Structural Test: Stress Analysis of the Bloem Relaxation Pod (SOLIDWORKS)

The structural test was performed to validate that the design can withstand the loads of daily use without risk of mechanical failure, excessive deformation, or long-term damage. The test was carried out as a static Finite Element Analysis (FEA) in SOLIDWORKS Simulation, which numerically calculates how the structure behaves when a person sits inside the pod.

The pod will be subjected to a 100 kg occupant load (equivalent to 1,600 N applied normal to the seat surface, including a 1.6× dynamic and safety factor) combined with the pod's own self-weight under gravitational acceleration. The analysis evaluates von Mises stress concentrations, particularly at critical locations such as the seat-to-rib junctions and the base support region, where stress is expected to be highest because that is where the load is transferred into the structure. The material's yield strength will be compared against the calculated maximum stresses to ensure a minimum factor of safety of 2.0, which is the standard engineering target for wooden seating structures. Displacement analysis will verify that deflections remain within imperceptible limits, ensuring user comfort and structural confidence.

The structural test passes if maximum stress values stay well below the material yield strength with adequate safety margins, and if no excessive deformation or structural instability occurs under the specified occupant load.

Critical areas such as the seat support region and the base of the pod were closely monitored for peak stress concentrations. The results indicate that the highest stresses are orders of magnitude below the material yield strength, confirming the structural adequacy of the Bloem design. The analysis also demonstrates that wall and seat displacements remain microscopic (less than the thickness of a human hair), ensuring the pod's integrity, comfort, and stability under operational conditions.

Overall, the structural test validates Bloem's ability to safely support a 100 kg occupant without risk of failure, supporting the prototype's viability for further development and real-world deployment in wellness environments.

Keywords

Four key results are extracted from a stress test, and each one tells a different part of the story:

- **Strain** — how much the material is being physically stretched or compressed.
- **Displacement** — how far each point of the structure physically moves under load.
- **Stress (von Mises)** —the primary measure of how close the material is to breaking.
- **Factor of Safety (FoS)** —represents how many times stronger the design is than it needs to be.

Occupant Load Calculation

The applied load was determined from the design occupant weight (100 kg) using Newton's second law, combined with a dynamic and safety multiplier that accounts for realistic usage conditions such as sitting impact and material variability.

Static occupant weight: $F = m \times g$

$m = 100$ kg (design occupant mass)

$g = 9.81\ m/s^2$ (gravitational acceleration)

$F_{static} = 100 \times 9.81 \approx 981$ N

Applied design load (with 1.6× combined dynamic and safety factor):

$F_{design} = 981 \times 1.6 \approx 1{,}600$ N

The factor of 1.6 accounts for the following real-world conditions that are not captured by a purely static analysis. First, a person rarely sits perfectly still; the act of sitting down creates a momentary impact load that can briefly exceed body weight by 1.5–2×. Second, real birch plywood contains natural variability such as small knots and density variations, so a margin is added to ensure the design tolerates these imperfections. Third, the analysis itself assumes an idealized material (linear-elastic isotropic), and a safety multiplier protects against any inaccuracy introduced by this simplification. This 1,600 N value is also more conservative than the European furniture standard EN 1728, which specifies 1,000 N as the static seat load test for chairs, providing additional confidence in the design's safety.

Material Properties

The pod is constructed from birch plywood.

The mechanical properties used in the simulation are summarized below.

Property	Value	Description
Elastic Modulus (E)	11 GPa	Stiffness; resistance to deformation
Poisson's Ratio (ν)	0.3	Lateral contraction under load
Density (ρ)	680 kg/m^3	Mass per unit volume
Yield Strength (σ_y)	40 MPa	Stress at which permanent damage occurs

Strain Analysis Results

The maximum equivalent strain observed in the Bloem pod was approximately 3.75×10^{-5}, which is equal to 0.00375%. This is approximately 267 times smaller than the elastic limit of birch plywood, confirming that the wood remains entirely within its linear elastic regime. In practical terms, this means that when the occupant stands up after using the pod, the structure returns perfectly to its original shape with no residual deformation. The pod's geometry will not change over years of repeated use, provided that material degradation from moisture or biological factors is independently managed.

As shown in Figure 1, the strain field is concentrated at the lower interior surfaces, where the seat transfers occupant weight into the rib structure. The upper dome of the pod displays nearly zero strain, confirming that this region is not load-bearing and serves a purely aesthetic and acoustic function.

