APPLYING FINITE ELEMENT ANALYSIS METHODS TO STRAIN GAGE DESIGN

Strain Gage Simulation

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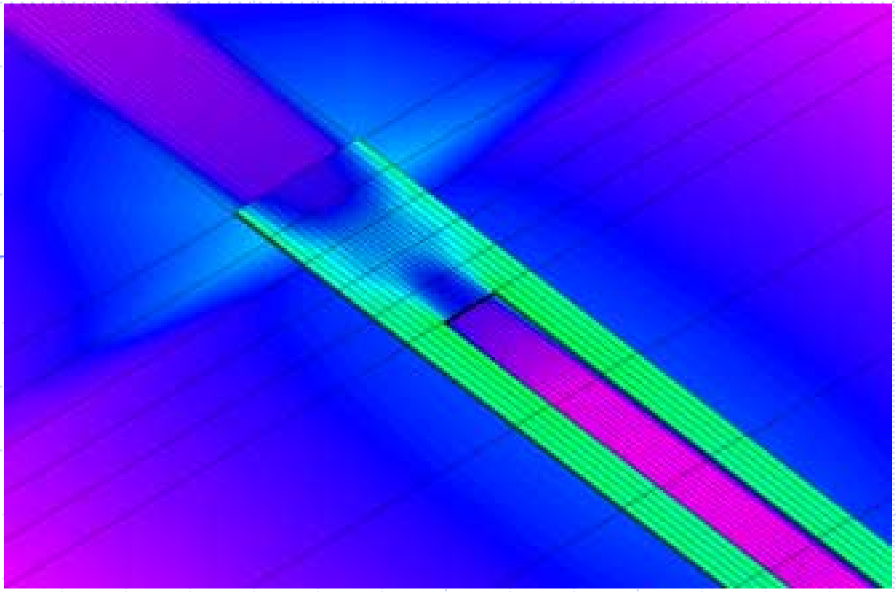
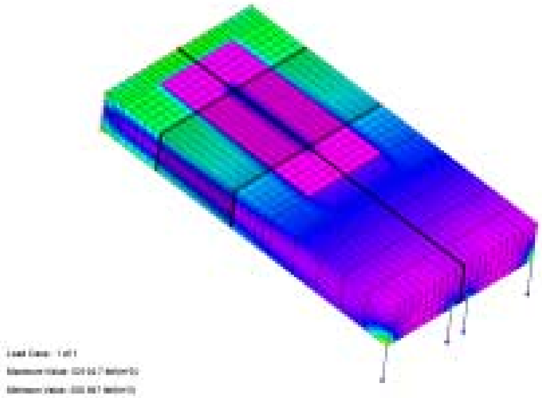
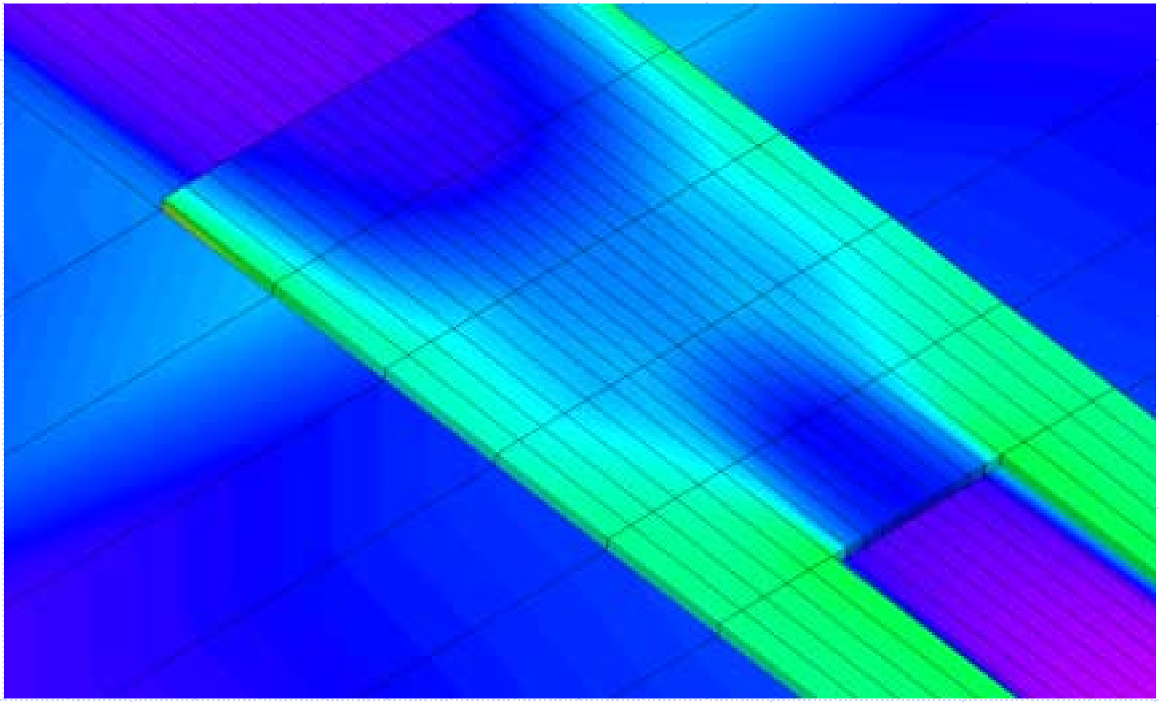


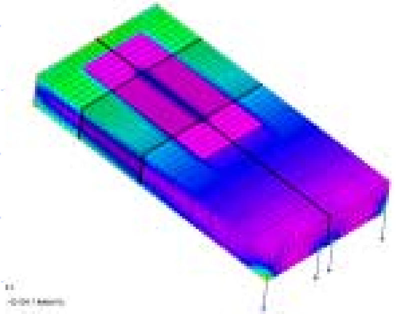

Load Case: 1 of 1



Abstract

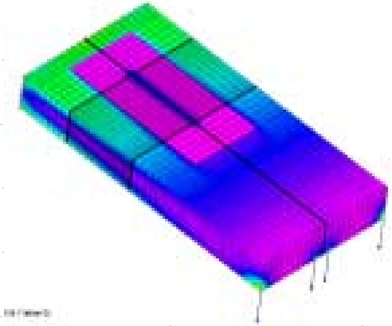
- Analysis of a strain gage utilizing tools that are typically available today on every engineer's desk. By studying the results of FEA on a simplified model of a strain gage, many critical aspects of a strain gage system can be investigated. Some of these aspects are explored here.
- All FEA was performed using Algor as the processor.
- All modeling and meshing was performed within Algor.

Basic Analysis

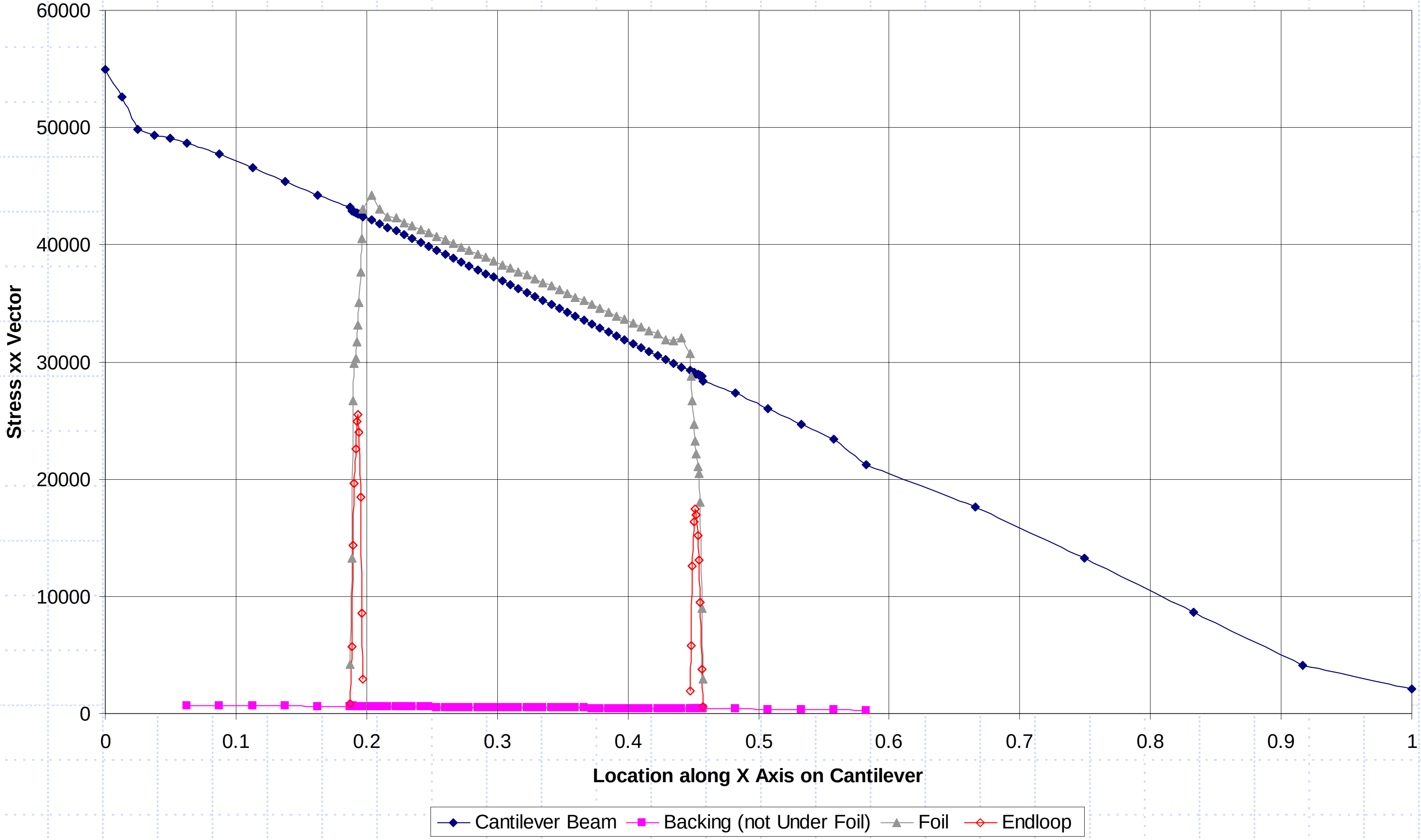


- Basic analysis centers around a simple cantilever beam. The beam is 1 inch long, 0.5 inch wide, and 0.10 inch thick.
- The cantilever was loaded on the end to create approximately 35 ksi in the center of the gage.
- This created 52.8 ksi at the rigid connection of the beam.
- The 35 ksi in the beam is a nominal value that would be common in transducer design.

