MAE 557: Mechanics of Composite Materials

Drop Test Simulation of an iPhone with and without a case on ABAQUS

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Abstract:

Mobile phones nowadays, are sensitive electronic devices, at the same time they are very important and expensive. We use them all the time and but there are some compromises when it comes to the build quality of these phones. All these mobile phones are made up of different sensors, cameras and several electronic parts which are made up of different materials, but they're all packed inside the chassis/frame as shown in Fig.1. There are other parts outside the package like screen and back panel. These two parts along with the frame are some of weakest parts in a mobile.

When we use a protective case for a mobile the chances of screen crack and the impact are really low compared to when we don't use one. So these protectors are used to reduce the impact loading on the mobile. There are different protectors made up of different materials but most of the materials used for these protectors are made up of different types of rubber. The protective backcase can also be used to reduce the chances even more.

A protective case is designed using different materials using a CAD software and then it can be tested along with smartphone model to observe different behaviors and properties when freely dropped from a 1m height from the ground in different angles with and without the case. we can observe different properties like stress, strain and energy absorption and also the behavior of the composite case on different impacts. We can also compare the time of impact and deformations that are caused/absorbed by the phone or the protective case. We can also compare these results and optimize the design of protective case.

Introduction:

Portable electronic devices, such as cell phones, tablets, and laptops have steadily become vital tools for life as technology has advanced. Smartphones are getting more powerful every day and almost everyone owns a smartphone. To make the users experience better, the manufacturers are using world class displays. However, due to the fundamental changes in these displays, there will be certain compromises within the screen causing more fragile behavior. The greater chance of smartphone failures, such as screen fracture is when people drop their phones. Full-screen smartphones have a higher impact point and a higher risk of dropping.

People drop their smartphones all the time. When they drop it, the probability of failure when it touches the ground is very high. Most of these impacts during the drop cause failures of different kinds like deformation of the external body, displacement of internal housing and mostly the screen fracture. So, people normally use a cover made up of different materials to protect their smartphones from drops like these. These covers mostly protect the whole body and are used to absorb all the impact loading without transferring the load to the mobile frame. But there are some cases where the phone lands in a particular direction with a cover and still manages to absorb some impact load.

Different parts inside the smartphone like Battery, PCB and the metal frame also absorb these impact loadings but do not cause major damages. Even with all these damages, the smartphones still function and are usable. But the major problem would be when the screen fractures. Then it should be replaced with a new one and there is no other choice. Therefore, there is a need to improve the chances of protecting these screens from the impact loading.

Using ABAQUS Explicit Dynamics, a model is developed and is simulated with similar assumptions on material properties and conditions that are similar to a free drop case in different scenarios on a ground and the results are observed. For this simulation, the smartphone model used is iPhone 12 with assumed geometry and material properties and the cover material used is polycarbonate. The main objective of this model is to compare the stresses caused in the screen region during their impact loadings with and without the polycarbonate cover on the iPhone along with the energy transfer within the sections.

Methodologies:

1. Theory of Impact:

The calculation for the impact time is given as:

$$v = \frac{d}{t}$$

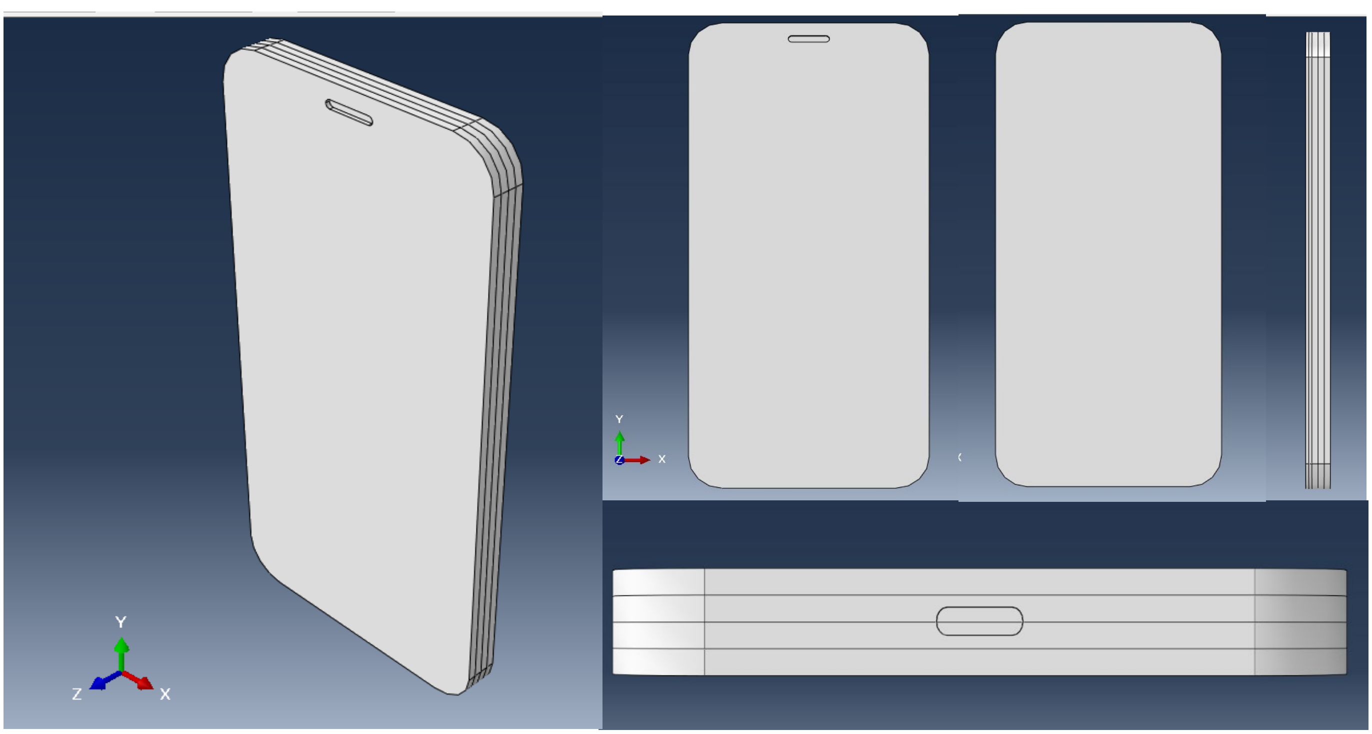
Here, we know that the velocity of the phone in a free fall is $v = 9.8\ m/s$

The distance from which the phone is being dropped in all the cases is $d = 1\ m$

