Why Using Finite Element Analyses to Optimize Cantilever Probe Card Design?

by

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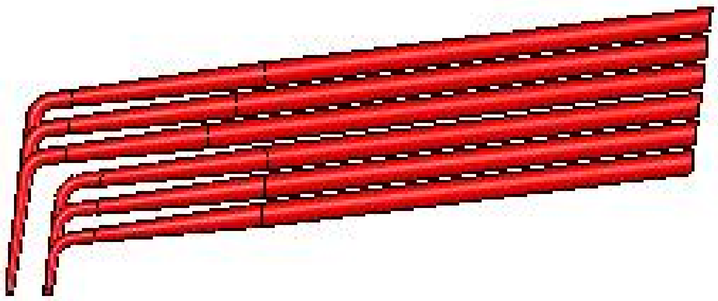
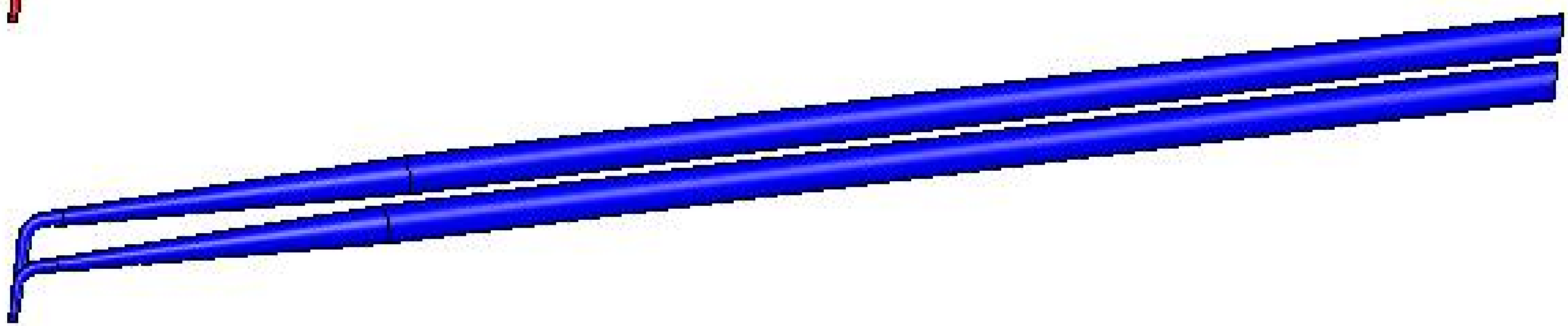
Which design would need Finite Element Analyses to optimize?

The present and near future



In the past



Comparison of past and present probe card design requirements which related to optimization of design

	PAST	PRESENT
Pitch	<u>Large pitch</u> • large wire DIA • longer beam • small tip length/beam length ratio	<u>Fine pitch</u> • small wire DIA • shorter beam • more probe layers • large tip length/beam length ratio
Pad size	<u>Larger & thicker pad size</u> • large tip DIA • large wire DIA • long scrub allowed • wider contact force range	<u>Smaller & thinner pad size</u> • small tip DIA • small wire DIA • short scrub required • small contact force required
Contact force	<u>Larger contact force</u> • fewer layer easier to achieve uniformity • not much depending on tip lengths	<u>Smaller contact force</u> • more layers, more rows • uniformity among layers, rows • low K, CUP (multiple touch downs)
Scrub	<u>Large scrub</u> • larger scrub • larger tip, more stable design • higher overdrive	<u>Small scrub</u> • much smaller scrub • smaller tip diameter • lower over drive (2mil) • uniformity among layers
Design optimization	<u>Small deformation simple beam</u> • Linear long beam formula •Short beam formula • Small deflection calculations	<u>Large deformation structure</u> • Nonlinear analyses required • Computing power (faster, better, cheaper) • FEA recommended

To study the changes in scrub length and contact force under 3 major manufacturing tolerances

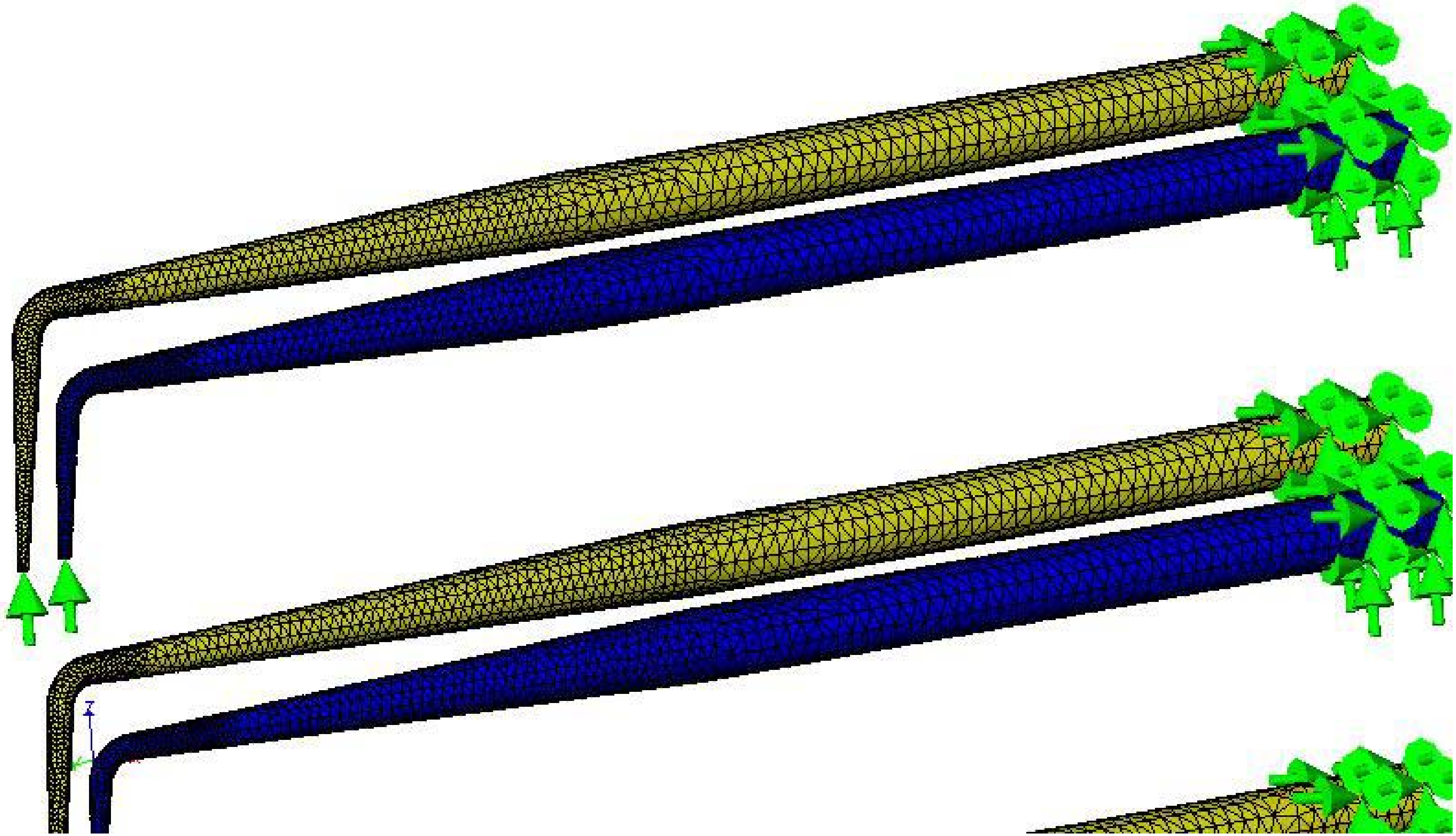
Variables:

