Meta-Material design for Tank Track pads

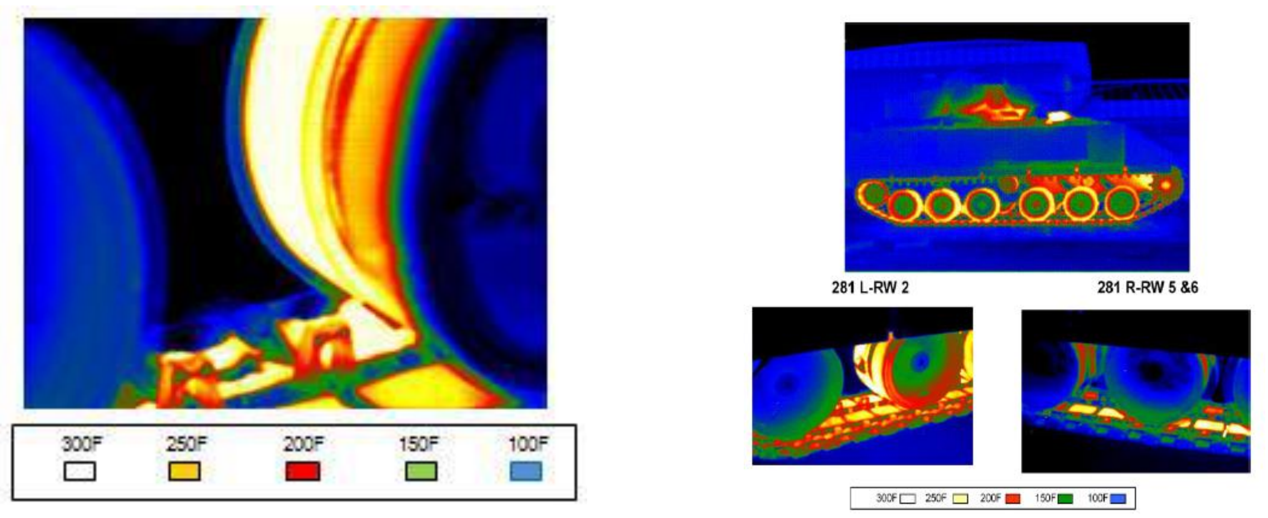
Sampath Venkata Dangeti

Dr. Georges Fadel, Dr. Paolo Guarneri

Clemson University, SC

Motivation and Background

- Results from investigations on tank track pad elastomers have revealed high temperatures at the contact surface between road wheels. The strength and structural integrity of elastomers tends to decrease at such temperatures causing negative effects on their life time and durability



- The dramatic increase in temperatures is attributed to the hysteretic properties of the tank track elastomers.

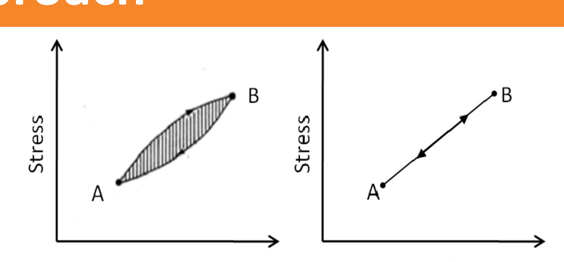
Abstract

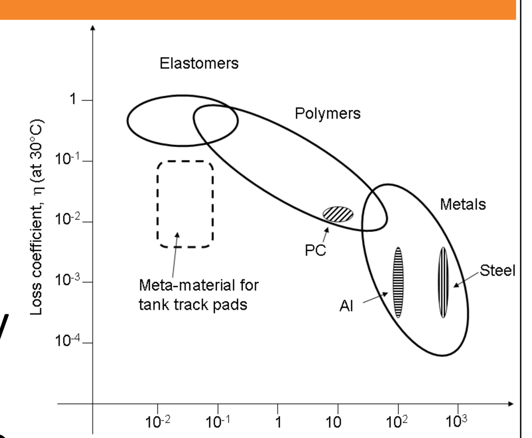
The idea of this project is to substitute the elastomer with an elastic material which does not suffer from hysteretic losses. The ideal design requires material properties which are not available in nature. Meta-materials could be tailored for the specific application with the target properties. The challenge here is the definition of optimal meta-material structure having required material properties.

Research Objectives

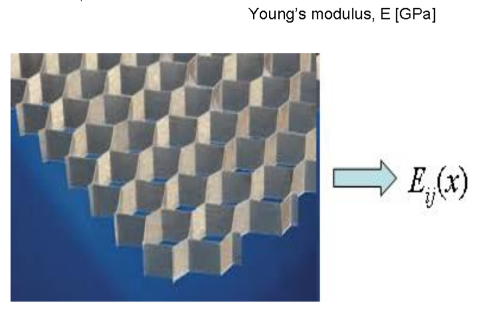
- To develop a methodology to be used in design of meta-materials to meet specific elastic requirements.
- To implement a method based on topology optimization to tailor meta-material properties.
- To solve track pad problem and demonstrate the method's applicability.