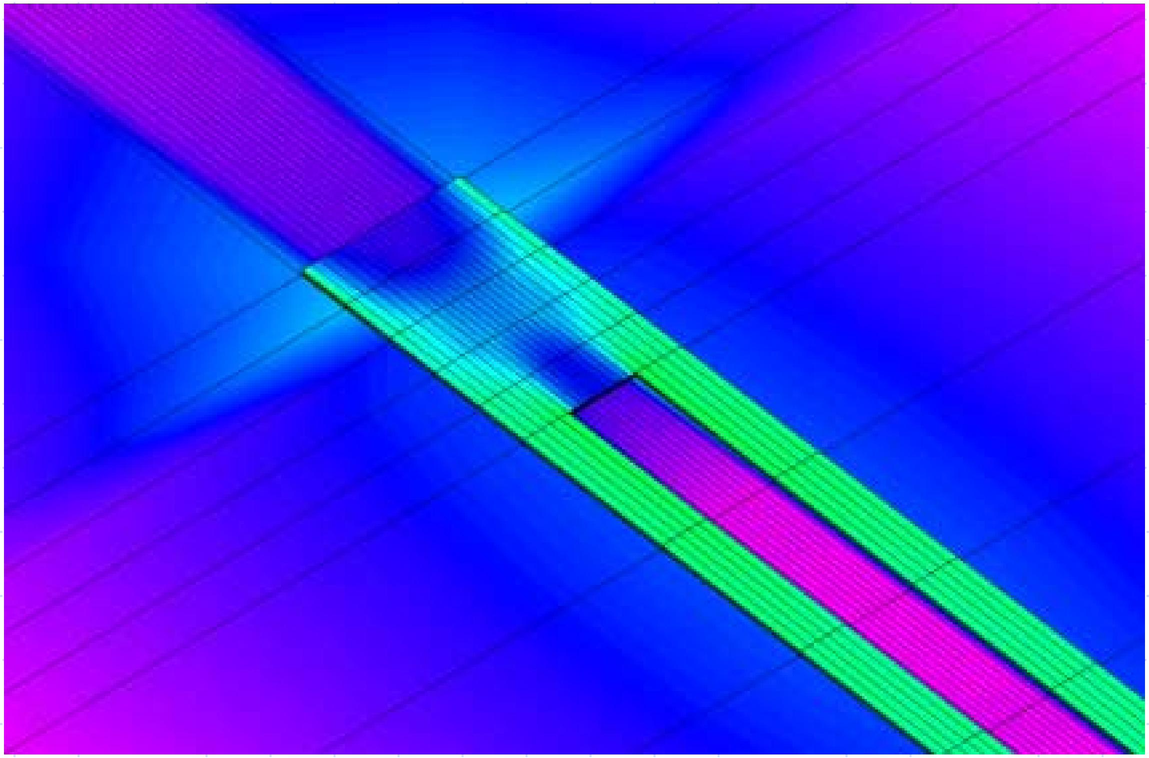
Basic Stresses



Basic System Stresses

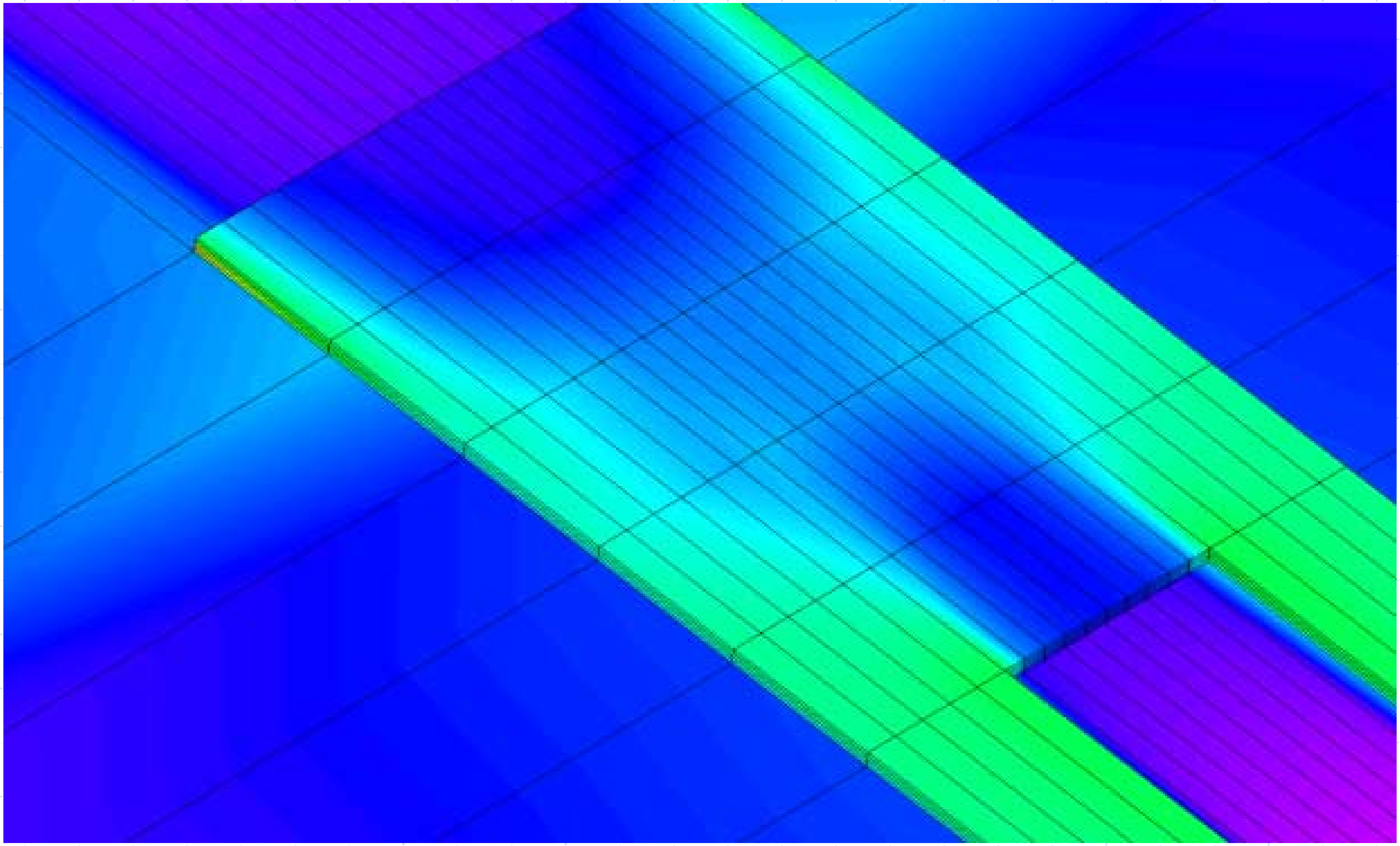


The Gage

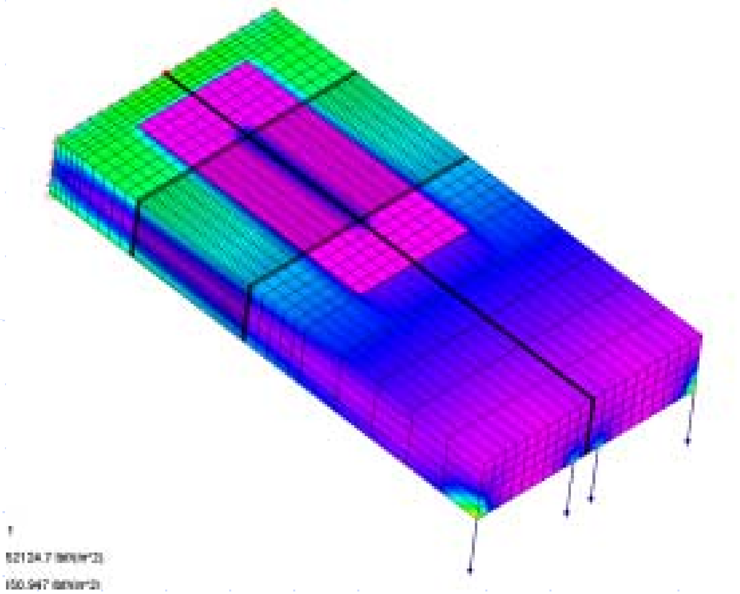


- The basic gage model has two grid lines: 2 mils wide and 250 mils long.
- Nominal endloop used is 7 mils wide and 10 mils long.
- Width between the grid lines is 3 mils.

The Gage



Gage Backing



- The insulation backing is nominally 0.52 inches long and 0.25 inches wide.
- Nominal thickness of the backing is 1 mil.

Design Variations Studied

- Endloop Lengths: 5 mils, 10 mils, and 15 mils
- Backing Thickness: ½ mil, 1 mil, 2 mils, and 5 mils
- Backing Material Properties represented: Kapton HN, Kapton VN, Upilex S, and soft epoxy
- Foil Thickness: 100 micro-inches, 200 micro-inches, and 300 micro-inches
- Foil Properties: Evanohm S (Nickel Chrome) and Constantan (Copper Nickel)

Design Variations

Analysis	Backing Thickness (in.)	Backing Type	Backing Modulus of Elasticity (psi)	Foil Thickness (micro-inches)	Foil Type	Foil Modulus of Elasticity (psi)	Endloop Length (in)
1	0.0010	Kapton HN	400000	200	Nickel Chrome	32000000	0.005
2	0.0010	Kapton HN	400000	200	Nickel Chrome	32000000	0.010
3	0.0010	Kapton HN	400000	200	Nickel Chrome	32000000	0.015
4	0.0005	Kapton HN	400000	200	Nickel Chrome	32000000	0.010
5	0.0020	Kapton HN	400000	200	Nickel Chrome	32000000	0.010
6	0.0050	Kapton HN	400000	200	Nickel Chrome	32000000	0.010
7	0.0010	Epoxy (soft)	200000	200	Nickel Chrome	32000000	0.010
8	0.0010	Kapton VN	600000	200	Nickel Chrome	32000000	0.010
9	0.0010	Upilex S	1280000	200	Nickel Chrome	32000000	0.010
10	0.0010	Kapton HN	400000	100	Nickel Chrome	32000000	0.010
11	0.0010	Kapton HN	400000	300	Nickel Chrome	32000000	0.010
12	0.0010	Kapton HN	400000	200	Copper Nickel	23500000	0.010

