THE STUDY OF MECHANICAL BEHAVIOR OF MICRO PATTERNS MADE OF PDMS MATERIAL UNDER COMPRESSIVE LOADING USING FINITE ELEMENT METHOD

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PDMS MATERIAL PROPERTIES

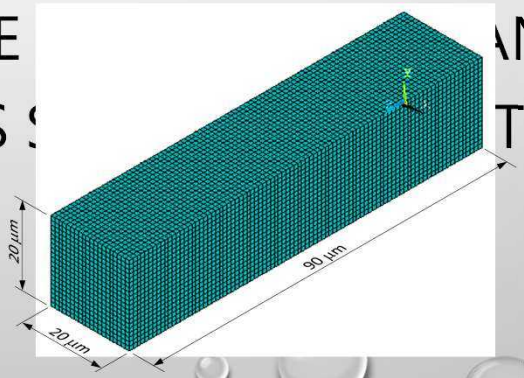
PDMS IS A RUBBERLIKE MATERIAL WHICH HAS NONLINER ELASTIC RESPONSE AND LOADING DIRECTION DEPENDENCE. THE STUDIED PDMS HAS RATIO OF A PDMS MONOMER TO A CURING AGENT RATIO OF 10:1.

MECHANICAL BEHAVIOR OF PDMS

MECHANICAL BEHAVIOR OF PDMS ALSO DEPENDS ON STRUCTURAL SIZES.

- **MICRO STRUCTURE**

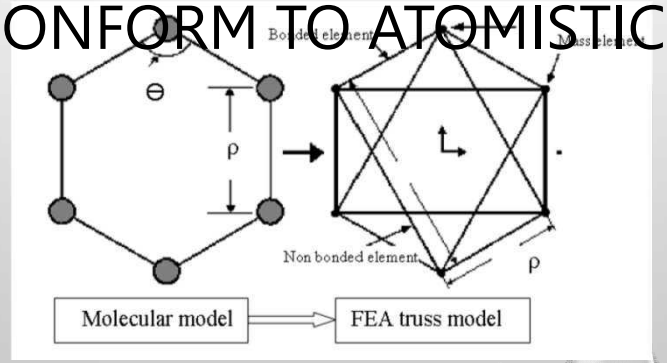
MICRO STRUCTURES COULD BE ANDARD FE PROGRAMS. THESE FE MODELS S TO CONTINUUM MECHANICS.



MECHANICAL BEHAVIOR OF MICRO STRUCTURES

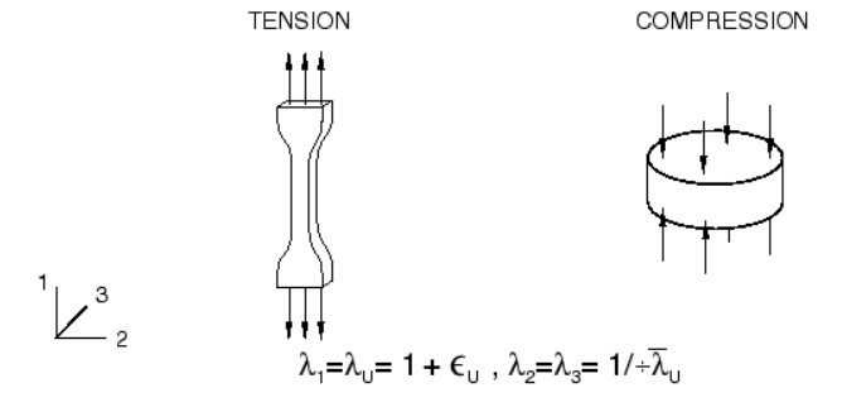
- **NANO STRUCTURE**

NANO STRUCTURES COULD BE MODELED WITH AN EQUIVALENT FE MODEL BY A GROUP OF TRUSS ELEMENTS. THESE FE MODELS CONFORM TO ATOMISTIC MODELLING.

