ELLISON TECHNOLOGIES

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Measuring Threaded Holes

It's a common question…

In PC-DMIS I can use the pitch function within a circle feature so the probe would "follow" the thread. How are tapped holes measured in Calypso?

I have a part with several threaded holes that I need to report TP on.

what is the best method of checking the position of threaded holes, i would like to stay away from flex plugs due to cmm time.

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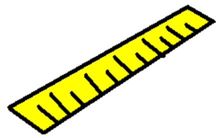

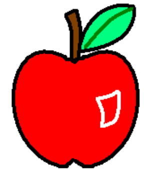

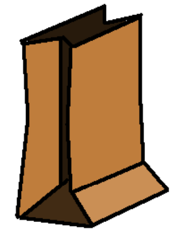

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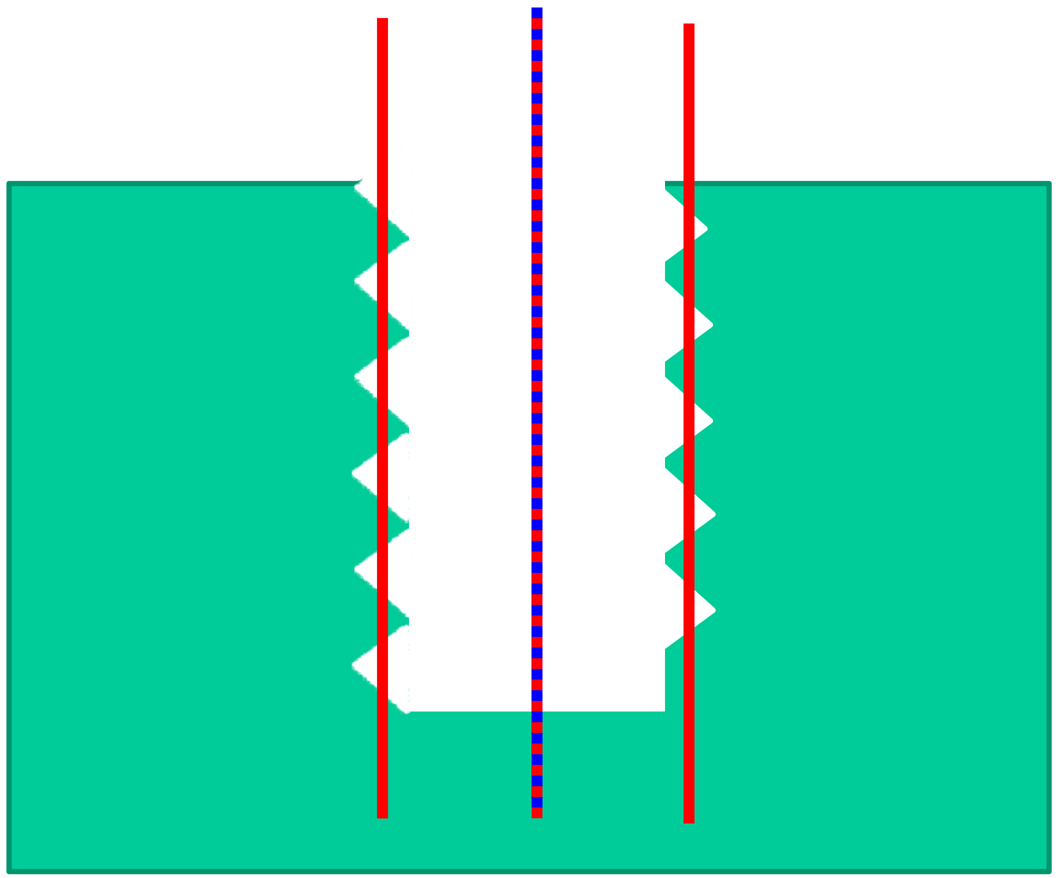
We have been checking a thread hole and they screwed a pin in the hole and were measuring od of pin for T/P. I’ve been trying to revise the program to check without pin to save some time. I am having trouble getting results.

Why the problems?

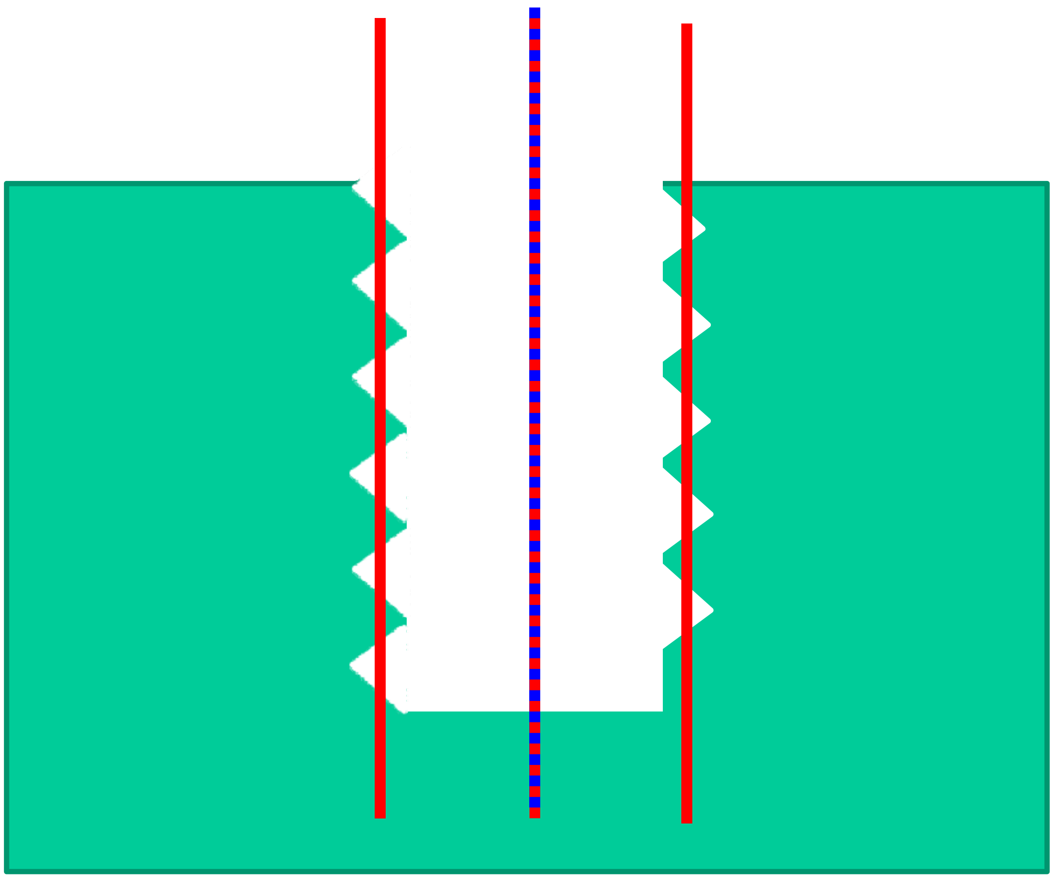
Here's how a common thread is made:



In a perfect world, pilot hole location (which we don't care about) is the same as the pitch location (which we care about)

If you haven’t noticed yet, this is not a perfect world…

Real parts can look like this:



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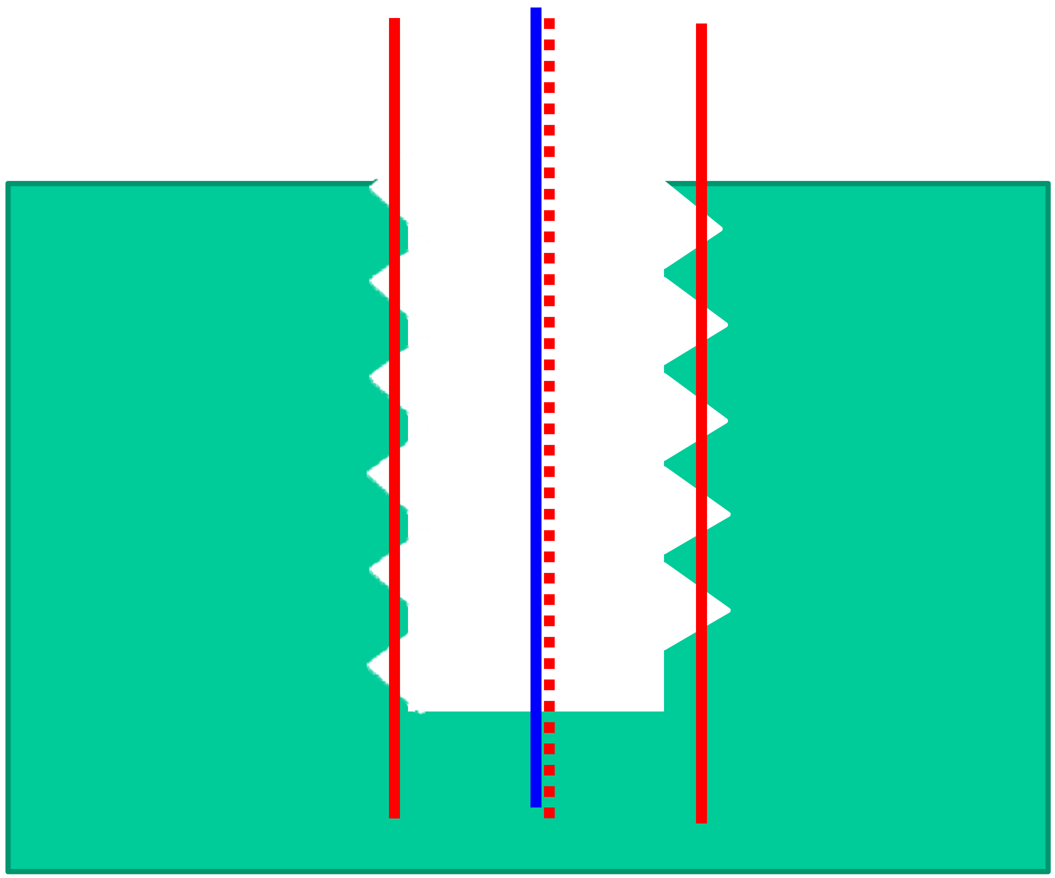

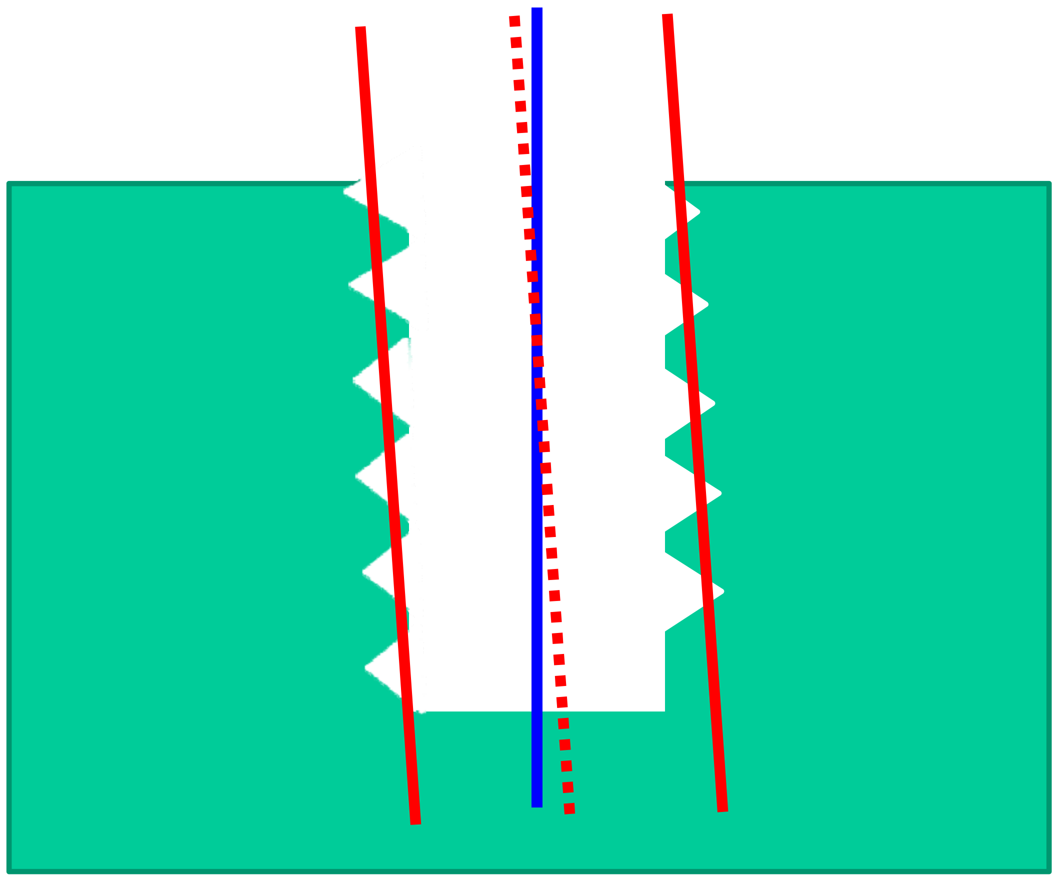

We can't directly measure the pitch diameter on a CMM.

What's a CMM programmer to do?

The traditional "accepted" method is to use a Thread Location gage.

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Threaded Hole Centerline Gages

Flexible

Solid

Tapered

Thread Lock

Variable

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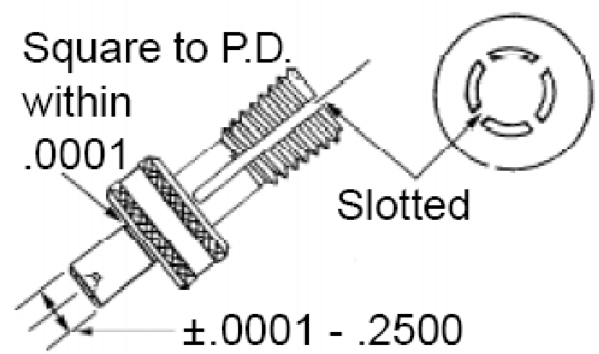
Centerline Hole Location Gages

Threaded hole location plugs are slotted* every 90° around the plug, and the pitch diameter is ground to assure positive location at the pitch diameter of the part being checked. Use to check centerline distance between two or more tapped holes. Normally used in pairs. Concentric to P.D. .0002 T.I.R.

Size (Inch)		EDP No.	Price
0-80	UNF	**480100**	90.00
1-64	UNC	**480200**	87.00
1-72	UNF	**480300**	87.00
2-56	UNC	**480400**	85.00
2-64	UNF	**480500**	85.00
3-48	UNC	**480600**	81.00
3-56	UNF	**480700**	81.00
4-40	UNC	**480900**	76.00
4-48	UNF	**481000**	76.00
5-40	UNC	**481100**	83.00
5-44	UNF	**481200**	83.00
6-32	UNC	**481300**	84.00
6-40	UNF	**481400**	84.00
8-32	UNC	**481500**	79.00
8-36	UNF	**481600**	79.00
10-24	UNC	**481700**	78.00
10-32	UNF	**481800**	78.00
12-24	UNC	**481900**	76.00

Size (Inch)		EDP No.	Price
5/16-18	UNC	**482500**	68.00
5/16-24	UNF	**482600**	68.00
3/8-16	UNC	**482800**	72.00
3/8-24	UNF	**482900**	72.00
7/16-14	UNC	**483100**	70.00
7/16-20	UNF	**483200**	70.00
1/2-13	UNC	**483400**	75.00
1/2-20	UNF	**483500**	75.00
9/16-12	UNC	**483700**	74.00
9/16-18	UNF	**483800**	74.00
5/8-11	UNC	**484000**	76.00
5/8-18	UNF	**484100**	76.00
3/4-10	UNC	**484400**	80.00
3/4-16	UNF	**484500**	80.00
7/8-9	UNC	**484800**	93.00
7/8-14	UNF	**484900**	93.00
1-8	UNC	**485200**	132.00
1-12	UNF	**485300**	132.00

Size (Metric)	EDP No.	Price
M4 X .7	**487500**	95.00
M5 X .8	**487600**	89.00
M6 X 1.0	**487700**	80.00
M8 X 1.25	**487800**	80.00
M10 X 1.5	**488000**	84.00
M12 X 1.75	**488300**	85.00
M12 X 1.25	**488500**	86.00



“precision” cylinder to be measured by the CMM.

Split threads spring tight into the pitch diameter.

Let’s Test it out!