The time of impact is calculated as $t = \frac{d}{v} = \frac{1}{9.8} = 0.102\ s$

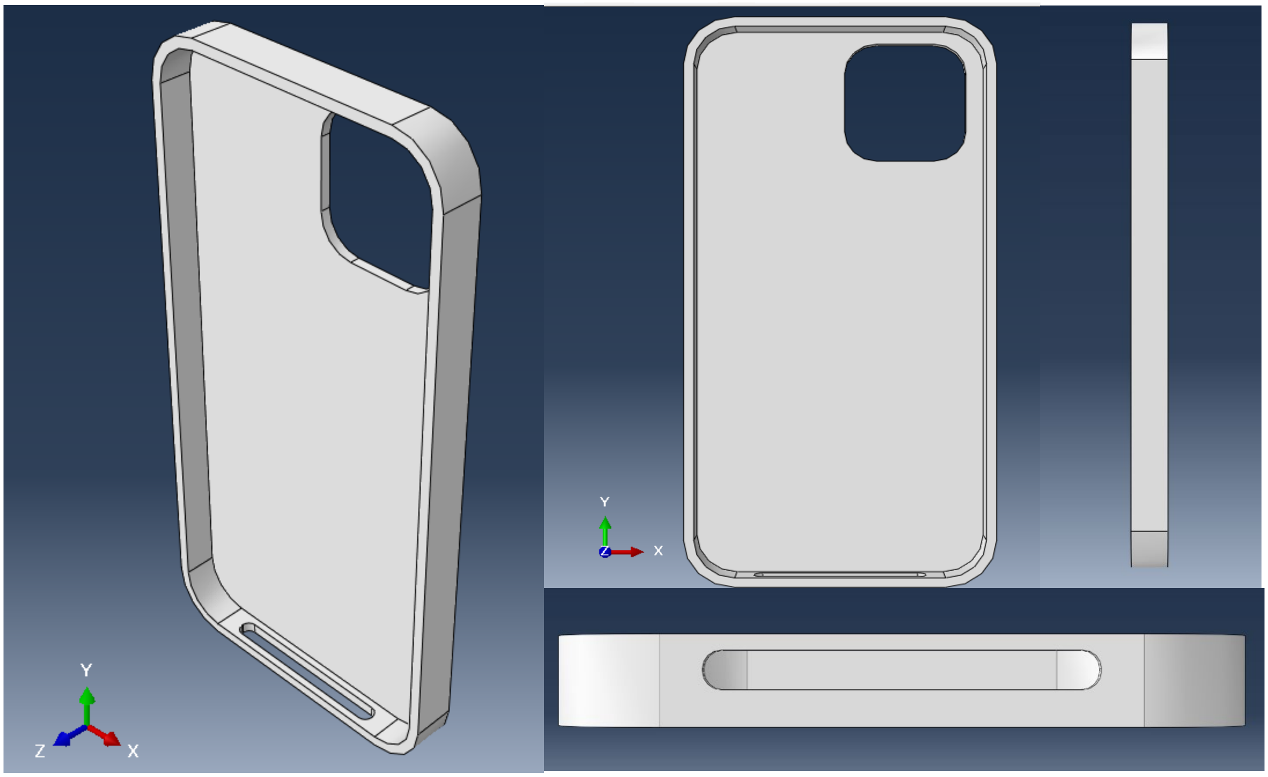
2. Modeling and Simulation:

Modeling of the smartphone: The model of the smartphone for this project is made in ABAQUS and the cell instance separation is used to create the layers in a rectangular block to give the material properties of different parts in a mobile to the geometry created. The extruded parts are separated into 5 layers and different material properties are given for each layer.

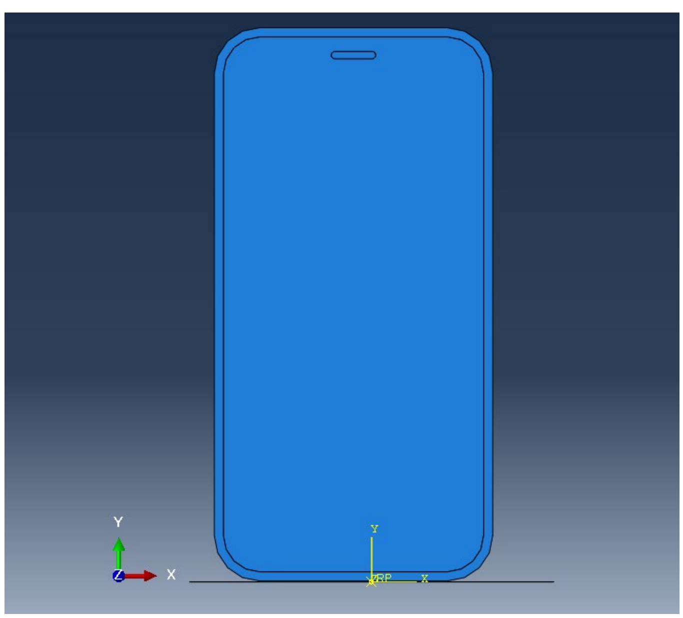


This is similar to stacking operations in a composite laminate. The 5 layers are then given additional constraints to develop a similar real model. The geometry created is given in fig 2.1.

The cover for the iPhone is created using the same method. Constraints like a cut for the camera and the charge slot on the back and bottom are created respectively. This also helps in reducing the weight of the cover as a whole body. The geometry of the cover is given in the fig below.



The assembled geometry is given below

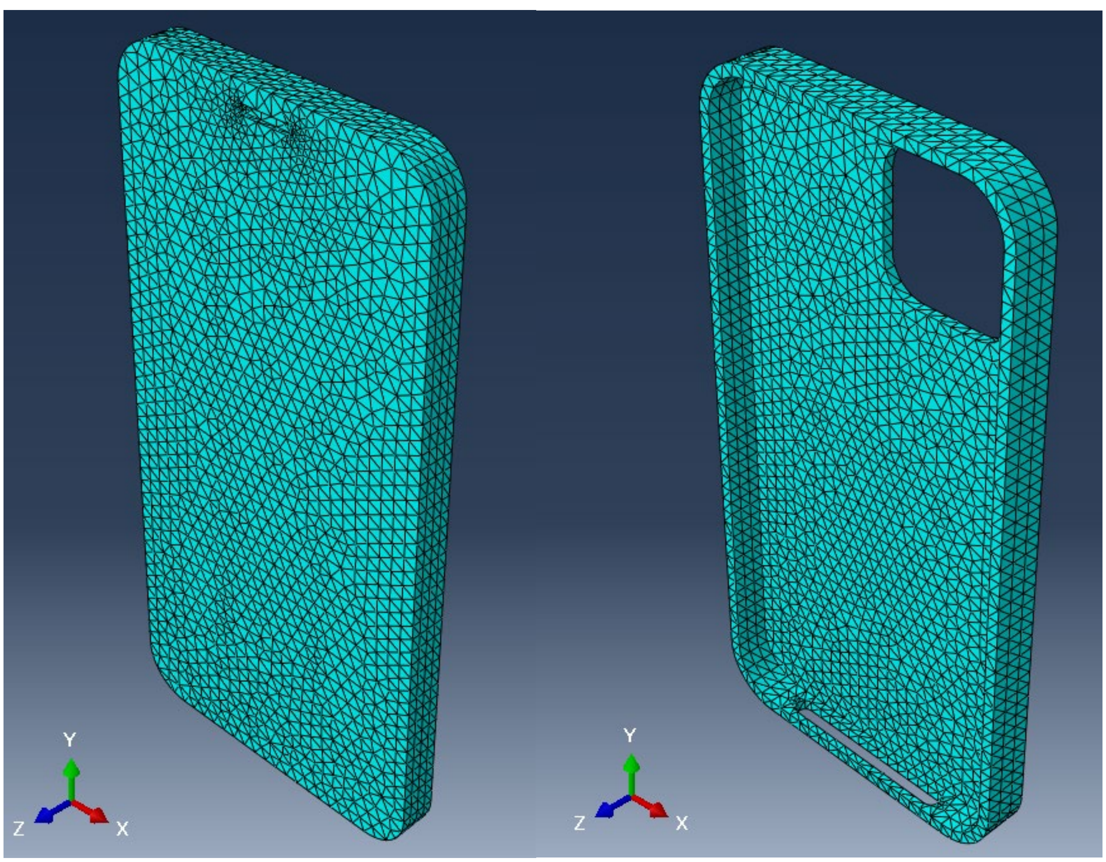


The material properties for each layer are given in the table 2.1 below:

