Iphone X Dropping Simulation via Abaqus

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Contents

1 Problem Statement

Cellphone, the most common electric device during the daily life, has really strict production specifications. Risk of damage is one important specification. When an external force or motion applied to a cellphone, the most likely damage part should be the outer glass screen. This is because the pressure and breakage resistance of glass are way smaller than other materials used for outer shell like aluminum or some polymers.

Most people has such experience that inadvertently drops cellphone to the ground. Sometimes, there is no damage appeared at screen; sometimes, only few small crack happened; sometime, whole glass is broken. These differences depend on many factors. For example, the materials of the cellphone case and ground, the contact angle between cellphone and ground, the initial velocity of cellphone, these all contribute a lot to the final result.

In this project, the main purpose is to find and analyze the result when cellphone drops into ground. Furthermore, it is also helpful to figure out what is going on when cellphone drops into ground with cases made by different materials. From the comparison, I can find the most suitable materials with best protection.

2 Test Plan

In this project, the whole simulation will be done in Abaqus. The cellphone used for this model is Iphone X plus. I assume the height of dropping point is 1 meter and no initial velocity applied to Iphone which means the velocity when the it contacts with ground is:

$$\frac{1}{2}mv^2 = mgh \Rightarrow v = \sqrt{2gh} = \sqrt{2 * 9.81 * 1} \approx 4.43m/s \tag{1}$$

Assuming the contact angle between Iphone and rigid ground is 45° and it is dynamic explicit motion. By running simulation via Abaqus, I can find the maximum principle stress at screen surface when iphone has no protection case and different materials of protection case. Then calculate the plane strain fracture toughness by Eq.2 and compare it with material's expected fracture toughness

$$K_c = Y\sigma_c\sqrt{\pi a} \tag{2}$$

where Y is a dimensionless parameter which equals to 1 when crack appeared at middle, σ_c is critical stress for crack propagation which can get from the results of simulations and a is the crack length which is assumed to be 1 μm. This result might not be exact because we can not predict the geometry of crack. The size and location of crack both contribute a lot for fracture toughness. However, it still works if I only want to know what happened in general and compare the protection ability for cases with different materials. Thus, we can get the safety factor for different materials case based on Eq.3.

$$Safety.Factor = \frac{K_c(Exact)}{K_c(FEA)} \tag{3}$$

3 Simulation Process

3.1 Iphone X dimensions

In order to simplify the simulation, I assume the Iphone X and case are both solid parts. The exact dimensions demonstrate as following figures. The unit used is millimeter. The thickness of the glass is 0.5 millimeter and thickness of case is 1 millimeter.