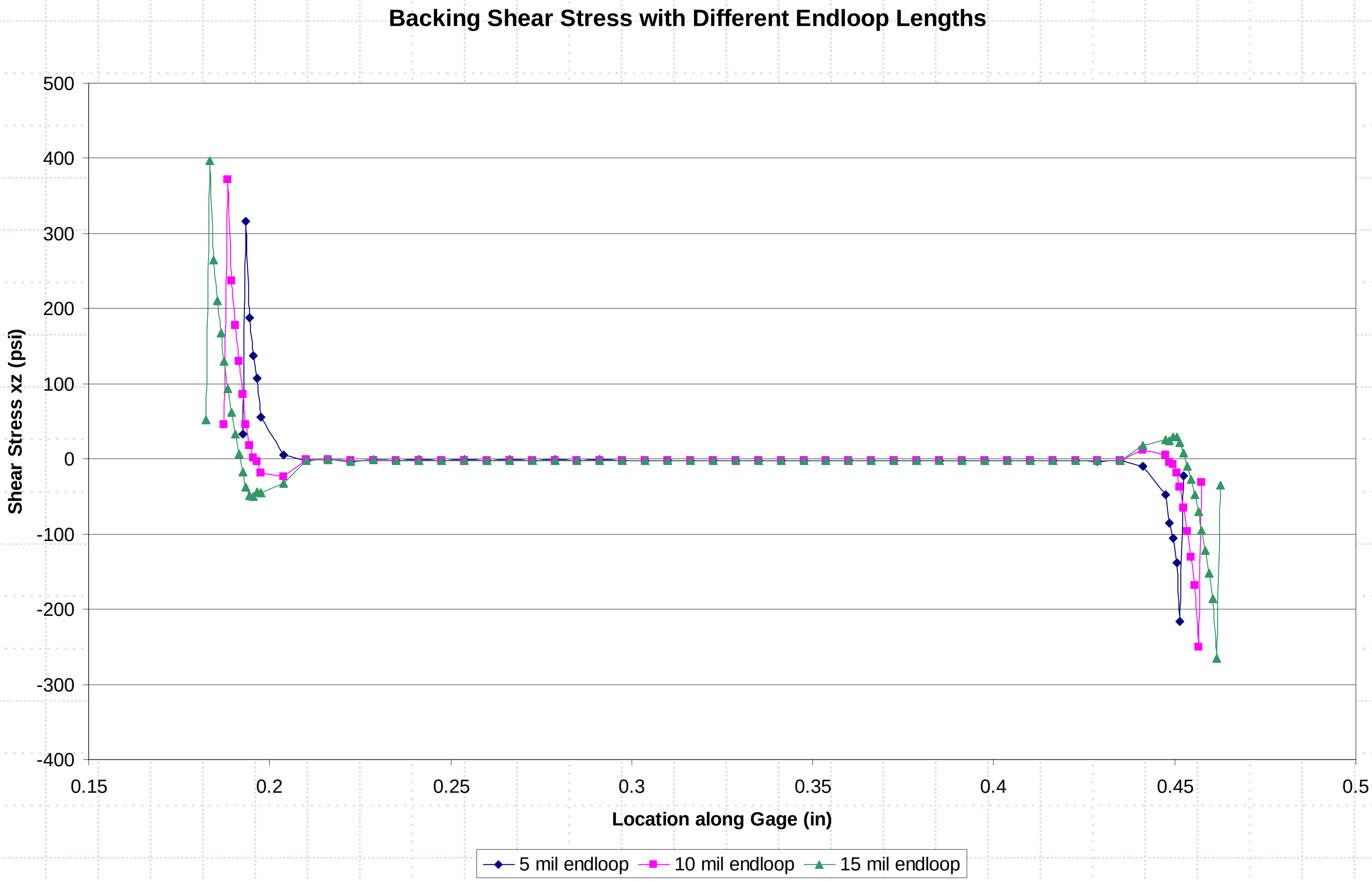
Data Analysis

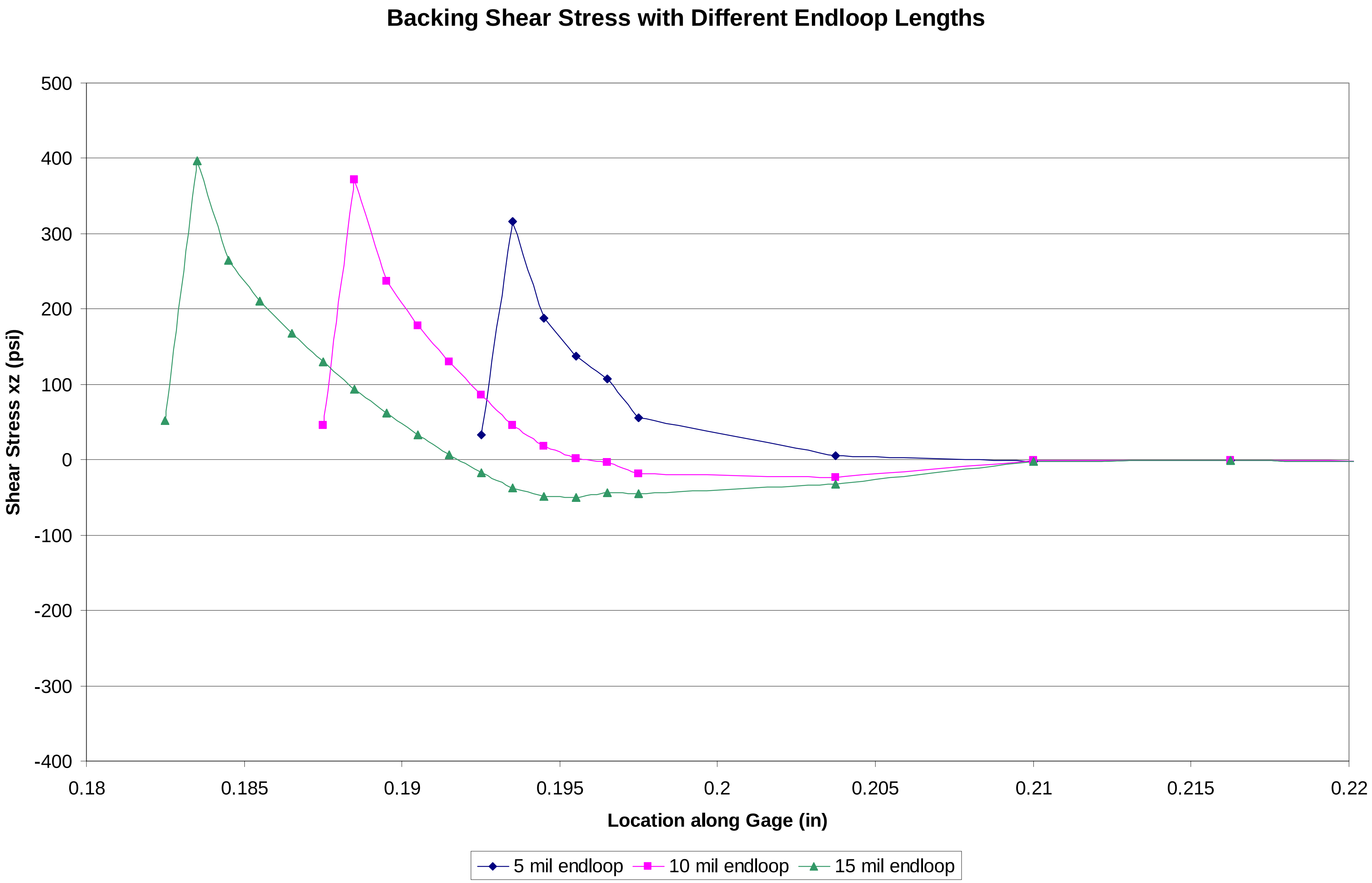
- After each of the analysis variations shown on the previous page was completed, the models were queried to extract stress information in the locations desired. This information was exported into Excel and comparison graphs were generated.
- Investigation into the stresses of the backing and foil are the areas of primary interest.
- Stresses in local areas of the gage are of interest because they will affect the performance and accuracy of the strain gage system.
- Other areas may be of interest as a result of current analyses presented here.

Variation One: Endloop Length

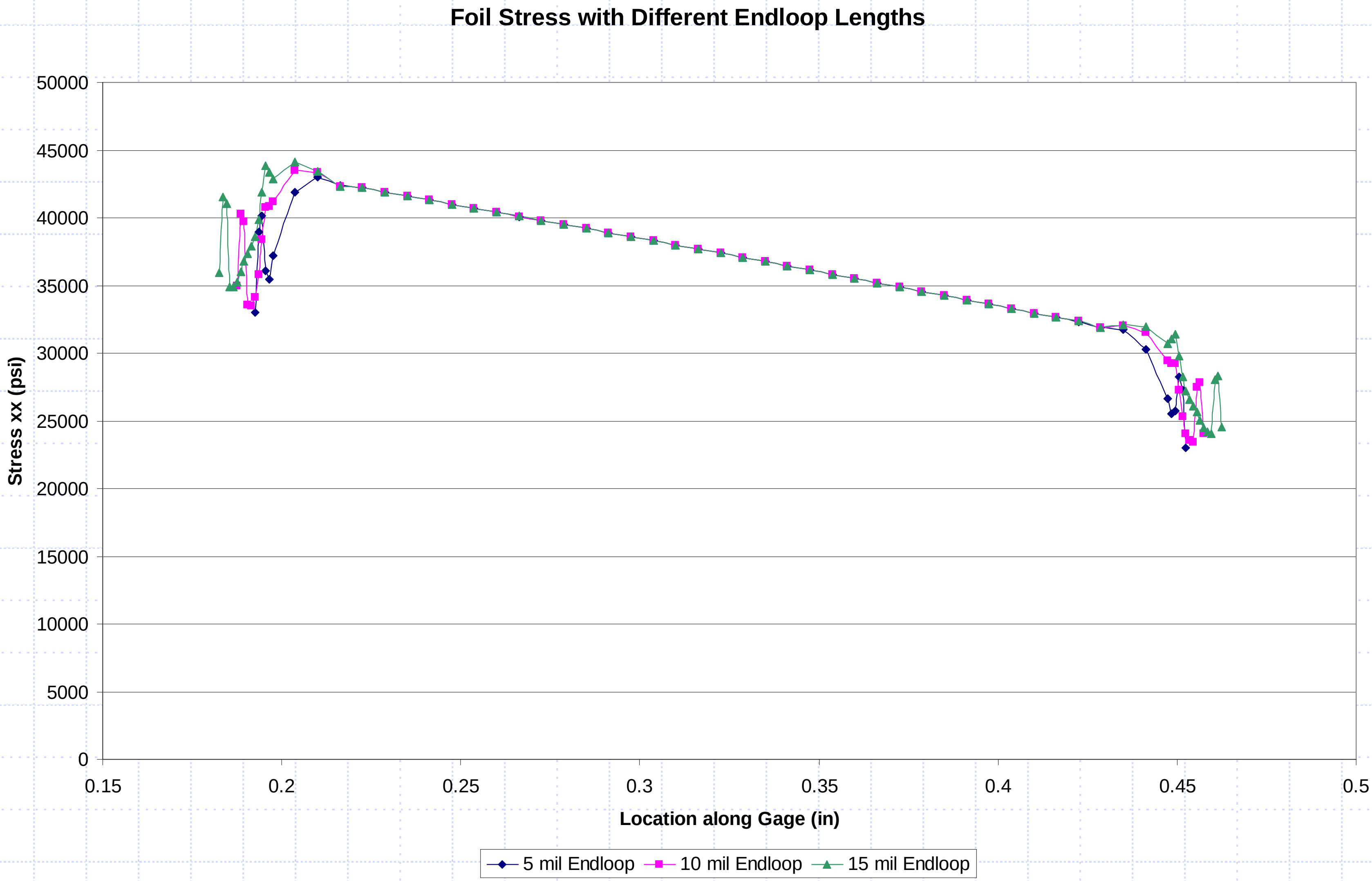
- Vary the length of the endloops.
- Lengths modeled: 5 mils, 10 mils, and 15 mils
- This is typically the first parameter to adjust the creep performance of a gage system.
- The longer the endloop, the more positive creep response from the gage system.

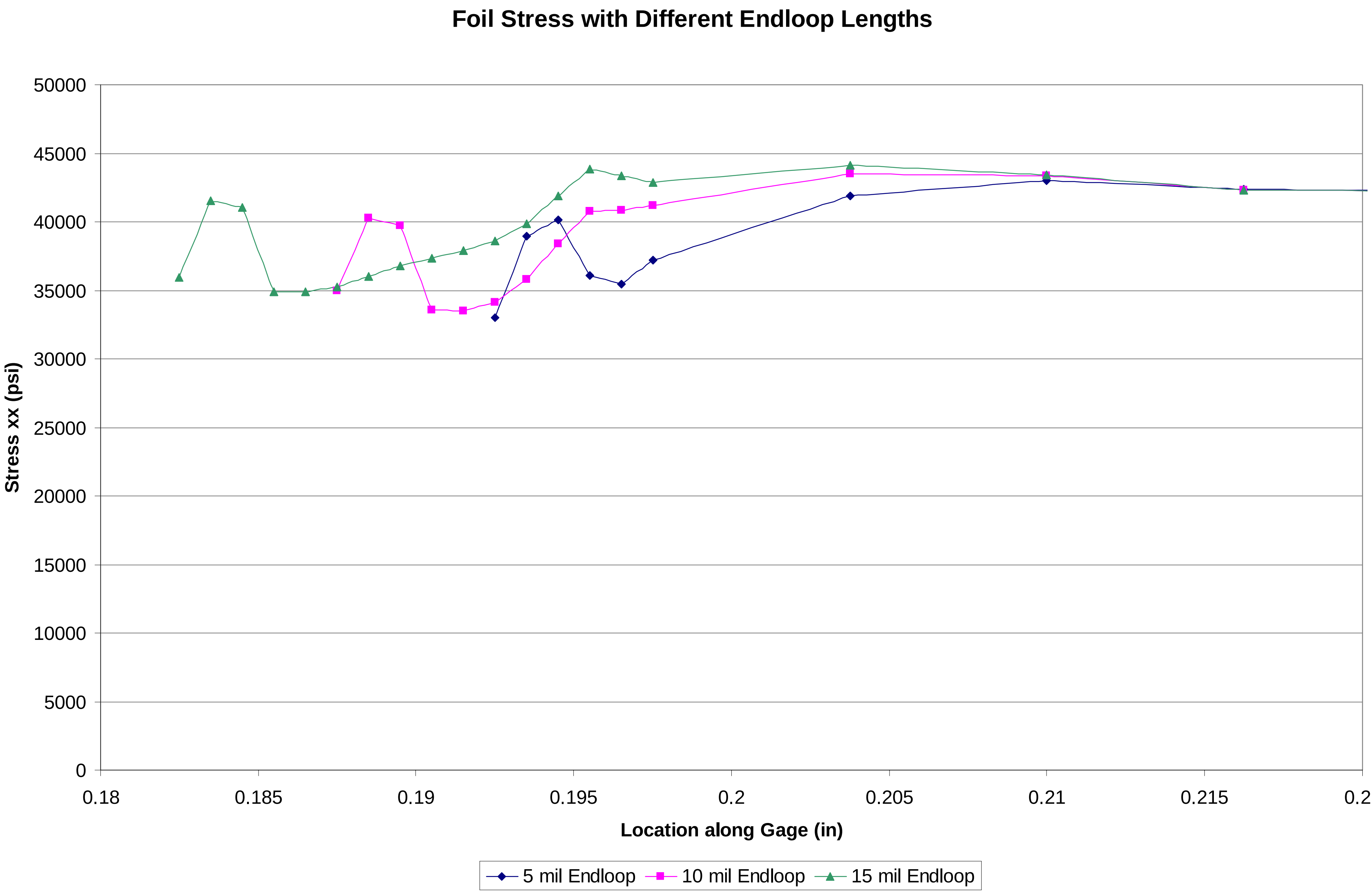
Backing Shear Stress




Backing Shear Stress with Different Endloop Lengths
Shear Stress xz (psi)
500
400
300
200
100
0
-100
-200
-300
-400
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location along Gage (in)
5 mil endloop
10 mil endloop
15 mil endloop