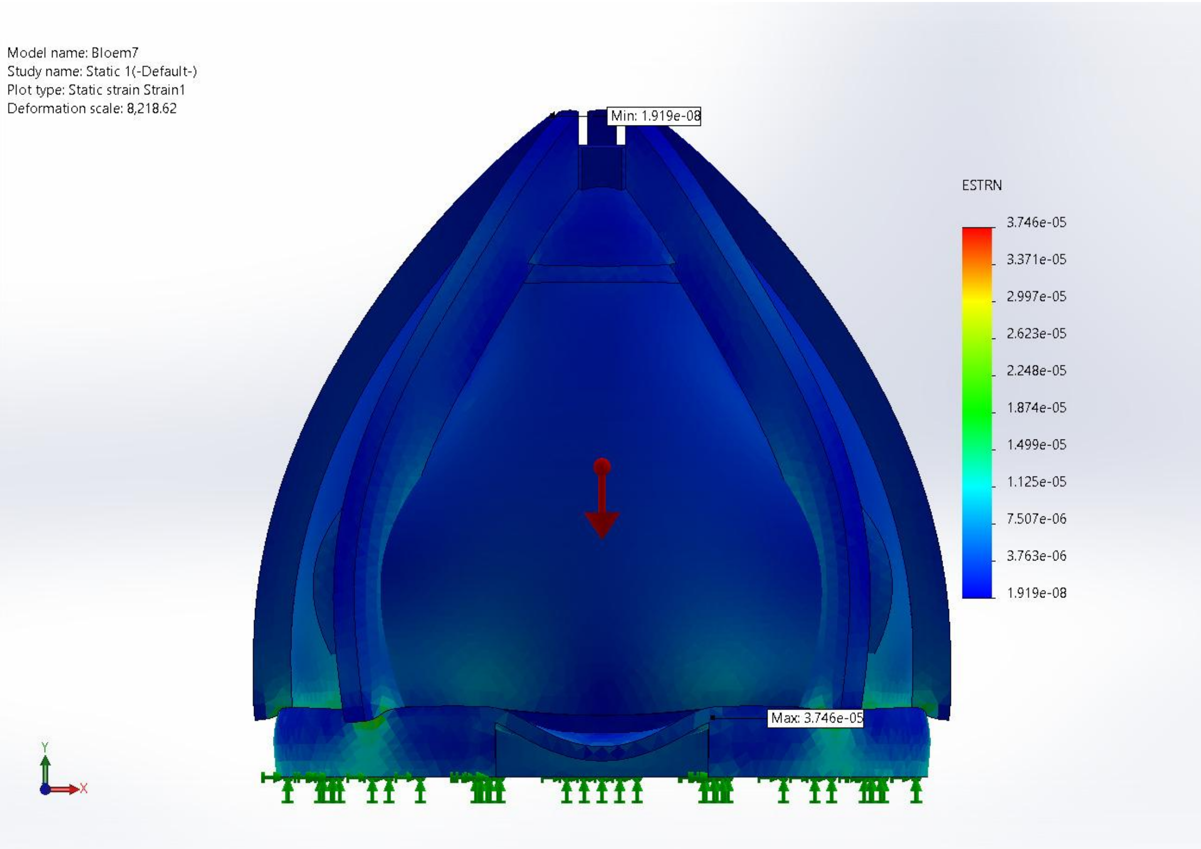

Figure 1: Equivalent strain (ESTRN) distribution across the Bloem pod under design loading. Maximum strain of 3.75×10^{-5} occurs at the seat support region, far below the elastic limit of birch plywood.

Displacement Analysis Results

The maximum resultant displacement (URES) observed in the Bloem pod was approximately 0.0388 mm, equivalent to roughly 39 micrometers, which is less than half the thickness of a typical human hair. This deflection is completely imperceptible to a human occupant and demonstrates exceptional structural stiffness. For comparison, the European standard EN 1728 considers any chair with deflection below 5 mm to be highly satisfactory; the Bloem pod is more than 100 times stiffer than this threshold.

Figure 2 shows that the largest displacements occur at the center of the seat surface and at the lower lateral regions of the shell, which is the expected behavior: these are the points furthest from the fixed base and closest to the applied load. The top of the dome shows essentially zero displacement, indicating that load is being efficiently distributed through the multi-rib structure rather than concentrated in any single weak path.

