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ME 56900
5/6/2021

Project data

The following assumptions were made for the analysis and testing performed.

- Average weight of an NBA player (Curcic, 2021). W = 961.2 N
- Angle of approach of basketball (Noah, 2017). $\theta = 45°$
- Mass of a basketball (Basketball, 2021). M = 0.625 kg
- Impact Velocity of a basketball (estimated) Vi = 4.5 m/s
- Bounce Velocity of a basketball (estimated) Vf = 4.3 m/s
- Contact time (estimated) $\Delta t = 0.1$ s

Estimated calculation of applied force by basketball

The following equation represents the conservation of momentum at the level of the basketball rim when in contact with a basketball. Using the estimated velocity of a basketball before contact *Vi*, the mass *M* of the basketball, the estimated time of contact *Δt* and final basketball velocity *Vf* I deduced the value of the force exerted on the rim.

$M*Vi + \Delta t*F = M*Vf$
$F= [(M*Vf)- (M*Vi)]/ \Delta t$
$F = 0.625*(4.5+4.3)/0.1$
$F = 55$ N

Model Details

The basketball hoop assembly obtained from Grabcad required a significant amount of modification and refinement due to flaws in the original design. The most significant change was that the backboard and rim had to be replaced. A new rim from Grabcad and a newly modeled backboard were used to replace the components on the original assembly. The hooks for the net on the new rim were removed due to their small geometry and negligible impact on the rim's structure. Other modifications involved using SpaceClaim to repair and prepare the model for ANSYS meshing. The downloaded model had many duplicate and inexact edges which had to be removed.

The following images show the mesh that was used for all tests that were performed. The size of mesh that was used for the supporting structure that is located behind the backboard had an automatic meshing method and a mesh sizing of 45mm, the backboard itself had a hex-dominant method of mesh size 25 mm, and the rim had also had a hex-dominant method that had a mesh sizing of 1.5mm. The total number of elements within the mesh was a little over 250 thousand elements and the total number of nodes was just over 1 million nodes.