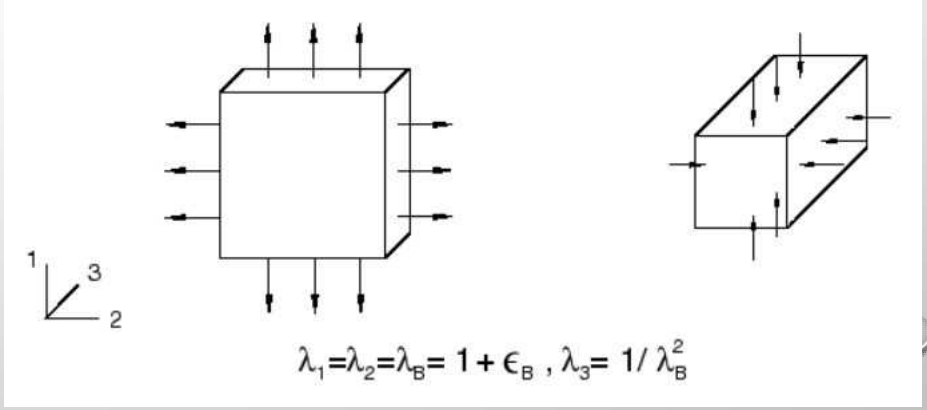


STANDARD TESTING FOR HYPERELASTIC MATERIALS

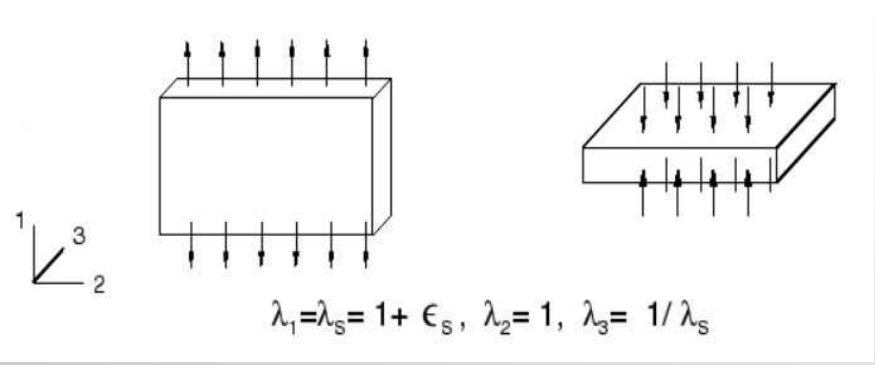
UNIAXIAL TEST



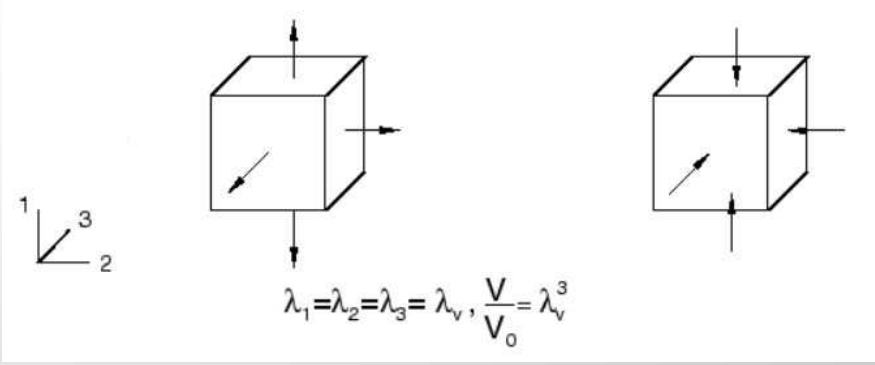
BIAXIAL TEST



PLANAR TEST



VOLUMETRIC TEST



https://abaqus-docs.mit.edu/2017/English/SIMACAEMATRefMap/simamat-c-hyperelastic.htm

HYPERELASTIC MATERIAL MODELS

- NEO-HOOKEAN MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = C_{10}(I_1 - 3) + \frac{1}{D_1}(J_{el} - 1)^2$$

WHERE C_{10} IS MATERIAL CONSTANTS, I_1 IS 1ST INVARIENT, J_{el} IS AN ELASTIC VOLUMETRIC RATIO AND D_1 IS CONSTANTS OF MATERIAL COMPRESSIBILITY.

- MOONEY-RIVLIN MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = \sum_{i=0,j=0}^{\infty} C_{ij}(I_1 - 3)^i (I_2 - 3)^j$$

WHERE C_{ij} IS MATERIAL CONSTANTS; I_1 AND I_2 ARE 1ST AND 2ND INVARIANTS RESPECTIVELY.

- OGDEN MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = \sum_{n=1}^{N} \frac{2\mu_n}{\alpha_n^2}\left[\left(\lambda_1^{\alpha_n} + \lambda_2^{\alpha_n} + \lambda_3^{\alpha_n}\right) - 3\right] + \sum_{n=1}^{N} \frac{1}{D_n}(J_{el} - 1)^{2n}$$

WHERE α_n AND μ_n ARE MATERIAL CONSTANTS AND N IS THE NUMBER OF TERMS IN THE EQUATION WHICH IS USUALLY BELOW 3.

- YEOH MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = \sum_{n=1}^{N} C_{n0}(I_1 - 3)^n + \sum_{n=1}^{N} \frac{1}{D_n}(J_{el} - 1)^{2n}$$

WHERE C_{n0} IS MATERIAL CONSTANTS AND D_n ARE THE MATERIAL COMPRESSIBILITY CONSTANTS AND N IMPLY THE NUMBER OF TERMS IN THE EQUATION WHICH ARE USUALLY BELOW 3.

- ARRUDA-BOYCE MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = \mu \sum_{n=1}^{5} \frac{C_n}{\lambda^{2n-2}}(I_1 - 3^n) + \frac{1}{D_n}\pi\left[\frac{J_{el}^2 - 1}{2} - ln(J_{el})\right]$$

WHERE μ IS THE INITIAL SHEAR MODULUS, C_n ARE MATERIAL CONSTANTS AND D_n ARE DOUBLE INVERSE BULK MODULUS CONSTANTS.

- POLYNOMIAL MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = \sum_{i+j=1}^{N} C_{ij}(I_1 - 3)^i (I_2 - 3)^j$$

WHERE C_{ij} IS MATERIAL CONSTANTS, I_1 AND I_2 ARE 1ST INVARIANTS AND 2ND INVARIANTS RESPECTIVELY.

