impact on the cell phone itself without any referring to the covers and their roles as a protector. Thus, studying the functional capability of the mobiles shields according to their materials performance is exceptionally important and need to be explored. Consequently, the reliability of different materials to protect the cell phone from the crash will be investigated in this work using Solidworks simulations. However, the effect of the impact on the mobiles was tested physically by (Bocko et al., 2016) using the innovated technique as high-frequency image analysis cameras. In the test, the cell phone dropped from a 1m height and impacted the floor with five different angles. Four
of them were impacted under controlled conditions such as bottom edge and its opposite where they labeled as case A and B respectively, the left bottom corner (case C) and its opposite (case D) with one uncontrolled impact (case E) in the alignment of the long edge of the cell phone. Before the test, a mobile phone type Nokia 500 RM-750 freckled in the face with white and black color in order to increase the snapshots ability of the cameras. The digital machine used to predict the deformation during impact by setting the capture frequency of the cameras. Regarding the impact stress developed in the phone, a three points’ reference line was selected on the patterned face of the apparatus to calculate the Von Mises stress formed considering the materials behave linear elastically due to the brittleness of the glassy screen of the cell phones. It is observed that case E recorded the highest value of about 140MPa compared to a mere of 50MPa for case C. Fortunately, none of the previous impact positions lead to macro crack in the screen.

The interest in modeling and analyzing simulation parameters effects on the mobile in impact continued with (Harysson, 2003). A geometry file with extension IGES of a mobile phone type Sony Ericsson T68 was imported from the company. The mobile dropped from a 1.5m height and a comparison between the output results as a function of meshing type (hexagonal and tetragonal) was analyzed using Abaqus package. It is concluded that for more than 6 simulations hexagonal mesh overwhelmed tetragonal discretions in term of processing time. Despite of that, the researcher focused in his work on the technical parameters related to the simulation process such as processing time, he concluded the difficulty of calculating stress during impact. However, an average Von Mises stress at nodes of hexagonal elements recorded a maximum value of 0.07. The authors did not provide any unit due to the difficulty of prediction the stress since the value of the stress continuously changes within a short time of millisecond order during impact as this was obvious in the video records provided by the software that is why he had to use the average value of the stress and focused on the numerical value regardless of the unit. On the other hand, Mobile accessories producers in their blogs and websites state that the mobile covers duties have not restricted to protection purposes only, indeed, customers’ personal desires are also a vital factor. So, they have to use a wide range of materials to satisfy the customers. For instance, Metals, leather, and wood are all raw materials for cover productions but plastics and rubber seems to be dominated over the others because of their low cost, high scratch resistance, and high resilience. So, different polymeric covers either flexible as both silicone rubber and thermoplastic polyurethane (TPU) or hard as polycarbonate and polypropylene were used to satisfy the different desires of the customers (mobile cases, 2016). Based on the aforementioned reasons it is obvious that testing the role of the mobile covers as a defender against strikes is a novel subject to contribute to it. The preference among three different types and widely use materials in mobile accessories industry will also be estimated.

1. THEORETICAL BACKGROUND

1.1. Materials Types and Properties

The materials that will candidate in this research due to their wide separation in the mobile accessories world are polycarbonate, silicone rubber, and thermoplastic polyurethane. Regarding polycarbonate, the enjoyed properties such as high impact endurance and transparency (Archer et al., 2015) make it desired by mobile accessories manufacturer. In addition to polycarbonate, silicone cover dominated over leather and plastic shelter as a result of low cost and flexibility that makes rubbery covers fit the cell phone apparatus regardless the complexity of their shapes and curved contour (Orth, n.d.). On the other hand, thermoplastic polyurethane has extraordinary mechanical properties such as high wear resistance and resilience to absorb the kinetic energy companies (Ellingham et al., 2017) which makes it sensible to bring the attention of accessories producers. Accordingly, mobile covers made from previous materials will characterize under impact stress using Solidworks program. Since the screens of the cell phones are the most prone to crash due to fragileness, protecting the glassy screen is a top concern. Consequently, a piece of widely used glass in manufacturing mobiles screen named Gorilla Glass (Corning Gorilla Glass 3, 2015) will be housed inside the gap of the covers instead of complex cell phone apparatus. Most of the technical data required by
the software cited from (Cambridge University, 2003) are shown in Tab.1. However, shear modulus for some materials was calculated theoretically using Eq.(1) (Beer, Dewolf, and Johnston, 2006).

