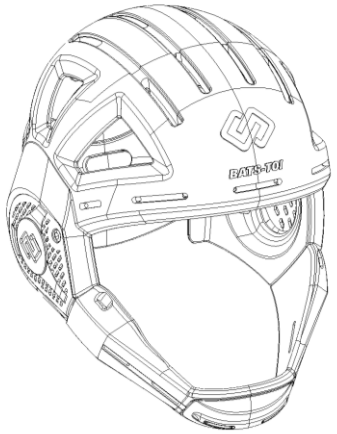
Simulations Review Presentation

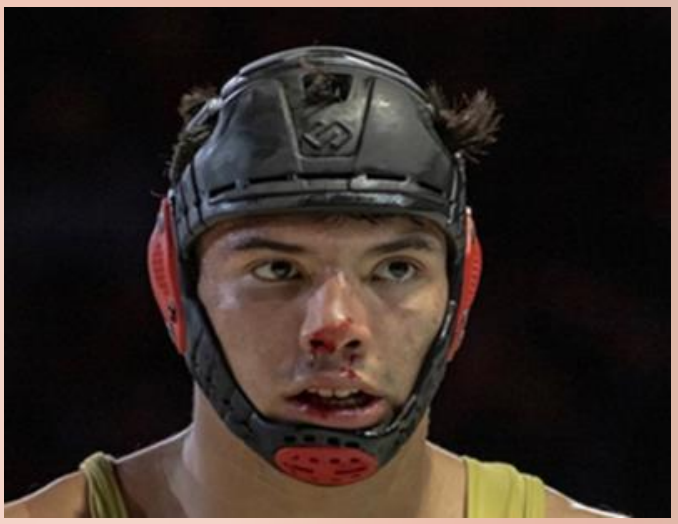
BATS-TOI



THE MERCADO® Headgear

Outline

1. Executive Summary
2. Updated Budget
3. Updated Schedule
4. Design overview
    1. Design selection
    2. Materials
    3. Boundary Conditions
5. Design Simulations (SW)
    1. Impact
        1. Assumptions
        2. Test
        3. Results
    2. Thermal
        1. Assumptions
        2. Test
        3. Results
6. Conclusion



Executive Summary

Design

a new wrestling head-gear

to protect

wrestlers against potential head and facial injuries, while being breathable, light, fitted, comfortable, yet durable in design.

Schedule

Past

- Headgear Design
- Simulations
- 3D Print

Present

- Finalize Lab Testing Procedures
- Finalize Materials
- Iterate and Finalize Design

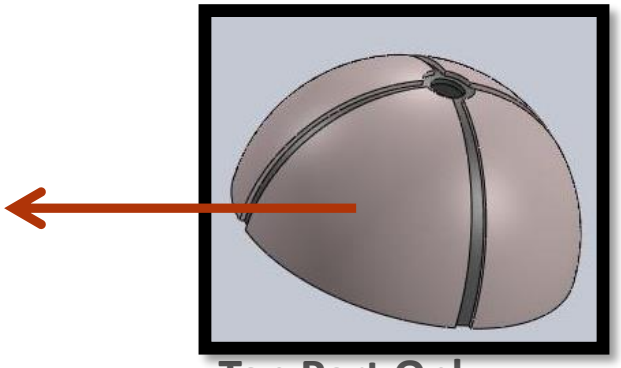
Future

- 3D print of Finalized Design
- Test Model in Lab

Design Overview

Design Selection; Top of the Headgear

Entire Headgear



Top Part Only

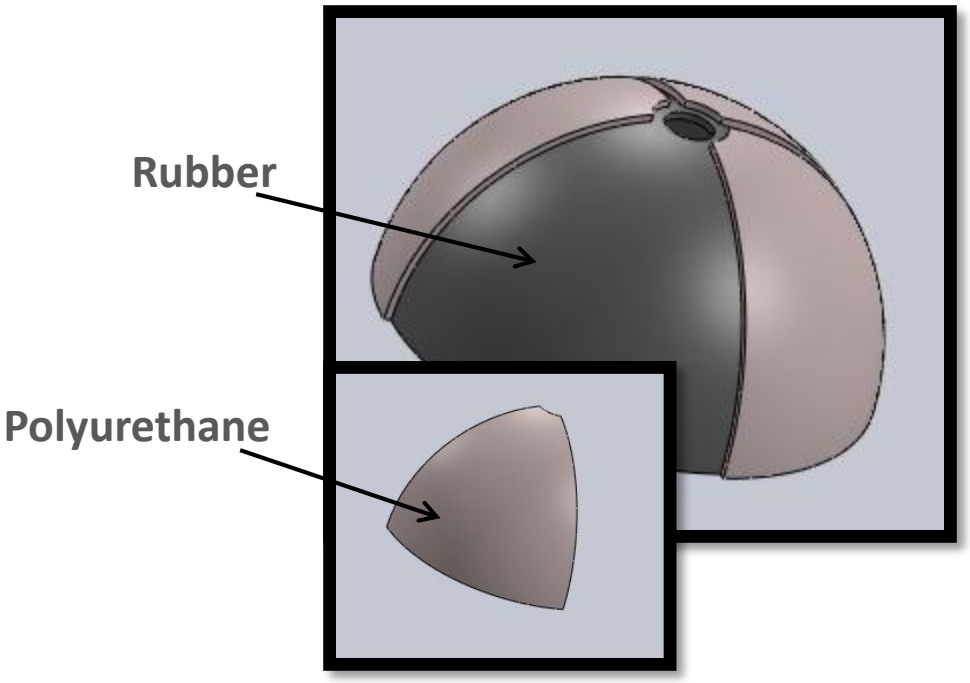
- **Why only the top?**
  - Head trauma risks - Top-of-head impacts have a higher risk of head trauma than impacts to the front, right, or back of the head (Guskiewicz et al. 2007)
  - Hyperthermia risks - Top-of-head and trunk have been demonstrated on thermography to have the most rapid heat loss (Gabrys et al, 1993)

Design Overview

Material Properties

Rubber:
- Elastic Modulus: 450GPa
- Poisson's Ratio: 0.15
- Mass Density: 2.8Mg/m^3
- Thermal Expansion: 4.2µ/C°
- Thermal Conductivity: 120 W/mK

Polyurethane:
- Elastic Modulus: 0.025GPa
- Poisson's Ratio: 0.39
- Mass Density: 1.2Mg/m^3
- Thermal Expansion: 125µ/C°
- Thermal Conductivity: 0.02W/mK



Values taken from MIT's Mechanical Properties Table

Simulations

The Force

- G-Force of 95
  - The minimal allowed impact to the head before fear of concussion

- Max G-force by weight class

$$W = \int F \cdot ds = Fd\cos\theta \quad \textbf{Equation 1}$$

$$Work = Potential\ energy + Kinetic\ energy$$

$$W = mgh + \frac{1}{2}mv^2 \quad \textbf{Equation 2}$$

- High School weight classes (lbs) with the average height per weight class (feet)
  106, 113: 5.2
  120, 126, 132: 5.5
  138, 145, 152: 5.8
  160, 170, 182: 5.11
  195, 220, 285: 6.1

***These weight classes are for high school (only)**

Simulations

The Force

Therefore using the heaviest and tallest wrestlers' values:

$$h = 6.1ft$$

$$m = 285lb$$

Average time a wrestler lifts and drops his/her opponent is about 2 seconds.