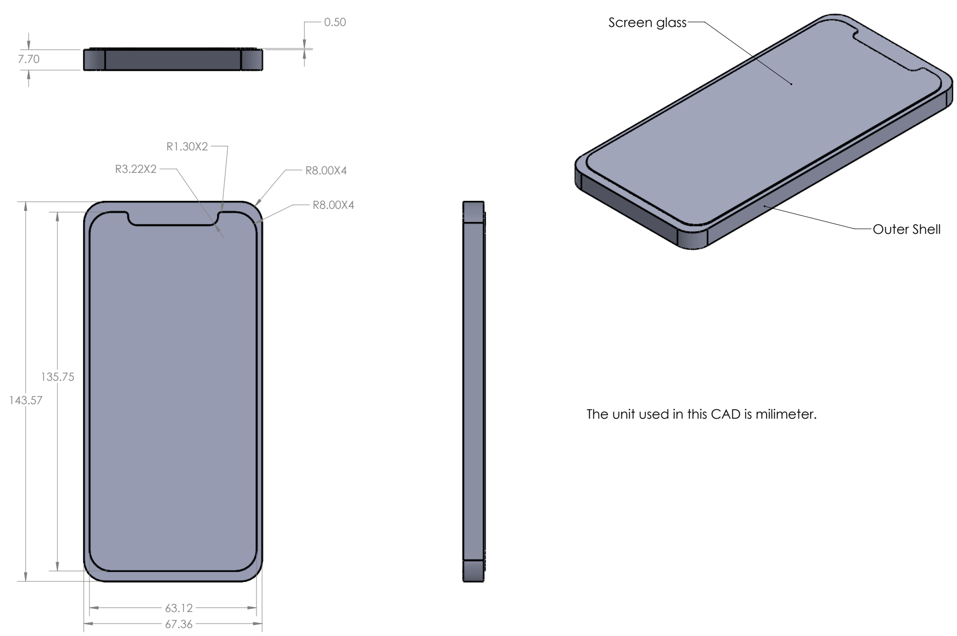

Figure 1: CAD of Iphone X

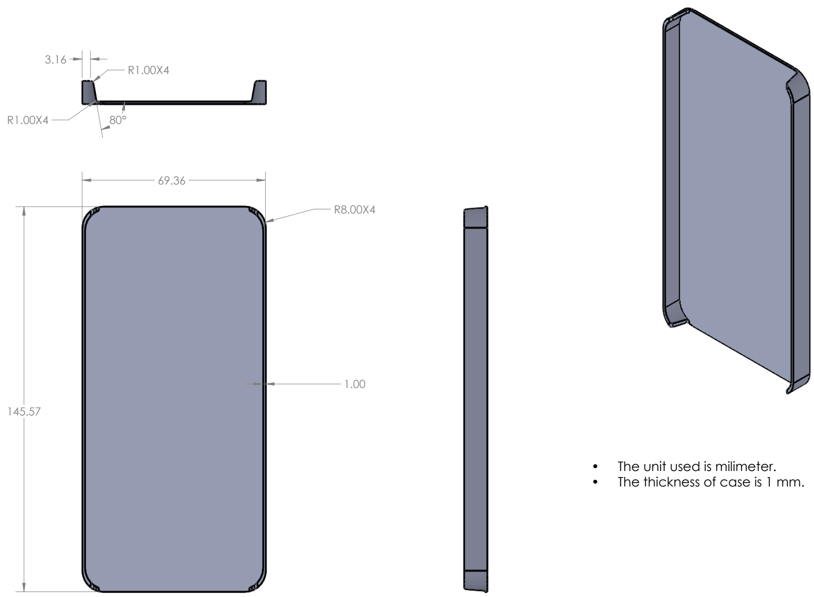

Figure 2: CAD of Iphone Case

3.2 Material properties

For real Iphone X outer shell, it's made by a number of different materials. It contains metals such as aluminum, titanium and iron. It also has some plastic component like polycarbonate. In this project, I assumed the outer shell is made by a singular material for easier analysis. I assume the outer shell is made by polycarbonate which takes the major percentages among all materials.

For the screen of the Iphone X, it is made by a specific glass called Gorilla glass produced by Corning Inc. For the Iphone case, I selected three popular materials in the market, which are polycarbonate, polyethylene and silicone rubber.

The mechanical properties of these materials are shown as Table 1.

Material	Density(kg/m^3)	Elastic Modulus(Pa)	Poisson's Ratio	Fracture Toughness
Polycarbonate	1210	$2.2*10^9$	0.37	
Polyethylene	920	$2.04*10^8$	0.425	
Silicone Rubber	1200	$2.5*10^7$	0.48	
Gorilla Glass	2430	$7.67*10^{10}$	0.21	$6.9*10^5(Pa*\sqrt{m})$

Table 1: Mechanical Properties of Materials in This Project[1,2,3,4]

3.3 Assembly

The assembly for this project is shown as Fig 3. The angle between cellphone and ground is 45 °. The distance between cellphone and ground is 0.05 meter.

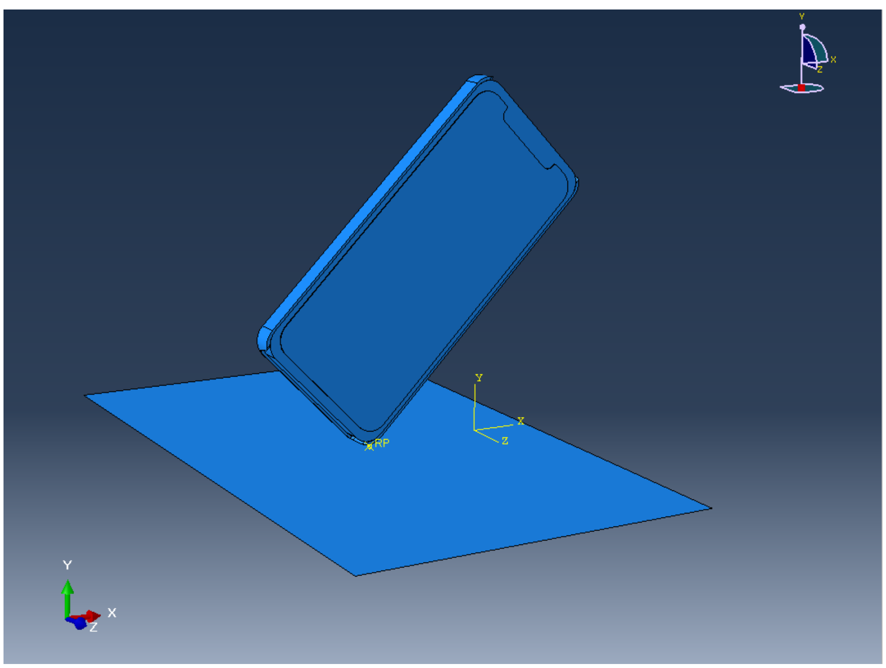

Figure 3: Test Assembly

3.4 Step description

The step defined is dynamic explicit simulation. The Nigeom setting is on. The total time period is 0.001 second and other setting is default as shown as Fig 4.

