Numerical Simulation of the new generation Non-Pneumatic Tweel™ and sand

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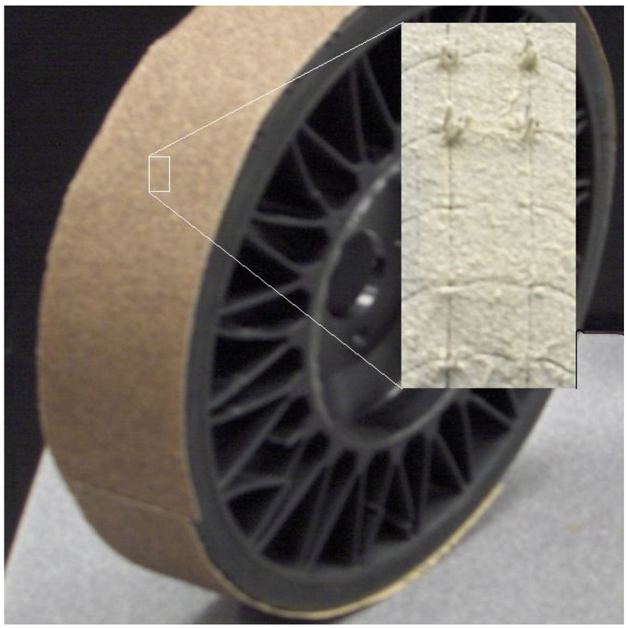
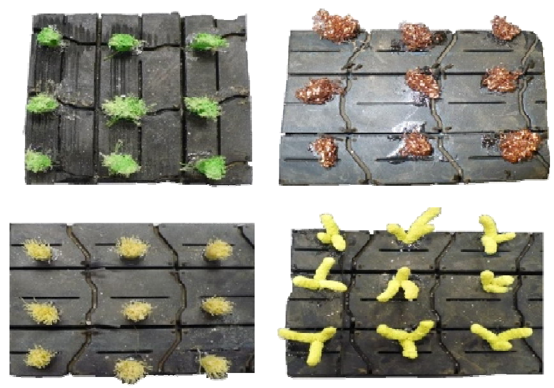
Objectives of the project

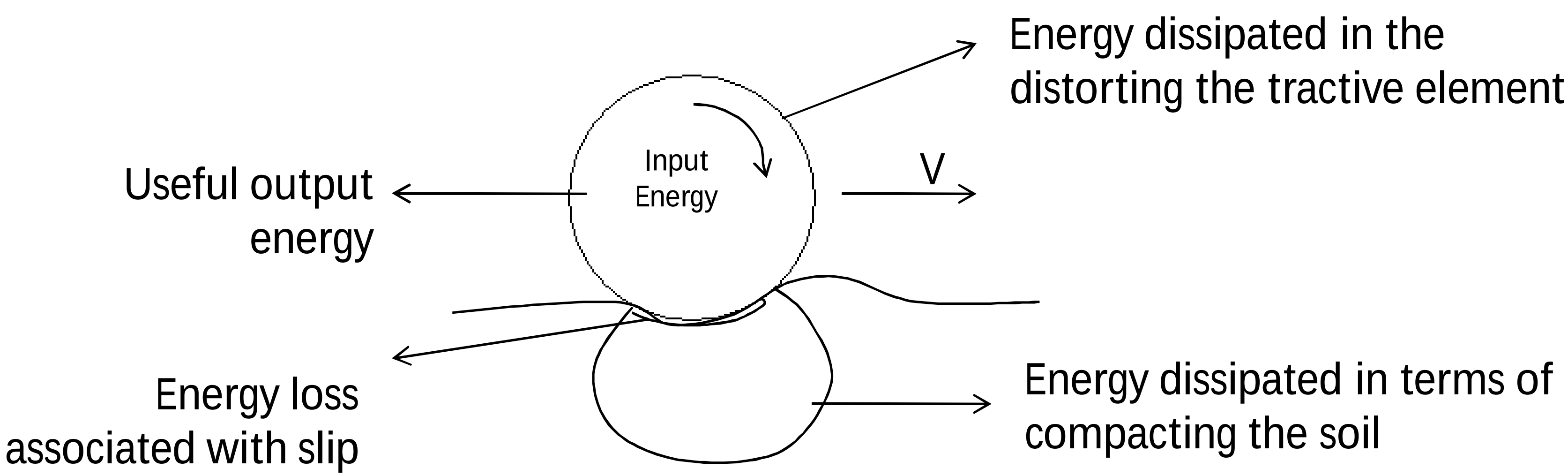
- To Improve the performance of tire on sand.
  - In other words traction
- To develop a full computational model for tire-sand interaction with an acceptable accuracy.
- To search for novel tread concepts that can avoid slip.