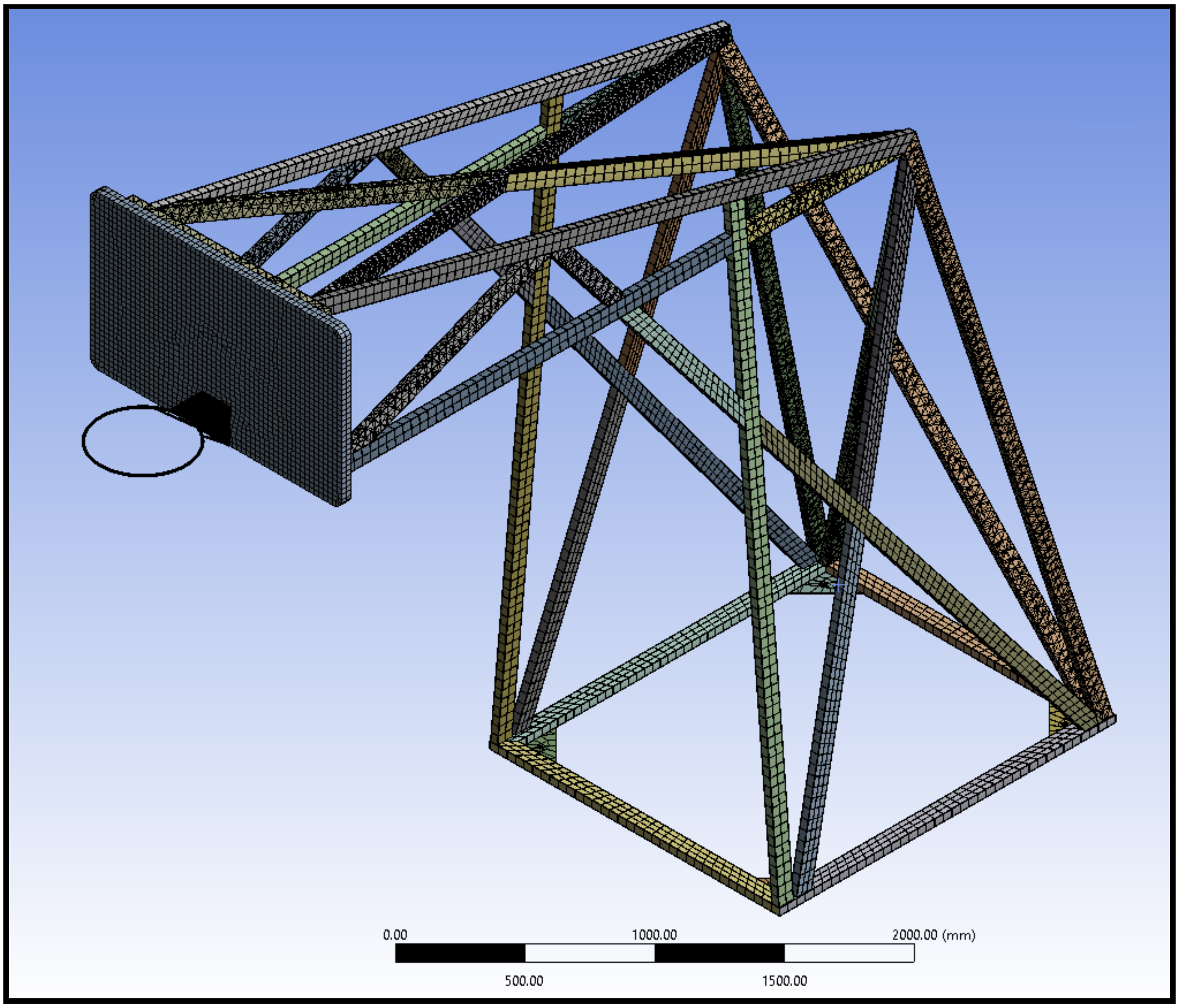

Figure 1: Total Mesh View

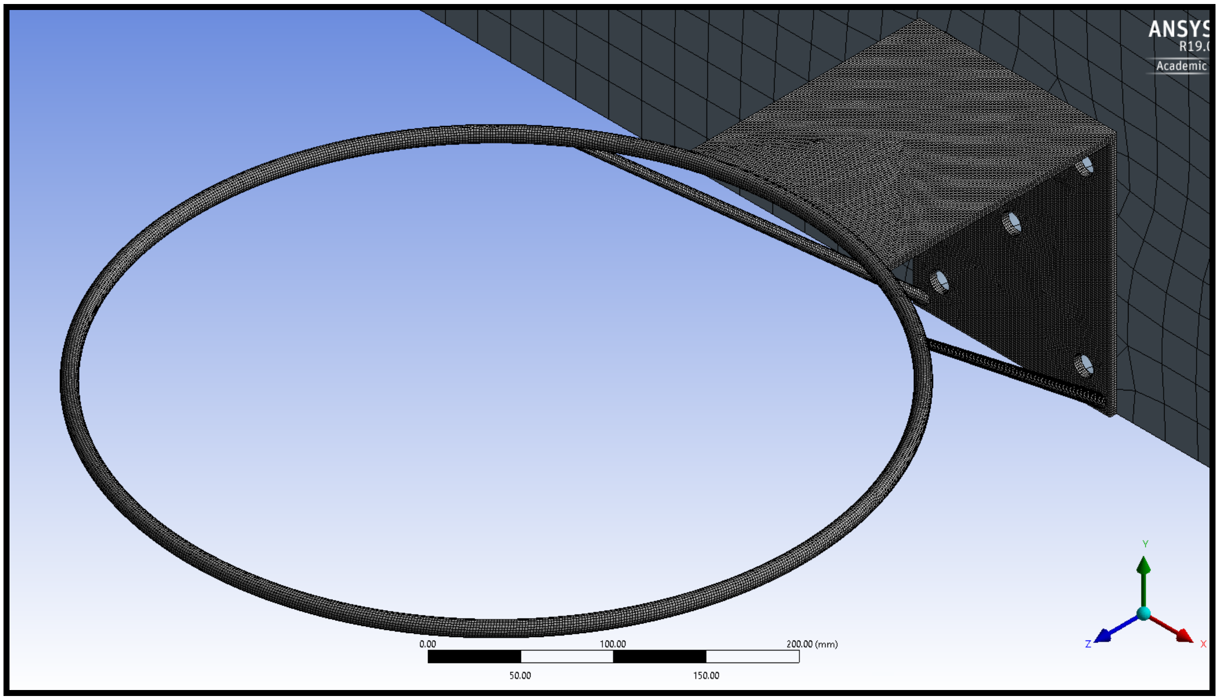

Figure 2: Rim Mesh View

Static Structural

The static structural analysis studied the effect of having an averaged sized NBA player hanging from the rim itself. The weight of the NBA player was applied as a force on the top of the rim that acted in the negative y direction.

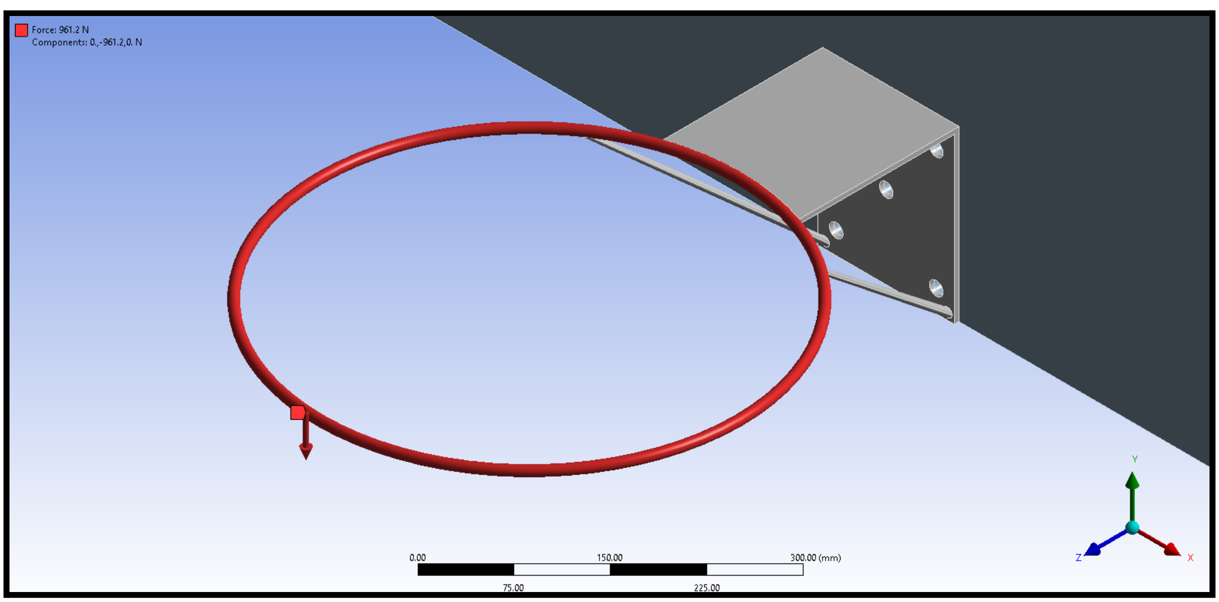

Figure 3: Force Condition

The fixed support acted at the base of support structure. The fixed supports were specifically placed on the plates that have the required holes for anchoring the structure.