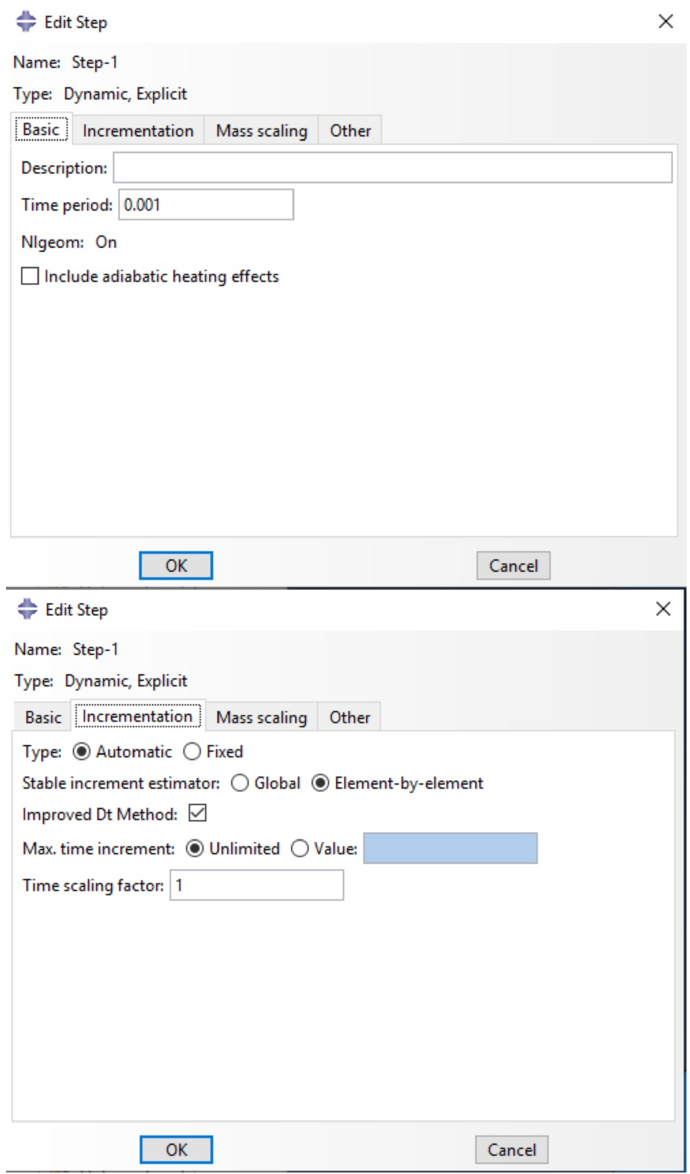

Figure 4: Step definition

3.5 Contact property

There is totally two contacts in this project. First contact is between the cellphone and case. The second one is the contact between the case and the ground. The contact properties is shown as Fig 5.

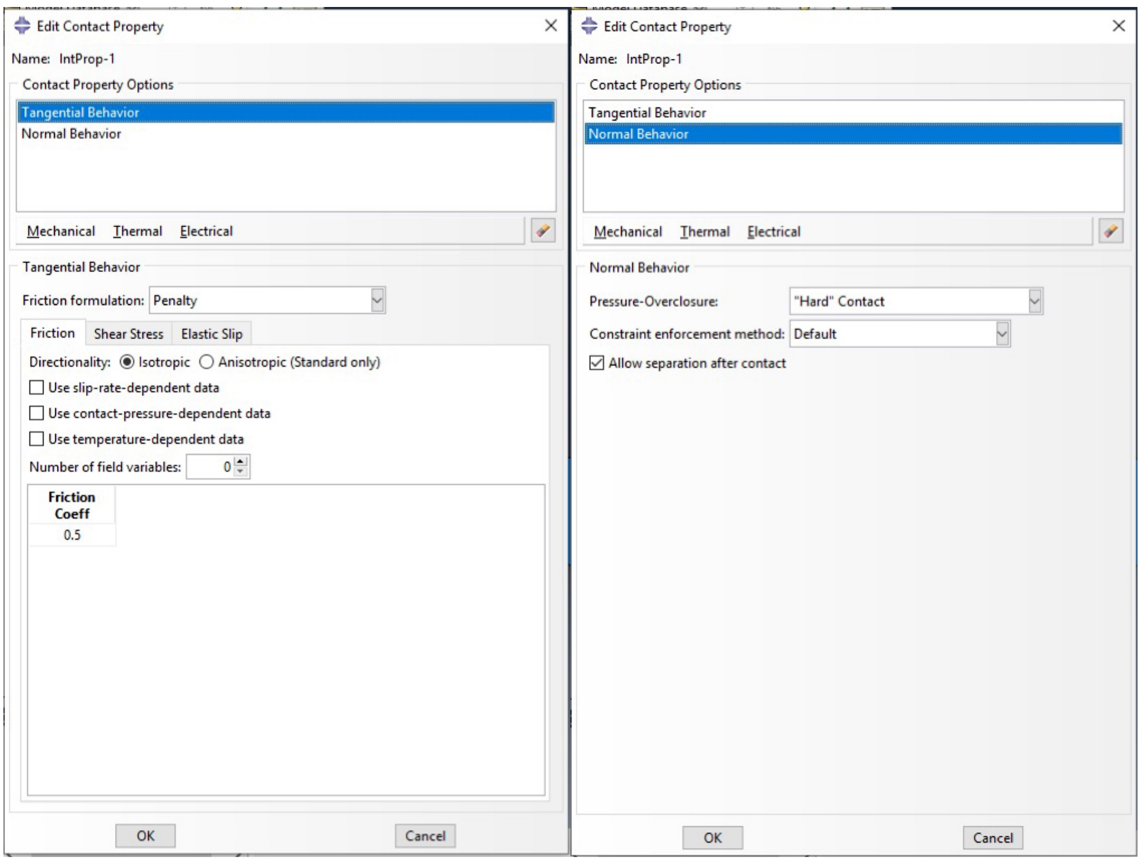

Figure 5: Contact Properties

The contact setting for cellphone and case is shown as Fig 6. The contact setting for case and ground is shown as Fig 7.

