Meta-material design for tank track pads

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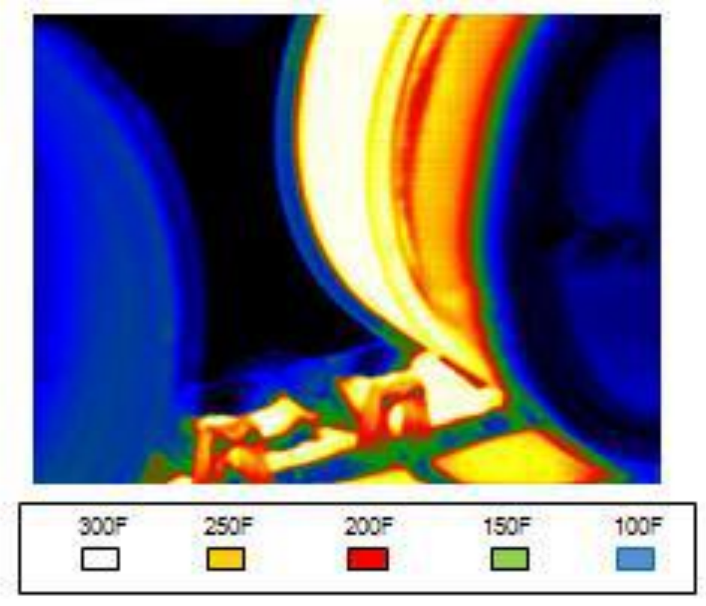
Motivation

- Drastic temperature increase in elastomer pads of military tanks due to hysteretic property of elastomers
- High temperatures decrease their strength and fatigue life

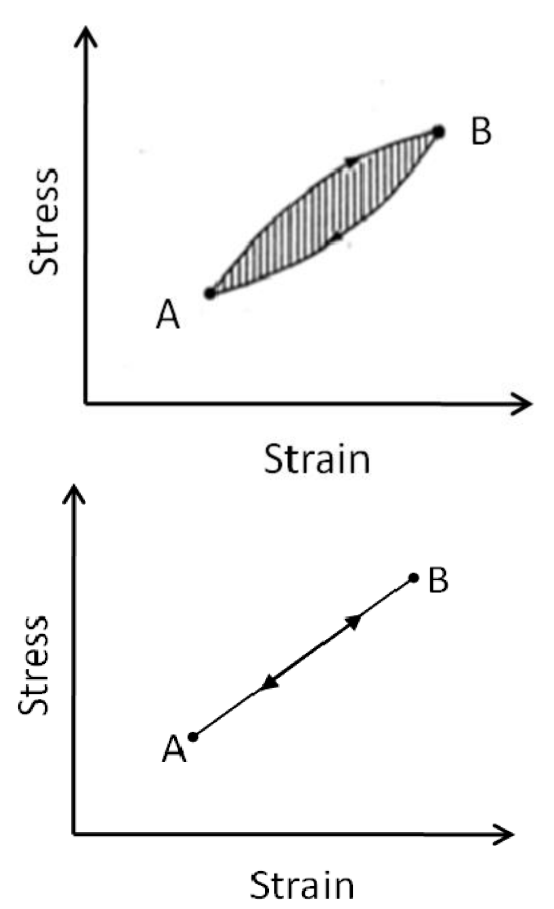


Thermal Map - Abrams Left Side (Bradford and Ostberg, 2009)

