Design and Optimization of Tank Track-Pad Meta-Material

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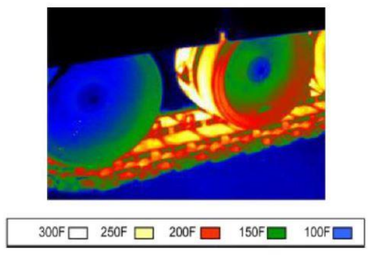
Overview

- The research project introduces a new method called the "**Synthesis Method**" for the development of unit-cell based meta-material structures that exhibit **non-linear deformation** behavior
- This approach helps develop a meta-material with improved life over a conventional elastomeric tank track-pad

Motivation

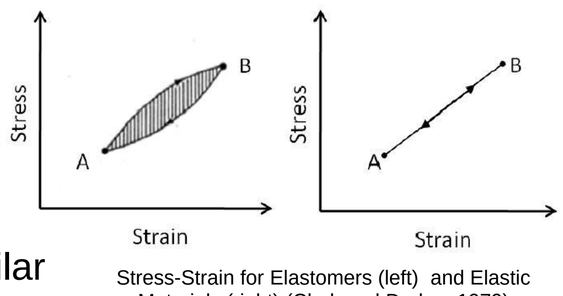
- The service life of the elastomeric backer-pad on the Abrams tank track system is limited due to high fatigue loads and subsequent temperature rise due to hysteresis.



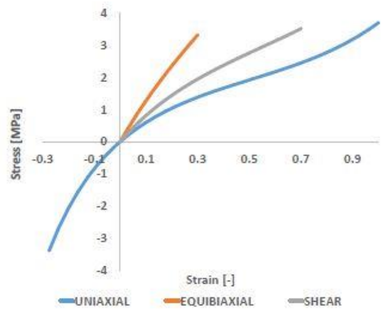
Thermal map – Abrams Left Side (Bradford and Ostberg, 2009)

Objective

- To develop a method to design an **elastic** meta-material which fulfils the following requirements:
  - ➢ It should exhibit non-linear compression characteristics similar to rubber
  - ➢ It should have improved fatigue life compared to the original rubber pad
- To validate the feasibility of designed meta-material as a replacement for the rubber track-pad



Stress-Strain for Elastomers (left) and Elastic Materials (right) (Clark and Dodge, 1979)



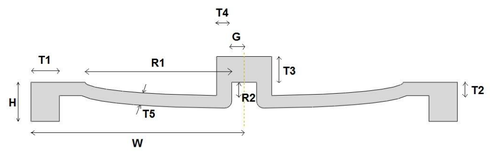
Stress-Strain Response of Current Elastomer on Tank (Dangeti, 2013)

Material Selection

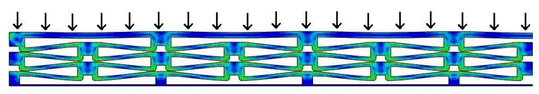
- A grade of Titanium alloy having a relatively lower ratio of Young's Modulus to Yield Strength is selected for the meta-material

Parametric Optimization

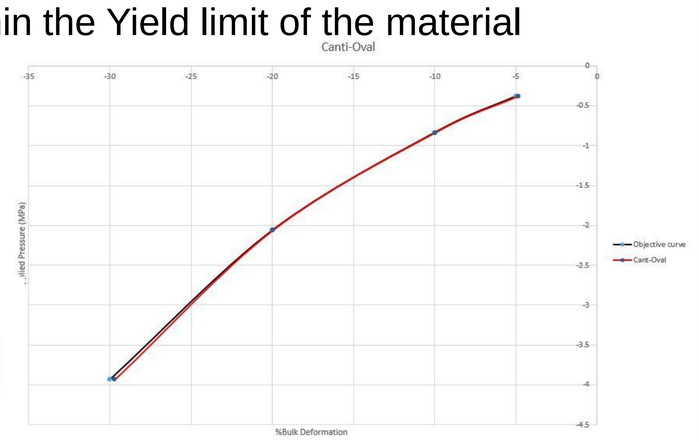
- The Unit-cell geometry is parameterized into 10 Design Variables
- Parametric optimization and design sensitivity analysis is carried out with static 2D FEA analysis
- Optimized unit-cell design is obtained that matches the Objective rubber stress-strain curve
- Stresses developed are within the Yield limit of the material