- Etched length (design window of 10%)
- Tip length (design window of 15%)
- Beam length (design window of 5%)

Constants:

- Beam angle
- Tip angle
- Tip diameter
- Knee bend radius
- Epoxy stiffness

Typical finite element mesh for cantilever probes



Compare different tip lengths, and etched lengths

Etched Length minus 10%

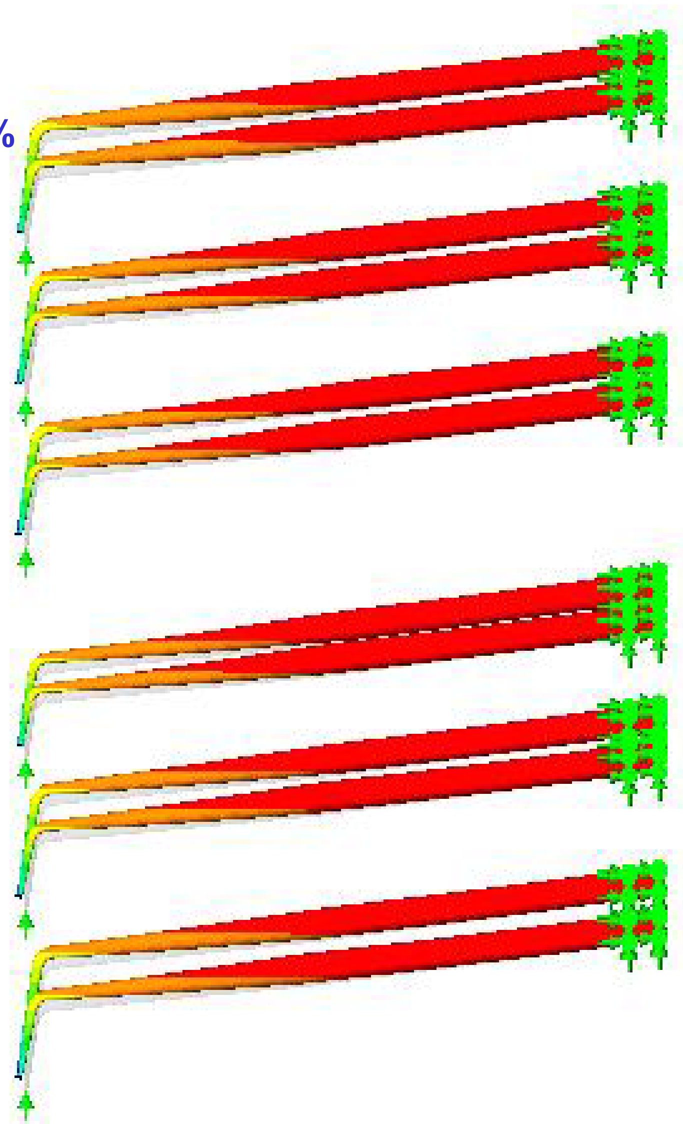
Nominal Etched Length

Etched Length plus 10%

Tip Length minus 15%

Nominal Tip Length

Tip Length plus 15%



CONSTANT

Beam Length

&

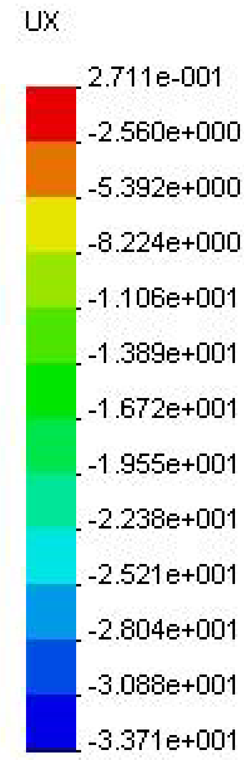
Tip Length

CONSTANT

Beam Length

&

Etched Length



Compare different beam lengths and extreme cases

Etched Length minus 10%
Tip Length minus 15%
Beam Length minus 5%

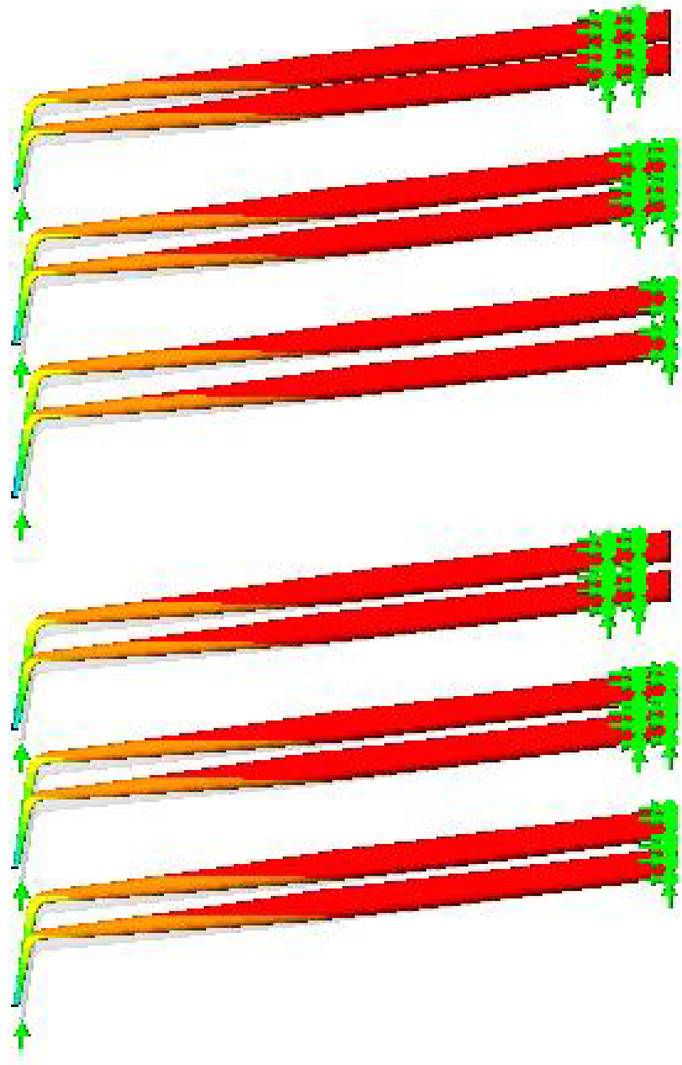
