BIBOLINK'S STRESS ANALYSIS

Group 5 – EPS@ISEP 2025

Overview

A stress analysis on BiboLink's structural elements and a critical assessment on the machine's resilience to the elements and abuse

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Stress Simulation and Analysis

Introduction

This paper has the objective of conducting a stress study on BiboLink, a smart water dispensing device that is installed on public spaces and allows consumers to be able to get water and supplements.

Introduction to FEM/FEA

When mechanical components have complex shapes, it becomes very challenging to find a simple way to predict the material behavior and whether they resist properly when functioning within their design limits. To better understand component behavior and response when submitted to stress, we can use a method called Finite Element Method (FEM). FEM is a numerical technique to simulate stress on materials and within it we can find the Finite Element Analysis (FEA) process that uses software to implement FEM. FEM is the mathematical basis to allow software to proceed to a Finite Element Analysis.

FEM discretizes the entire system or, put simply, divides a complex system into a much simpler, finite number of elements with a specific shape, size and also their own properties. Then, by applying frontier conditions to each element and creating a mathematical, defined, solvable system of equations, FEM can provide us with the way the entire system behaves (i.e. a car part) and with the values provided, allows us to understand if the material will be able to resist such stresses and also their deformation and strain, which can also be useful since a material can definitely resist forces and still be permanently deformed or fragilized by whatever is requested from it.

Creating an accurate model for BiboLink for accurate results

BiboLink is a cylindrically shaped water dispensing machine comprised of two 3-millimetre layers of 316 steel and an inner tubular chassis also made from the same steel. To accurately predict its behavior in the most extreme of cases, the machine has been approximated by designing a metallic cylinder with the combined thicknesses of the two outer layers (which are still more fragile than the machine itself since the kinks and fixtures of the machine add even more rigidity and resilience to an already resistant cylindrical shape) and by simulating the inner chassis as a truss structure inside SolidWorks software.

When it comes to the inner chassis and components, the stresses to which they are submitted during normal functioning are negligible, so it is unnecessary to simulate those. However, when it comes to street use, there is a very specific case on which the machine should be studied and understood if it would break or get any kind of damage from it – vandalism.

It is a known fact that sometimes things in the streets are subject to vandalism and other types of abuse, be it from nature or even from enraged people during protests. Since the steel chassis wouldn't really be a problem towards nature's abuses, especially since the machine should not be able to resist a typhoon or high magnitude earthquake and the positioning of the machine should also be chosen wisely and will not be put in places that people can easily access with vehicles (i.e. sidewalks and public parks) the most aggressive kind of abuse the machine can receive is by people actually hitting on it. For that BiboLink has been studied taking abuse by four people kicking it and an exaggeratedly heavy person jumping on top of it.

To get a sense of the types of damage a human being could also be due to the machine, the magnitude of forces used in this study were the ones produced by some of the hardest kicking people in the world, combat athletes.

Combat fighters can achieve forces upwards of 3500 N when kicking (Busko). Since these are some of the most extreme types of kicks a human being can inflict on another human, forces of such order of magnitude have been used and even slightly exaggerated for the calculations to guarantee a palpable result when it comes to BiboLink sustaining high amounts of force, even though the machine's more rigid body would actually impede some people from kicking as hard as they normally would when in combat due to the fact that it could generate injury to the kicker.

When it comes to the inner structure, the inside of the structure isn't designed with a lot of force in mind since the outer part of the machine is already designed to take most of the impact. Even though it is not conceived to withstand such abuse, it was still strengthened to make it more resilient and was still simulated with the kind of force an above-mentioned kick would be able to produce.