(Accura, 0.050mm tolerance)

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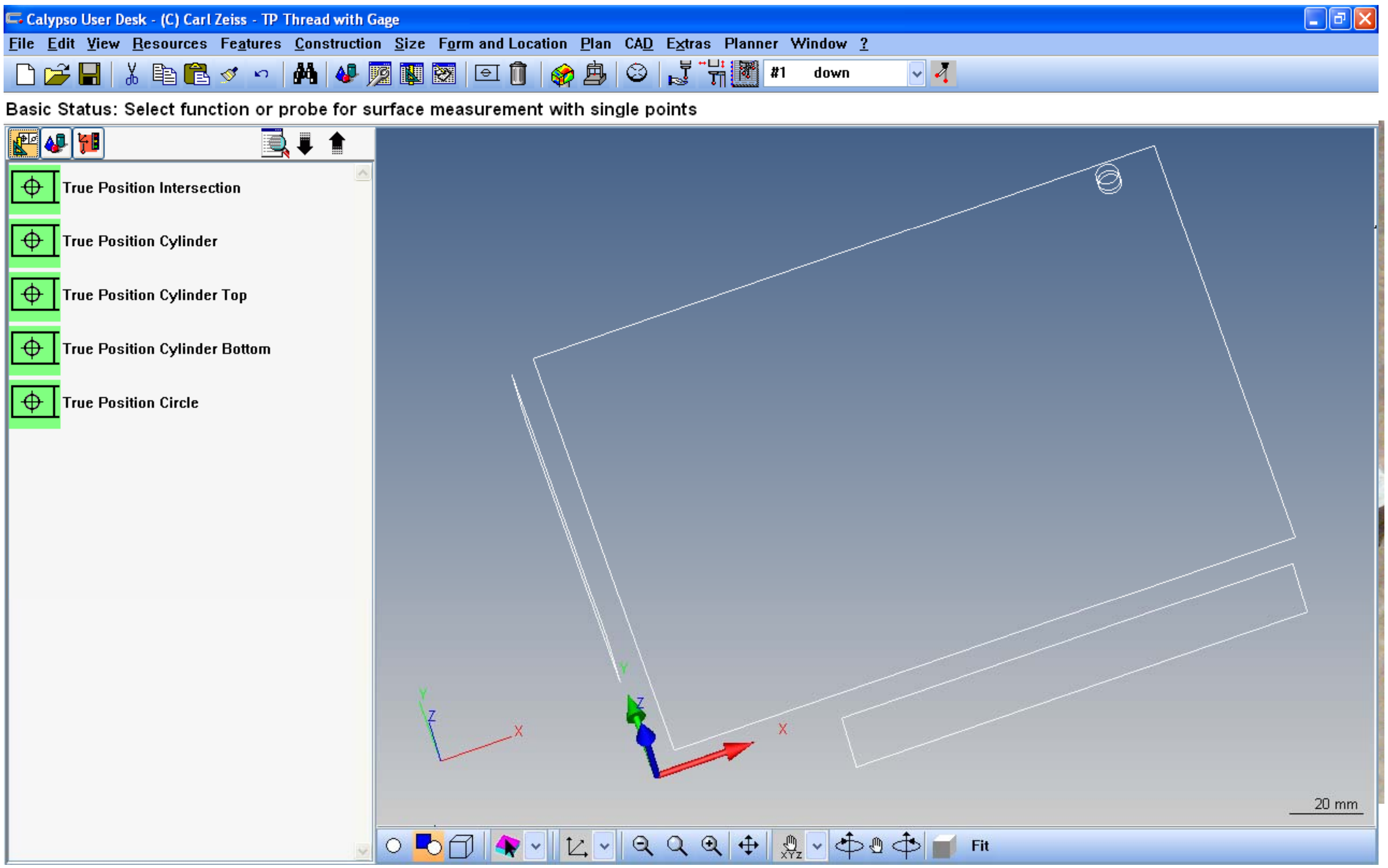
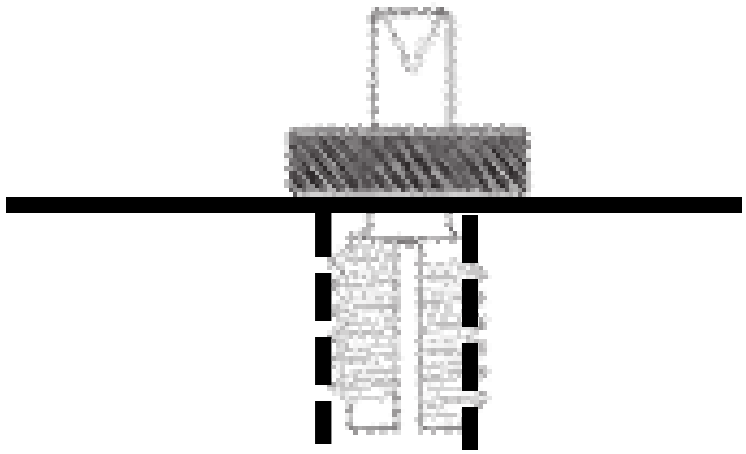


Luncheon Learn

- True Position Intersection
- True Position Cylinder
- True Position Cylinder Top
- True Position Cylinder Bottom
- True Position Circle



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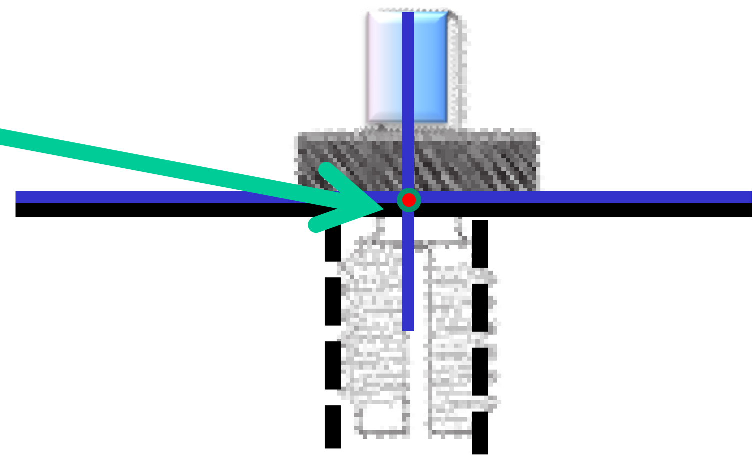

LUNCHEON LEARN

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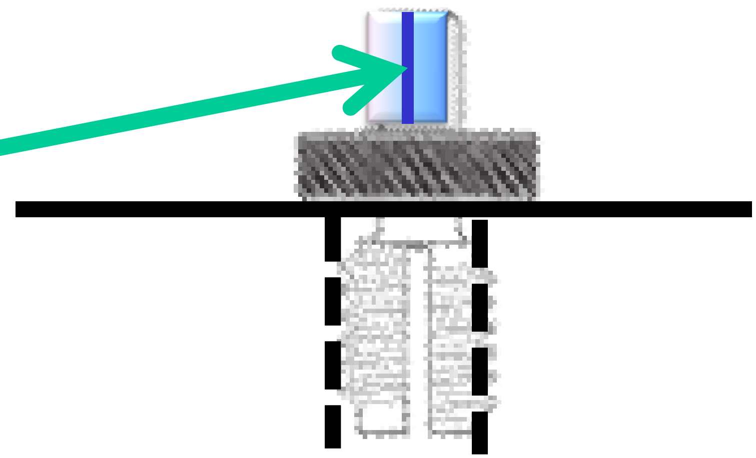

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- ⌖ True Position Intersection
- ⌖ True Position Cylinder
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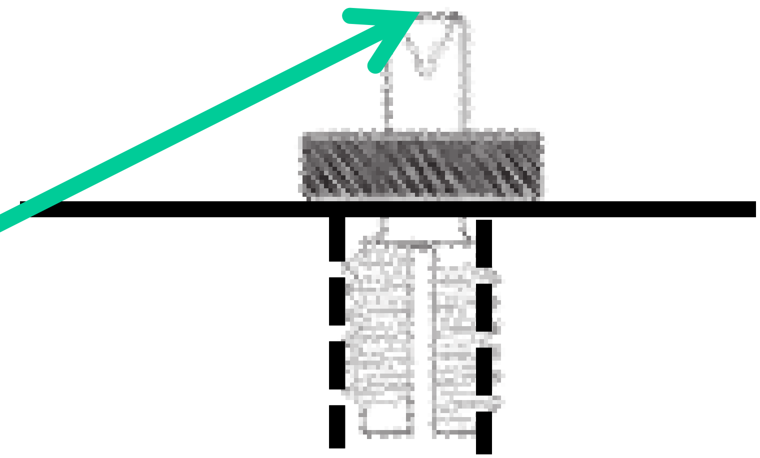

- True Position Intersection
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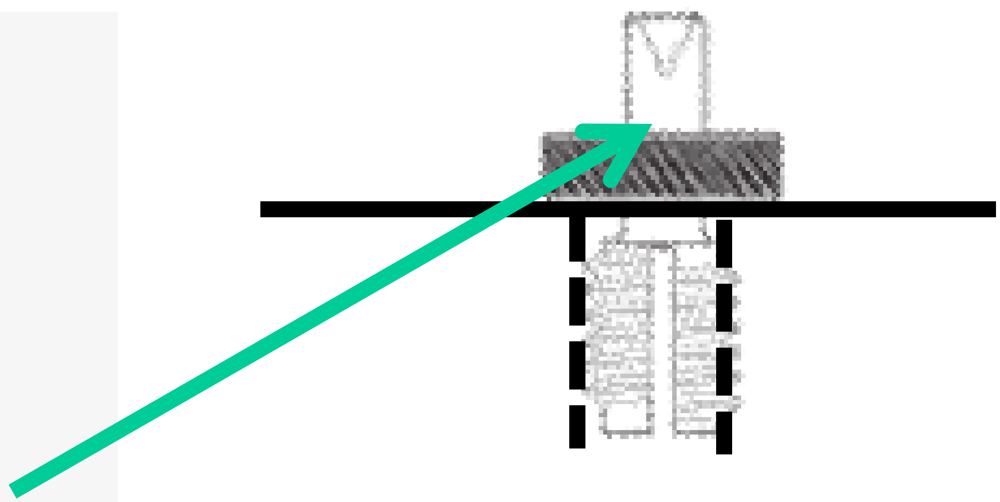
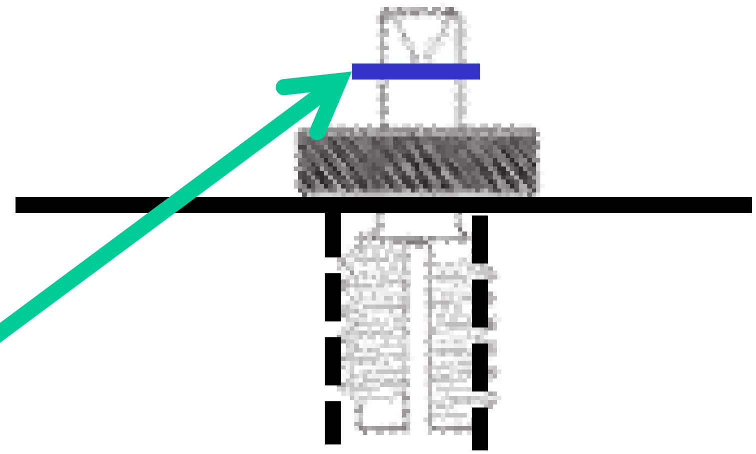
- True Position Cylinder Top
- True Position Cylinder Bottom
- True Position Circle

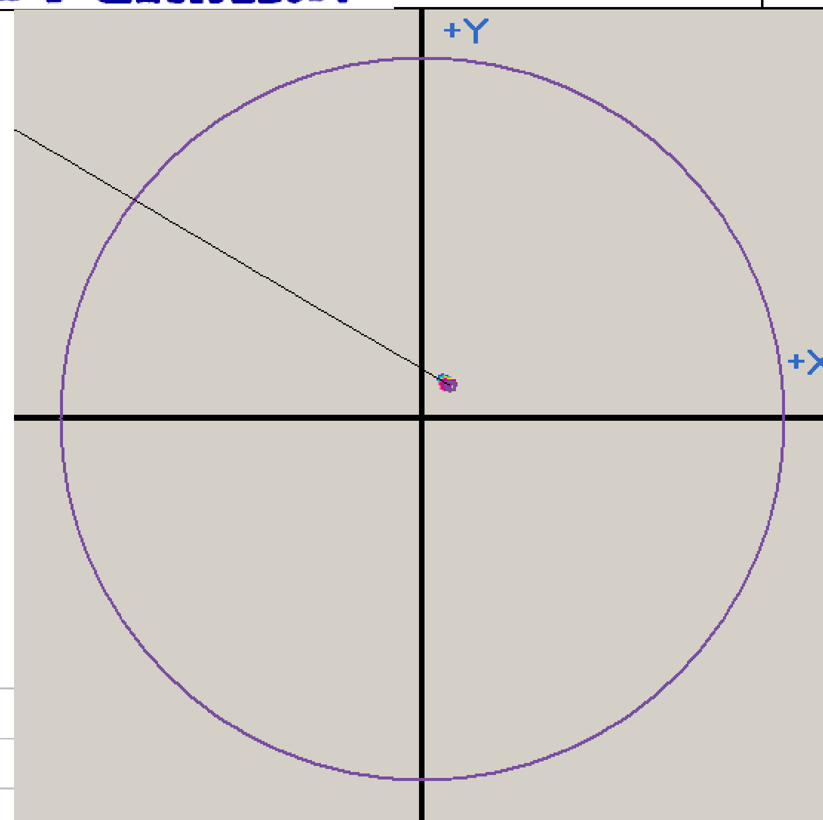


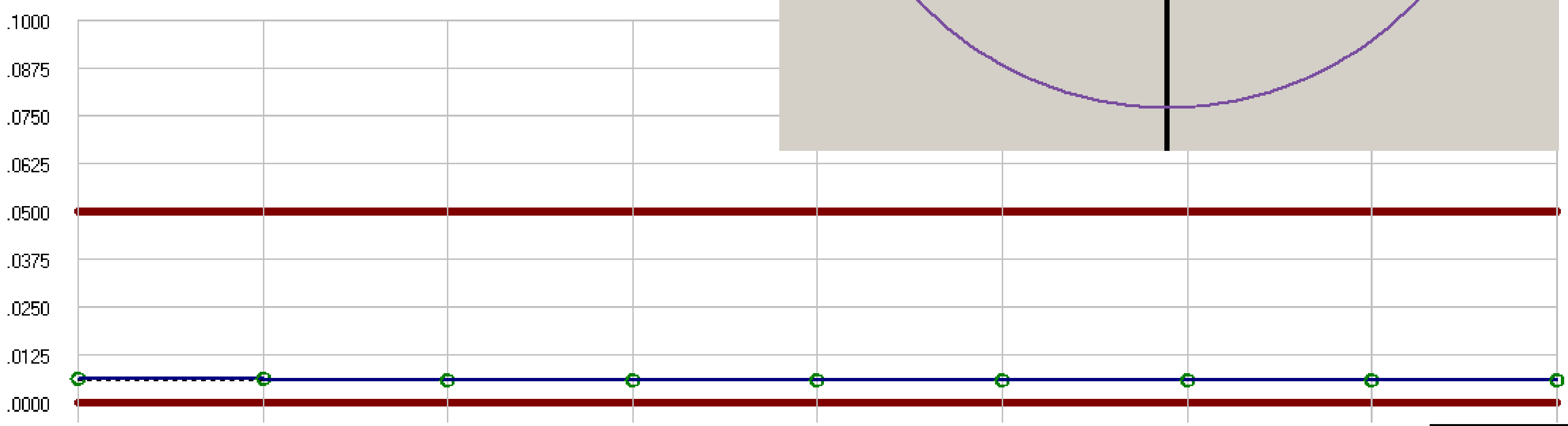
- True Position Intersection
- True Position Cylinder
- True Position Cylinder Top
- True Position Cylinder Bottom
- True Position Circle