Mechanics of tire-terrain interaction

- Output energy = Input energy – Energy losses(losses due to motion resistance)
- Traction forces = Drawbar-pull + Work energy/unit travel distance

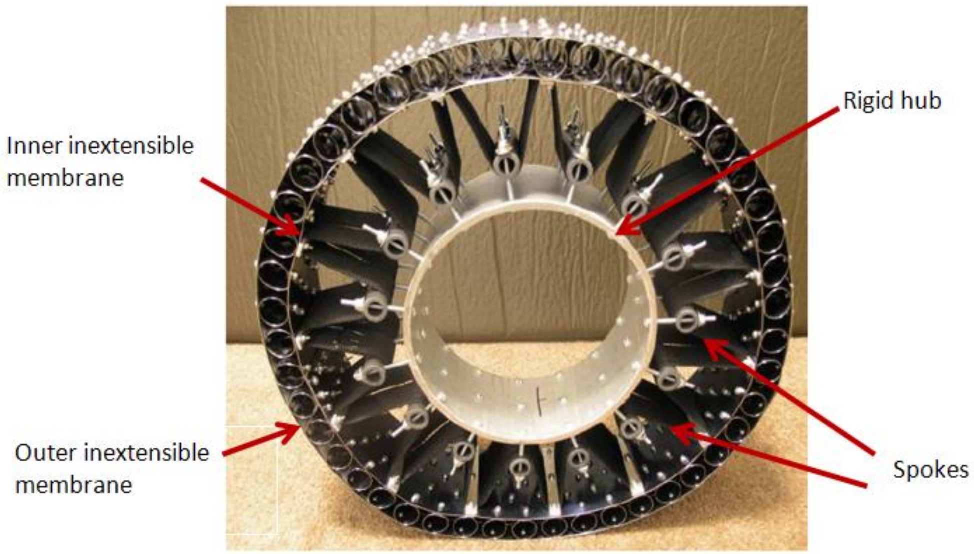


Modeling Techniques

- Analytical models (Bekker, 1969)
- Empirical models (Yong and Fattah, 1986)
- Computational models
  - FEM (Fervers, 1996)
  - DEM (Nakasimha *et al.*, 2003)
- FEM is employed for the simulation due to less computational effort and acceptable levels of accuracy
- Soil is treated as Elasto-plastic solid. Tweel™ is treated as a deformable body.

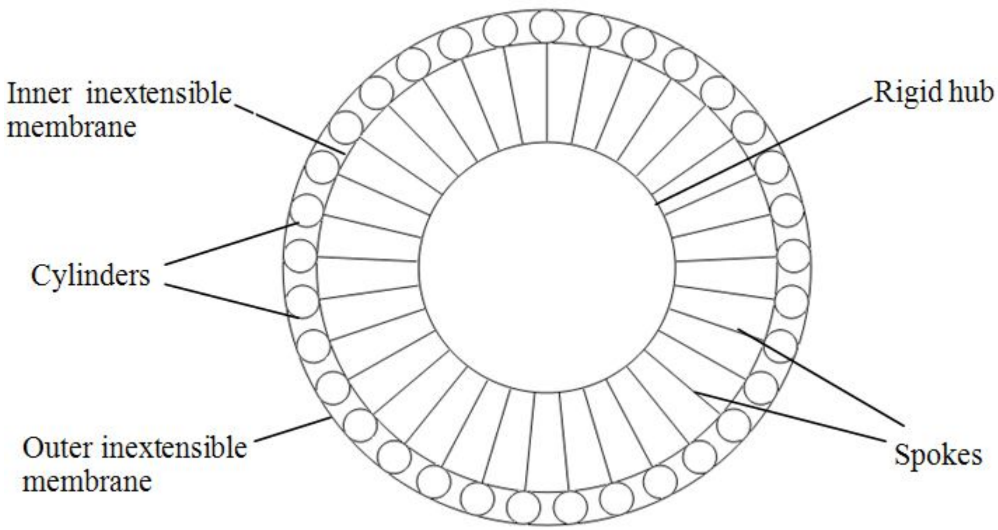
Segmented cylinder Tweel™

- Typical properties of pneumatic tires carried to Tweel™:
  - Low contact pressure
  - low stiffness
  - high load carrying efficiency
  - low energy loss from obstacle impact
- In addition to being non-pneumatic makes it flexible enough to withstand extreme temperatures on both terrains.