Nominal Dimensions

Etched Length plus 10%
Tip Length plus 15%
Beam Length plus 5%

Beam Length minus 5%

Nominal Beam Length

Beam Length plus 5%



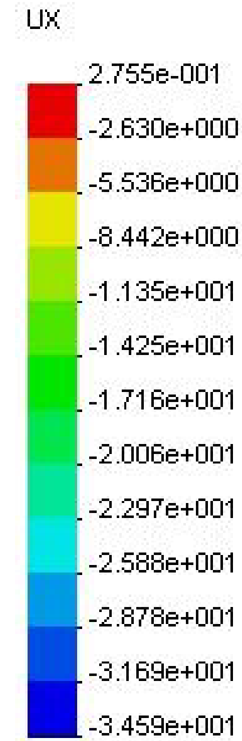
EXTREME VALUES

CONSTANT

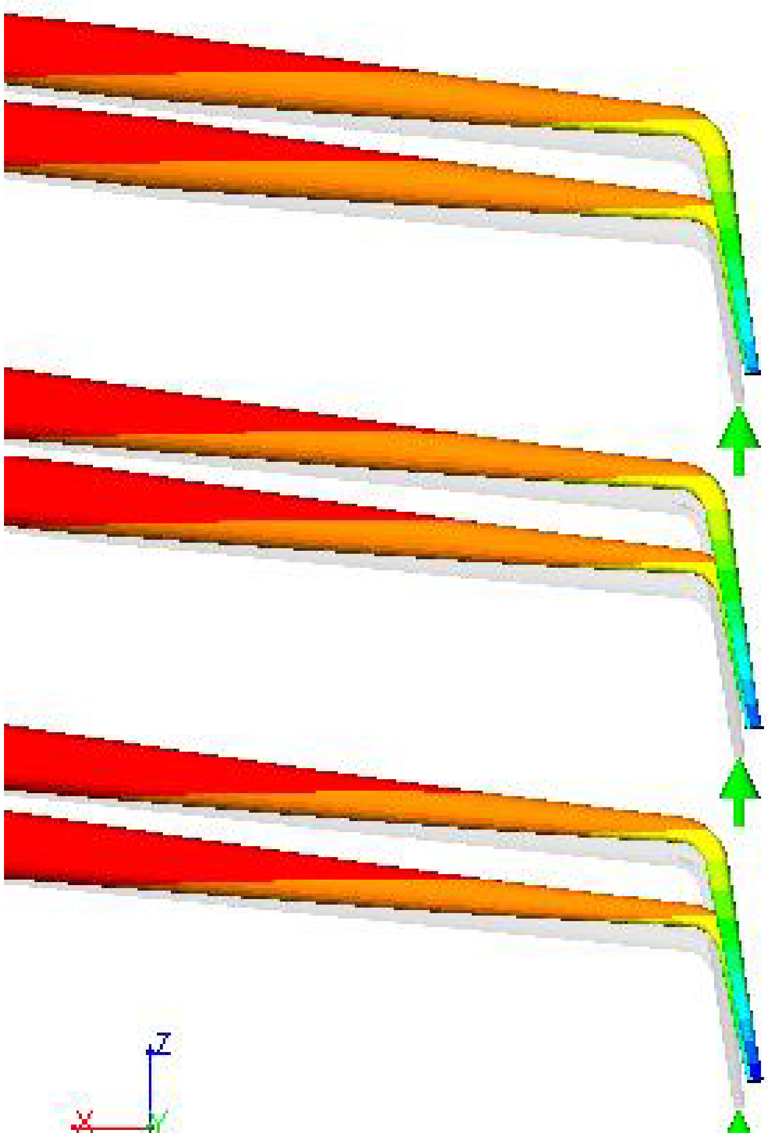
Etched Length

&

Tip Length



Compare scrub lengths & contact forces between different etched lengths



Nominal Etched Length minus 10%

Scrub reduced by 7%

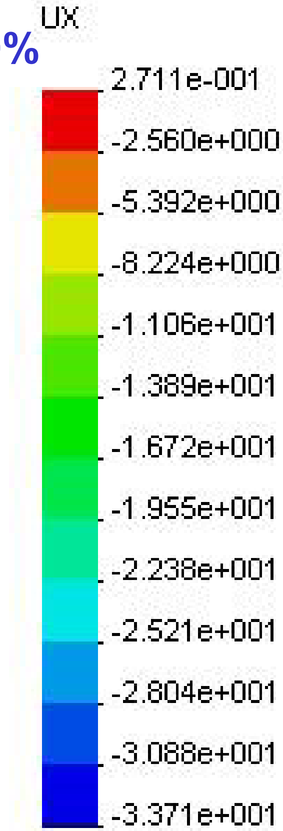
Contact force increased by 11%

Nominal Etched Length

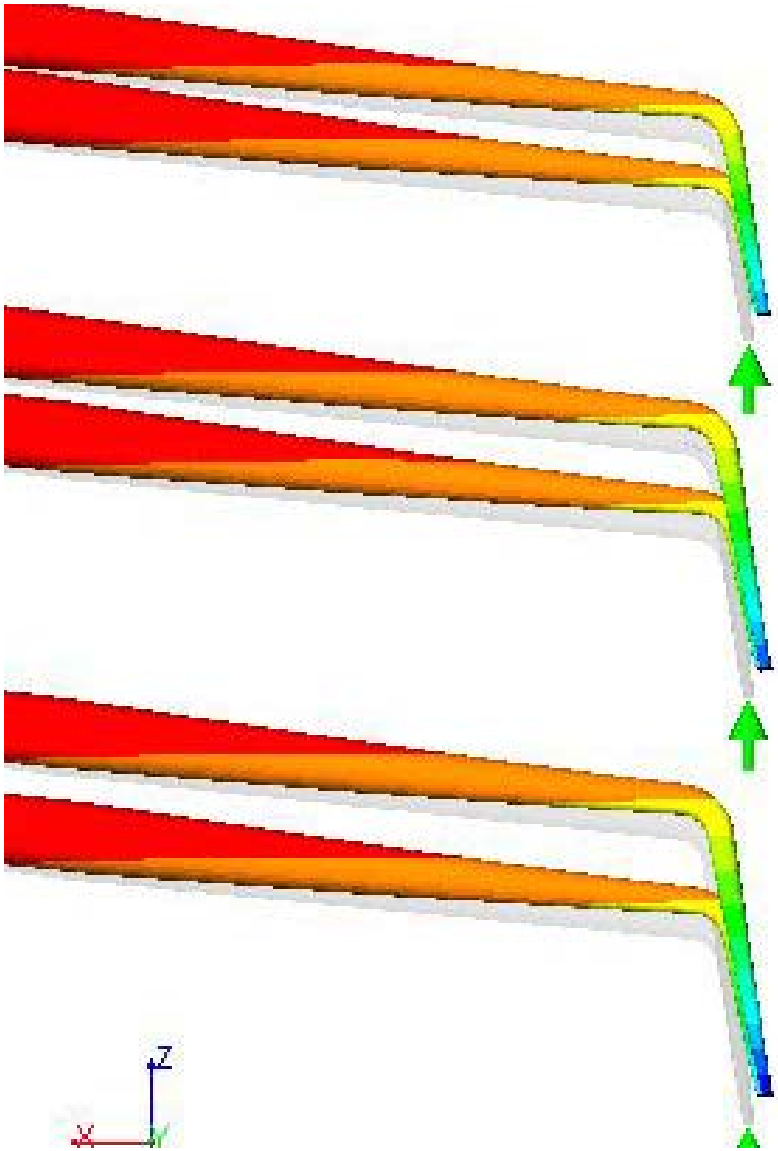
Nominal Etched Length plus 10%

Scrub increased by 7%

Contact force reduced by 12%



Compare scrub lengths & contact forces between different tip lengths



Nominal Tip Length minus 15%