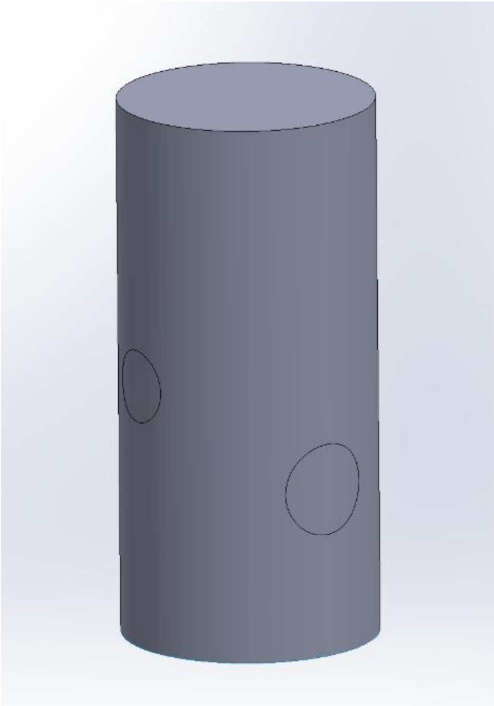

Figure 1 - BiboLink's Shell

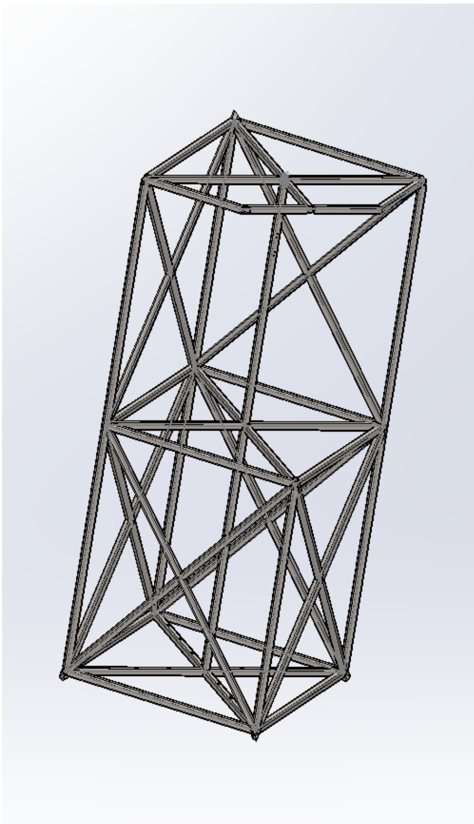

Figure 2 - BiboLink's Chassis

Material specifications

The machine is built using 316 Stainless Steel to provide high resistance to corrosion and make it very resilient to abuse or the elements.

Material Characteristics	Specific Value for Material
Mass Density	8000 Kg/m^3
Elastic Modulus	1,93 x 10^5 MPa
Tensile Strength	5,8 x 10^2 MPa
Yield Strength	1,72 x 10^2 MPa
Poisson's Ratio	0,27

Table 1 - Material properties for BiboLink's simulated parts (SolidWorks)

Machine's movement restrictions for proper simulation results

Since the machine is comprised of a cylindrical outer body and an inner chassis the machine can be fixated by taking advantage of its own geometry. For both the outer shell and the inner chassis the bottom part has been fixed as a way to restrict the triaxial and rotation movement for the part being simulated. The green pointers represent geometry parts that are fixed, in this case, the bottom circular edge of the outer cylinder and the corner knots of the inner chassis.