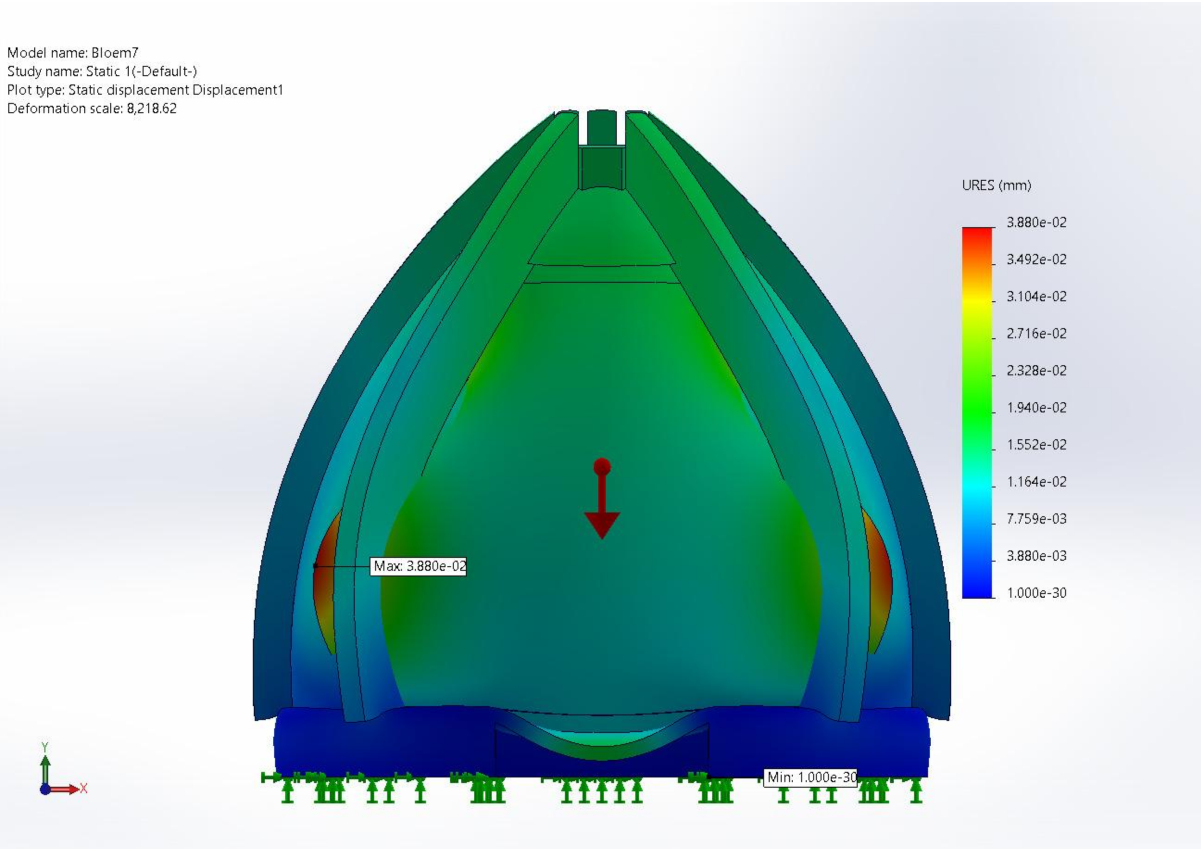

Figure 2: Resultant displacement (URES) distribution under occupant loading. Maximum deflection of 0.0388 mm occurs at the seat region, confirming an exceptionally stiff structural response.

Stress Distribution Results

The maximum von Mises stress observed in the Bloem pod was approximately 0.15 MPa, occurring at the base support region where the seat transfers occupant load into the structural base ring. Compared to the assumed yield strength of birch plywood (40 MPa), this represents only 0.375% of the material's strength capacity. The pod is therefore stressed to approximately 1/267th of what would cause yielding, an extraordinary safety margin that reflects the inherently over-engineered nature of wooden furniture structures.

Figure 3 reveals that stress is well distributed across the pod, with no sharp concentrations or worrying hotspots. The bulk of the structure (including the upper dome, the central rib region, and most of the shell panels) operates at near-zero stress. The slight increase visible at the lower base region is expected behavior, as this is the natural load path from the seat to the floor through the structural base. The smooth, gradual transitions in the stress field indicate that the structural geometry is efficiently sharing the load rather than forcing it through narrow channels that could become fracture initiation points.