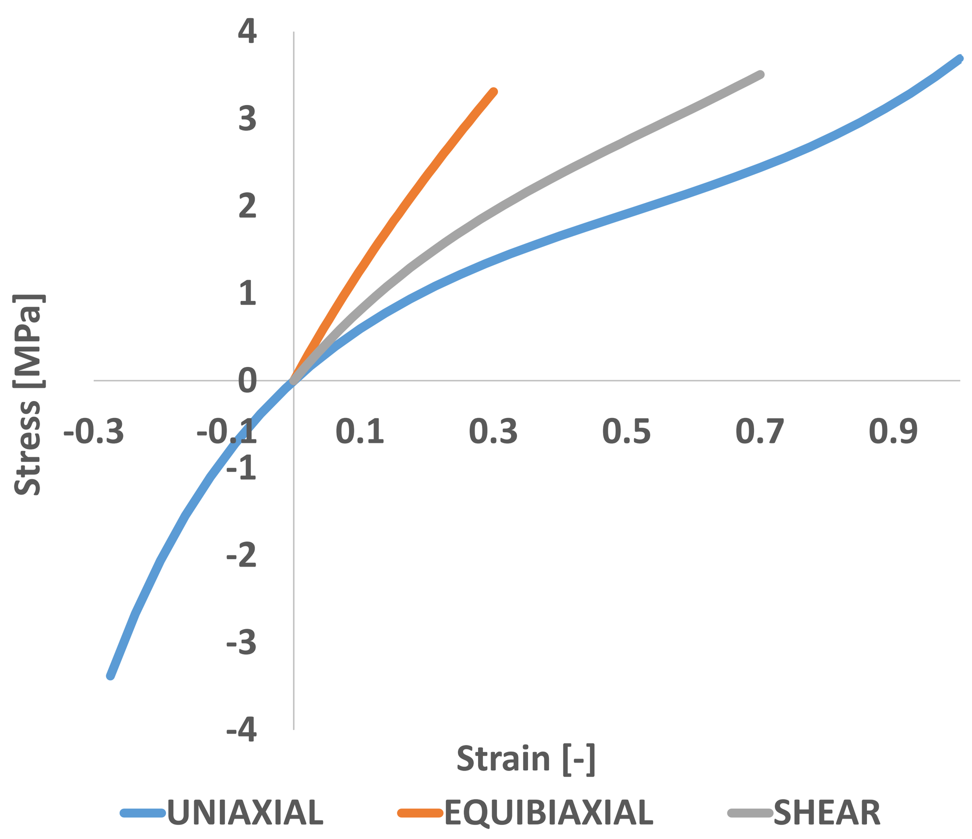
Goal and Methodology

Replace the elastomeric material with an elastic meta-material to eliminate hysteretic losses

- Design a meta-material whose stress-strain curve matches the elastomer in uniaxial compression
- Validate feasibility of obtained meta-material for use on a tank



Stress-Strain for Elastomers (top) and Elastic Materials (bottom) (Clark and Dodge, 1979)



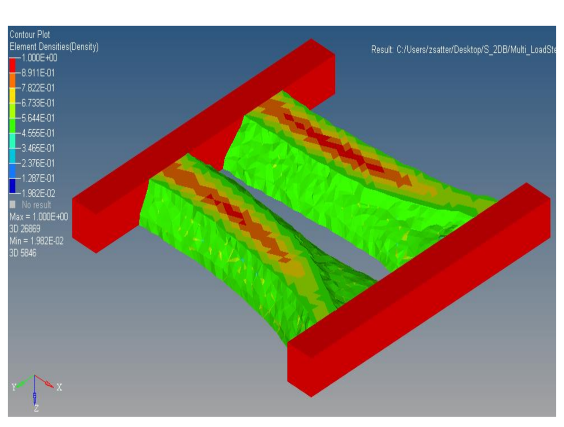
Stress-Strain Response of Current Elastomer on Tank (Dangeti, 2013)