Scrub reduced by 10%

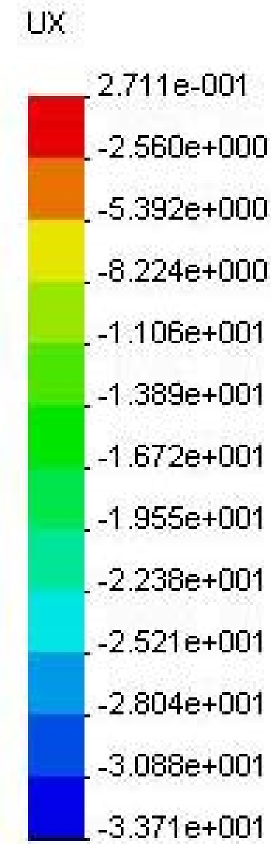
Contact force reduced by 7%

Nominal Tip Length

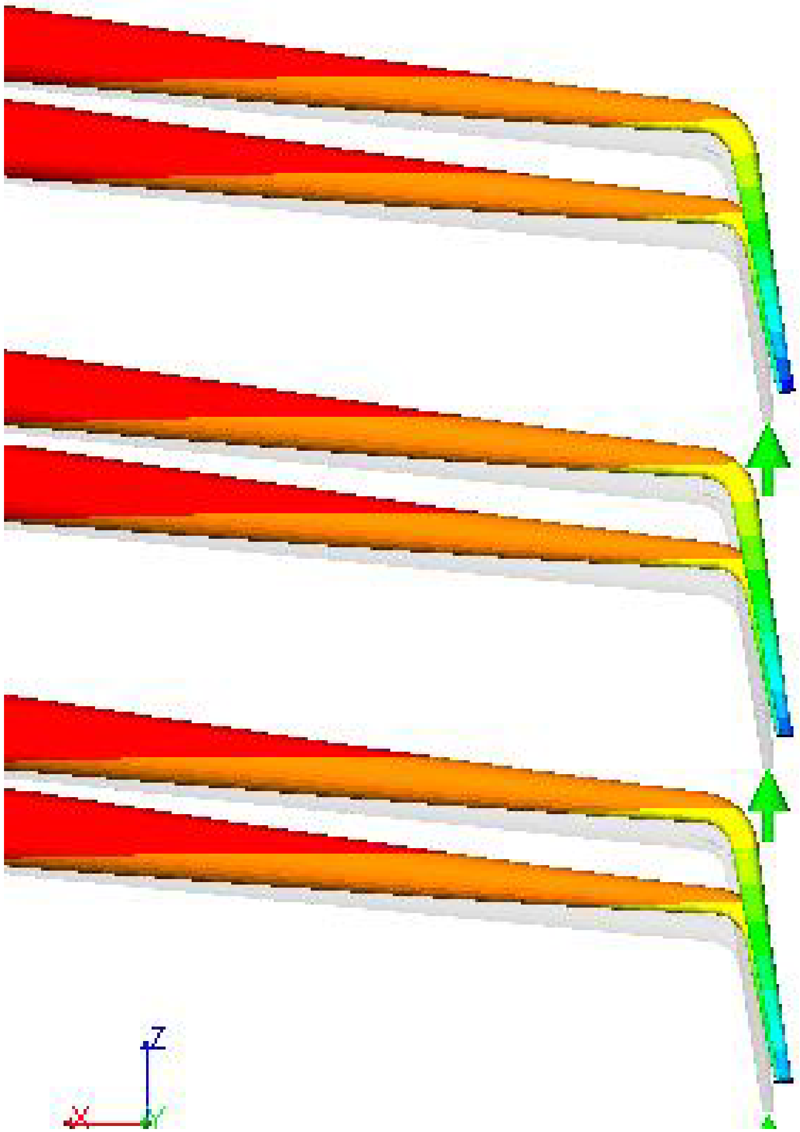
Nominal Tip Length plus 15%

Scrub increased by 9%

Contact force increased by 5%



Compare scrub lengths & contact forces between different beam lengths



Nominal Beam Length minus 5%

Scrub increased by 7%

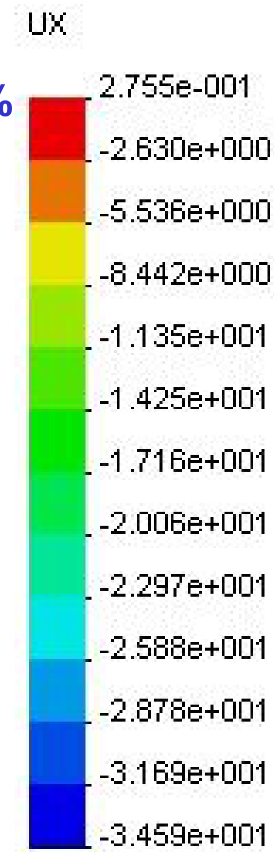
Contact force increased by 12%

Nominal Beam Length

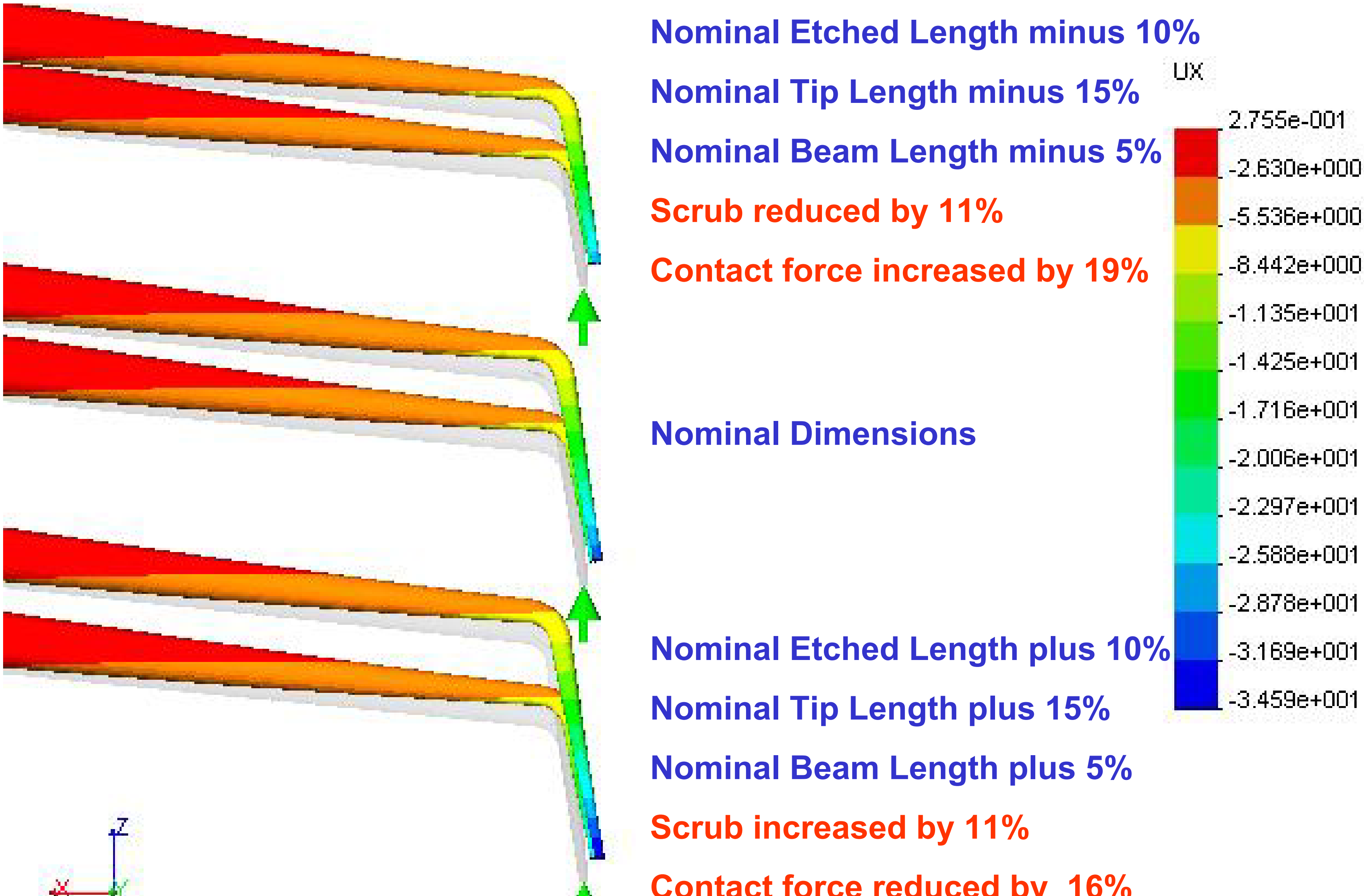
Nominal Beam Length plus 5%

Scrub reduced by 5%

Contact force reduced by 9%



Compare scrub lengths & contact forces between extreme sets of combined tolerances



Nominal Etched Length minus 10%

Nominal Tip Length minus 15%

Nominal Beam Length minus 5%

Scrub reduced by 11%