2D Tweel™ Model

- 2-D FEM Model of tire replicating the prototype is shown in figure.



Soil Modeling

- Soil can be modeled using four elasto plastic models:
  1. Drucker-Prager model (Classical, Drucker-prager/cap model)
  2. Mohr-Coloumb model
  3. Critical state theory
  4. Lade's single hardening model
- For the analysis, sand is represented by elastoplastic Drucker-prager/Cap model that uses the results obtained from triaxial tests and consolidation test.

Soil properties

- By using Drucker-prager/cap plasticity constitutive law.

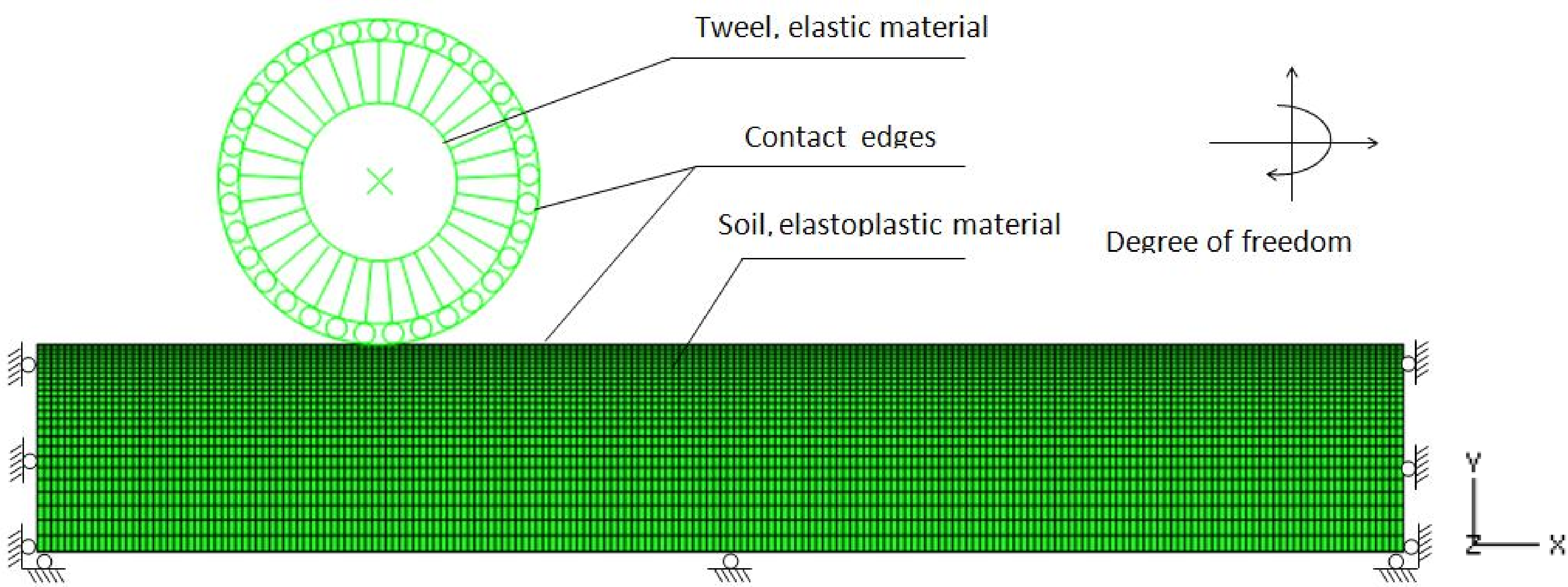
Properties of soil used for ABAQUS:Drucker-Prager/Cap model*

Material parameters	Value
Young's modulus, E	8500 kPa
Poisson's ratio, ν	0.32
Angle of friction, β	55.8°
Material cohesion, d	10.0 kPa
Cap eccentricity, R	0.45
Initial value of volumetric plastic strain	0
Flow stress ratio	1

* Taken from literature for the Lebanon sand found in NH.