Foil Stress


Foil Stress with Different Endloop Lengths
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Stress xx (psi)
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Location along Gage (in)
5 mil Endloop
10 mil Endloop
15 mil Endloop

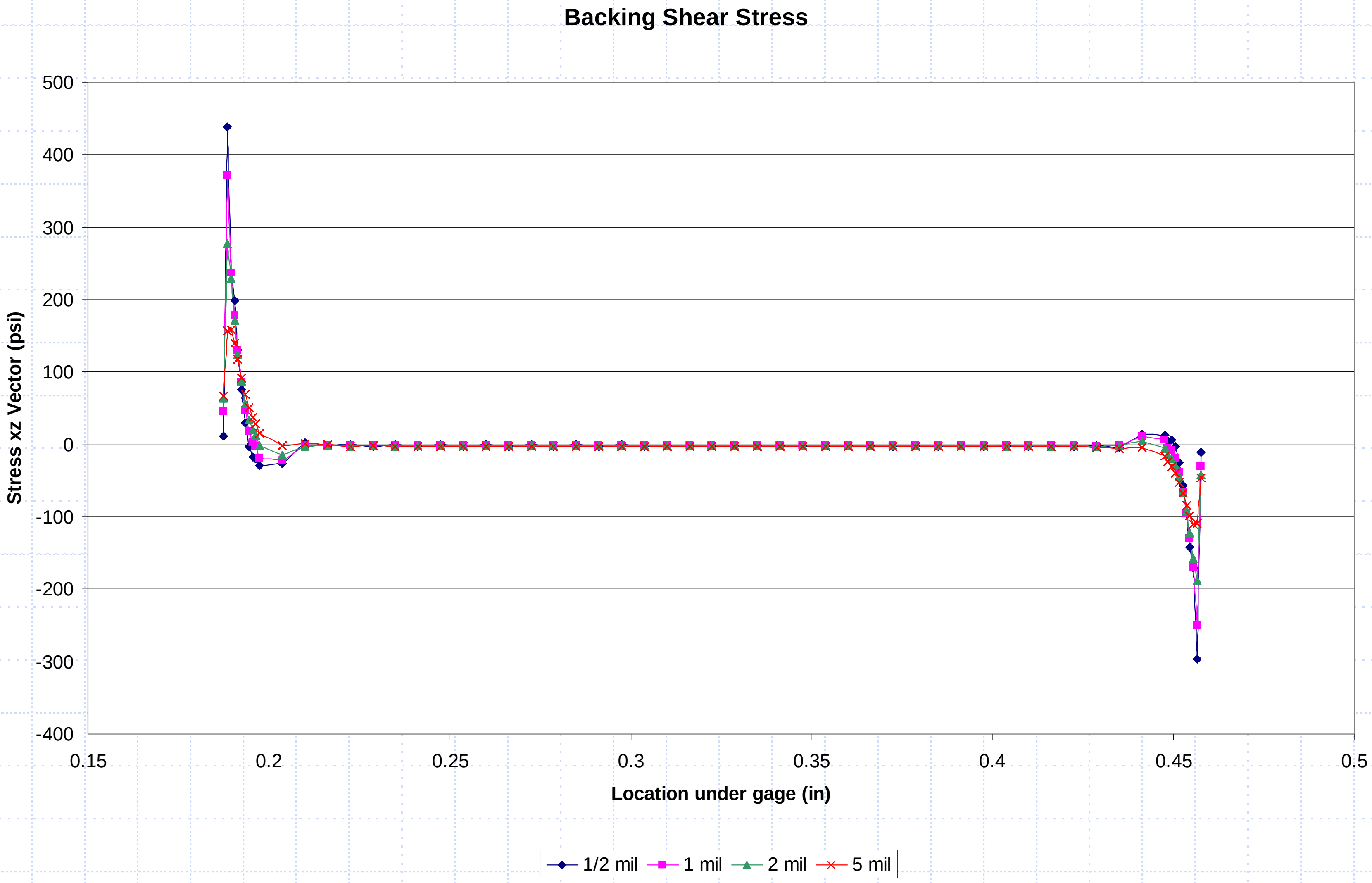


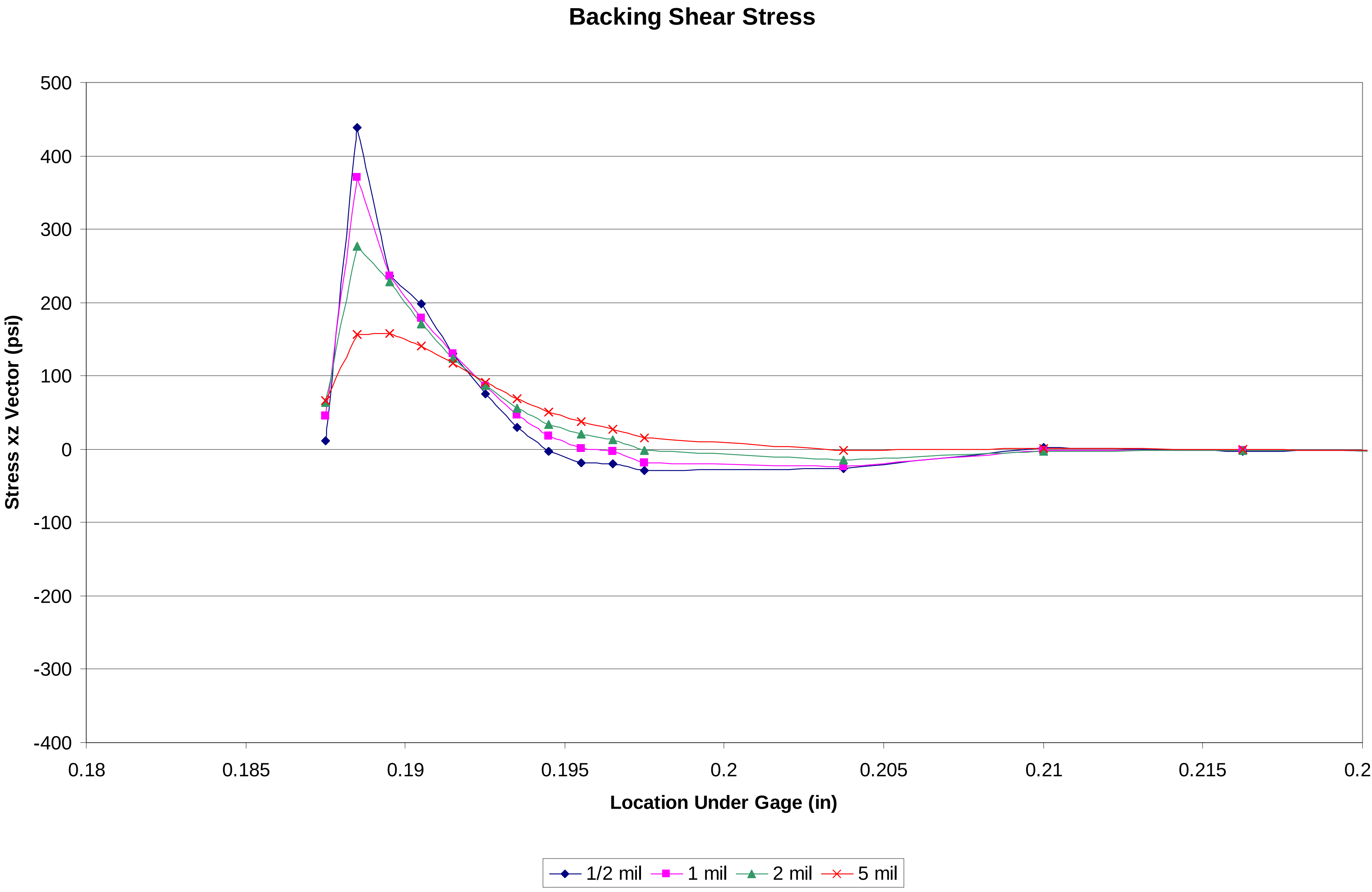
Foil Stress with Different Endloop Lengths

Variation Two: Backing Thickness

- Vary the thickness of the backing.
- Thickness modeled: ½ mil, 1 mil, 2 mils, and 5 mils

