Effect of Rim Width on Tire Stress

ANSYS Finite Element Analyses

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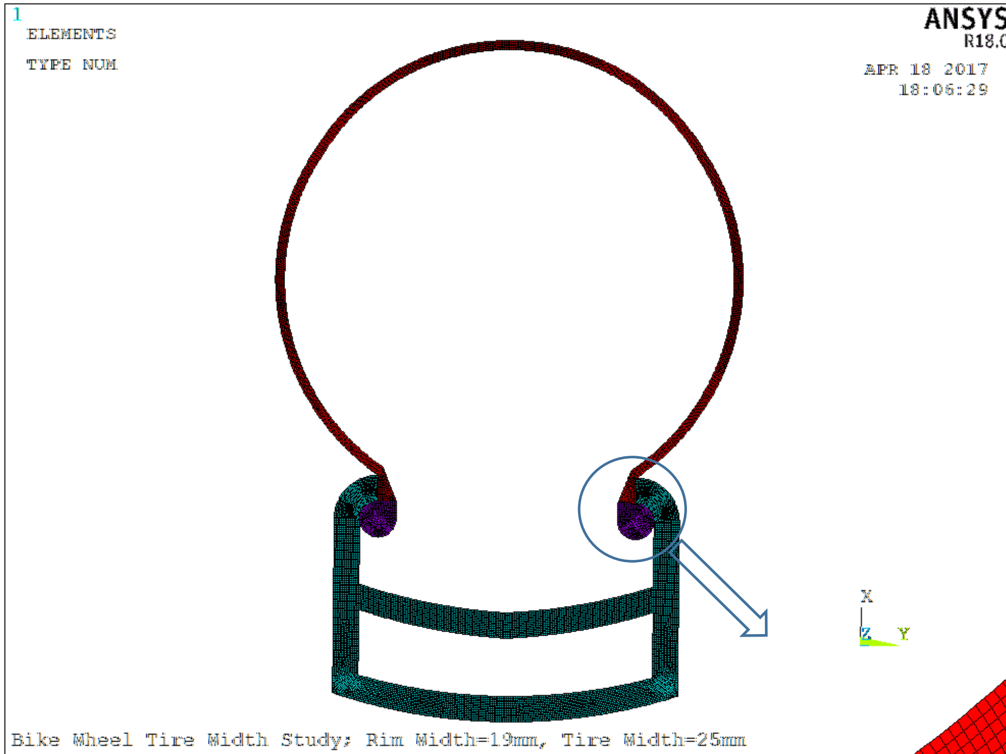
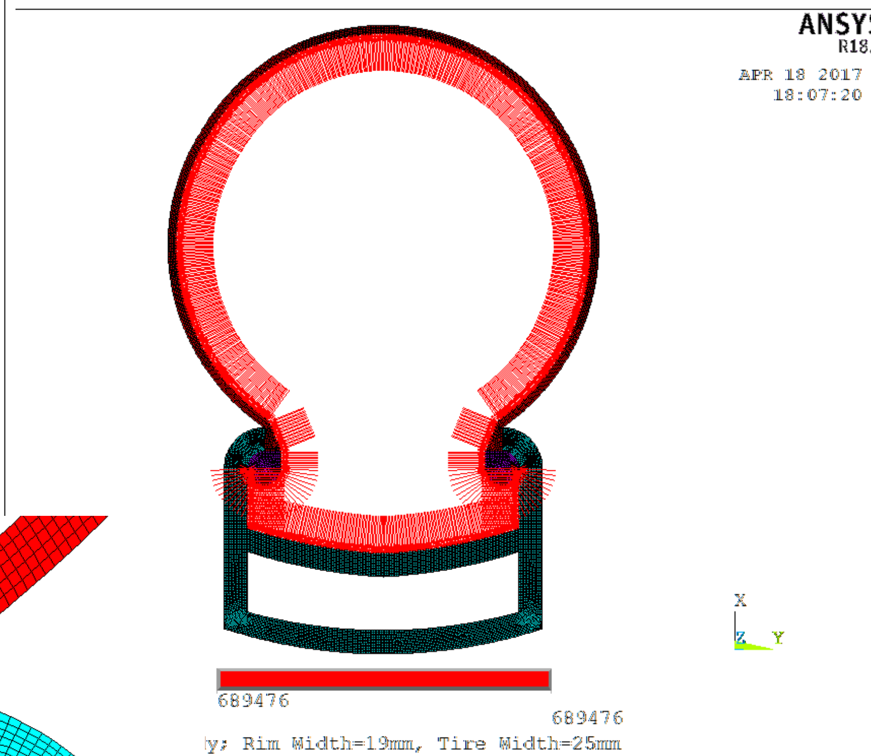
Overview