Part	**Material**	**Density**	**Young's Modulus**	**Poisson's Ratio**
Glass	Alumina Silicate	2.43E-09	77000	0.21
PCB	Al6063-T6	2.40E-09	11000	0.25
Battery	Battery	2.40E-09	70000	0.29
Back Panel	Stainless Steel	1.20E-09	2190	0.35
Cover	Polycarbonate	1.21E-09	244000	0.37

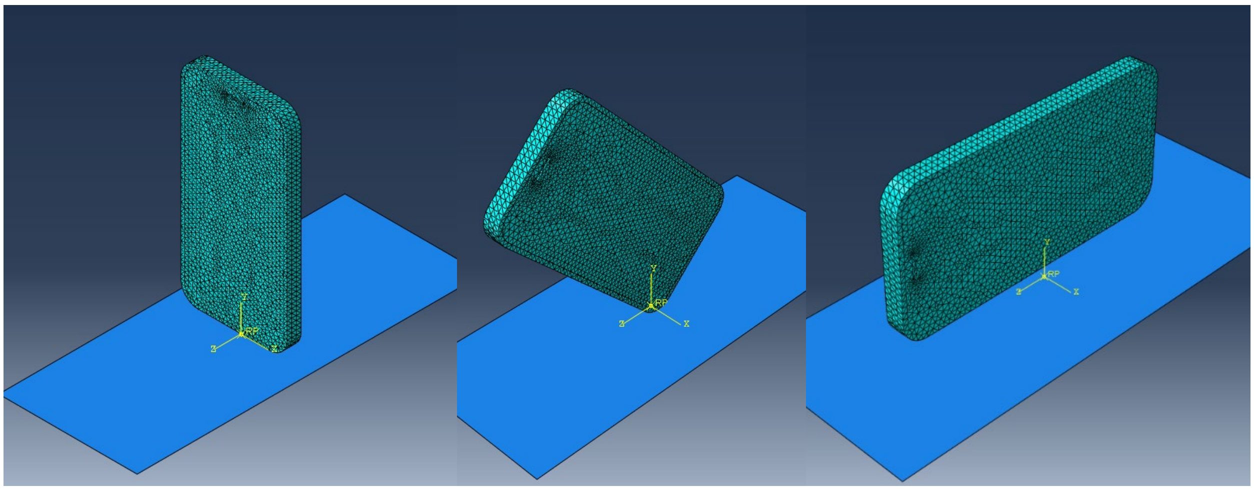
Mesh generated for the simulation is given in the table below:

Part	**Element Type**	**Mesh Size**
Phone Model	Tetrahedral	3mm
Cover	Tetrahedral	3mm



The setup used for this simulation for all the 3 cases with and without the cover is given below:

a) Impact on the bottom face
b) Impact on the bottom right corner with an angle of 45° with the ground
c) Impact on the left side face with the ground.

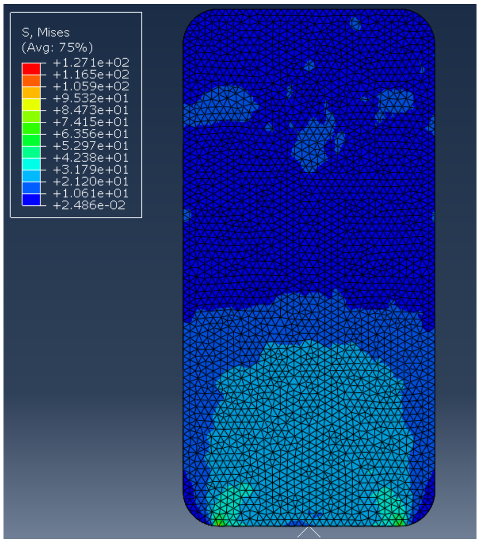


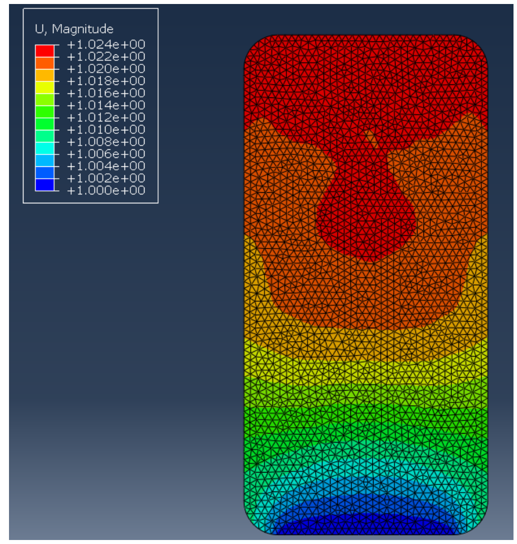
The main observation in this project is the stresses induced on the glass screen with and without the cover to protect it. So to make the glass layer of the model brittle in ABAQUS, there were some extra properties from the table that were given.

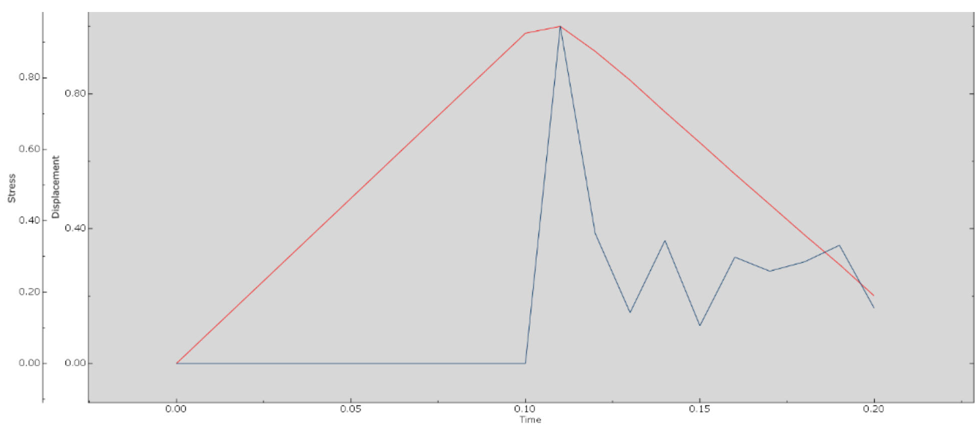
	Direct Stress after Cracking	Direct Cracking Strain
Brittle Cracking	36.8	0
	34.1	0.000333
	21.1	0.000667
Direct Cracking Failure Strain		1E-06
Brittle Shear	Shear Retention Factor	Crack Opening Strain
	1	0
	0.5	0.001
	0.25	0.002