Unit Cell with Design Variables



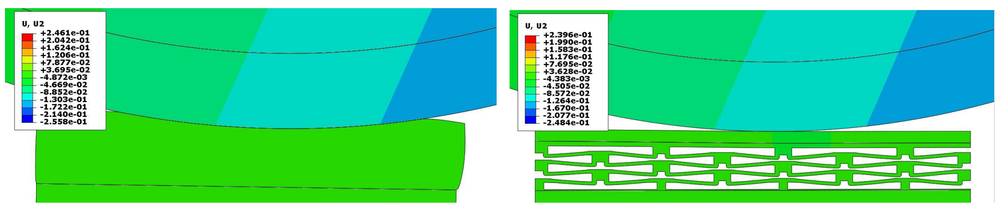
Deformed Meta-Material under Static loading



Optimized Applied Pressure - % Bulk deformation curve

Dynamic Analysis Comparison

- Dynamic analysis simulating tank wheel roll-over on track-pad assembly carried out to validate the meta-material design obtained
- Original rubber pad and the meta-material pad show similar deformation behavior



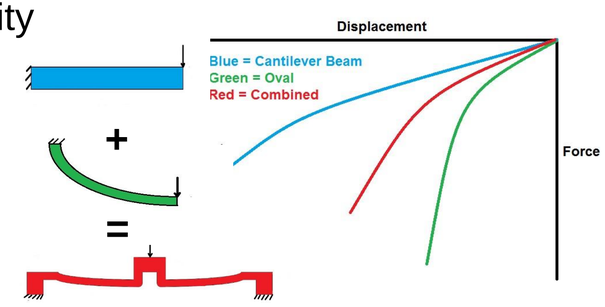
Deformation plot of Rubber (Left) and Meta-Material (Right) track-pad during wheel roll-over event

Video link for dynamic analysis

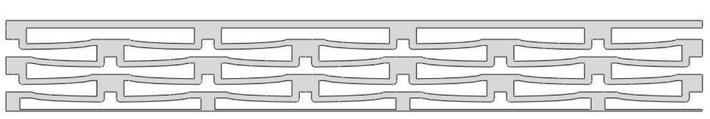
Progress Made

Synthesis Method:

- This method makes use of the force - displacement relationships of primitive structures
- Two or more primitive structures are combined to form a unit-cell
- These unit-cells are then assembled periodically to form a meta-material structure such that each unit-cell undergoes similar deformation
- Parametric Optimization and Design Sensitivity analysis is carried out to match the target stress-strain curve
- The resulting structure captures the material non-linearity by introducing geometric non-linearity



- Both the cantilever beam and the oval exhibit varying levels of non-linear behavior
- These two structures are combined to form a unit-cell based meta-material with tunable force – displacement characteristics



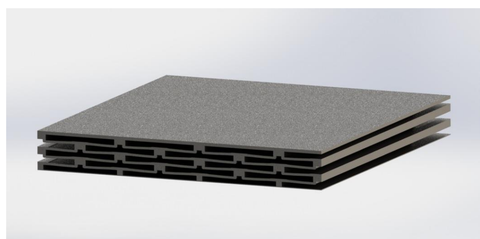
Unit-Cell Based Meta-material Development by Synthesis Method

Intellectual Merit and Broader Impacts

- The "Synthesis Method" introduces a new design method for developing unit-cell based meta-material structures with non-linear deformation behavior
- The method can be broadened to design non-linear meta-material structures for various applications

Conclusions and Future Work

- Using the "Synthesis Method", a Meta-material has been designed that shows bulk deformation behavior similar to the original rubber in the track-pad assembly.
- Future work includes:
  - ➢ Expanding the Finite Element Analysis to 3D framework
  - ➢ Carrying out a high cycle fatigue analysis
  - ➢ Implementing Design for Manufacturing and Assembly aspects in the pad design
  - ➢ Physical Testing of the Meta-material pad on the tank



Rendered Image of the Canti-oval meta-material

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