Run it 10 times in the same place to prove program repeatability…

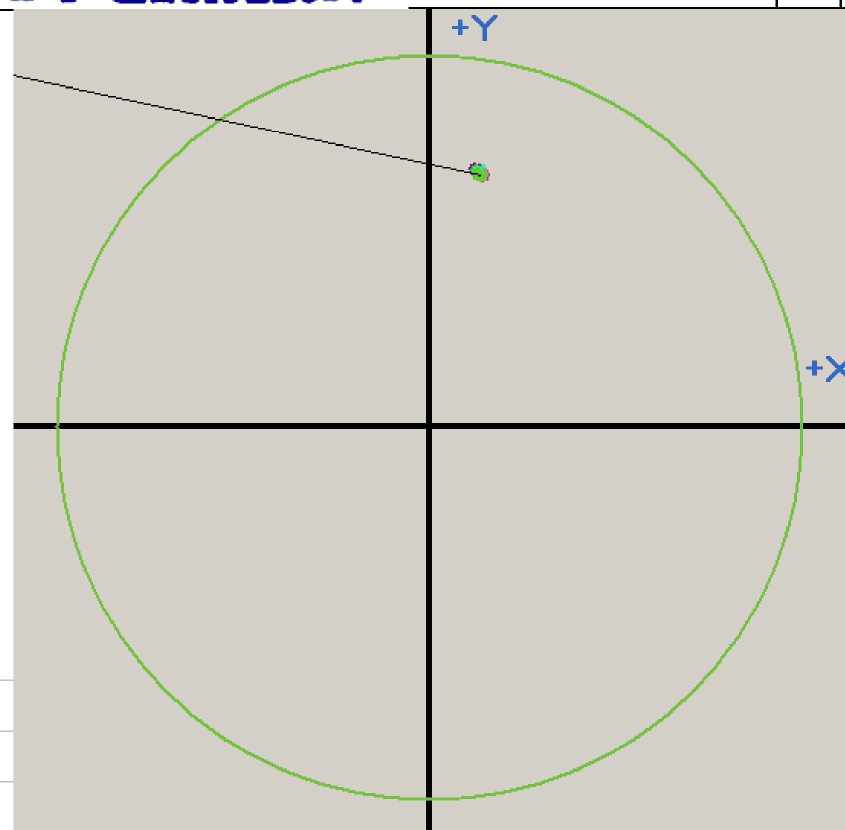
True Position Intersection

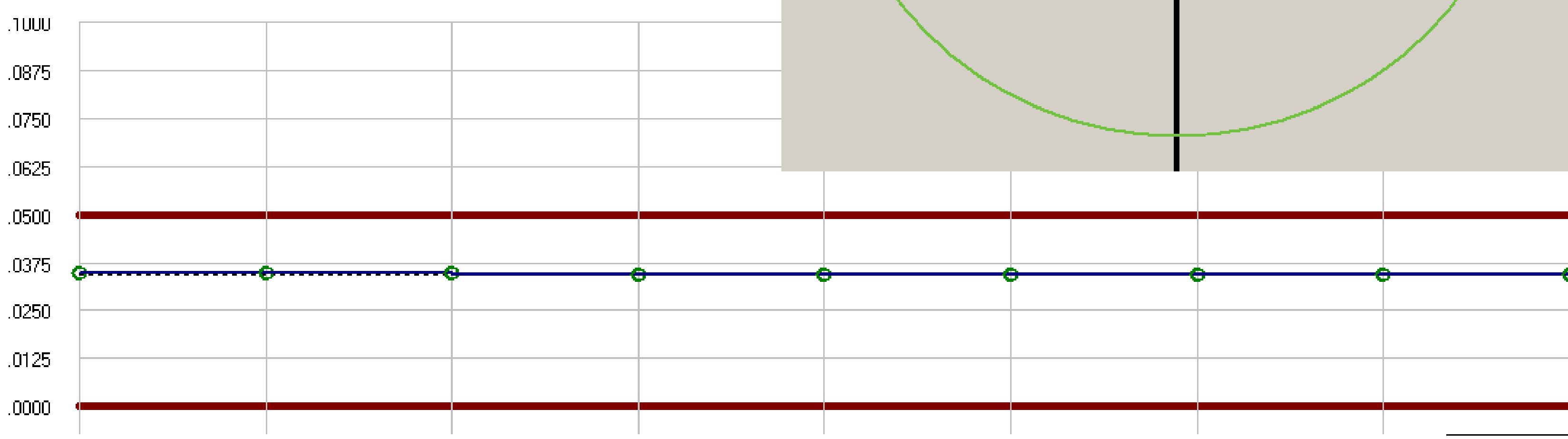




LuncheoN Learn

True Position Cylinder Bottom





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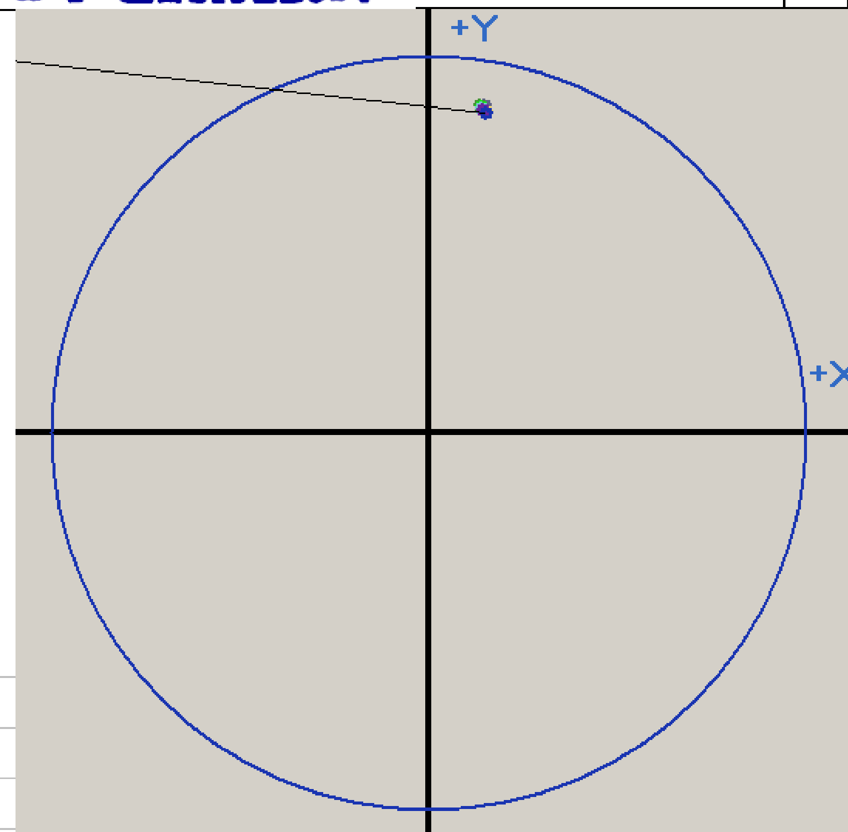
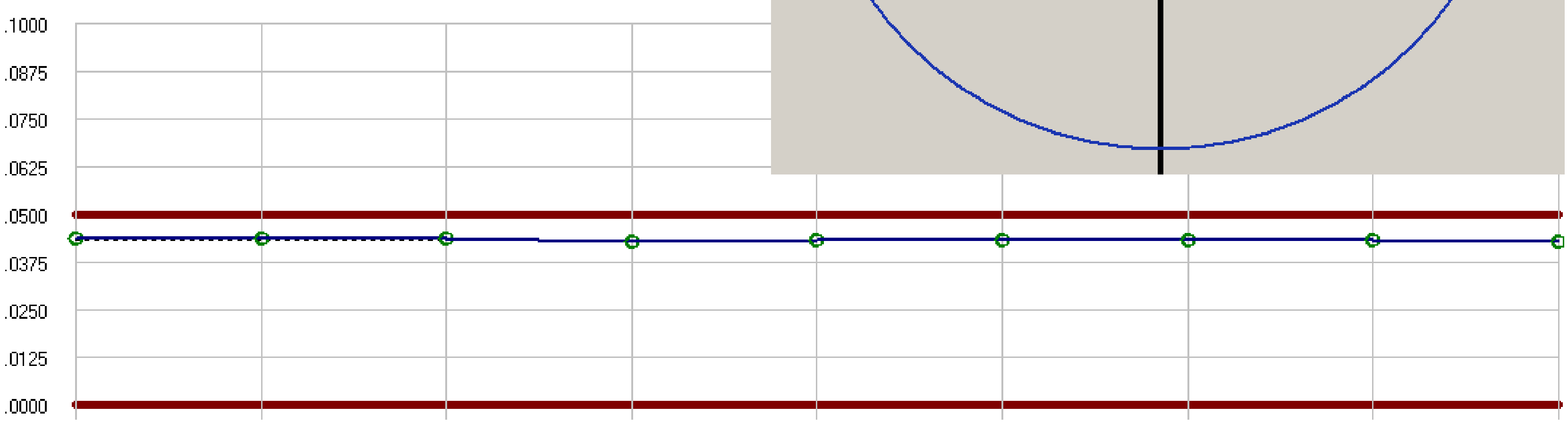
True Position Circle





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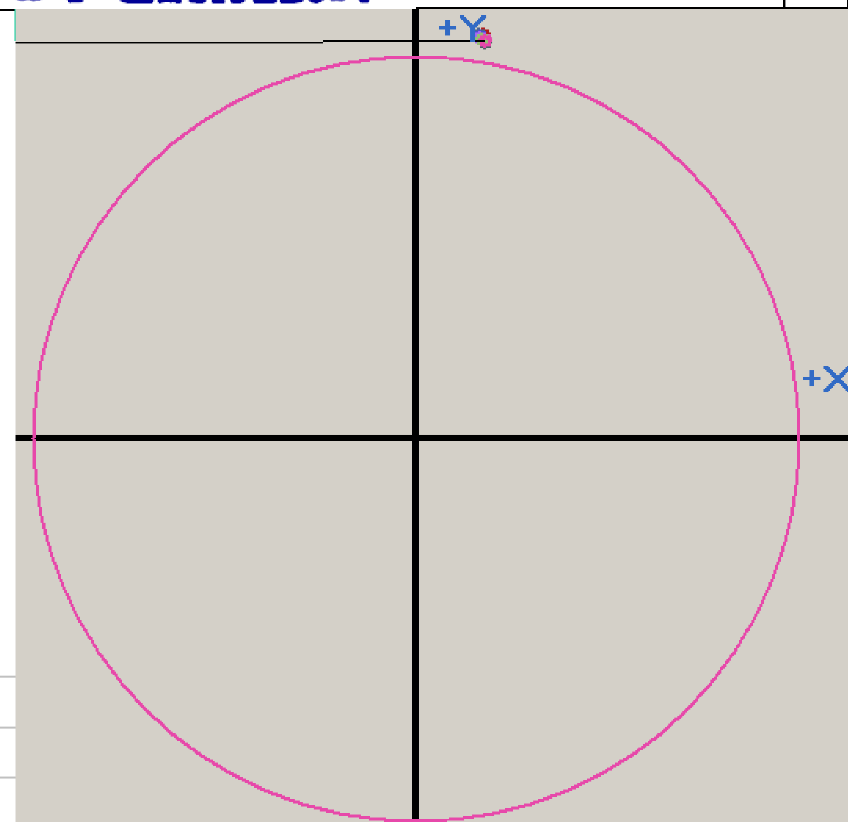
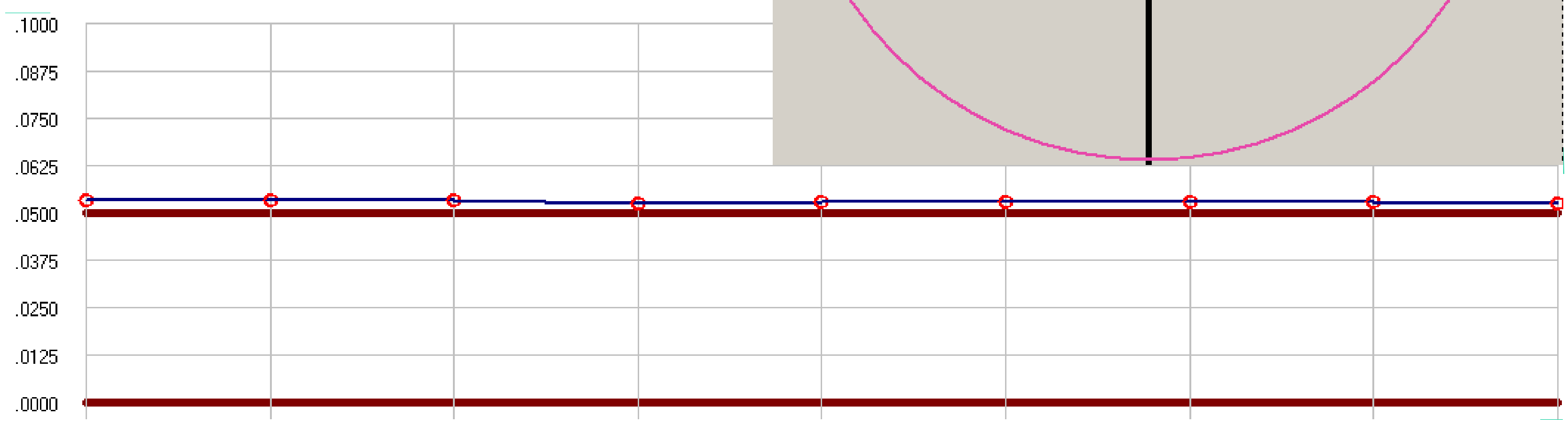
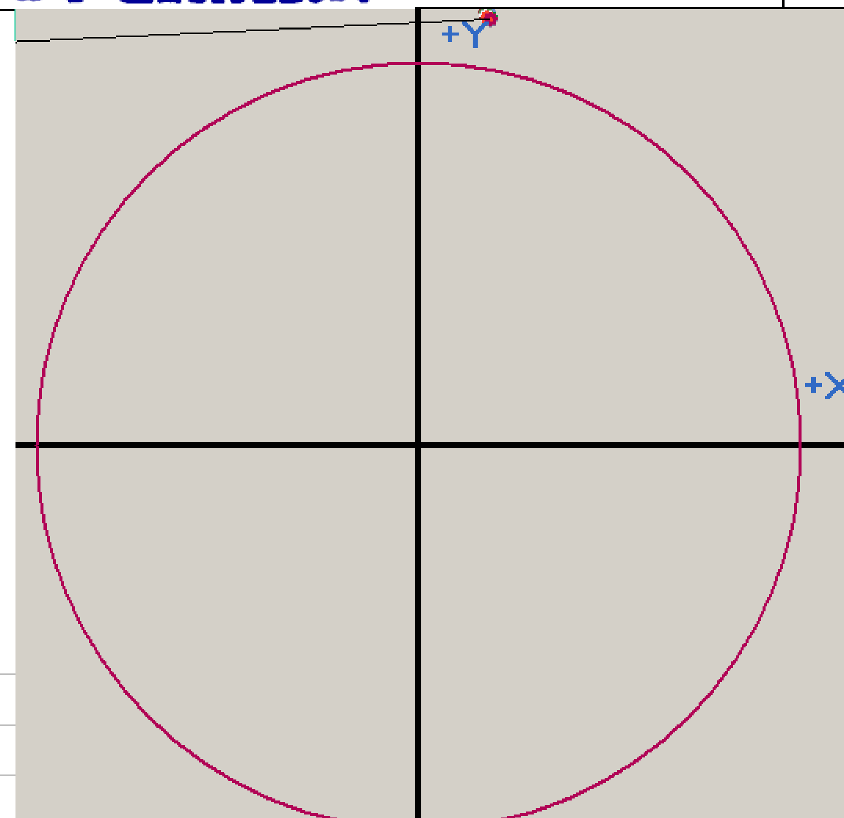
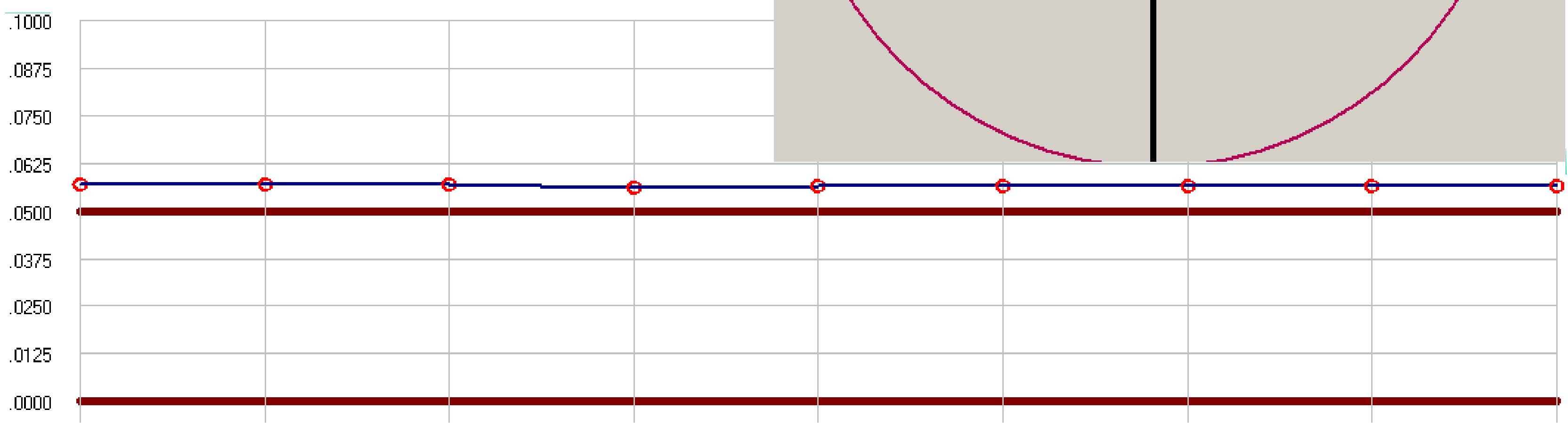
True Position Cylinder





True Position Cylinder Top



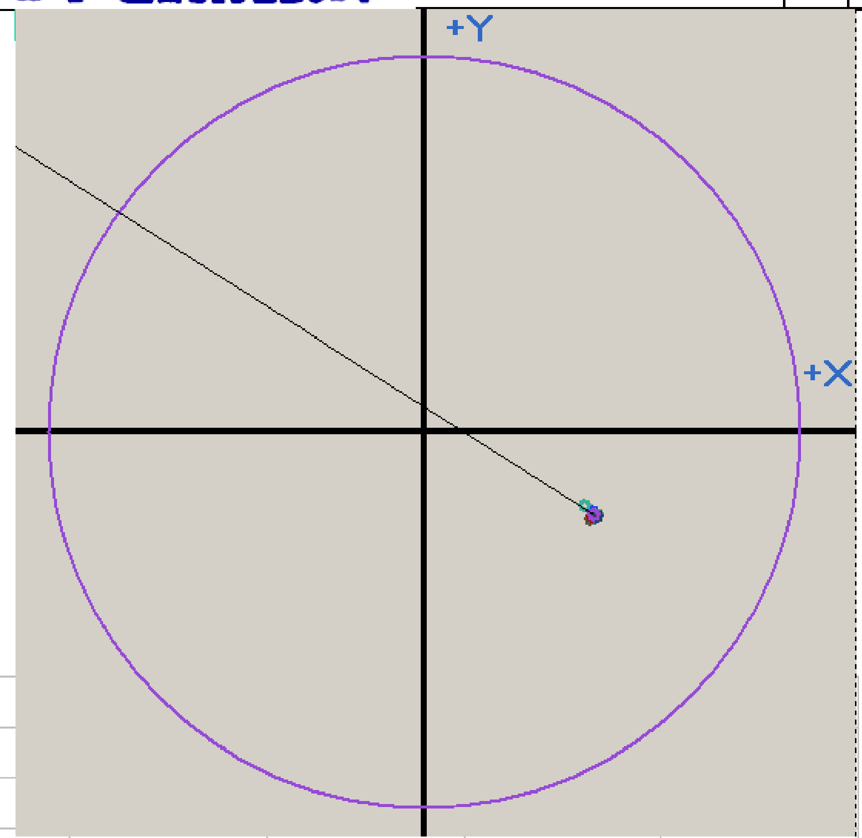


Good repeatability.
Program is fine.