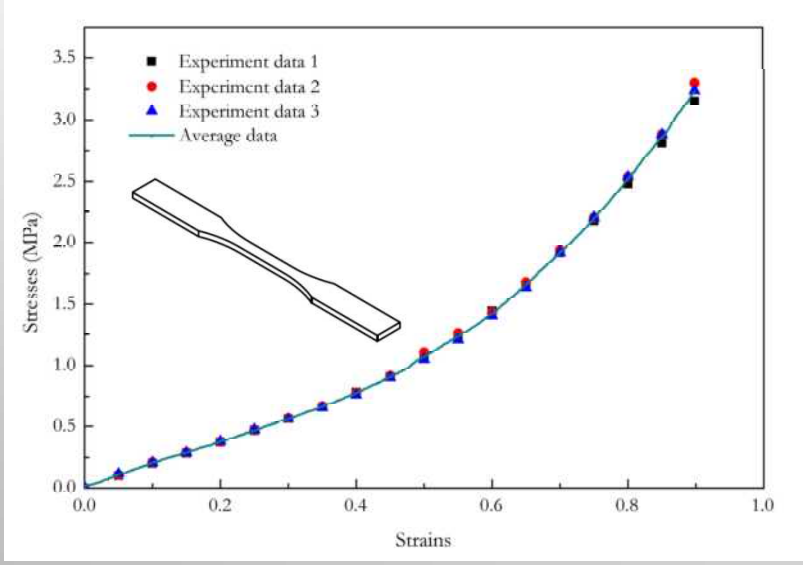
- GENT MODEL: THE STRAIN ENERGY IS WRITTEN AS

$$W = -\frac{EI_m}{6} log\left[\frac{I_m}{I_m - I_I^*}\right]$$

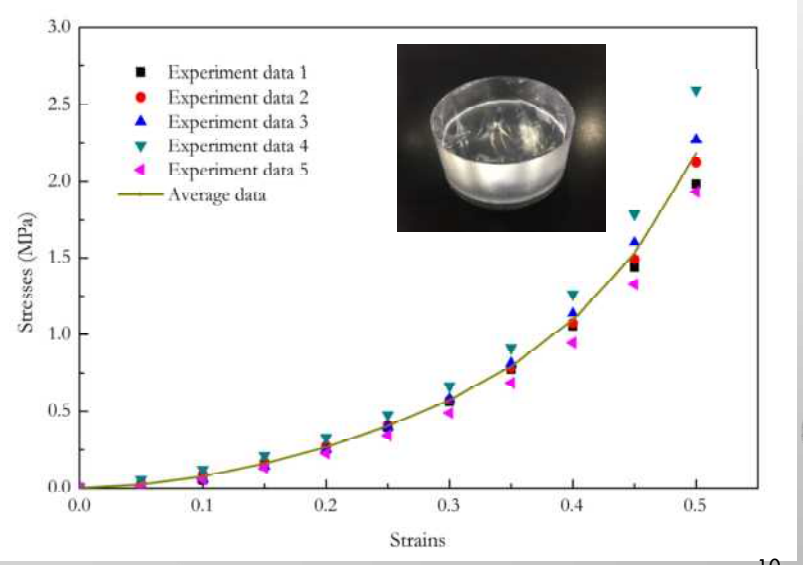
WHERE E AND I_m IS MATERIAL CONSTANTS.