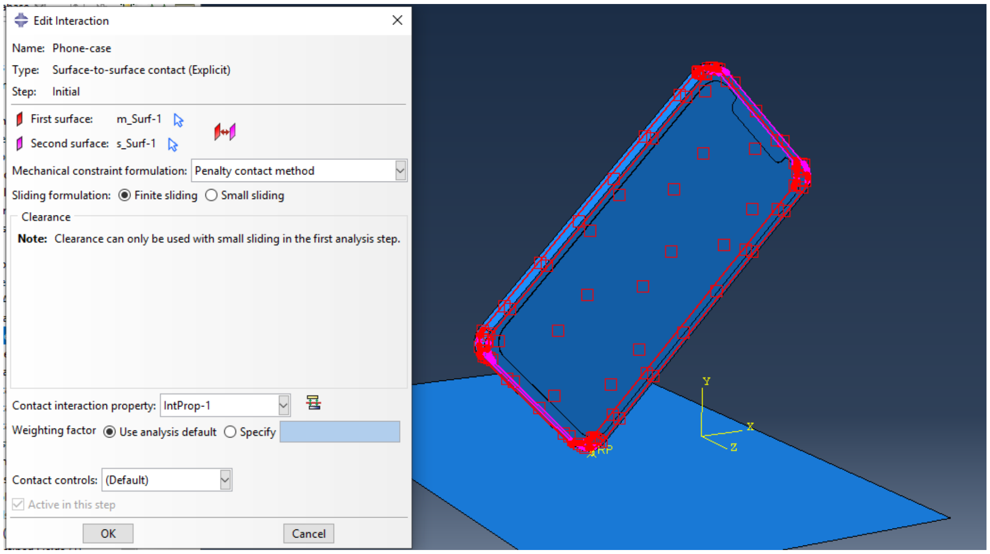

Figure 6: Contact between Cellphone and Case

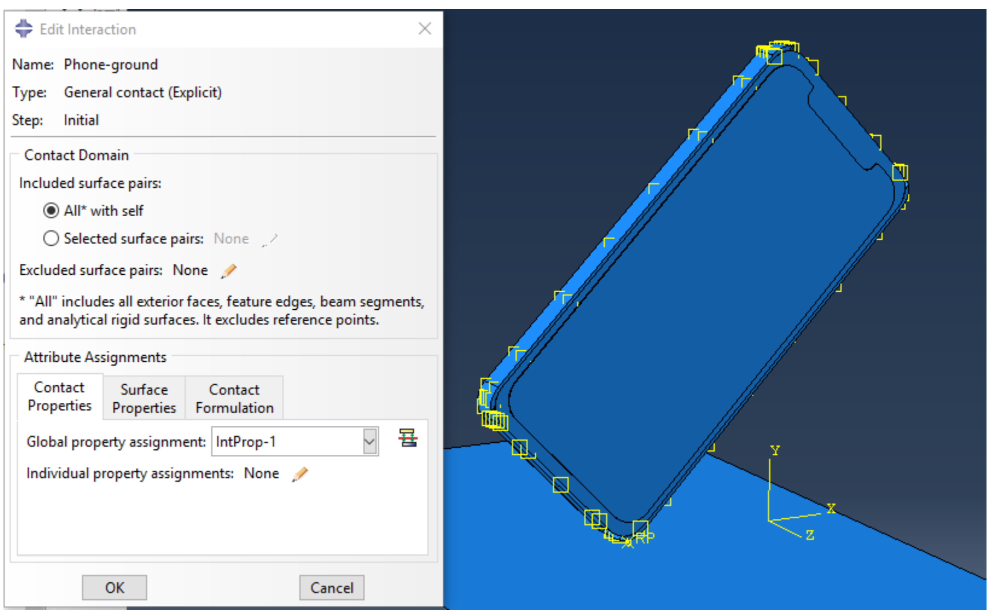

Figure 7: Contact between Case and Ground

3.6 Boundary conditions and loading

There are two boundary conditions for this project. First one is to fix the ground. I created a reference point at middle of rigid ground, then set U1=U2=U3=UR1=UR2=UR3=0 at that point.

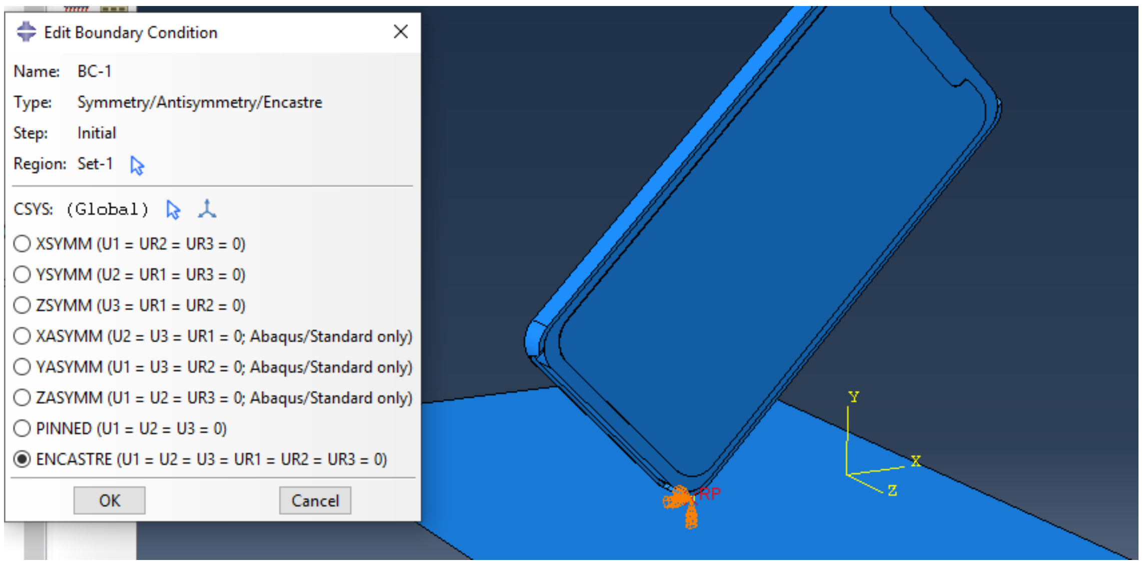

Figure 8: Boundary Condition of Reference Point

From the calculation I got the velocity when cellphone contact with ground which is 4.43 m/s. Thus, I set velocity field of cellphone and case at y2 direction is -4.43 as shown at Fig 9.

