# Virtual verification of the BB V2

## FEM and FEA

A FEA (Finite Element Analysis) study will be performed in this chapter. Within the FEM (Finite Element Method) type of analyses, the FEA study can be found. FEM is a general method, while FEA is a specific process. FEM can be applied to any system that can be discretized into finite elements, while FEA depends on the problem and the model you are analyzing. FEM is a theoretical concept, while FEA is a practical too. FEM provides the mathematical foundation, while FEA requires software and hardware to implement it. In this chapter an FEA study will be performed using SolidWorks software. In the study a mesh will be made to create a finite element model of the system. The purpose of the calculations considered here, is to examine the effect on the BB V2 at a predetermined load, taking into account a safety factor of 1,5.

FEM stands for finite element method. It is a mathematical technique that divides a complex system into smaller and simpler parts called finite elements. Each element has a specific shape, size, and properties. By applying equations and boundary conditions to each element, you can approximate the behavior of the whole system. FEM is useful for solving problems involving stress, heat, fluid flow, vibration, and other physical phenomena.

FEA stands for finite element analysis. It is the application of FEM to a specific problem or design. FEA involves creating a finite element model of the system, choosing the appropriate material properties and loading conditions, performing the calculations, and interpreting the results. FEA can help you optimize your design, test its performance, and identify potential failures.

## Adjustments

However, some things still needed to be adjusted/removed from the current CAD file of the BB V2. All unnecessary features such as rounding and chamfers were removed. Parts and subassemblies that don't contribute to the structural integrity of the model will also be removes. This way, there will be no unnecessary calculations that will not affect the strength calculation and will only take up time. The entire file has thus been de-featured and simplified to streamline the process of the study.

## Materials and External Load

### Materials

The parts of this calculation are made of different materials (customized and from the SolidWorks Standard library). However, the materials of the parts that influence its integrity were chosen during the 'Material Comparison'. In this chapter the advantages and disadvantages as well as the environmental impact of all materials were compared. For the frame and the doors stainless steel was chosen. This has an impact on the yield strength of the product and also the weigh.

For the stainless steel the most common form was chosen, namely AISI 304. (From the SolidWorks standard library) Properties for specific parts of the assembly:

| Property | Value | Units |
|---|---|---|
| Elastic Modulus | 190000 | N/mm^2 |
| Poisson's Ratio | 0.29 | N/A |
| Shear Modulus | 75000 | N/mm^2 |
| Mass Density | 8000 | kg/m^3 |
| Tensile Strength | 517.017 | N/mm^2 |
| Compressive Strength | | N/mm^2 |
| Yield Strength | 206.807 | N/mm^2 |
| Thermal Expansion Coefficient | 1.8e-05 | /K |
| Thermal Conductivity | 16 | W/(m·K) |
| Specific Heat | 500 | J/(kg·K) |
| Material Damping Ratio | | N/A |

*Figure 1: Stainless steel properties*

## Load

The first test shows the integrity of the construction carrying other BB V2's. This test is performed to simulate the mounting of 4 beetle breeders onto each other. The 4 beetles breeders mount to a height of 1,60 m. The amount of breeders that are mounted in this test is 4 because when the breeders reach a height of 1,60 m, they are all still operable by the average man and woman. A fifth breeder would make it impossible to operate all breeders for an average woman. The test simulates the bottom BB V2, carrying 3 other beetle breeders.

The weight of one beetle breeder is 20 kilo (incl. all interna features, decorations and organisms) and the gravitational acceleration is 9,81 $\frac{m}{s^2}$ . The force of gravity is perpendicular downwards. these factors determine the force on the bottom beetle breeder.

$$20\ kg * 3\ BB\ V2 * \frac{9{,}81\ m}{s^2} = 588{,}6\ N$$

The force the bottom beetle breeder needs to be able to carry is 588,6 N. This force will be used in the calculations.