Approach





- Analysis of current system to identify operating conditions.
- Understanding operating conditions to determine influential mechanical properties.
- Structural design of meta-material exhibiting these properties based on topology optimization.



Properties of material used currently

Material Used : Custom formulated , carbon-black filled Styrene Butadiene Rubber (SBR)

General properties of rubber

Mechanical Properties	Thermal Properties
Density: 940 kg/m^3	Glass Temp: -65 – -50^{o}C
Elongation: 250-700%	Service Temp: -30 – 70^{o}C
Tensile Strength: 10-25 MPa	Specific Heat: 1880-2000 J/kgK
Young's Modulus: 2-10 MPa	Thermal Conductivity: 0.2-0.25 W/m.K
	Thermal Expansion: 6.7 e-6/K

Properties of various vulcanizates

Properties \ Compounds	F1	F2	F5	F6
Specific Gravity	0.95	1.11	1.08	1.16
Optimum Cure Time at 160^{o}C, min	9	9	8	8
Hardness, Shore A	40	68	47	80
Tensile Strength, MPa	16	35	15	33
300 % Modulus, MPa	1.8	17	3	25
Ultimate Elongation, %	1000	520	800	400
Tear Strength, N/cm	300	1050	500	571

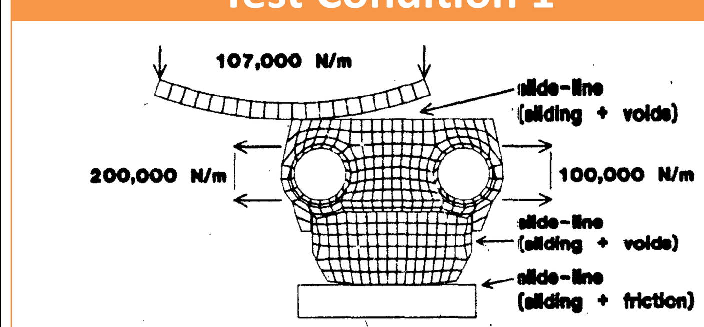
Rubber = ↑Compliance ↑Hysteresis

Elastic meta-material = ↑Compliance ↓Hysteresis

What properties to be targeted?? Possibly elastomer moduli G, E..

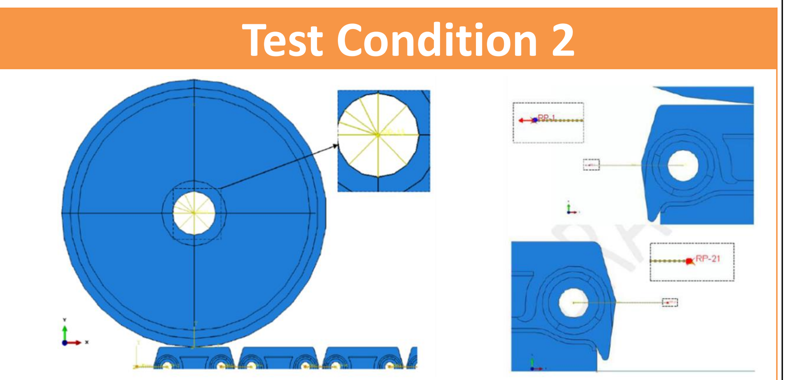
Loading Conditions

Test Condition 1



- Rolling of roadwheel simulated, considering it to be frictionless sliding.
- Weight of the tank applied to the track via roadwheel rolling across the track pad. It traverses track pad three times so as to achieve a steady state hysteresis.
- A slideline is placed at bottom of the pad and rigid flat surface to represent roadway contact in realistic manner.

Test Condition 2



- Vertical DOF constrained in vertical direction for ground pad. Links between track pads represented via solid beams.
- 5000 lbf force in negative x-direction at the right end and the left end is fixed to simulate the tension.
- Dynamic load simulated by 8000 lbf to road wheel spindle. A linear velocity of 771 inch/sec and 62.8 rad/sec to simulate rotation.

Forces on tank track pads

Assuming velocity of tank = 30mph = 13.4112m/s

Power developed by Engine = 1120 kW

Assuming no power losses,

Power available at drive sprocket P = 560 kW

This power is utilised to turn the sprocket and pull the track pads.