Using t=2s and the distance to be the height of the wrestler who is, h-6.1ft gives:

$$v = \frac{6.1}{2} = 3.05\frac{ft}{s}$$

Therefore plugging into Equation 2

$$W = 285 \times 32.2 \times 6.1 + \frac{1}{2} \times 285 \times 3.05^2 = 55{,}979 + 1325 = 57{,}304\ ft \cdot lb_f$$

Now using Equation 1

$$F = \frac{W}{d} = \frac{57{,}304}{6.1} = 9394\ lb_f$$

This seems like a big number, but when converted to Gs:

9394lbf which is 292Gs or 1298N

Sanity check: Purude research on football head trauma found football players sustain 289 Gs
For comparison, the average g-force experienced by military fighter pilots is 9 Gs

Design Overview

Boundary Conditions

Force:

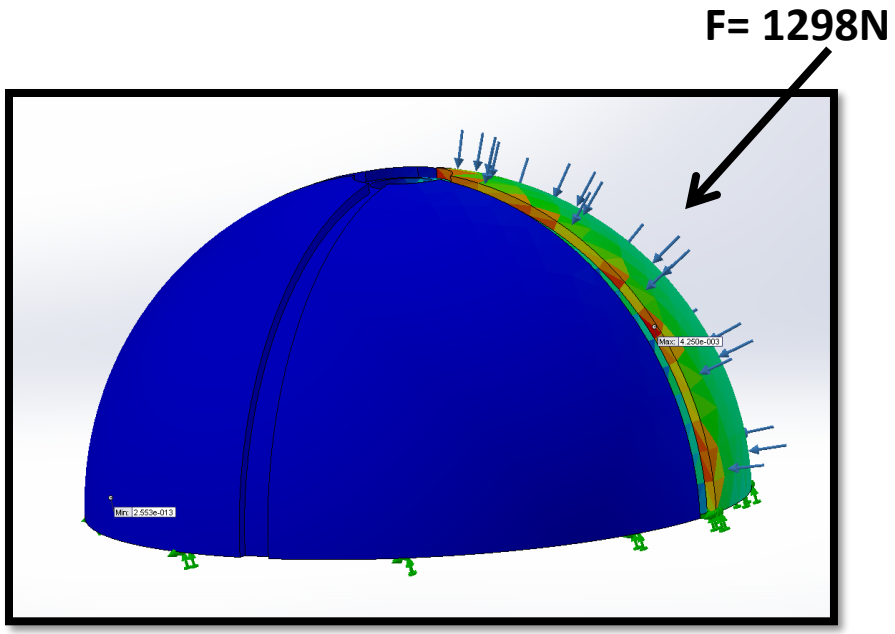
- F=1298N
- Applied on face of front wedge
- Limits: Minimum 0N, Maximum 1298N

Fixed Boundaries

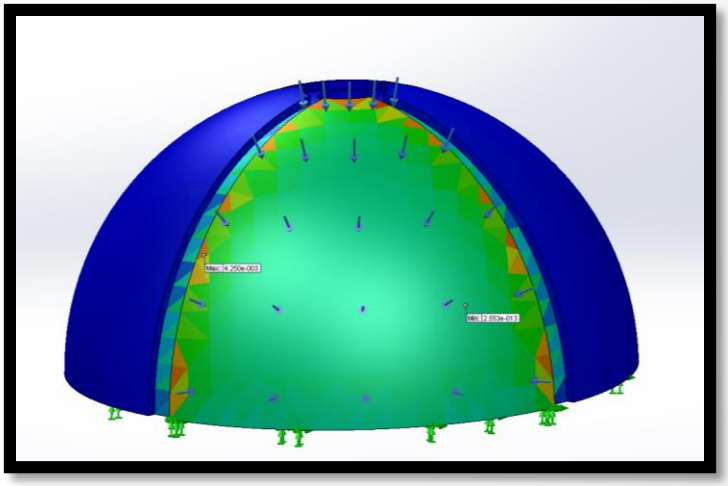
- Fixed inner shell
- No penetration of wedge

Temperature:

- Ambient: 25°C ~ 298K
- Head: 40°C ~ 313K
  - Worst Case
- Limits: Minimum 25°C, Maximum 40°C

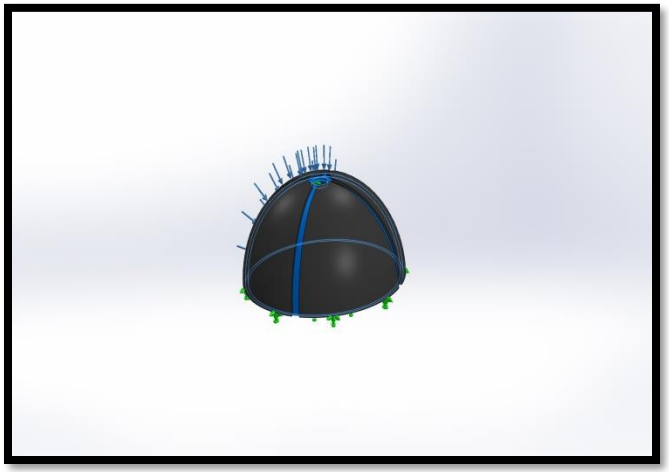


Impact Simulation



Simulations

1. Impact



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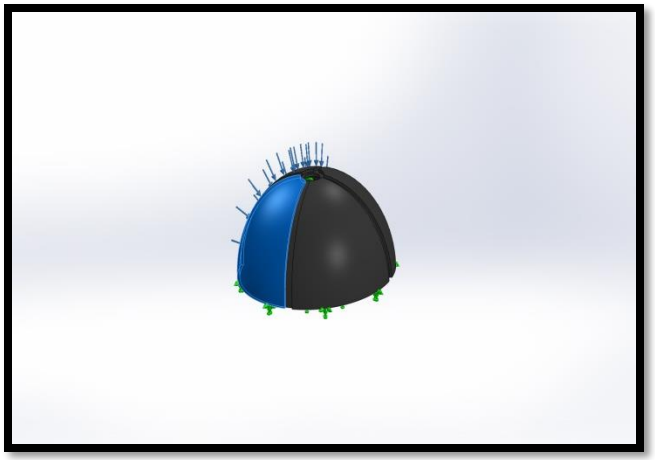


Simulations

1. Impact

The minimal allowed impact to the head before fear of concussion is 95Gs

Weight (kg)	Max Theoretical Stress (N/m^2)	Concussion Limit 95Gs to (N/m^2)
48.1	20473.49	13393.67
51.3	21825.51	14278.16
54.4	23203.99	15162.65
57.2	24364.19	15920.78
59.9	25524.39	16678.91
62.6	26715.02	17437.04
65.8	28070.13	18321.53
68.9	29425.24	19206.02
72.6	30892.80	20216.86
77.1	32823.60	21480.41
82.6	35140.56	22996.68
88.5	37792.48	24639.30
99.8	42637.67	27798.18
129.3	55235.16	36011.28

Without Headgear

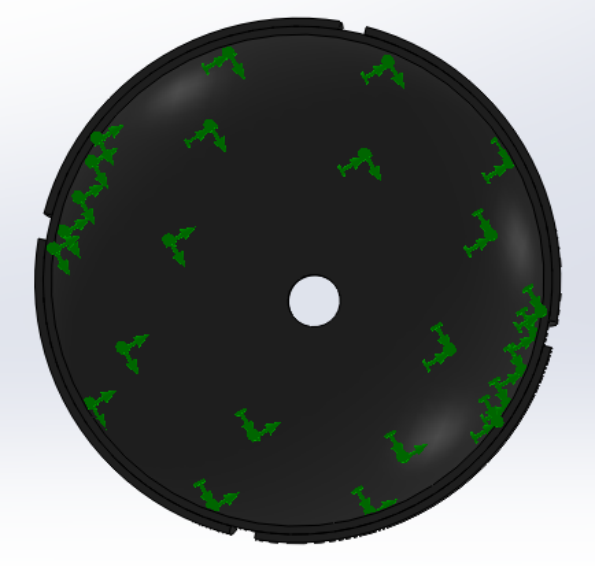
*These weight classes are for high school (only)