PDMS MATERIAL PROPERTIES

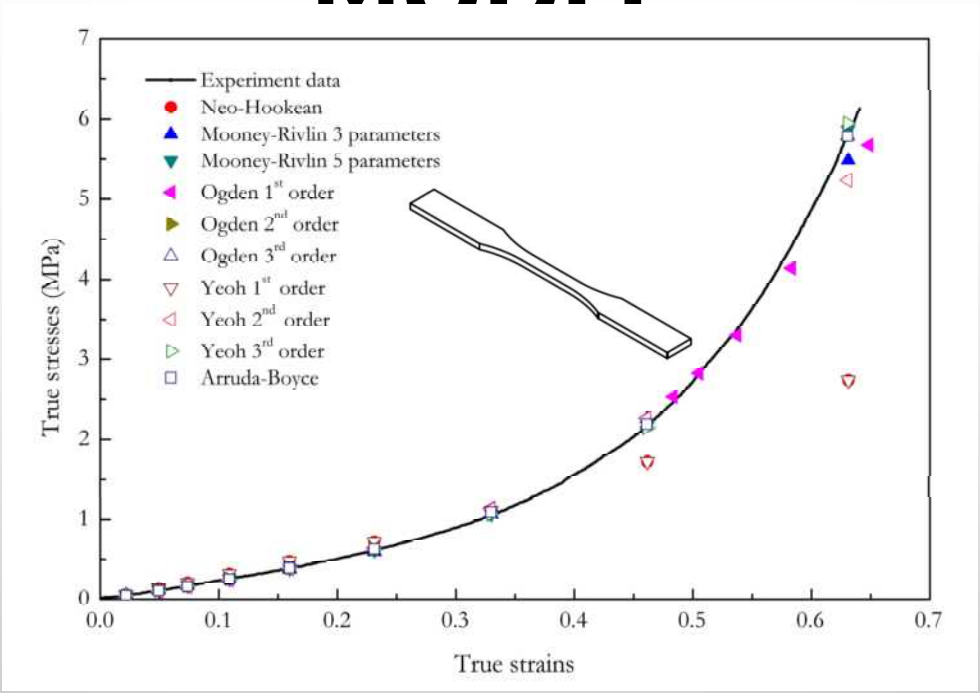
TENSILE TEST DATA



COMPRESSIVE TEST DATA

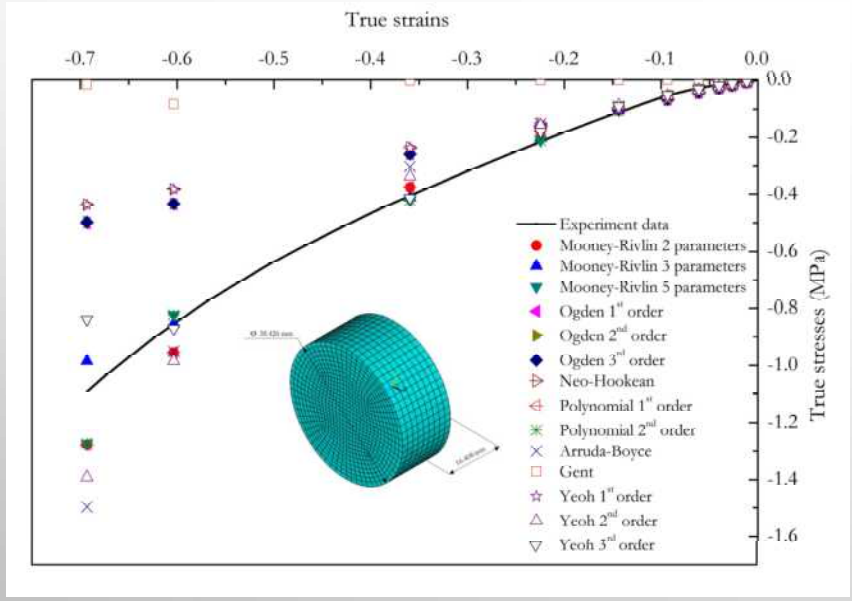


FE RESULTS FROM TENSILE TEST MODEL

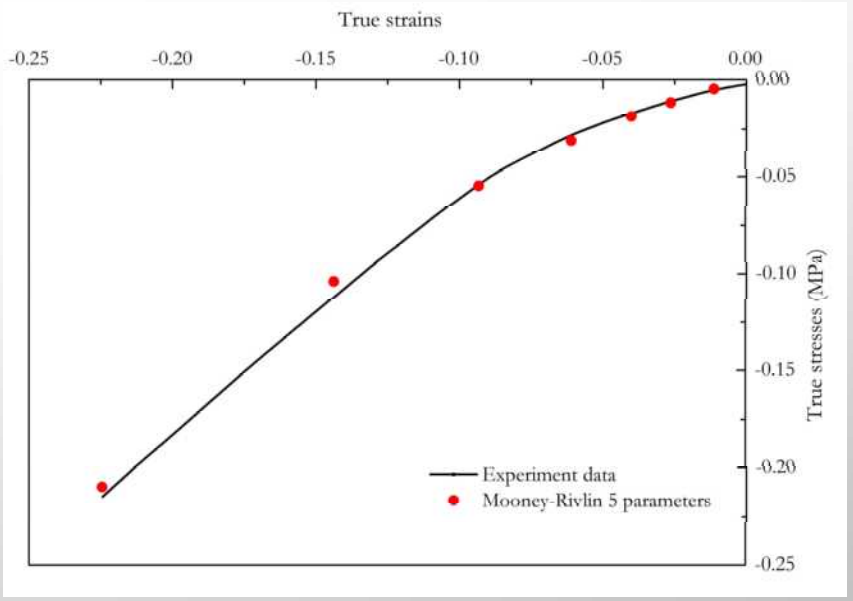


Plot of true stresses vs true strains of each material models compared to experiment data.