Considering the drive sprocket,

Torque on Sprocket = C

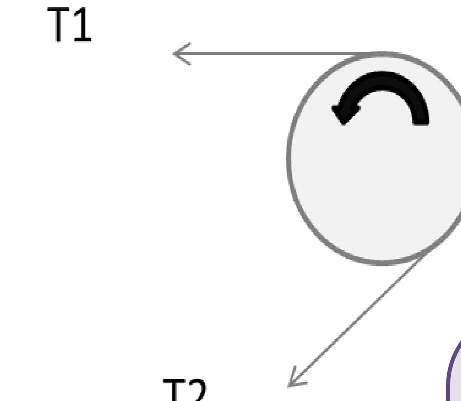
$T_2*R - T_1*R - C = 0$

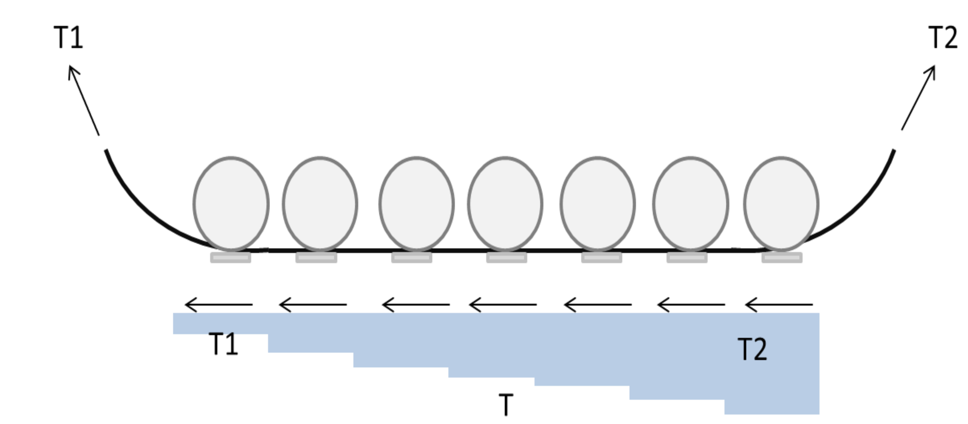
$\Rightarrow C = (T_2 - T_1)*R$

$\Rightarrow T_2 - T_1 = C/R = F$

$\Rightarrow T = T_2 - T_1$;

T would be used to Calculate F_p.





Understanding operating conditions and predicting stresses and strains will reveal the properties that should be mimicked by meta-material

Compressive Force is due to load on each road wheel station

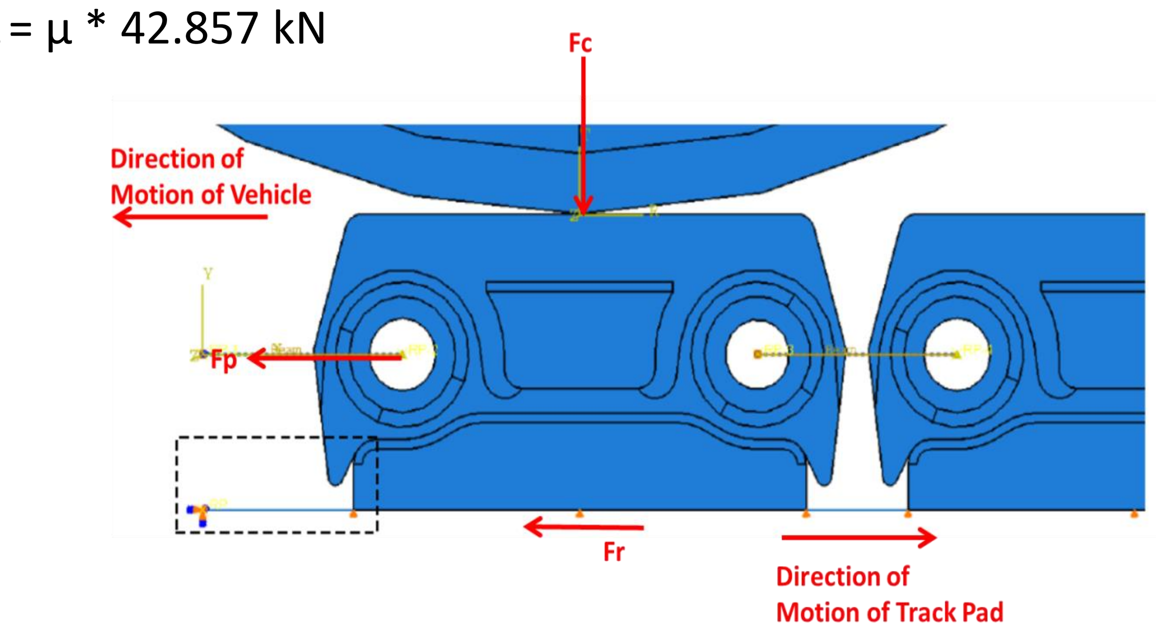
Assuming weight of vehicle = 600,000N

Load uniformly distributed over 14 road wheel stations.

$\Rightarrow$Force F_c = 42.857 kN

$\Rightarrow$Maximum traction force due to the asphalt-track friction coefficient μ

$F_r = \mu * 42.857$ kN



Expected Results

- Engineering tool for meta-material analysis and design.
- Structure of meta-material with targeted mechanical properties.
- Reduced hysteretic losses and, consequently, reduced operating temperature in the engineered meta-material structure so as to avoid material deterioration.
- A meta-material synthesized so as to have both high compliance and low loss coefficient.

ACKNOWLEDGEMENTS

CEDAR Clemson Engineering Design Applications and Research