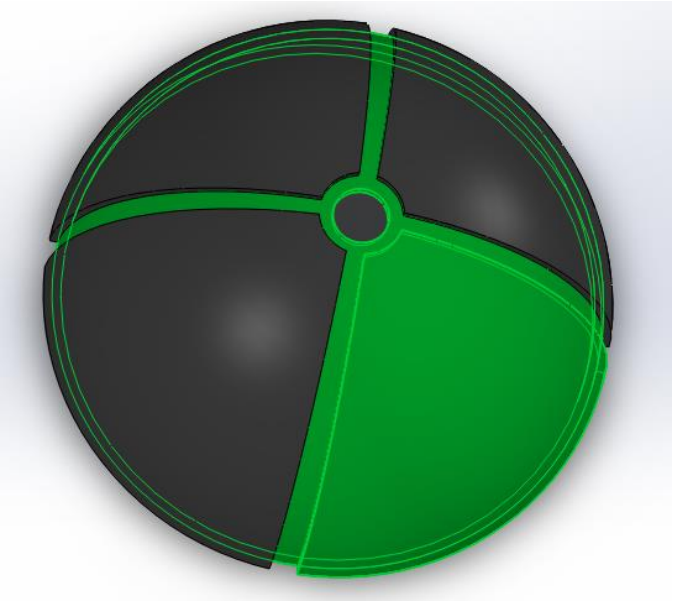
Simulations

1. Impact

Boundary Conditions:

- Inner shell is set as a fixed geometry
- No penetration allowed between wedge and inside shell





Simulations

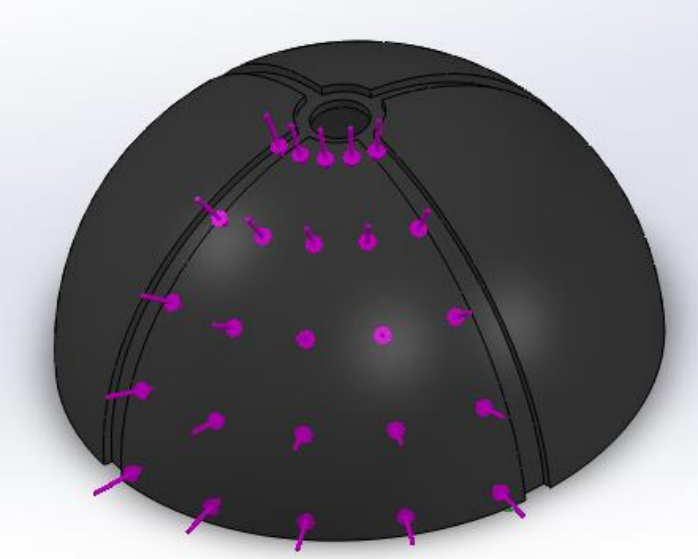
1. Impact

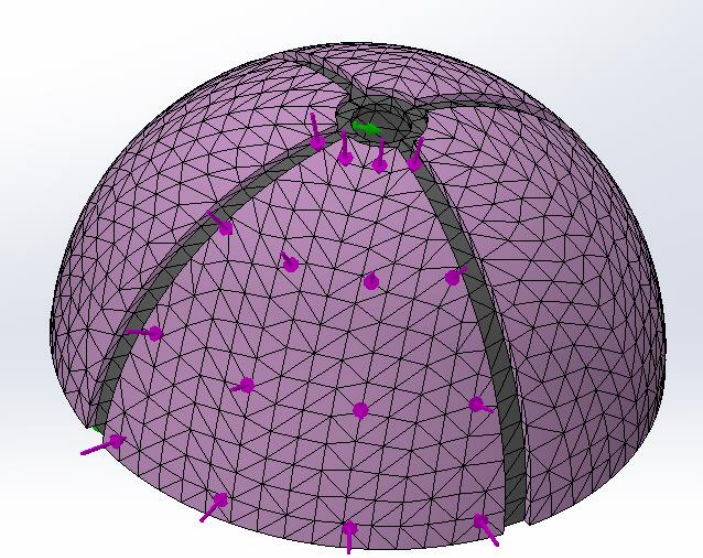
- Maximum stress applied is 55,235N/m^2
- Limit: maximum Impact stress before head trauma was calculated to be 36,011N/m^2 (95Gs)
- The desired result is to keep the impact experienced below this value
- The simulation is performed for four different forces (per weight class): 1298N, 1002N, 888N, 826N

Simulations

1. Impact

- The impact force is applied to the front wedge of the headgear
- The model is then meshed to get the most accurate results