\[ G = \frac{E}{2(1 + \nu)} \]  

Where \( G \): shear modulus, \( E \): modulus of elasticity, and \( \nu \): Poisson’s ratio

1.2. Theory of Impact

Dropping of cell phones may take the breath of the owners especially if they are expensive mobiles as iPhones. For this reason, housing the apparatus with covers and investigating the type of covers’ materials during impact is a great concern. We can imagine impact either as a weight falling on the test object or a test object striking a rigid surface. In this research, the latter case in which the mobile cover is the test object will be considered. Impact load and deflection can be derived from energy balance theory which is based on a simple system contain a spring and falling weight as shown in Fig.1. The potential energy of the weight (W) falling from height (H) will be transformed completely into kinetic energy which in turn into strain energy according to the equation below.

Total potential energy (PE) = strain energy  

\[ \text{PE} = WH + W\delta \]  

Where \( \delta \) is deflection

The strain energy (SE) in the spring is equal to the area under the force-displacement curve see Fig.2 and for a linear behavior spring

this will be equal to

\[ \text{SE} = \frac{1}{2}K\delta^2 \]  

And the force in the spring related to the displacement according to

\[ F = K\delta \]  

Where \( k \) is the stiffness of the spring From Eq.(2) and Eq.(3) we can derive the equation of deformation as follow:

\[ Wh + W\delta = \frac{1}{2}K\delta^2 \]  

Using quadratic equation the displacement will be

\[ \delta = \frac{W\pm\sqrt{W^2+2KWh}}{K} \]  

This simplifies to

\[ K\delta = W + W\sqrt{1 + \frac{2Kh}{W}} \]  

In the previous equations, the deflection of the spring can represent the deformation of a test object (as mobile cover in this case) when it strikes hard surface (Attaway, n.d.).

2. MODELING BY SOLIDWORKS 2017

The mobile cover in this research designed in a shape and dimensions that fits a cell phone of brand iPhone 5S. The materials property implemented to Solidworks 2017 and the behavior of the materials assumed to be linear isotropic elastic since, for full protection purpose, it is required from covers to perform within the elastic range. The boundary condition applied in a manner similar to the circumstances of the mobile cover function in real life, that is, the cover is dropped from a 1m height and strikes the ground under the effect of its own weight. The software run in order to simulate the effect of the impact on the covers based on their materials types. Von Mises stress was the criterion of comparison between the covers. In addition to that, deformation produced during impact is another measure of assessment. Regarding the mobile weight, it is assumed that a glassy piece fills the cover gap as mentioned before. However, the design of the cover along with meshing map as provided by Solidworks report is shown in Fig.3 below.

3. RESULTS AND DISCUSSIONS

3.1. Extraction Yield

The mobile cover dropped from a 1m height and impacted the ground under the effect of gravitational force. The Von Mises and deformation results of the simulation are listed in Tab.2 below. Unfortunately, silicone rubber subjected to high stress exceeding its yield point of 5.5 MPa (Cambridge University, 2003) indicating failure of the cover. Now, the competition restricted between polycarbonate and thermoplastic polyurethane rubber. It is obvious that polycarbonate outperformed thermoplastic polyurethane rubber due to a minimum value of stress produced during impact as shown in Fig.4.
Lower stress means that the cell phone housed inside cover will be protected against damage.