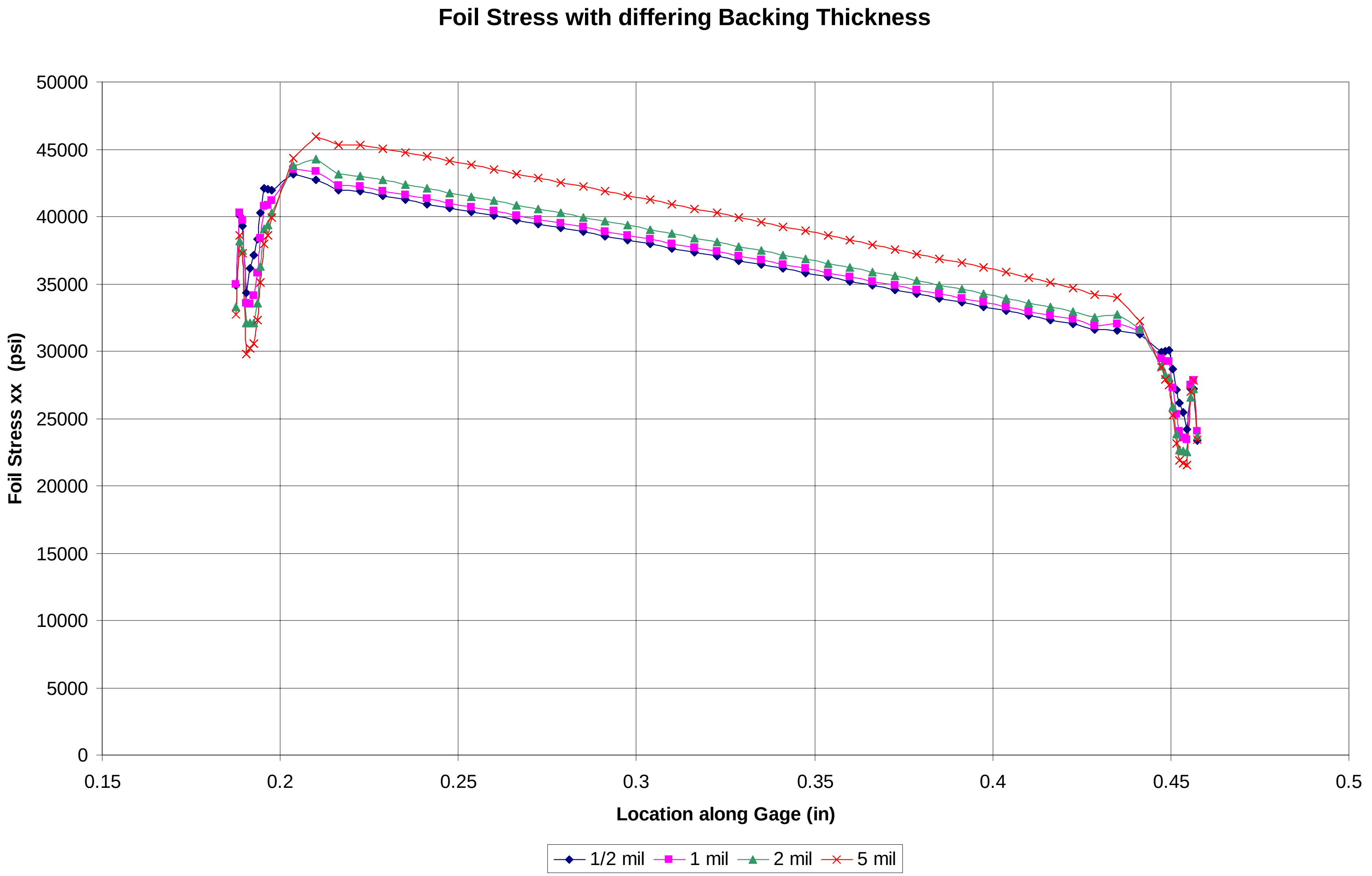
Backing Shear Stress

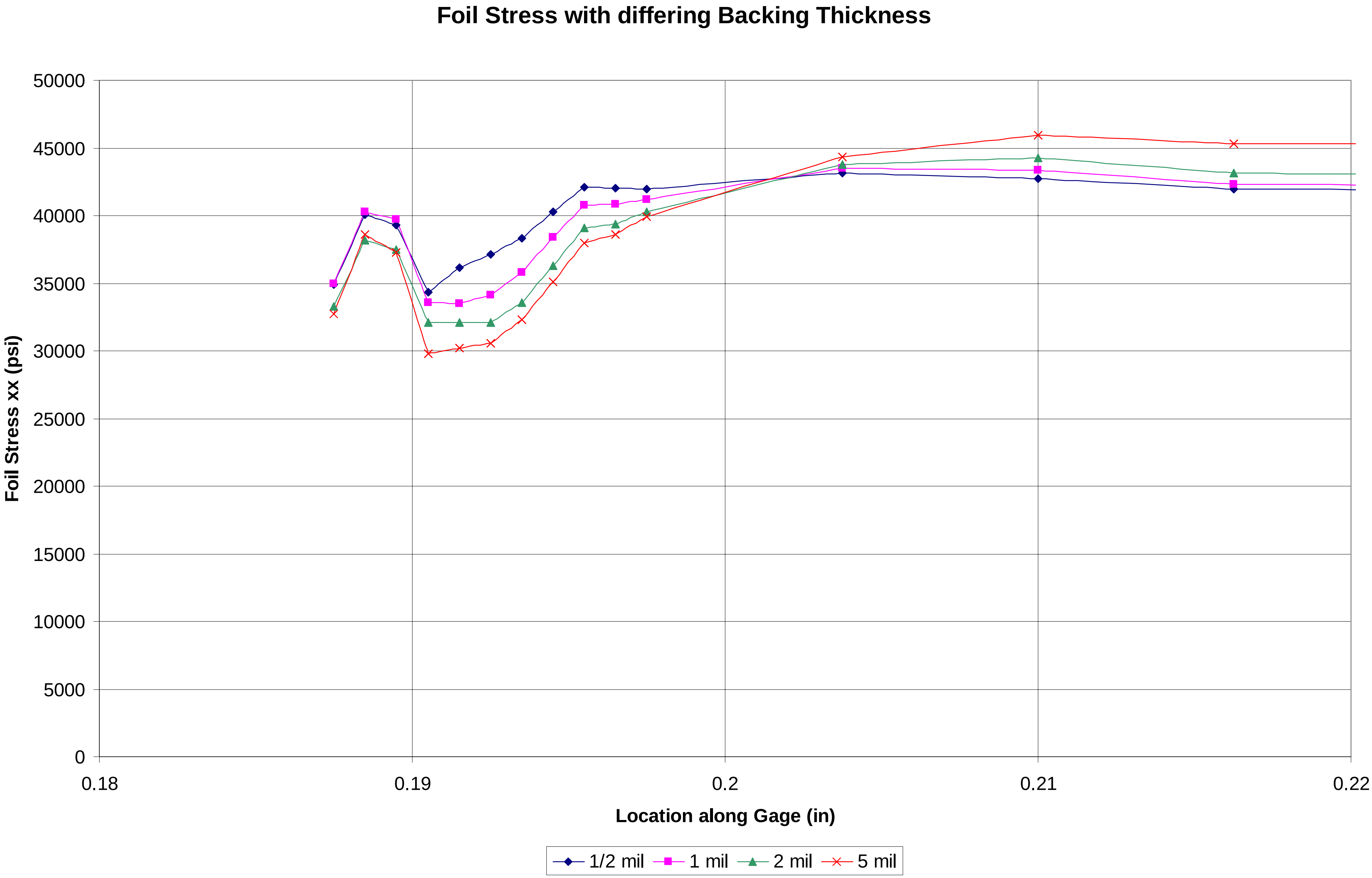




Backing Shear Stress
Stress xz Vector (psi)
500
400
300
200
100
0
-100
-200
-300
-400
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location Under Gage (in)
1/2 mil
1 mil
2 mil
5 mil

Foil Stress by Backing Thickness

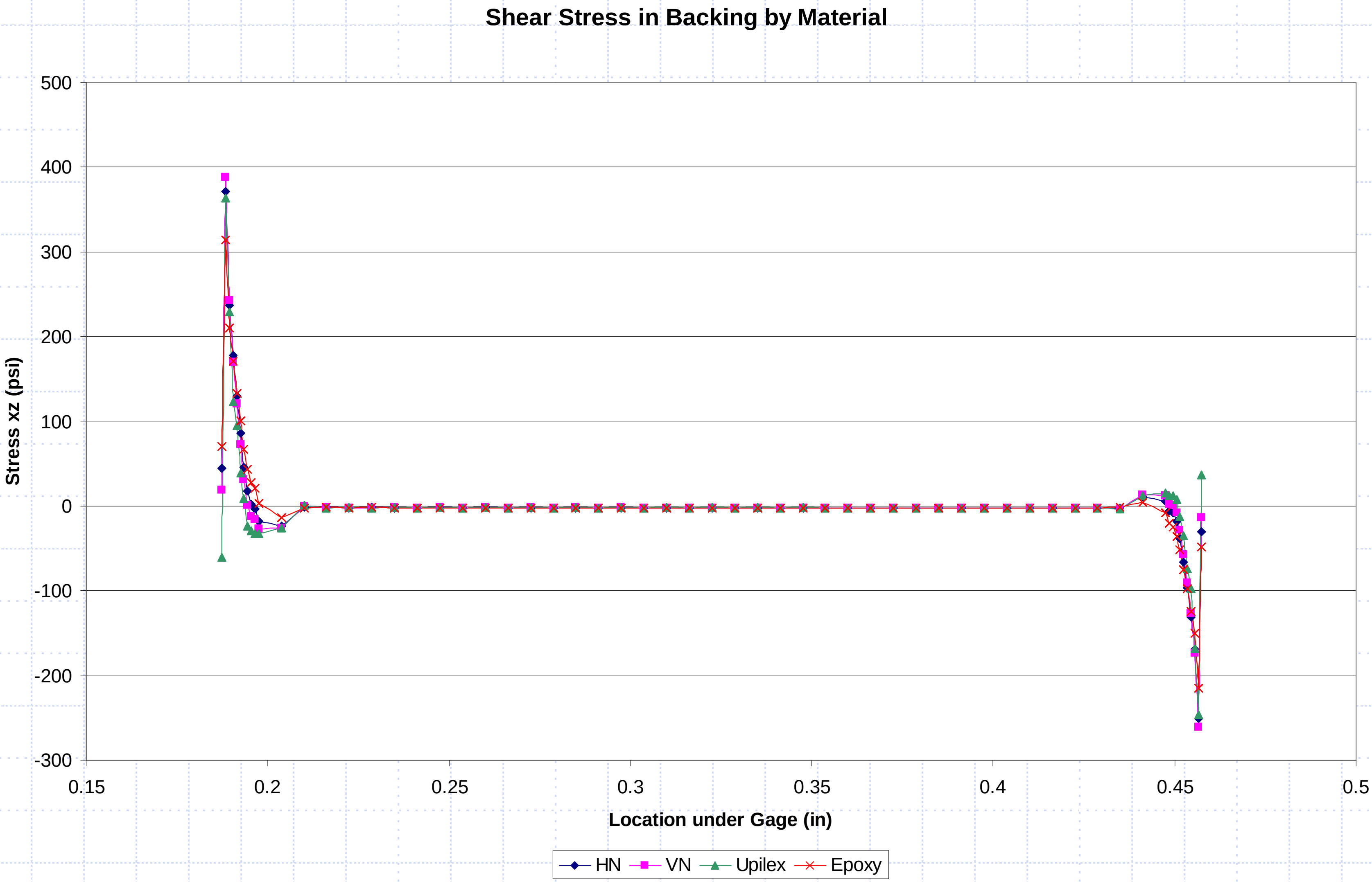


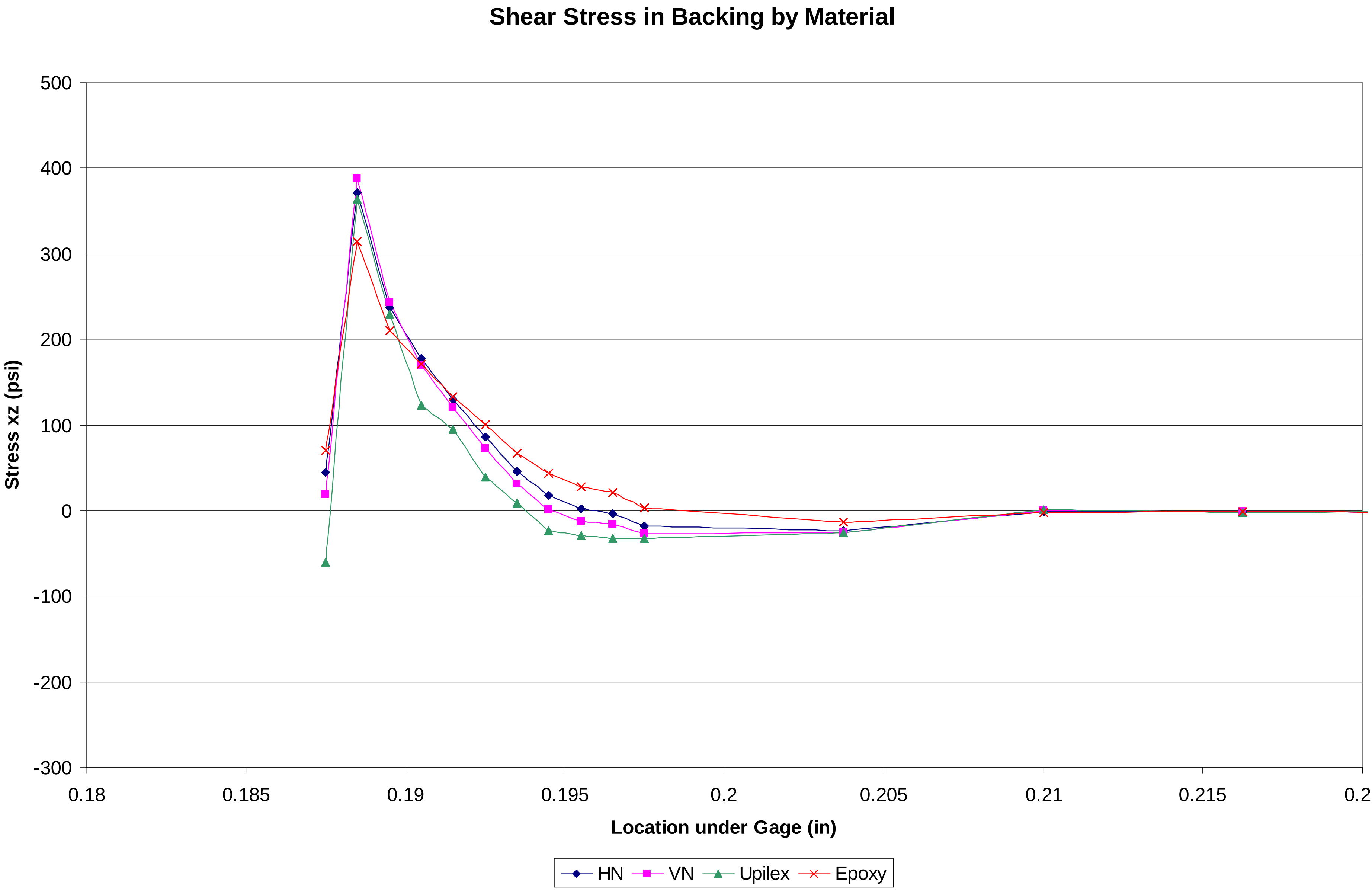
Foil Stress with differing Backing Thickness
Foil Stress xx (psi)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.18
0.19
0.2
0.21
0.22
Location along Gage (in)
1/2 mil
1 mil
2 mil
5 mil