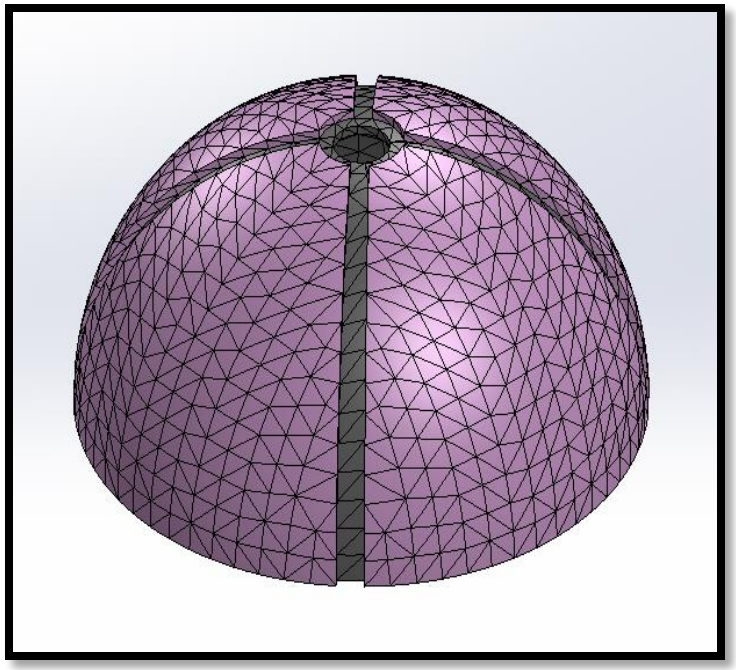


Simulations

2. Impact

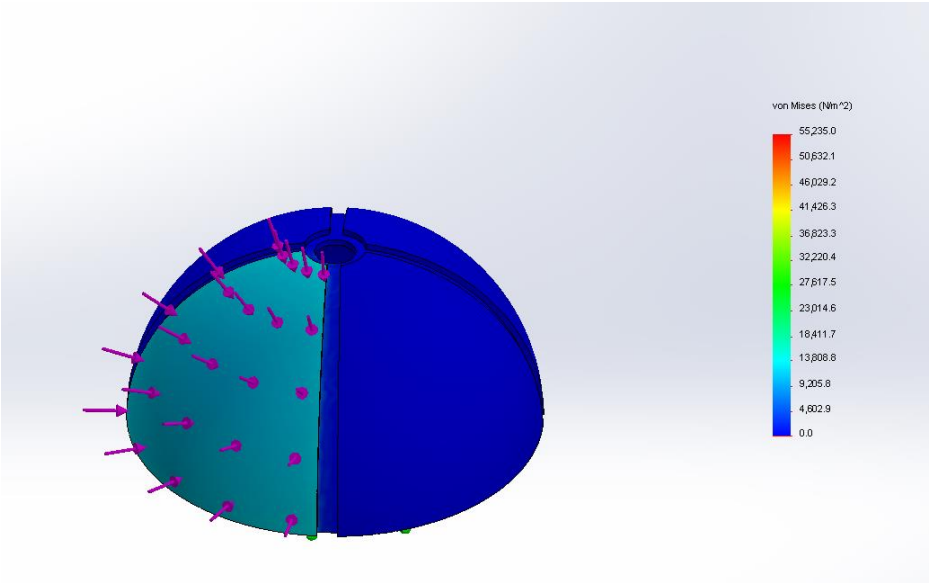
Meshing

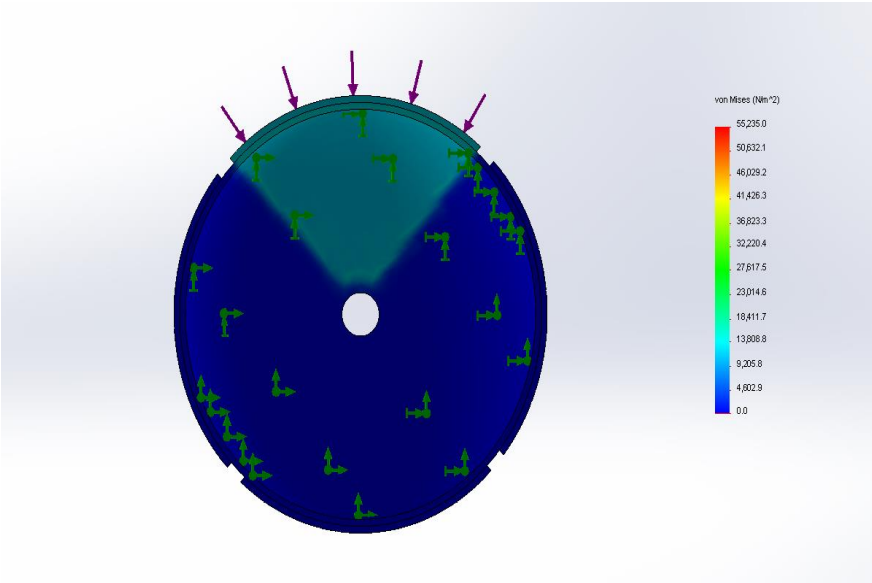
- Type: **Solid Mesh**
- Element Size: **0.239 in**
- # of Elements: **29576**
- # of Nodes: **53134**



Simulation Impact

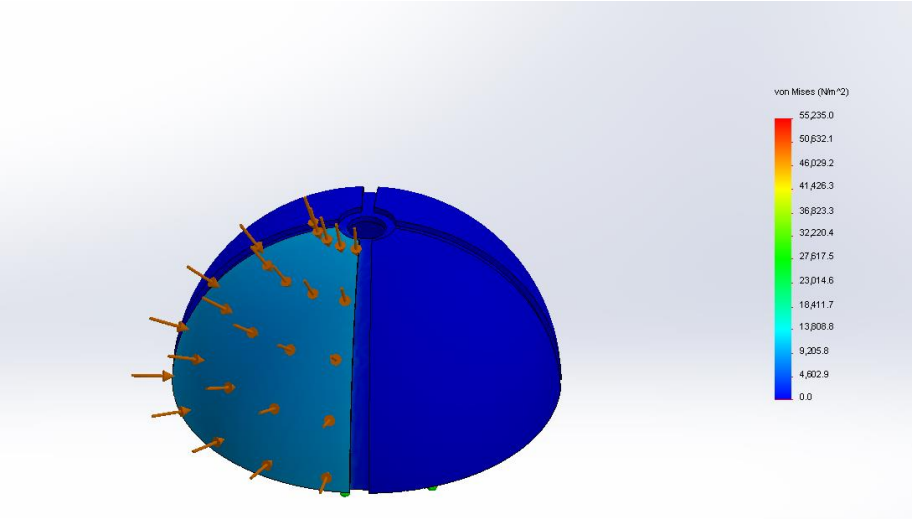
- The Simulation is then run
- For a force of 1298 N