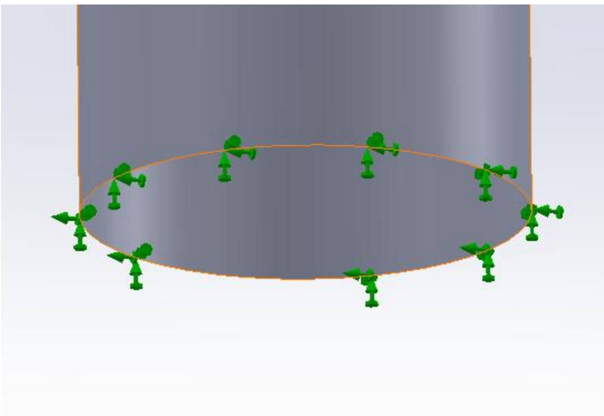

Figure 3 - Geometric fixtures for the outer cylindrical shell

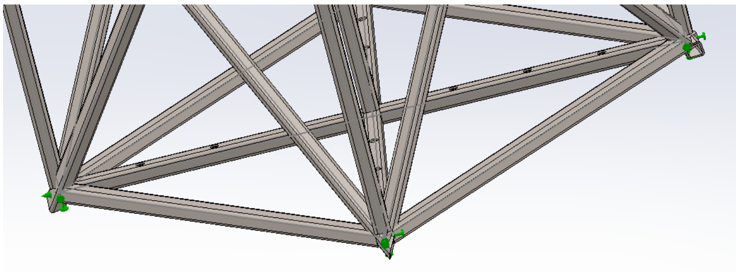

Figure 4 - Fixture Points for the machine's inner chassis

Mesh Specifications

The finest mesh quality was used to obtain the most refined results possible on the stresses applied to the machine and with that a result that is closest to reality. For the cylinder a shell element has been created by the program to represent the machine with blended curvature-based elements and then a thickness was defined for the outer layer. The inner chassis with a beam mesh.

Element size (Maximum equals minimum)	43.7 mm
Total number of elements	5912
Total number of Nodes	11883

Table 2 - Mesh characteristics for the outer shell

Element size (Maximum equals minimum)	Non-applicable
Total number of elements	705
Total number of Nodes	718

Table 3 - Mesh characteristics for the inner chassis

Results

Outer Casing

As mentioned above, forces with inflated numbers have been applied, since the objective is for the machine to be very resilient. To the outer shell, a force of 2000N simulating a person of roughly 200 Kg jumping on the machine has been applied, while also having 4 kicking forces between 3800 and 5000 N being applied to it in areas that roughly correspond to a human foot.