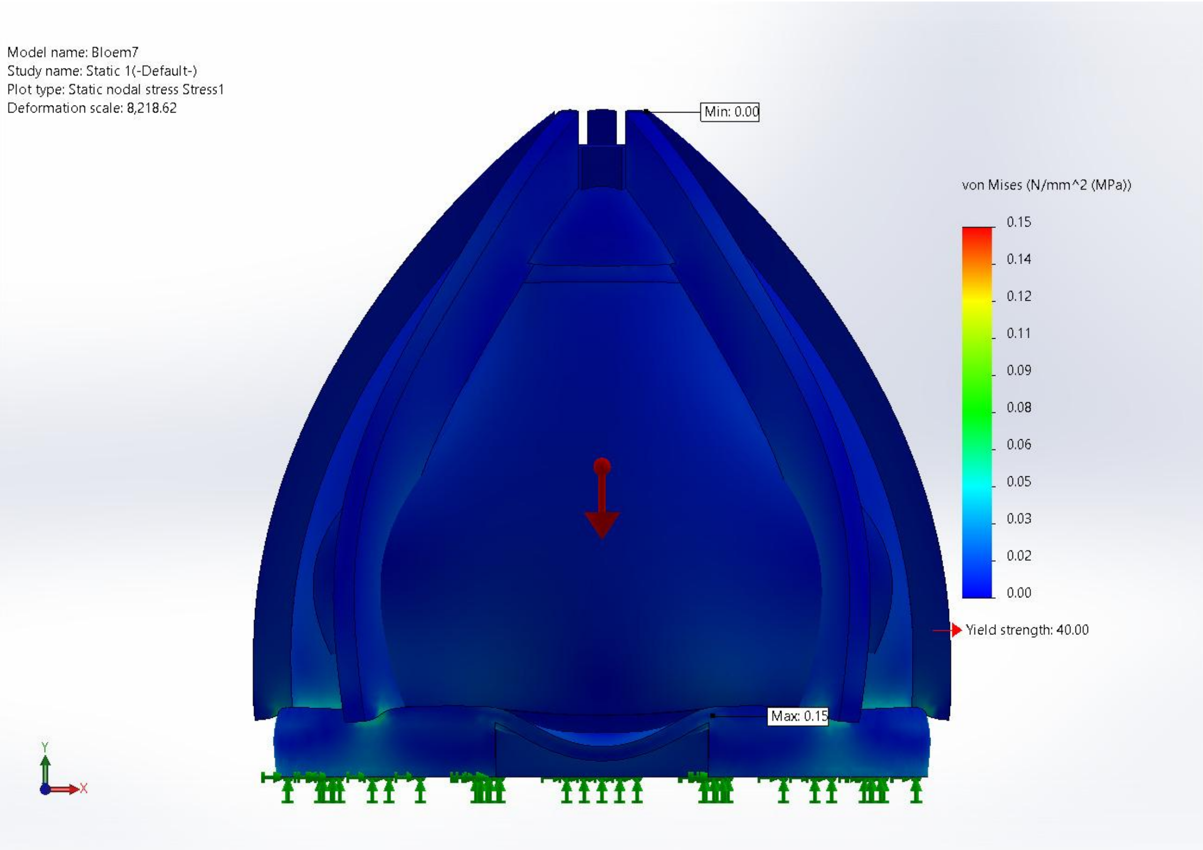

Figure 3: Von Mises stress distribution under design loading. Maximum stress of 0.15 MPa at the base support region is 267 times smaller than the material yield strength of 40 MPa.

Factor of Safety Analysis

The minimum Factor of Safety observed across the entire Bloem pod was approximately 261, which is more than 130 times the standard target for furniture (FoS = 2). This extraordinary value confirms that the pod is overwhelmingly safe for its intended occupant load. The visualization upper limit in Figure 4 has been set to 5 to highlight any potential weak regions; no area of the pod falls below this threshold, meaning the entire structure operates at FoS values exceeding 5 (and in most regions, exceeding several thousand).

It is important to interpret this result with engineering honesty. A factor of safety this high does not mean the design is wasteful or over-built; it reflects the fundamental reality that a wooden multi-rib structure capable of carrying its own self-weight, supporting curved shell panels, and resisting impact loads is inherently strong against a single seated person. Realistic limits in practice come from other sources not captured by this static stress analysis, such as the integrity of glued joints, long-term creep under sustained loading, moisture cycling effects, and potential buckling instability of slender ribs. These factors would be addressed in subsequent design iterations and physical prototype testing.