Contact force increased by 19%

Nominal Dimensions

Nominal Etched Length plus 10%

Nominal Tip Length plus 15%

Nominal Beam Length plus 5%

Scrub increased by 11%

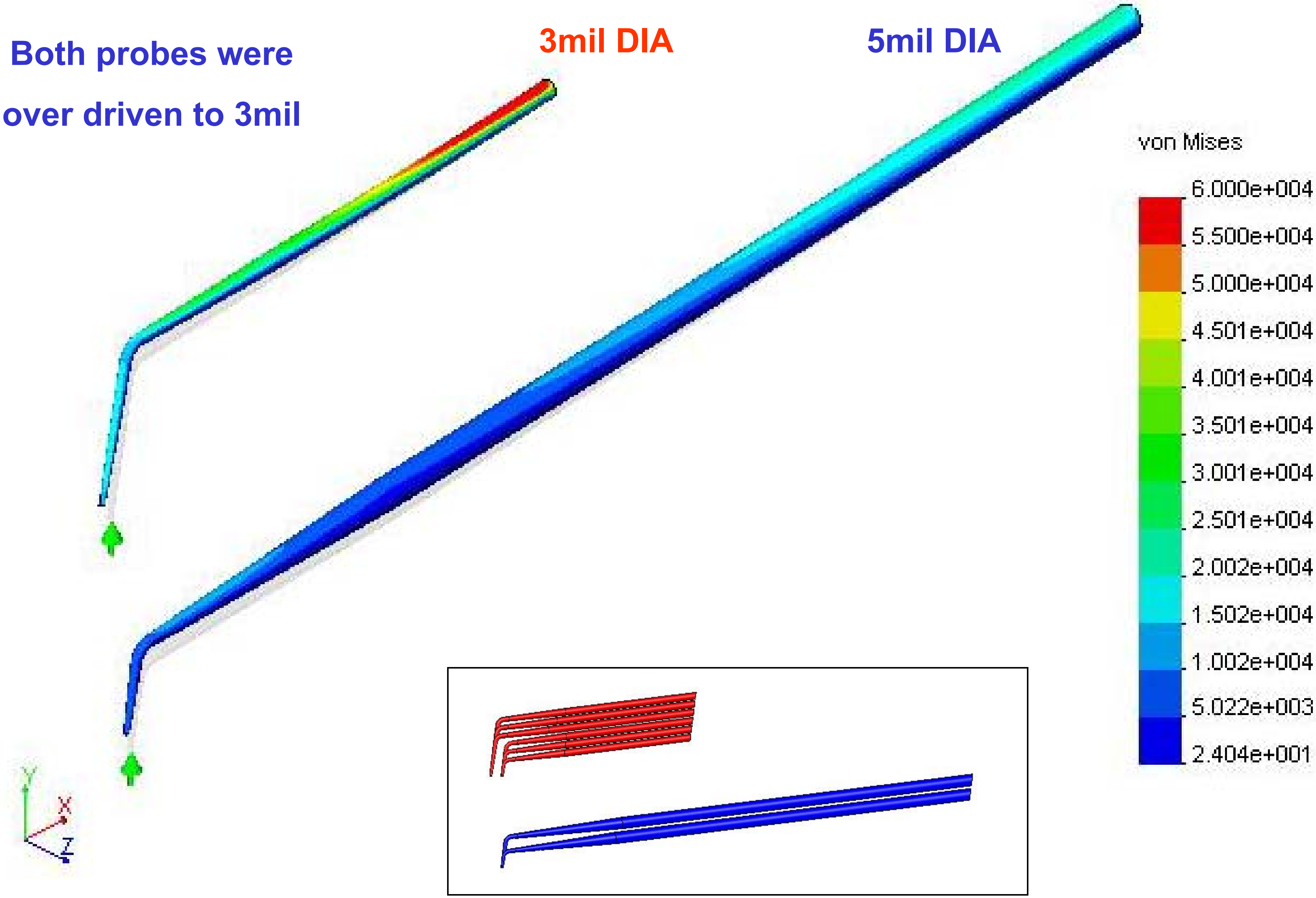
Contact force reduced by 16%

Other uses of FEA to optimize for:

- Life of probes (reduce maximum stress or move critical locations around)
- Stability of the probe structure
- Best beam angle for clearance and scrub length
- Best tip angle for clearance and scrub length
- Best knee bend radius to reduce stress and allow maximum clearance
- Effect of different epoxy types to the behavior of probes
- Friction
- Amount of metal cutting to allow multiple touch downs on low K or CUP (circuit under pads) wafers
- Pad structure (low K, CUP)