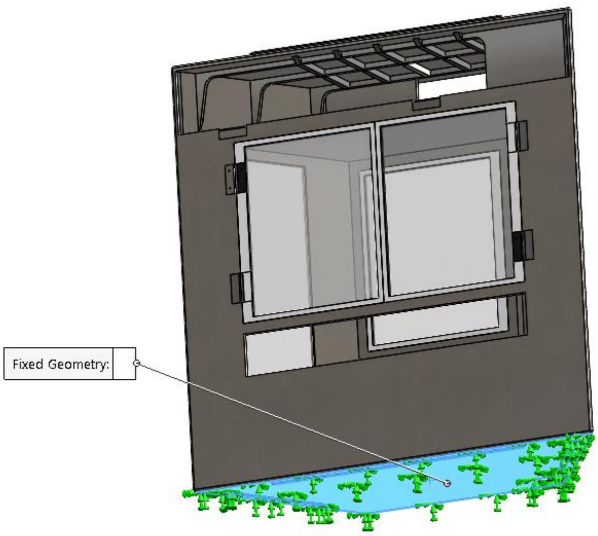



*Figure 2: Fixture Placement*

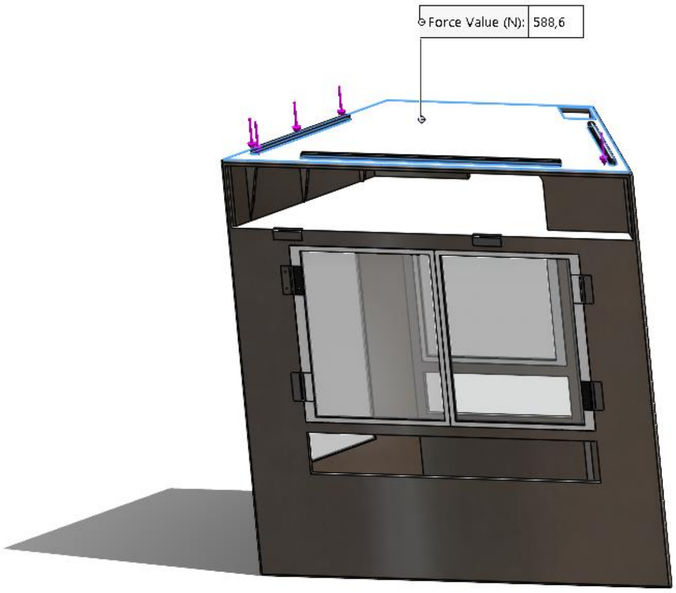



*Figure 3: Load Placement*

## Meshing

After setting all settings, the mesh still needs to be determined. A relatively small mesh will be used in this study (curvature-based mesh), as there are fillets and other details in the product that were unable to be deleted. Chosen mesh size is max 7mm and min 1mm. Everything in processing is now complete and the calculations can be started.

## Final Test

The first test shows the integrity of the construction carrying other BB V2's. This test is performed to simulate the mounting of 4 beetle breeders onto each other. The test simulates the bottom BB V2, carrying 3 other beetle breeders.

The estimated weight of one beetle breeder is 20 kilo as the construction already reaches the weight of 18 kg. The 20 kg estimate includes all internal features, decorations and organisms. The gravitational acceleration is 9,81 $\frac{m}{s^2}$ . These factors determine the force on the bottom beetle breeder.

$$20\ kg * 3\ BB\ V2 * \frac{9{,}81\ m}{s^2} = 588{,}6\ N$$

The force the bottom beetle breeder needs to be able to carry is 588,6 N. This force will be used in the calculations.

Running the study revealed that a large displacement was causing problems. Therefore, multiple advanced modifications were performed and tested. Multiple sets of ribs were added to the construction to enhance the sturdiness. During each test the mesh was created the same way as before the optimalisations.