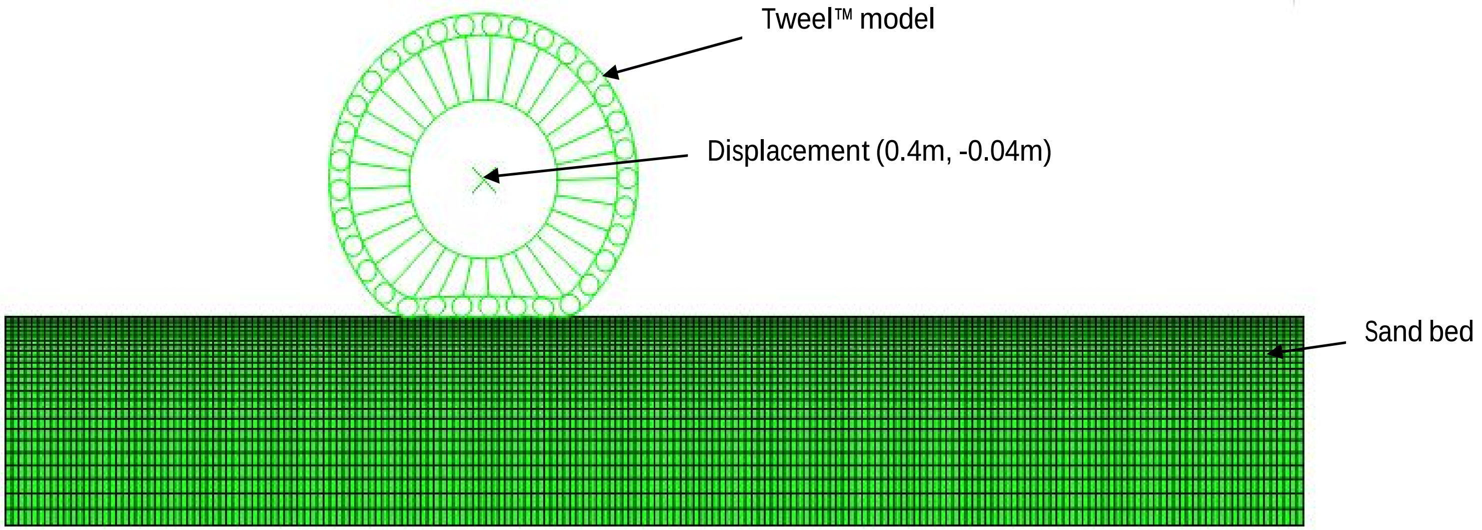
Interaction model

- From the simulation model, soil deformation, distributions of different stresses in both sand and Tweel™ and distributions of contact pressure along the contact patch at all instances are expected.

