Simulation Files - Stress Analysis

Team 2 - Billy

1. Introduction

To check that our product was sufficiently resistant and correctly designed, a stress analysis was carried out on a selected part. In the case of Billy, little stress is exerted on it because it doesn't have to move and the pill dispensing mechanism doesn't exert much stress because it doesn't move a large mass. In this section, the team therefore chose to study an extreme stress during inproper use of the pill dispenser.

It was therefore decided to study the case where a child would want to obtain the reward by force. To determine the effort involved, the team looked at the case where a child would stand on the sphere. Billy is designed for children aged between 8 and 12, and according to the World Health Organization (WHO), the average weight of a 12-year-old child is 42 kg for a girl **[Proxim, 2014]**.

The simulation method used is the Finit Element Method (FEM), which consists of dividing a model into several small interconnected sections to form a mesh. Conditions are then defined (limits, materials, fixations, forces) to configure the simulation. The simulation then shows the effects of the defined conditions on the part being studied.

The objective of the simulation was to evaluate the capacity of the structure and the material to withstand the maximum load in an inapropriate use. So a weight of 42 kg corresponds to an effort of 412.02 N, taking into account the gravitational acceleration (9.81 m/s²). In order to be certain that our sphere was correctly dimensioned, a new analysis was carried out with a safety factor of 2, giving a force of 824.04 N.

2. Model informations

The part that the team decided to study si the sphere, see Figure 1Figure 1. It is 200 mm in diameter and 2.5 mm thick. There is a hook for the lock on the inside and a hinge system in the back.

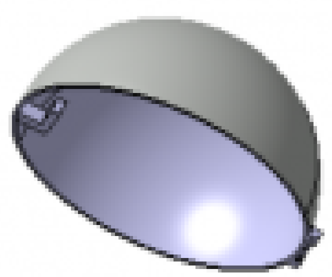

Figure 1 : Sphere

3. Material specification

The material used is polymethyl methacrylate (PMMA), also known as plexiglass. Here are its mechanical properties in Tableau 1 below:

Tableau 1 : Mechanical properties PMMA.

Property	Value
Density	1190 kg/m^3
Modulus of elasticity	2770 N/mm^2
Mass density	1190 kg/m^3
Yield Stress	70 MPa
Specific Heat	1250 J/(kg.K)
Thermal conductivity	0,21 W/(m.K)

4. Load

The forces applied to the dome are as follows:

- Force: 824.04 N

The force, defined earlier, was applied to a defined area and not to the entire surface of the sphere. A circle 8 centimetres in diameter was defined on the top of the sphere. This circle represents the surface area of a person standing on the dome. The forces were then applied perpendicular to the ground and not to the sphere, as shown below in Figure 2:

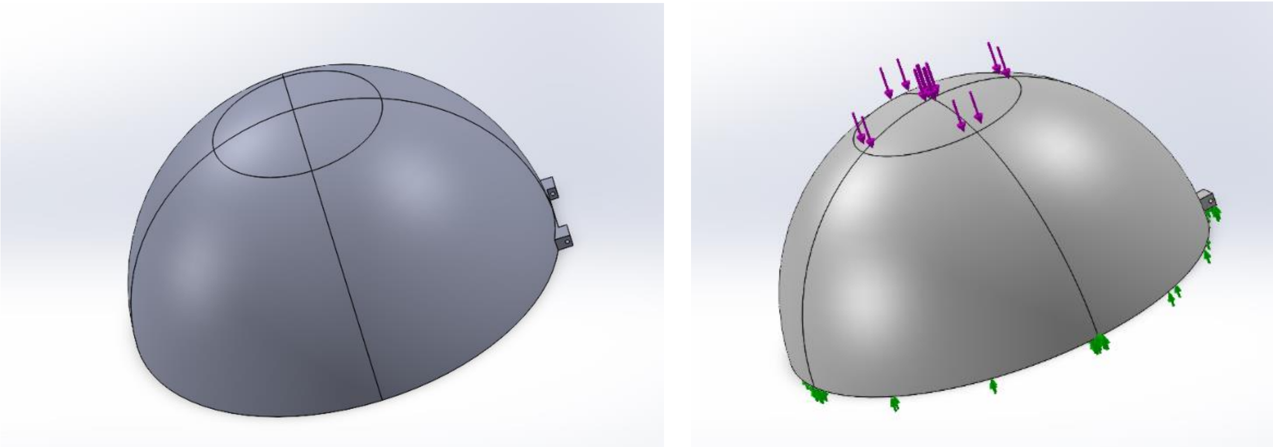

Figure 2: Circle and force applied to the dome

5. Mechanical connection

Before that the simulation can be run, we need to define the various connections on our part. First of all, a planar link has been defined below the surface of the dome. This will allow the dome to deform in this plane without going through it. Finally, 2 other points have been created to lock the dome in translation. The advantage of using points here is that they won't prevent the dome from deforming at the bottom. The mechanical connections can be seen in Figure 3. This simulation is therefore very close to what would happen in a real-life situation.

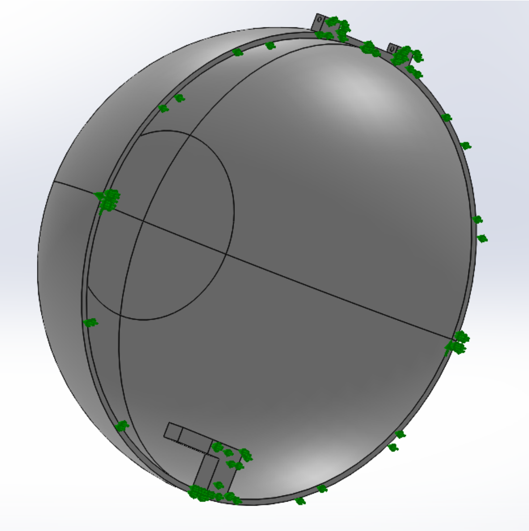

Figure 3: Mechanical connections applied to the sphere.

6. Mesh

The last step before running the simulation is to define the mesh size. The smaller the mesh size, the more accurate the result will be, but the longer the calculation will take. In this analysis, the team ran the simulation several times to see the impact of the mesh size on the simulation result. This will be discussed in the conclusion of the analysis. The following results were obtained with the smallest possible mesh size of 1 mm. The informations corresponding to the mesh used can be seen in Tableau 2.

Tableau 2: Mesh informations

Max element size	1 mm
Min element size	0,2 mm
Total number of nodes:	2110322
Total number of elements	1367805

7. Results :

Von Mises :

The first result obtained by the team is the maximum Von Mises stress that the dome can withstand. This can be seen in the Figure 4 below:

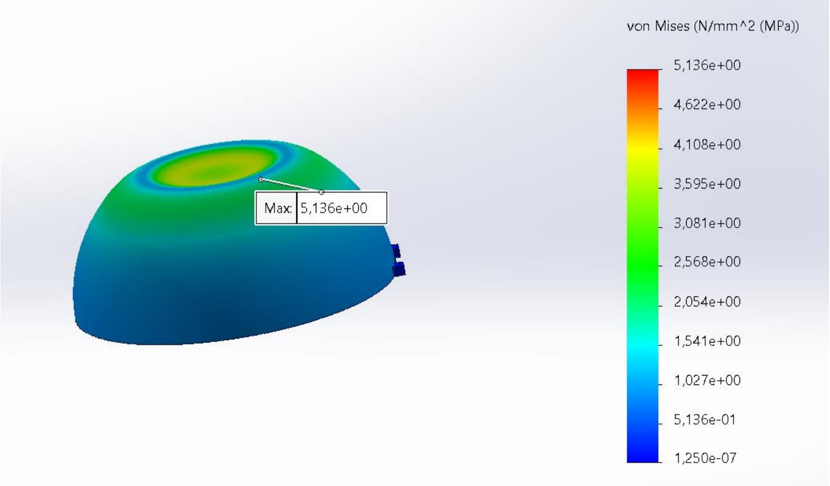

Figure 4: Von Mises results

The maximum stress applied here is 5.136 MPa. As PMMA's yield limit is 70 MPa, this stress is well below what our material can withstand.