FE RESULTS FROM COMPRESSIVE TEST MODEL

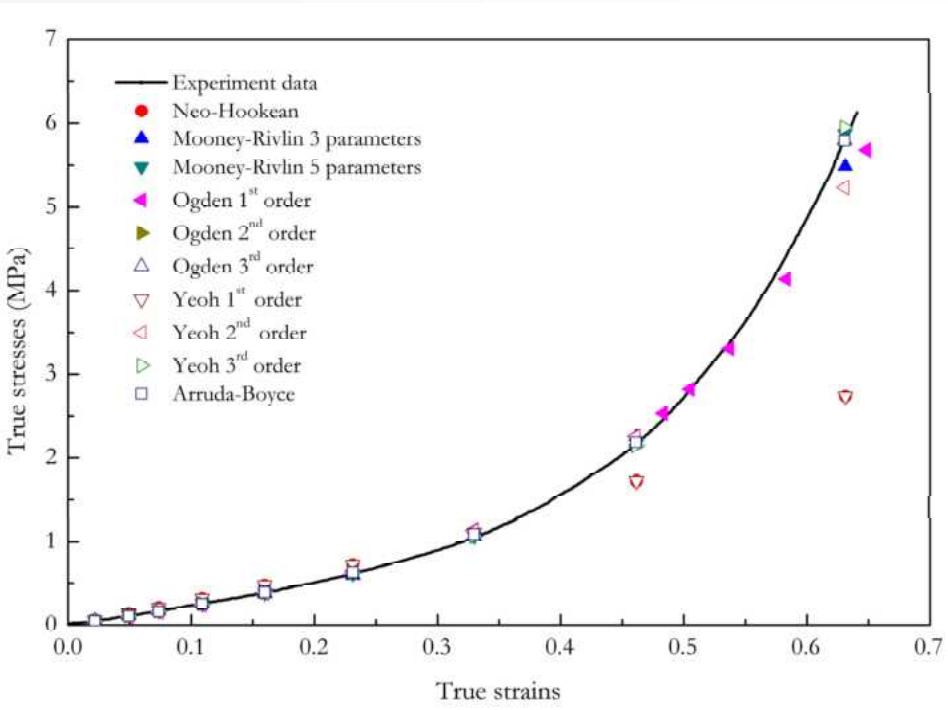


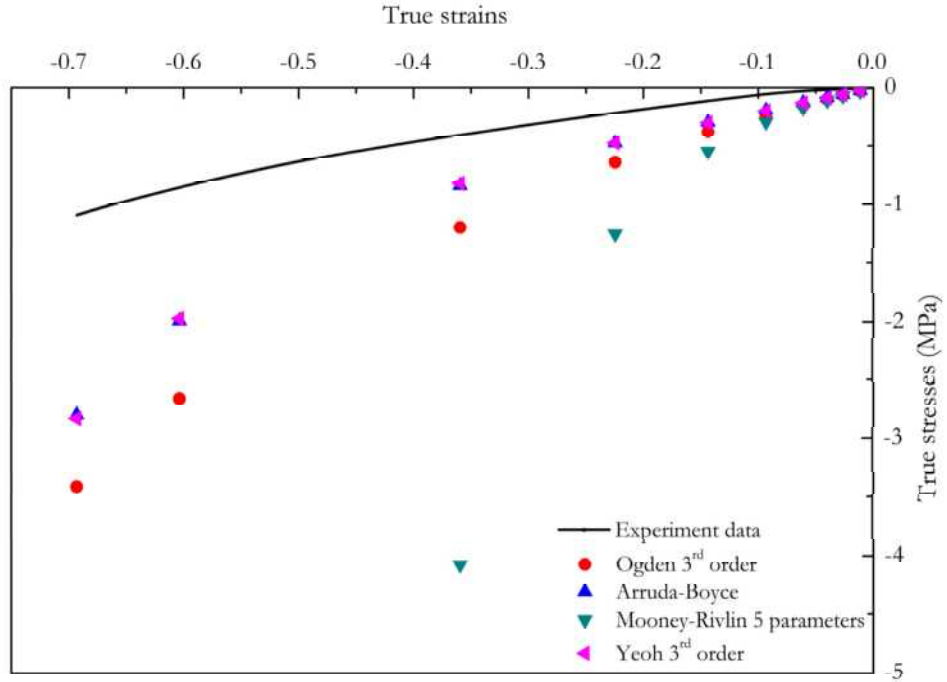
Plot of true stresses vs true strains of each material models compared to experiment data.



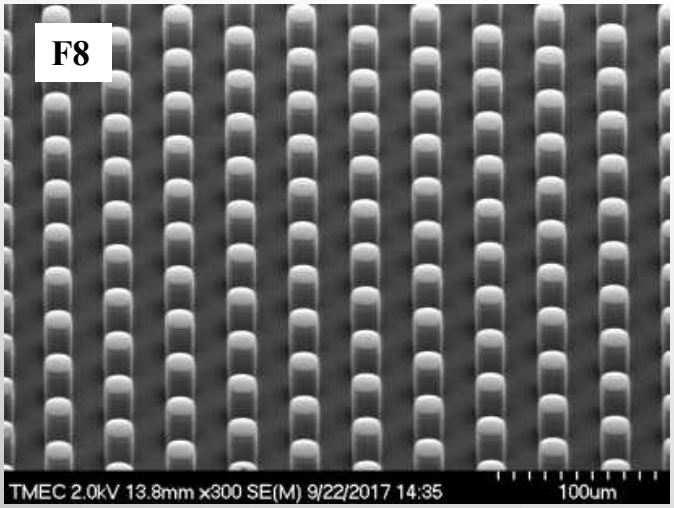
Plot of true stresses vs true strains of Mooney-Rivlin 5 parameters model compared to experiment data under the low strain range ($\varepsilon_z \leq 0.225$).