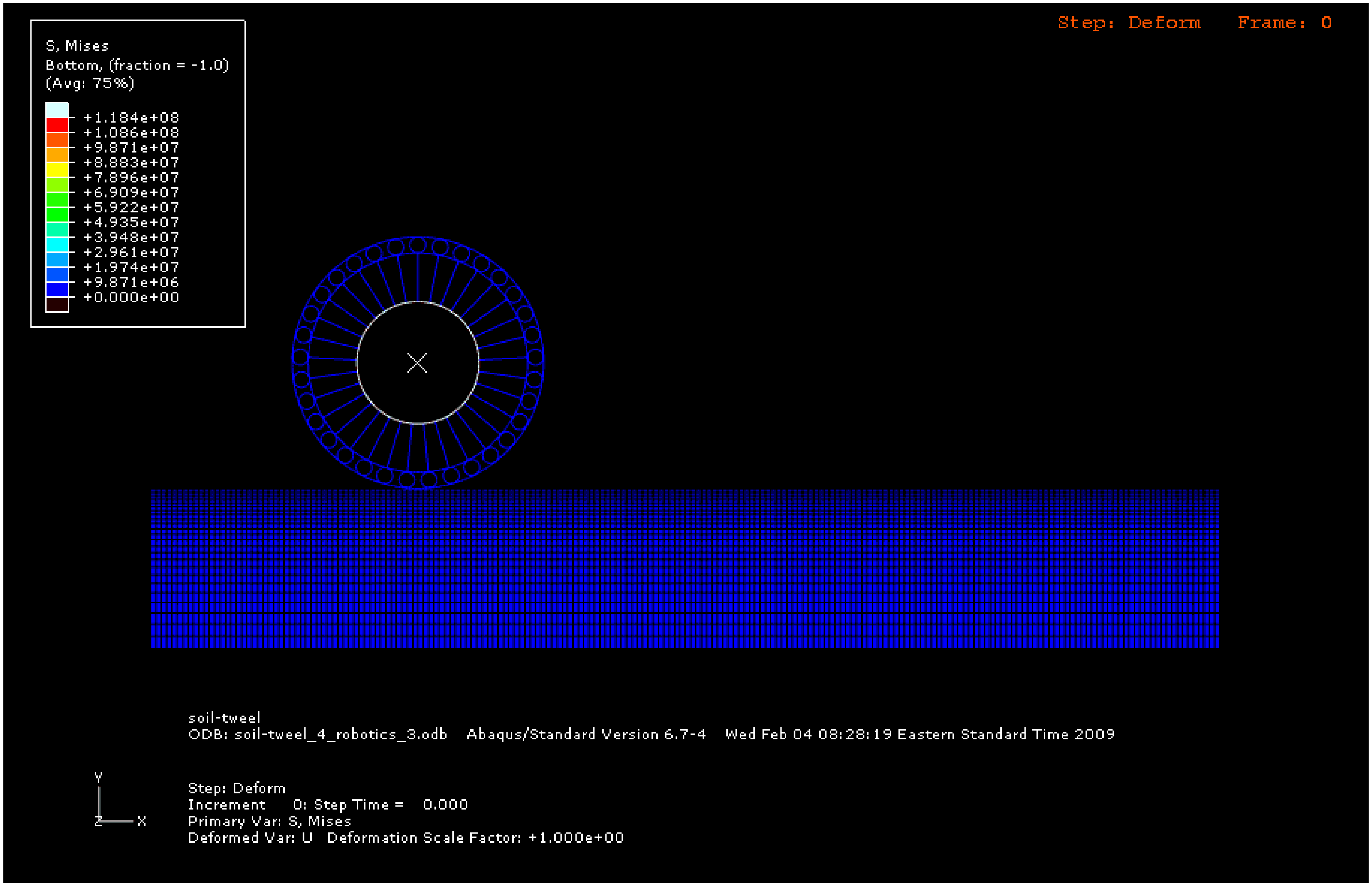


Numerical results (1)

- Two loading steps:
  - Initial loading to deform Tweel™
  - Final step for displacing the Tweel™
- Deformation in Tweel™ is more because the spokes can't withstand compression.



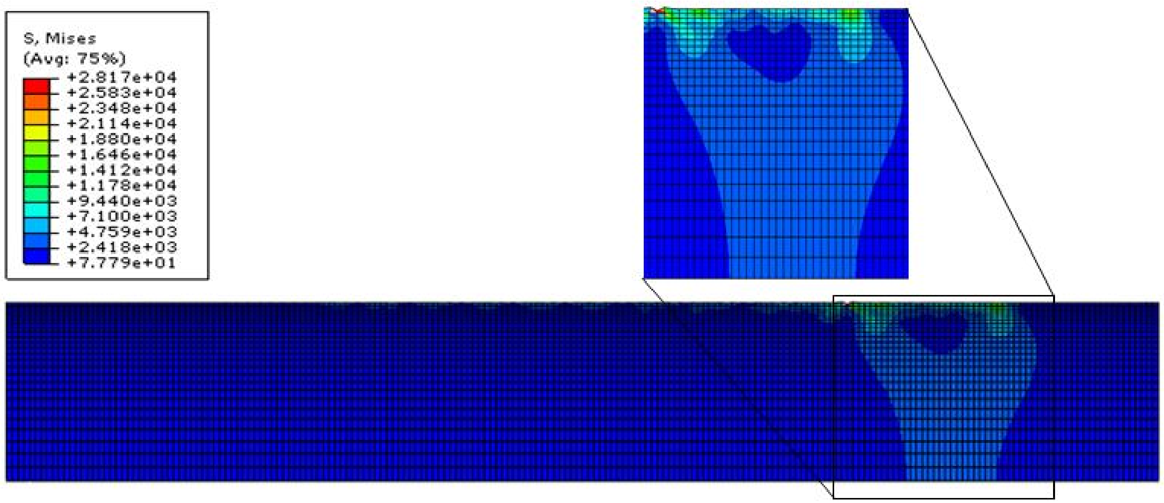
Numerical results(2)