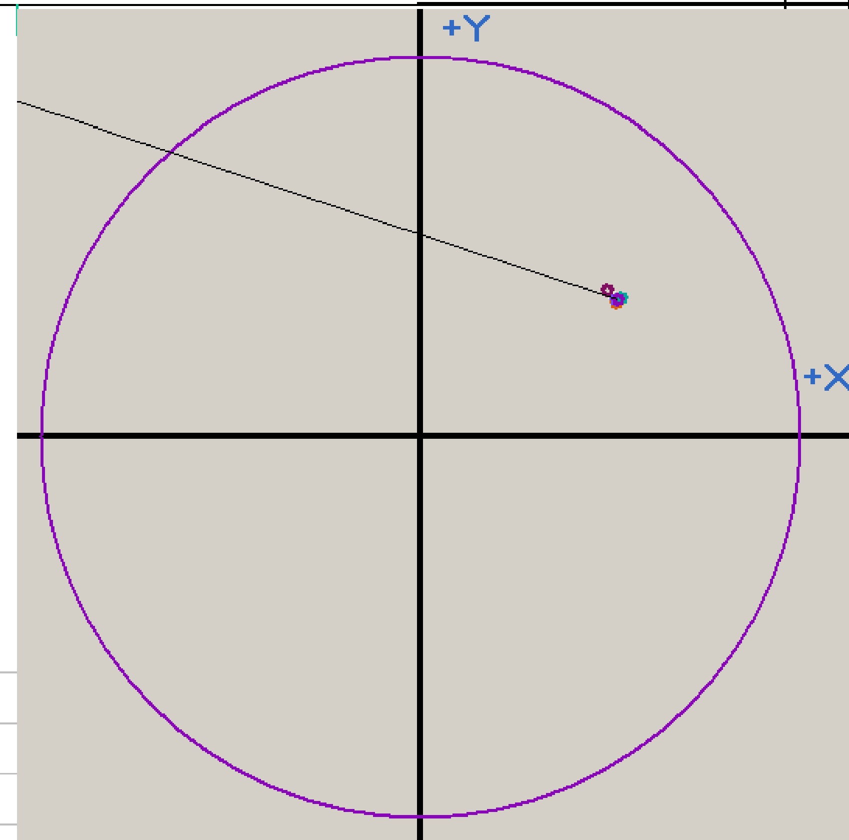
Difference in answers
show a tilt of the thread.

Run it 10 times and reload to prove fixture method...

True Position Intersection



True Position Cylinder Bottom



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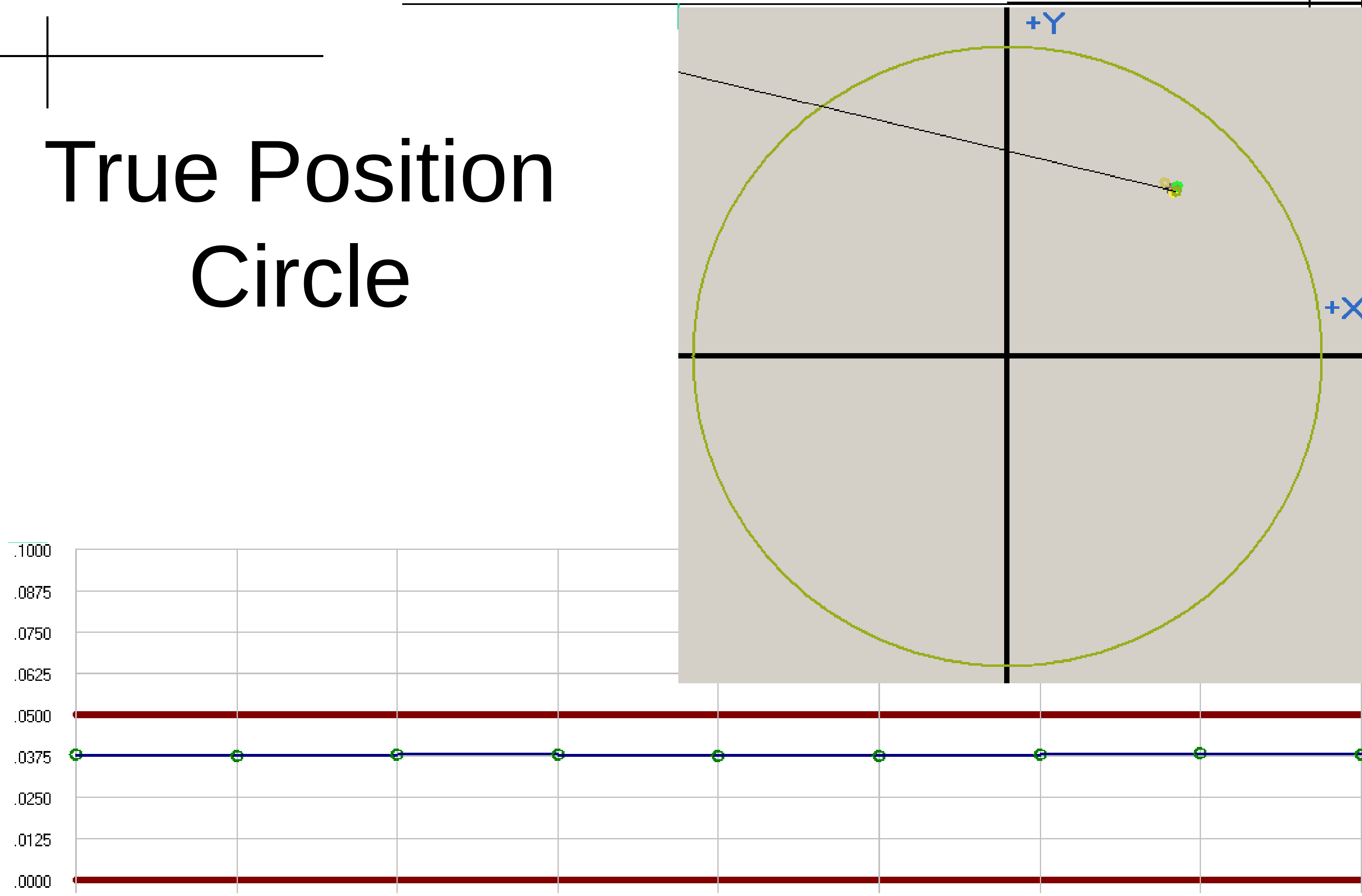
True Position Circle



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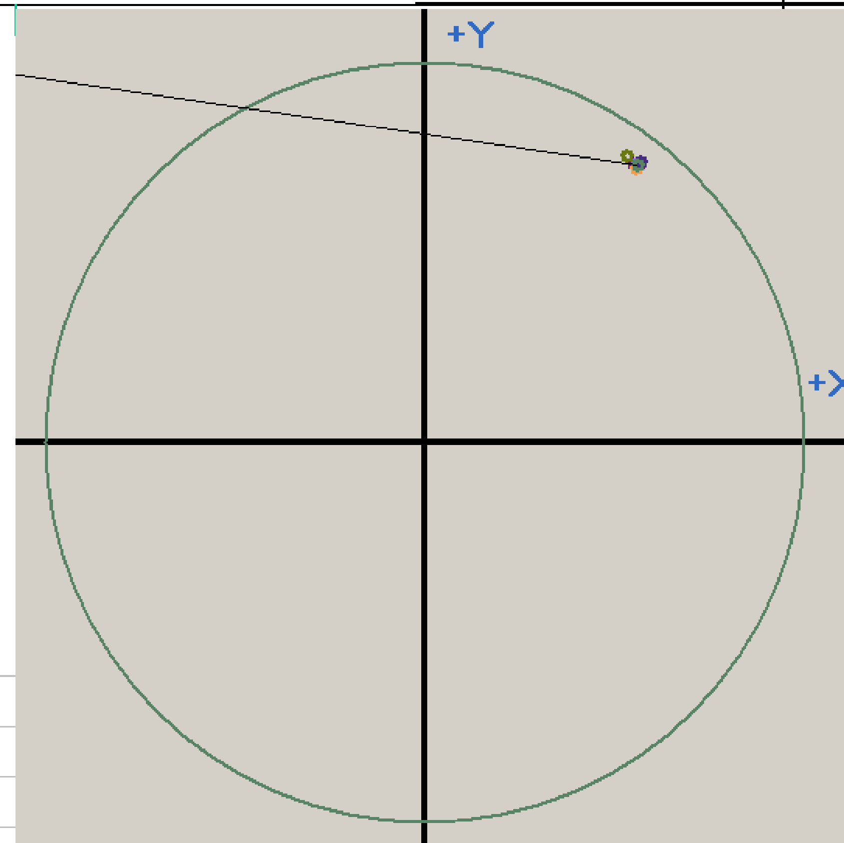
True Position Cylinder



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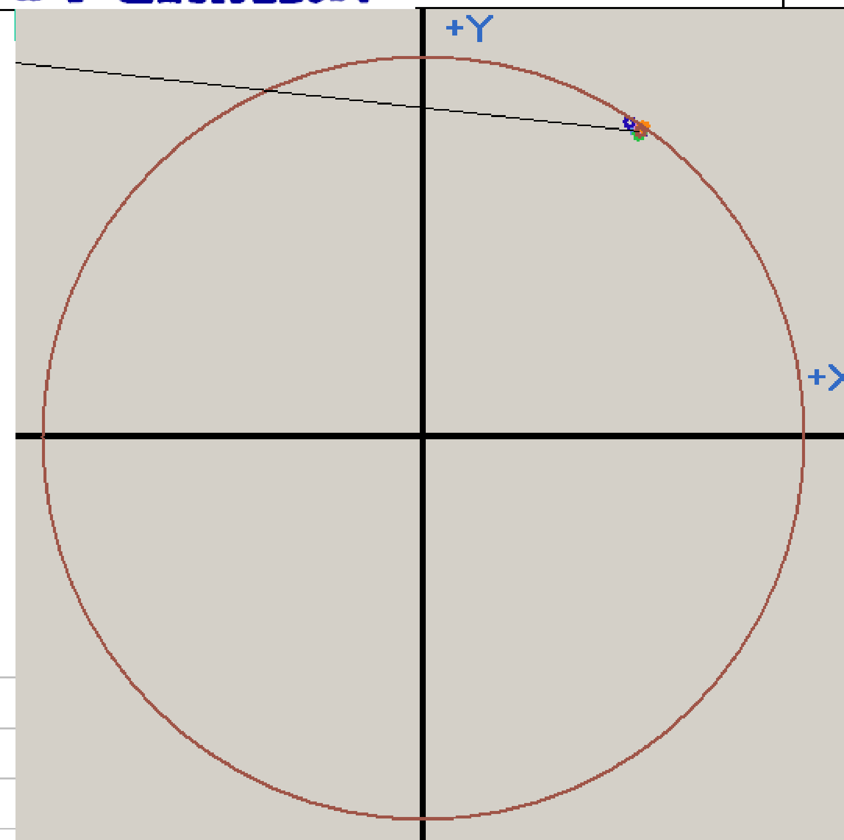
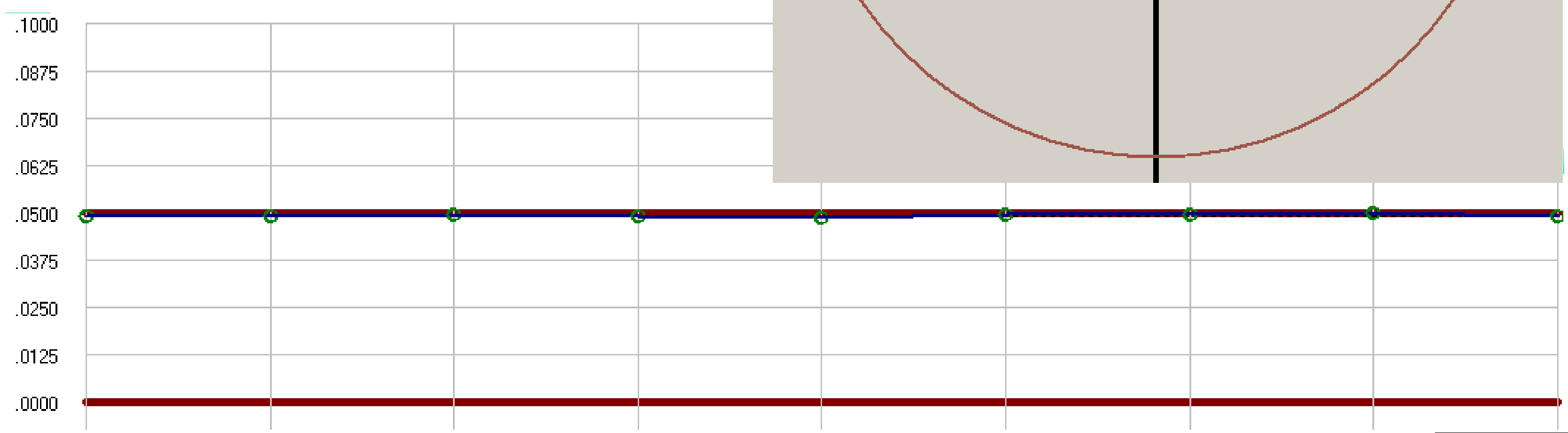
True Position Cylinder Top





Good repeatability. Fixture is fine.

Same pattern of answers up the pin.

Why the different answer from first test?

Run it 10 times and screw/unscrew flexible thread position gage to prove gage repeatability…

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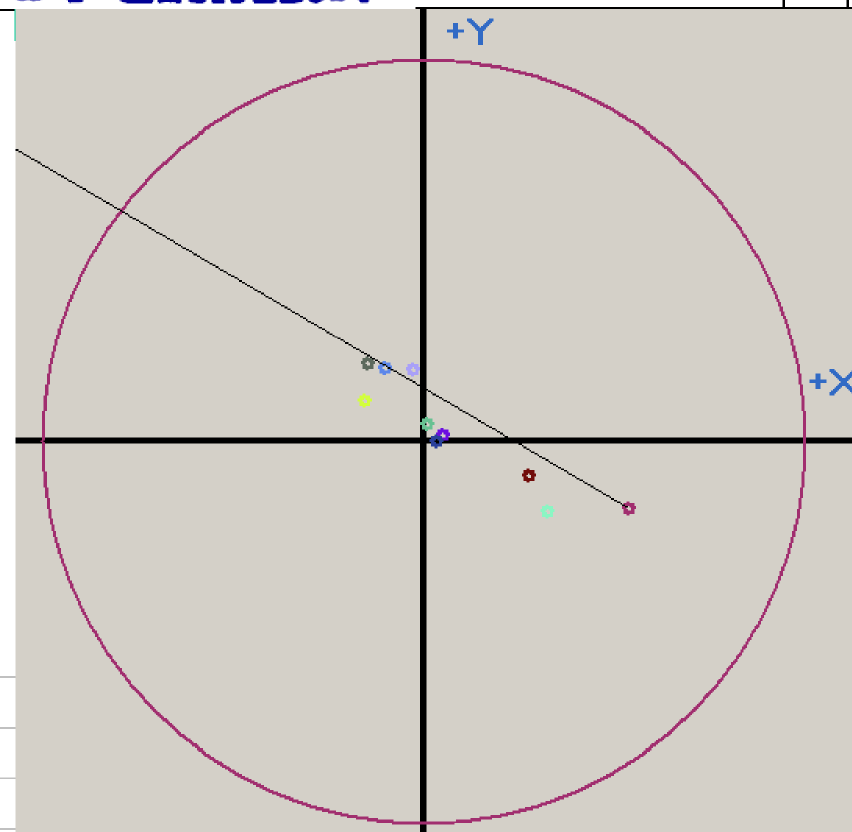
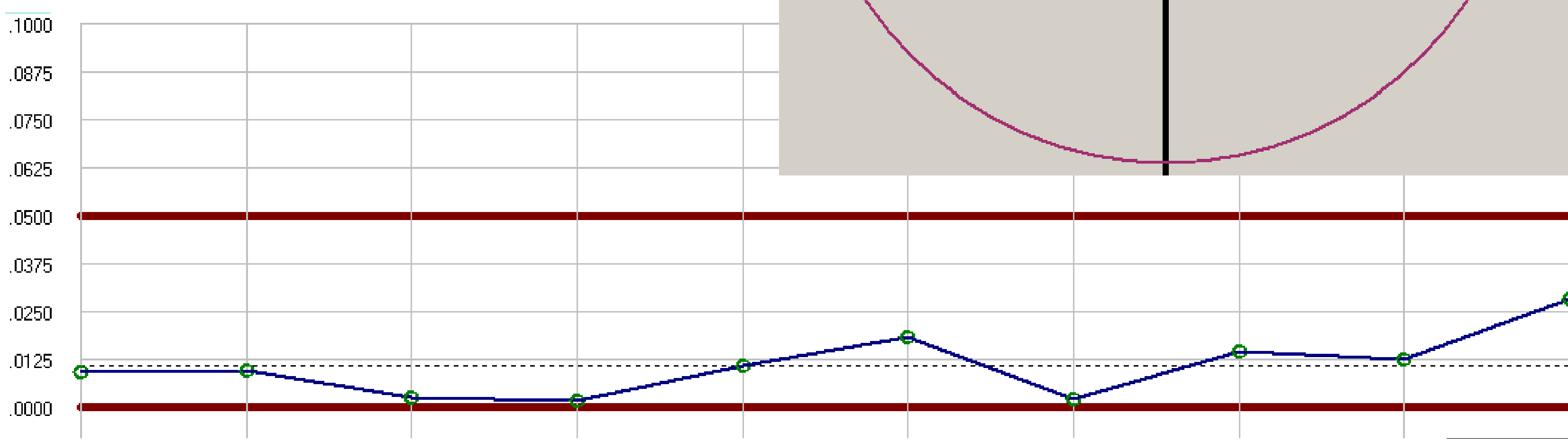
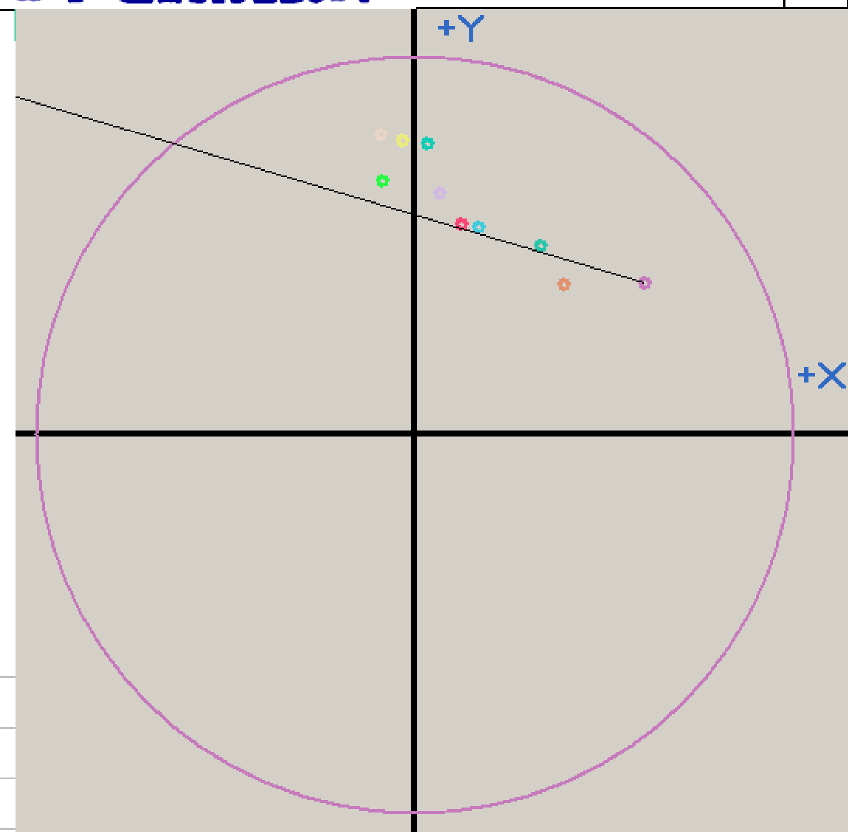
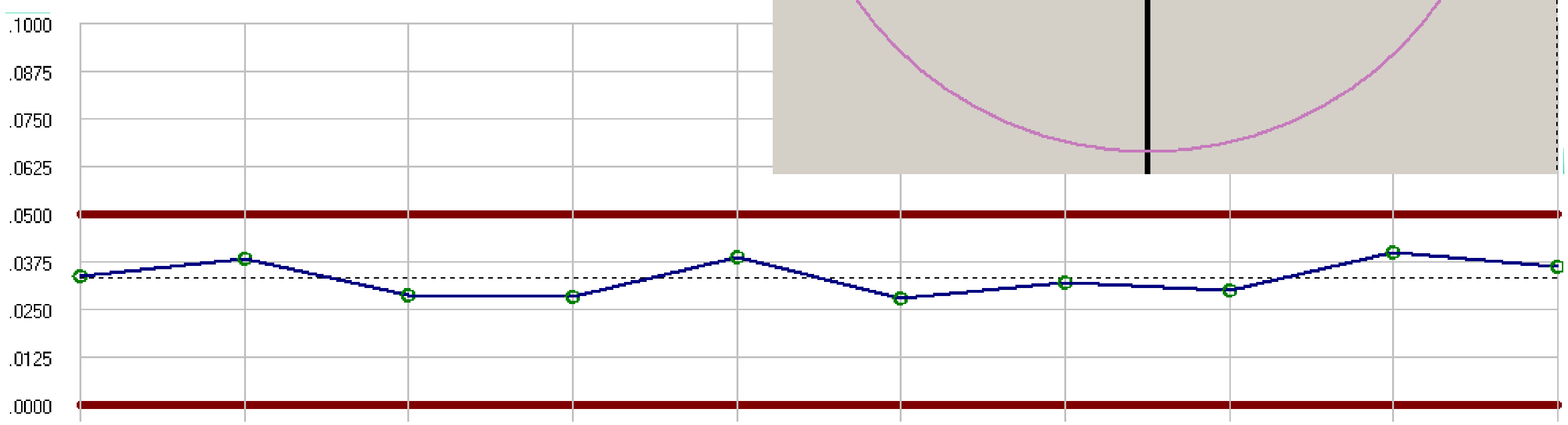
True Position Intersection