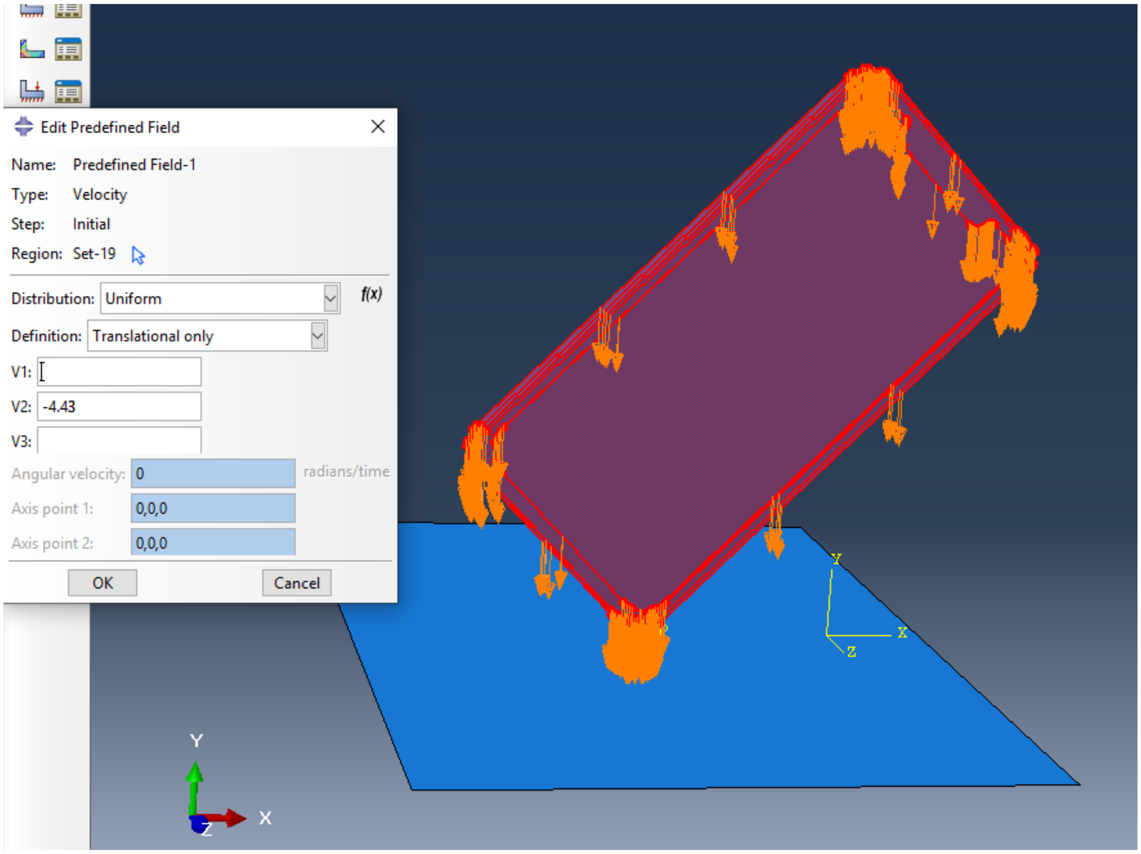

Figure 9: Velocity Field for Cellphone

3.7 Mesh information

The element types used in this project is 10-node modified quadratic explicit tetrahedron element (C3D10M). The global size for the mesh is 0.0064 meter. The details of mesh as shown as Fig 10.