- Finite element analyses of a bicycle tire and rim was completed to determine the effect of the rim width on the stresses in the tire.
- Two models were created for the comparison. One rim is 19 mm wide while the other is 25 mm.
- All other features were exactly the same between the models. The tire distance from bead to bead was kept the same for both models. FE mesh density was also the same. In this way, comparison should be very accurate.
- The material properties for the tire and bead are simplified as isotropic. A real tire with a fiber based casing is probably orthotropic with variations for different layers. However, because both models have the same properties, the effect of rim width will be correct.
- Stress concentration at rim and tire bead corners are modelled as sharp corners so will not be accurate. The goal of this FEA is comparison, not life prediction so this is considered adequate.

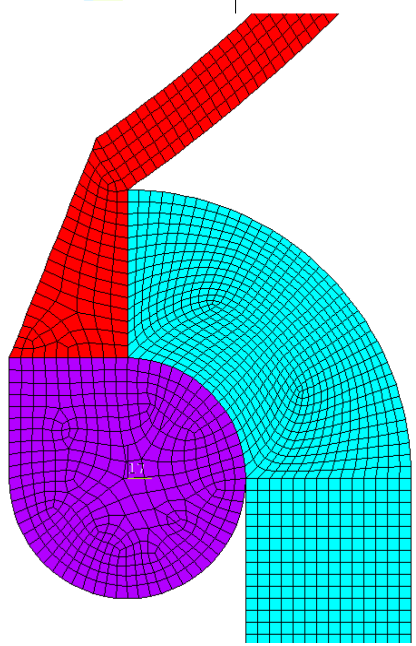
Finite Element Model



Pressure Loading = 6.89 Bar

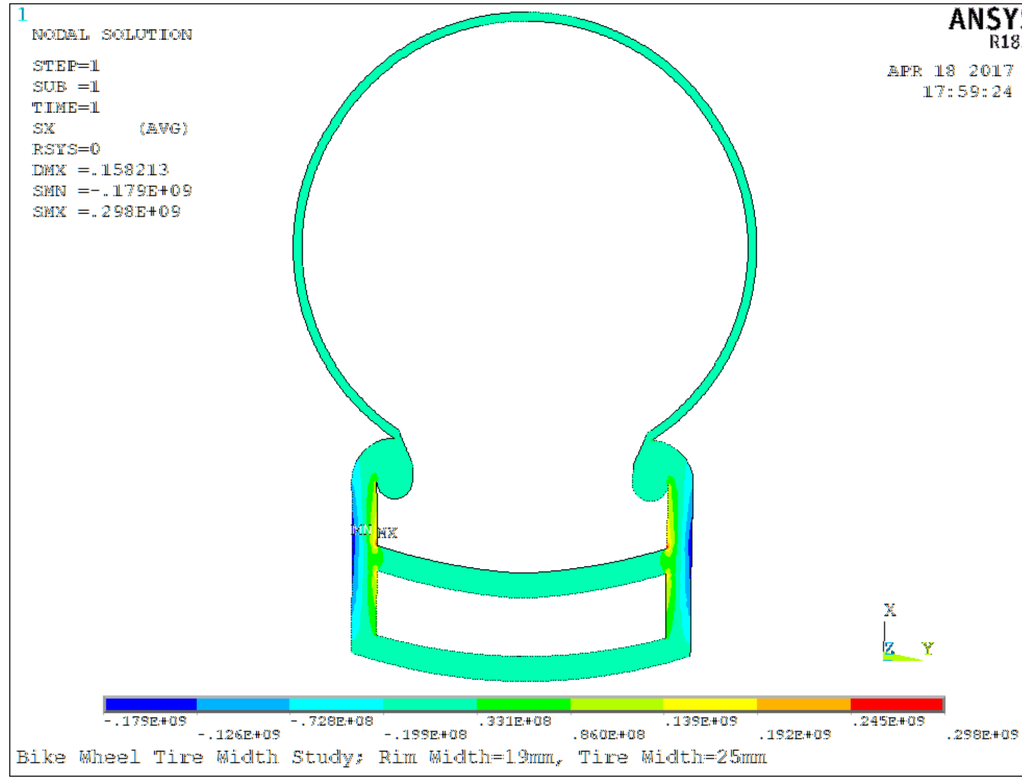


- 13,200 Axisymmetric Elements (center is at wheel axle), predominately quadrilaterals.
- Rim material is aluminum.
- Tire material is based on Kevlar but is simplified as isotropic.