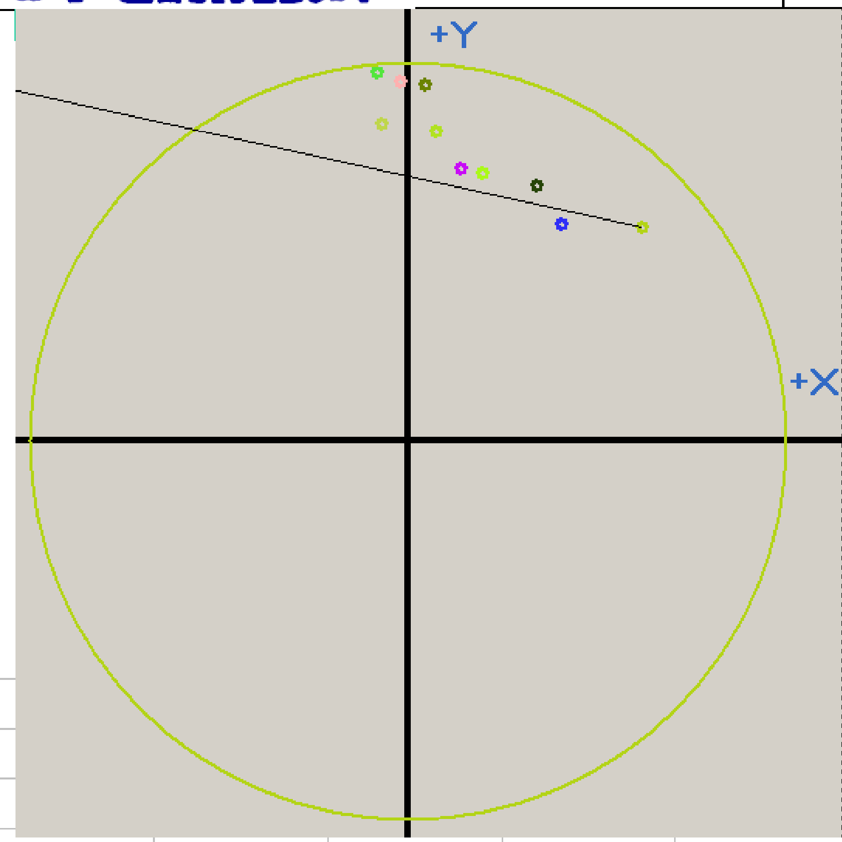
True Position Cylinder Bottom

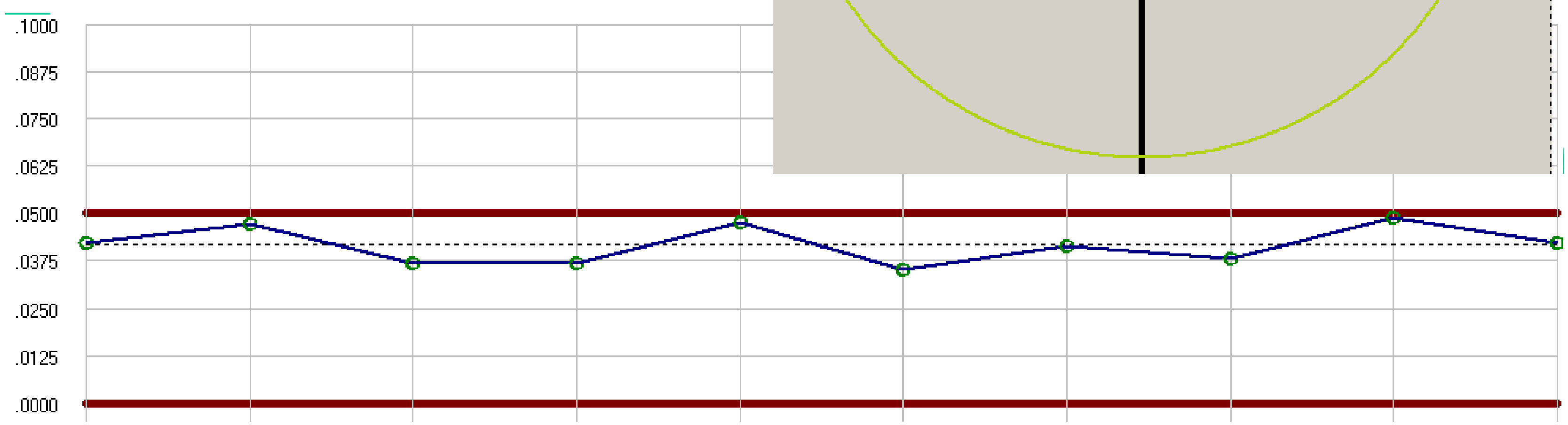




Luncheon Learn

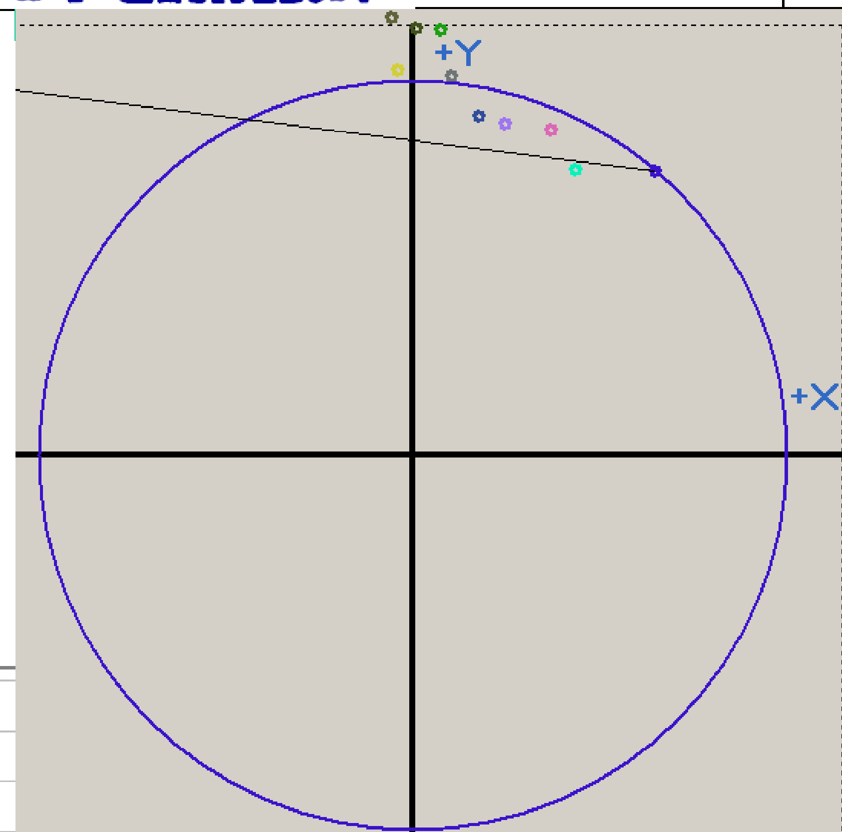
True Position Circle

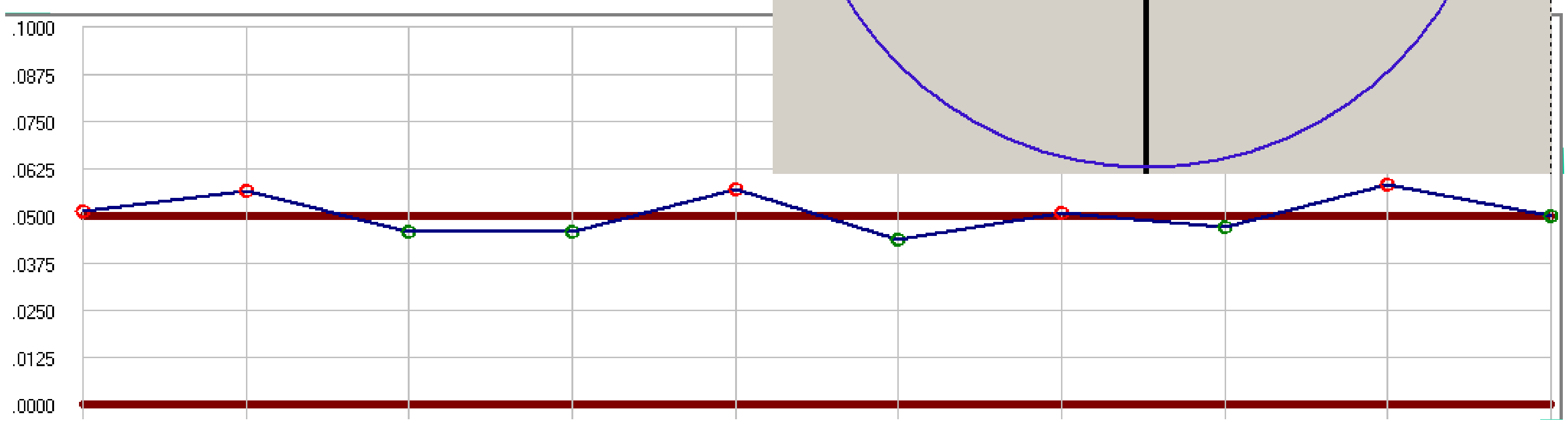




Luncheon Learn

True Position Cylinder





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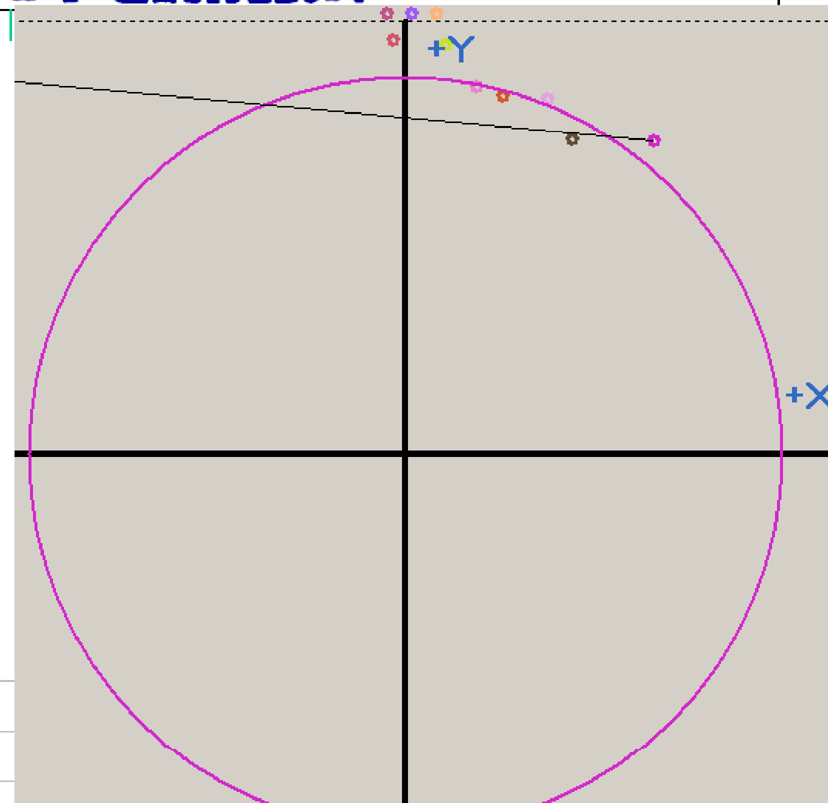
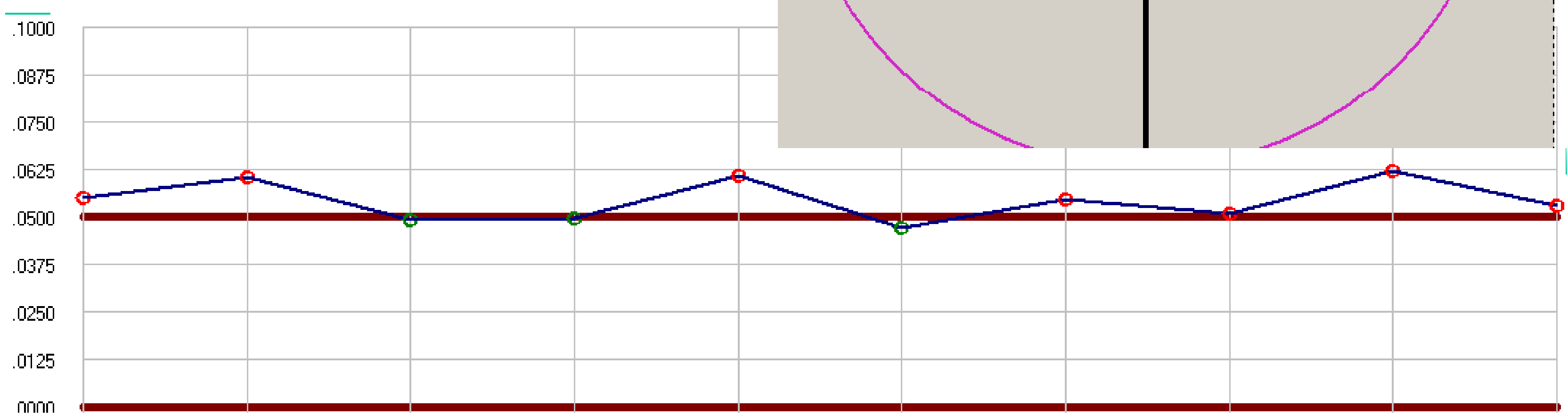
True Position Cylinder Top





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Bad repeatability.