von Mises stress distribution

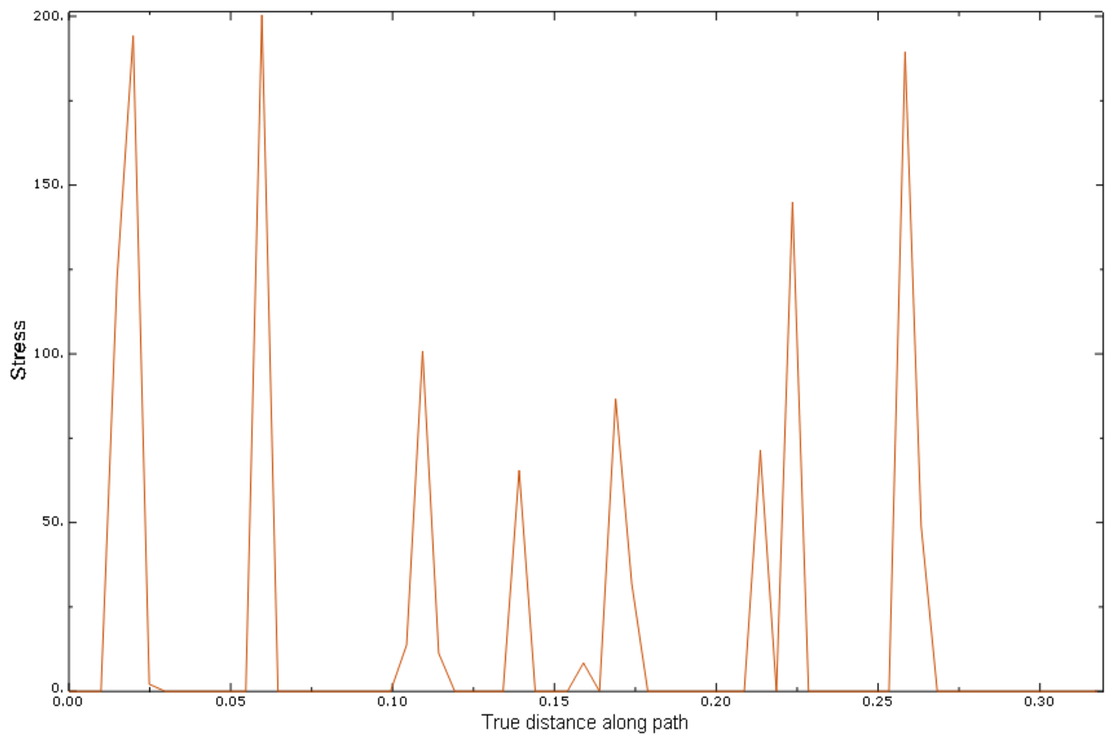
Numerical results (3)

- The deformations in sand are permanent after the Tweel™ passes by, since sand is treated as elasto- plastic solid indicating that the residual stresses are permanent.



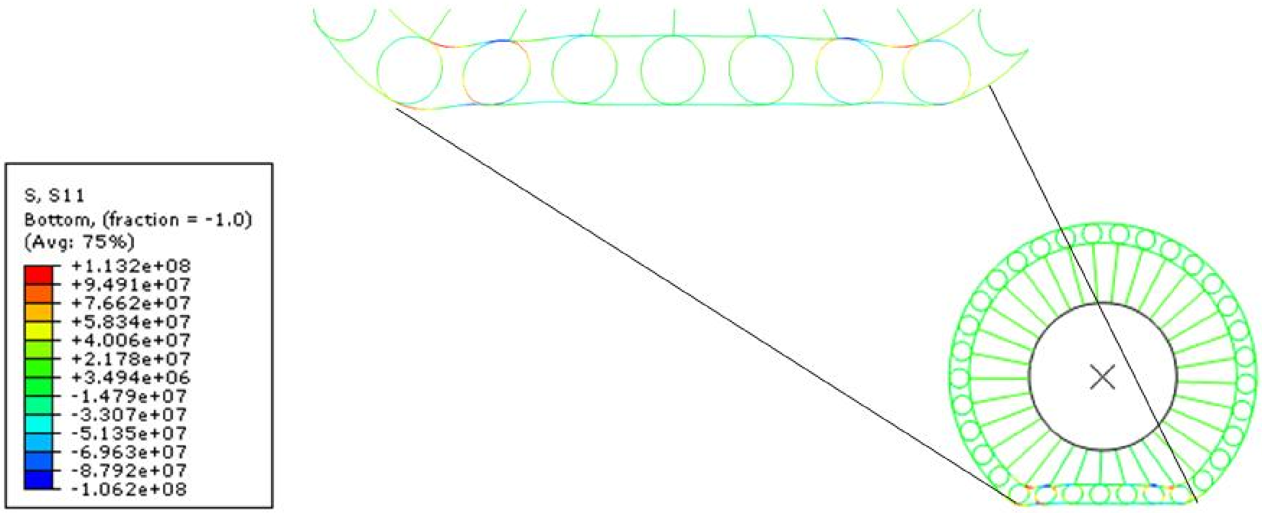
Numerical results(4)

- This low contact pressure can cause less deformation of sand reducing the bulldozing effect.
- Long contact path accounts for low contact pressure i.e. relatively uniform contact pressure.