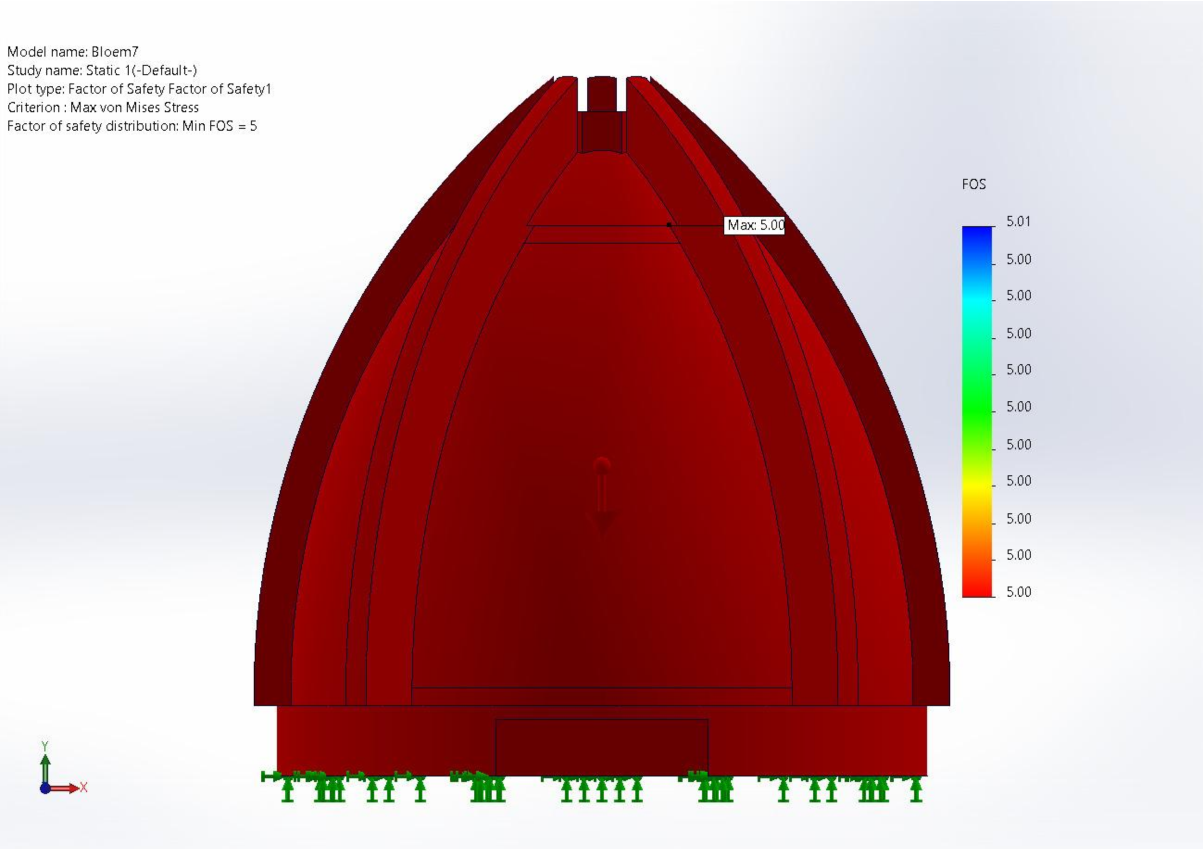

Figure 4: Factor of Safety distribution based on the von Mises stress criterion against the material yield strength. Minimum FoS = 261 confirms the Bloem pod safely supports the design occupant load with substantial structural margin.

Results Summary

The four key results are summarized in the table below, alongside the engineering interpretation for each.

Metric	Maximum Value	Material Limit	Verdict
Strain (ESTRN)	3.75×10^{-5}	~ 1×10^{-2} (elastic limit)	**PASS (267× margin)**
Displacement (URES)	0.0388 mm	5 mm (EN 1728 target)	**PASS (129× margin)**
Von Mises Stress	0.15 MPa	40 MPa (yield)	**PASS (267× margin)**
Factor of Safety	261 (minimum)	2.0 (furniture target)	**PASS (130× margin)**

Conclusion

The structural stress test confirms that the Bloem relaxation pod safely withstands the design occupant load of 1600 N (representing a 100 kg user with a 1.6× combined dynamic and safety factor) combined with the pod's self-weight under gravity. The simulation results demonstrate that the maximum von Mises stress (0.15 MPa) occurs at the base support region and remains 267 times smaller than the material's yield strength, ensuring that the minimum factor of safety of 261 exceeds the standard target of 2.0 for furniture structures by a margin of more than 130 times.

The displacement analysis further verifies that deformations remain microscopic, with a maximum deflection of 0.0388 mm at the seat region — less than half the thickness of a human hair. This sub-millimeter response confirms that the pod will feel solid and unyielding to its occupants, contributing to the sense of safety and tranquility that is central to the Bloem user experience. The strain results corroborate this finding, with the maximum equivalent strain (3.75×10^{-5}) staying entirely within the elastic regime, meaning the pod will return perfectly to its original shape after each session without any cumulative damage.

Taken together, these results validate the structural soundness of the egg-shaped multi-rib birch plywood construction. The Bloem pod is confirmed to be safe and durable for its intended wellness application, supporting the prototype's progression toward physical manufacturing and real-world deployment. Future structural work should focus on aspects not captured by this static analysis, including joint integrity (glued and doweled connections), long-term creep under sustained loading, moisture and environmental effects, and dynamic impact loading scenarios such as occupants sitting down forcefully. These additional studies, combined with the strong static performance demonstrated here, will provide a complete picture of the pod's structural lifecycle.

Worst-Case Scenario: Concentrated Load Analysis

To further validate the structural integrity of the Bloem pod under a more demanding loading condition, a second simulation was performed in which the full 1600 N occupant load was concentrated onto a 200 × 200 mm patch representing the realistic leg contact area of a seated person. This approach produces significantly higher local pressure than the distributed load scenario and represents a worst-case condition, as real occupant contact is never perfectly spread across the entire seat surface. The pressure applied was 0.04 N/mm², calculated by dividing 1600 N by the 40,000 mm² contact area.

Figure A — Load Application (where the force is applied)

The concentrated load was applied using the Split Line tool in SOLIDWORKS to isolate a 200 × 200 mm square patch on the seat surface, positioned at the center of the seat where a person's legs and buttocks make primary contact. As shown in Figure A, the 1600 N force is applied exclusively to this small patch, with the surrounding seat area carrying no direct load. This setup ensures that the simulation captures the high local pressure that occurs in realistic seating conditions rather than assuming an idealized uniform distribution.