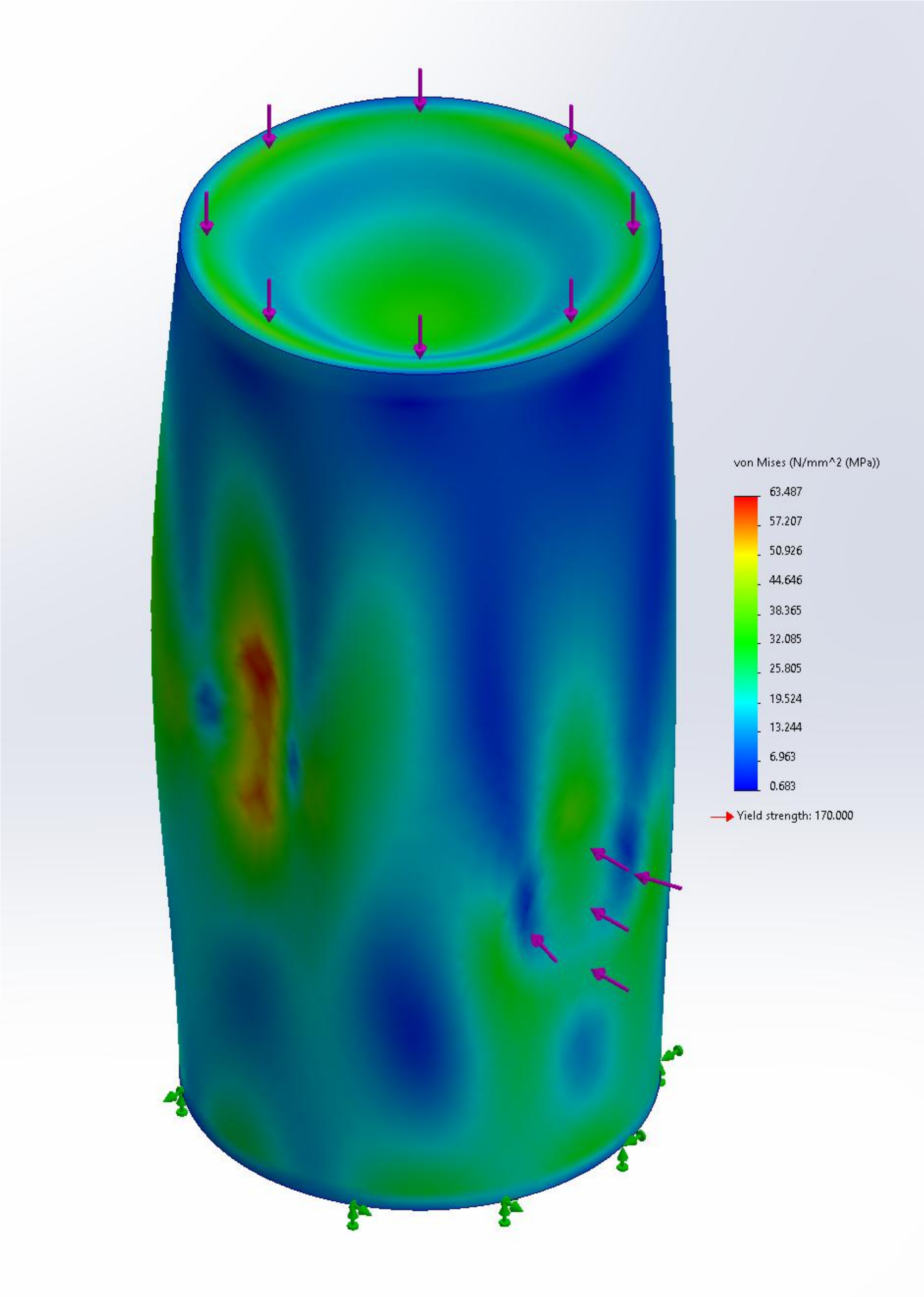

Figure 5 - Stress results from outer case simulation (exaggerated scale for viewing purposes)