Example 1: FEA is used in reducing maximum stress and prolong probe life

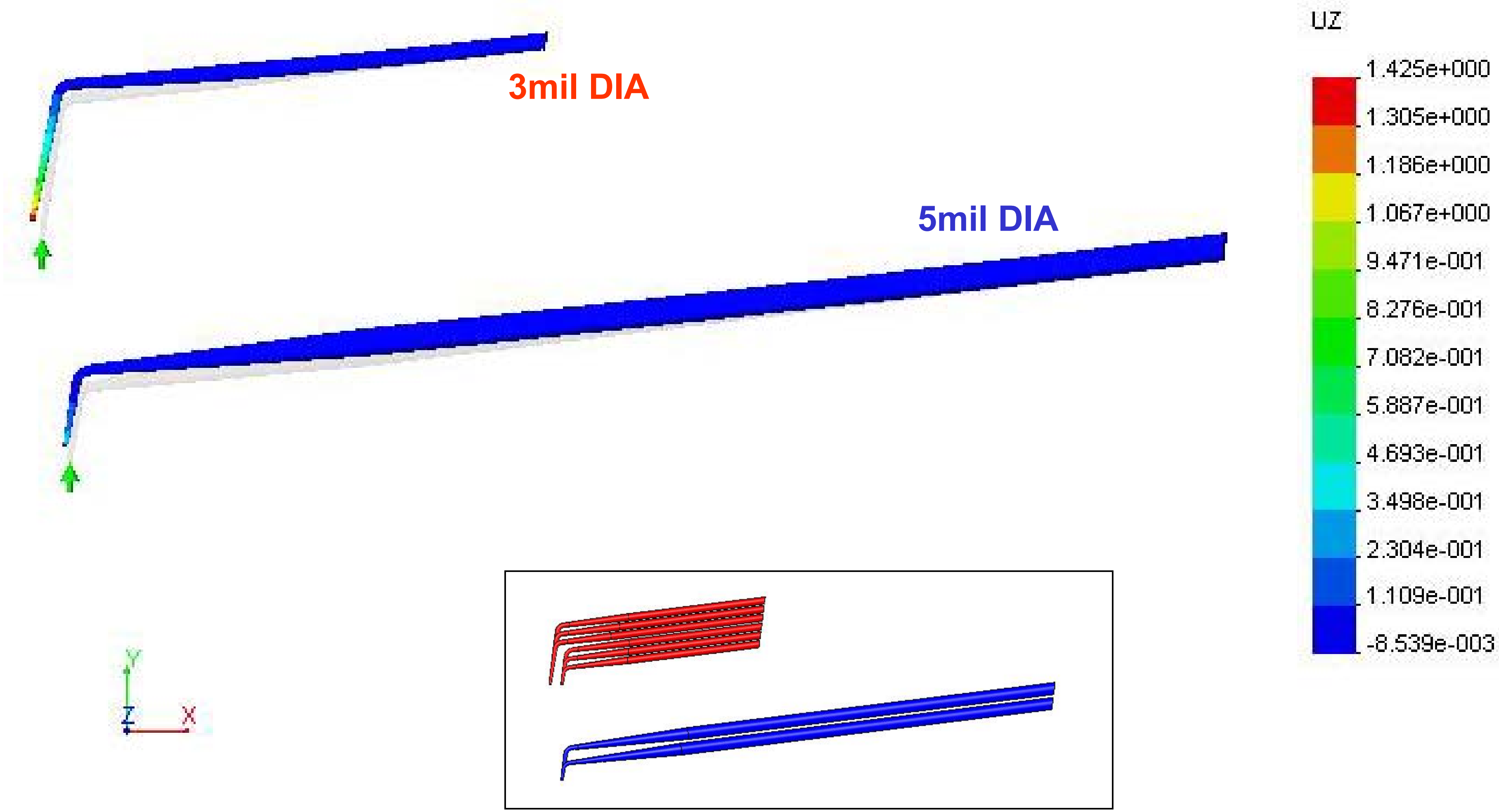
Both probes were over driven to 3mil



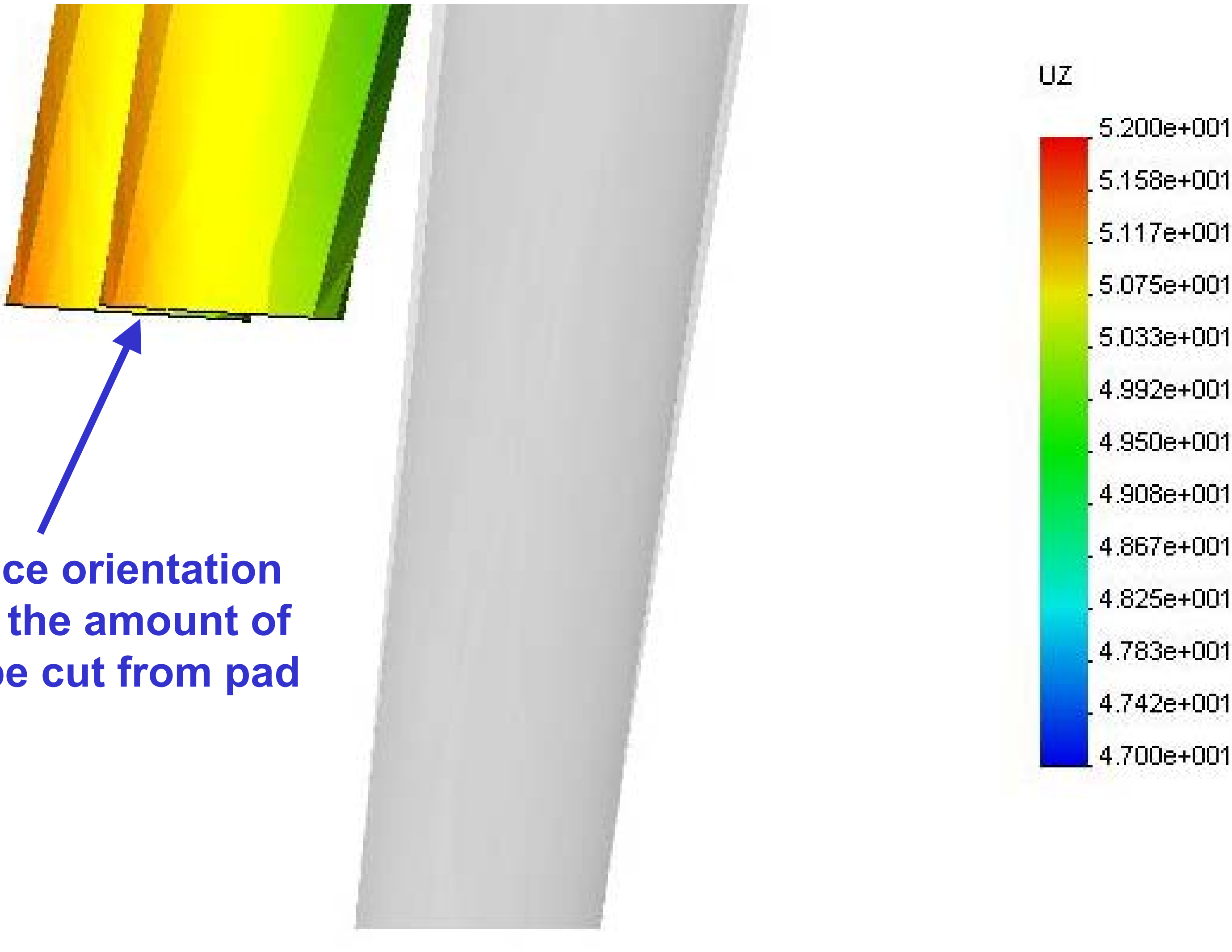
Example 2: FEA is used in stabilizing the probe structure