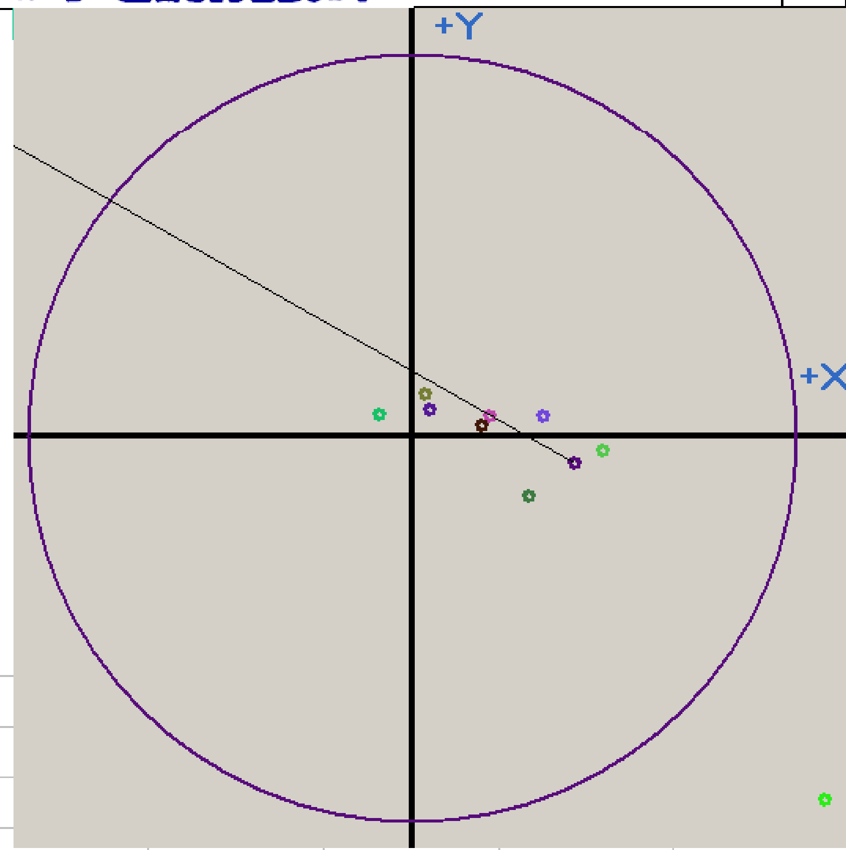
What's Going On?

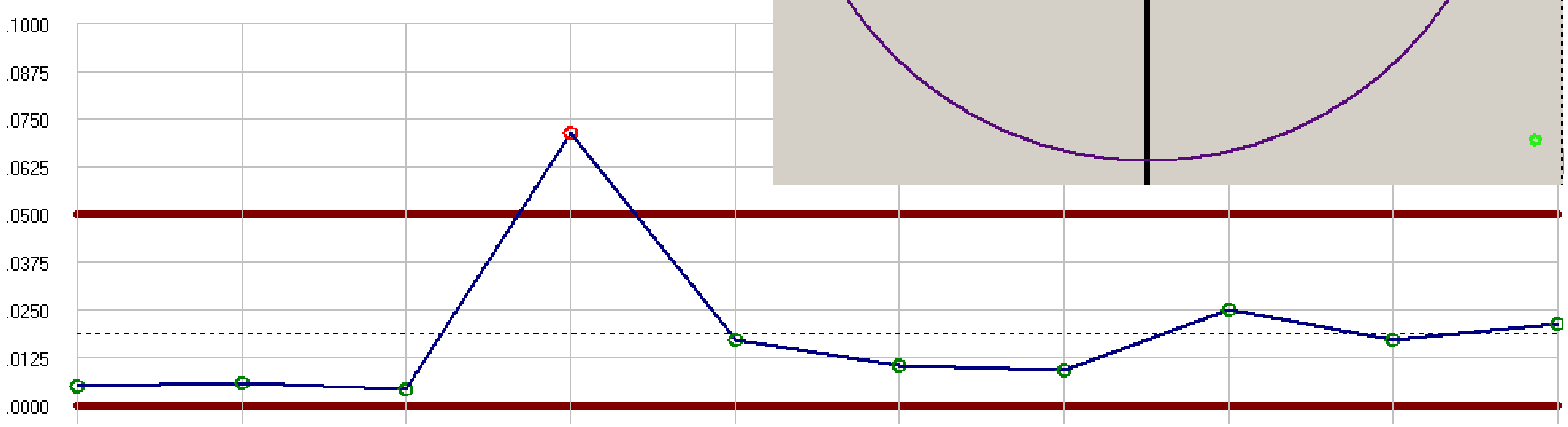
More testing!

Just looking at INTERSECTION results
Remove/Replace Plug

(Duramax, 0.050mm tol)

True Position Intersection





Same stuff.

Let's think about what's going on.

(I hate that…)

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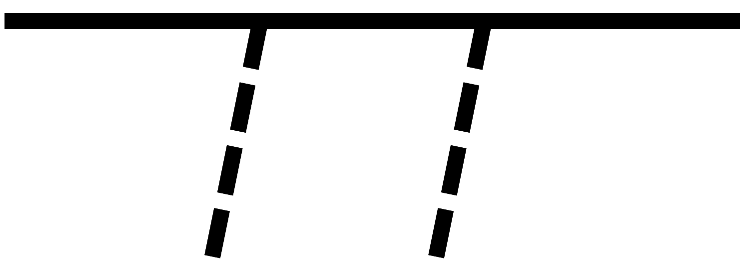

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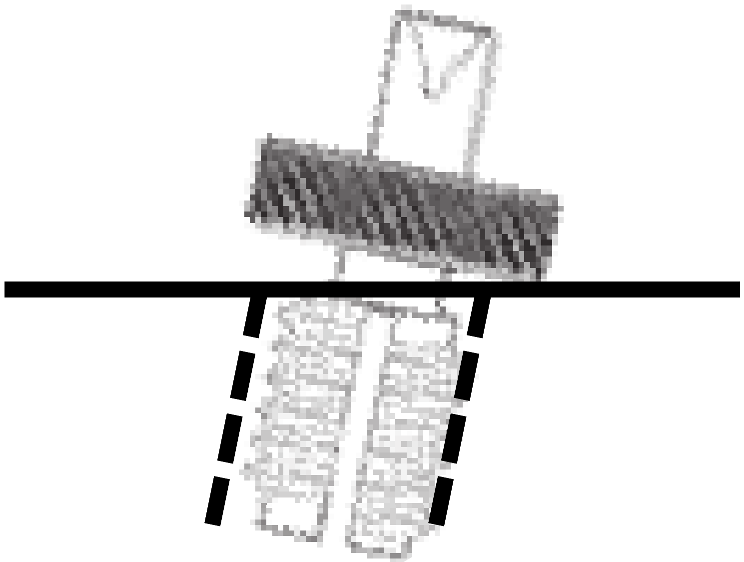
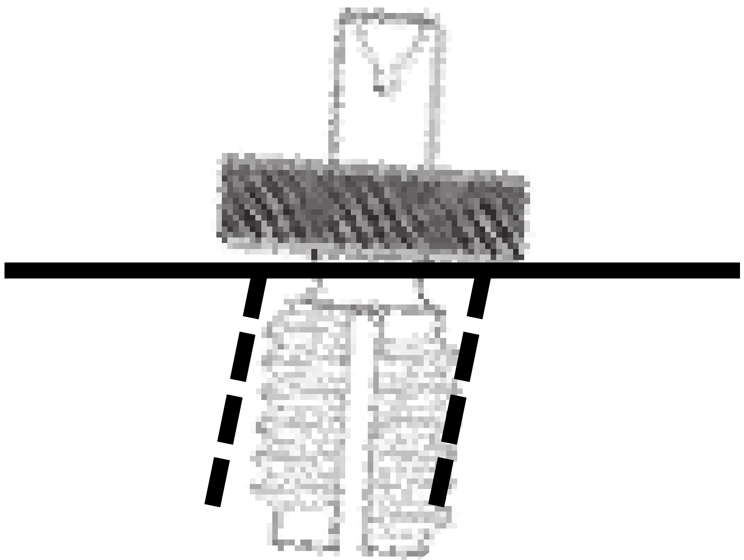
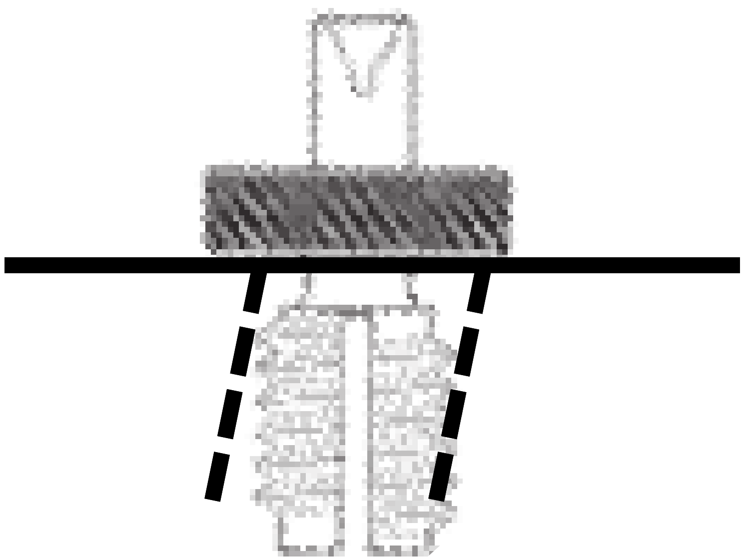
Tighten up a little…



A little more…





Ahhh…

So, based on how I tighten the plug, the center will move.

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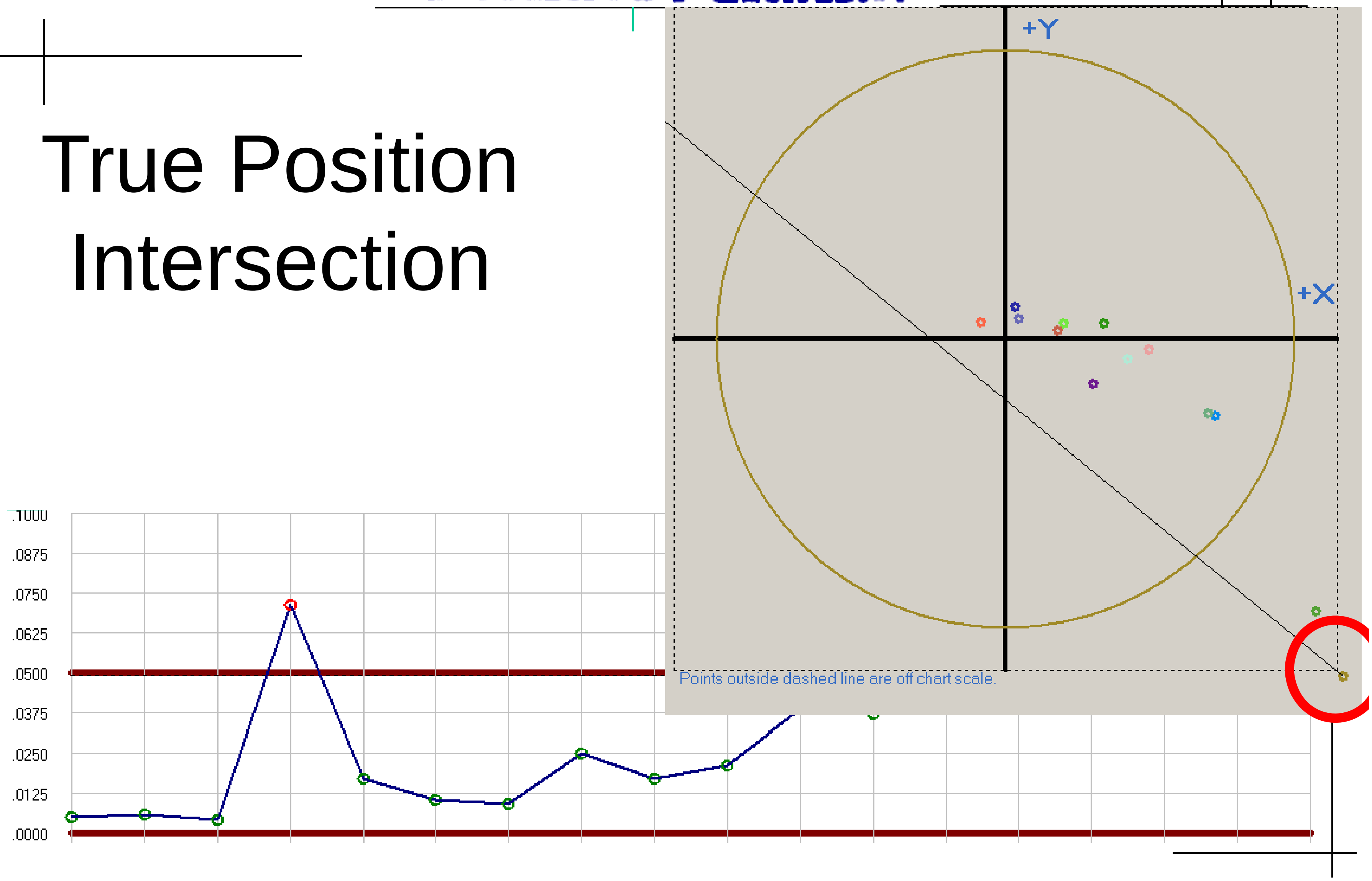
Just looking at INTERSECTION results

Remove/Replace Plug, but Don’t tighten!

(Duramax, 0.050mm tol)

True Position Intersection



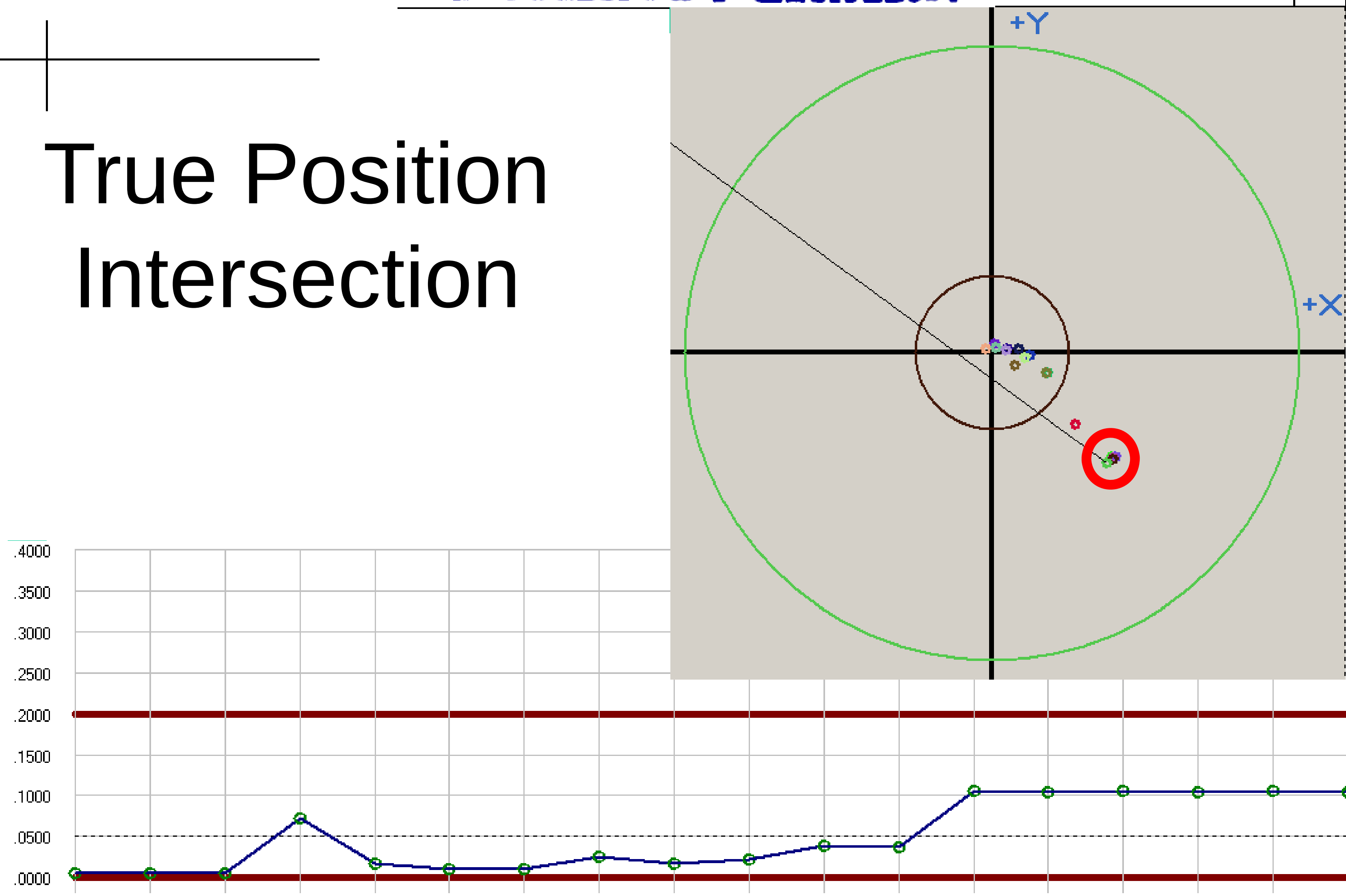
Wow!

Outside of 0.050mm tolerance!

Increase the tol to 0.200mm!