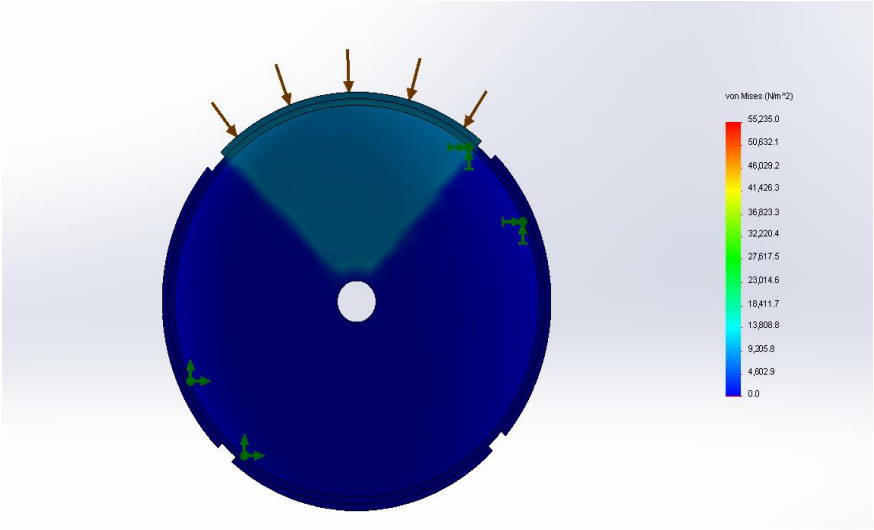




Simulation-Impact

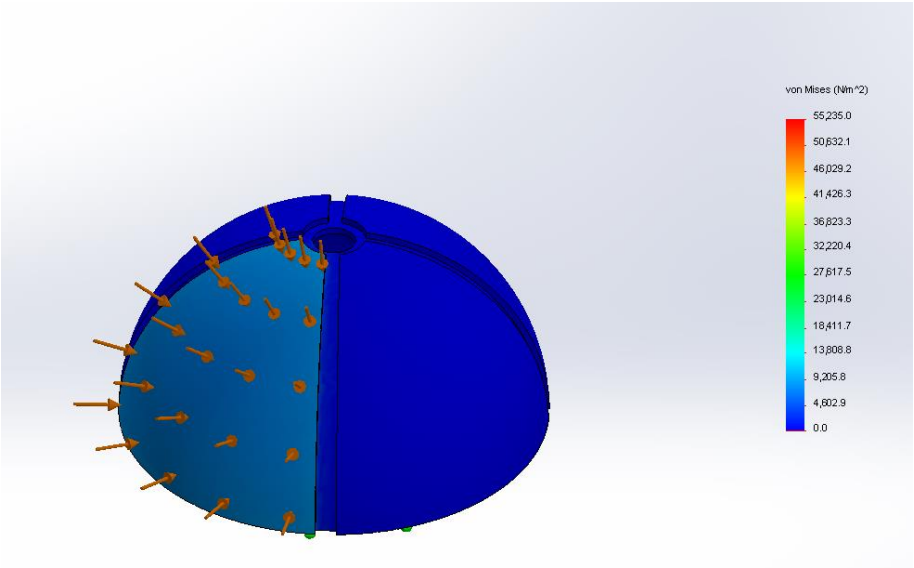
- For a force of 1002N

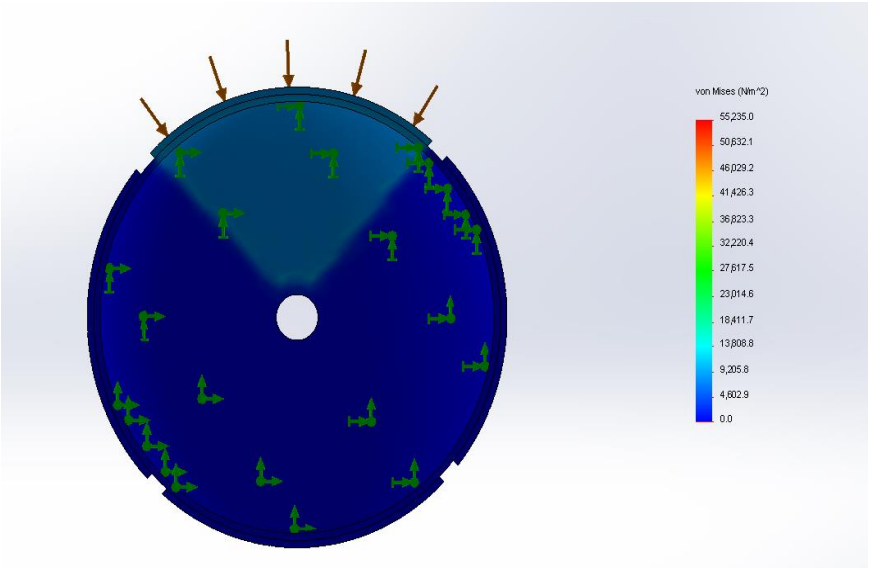




Simulation-Impact

- For a force of 888N

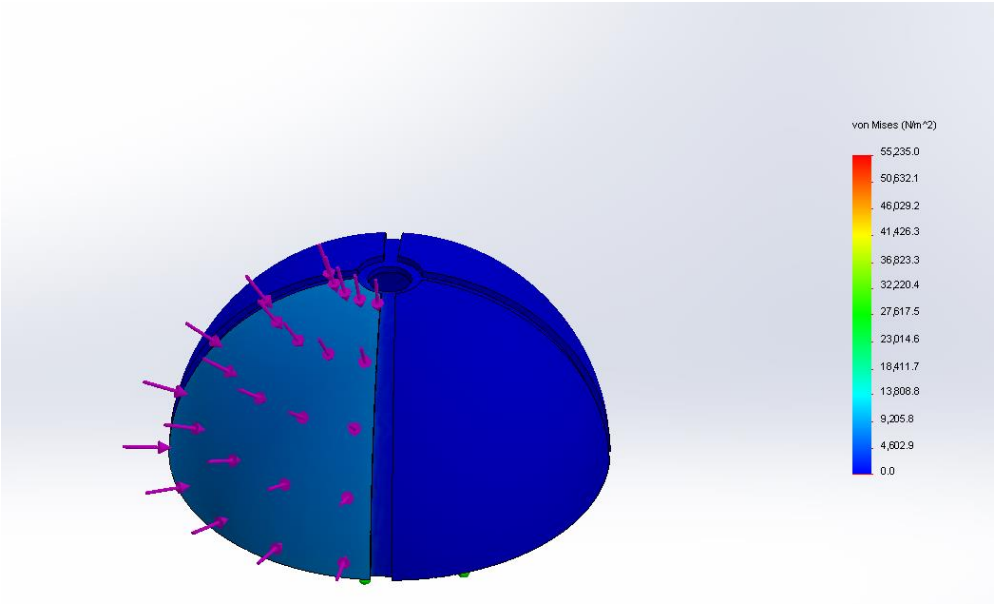


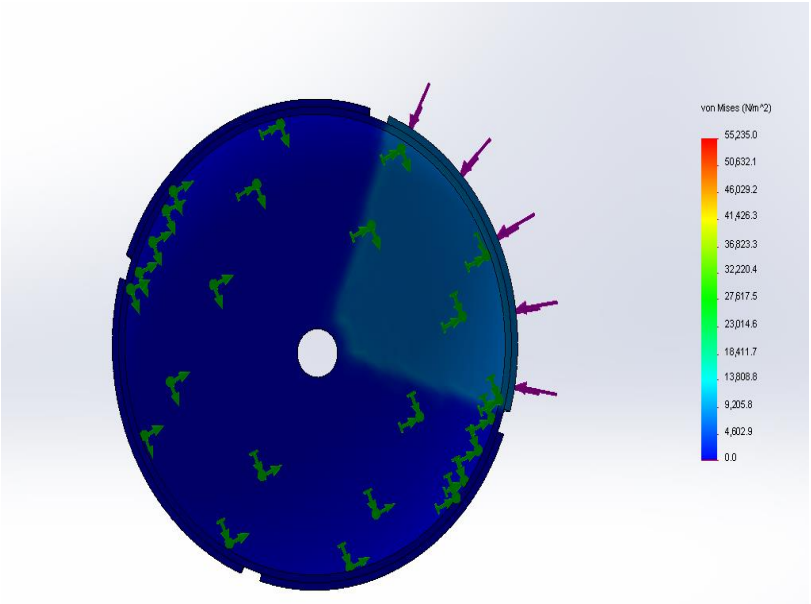


Simulations

1. Impact

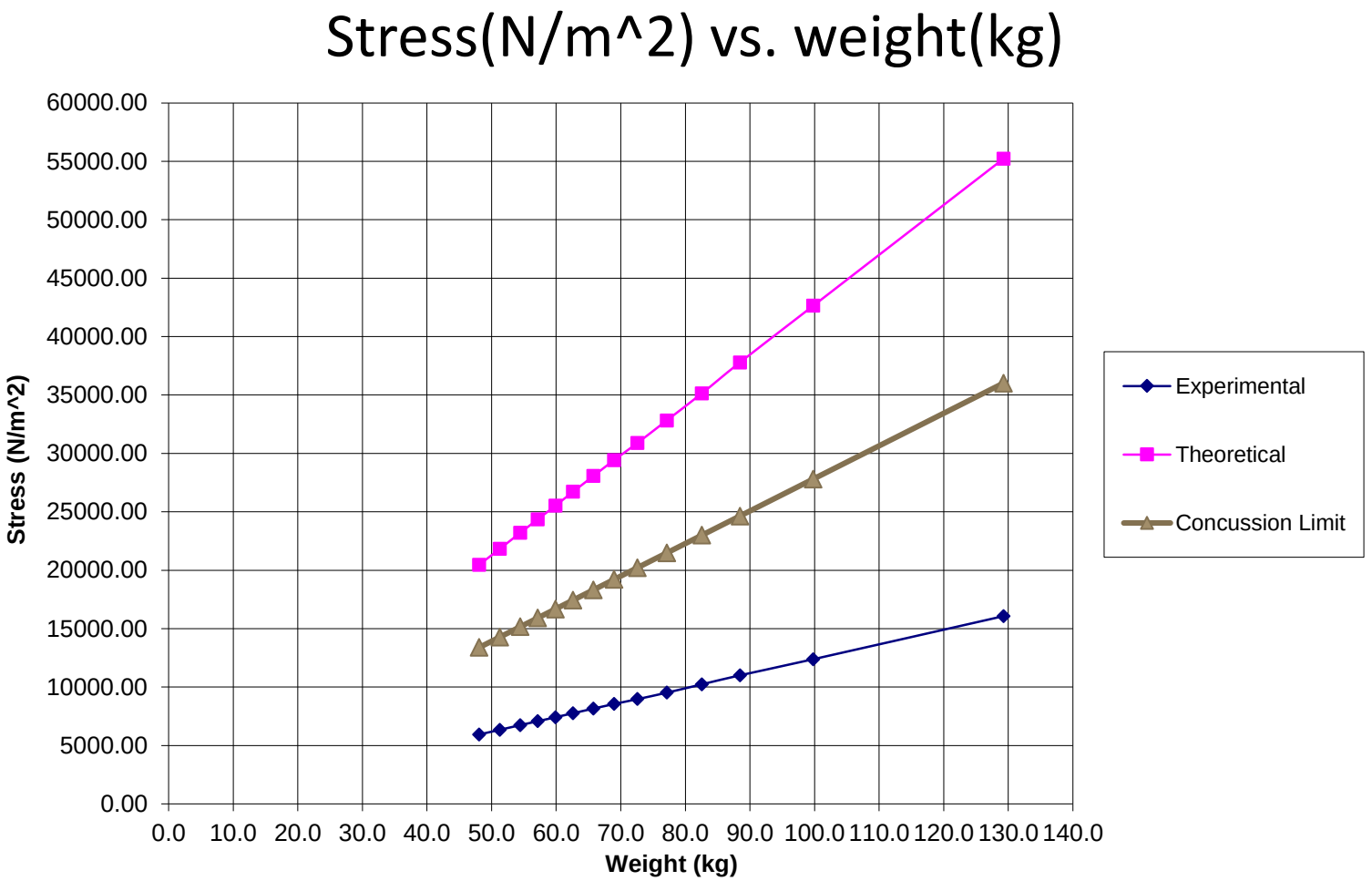
- For a force of 826N





Simulations

1. Impact



Simulations

1. Impact

With the headgear the impact stress is well below the limit for head trauma (95Gs)