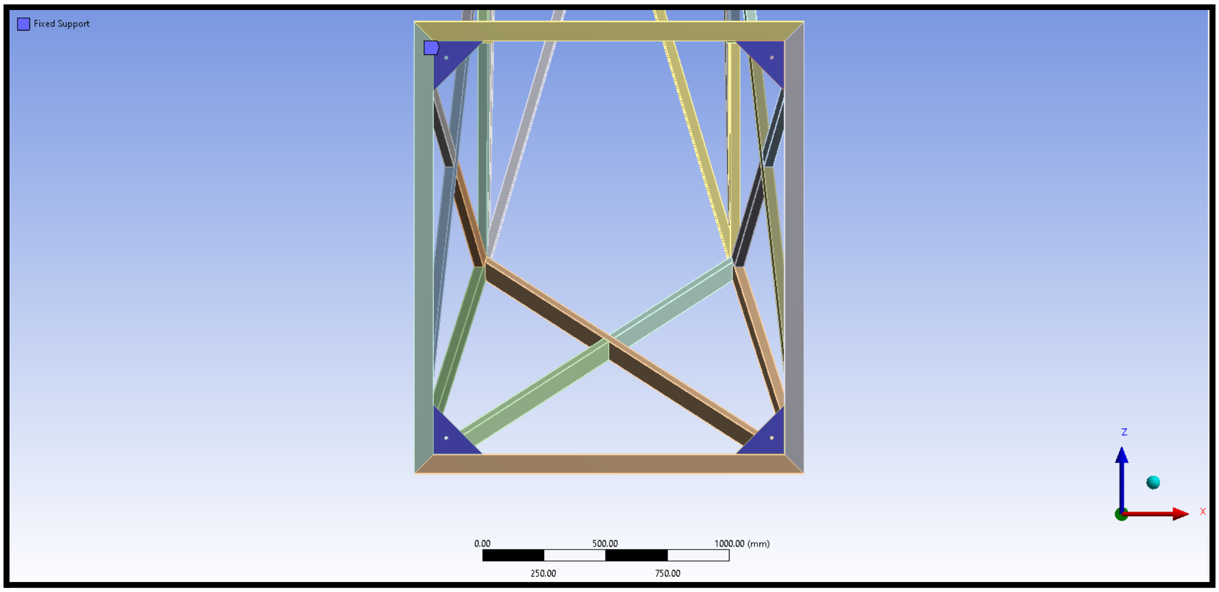

Figure 4: Fixed Support Condition

Transient Analysis

The Mode-Superposition method was used for performing a transient analysis of the basketball hoop. This method consists of doing a preliminary modal analysis in order to determine the response characteristics of the structure. For this analysis, the model was fixed at the same fmy mounting points as in the static structural analysis. These results were then passed to the transient analysis where they were used to determine the transient response of the system to an applied load of 961.2 Newtons on the rim. This load was applied in the same manner as shown in figure 3. The overall setup of the analysis with the Mode-Superposition method is shown below.

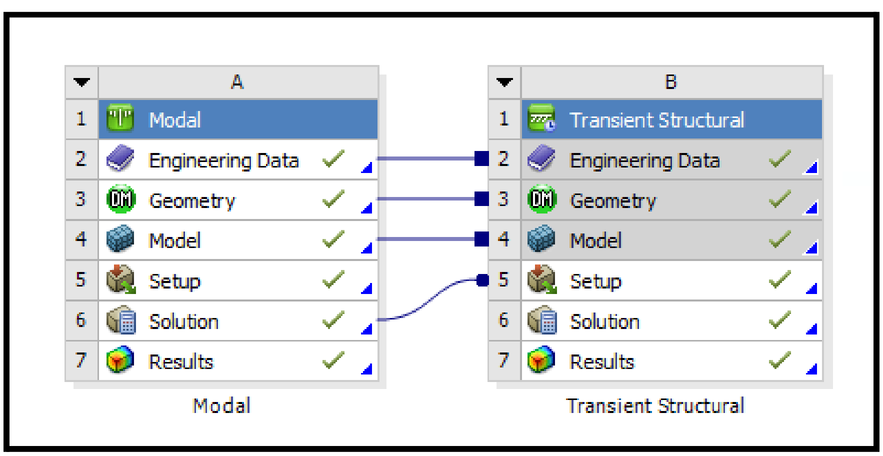

Figure 5: Transient Analysis Setup in Workbench

The only other analysis settings that had to be specified for the transient analysis were the number of substeps and the end time. At first, an end time of 1 second was used along with 500 substeps. From the results of this initial analysis, it was determined that a shorter run time would be sufficient in representing the data. A run time of 150 milliseconds was selected. Next, the simulation was run multiple times as the number of substeps was gradually reduced to ensure the results remained consistent. A final substep number of 50 was chosen. The step controls can be seen in the following figure.

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	0.15 s
Auto Time Stepping	Off
Define By	Substeps
Number Of Substeps	50.
Time Integration	On
Options	
Include Residual Vector	No
Output Controls	
Damping Controls	
Analysis Data Management	
Visibility	

Figure 5: Transient Analysis Step Control Settings

Fatigue Analysis

A fatigue analysis was done on the basketball hoop model, and its goal was to determine how long I should expect it to fail under applied loadings. The results of this analysis were obtained thanks to the alternating mean stress data available in the Ansys library for structural steel shown in Figure 1. (1998 ASME BPV code).

Table of Properties Row 13: Alternating Stress Mean Stress

	A
1	Mean Stress (Pa)
2	0
*	

	B	C
1	Cycles	Alternating Stress (Pa)
2	10	3.999E+09
3	20	2.827E+09
4	50	1.896E+09
5	100	1.413E+09
6	200	1.069E+09
7	2000	4.41E+08
8	10000	2.62E+08
9	20000	2.14E+08
10	1E+05	1.38E+08
11	2E+05	1.14E+08
12	1E+06	8.62E+07
*		

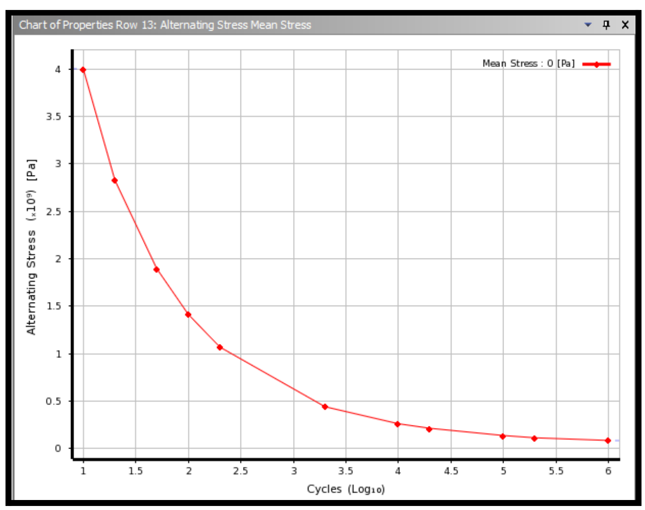

Figure 6: Alternating Stress Mean Stress Data

The design life was set to one million cycles (1*10E6.) The type of analysis is a stress life , with a mean stress theory set to the Goodman method, and Von-Mises stress as the stress component of the analysis.

The fatigue analysis results I was specifically looking for are the minimum fatigue life cycle, the safety factor across my model parts, the damage, biaxiality indication and fatigue sensitivity of my overall model.