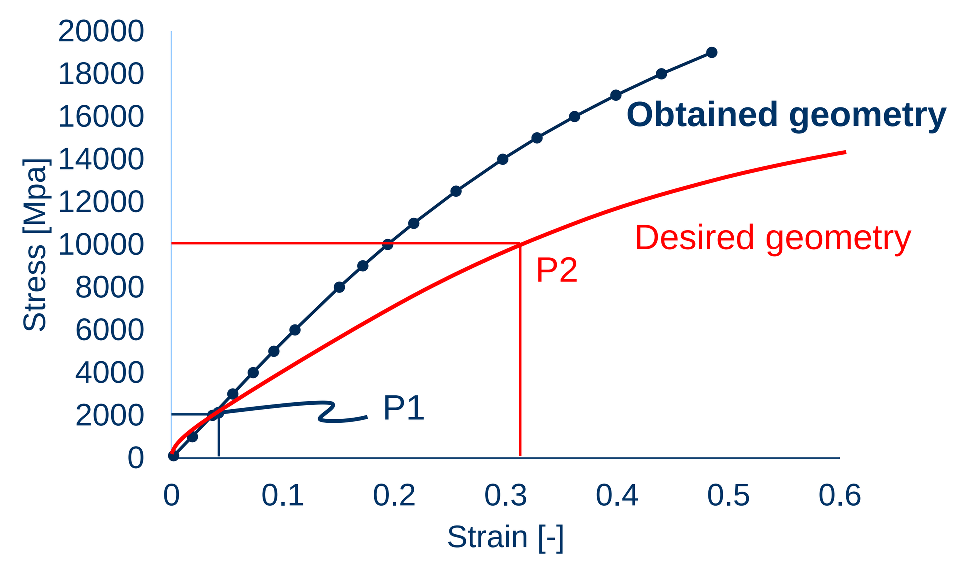
Objectives

- To develop a framework in which to design a meta-material that achieves desired stress-strain responses
- To implement topology and/or parametric optimization and tailor meta-material to desired stress-strain response

Topology Optimization (TO)

- Attempted to converge to uniaxial tension curve using one unit cell via TO in HyperWorks Optistruct
- Could not converge to entire stress-strain curve without imposing repeating BCs – beyond capabilities of commercial software
- Low number of unit cells limits applicability of homogenization theory