Since we modeled the material behavior linear elastically the previous results could be explained by considering the modulus of elasticity. Polycarbonate enjoys with the highest value of Young modulus (2.44 GPa) which is 22% higher than that for thermoplastic polyurethane rubber. In addition to that, the lowest deformation value of polycarbonate cover shown in Fig.5 compared to that found in the other covers also confirms the overwhelming reason. Another fact that determines the superiority of polycarbonate skin is the spectrum of stress distribution in Gorilla Glass: it is observed that the screen housed in polycarbonate cover subjected to lower stress during the strike as it is obvious by green color in Fig.4. The stress contour within the glassy screen reached a maximum value of bout 27 MPa for polycarbonate skin compared to more than 28 MPa in thermoplastic polyurethane cover. Despite that polycarbonate outperformed thermoplastic polyurethane rubber, the differences in the mechanical performance are negligible indicating that thermoplastic polyurethane could be an alternative option of polycarbonate. Moreover, to polish the performance of the covers as an effective means to protect cell phones, unprotected piece of Gorilla Glass dropped from a 1m height and impacted the ground at the bottom edge. The dynamic stress exceeded 64MPa (see Fig.s 6-2) compared to approximately 27MPa for covered glass as discussed before. On the other hand, the model of Gorilla Glass was verified because the Solidworks results were comparable to that obtained in the experimental works cited in the literature. For example, the maximum Von Mises stress for a point at the bottom of the Gorilla Glass was close enough to that obtained by Bocko et al, 2016 for point 3 colored in blue. Both of points 1 and 3 in Fig.6-1 are the heading of a display straight line on the cellular phone face as discussed previously in the literature whereas point 2 is the mid-distance between them. Neglecting the minor differences between the two curves it is obvious that the stress, in either case, reached a maximum value of about 65MPa see Fig.6. The differences as variation in time order and divergence of the stress values at the end of impacting time may be originated from the fact that Bocko et al impacted a whole cell phone with all tiny interior parts and real life shape whereas in this model only the screen glass in the form of cell phone was tested as the most fragile part of the mobile. Accordingly, the maximum stress observed in the Gorilla Glass recorded at the bottom corners was close to that obtained in case C by (Bocko et al, 2016). It is obvious that the stress at the bottom point (blue line) recorded a maximum value of 50MPa which is close enough to the Solidworks output see Fig.7.

1. CONCLUSIONS

Mobile cover made of silicone rubber failed in the impact since the formed stress exceeded the allowable limit of yield strength. Furthermore, polycarbonate shelter was superior to thermoplastic polyurethane rubber cover due to the highest modulus of elasticity. In addition to that, housing cell phone in polycarbonate will secure the glassy screen more due to subjecting to lower stress which in turn leads to lower deformation during impact. On the other hand, verification of the simulation process was done by comparing the results to the experimental works cited in the literature. It is found that maximum Von Mises stress at the corners and bottom edge of the Gorilla Glass were satisfactory close to the result obtained by Bocko et al.

Conflict of Interest (1)

| Table (1) Technical Data of Materials |
|--------------------------------------|
| Properties, Polycarbonate, Silicone, Thermoplastic, Gorilla Rubber polyurethane rubber glass[d] |
| Elastic modulus (GPa) | 2.44 | 0.020 | 2.07 | 69.3 |
| Poisson’s ratio | 0.37[a] | 0.49[b] | 0.45[c] | 0.22 |
| Shear modulus (MPa) | 890 | 6.7 | 713 | 28500 |
| Mass density (Kg/m³) | 1210 | 1800 | 1240 | 2390 |

a Chin, 2007 b Itoh, and Yamada, 2006 c Ivankovic, and Kanyanta, 2010 d Corning Gorilla Glass 3, 2015

Table (2) The Results of Impact Tests
| Mobile cover               | Von Mises Stress (MPa) | Deformation (mm) |
|---------------------------|------------------------|------------------|
| Polycarbonate             | 46.37                  | 3.65e-1          |
| Thermoplastic Polyurethane (TPU) | 47.64                  | 3.688e-1         |
| Silicone rubber           | 11.46                  | 8.435e-1         |

Figure 1: falling weight onto a spring (test object)

Figure 2: force-displacement curve for a spring, the strain energy is equal to the area under the curve

Figure 3: to the left the design of the mobile cover to the right the meshing map of Solidwork

Figure 4: Von Mises stress in 1. Polycarbonate, 2. Thermoplastic polyurethane, and 3. Silicone rubber covers
Figure 5: deformation in 1. Polycarbonate, 2. Thermoplastic polyurethane, and 3. Silicone rubber covers

Figure 6: Comparison of the results obtained at bottom edge in this research to the experimental outputs cited in the literature review. To the left. The result of the experimental test and to the right. The results of the simulation

Figure 7: Comparison of the results at corner obtained in this research to the experimental outputs cited in the literature review. To the left. The result of the experimental test and to the right. The results of the simulation

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