Variation 3: Backing Material Properties

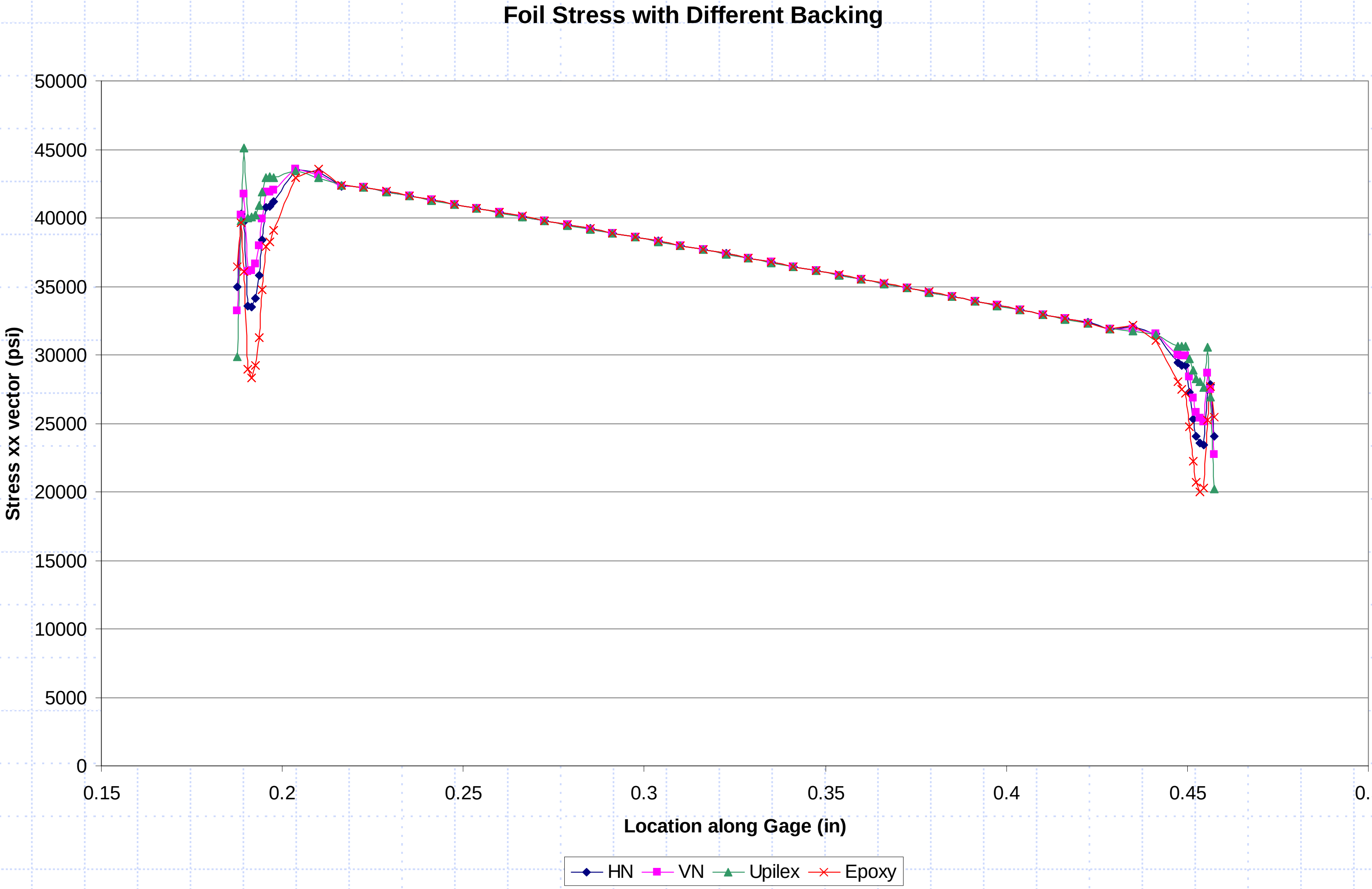
- Vary the stiffness of the backing by simulating different material types.
- Simulated Backings: soft epoxy, Kapton HN, Kapton VN, and Upilex S
- All backing thickness modeled for this variation is 1 mil.
- Modulus of Elasticity is the key parameter that FEA requires.

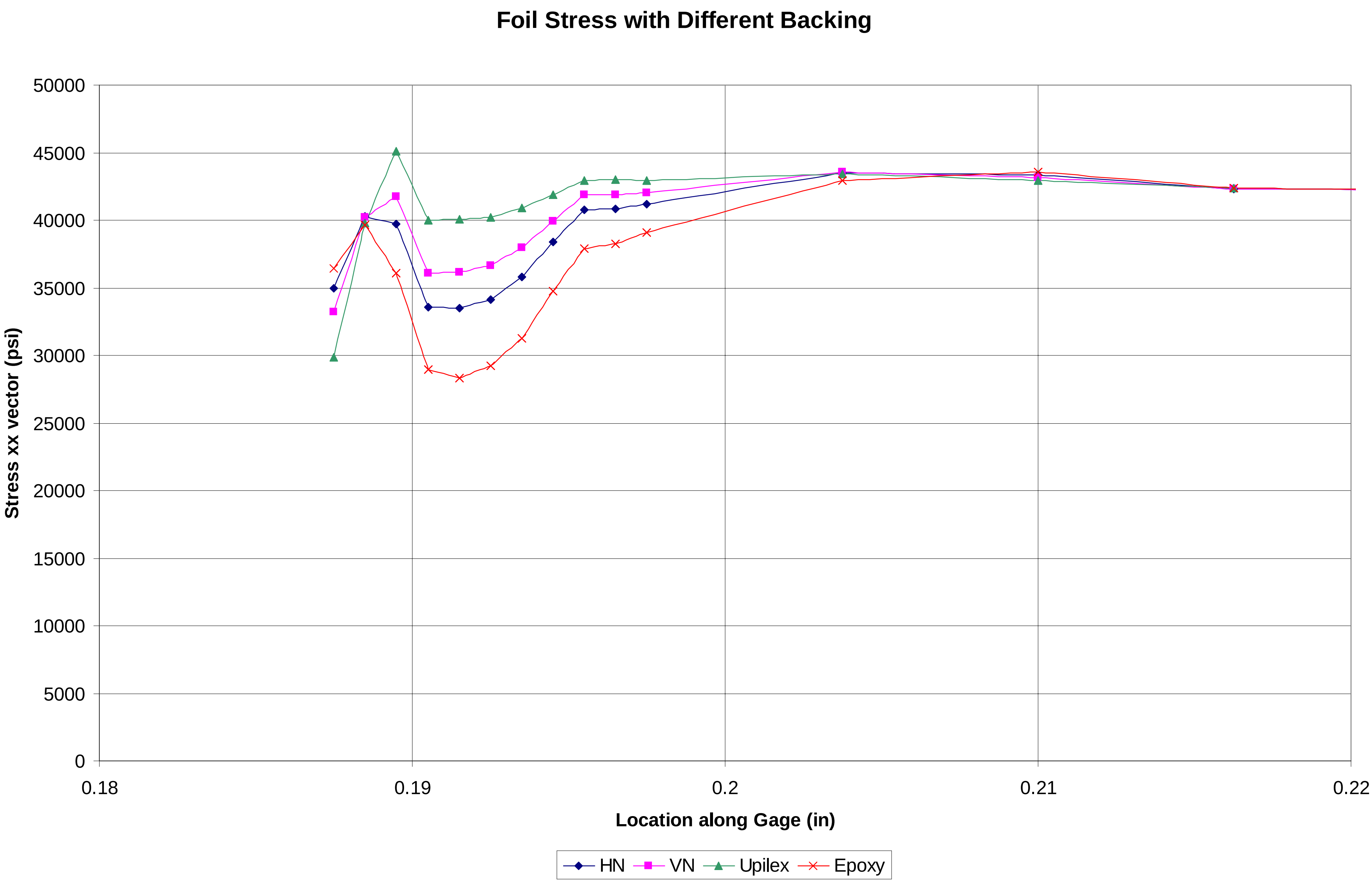
Backing Shear Stress




Shear Stress in Backing by Material
Stress xz (psi)
500
400
300
200
100
0
-100
-200
-300
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location under Gage (in)
HN
VN
Upilex
Epoxy

Foil Stress

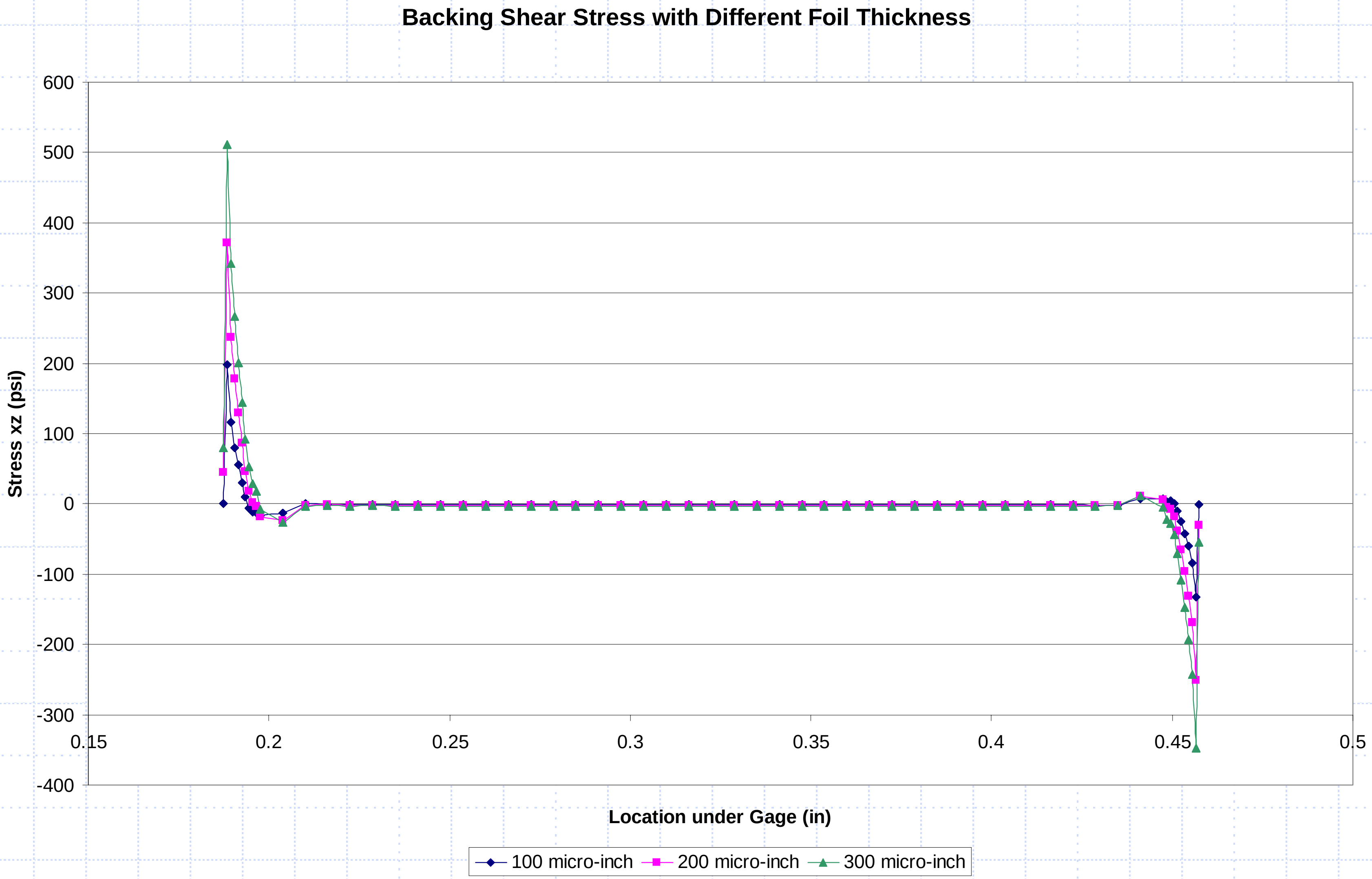

Foil Stress with Different Backing
Stress xx vector (psi)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Location along Gage (in)
HN
VN
Upilex
Epoxy