Additional figures and plots

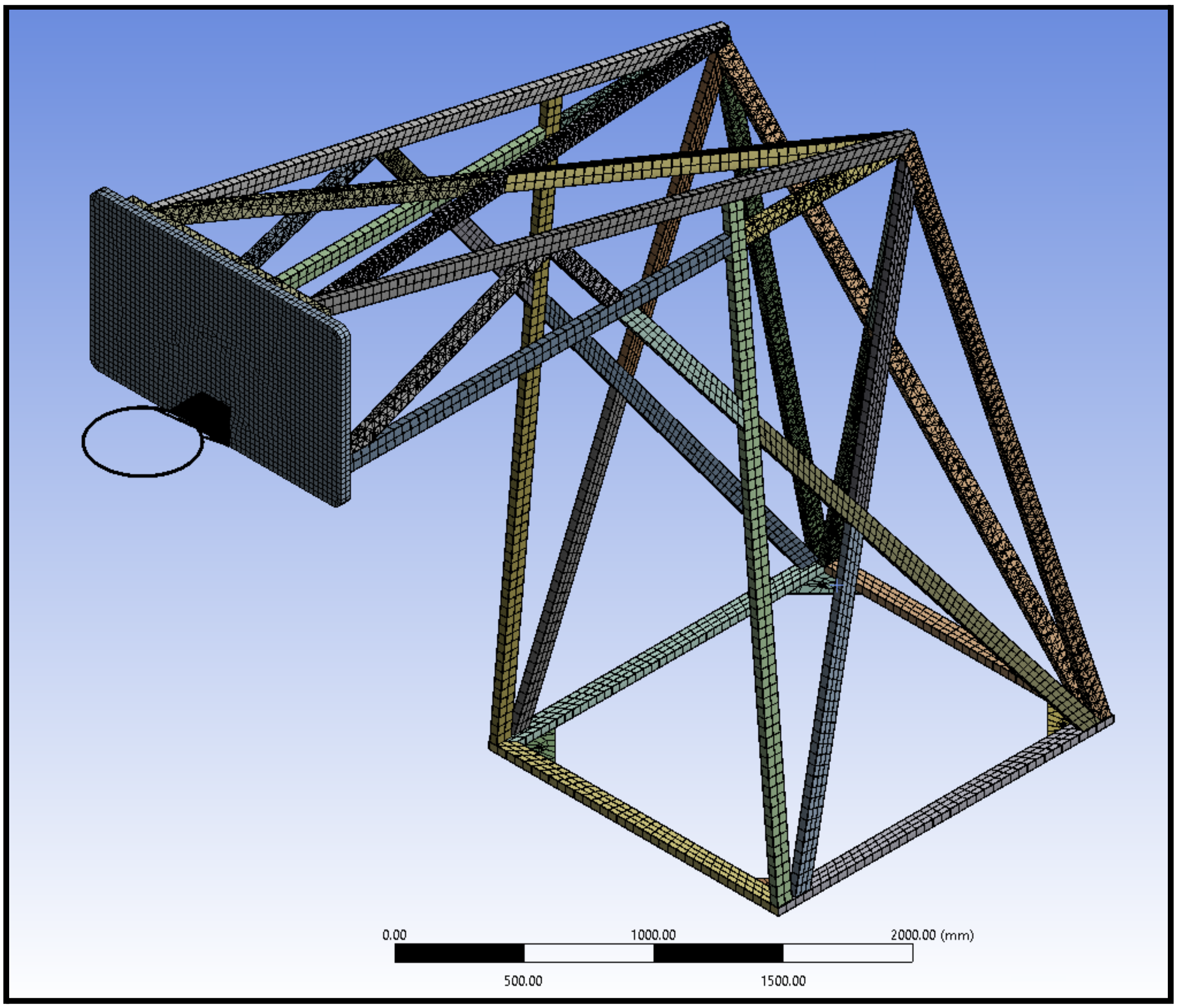

Figure 1: Total Mesh View

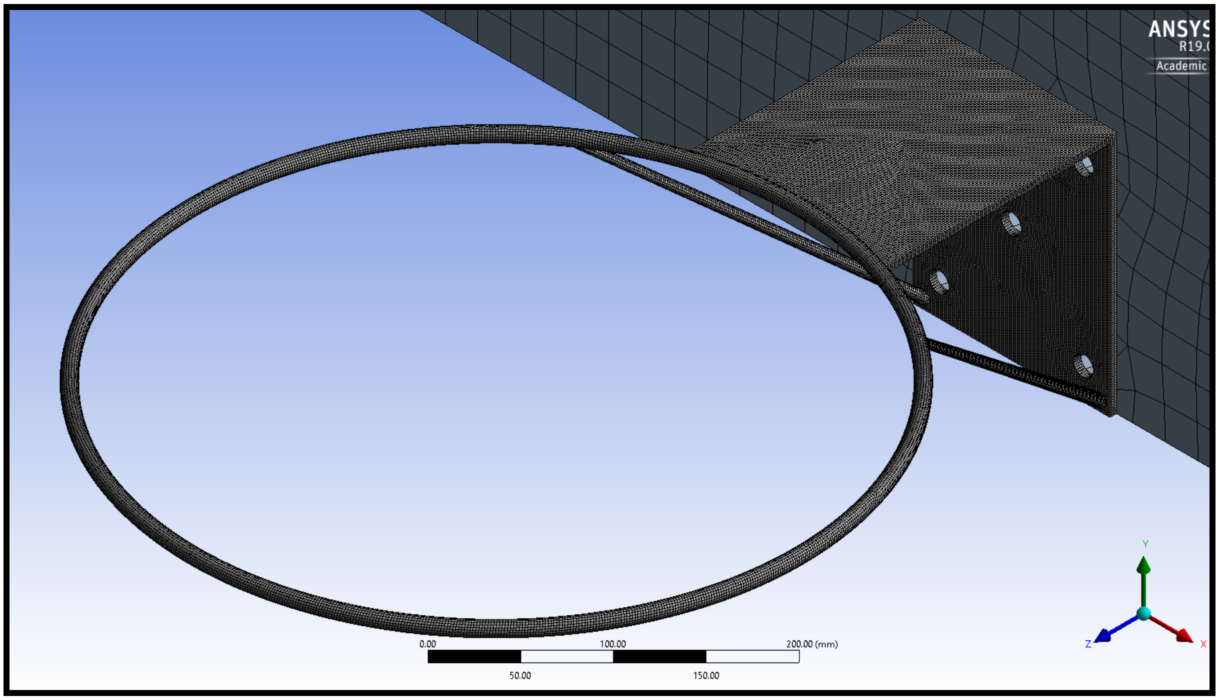

Figure 2: Rim Mesh View

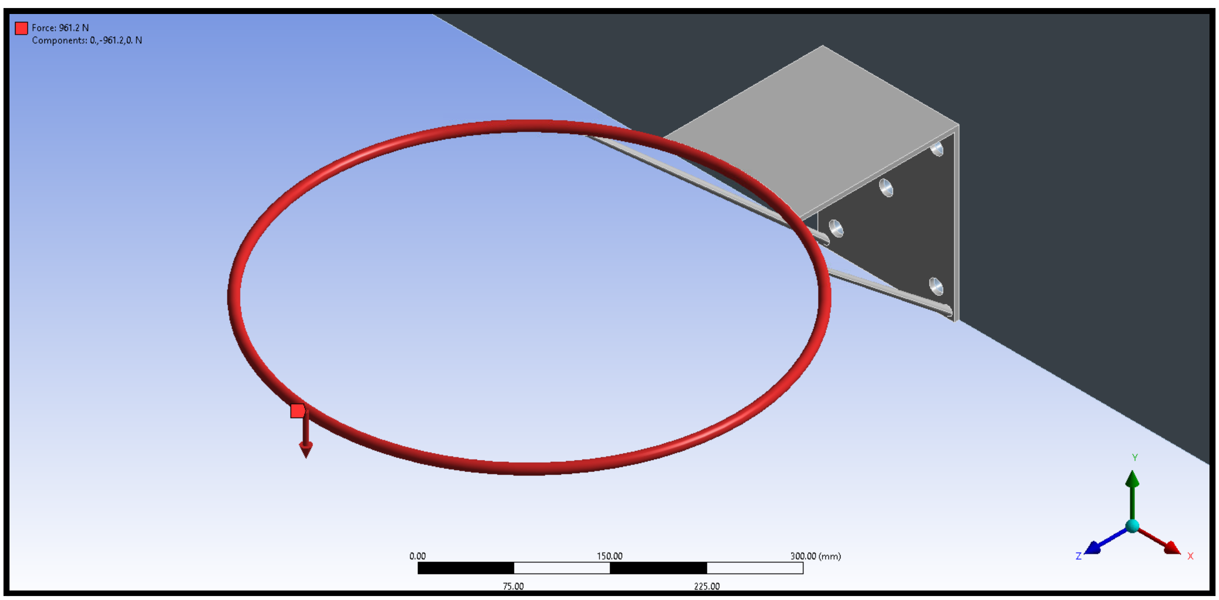

Figure 3: Force Condition