Weight (kg)	Max Theoretical Stress (N/m^2)	Concussion Limit 95Gs to (N/m^2)	Experimental Stress (N/m^2)
48.1	20473.49	13393.67	5951.96
51.3	21825.51	14278.16	6348.39
54.4	23203.99	15162.65	6750.33
57.2	24364.19	15920.78	7086.19
59.9	25524.39	16678.91	7422.06
62.6	26715.02	17437.04	7768.93
65.8	28070.13	18321.53	8165.36
68.9	29425.24	19206.02	8556.29
72.6	30892.80	20216.86	8974.74
77.1	32823.60	21480.41	9525.34
82.6	35140.56	22996.68	10241.10
88.5	37792.48	24639.30	11012.00
99.8	42637.67	27798.18	12388.40
129.3	55235.16	36011.28	16077.50

*These weight classes are for high school (only)

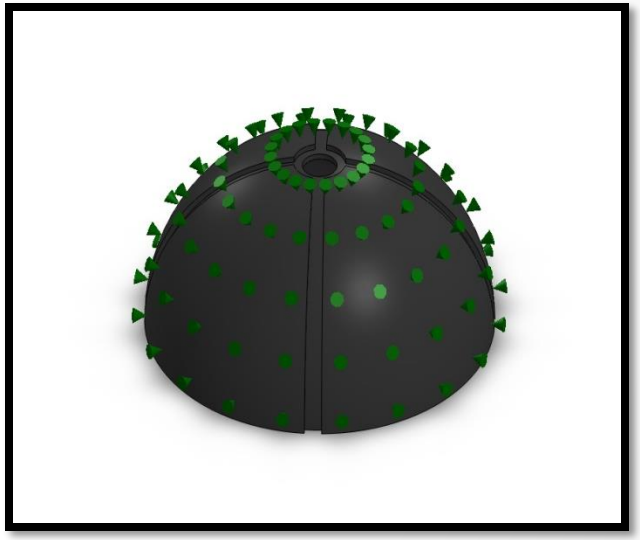
Simulations

1. Impact

Results

- The experimental line is below the theoretical
- For every weight class our headgear protects against head trauma (95G) with the smallest difference being 14,500 N/m^2 with the largest being about 40,000 N/m^2
- The materials we chose and the geometry are working and help to protect against head trauma

Thermal Simulation



Simulations

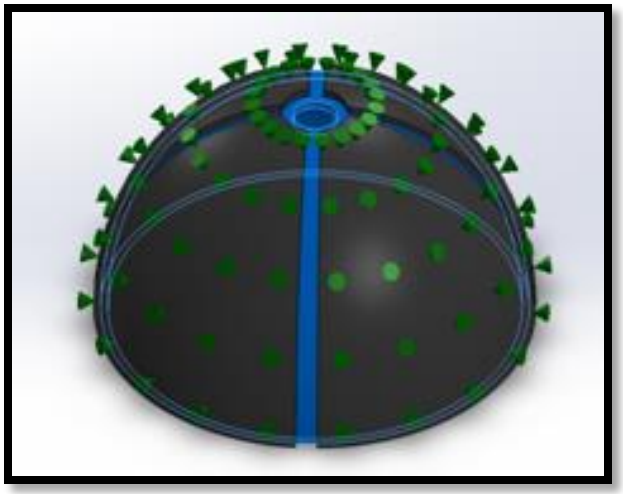
2. Thermal

Assumptions

- Convection
  - Headgear and Outside Air
  - Headgear and Wrestler's Head
- Temperature Gradient
  - Headgear and Wrestler's Head
- Hair Insulation
  - Not considered

Simulations

2. Thermal



Rubber:
- Elastic Modulus: 450GPa
- Poisson's Ratio: 0.15
- Mass Density: 2.8Mg/m3
- Thermal Expansion: 4.2µ/C°
- Thermal Conductivity: 120 W/mK

Polyurethane:
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- Poisson's Ratio: 0.39
- Mass Density: 1.2Mg/m3
- Thermal Expansion: 125µ/C°
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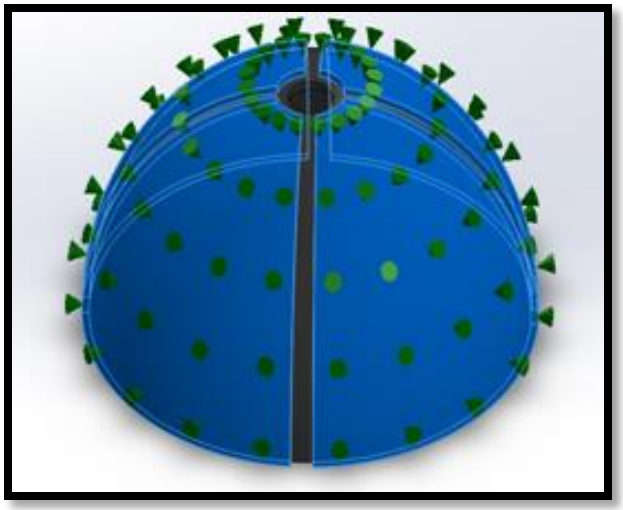
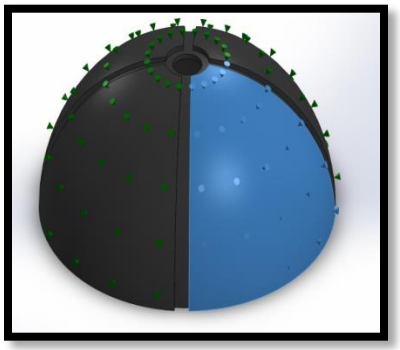


Simulations

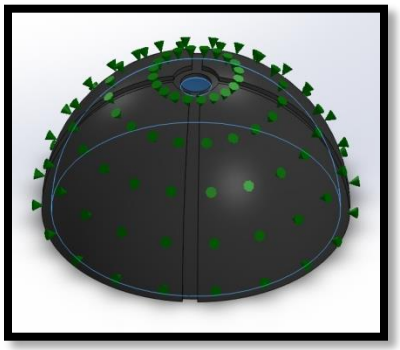
2. Thermal

Analysis Conditions

- Convection applied on 4 wedges
  - h = 0.352 W/m²K
  - T = 298 K (25°C)



- Convection applied on Flexible Layer
  - h = 119,512 W/m²K
  - T = 313 K (40°C)