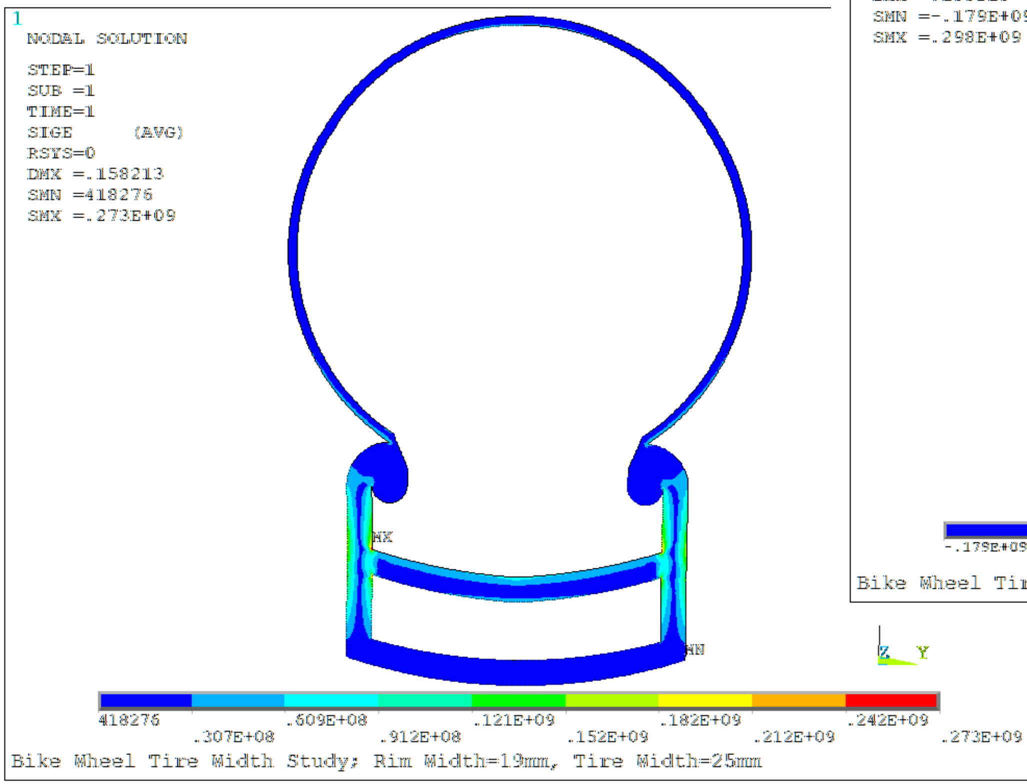


19 mm Wide Rim, 25 mm Tire

Radial Stress (Pascals)
referenced to wheel axle



Equivalent Stress (Pascals)

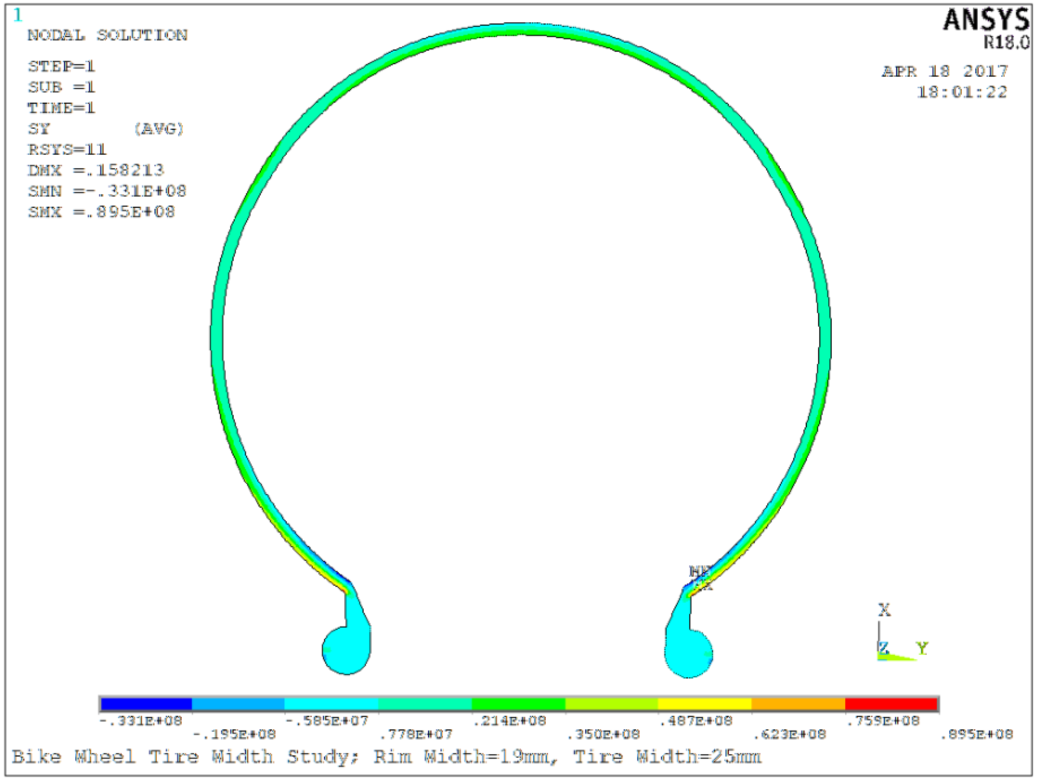


Maximum stresses are in the rim and are caused by pressure forcing the rim side walls open.