FEA ERROR RESULTING FOR USING TENSILE TEST DATA TO SIMULATE COMPRESSIVE LOADING

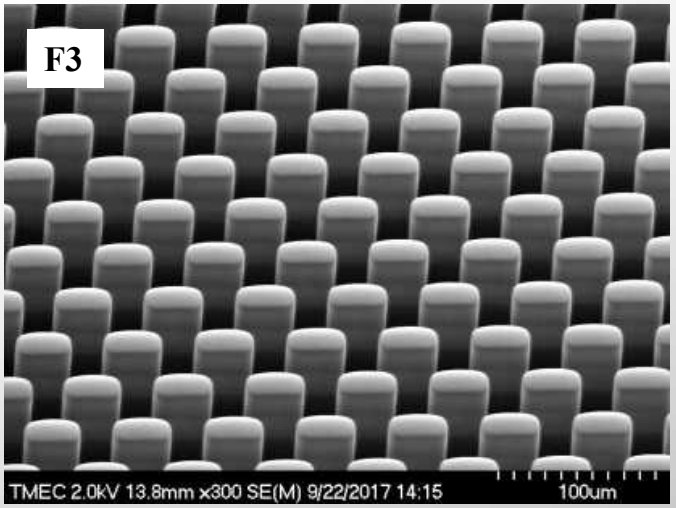




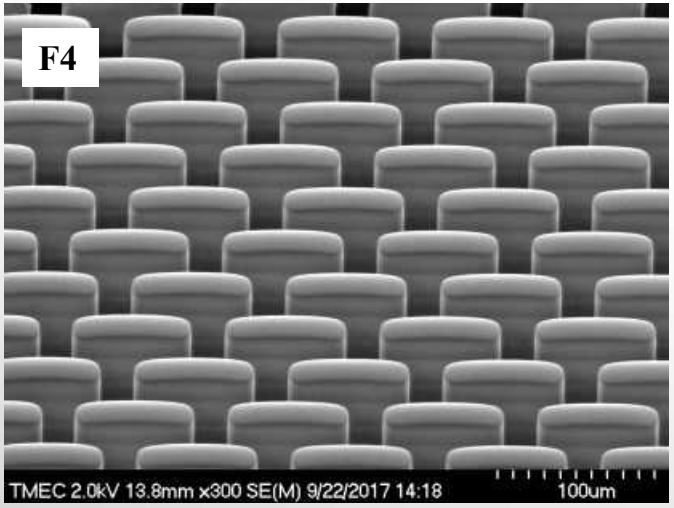
MICROPILLAR PATTERNS



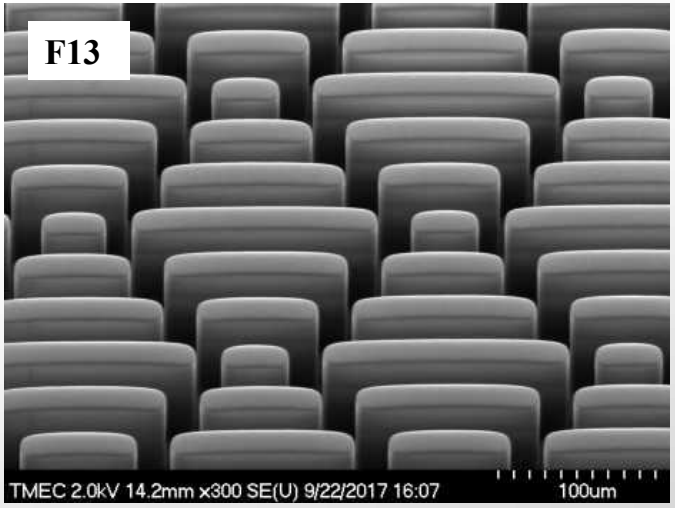
Water contact angle = 143.6°



Water contact angle = 139.6°



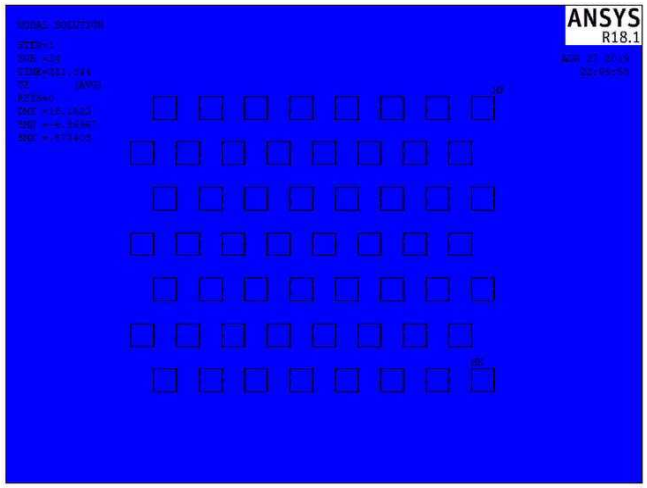