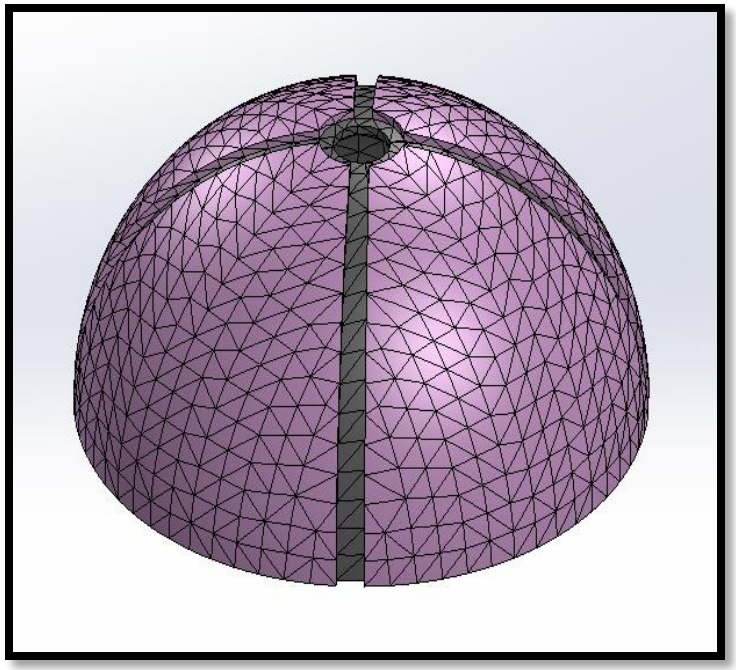
- Thickness is 0.16 in or 0.0041m

Simulations

2. Thermal

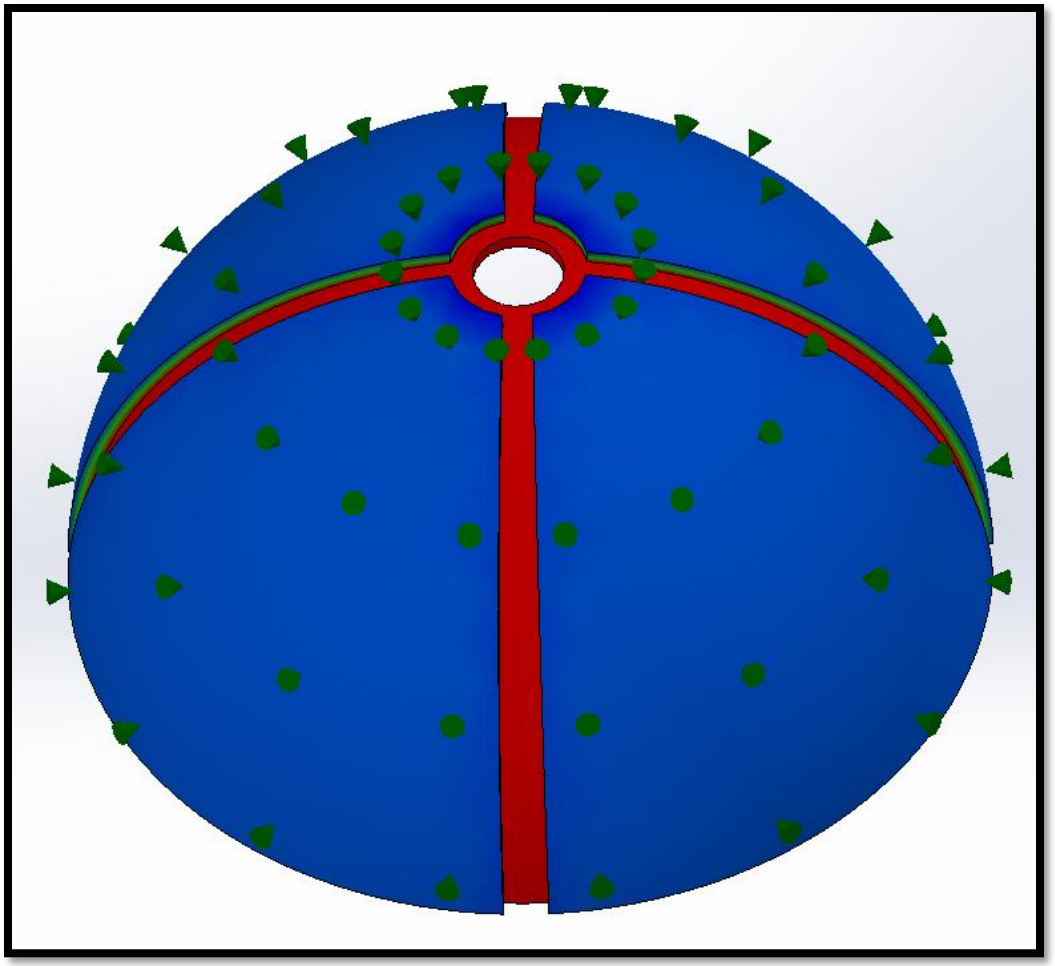
Meshing

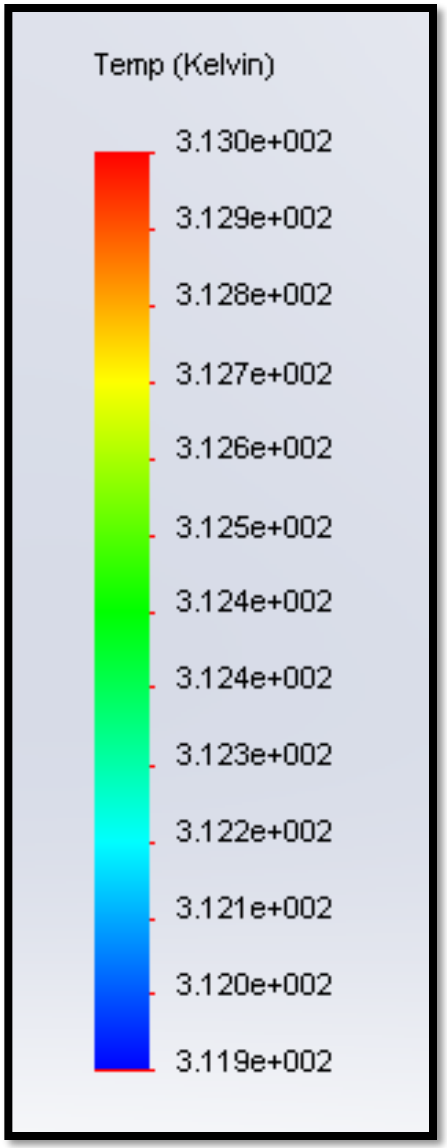
- Type: **Solid Mesh**
- Element Size: **0.48 in**
- # of Elements: **7622**
- # of Nodes: **13408**