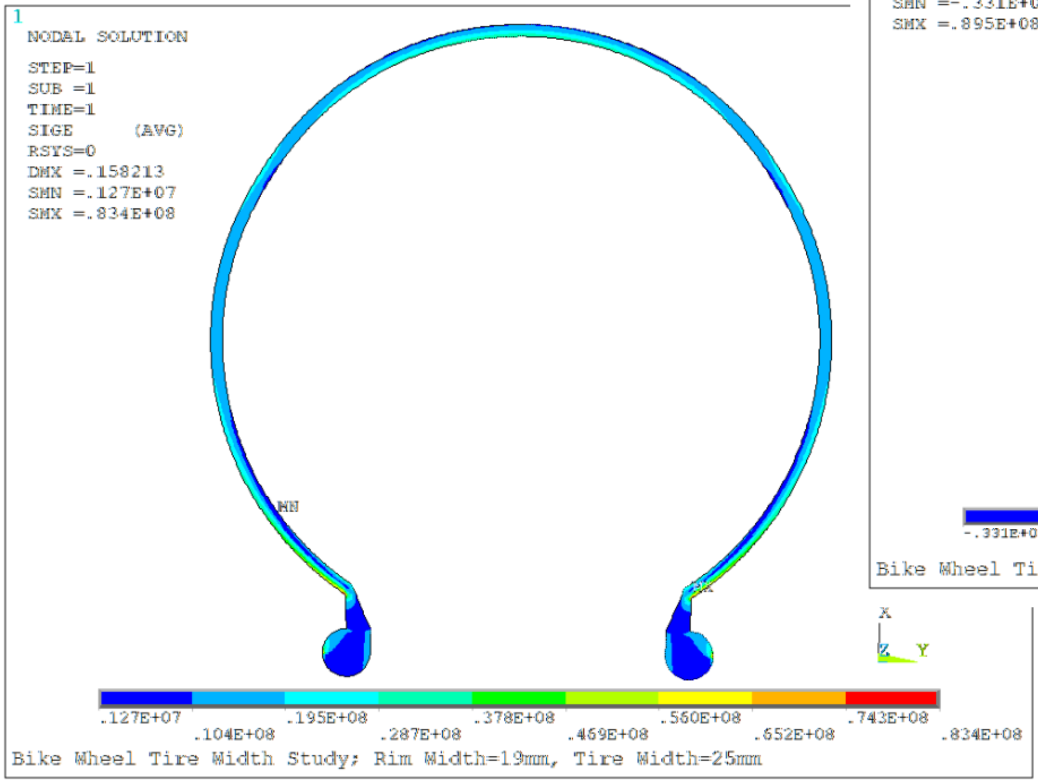
19 mm Wide Rim, 25 mm Tire

Stresses in Tire -rim is removed from plots for clarity.