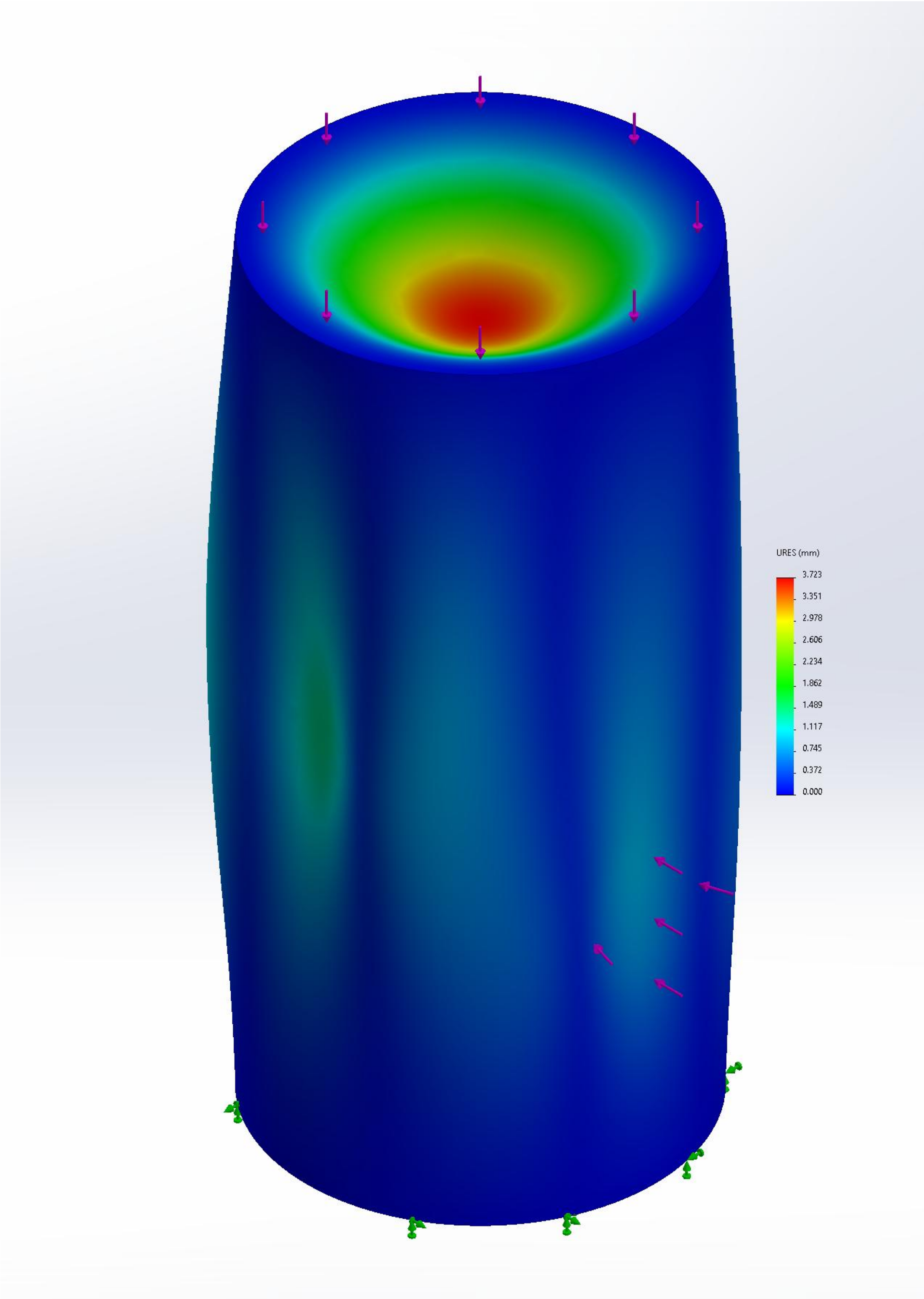

Figure 6 - Displacement results from outer case simulation (exaggerated scale for viewing purposes)