Simulations

2. Thermal





Simulations

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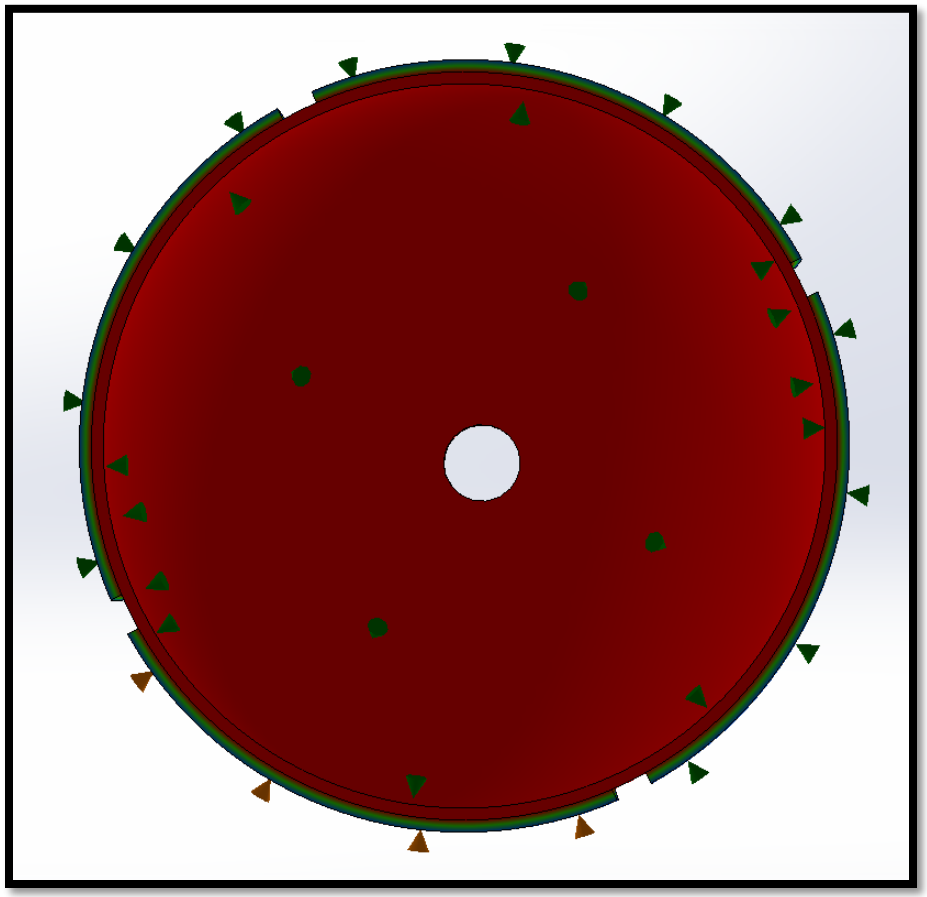
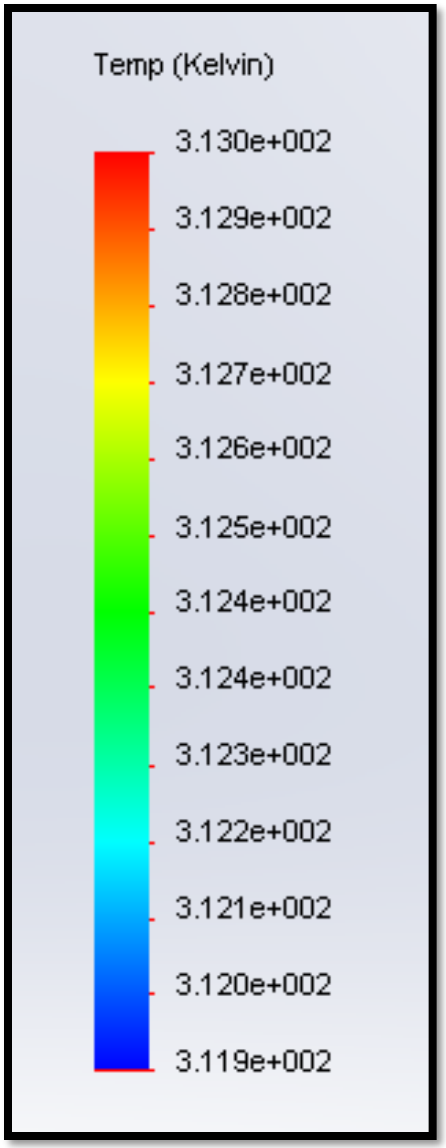
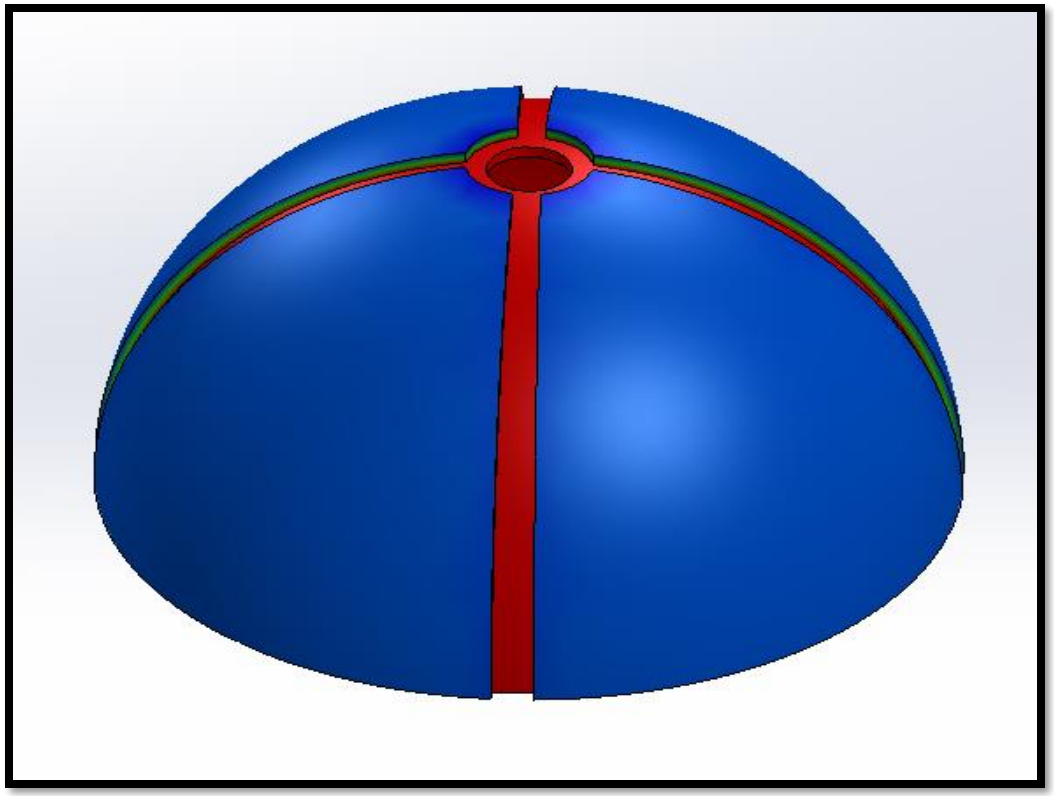


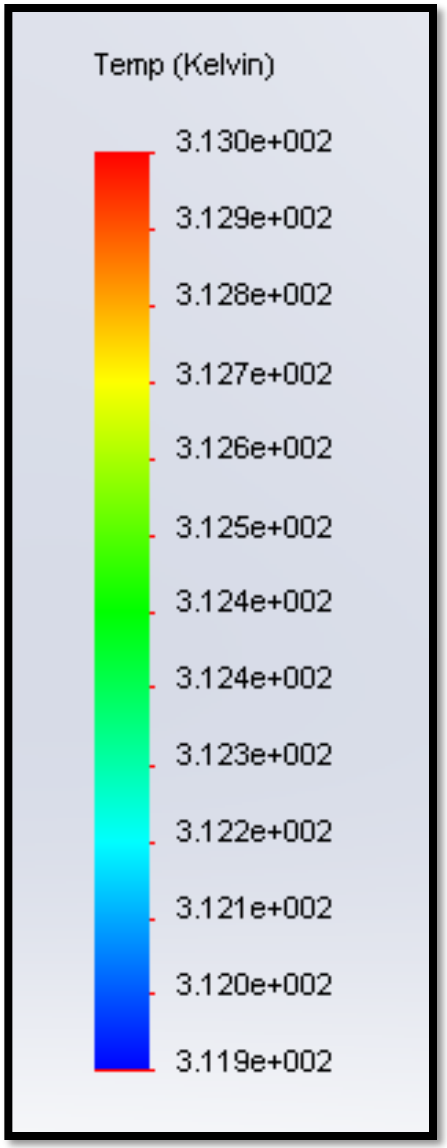


Simulations

2. Thermal

Max Temp. = 313 K **Min Temp. = 311 K**





Simulations

Results

- Difference of 2K (2°C) between max and min temps
- Cooling is seen between layers of headgear
- Material & Design selection allowed for breathability of headgear

Conclusion

- Success
  - The results were as expected
- Impact assumptions verified:
  - Significant reduction of impact to the head
    - From 55235N/m^2 to 16078N/m^2
- Thermal assumptions verified:
  - Breathability and the convection of heat through the headgear
  - Decreased temperature
    - From 313K to 311K

- **Next**
  - Lab testing of the model

References

- www.nmu.edu – wrestling pictures
- -Supporting research for force/acceleration in Gs
- http://www.ehow.com/how-does_4568048_mouth-guards-prevent-concussions.html#ixzz2DrvBE0mb How chins strap help prevent concussion
- https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcQcSFq5TWRHg3D9vZFdJd1Zu4I28cE-eVAop2Pi34lIKMSFT7A Snaps image
- https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcShByrbFQ2iFuWem5nc1PMHFDWHMflf42y6BkxKWqepK_VkfBbC Backpack Clip Image
- http://www.springerplus.com/content/pdf/2193-1801-1-2.pdf - Top of head concern
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC164365/ - Head and trunk most rapid heat loss
- http://web.mit.edu/course/3/3.11/www/modulus/props.pdf - MIT's mechanical properties table

WARNING

WHILE THE MERCADO® HAS UNDERGONE EXTENSIVE RESEARCH, MATERIAL DESIGN AND IMPACT TESTING NO HELMET OR HEADGEAR CAN PREVENT SERIOUS HEAD OR NECK INJURIES, SUCH AS CONCUSSION, A PLAYER MIGHT RECEIVE WHILE PARTICIPATING IN CONTACT SPORTS.

PLAY SAFE

Simulations Review Presentation