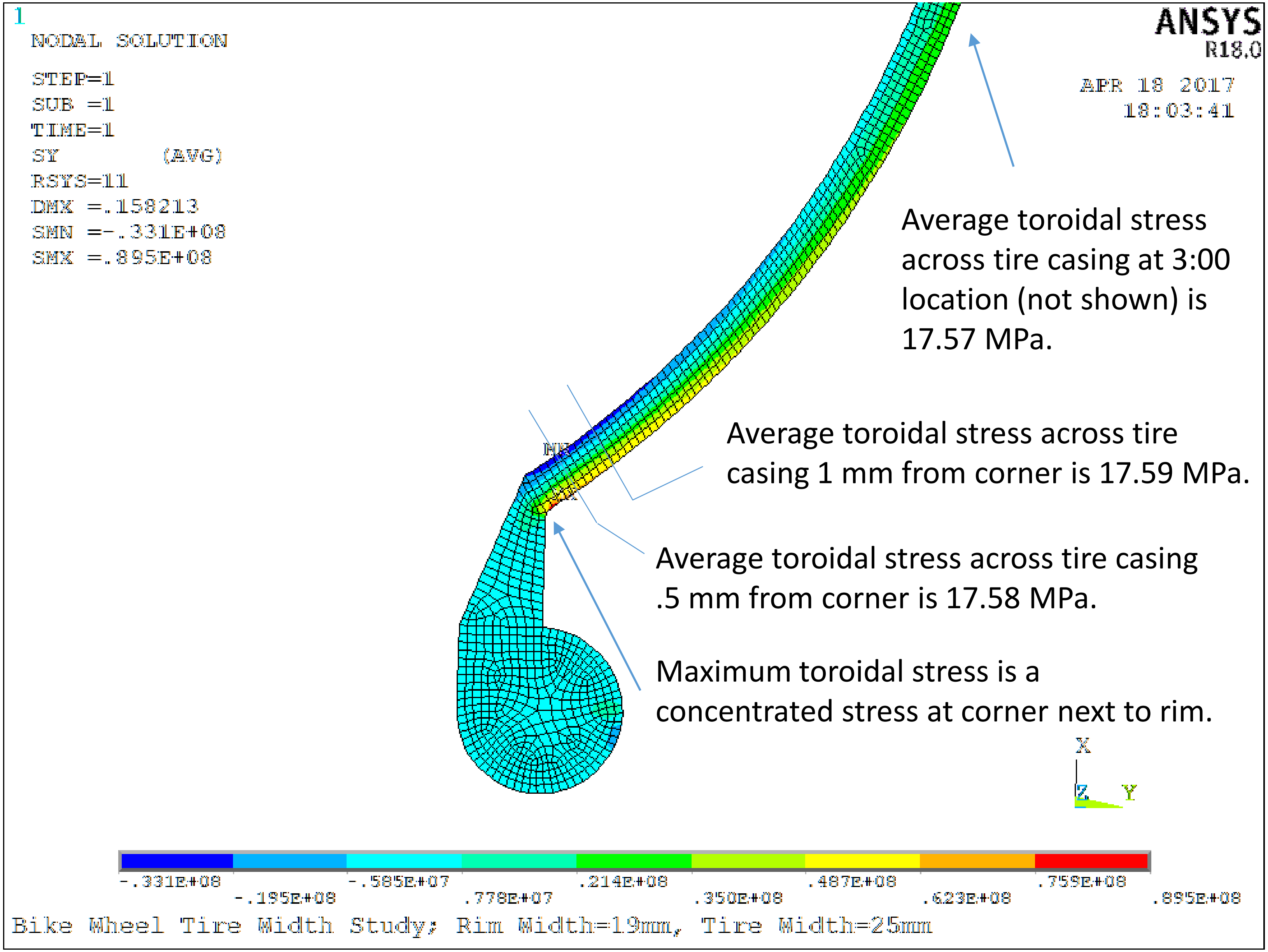
Toroidal Stress (Pascals)
referenced to wheel axle



Equivalent Stress (Pascals)