Both probes were over driven to 3mil,

contact at edge of tip, offset from center

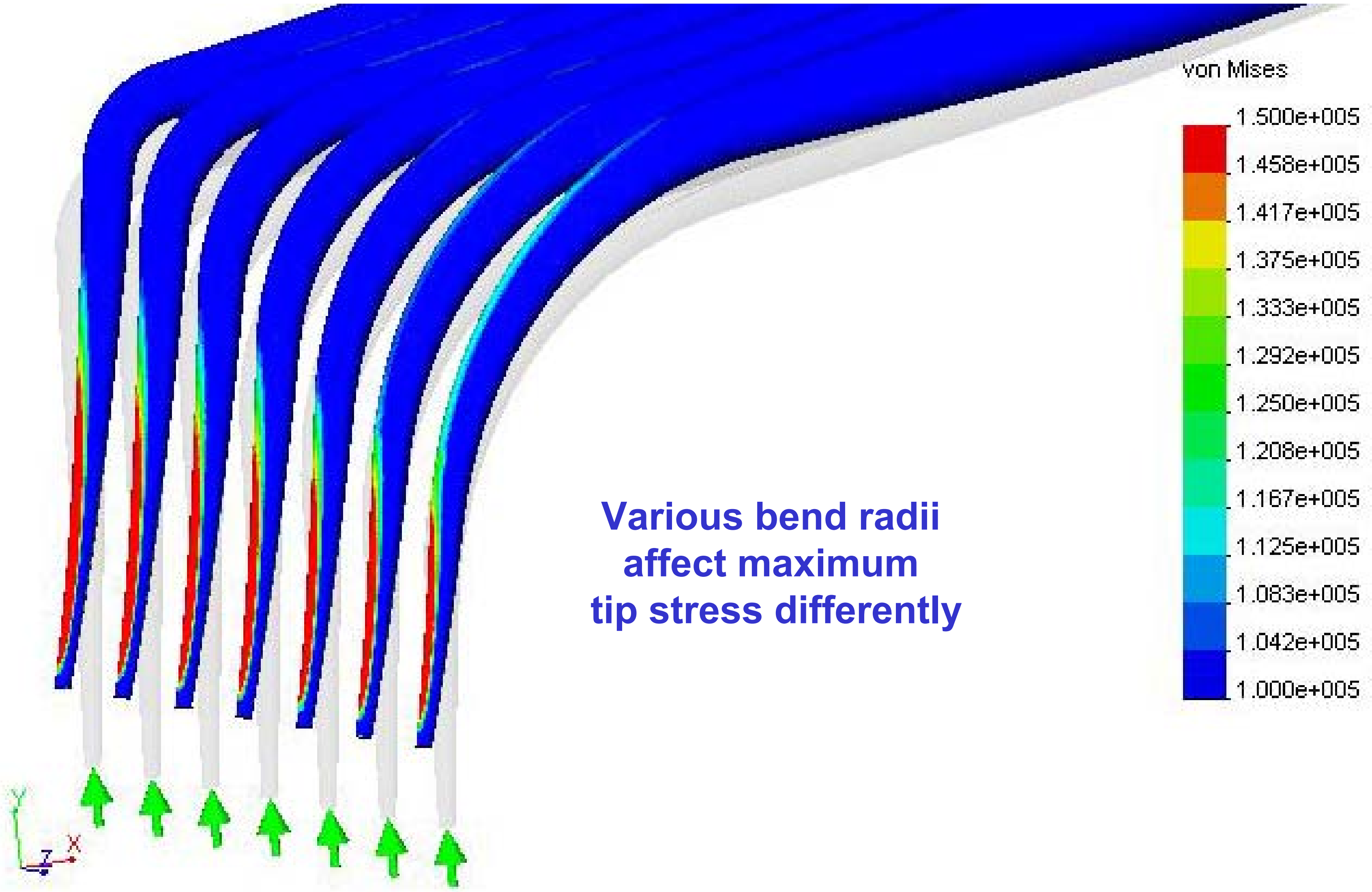


Example 3: FEA is used in optimizing tip metal cutting angle



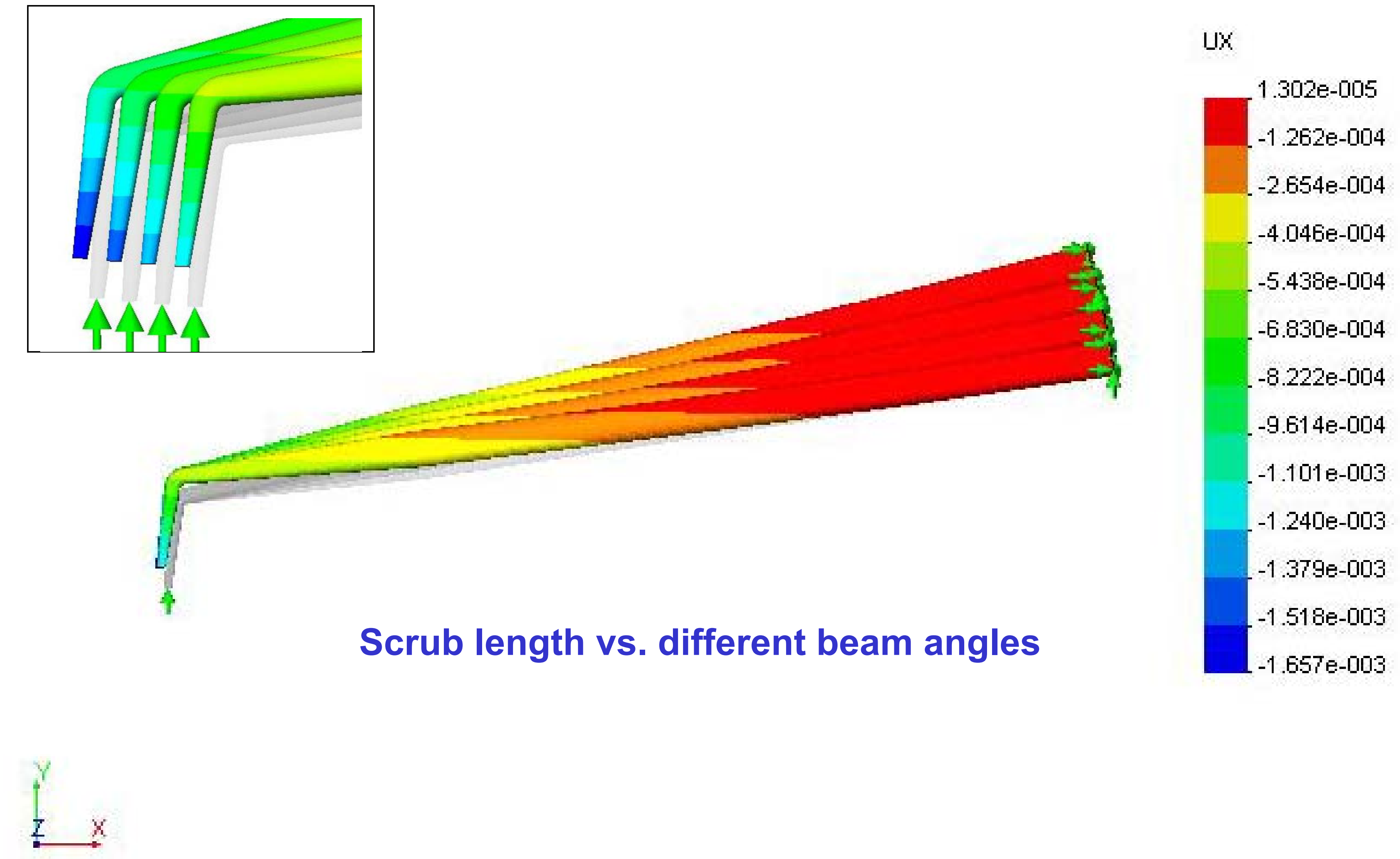
Tip surface orientation will affect the amount of metal to be cut from pad