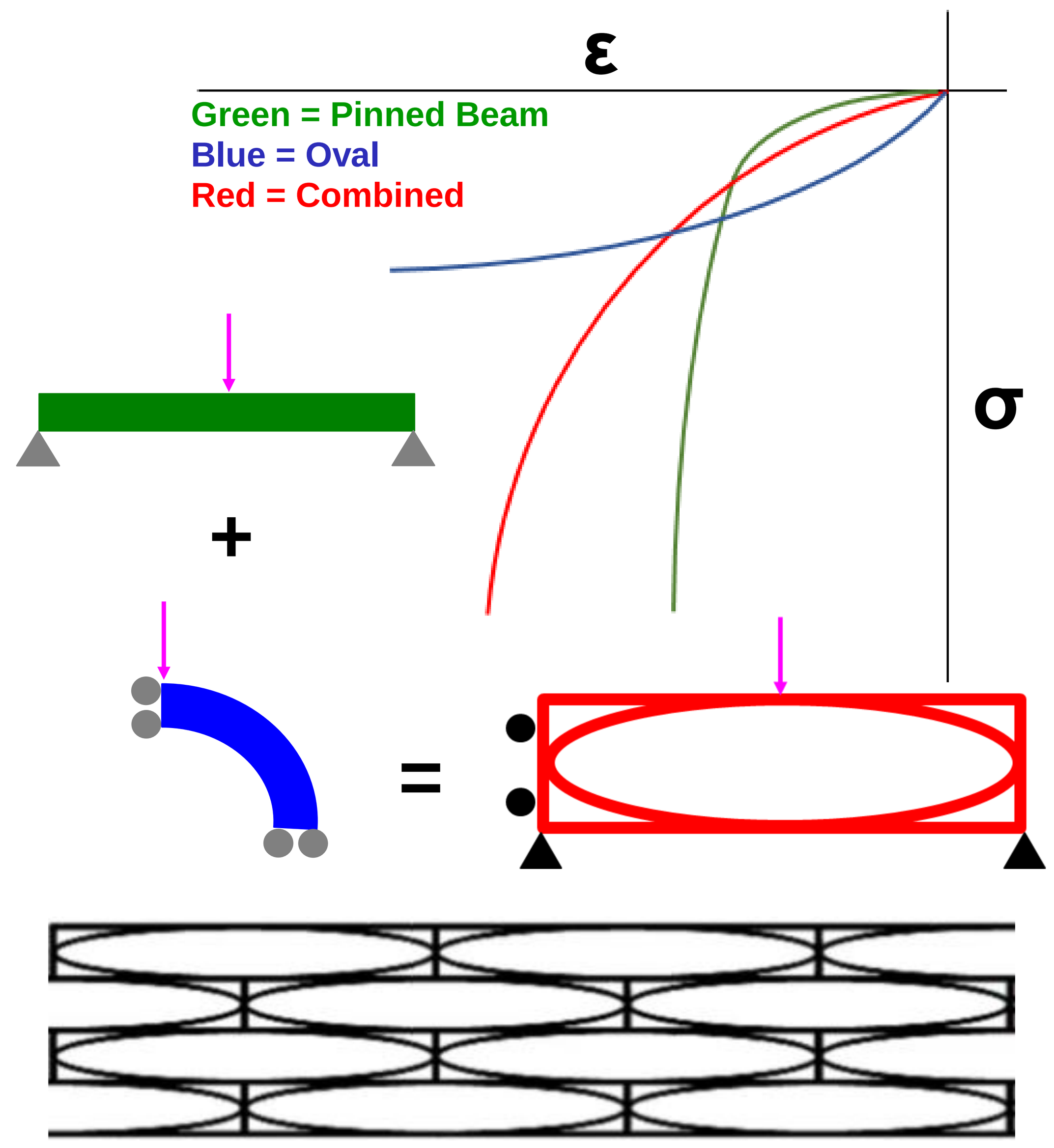

Converged Unit Cell via TO in Optistruct



Stress-Strain Curve not Converging using TO

Unit Cell Design

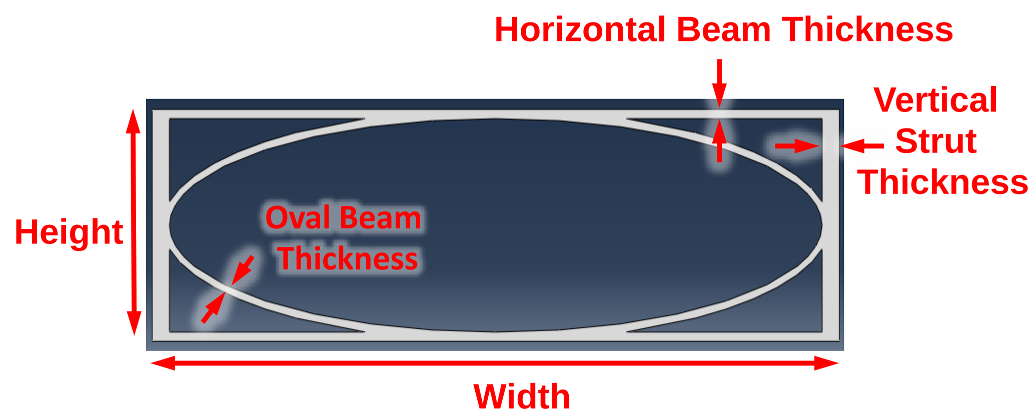
- Pinned-pinned beam stiffens rapidly when compressed
- Oval structure softens as compressed
- Combining the structures results in a compound structure with tunable stress-strain response
- "BrickOval" unit cell offset each layer such that vertical strut causes bending of horizontal pinned-pinned beam in layer below



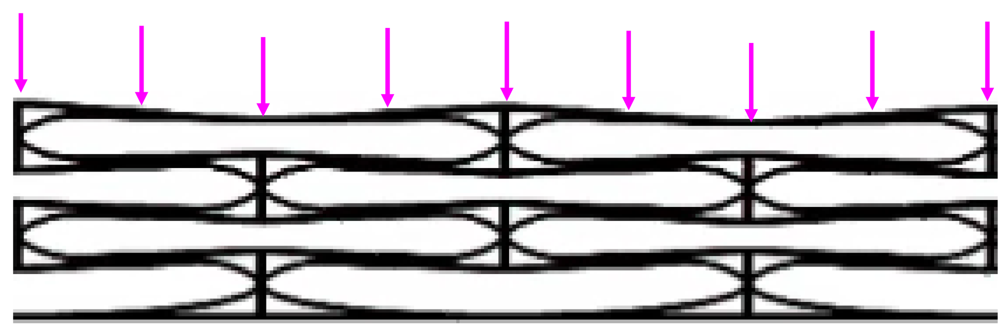
Development of the "BrickOval" Unit Cell