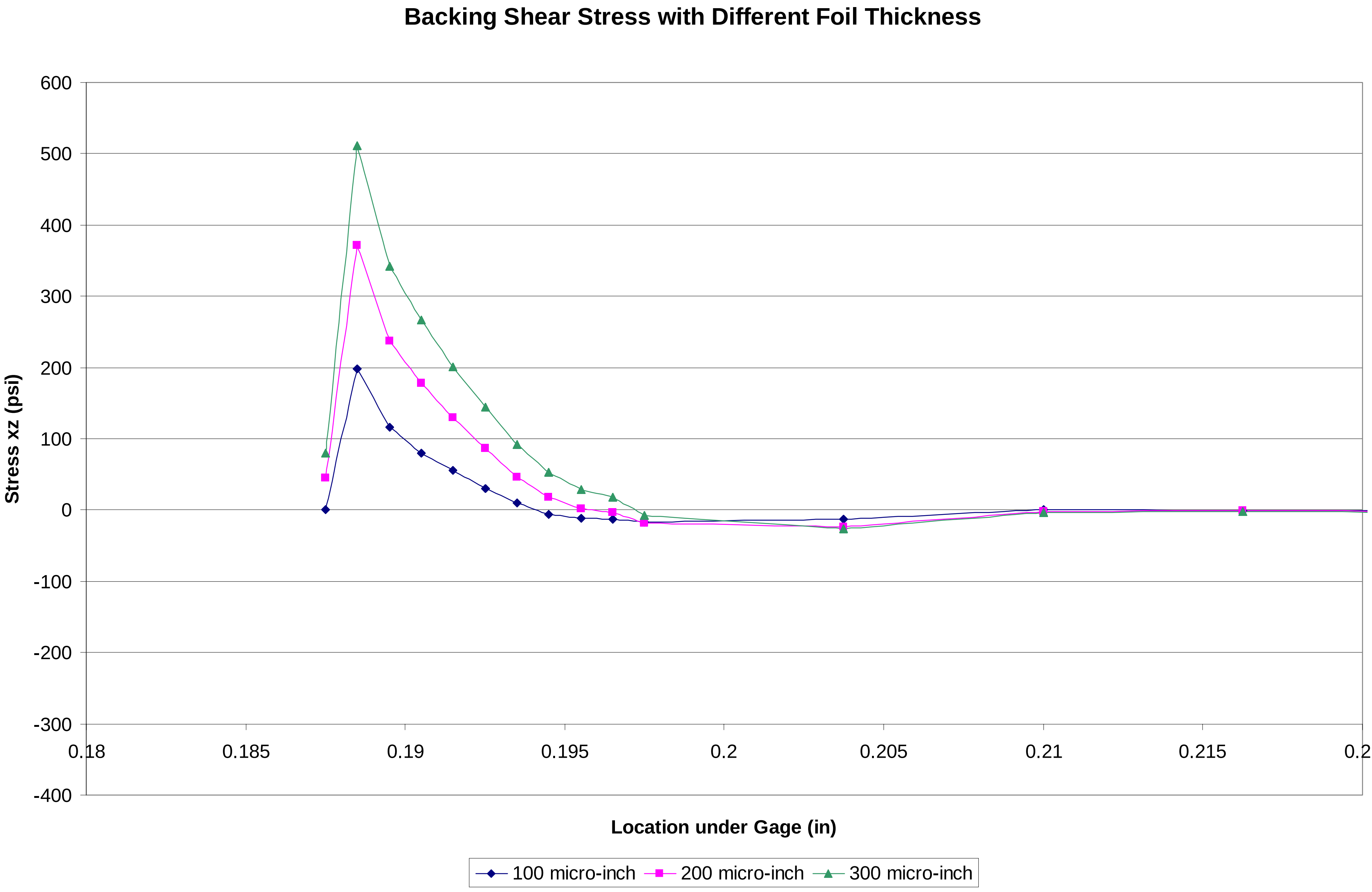

Foil Stress with Different Backing
Stress xx vector (psi)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.18
0.19
0.2
0.21
0.22
Location along Gage (in)
HN
VN
Upilex
Epoxy

Variation 4: Foil Thickness

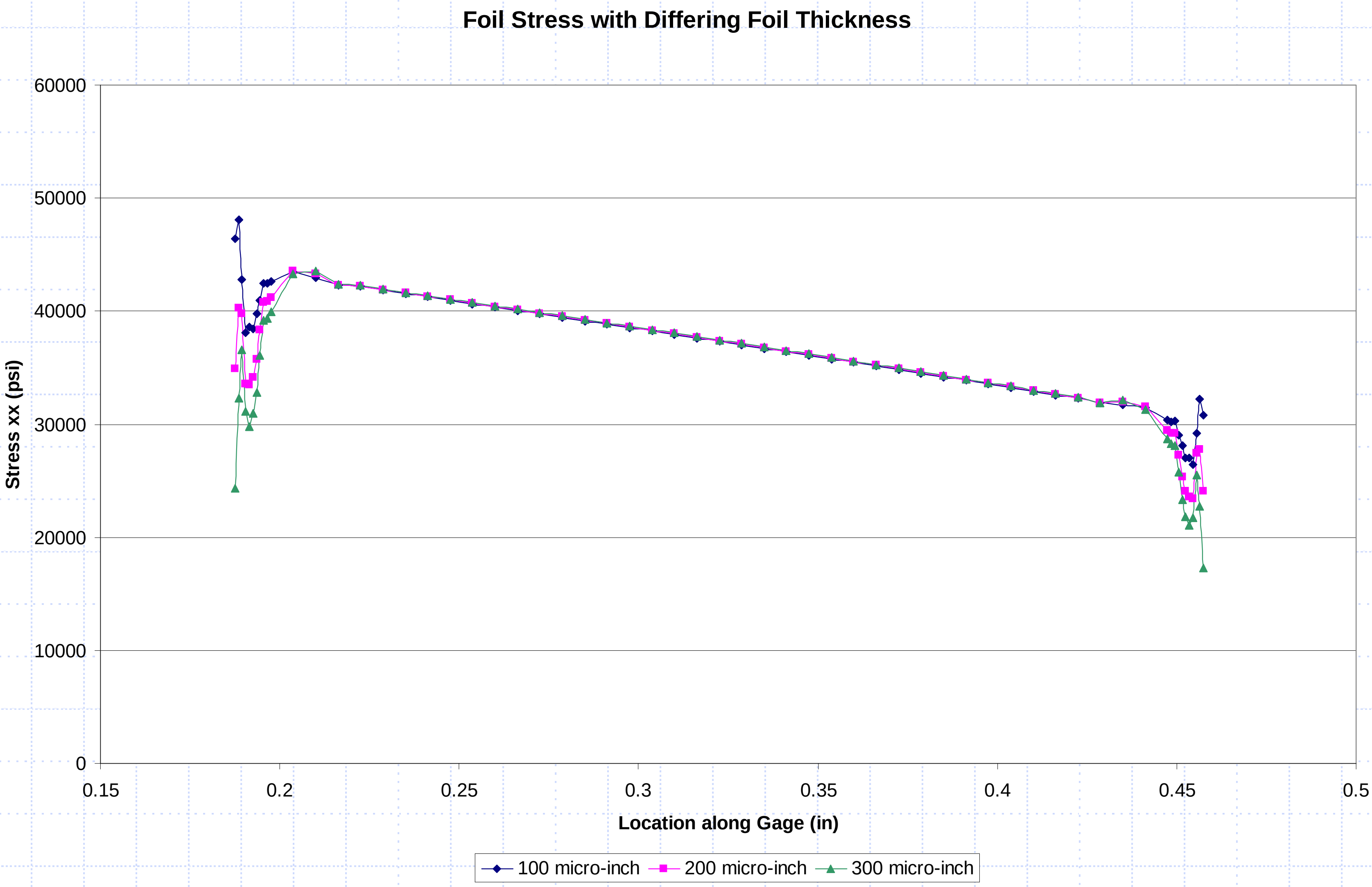
- Vary the thickness of the foil.
- Foil Thickness modeled: 100 micro-inches, 200 micro-inches, 300 micro-inches
- The foil type was kept constant.
- The backing type and thickness was kept constant.

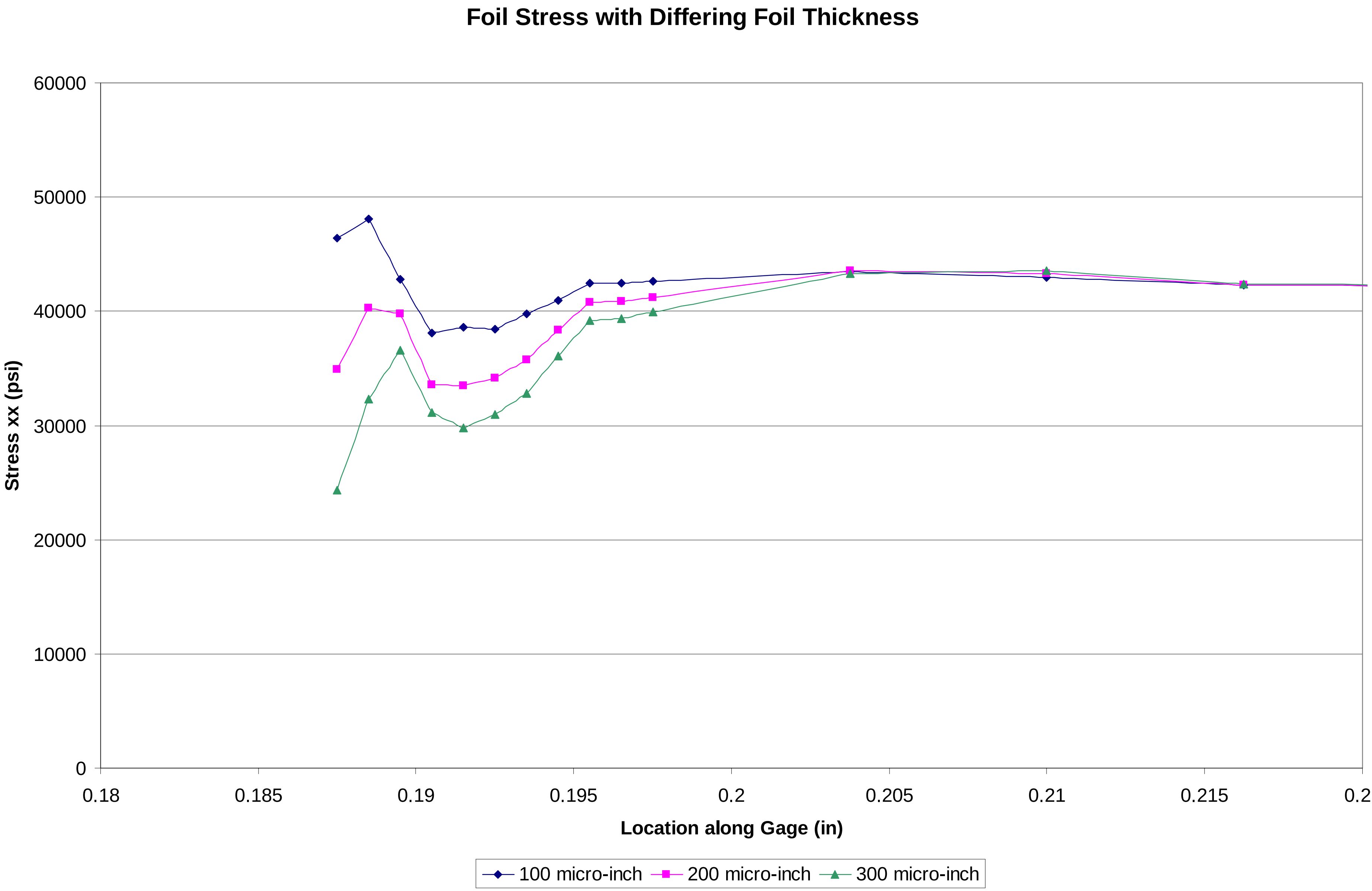
Backing Shear Stress




Backing Shear Stress with Different Foil Thickness
Stress xz (psi)
600
500
400
300
200
100
0
-100
-200
-300
-400
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location under Gage (in)
100 micro-inch
200 micro-inch
300 micro-inch