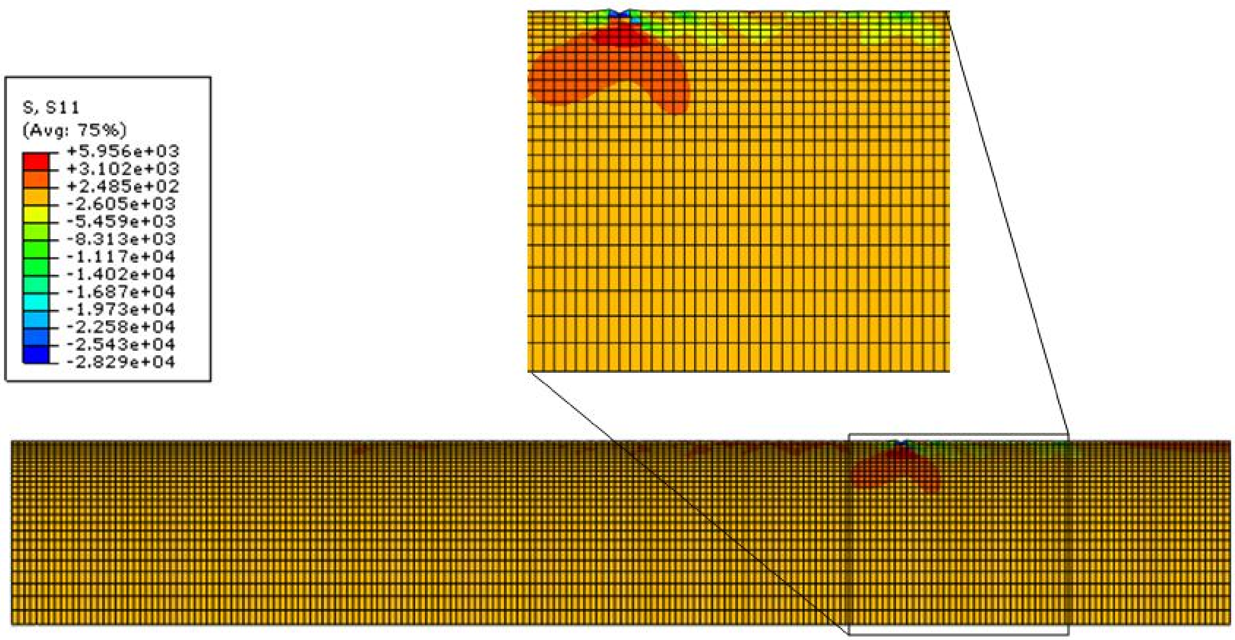
Numerical results (5)

- σ_{11} distribution in Tweel™ at final instant



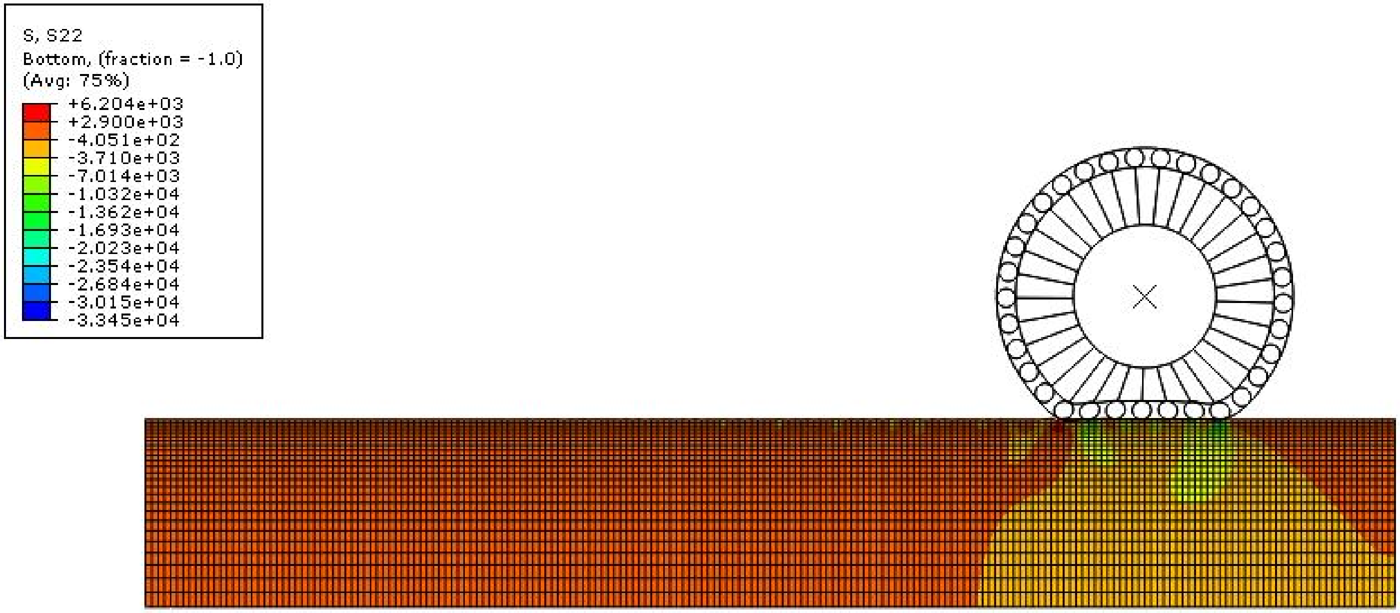
Numerical results (6)