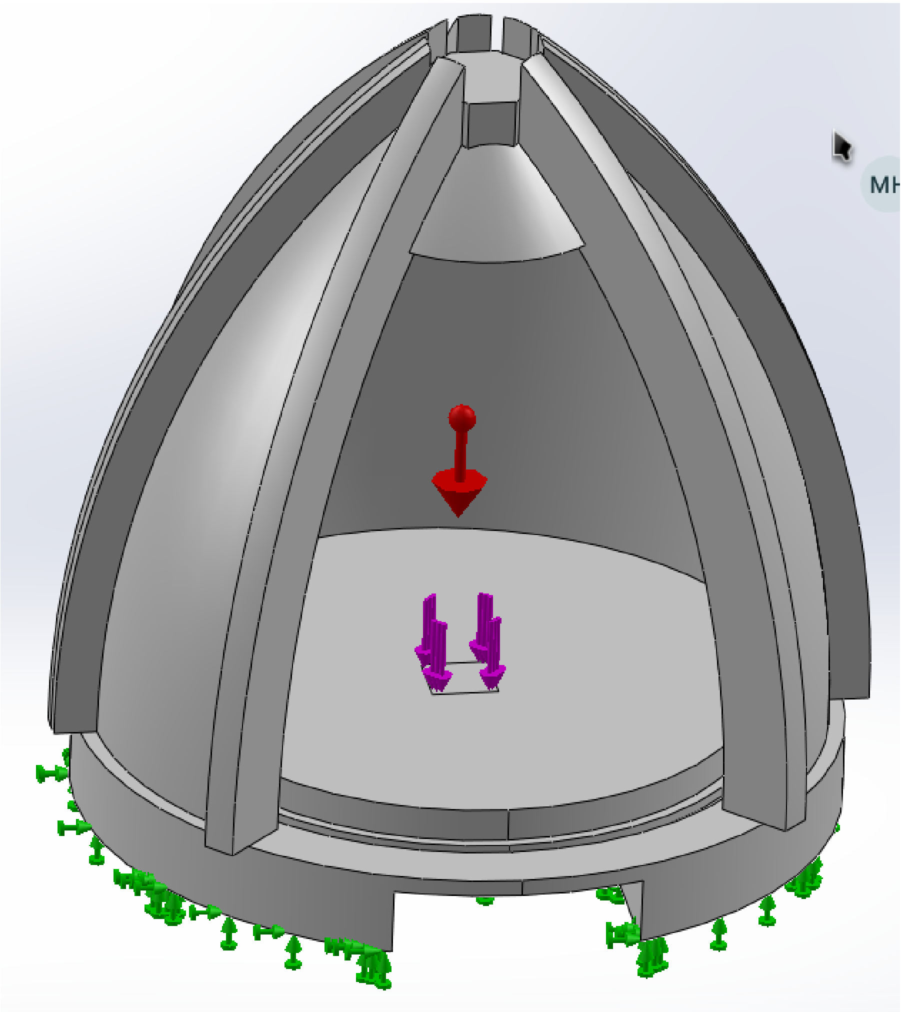

Figure A: Load application showing the 1600 N force concentrated on a 200 × 200 mm patch at the center of the seat surface, representing the worst-case human leg contact area.

Figure B — Stress Distribution (worst-case)

The maximum von Mises stress observed under the concentrated load scenario was approximately 0.10 MPa, occurring directly beneath the 200 × 200 mm contact patch where the pressure intensity is highest. Compared to the assumed yield strength of birch plywood (40 MPa), this represents 0.25% of the material's strength capacity, confirming that the structure remains within safe limits even under this demanding worst-case condition. As shown in Figure B, the stress concentrates locally beneath the loaded patch and dissipates rapidly through the surrounding rib structure, demonstrating that the multi-rib construction effectively distributes even highly localized loads without creating dangerous stress concentrations elsewhere in the pod.

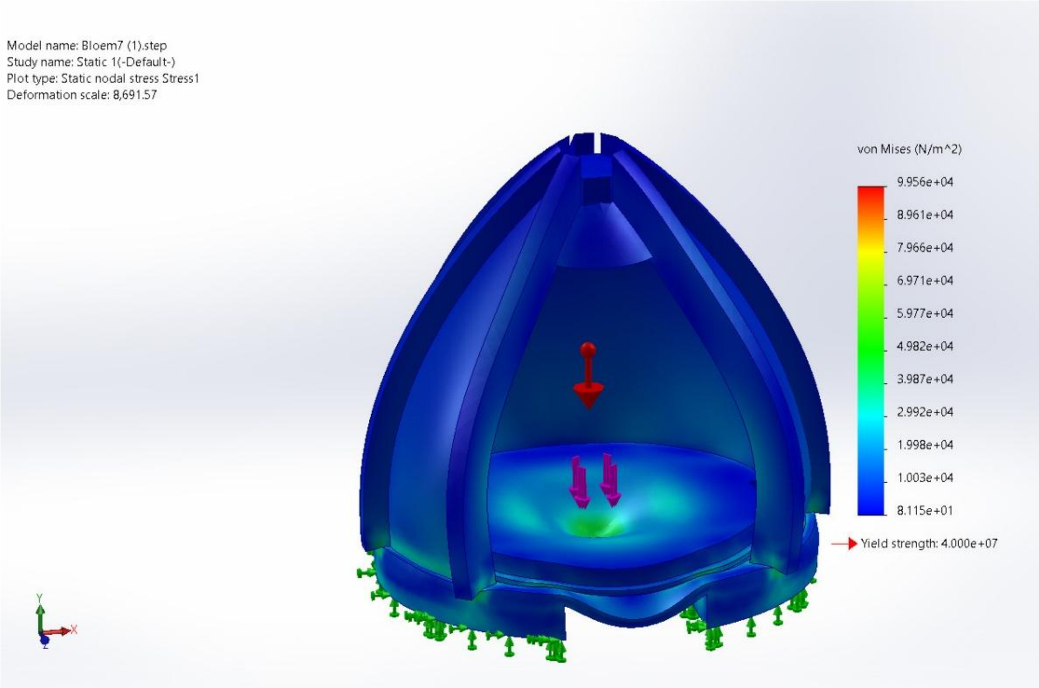

Figure B: Von Mises stress distribution under the concentrated 1600 N worst-case load.