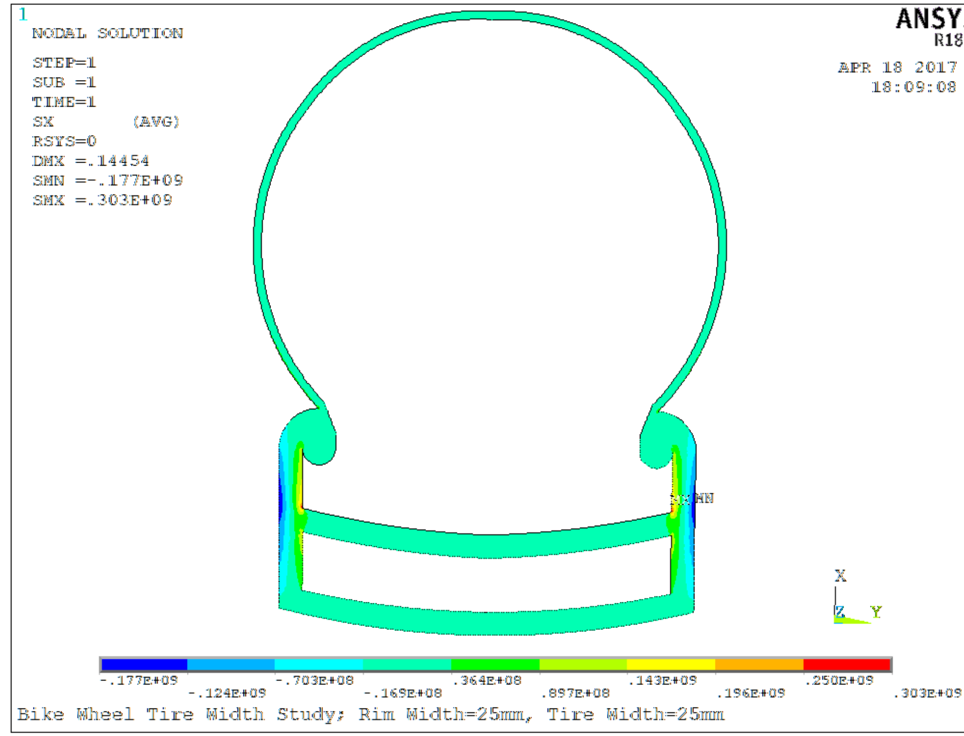
19 mm Wide Rim, 25 mm Tire



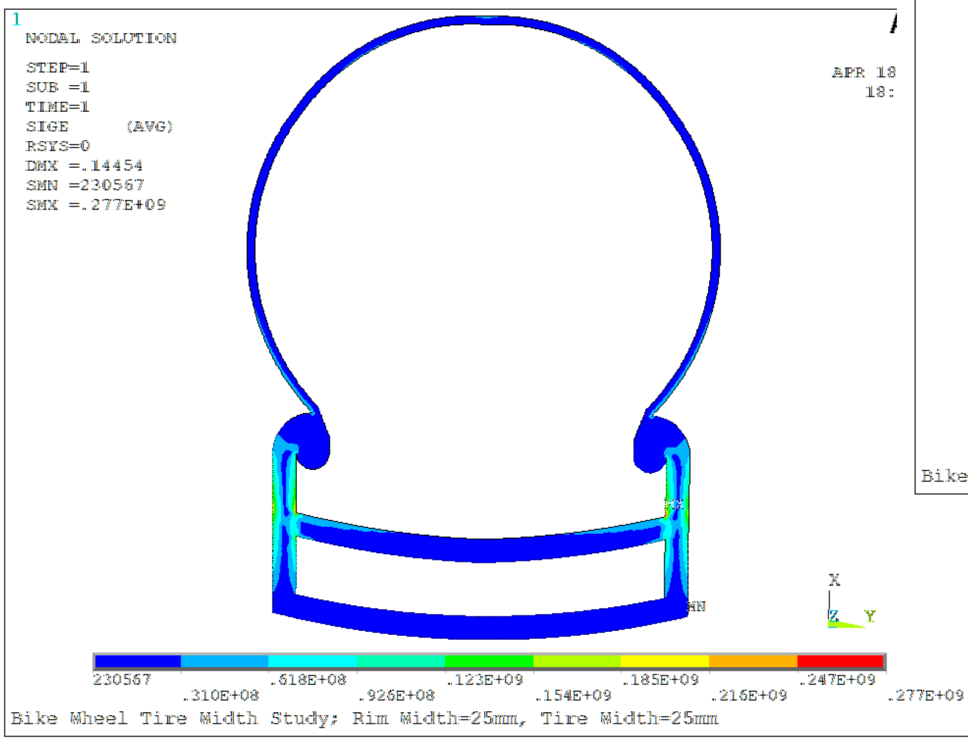
Average toroidal stress across the casing is consistent throughout the tire.

25 mm Wide Rim, 25 mm Tire

Radial Stress (Pascals) referenced to wheel axle



Equivalent Stress (Pascals)