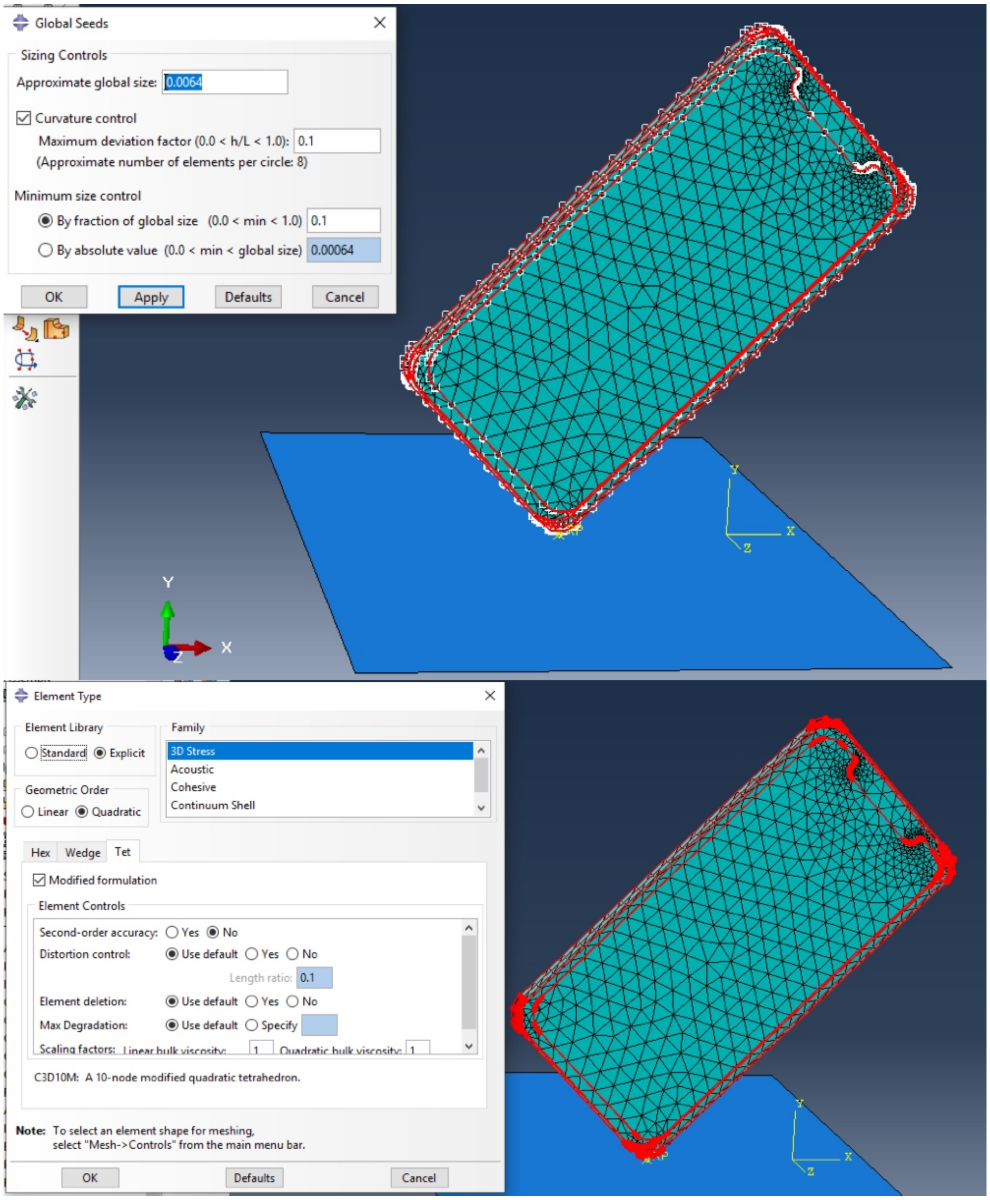

Figure 10: Mesh Information

4 Results and Discussion

The situations of stress distribution and spread are similar for all four tests. When cellphone just contacts with ground, the stress concentrates around the contact point. Then stress begins to increase and spread inside the cellphone. When the stress reaches the maximum, the cellphone will bounce and the stress begins to decrease and continue spreading inside the cellphone. The Fig 11 shows whole process of stress spread inside Iphone X with polycarbonate case. The cellphone is falling at first figure where no stress generated. Stress appearing at second one which means the cellphone begins contact with ground. Then the stress keeps increasing and spread until the ninth picture which reaching the maximum stress. Then stress begins decreasing but keeping spread inside the cellphone.

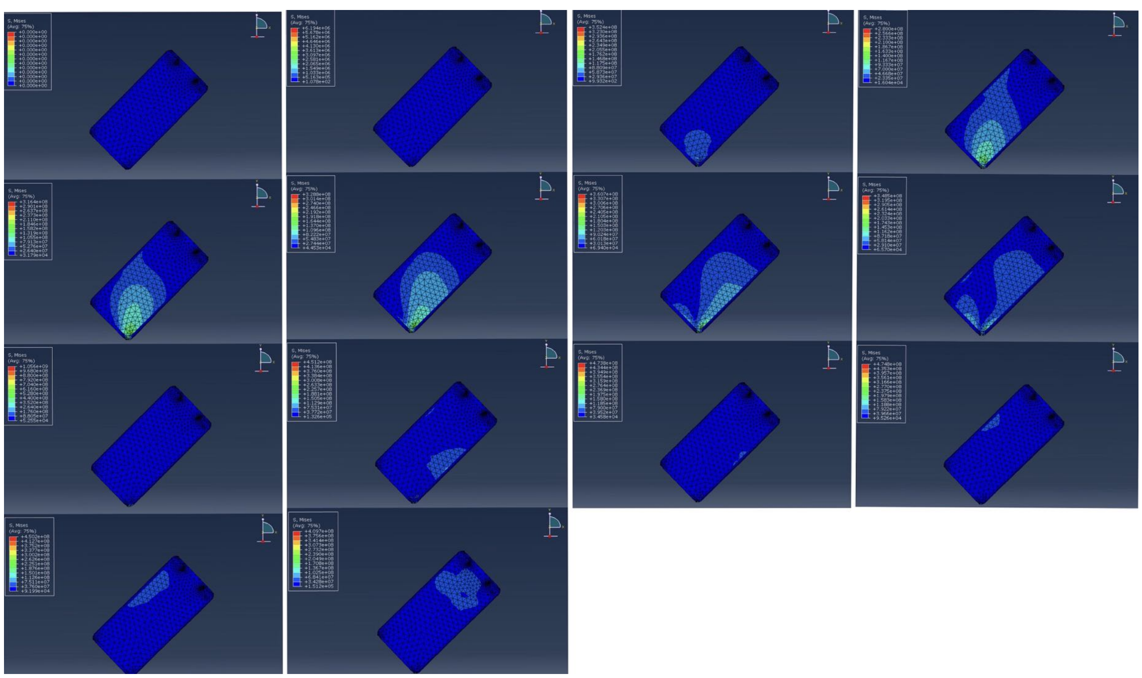

Figure 11: Stress Spread in Cellphone

The above figures show the stress for whole cellphone including case, outer shell and glass. However, in order to demonstrate the protection ability for glass by three different materials, it is best to analyze the glass separately. The maximum principle stress at glass surface during the whole process are shown as Fig 12,13,14 and 15 for no case, polycarbonate case, polyethylene case and silicone rubber case respectively.