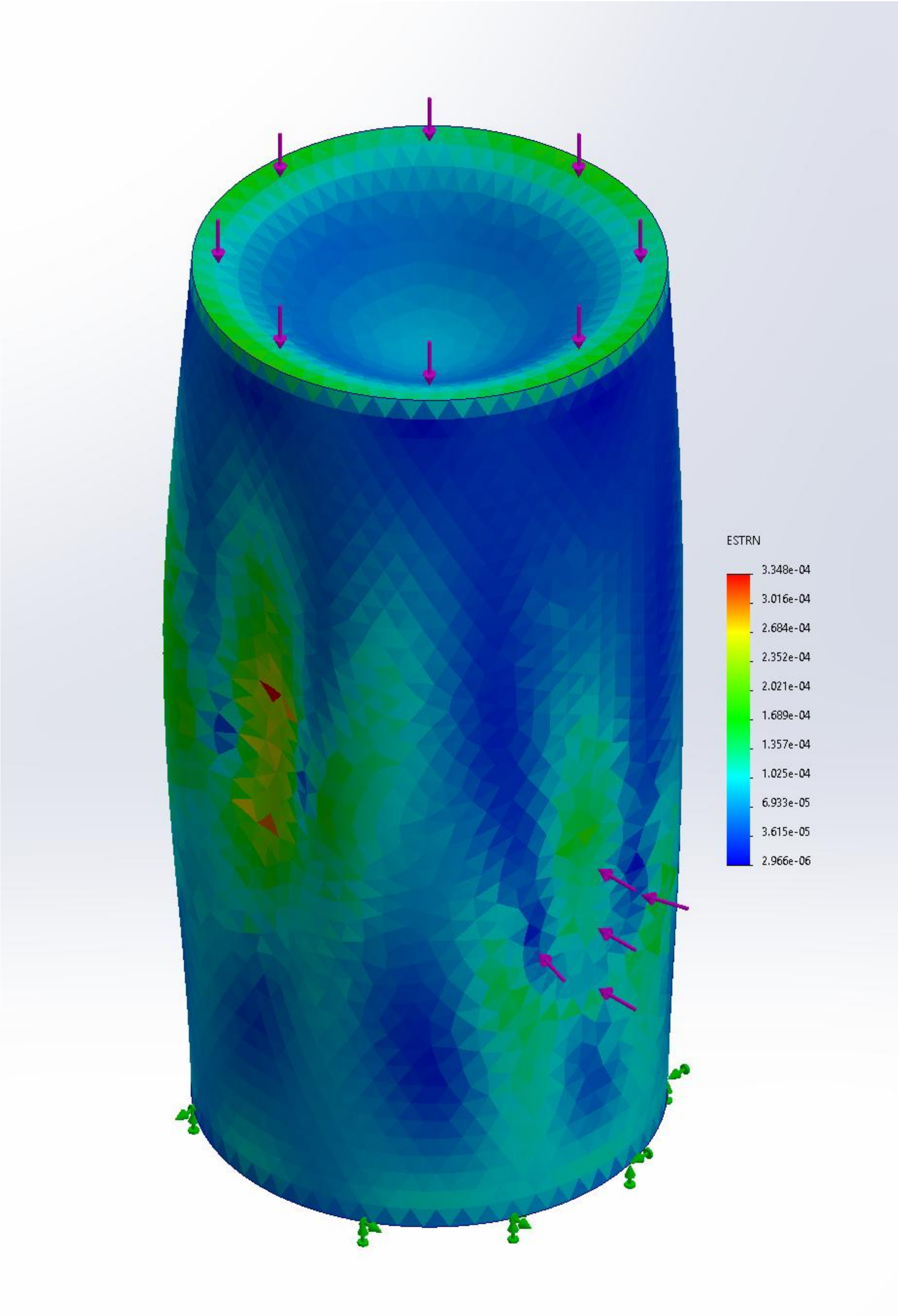

Figure 7 - Strain results from outer case simulation (exaggerated scale for viewing purposes)

When it comes to the stress applied to the cylinder, the machine holds up very well, with tensions that go to almost 63,5 MPa which is far from the 580 MPa tensile strength value for this specific type of steel. Also, when it came to displacement and strain, the value obtained was very low, also showing that the machine will bounce back to its original shape from any kind of deformation when these kinds of forces are applied to it. This means that the outside of the machine is more than capable enough when it comes to sustaining prolonged, intense kinds of abuse.