Luncheon Learn

True Position Intersection

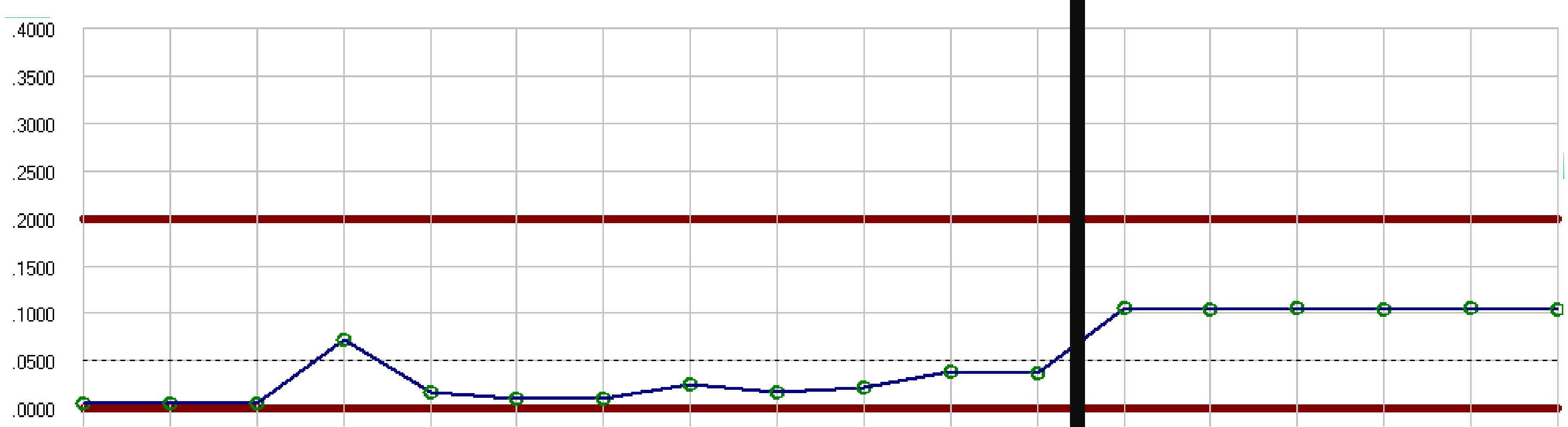


“Tight” flex plug

0.067mm repeatability

“loose” flex plug

0.002 (!) mm repeatability



We are in BUSINESS!

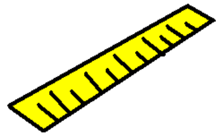
Now, back to the original question:
How do you best measure a threaded hole
(without the plug)?

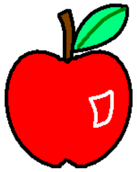
Calculating Gradient/Slope

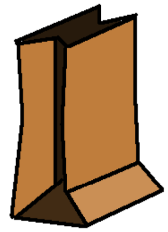
(aka lead or pitch)

3/8 – 16 UNC = 16 threads/inch
Gradient/Slope = 1/16 or 0.0625” or 1.5875mm

M10x1.5 = 1.5 mm of lead per rev
Gradient/Slope = 1.5mm or 0.0591”







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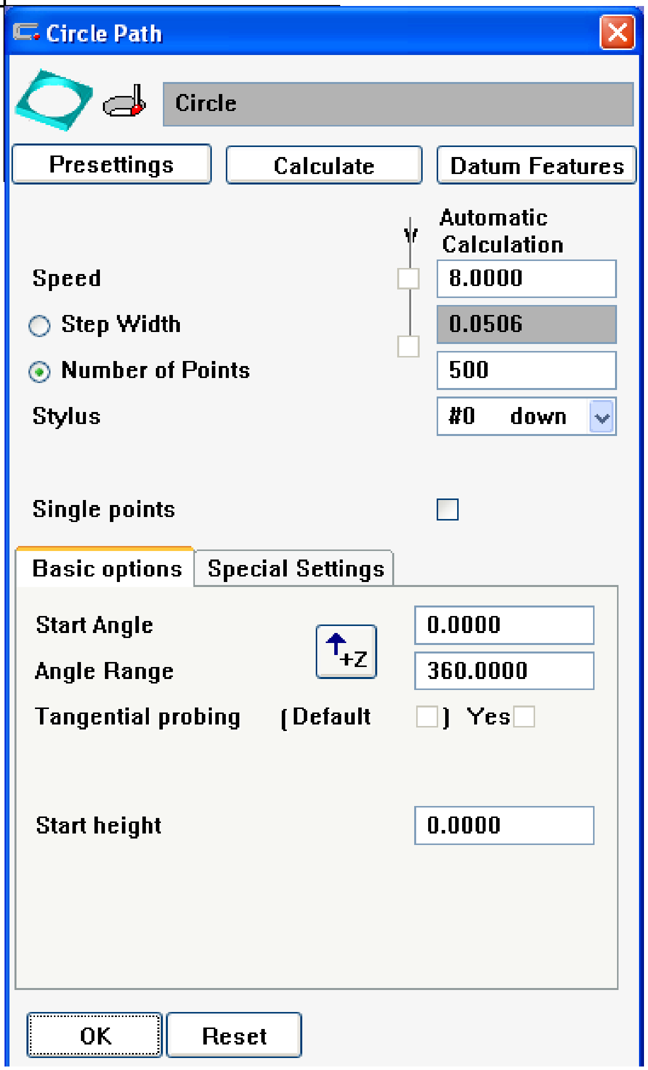
Measurement Strategy #1

A circle.

Concept: Who Cares, Close enough.


Circle Path
Circle
Presettings
Calculate
Datum Features
Automatic Calculation
Speed
8.0000
Step Width
0.0506
Number of Points
500
Stylus
#0 down
Single points
Basic options
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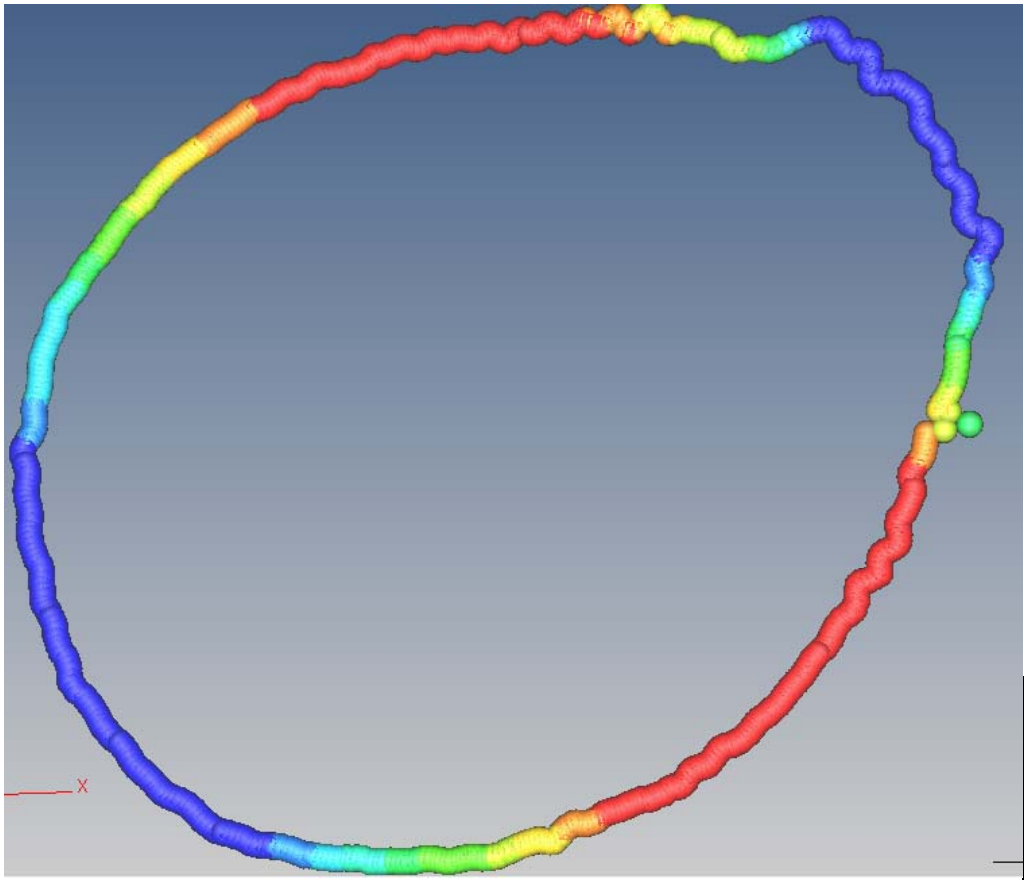
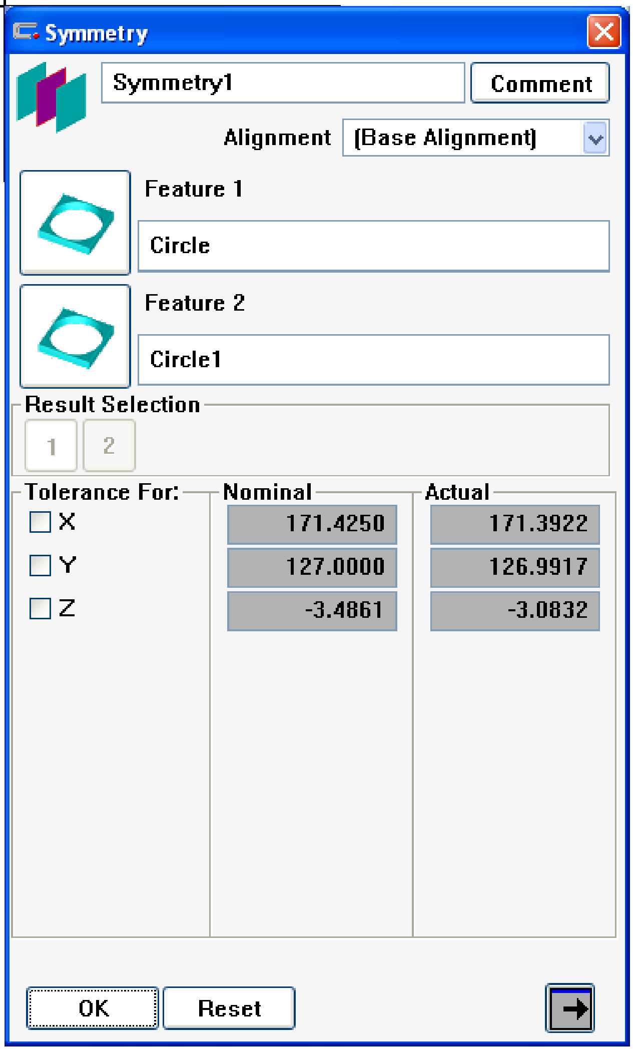
+Z
Tangential probing
(Default) Yes
Start height
0.0000
OK
Reset

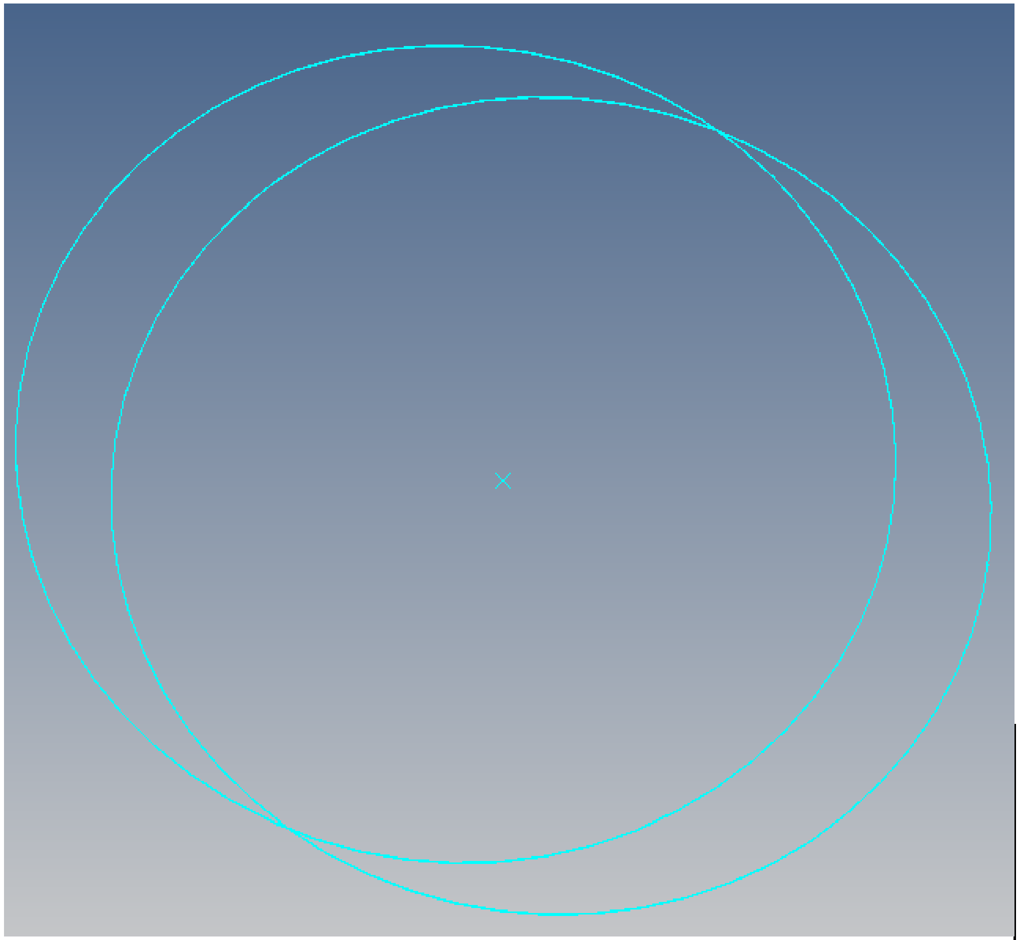

X

Measurement Strategy #2

Symmetry between Two Circles, ½ Pitch apart

Concept: Average of shifted circle centers will be real center


Symmetry
Symmetry1
Comment
Alignment
(Base Alignment)
Feature 1
Circle
Feature 2
Circle1
Result Selection
1
2
Tolerance For:
X
Y
Z
Nominal
171.4250
127.0000
-3.4861
Actual
171.3922
126.9917
-3.0832
OK
Reset