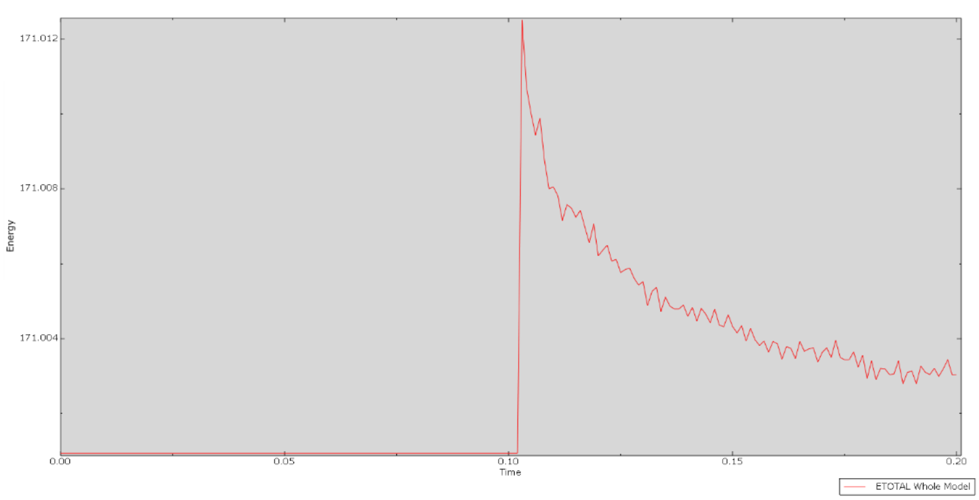
Results:

Case 1 : Bottom surface

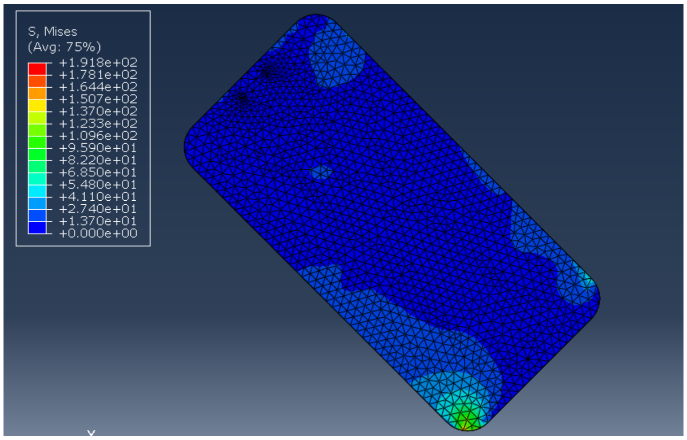


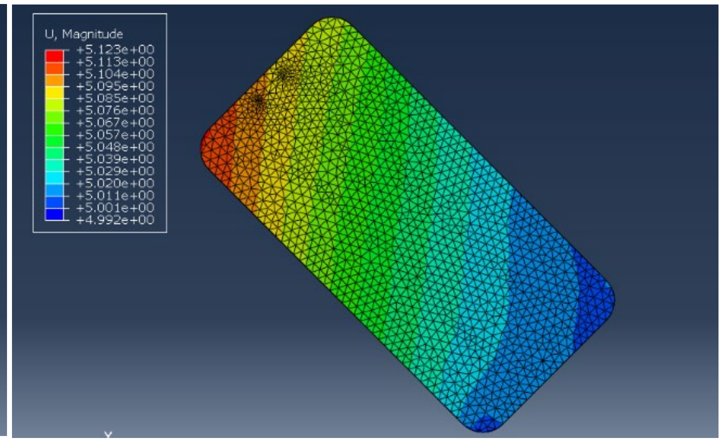


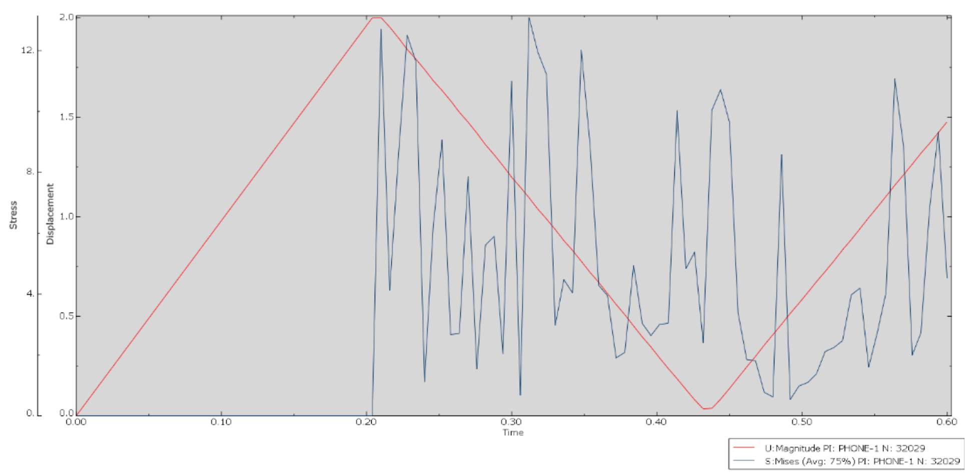


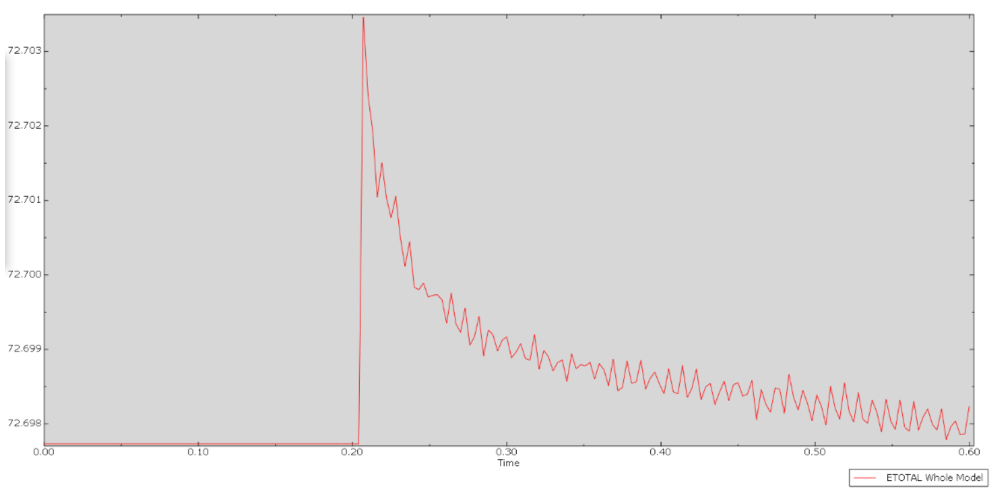


Case 2 : Corner

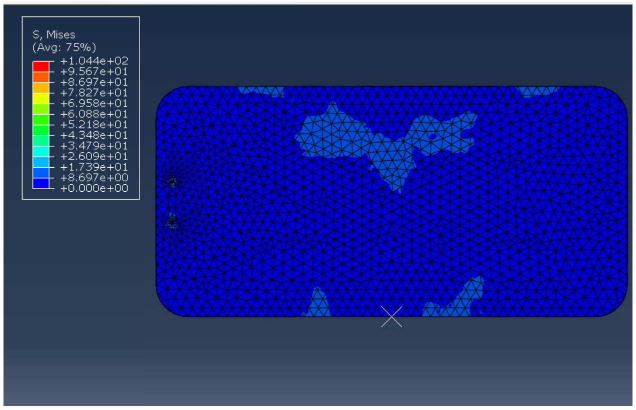


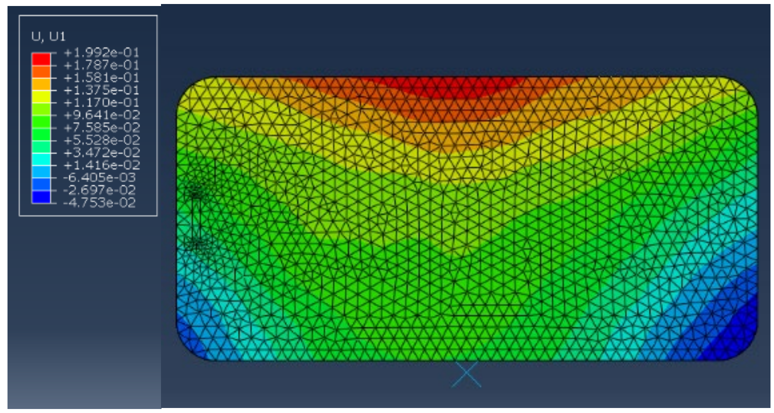


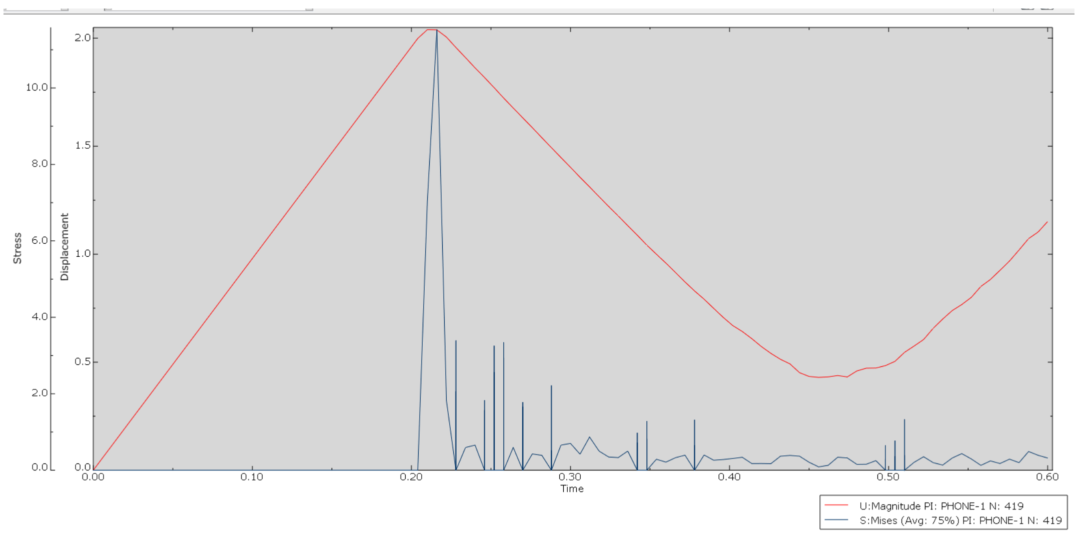