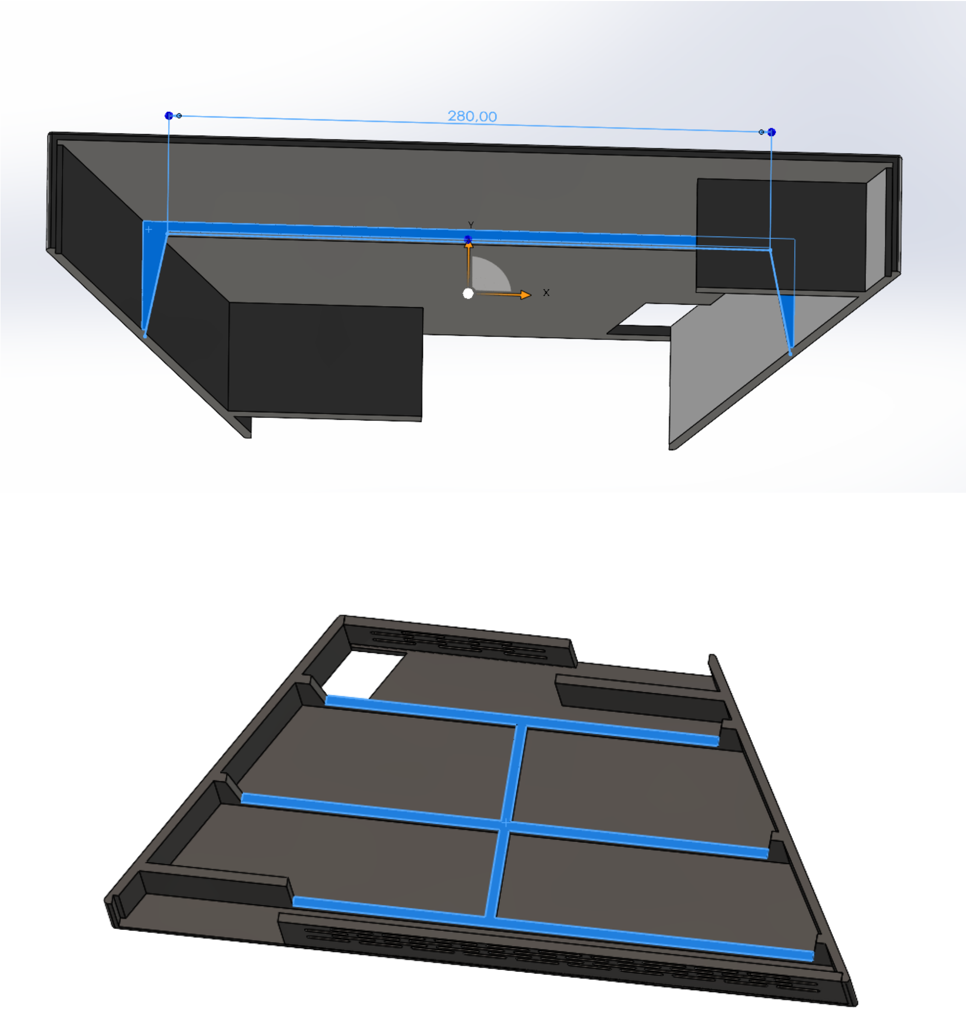
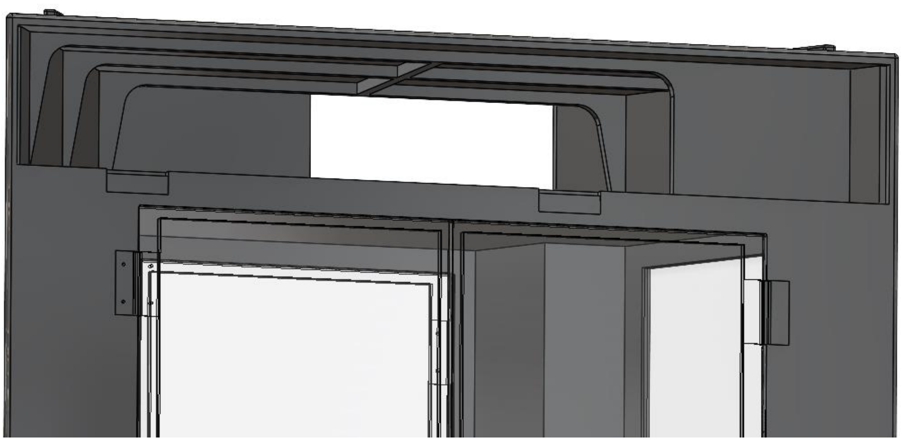