Displacement :

Then, the displacement was studied to see how much our dome would be modified by this force. The results can be seen in Figure 5.

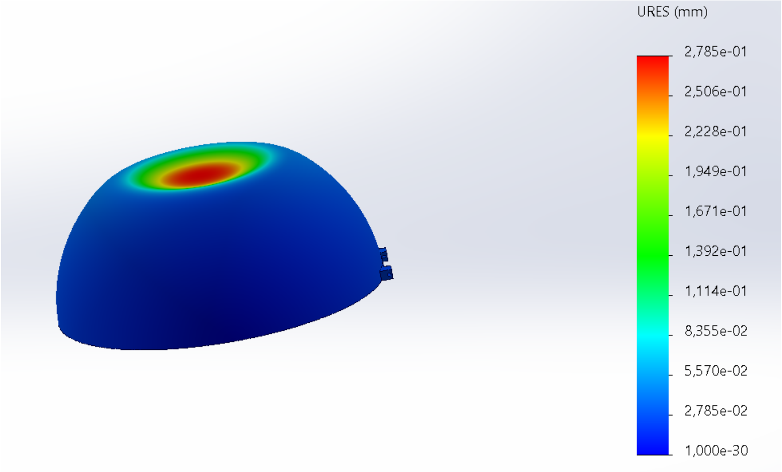

Figure 5 : Displacement results

We can see above that the force applied generates a displacement of 0,2785 mm, which is very small, so we can neglect the consequences of this force on the displacement.

Factor of safety :

A final analysis of the safety coefficient was carried out. Although the effort applied is already 2 times greater than the inappropriate case studied, which therefore already corresponds to a factor of safety of 2, the analysis shown below in Figure 6 allows us to define that the minimum factor of safety is applicable to our sphere is 15, which is well above our needs.

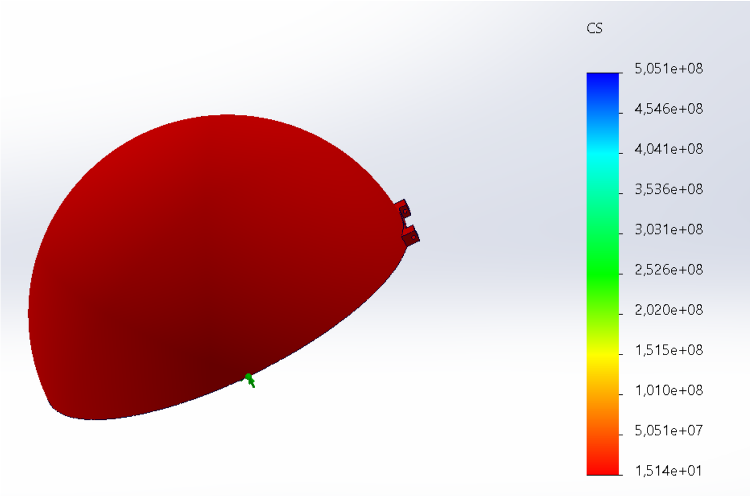

Figure 6: Factor of Safety results

8. Conclusion:

After performing a structural simulation using the finite element method (FEM) on a the sphere constructed of plexiglas (PMMA), a solid and conclusive conclusion was obtained. The simulation evaluated the capacity of the structure and material to withstand the maximum load in an inapropriate use. The results obtained are more than satisfactory and show that the material chosen is optimal for our use and for Billy, particularly as the factor of safety determined during the simulation is 15, which is much higher than the team had hoped for. As explained earlier, the simulation was carried out with a 1 mm mesh. The Tableau 3 below shows the maximum stress results obtained for different mesh sizes.

Tableau 3: Comparison of mesh dimension and maximum stress.

Mesh dimension (mm)	Maximum stress (MPa)
30	4,248
20	4,636
14	4,887
8	5,098
5	5,116
3	5,126
1	5,136

We can see that with a mesh size of 5 mm or less the result changes only a little bit. We can therefore conclude that using a mesh size of less than 5 mm is not really necessary, as the result will be virtually the same and the calculation time will be shorter. Finally, it should be noted that these results were obtained by running virtual simulations and that slight differences may appear when tested on the physical product.