Water contact angle = 135.6°



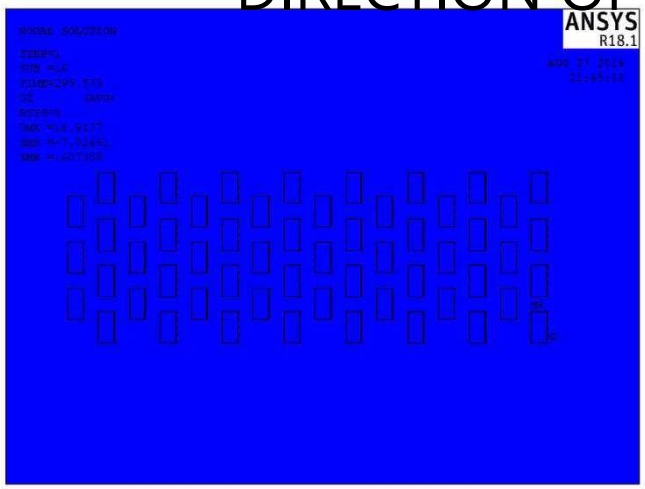
Water contact angle = 134.7°

FE RESULTS

DEFORMATION IN THE Z-DIRECTION OF F8

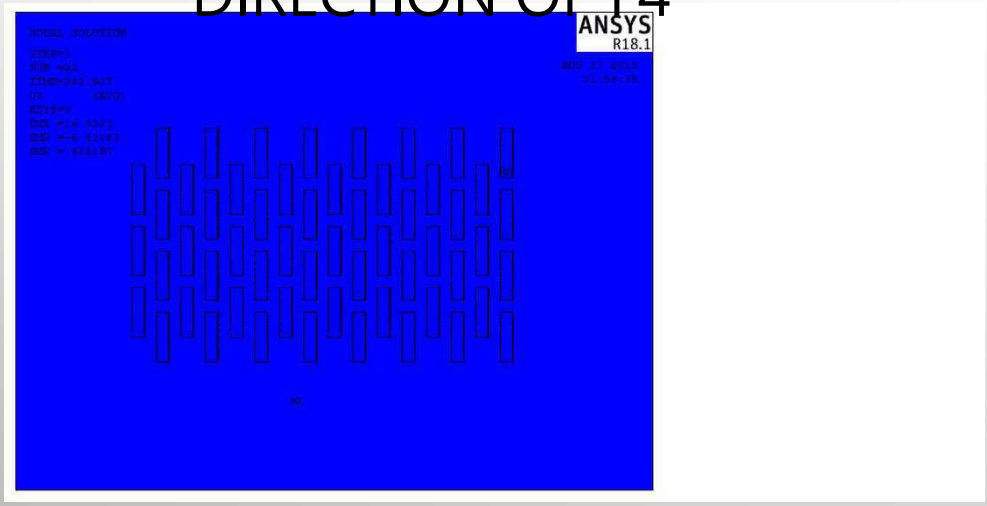


DEFORMATION IN THE Z-DIRECTION OF F3

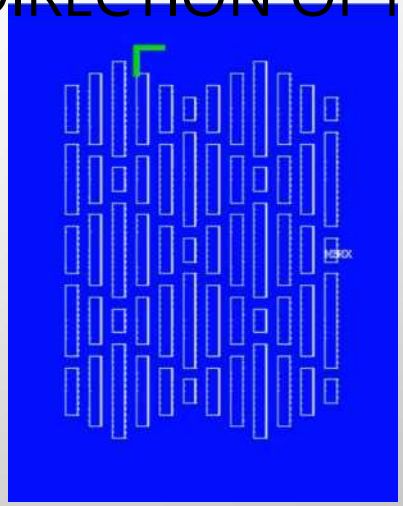


FE RESULTS (CONT.)