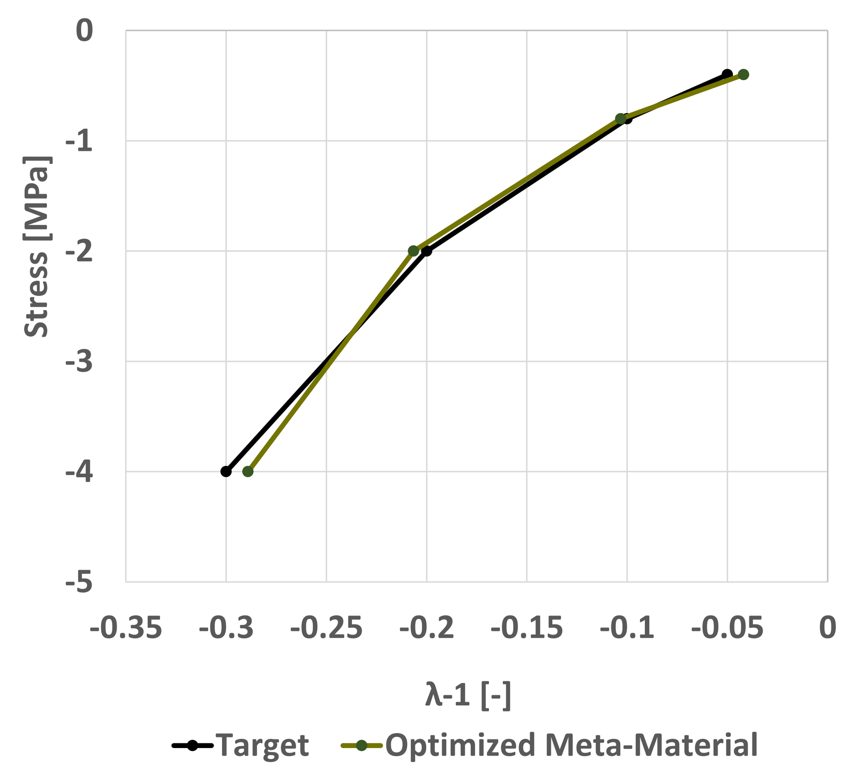
Parametric Optimization (PO)

- Horizontal beam thickness, oval thicknesses, and unit cell width are the crucial parameters
- Obtained geometry via PO by coupling ModeFRONTIER with Abaqus
- Rubber stress-strain curve matched by optimizing the crucial parameters of steel meta-material



"BrickOval" Unit Cell Parameters

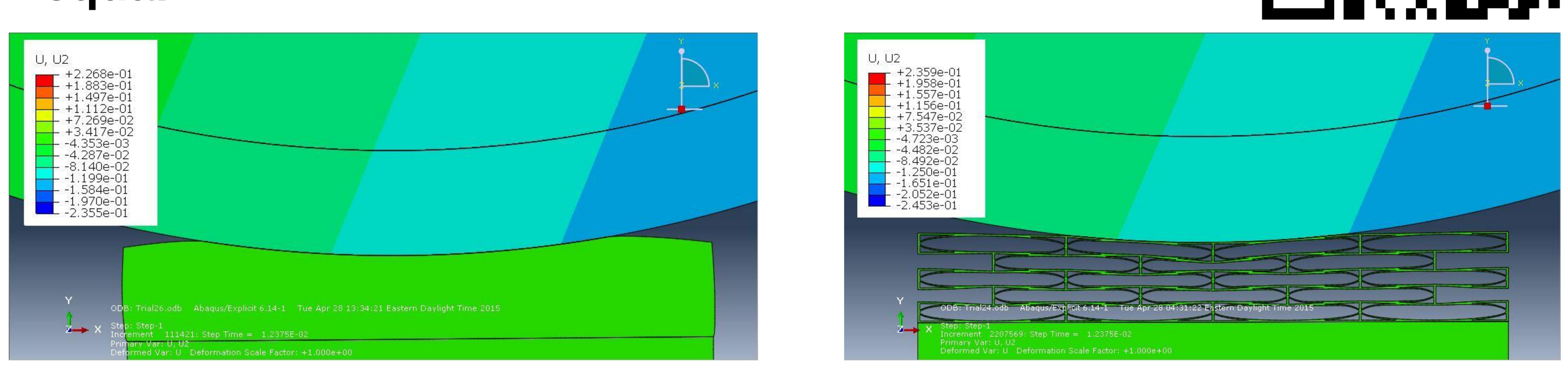

Static Deformed "BrickOval" Meta-Material



Stress-Strain Curve Converging Using PO

Dynamic FEA Comparison

- Dynamic FEA completed for meta-material from PO and compared to that of current elastomer
- Overall vertical deformations are practically equal


Dynamic FEA Comparison of Current Elastomer (left), Optimized Meta-Material (lower-right), and video link (top-right)

Future Work

- Reduce max stresses below yield stress for constitutive material
- Validate meta-material via dynamic simulations
- Expand to 3D framework to include complex operating and failure scenarios

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