Figure C — Displacement (worst-case)

The maximum resultant displacement observed under the concentrated load was approximately 0.0367 mm, occurring at the center of the loaded patch where the pressure is applied. As shown in Figure C, the deflection pattern radiates outward from the contact zone, with the surrounding seat area and structural ribs showing progressively smaller displacements. The base of the pod remains essentially stationary, confirming that the fixed boundary conditions are correctly transferring loads to the floor. Even under this concentrated worst-case loading, the maximum deflection remains within acceptable structural limits, demonstrating that the pod's stiffness is sufficient to resist localized point loading without noticeable deformation.

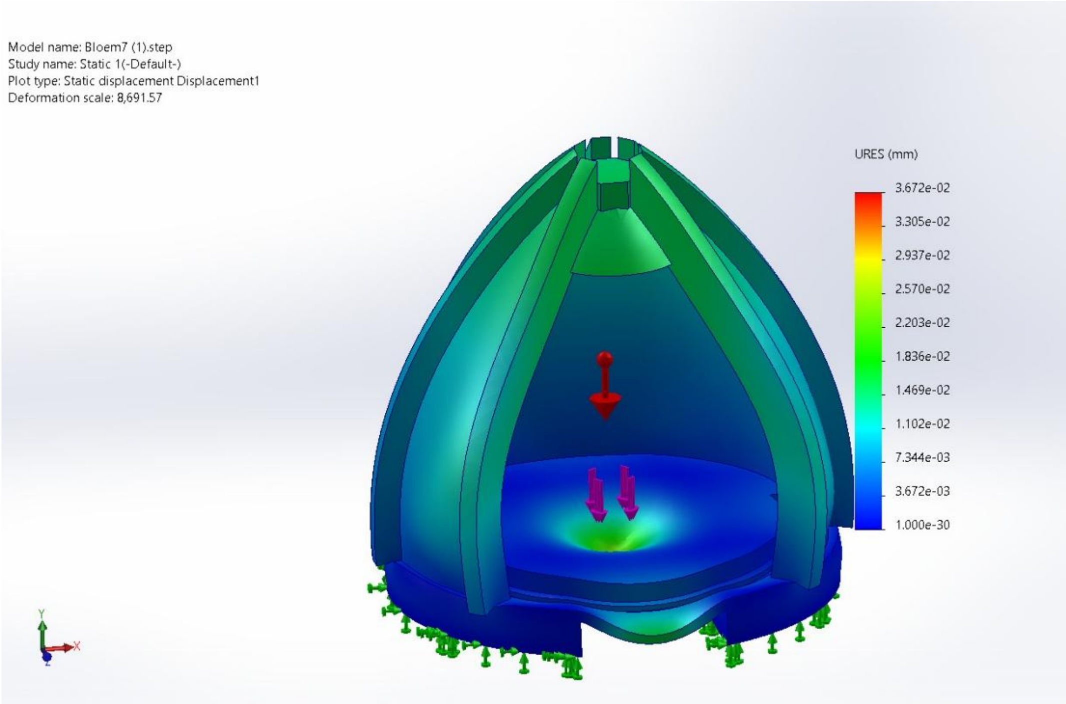

Figure C: Resultant displacement (URES) distribution under the concentrated worst-case load.

Figure D — Strain (worst-case)

The maximum equivalent strain observed under the concentrated load was approximately 3.649×10^{-5}, occurring directly beneath the loaded patch. As shown in Figure D, the strain field is tightly localized around the contact zone, with the remainder of the pod structure showing significantly lower strain values. This localized pattern confirms that the wooden ribs and shell panels surrounding the contact area are successfully absorbing and redistributing the concentrated load. The maximum strain value remains within the elastic regime of birch plywood, meaning the material will return to its original shape after the load is removed and no permanent deformation is introduced by even this worst-case loading condition.