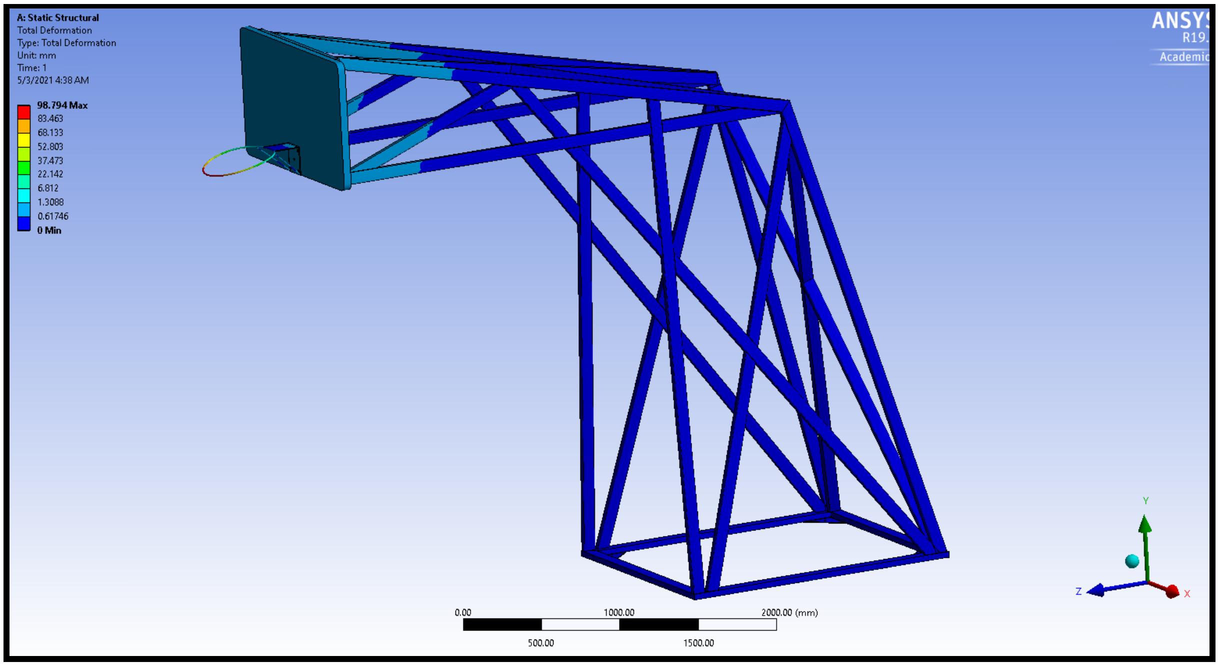

Figure 4: Total Displacement

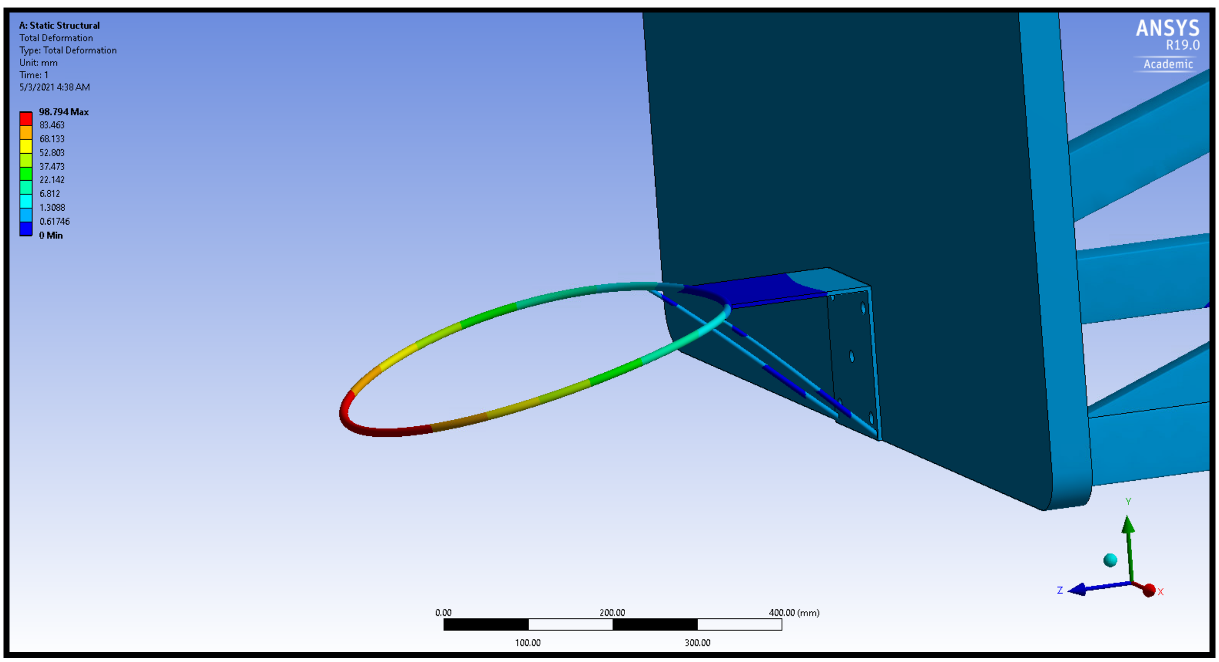

Figure 5: Rim Total Displacement

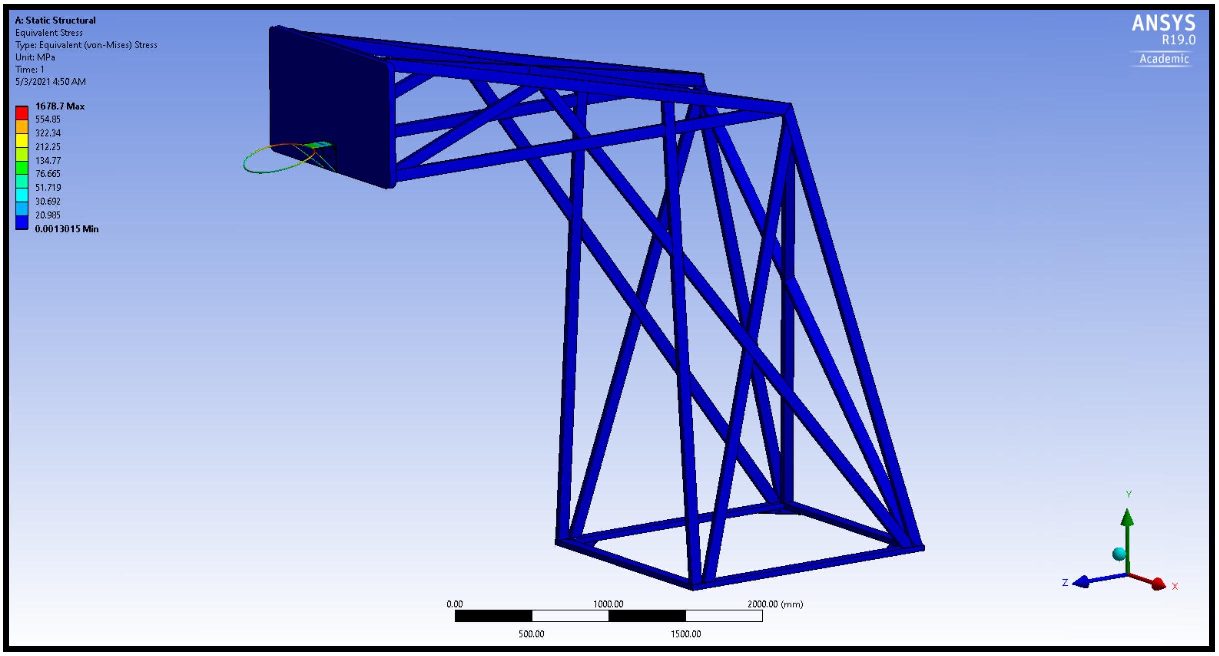

Figure 6: Equivalent Stress