Example 4: FEA is used in optimizing the best bend radius



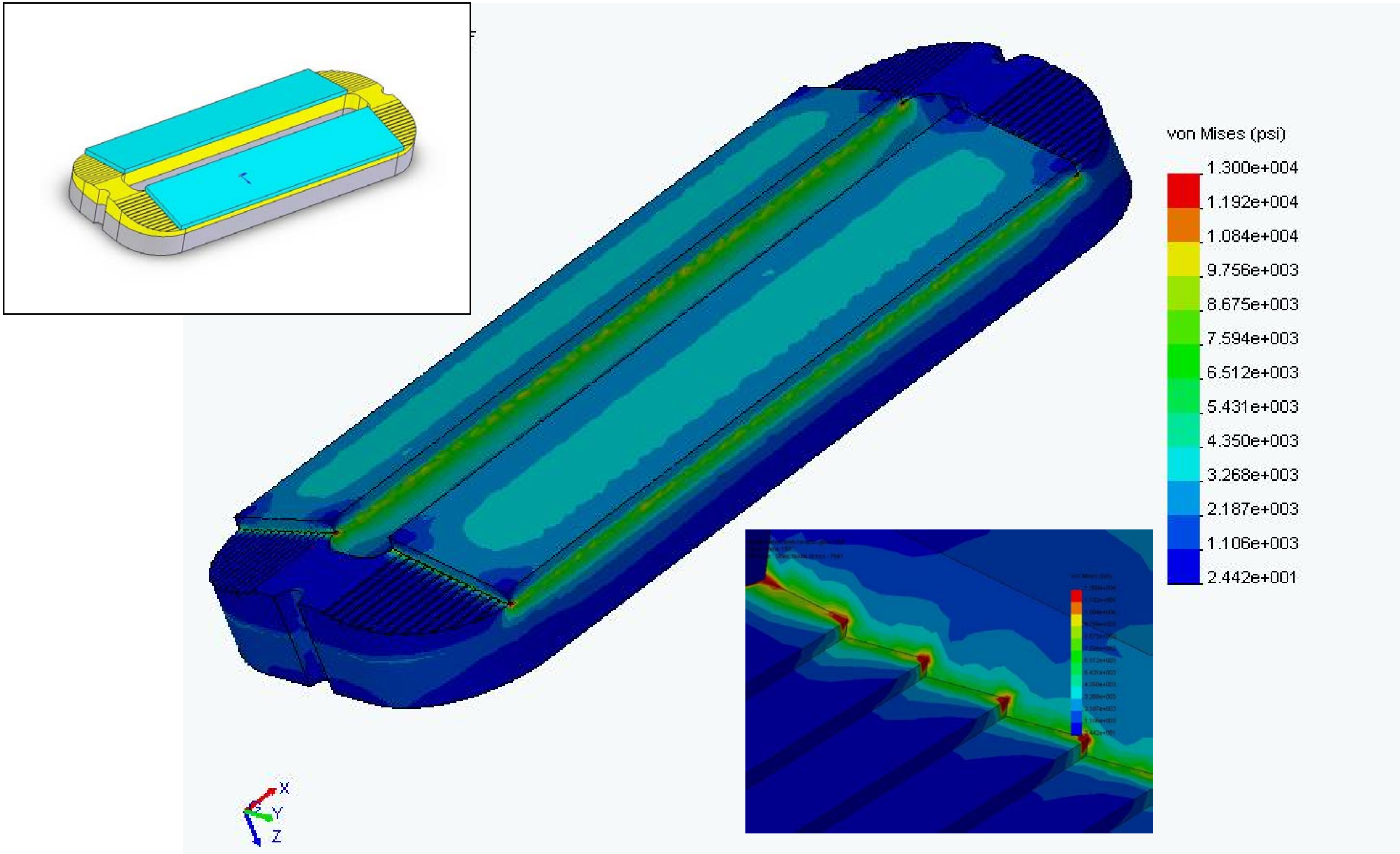
Various bend radii affect maximum tip stress differently

Example 5: FEA is used in optimizing the best beam angle



Scrub length vs. different beam angles

Example 6: FEA is used in optimizing design using different epoxies

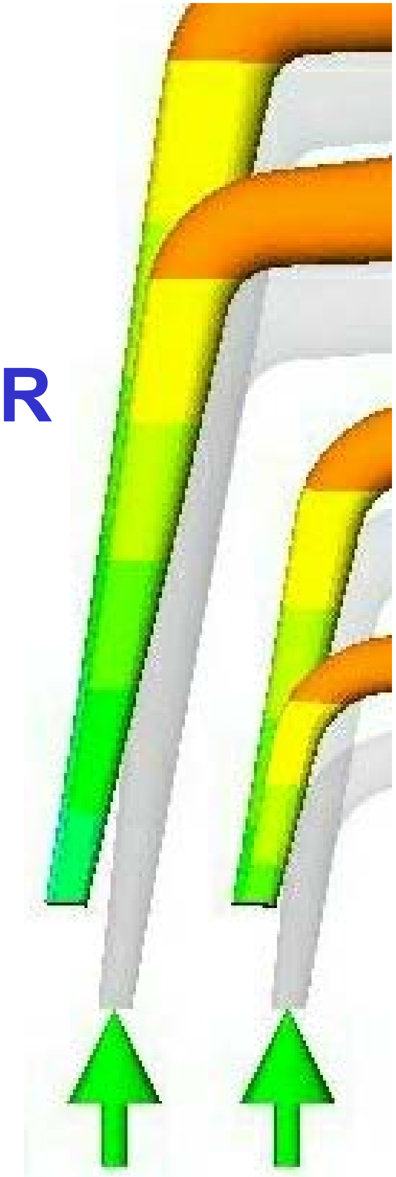


Actual design case of optimized vs. conventional design

Actual case: Before and after FEA optimization (no friction)

BEFORE

AFTER



Actual case: Before and after FEA optimization with friction

BEFORE

AFTER

Summary: Why FEA?

- It's an efficient and economical way to optimize probe card design while providing customers with an expectation of performance before manufacture.
- A necessary tool to address today's industry requirements since conventional calculations no longer offer the precision and accuracy needed to adequately predict scrub marks, contact force, probe life, etc.
- It helps pinpoint which manufacturing tolerances are the most critical to a customer's certain design requirement and where to focus quality control measures that will ensure that the card will be made and perform as requested.
- Provides customers with the best designs options tailored to their specific design constraints. Customers can make pad layout tradeoffs prior to committing these design options to silicon.