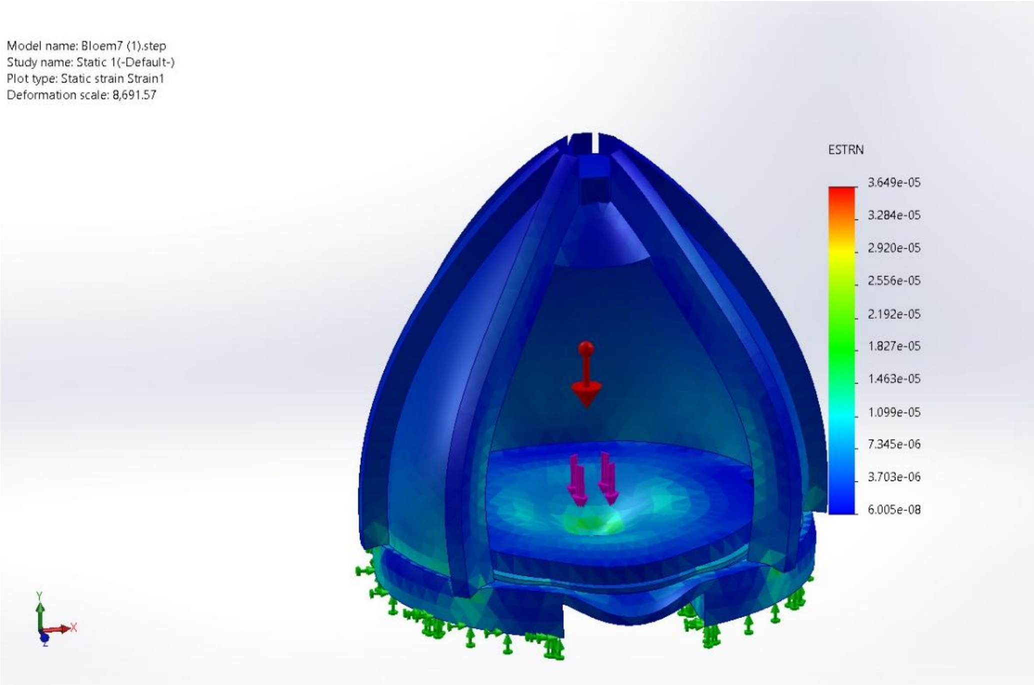

Figure D: Equivalent strain (ESTRN) distribution under the concentrated worst-case load.

Figure E — Factor of Safety (worst-case)

The minimum Factor of Safety observed under the concentrated load scenario was approximately 402, occurring at the location of peak stress directly beneath the 200 × 200 mm contact patch. As shown in Figure E, the visualization upper limit has been set to 5 to clearly highlight any regions approaching the safety threshold. Even under this worst-case concentrated loading, the minimum factor of safety exceeds the standard engineering target of 2.0 for wooden seating structures, confirming that the Bloem pod maintains adequate structural margin across all loading conditions. The rapid transition to higher FoS values away from the contact zone further demonstrates the effectiveness of the rib structure in distributing concentrated loads.

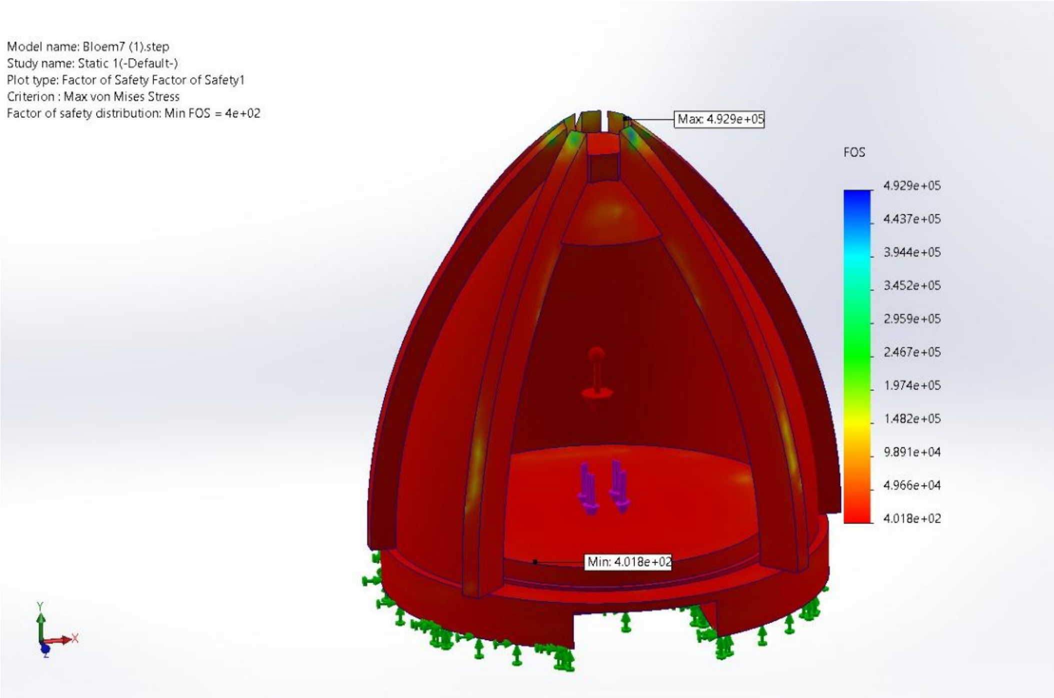

Figure E: Factor of Safety distribution under the concentrated worst-case load. Minimum FoS of 402 at the contact patch confirms structural safety under the most demanding loading scenario.