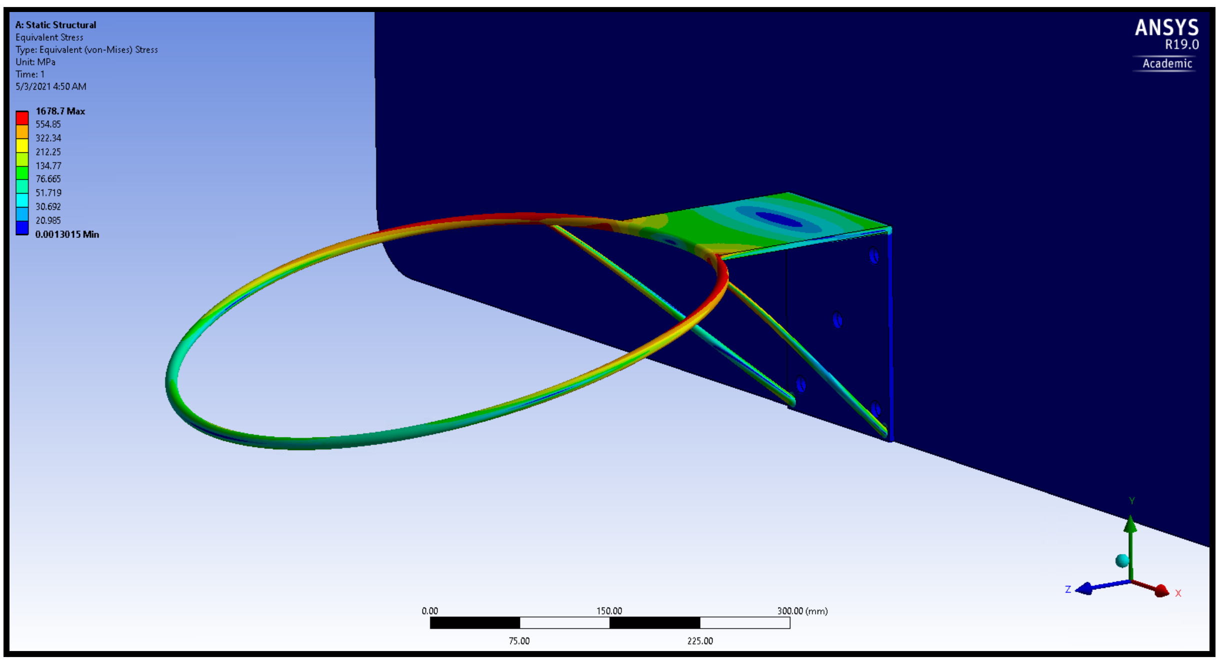

Figure 7: Rim Equivalent Stress

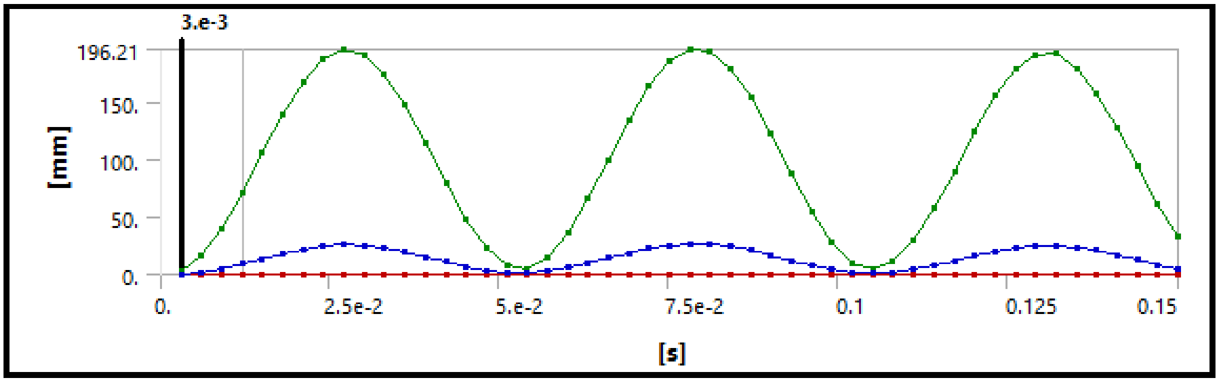

Figure 8: Transient Response Plot of Total Deformation

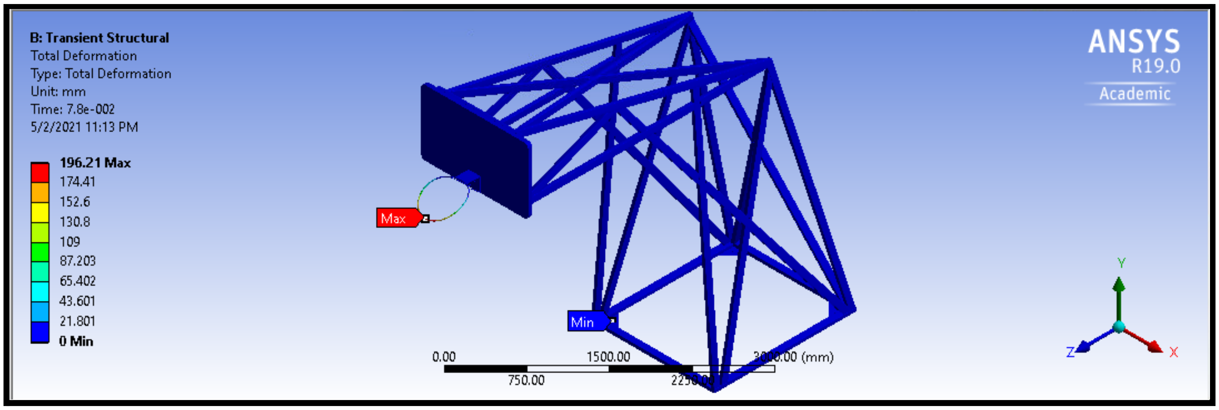

Figure 9: Transient Analysis Total Deformation