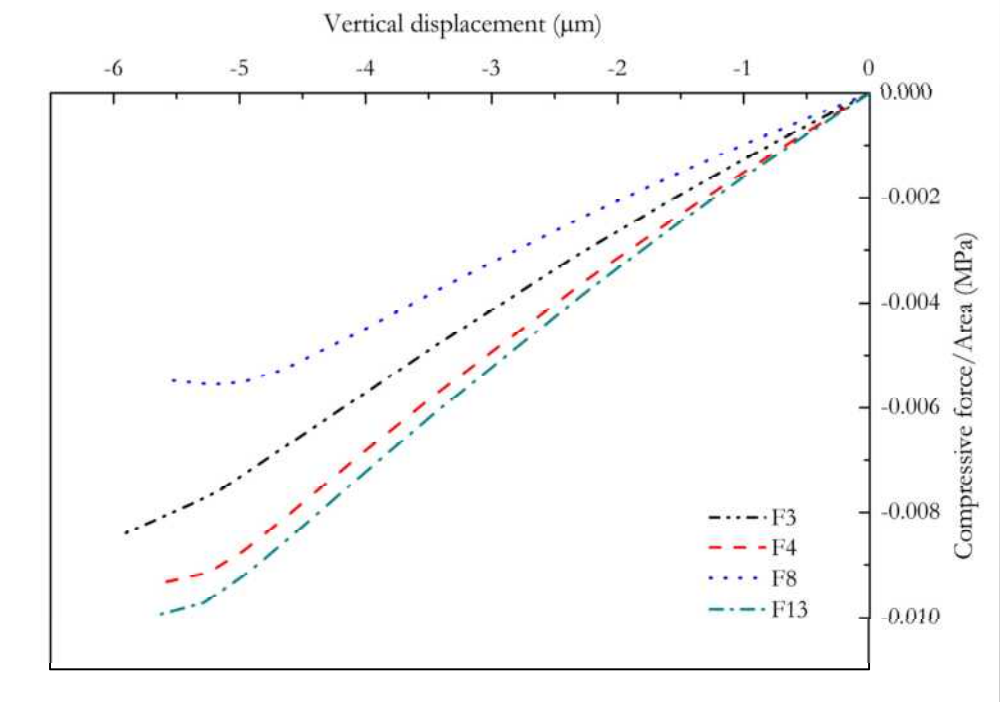
DEFORMATION IN THE Z-DIRECTION OF F4



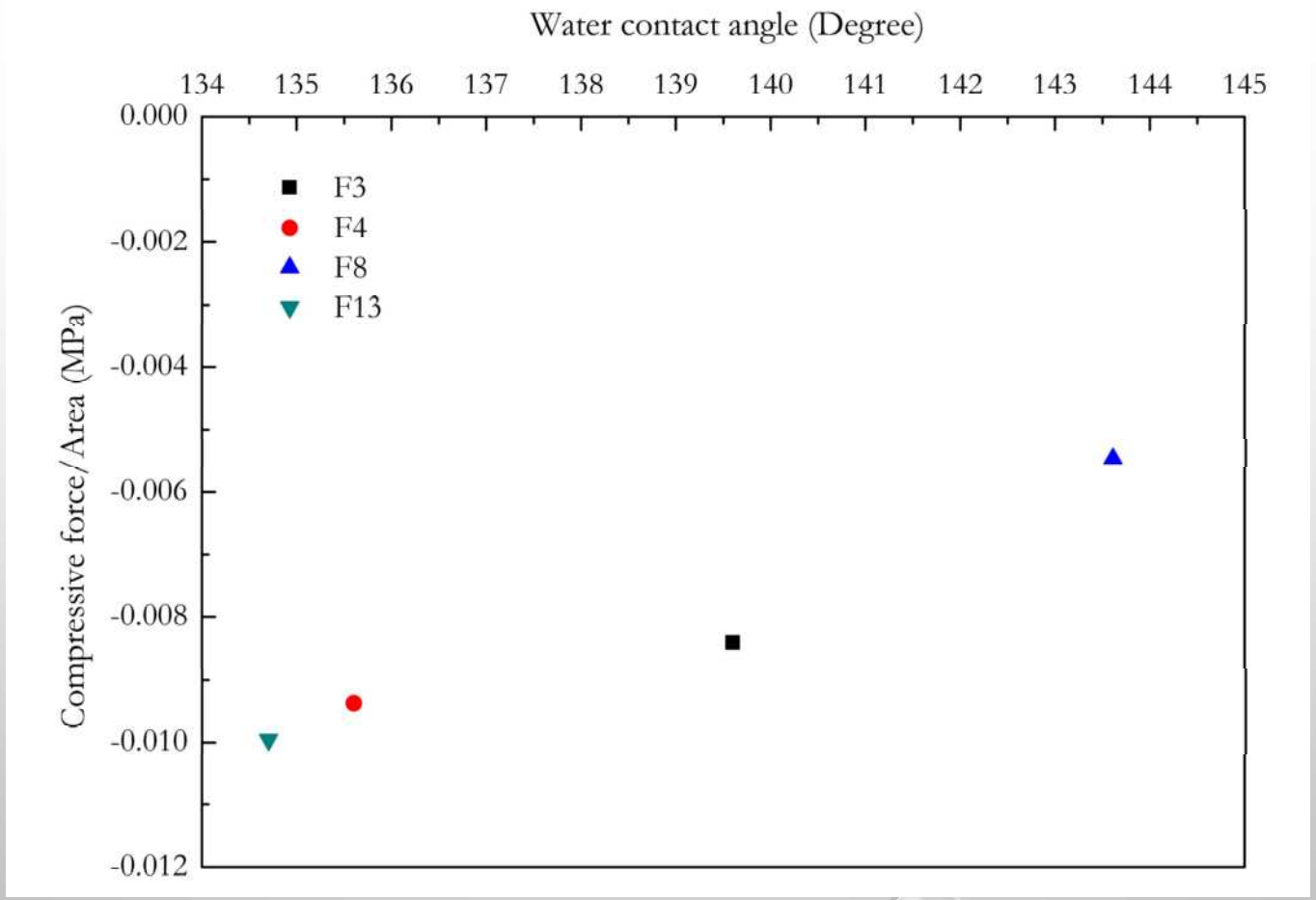
DEFORMATION IN THE Z-DIRECTION OF F13



EFFECTS OF INTERACTION BETWEEN MICROPILLARS



PLOT OF COMPRESSIVE FORCE PER AREA VS VERTICAL DISPLACEMENT OF EACH MICRO STRUCTURES COMPARED BY BASE THICKNESS OF 150 μM.


Water contact angle (Degree)
134
135
136
137
138
139
140
141
142
143
144
145
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
Compressive force/Area (MPa)
F3
F4
F8
F13

F8

F3

F4

THANK YOU