Chassis

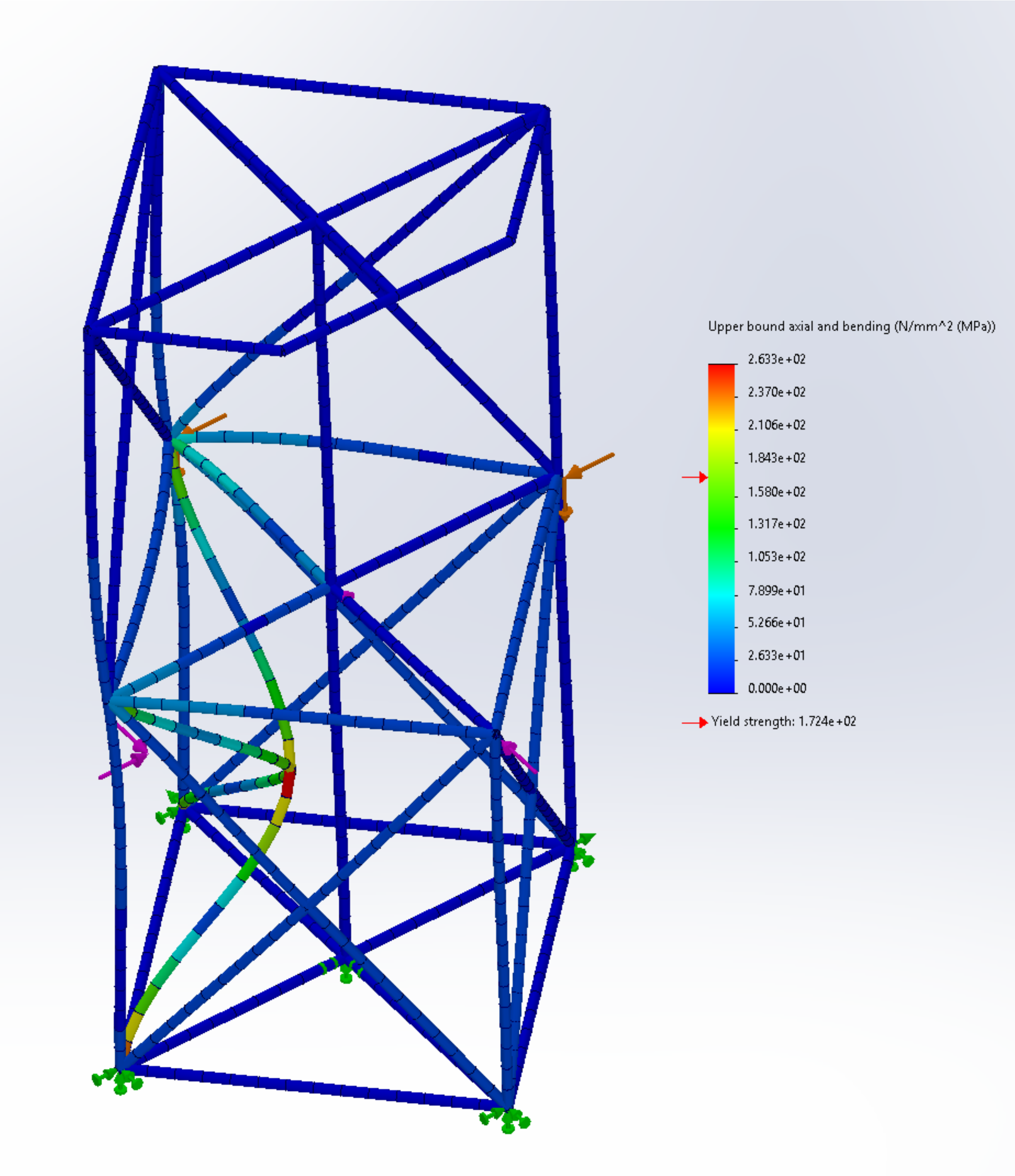

Figure 8 - Stress results from the chassis simulation (exaggerated scale for viewing purposes)