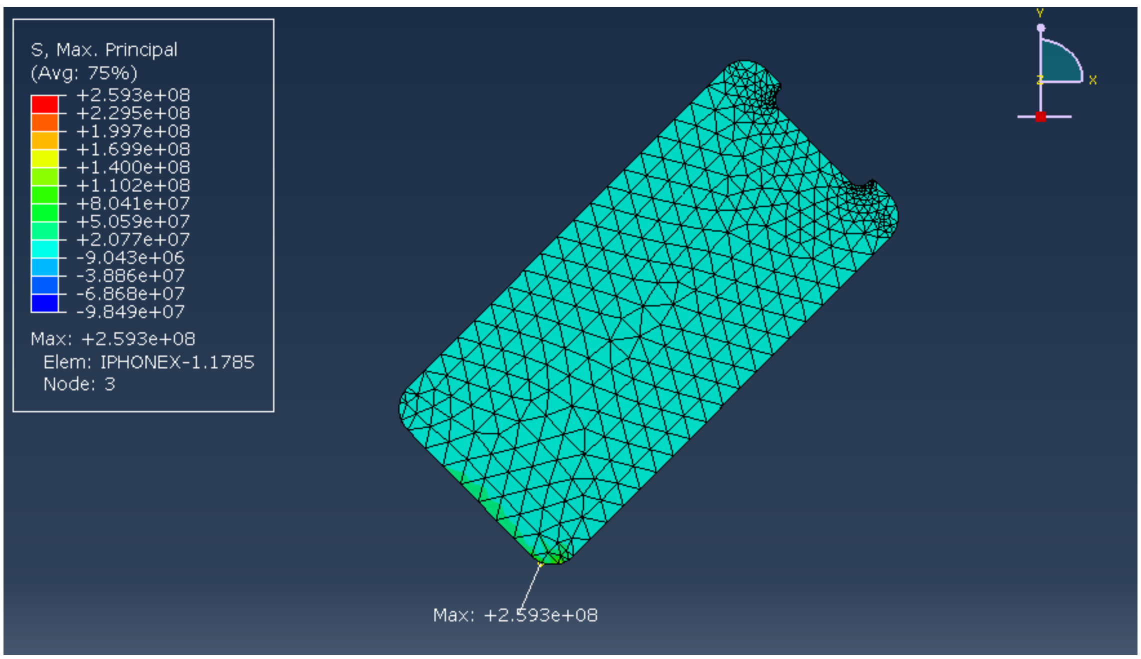

Figure 12: Maximum Stress for No Case

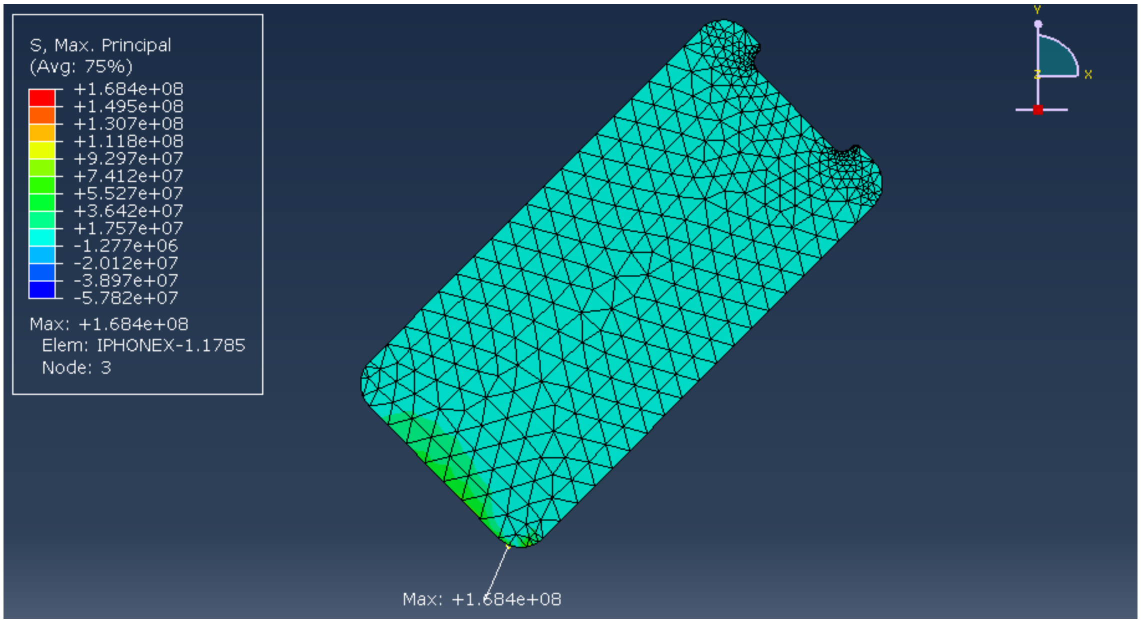

Figure 13: Maximum Stress for Polycarbonate Case

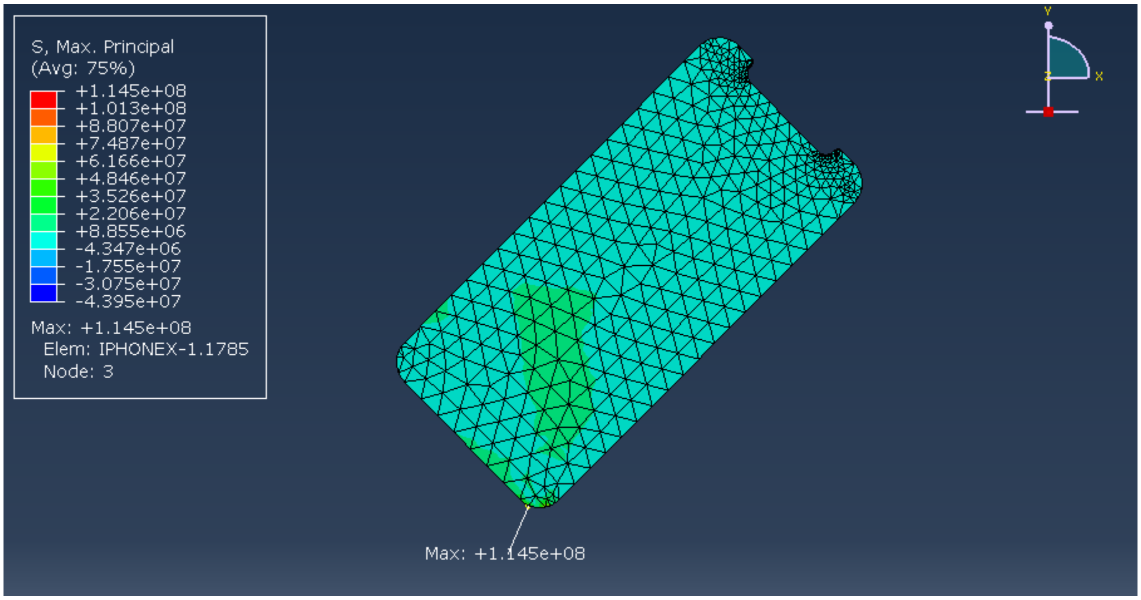

Figure 14: Maximum Stress for Polyethylene Case

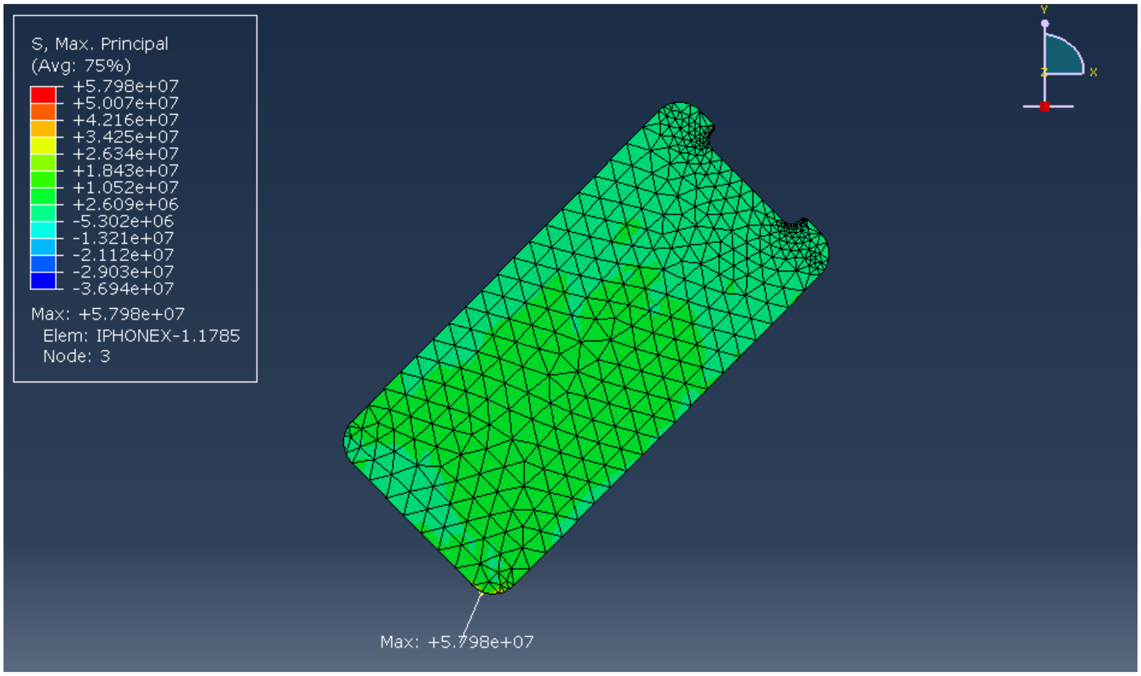

Figure 15: Maximum Stress for Silicone Rubber Case

From the above figures we can tell, the location that maximum principal stress appeared is same for all different materials. However, the magnitude is different depending on the materials properties. From the results we know, the stress is largest when cellphone drops into ground without case which means the case does protect the phone screen.

From the observation of the result in Abaqus, there is tiny deformation appeared at contact point for polycarbonate and polyethylene case, but is is hard to recognize if not zooming in. For silicone rubber, the deformation is much larger that you can easily recognize. This is because the silicone rubber has least elastic modulus. If assuming there is no energy loss during the whole process, the kinetic energy will convert to strain energy like Eq 4. C is the stiffness of material which is proportional to elastic modulus. The velocity is constant, the silicone rubber has least stiffness comparing with other materials, thus, the deformation of silicone rubber should be largest.

$$\frac{1}{2}mv^2 = \frac{1}{2}C\epsilon^2 \tag{4}$$

Similarly, we can predict the result of maximum stress by following equation. S is the compliance of materials which is inverse of the stiffness. Since the velocity is constant, the less elastic modulus will lead to larger compliance. Hence, the stress should be less. The stress of silicone rubber should be least which is confirmed from the above results from Abaqus simulation.