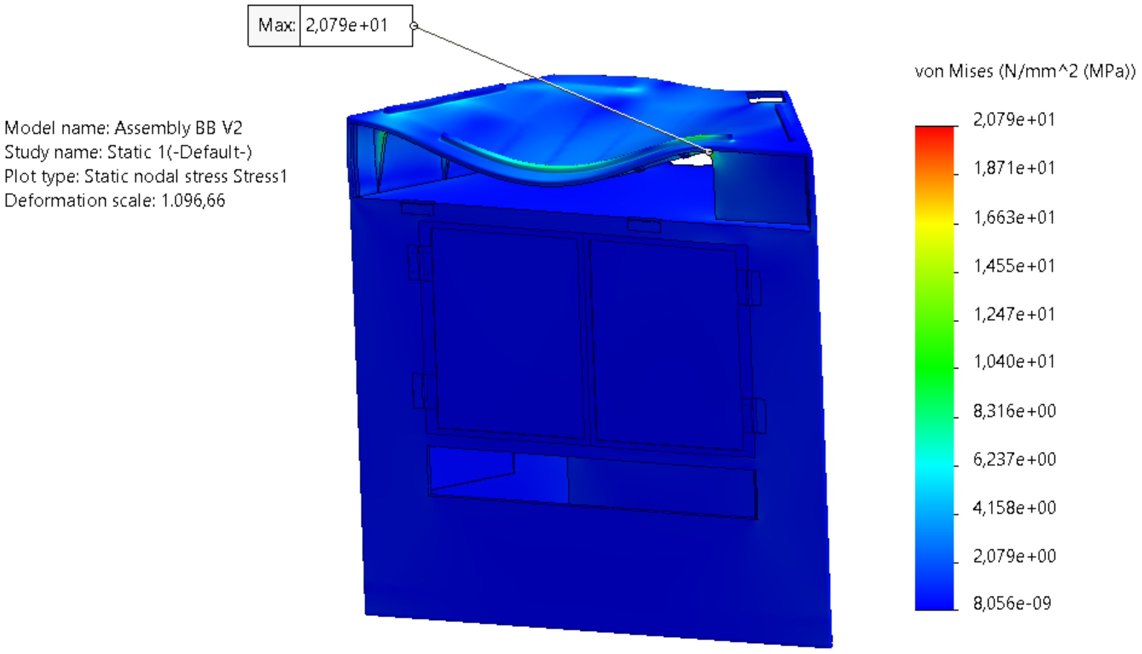