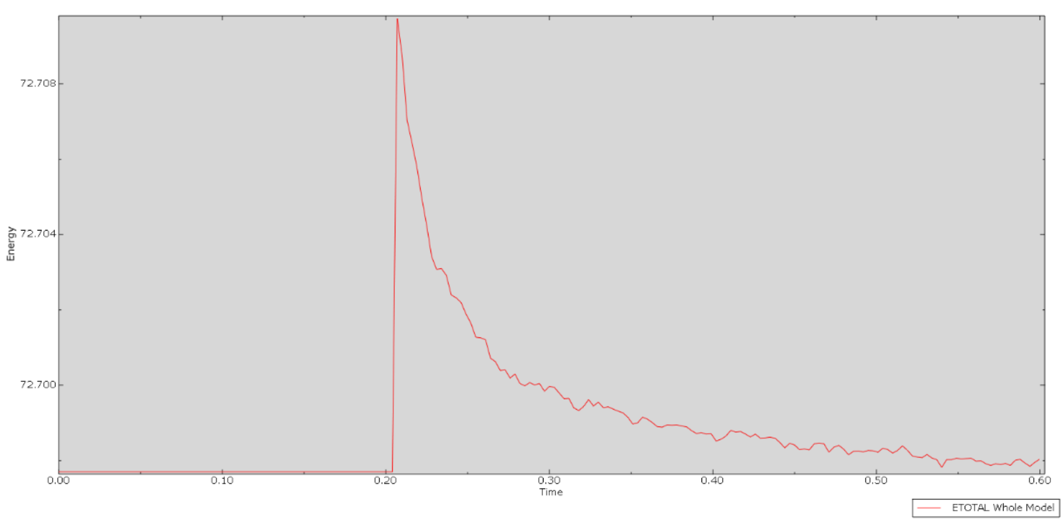


Case 3 : Side face



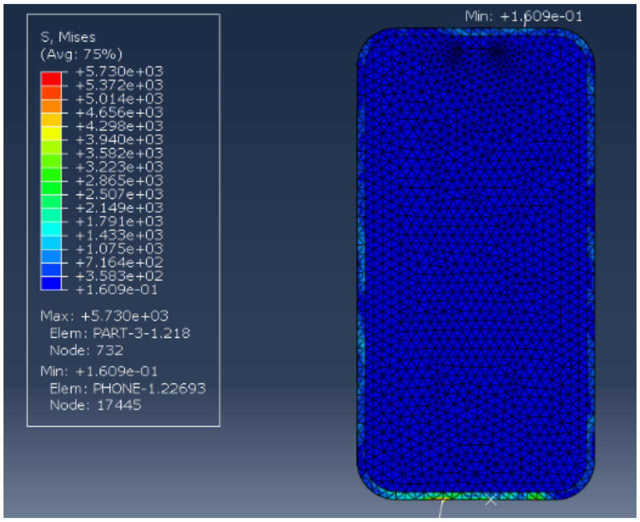


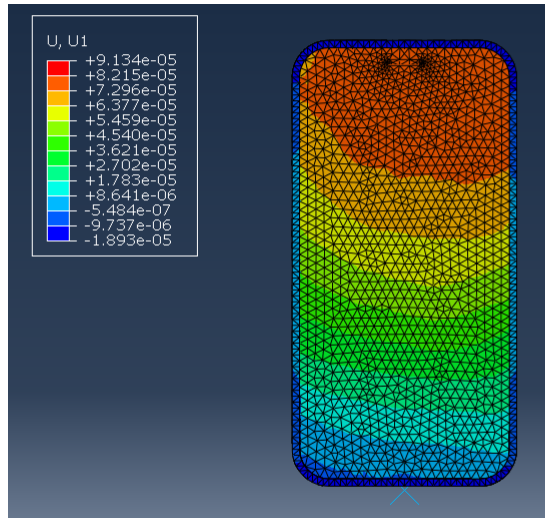


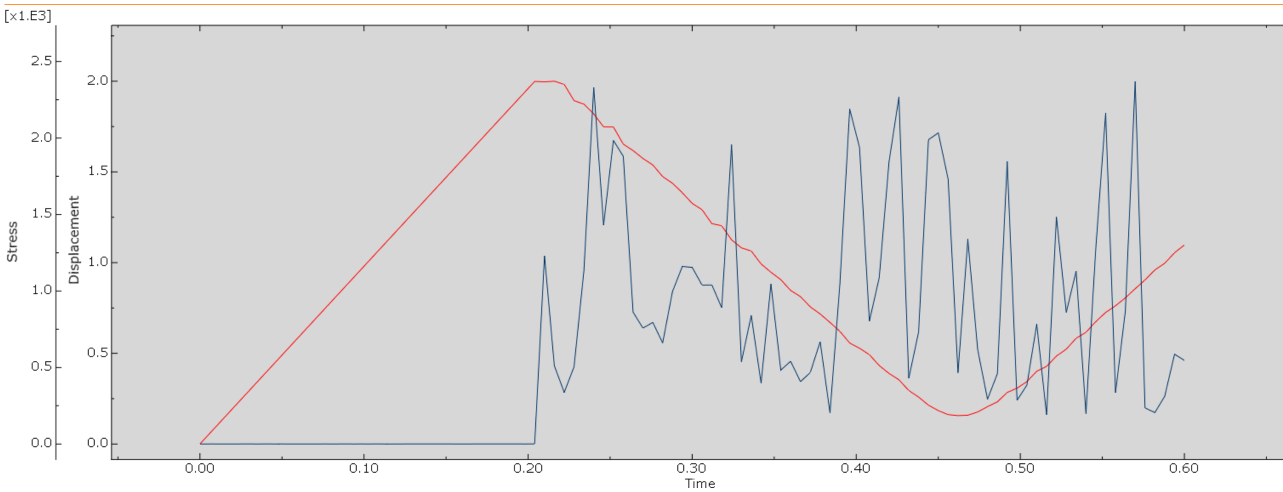


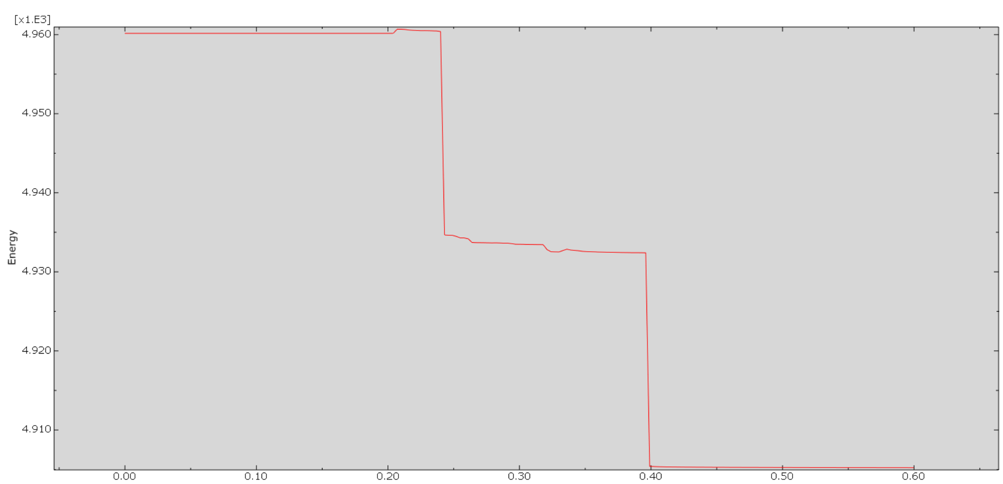
With cover

Case 1 : Bottom surface

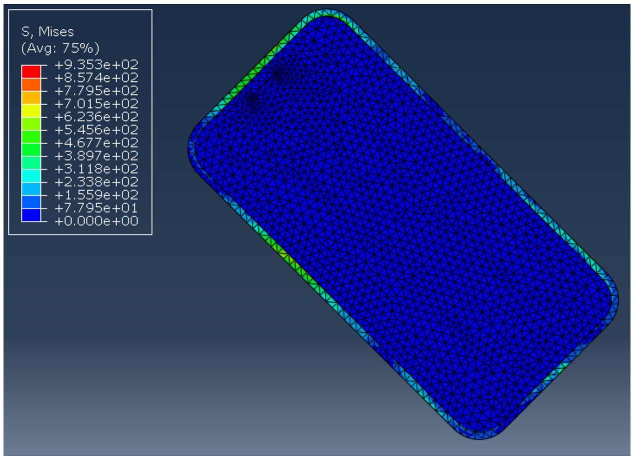