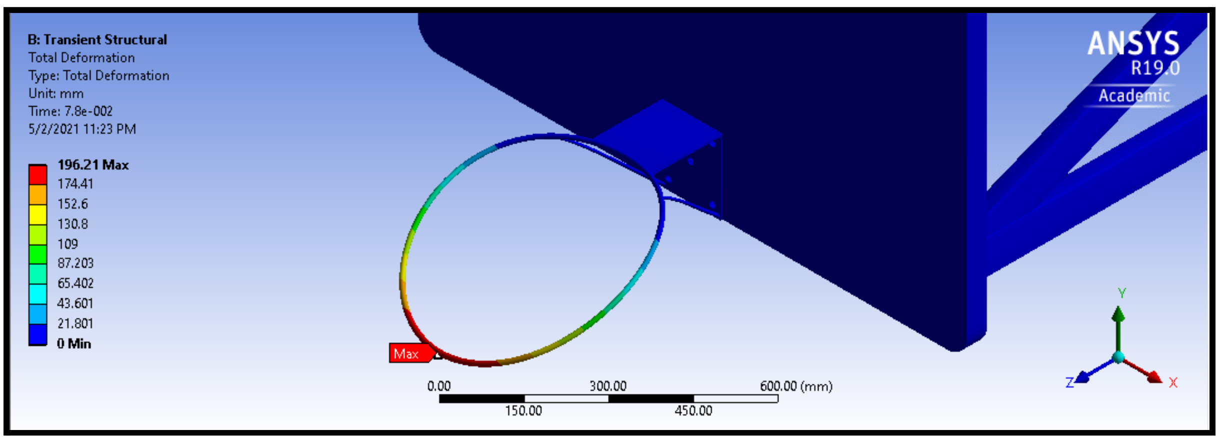

Figure 10: Transient Analysis Total Deformation on the Rim

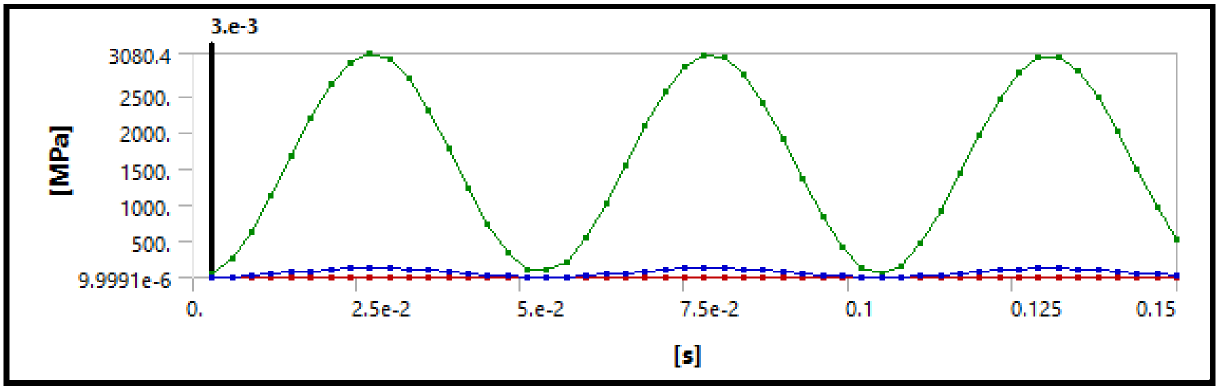

Figure 11: Transient Response Plot of Equivalent Stress