$$\frac{1}{2}mv^2 = \frac{1}{2}S\sigma^2 \tag{5}$$

After knowing the maximum principal stress, we can calculate the maximum fracture toughness at screen for all four tests by Eq 2. By comparing with critical fracture toughness, safety factor of different materials can be calculated by Eq 3 which are shown as following table.

Material	Principal Stress(Pa)	Fracture Toughness(Pa*$\sqrt{m}$)	Safety Factor
No Case	2.59*10^8	4.6*10^5	1.5
Polycarbonate	1.68*10^8	2.98*10^5	2.31
Polyethylene	1.15*10^8	2.03*10^5	3.4
Silicon Rubber	5.8*10^7	1.03*10^5	6.71

Table 2: Safety Factor for Different Materials

5 Conclusion

In this project, I simulated the situations when an Iphone X dropping into ground without case and with three different cases. The results from Abaqus confirmed my predictions. The stress locates at contact point when the contact just happened. Then, the contact continues for a little time. At this period, the stress and deformation begins increasing until reaching the maximum. After that, the cellphone will bounce and stress begins decreasing and spread inside the cellphone. The deformed part begins to restore to its original shape.

For the glass protection for different cases, the silicone rubber has best protection ability. The safety factor of cellphone with silicon rubber case is about four times than that without case. The protection ability depends on the material properties. The lower elastic modulus it is, the lower maximum principal stress it will have.

6 References

References

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