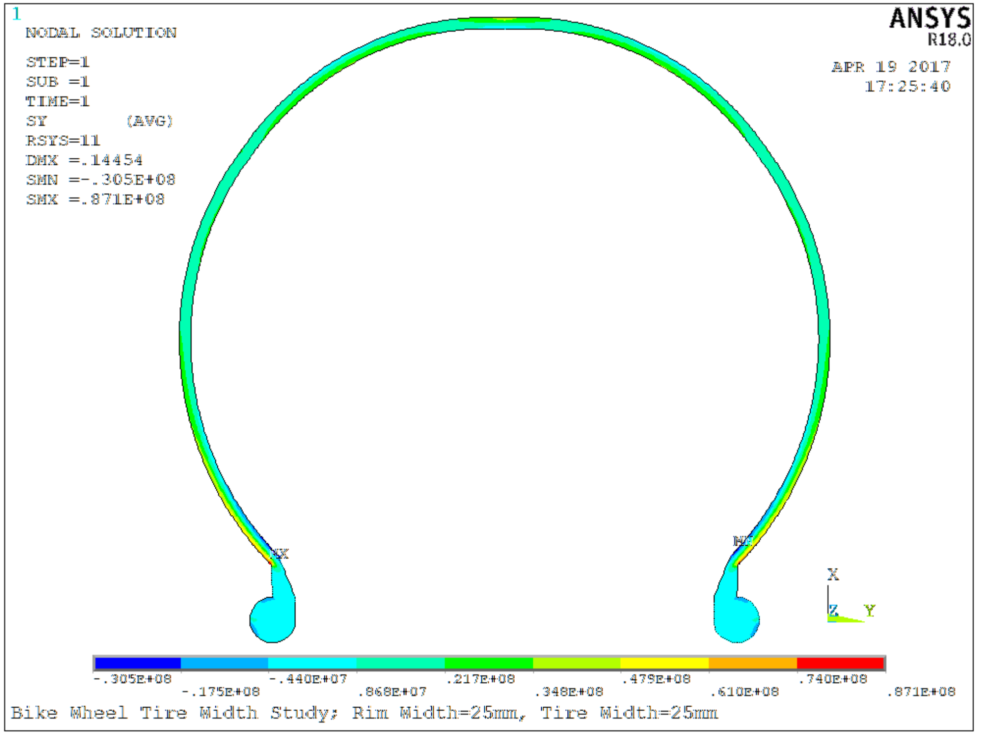


Maximum stresses are in the rim and are caused by pressure forcing the rim side walls open.

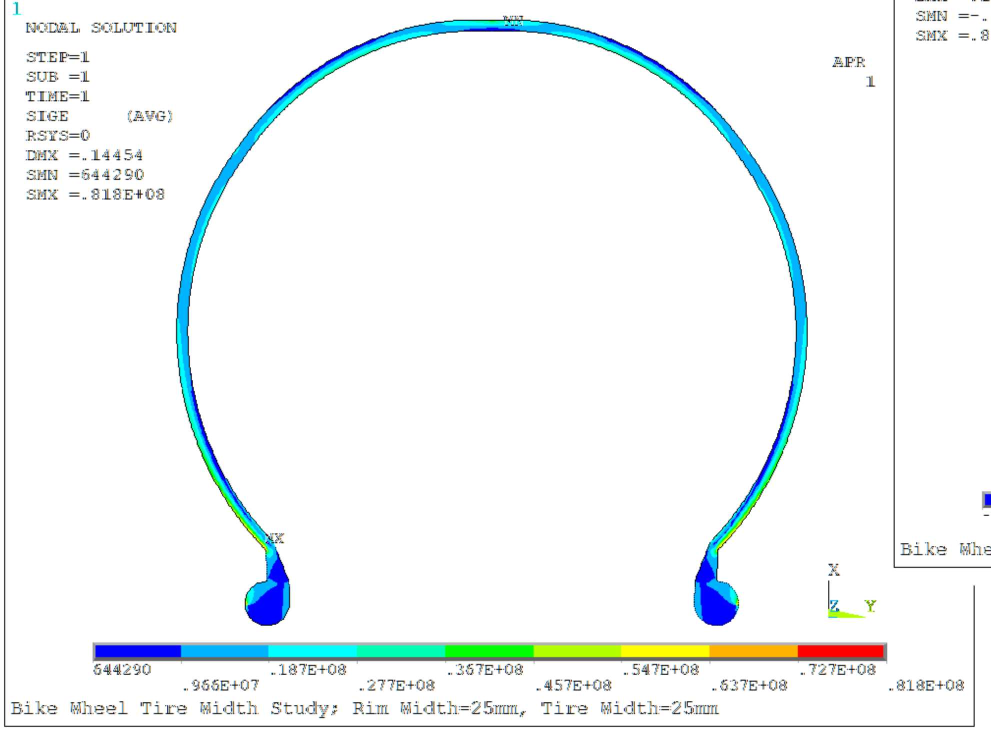
25 mm Wide Rim, 25 mm Tire

Stresses in Tire -rim is removed from plots for clarity.