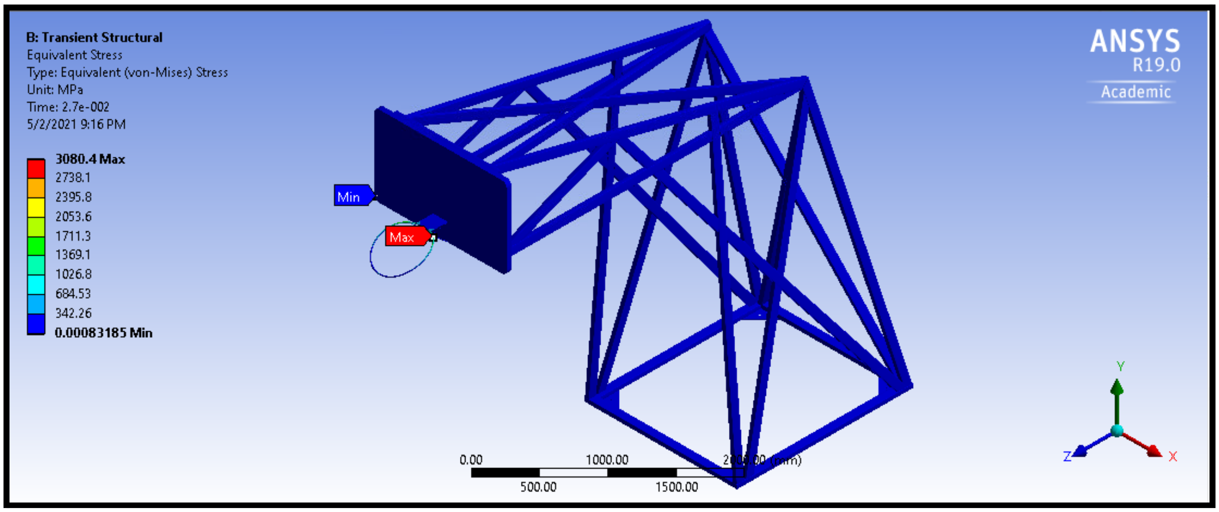

Figure 12: Transient Analysis Equivalent Stress

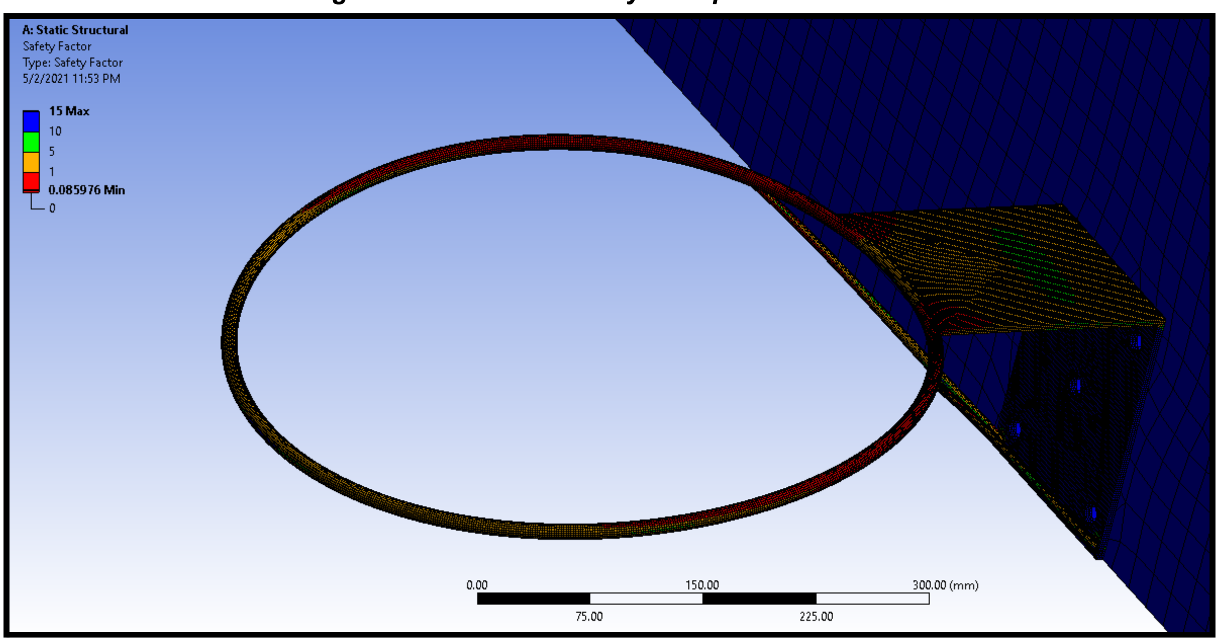

Figure 13: Safety factor result case 1 (dunk)

References

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