- σ_{11} distribution in sand at final instant



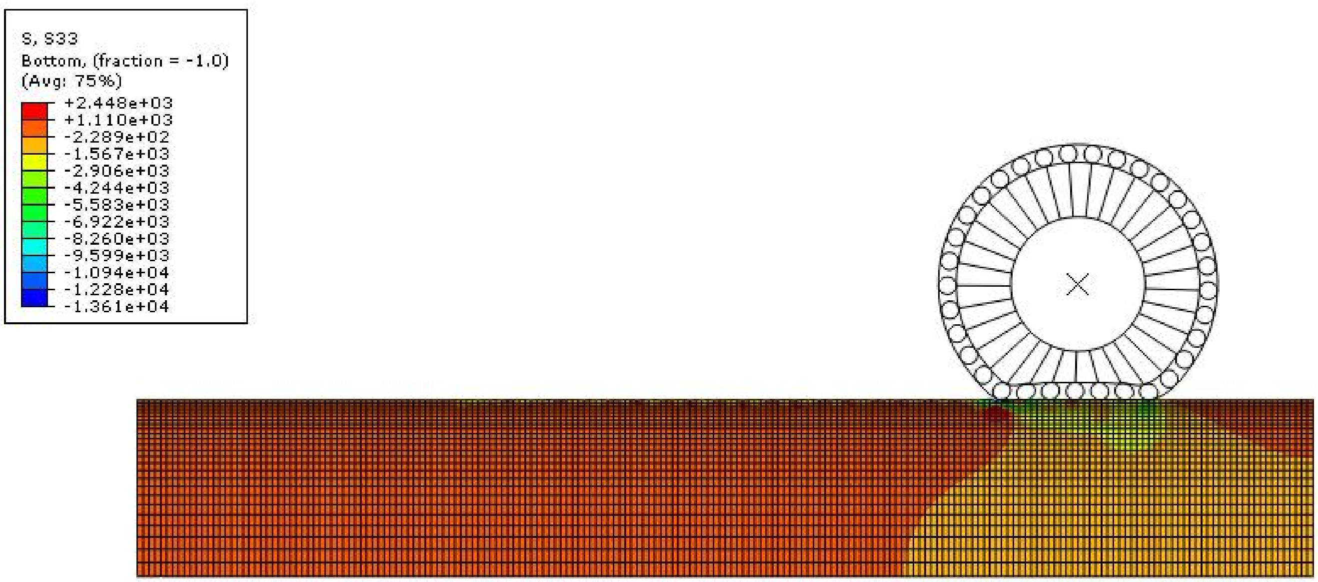
Numerical results (7)

- σ_{22} distribution in sand at final instant



Numerical results (8)

- σ_{33} distribution in sand at final instant



Conclusions

- FEM code-ABAQUS is used to perform the simulation.
- Soil is modeled using elasto-plastic Drucker-Prager/cap model.
- The Numerical results show that there is a relatively low contact pressure observed for this Tweel™ model.

Future Work

- The work presented will be used as a basis for improving the performance of the Tweel™ on sand.
- Several Tweel™ that can give better tractive performance will be investigated.
- Ways to induct Tweel™'s pressure profile into another wheel model needs to be explored.
- After developing tire-model that have better traction based on pressure profiles, influence of tread profiles will be studied to find ways to improve traction further.

Questions??

Thank you for your Attention!!