*Figure 4: Advanced modifications on structure*



# Results

## Von Mises Stresses (N/mm²)

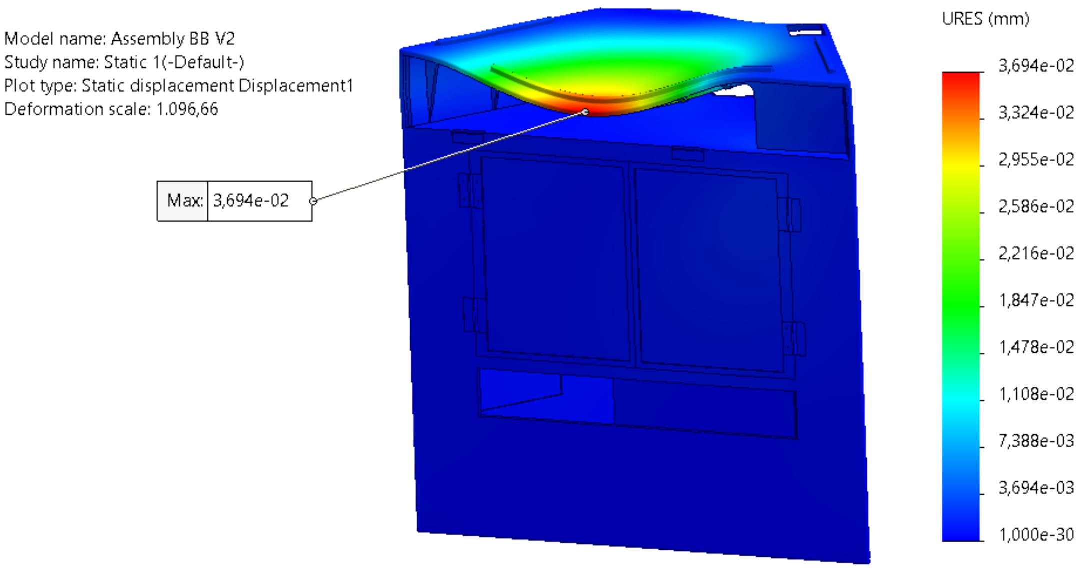



Maximum von mises stress = 20,79 N/mm². The maximum stress with safety factor 1,5 is:

$$\frac{206{,}807\ N/mm^2}{1{,}5} = 137{,}871\ N/mm^2$$

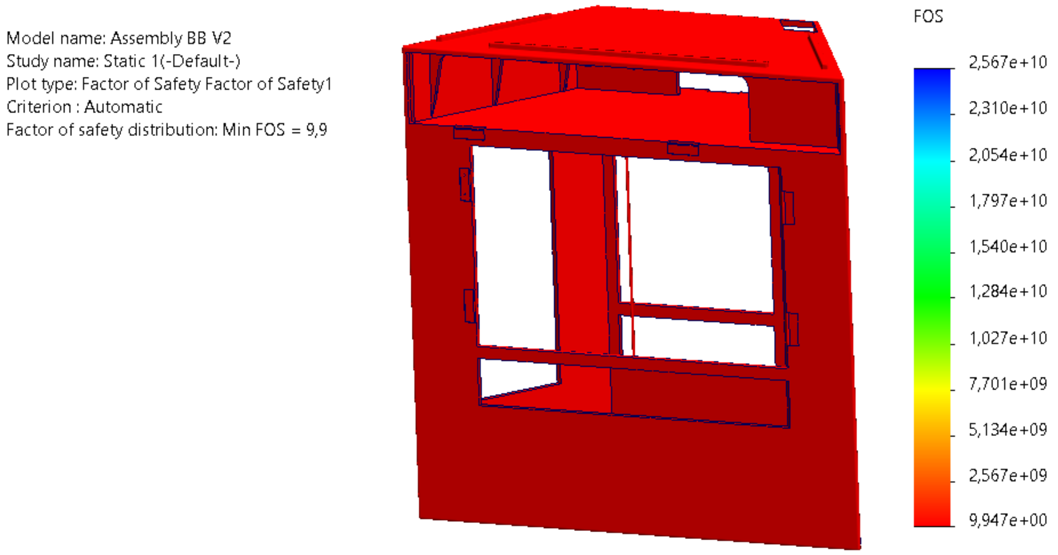
The calculated stress (20,79 N/mm²) is thus not too high. There is not too much stress in the beetle breeder.

## Deformations




Maximum deformation = 0,03694 mm. This deformation is acceptable and furthermore an enormous optimalisation due to the modifications to the structure.

### Factor of Safety whole (FOS)




Minimum factor of safety here is 9,9 which is higher than the minimum value of 1,5.
The FOS will increase by, for example, changing the material by one with a higher Yield strength.
This statement is proven by the following formula: FOS = (Yield Strength/ max permissible Von Mises)

## Conclusion

During this virtual verification, it was checked whether the BB V2 would withstand a force of 588,6 N. The results showed that the device could undergo force. However, successfully undergoing this force was possible only after adjusting materials and dimensions. The entire model except from the top of the technological compartment still looked reasonably blue and could undergo heavier loads. Overall, the FOS are still well above the minimum. For this analysis, the minimum limit of 1.5 for the FOS remained intact. Further studies can be done to discover the maximum amount of beetle breeders that can be mounted onto each other.