Foil Stress

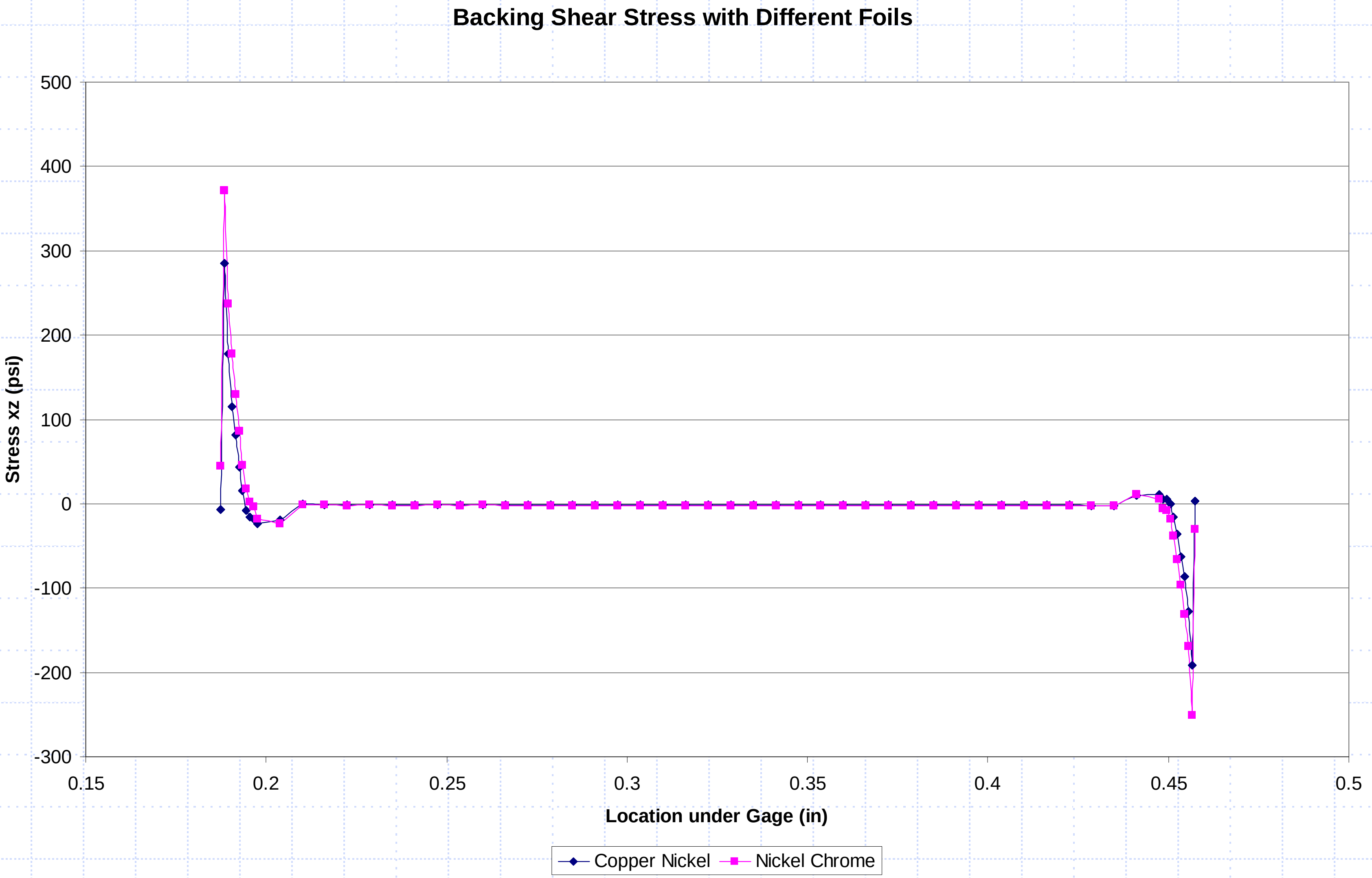

Foil Stress with Differing Foil Thickness
Stress xx (psi)
60000
50000
40000
30000
20000
10000
0
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Location along Gage (in)
100 micro-inch
200 micro-inch
300 micro-inch

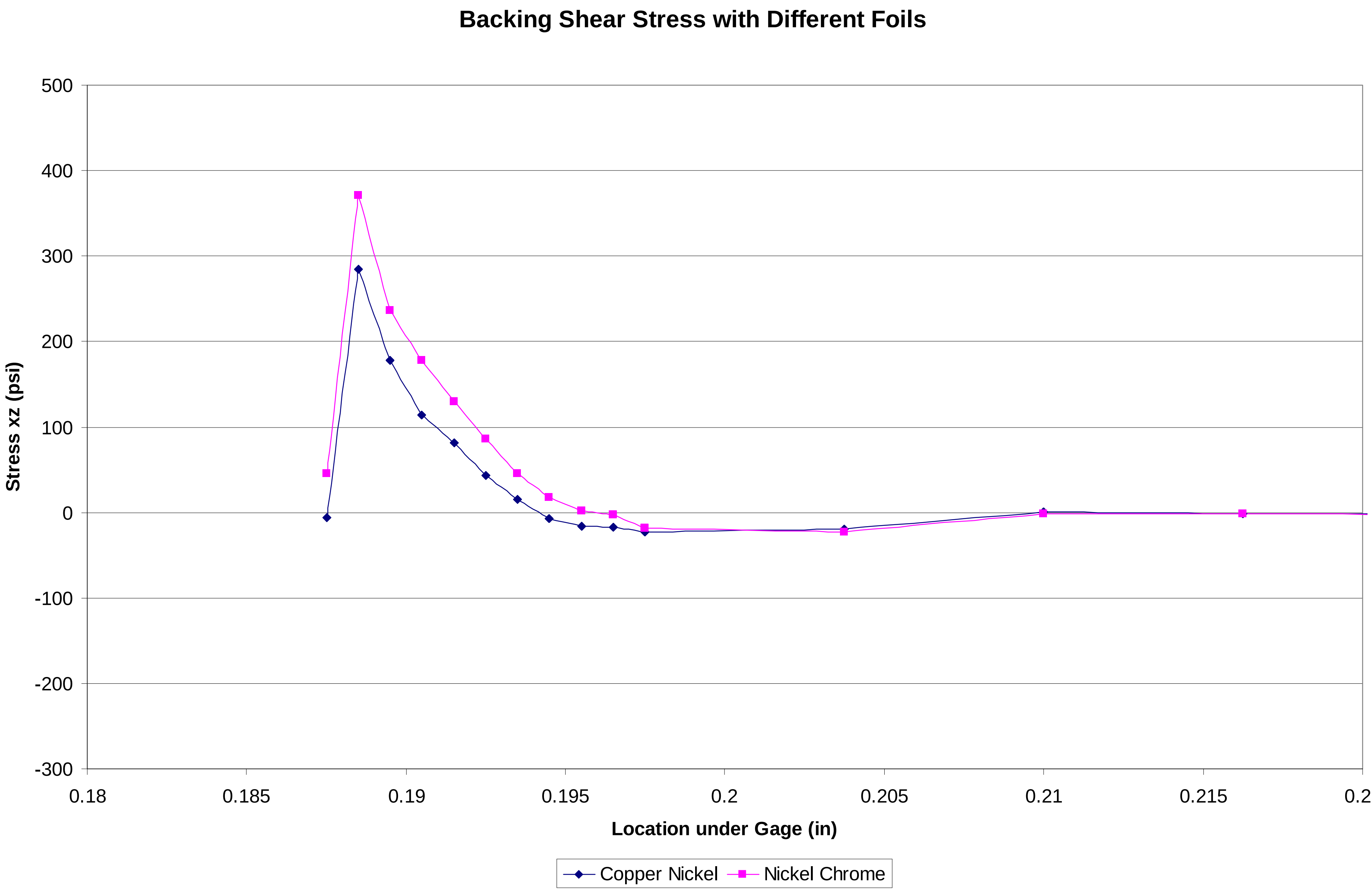

Foil Stress with Differing Foil Thickness
Stress xx (psi)
60000
50000
40000
30000
20000
10000
0
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location along Gage (in)
100 micro-inch
200 micro-inch
300 micro-inch

Variation 5: Foil Material Type

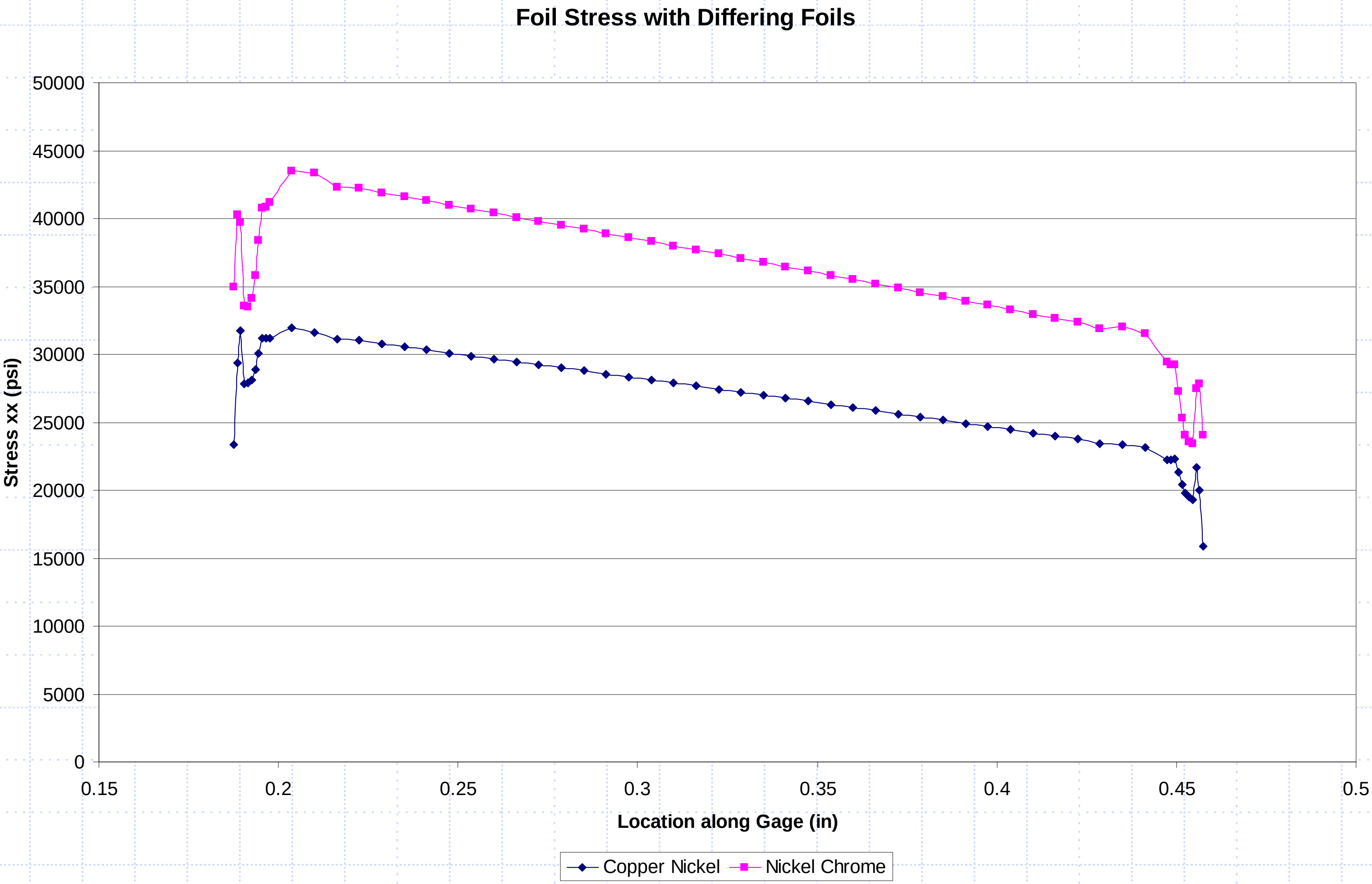
- Two materials were modeled by varying Modulus of Elasticity.
- Simulated Materials: Evanohm S (Nickel Chrome) and Constantan (Copper Nickel)
- The backing type and thickness was kept constant.
- The foil thickness was kept constant.

Backing Shear Stress




Backing Shear Stress with Different Foils
500
400
300
200
100
0
-100
-200
-300
Stress xz (psi)
0.18
0.185
0.19
0.195
0.2
0.205
0.21
0.215
0.22
Location under Gage (in)
Copper Nickel
Nickel Chrome

Foil Stress


Foil Stress with Differing Foils
Stress xx (psi)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Location along Gage (in)
Copper Nickel
Nickel Chrome

Summary and Conclusions

- FEA methods allow investigation of many scenarios to discover details that are important to strain gage design.
- FEA methods allow investigation of materials and designs that may not be possible without extensive investment of capitol.
- FEA methods allow investigation of small design variations without the need to invest in tooling.
- Strain Gage Designs can be compared to an existing knowledge base for improvement of key parameters.
- FEA methods promote “What If?” investigations.

Summary and Conclusions cont’d

- Key information may be inferred from FEA:
- Relative creep performance of different gage designs.
- Certain designs may be overstressing the mechanical properties of the backing which leads to hysteresis or creep problems in the gage system.
- Accuracy of the system may be compromised by excessive thickness in the backing.
- How tightly do tolerances need to be controlled on key thickness parameters to achieve consistent gage performance?

Summary and Conclusions cont’d

- What affects accuracy of the FEA process?
- Key parameter is the element size. How small has the model been sliced and diced to mimic the real world?
- Boundary conditions. How accurately do the model conditions actually represent real world conditions?
- Load introduction. How well do the load introduction methods mimic what is occurring in the real world?
- Geometry accuracy. How accurately does the geometry represent the real world, i.e.: fillets, blends, and chamfers?
- Common Sense and an understanding of what is being modeled.

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