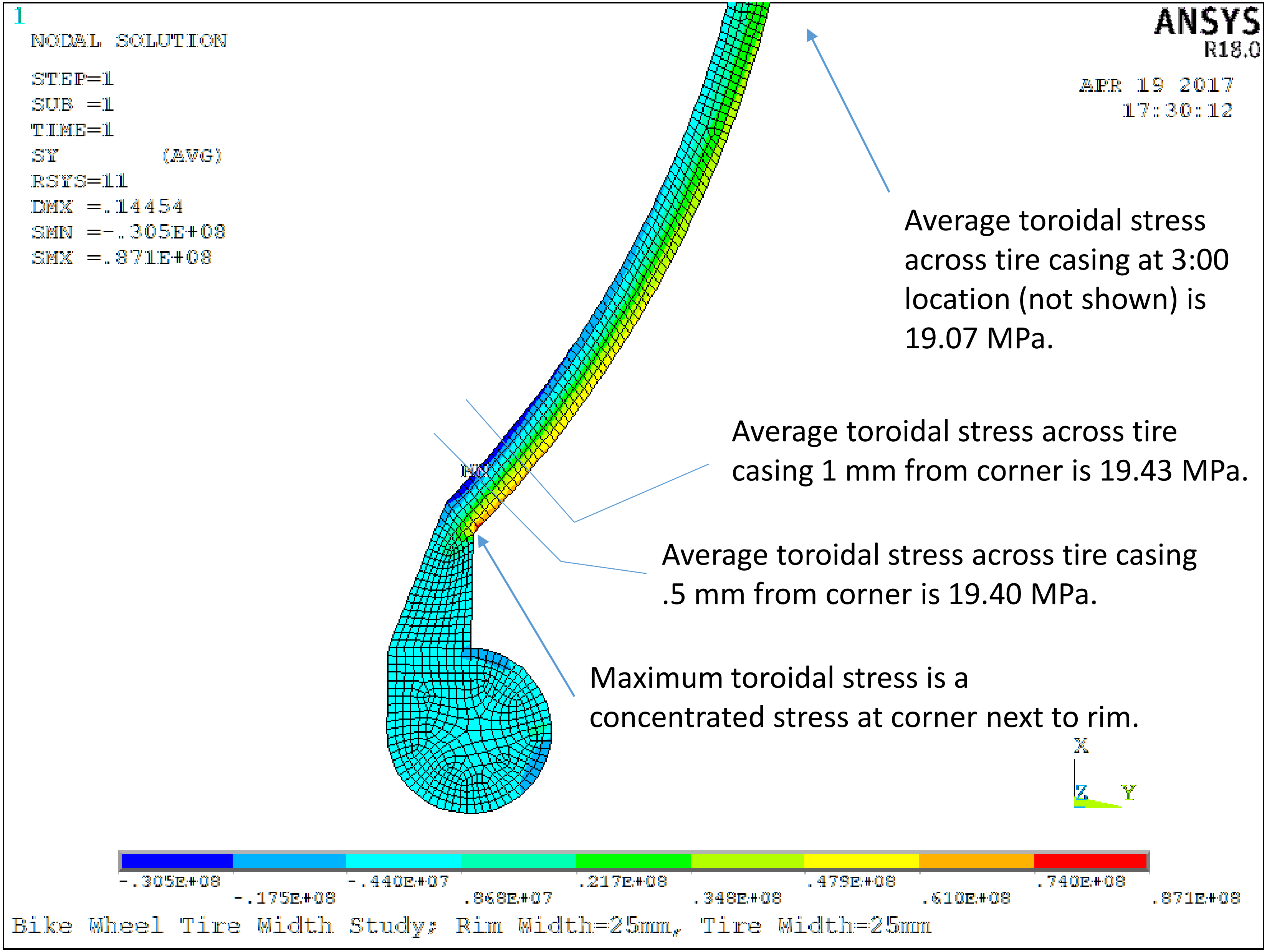
Toroidal Stress (Pascals)
referenced to wheel axle



Equivalent Stress (Pascals)



25 mm Wide Rim, 25 mm Tire



Average toroidal stress across the casing is consistent throughout the tire.

Summary of Results

tire width	19 mm	25 mm	%Δ
Maximum Stress			
rim σ_{eqv} (MPa)	273	277	1.5%
rim σ_{radial} (MPa)	298	303	1.7%
tire σ_{eqv} (MPa)	83.4	81.8	-1.9%
tire $\sigma_{toroidal}$ (MPa)	89.5	87.1	-2.7%
Average Toroidal Stress Across Casing			
σ_{avg} .5 mm from rim edge (MPa)	17.58	19.40	10.3%
σ_{avg} 1 mm from rim edge (MPa)	17.59	19.43	10.5%
σ_{avg} 90 degrees, 3:00 (MPa)	17.57	19.07	8.6%

- Average toroidal stress in the tire increases about 10% for rim increase from 19 to 25 mm.
- Stress in the rim also increases about 1.6%.
- The tire maximum stress which includes the stress concentration at the tire bead decreases about 2% going to the wider rim. The reason for this stress decrease is the corner is straighter, less sharp with the wider rim thus causing a lower stress concentration.

Explanation for Stress Increase

- Wider rim has greater cross-sectional area resulting in more force from the pressure.
- Approximating the area with a circle and calculating stress from basic equation:
  - Radius = $\sqrt{Area/\pi}$
  - Stress=Pressure*Radius/ thickness
  - For 19 mm wide rim:
    - Stress= 18.6 MPa
  - For 25 mm wide rim:
    - Stress= 20.3 MPa
- Stress increases 9% compared to 10% from FEA. Also note that this hand calculated stress is very similar to the FEA.
- Area increase explains the increased stress. Other factors such as changed shape of tire not needed for explanation.