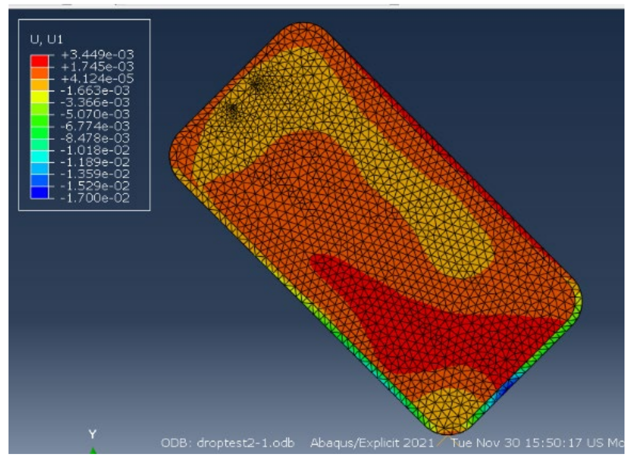


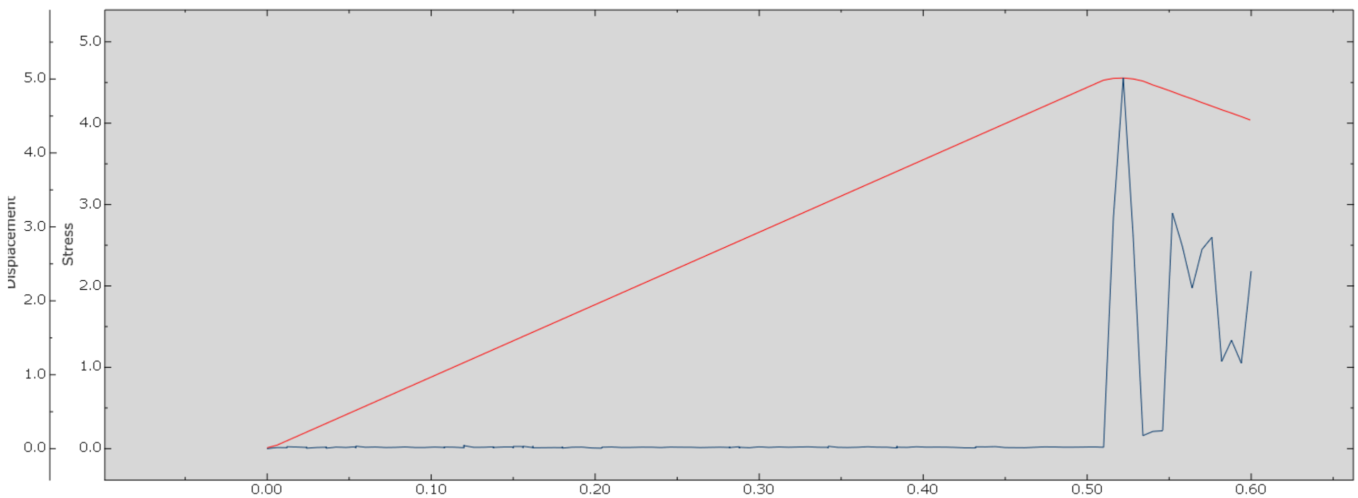


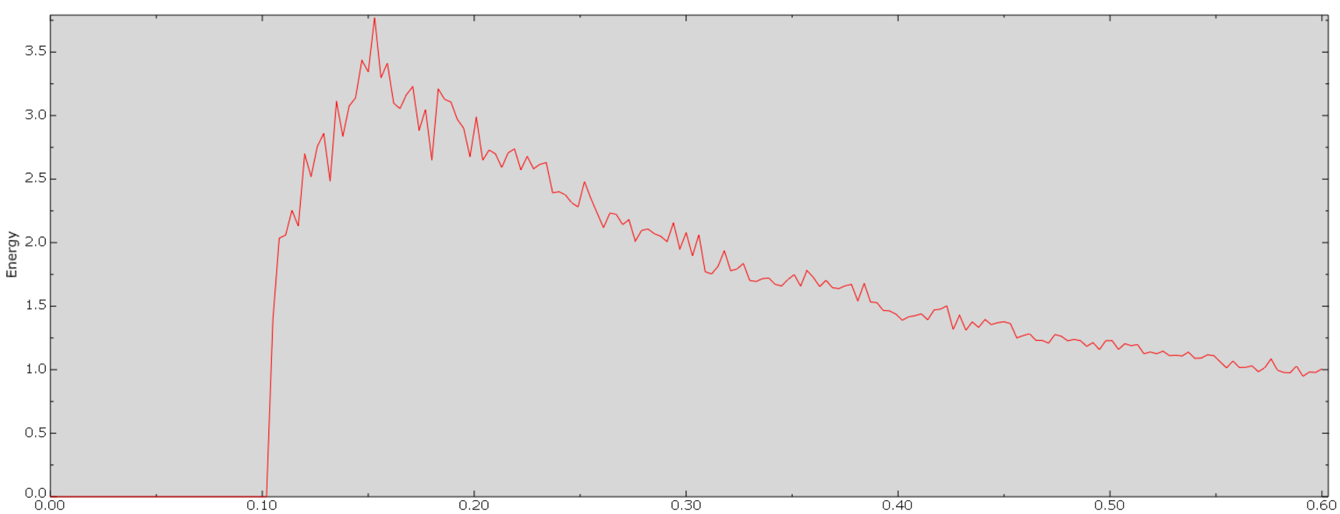


Case 2 : Corner

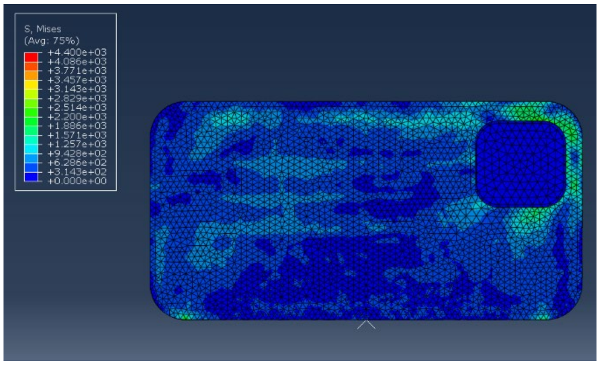


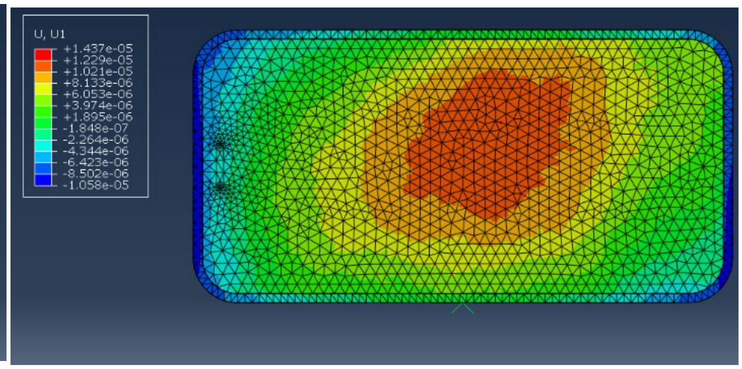






Case 3 : Side Face





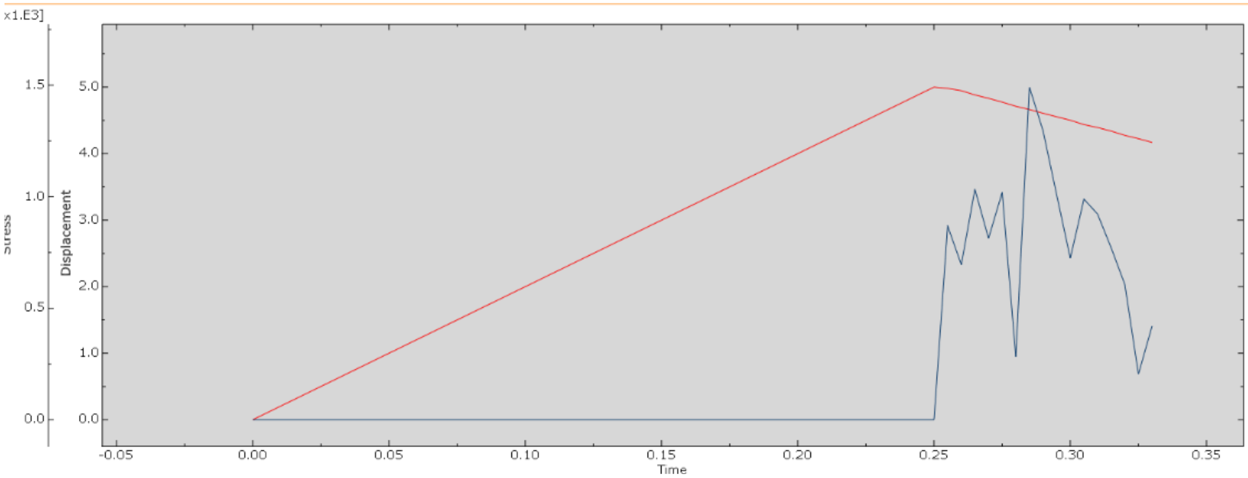


Figure 1:

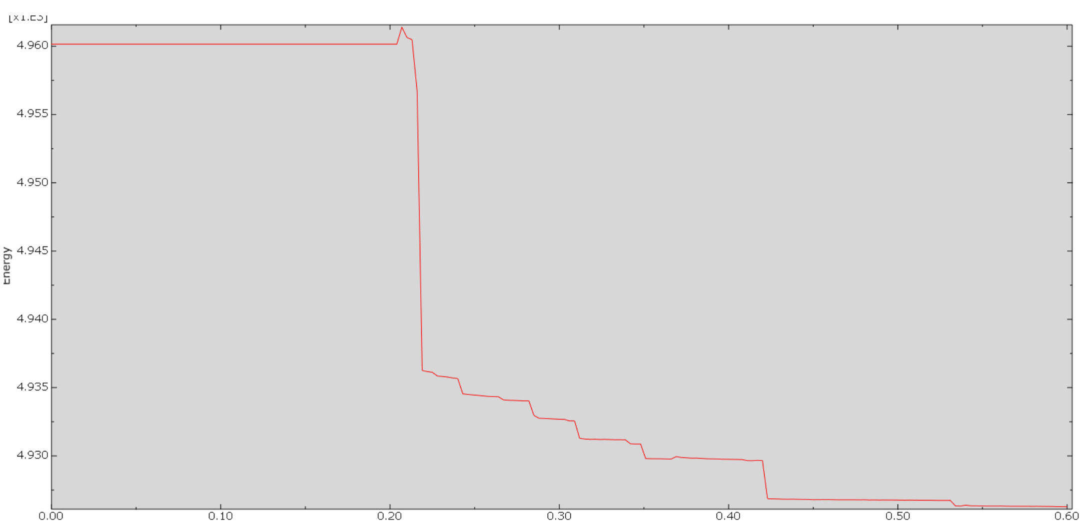


Figure 2:

Discussions:

The assumptions that are made for this simulation are:

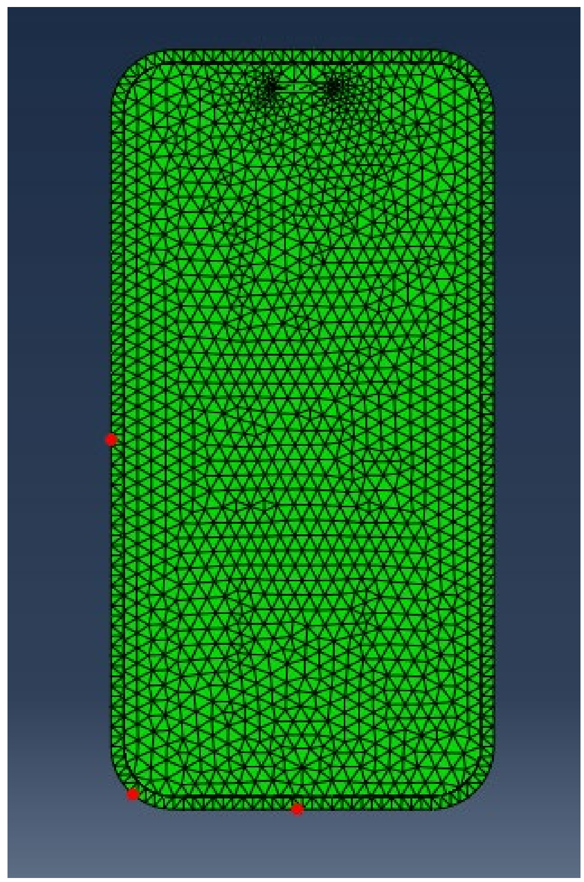
- Geometry – The geometry of the iPhone 12 is taken exactly but some of the parts of the geometry are not taken into consideration like the speaker holes, the volume and power buttons as they increase the time of computation for the problem.
- Materials – The materials and their properties that are considered are taken from some references mentioned below but they might not be accurate with the real iPhone 12 model.

To observe the stresses and deformations from the above simulations, we have selected 3 different nodes on the mesh and all the results are compared with one another.

For the bottom impact, the node on the bottom face is selected.

For the corner impact, the node on the bottom left corner is selected.

For the side face impact, the node on the middle of the side face is selected.



Max. Stresses Observed	Without Cover (MPa)	With Cover (MPa)
Bottom Face	127.1	573
Corner	181.8	935.3
Side Face	104.4	440

The stresses that are observed on the body of the phone in all the cases are given below:

Stresses on the mobile body	Without Cover (MPa)	With Cover (MPa)
Bottom Face	127.1	103
Corner	181.8	126.7
Side Face	104.4	88.5

From the above the table, we can say that the stresses on the body of the phone are low when the cover is used. So, the failure cases can be decreased when we use a protective case like polycarbonate from the above simulations.

Advantages:

- Most of the simulations available consider either the body as a whole or use homogenous material for the whole body. But in this case, we used a slab model like a composite laminate and used different material for each ply. This will improve the accuracy of the simulation results and brings them closer to the real model.
- The material properties considered for the glass are taken along with brittle fracture cases unlike most of the other simulations. This provides a new case to the available studies on the drop test of a mobile phone where the study is particularly on the glass screen.

Disadvantages:

- The simulation only used a mesh size of 2 mm due to the constraints with the software, whereas we can go as low as 0.25 mm to get more accurate results for deformation and energy transfer.
- Since the focus of the study is completely on the glass screen, some other properties of a smart phone are not considered like the heat produced in the device along with several other parts inside the mobile.
- This simulation is completely focused on the initial impact whereas in real life, there will be multiple impacts in a free drop condition on uneven surface which are not considered due to the computational time. But these impacts cause more changes to the phone body.

Conclusion:

The above study proves that the stresses on a phone during impacts from a free drop are under the safety conditions when there is a protective case on it. Otherwise, it might affect the glass screen and a fracture can be noticed in some cases.

Although the material properties taken into consideration are similar to the actual materials used for the production of these screens and other parts of the phone, there are several other parts in a phone and various other factors that affects the glass screen fracture. Some of them are the actual cameras, volume and power buttons as well as the speaker holes. They are also very important factors while testing like this but due to the amount of computational power and complexity in the design model, these factors are not considered.

There are other circumstances where the phone might bounce and take another hit on the ground due to the nature of other material on it or the ground. Also a case where the ground is uneven and the point of contact is directly on the glass screen. But the study of these cases can give us better results about the performance of the screen under different conditions.

The Polycarbonate protective case is helping in reducing the stresses on the mobile phone body during a free drop under gravity and protecting the glass screen from fracture.

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