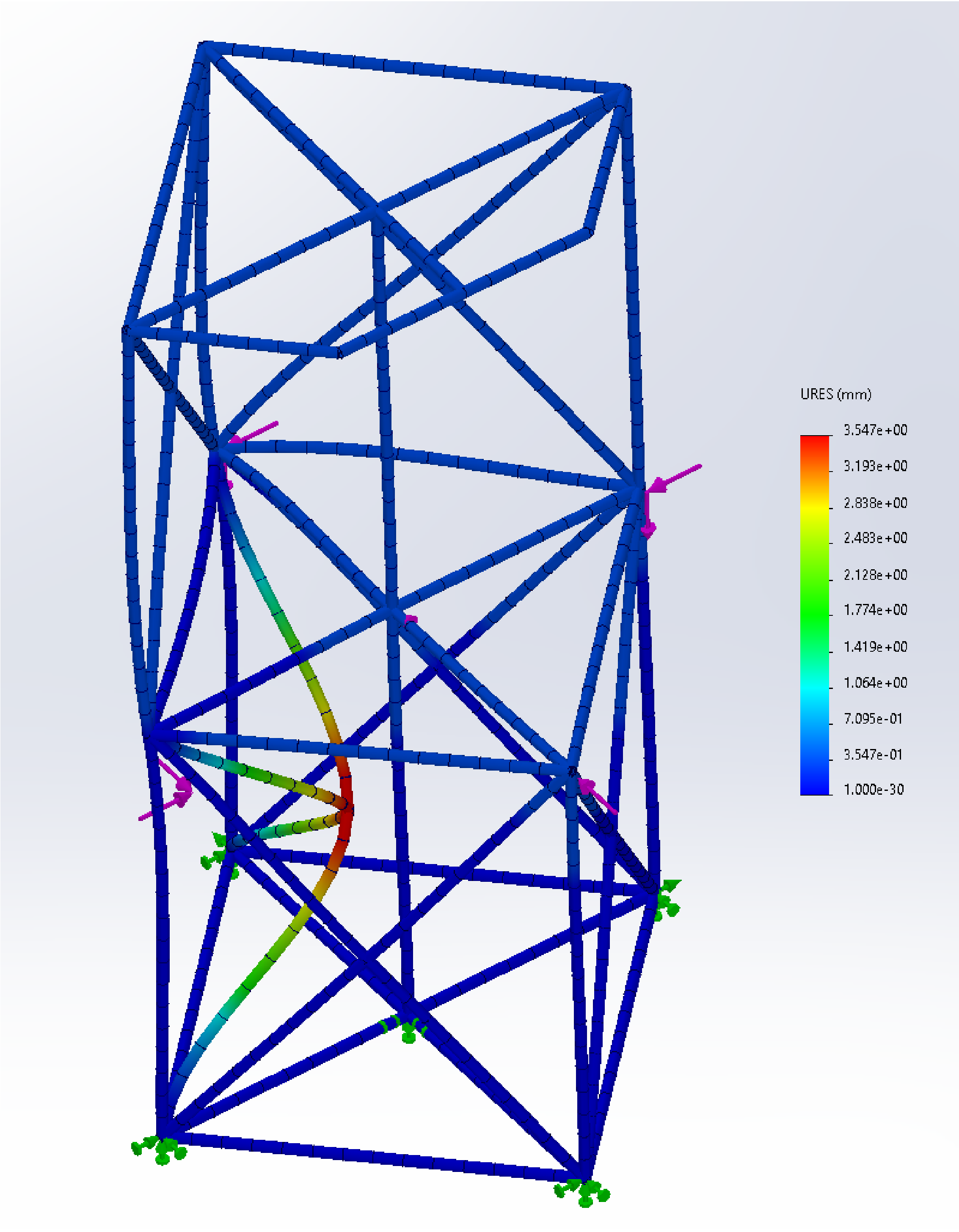

Figure 9 - Displacement results from the chassis simulation (exaggerated scale for viewing purposes)

As can be seen in the images the 316 steel is still far away from its maximum capabilities and the displacements are still well within a range that would not damage the parts.

Factor of Safety

When it comes to the factor of safety, considering that the stress induced into the outer layer was almost 63,5 MPa and to the chassis was 263,3 MPa we can calculate the safety coefficient for both parts.

Since the 316 steels can handle 580 MPa:

For the shell:

$$Factor\ of\ Safety = \frac{Stress\ Capacity}{Real\ Stress} = \frac{580}{63.5} \approx 9{,}1$$

For the chassis:

$$Factor\ of\ Safety = \frac{Stress\ Capacity}{Real\ Stress} = \frac{580}{263.3} \approx 2{,}2$$

Conclusion on the results obtained

From, the values obtained in these simulations and also from a critical analysis on the results, we can most definitely conclude that the machine will, in fact, stand the test of time and will be able to not only resist the elements based on the materials chosen but also resist very well to abuse from third parties, which guarantees that BiboLink will not only keep functioning but also be able to be used by everyone even after it is punched and kicked hard.

References

Busko, K. (s.d.). *Measuring the force of punches and kicks among combat sport athletes using a modified punching bag with an embedded accelerometer*. Taken from Researchgate: https://www.researchgate.net/publication/297700506_Measuring_the_force_of_punches_and_kicks_among_combat_sport_athletes_using_a_modified_punching_bag_with_an_embedded_accelerometer