Measurement Strategy #3

One circle, Two Circle paths, ½ Pitch apart

Concept: Same theory as Symmetry, but no construction step

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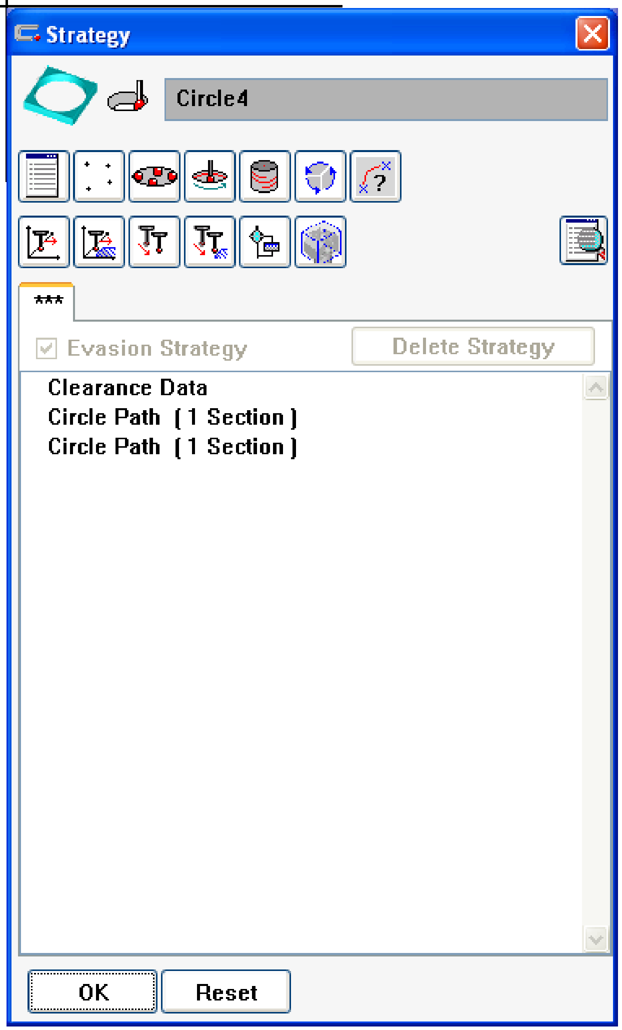
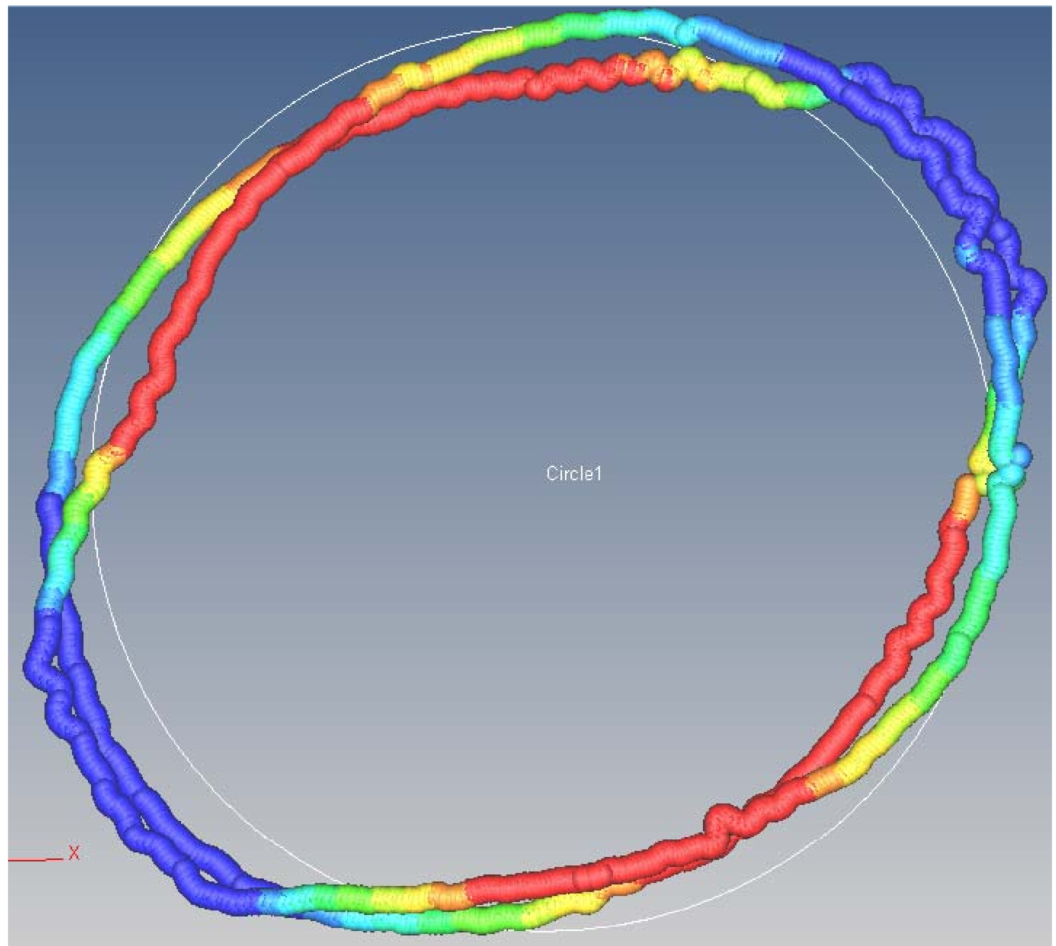
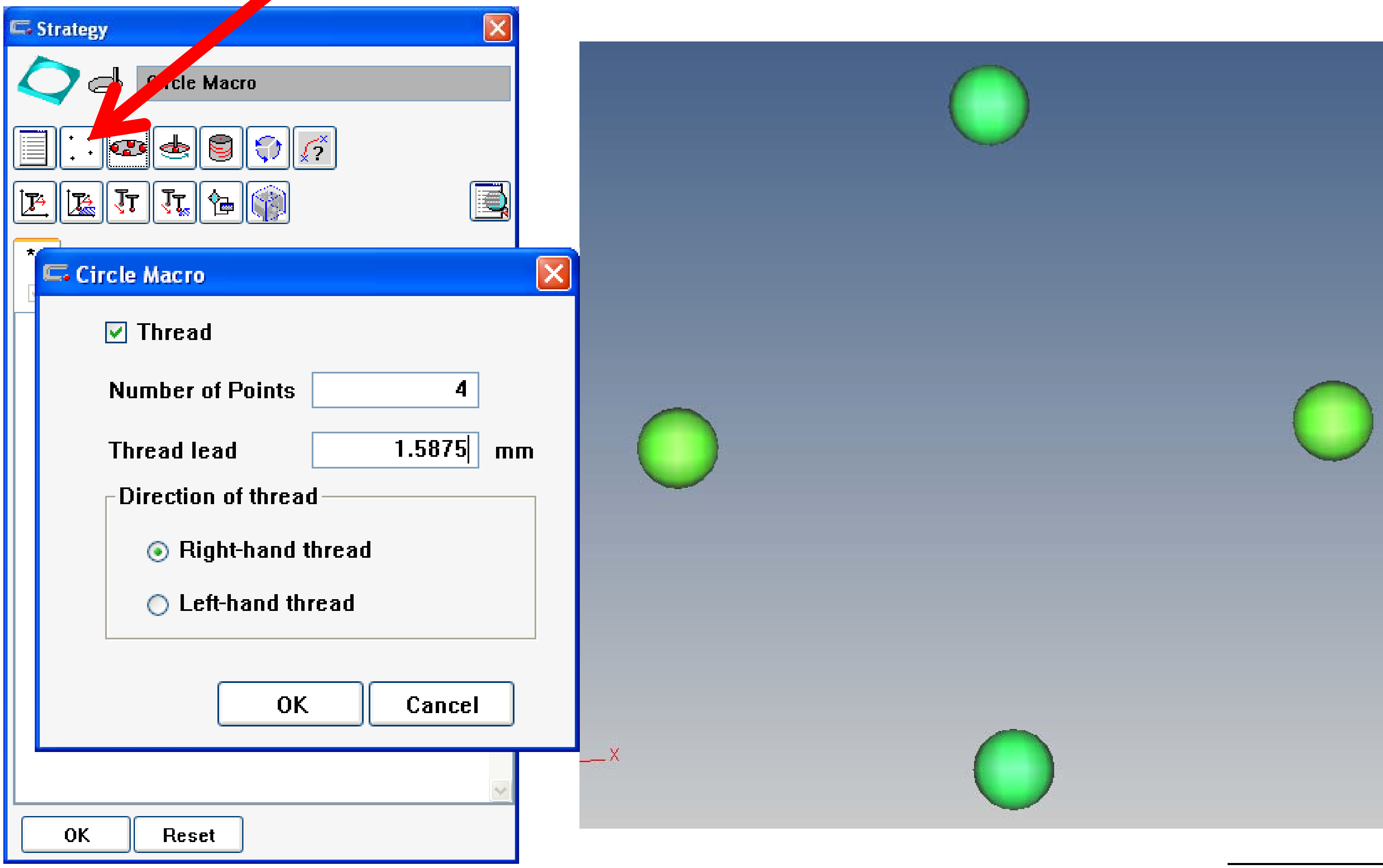




Measurement Strategy #4

Calypso's Circle Macro

Concept: The Thread routine in the software MUST be good.


Strategy
Circle Macro
Circle Macro
Thread
Number of Points 4
Thread lead 1.5875 mm
Direction of thread
Right-hand thread
Left-hand thread
OK
Cancel
OK
Reset
X

Measurement Strategy #5

circle with helix path on pitch

Concept: Center will be good, Who cares where it is measured, as long as it follows thread pitch.

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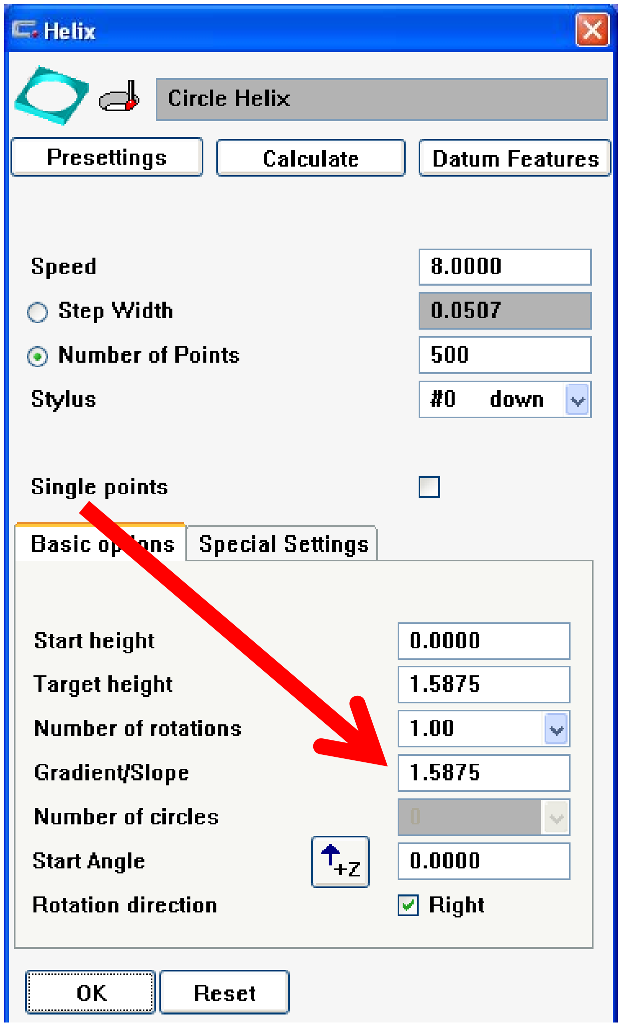

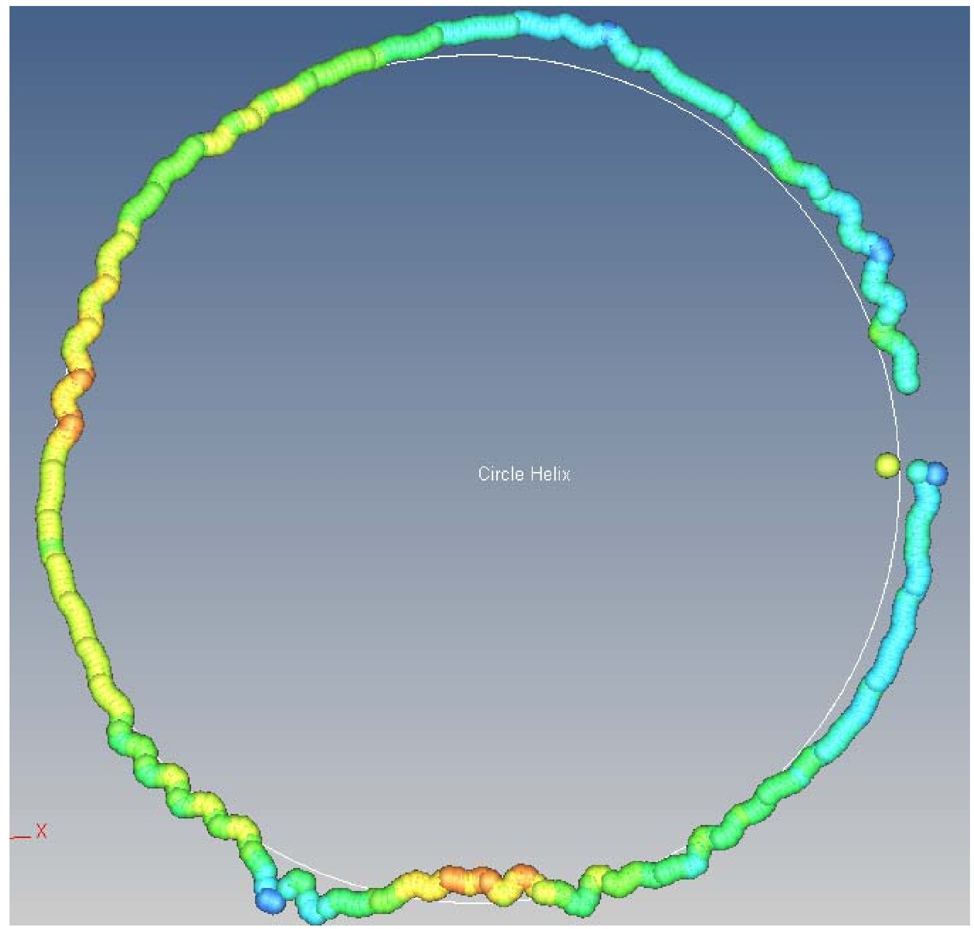

Measurement Strategy #6

Cylinder with 3 pitch helix revolutions

Concept: Measuring a cylinder to get an axis is better than just a circle.

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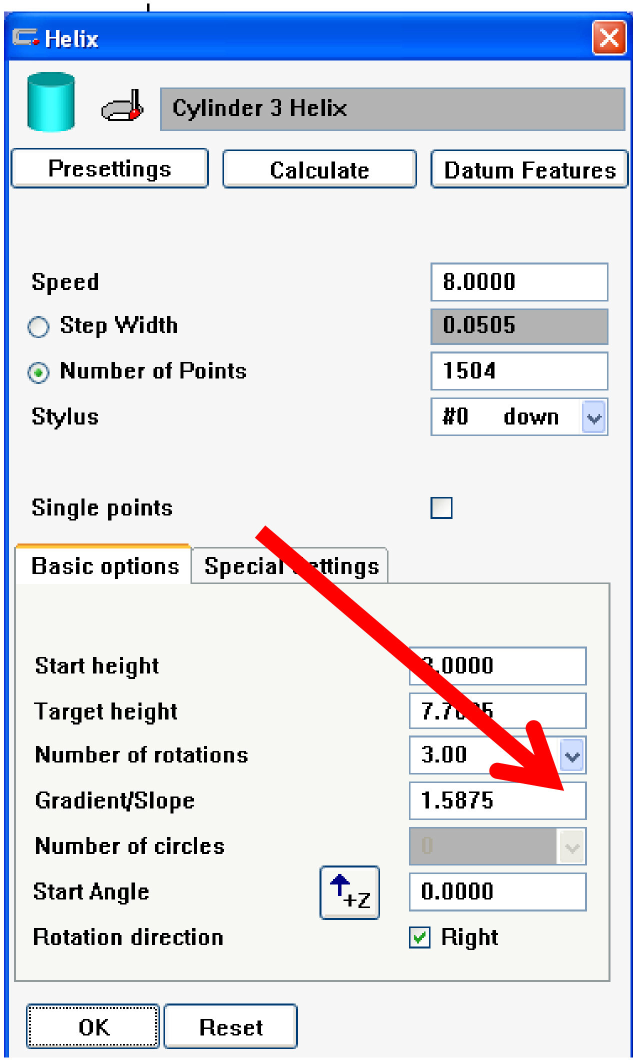

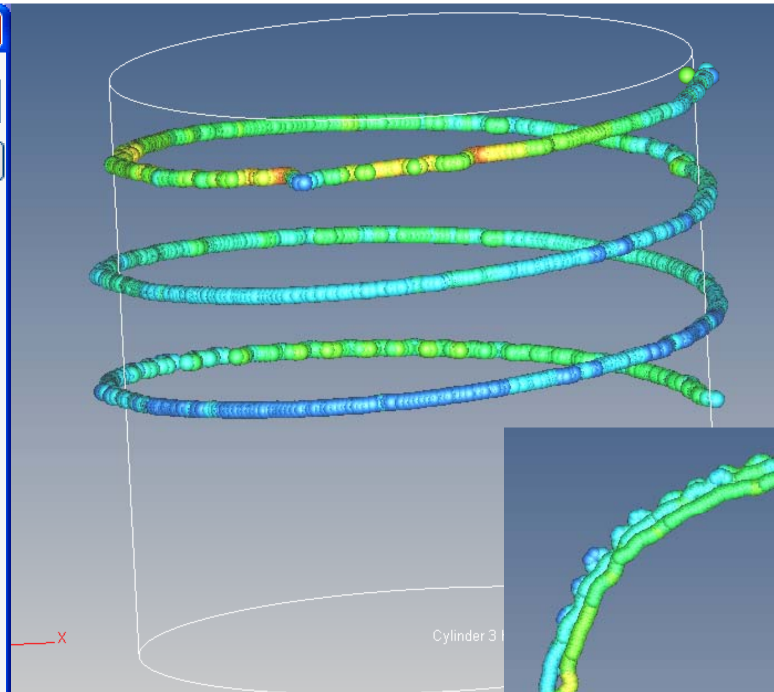

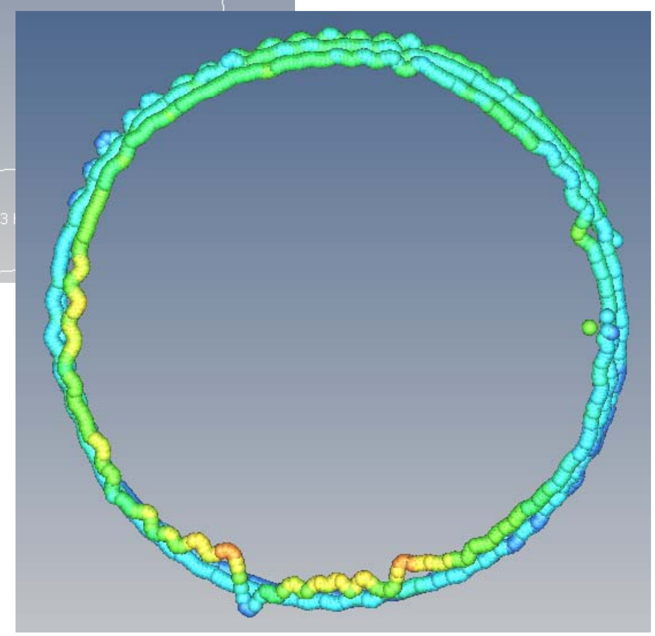

Measurement Strategy #7

Cylinder with 5 pitch helix revolutions

Concept: 5 revs must be better then 3!

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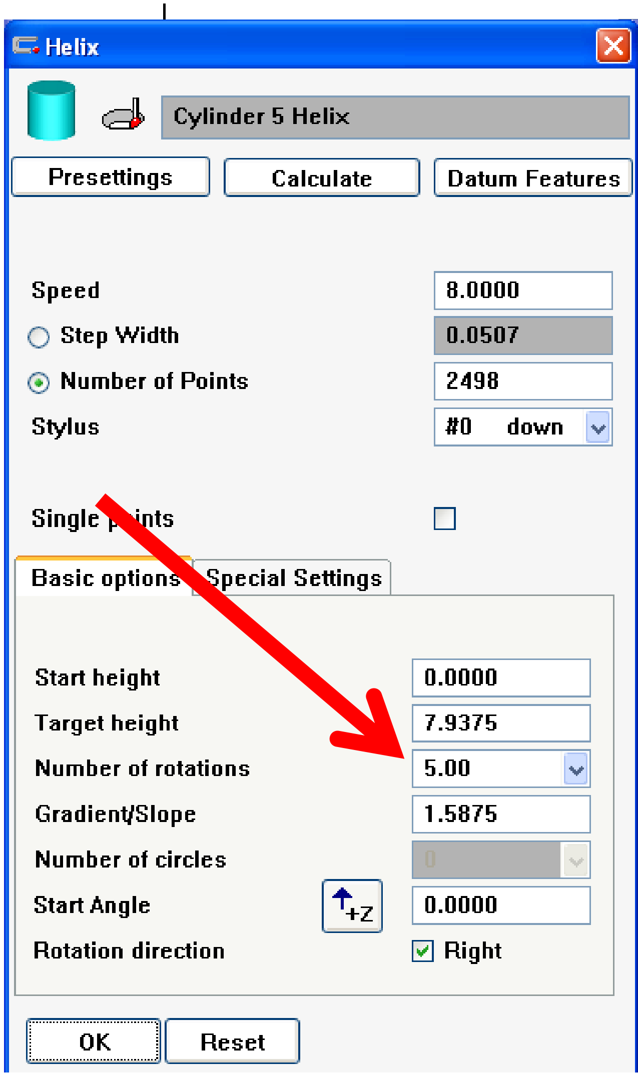

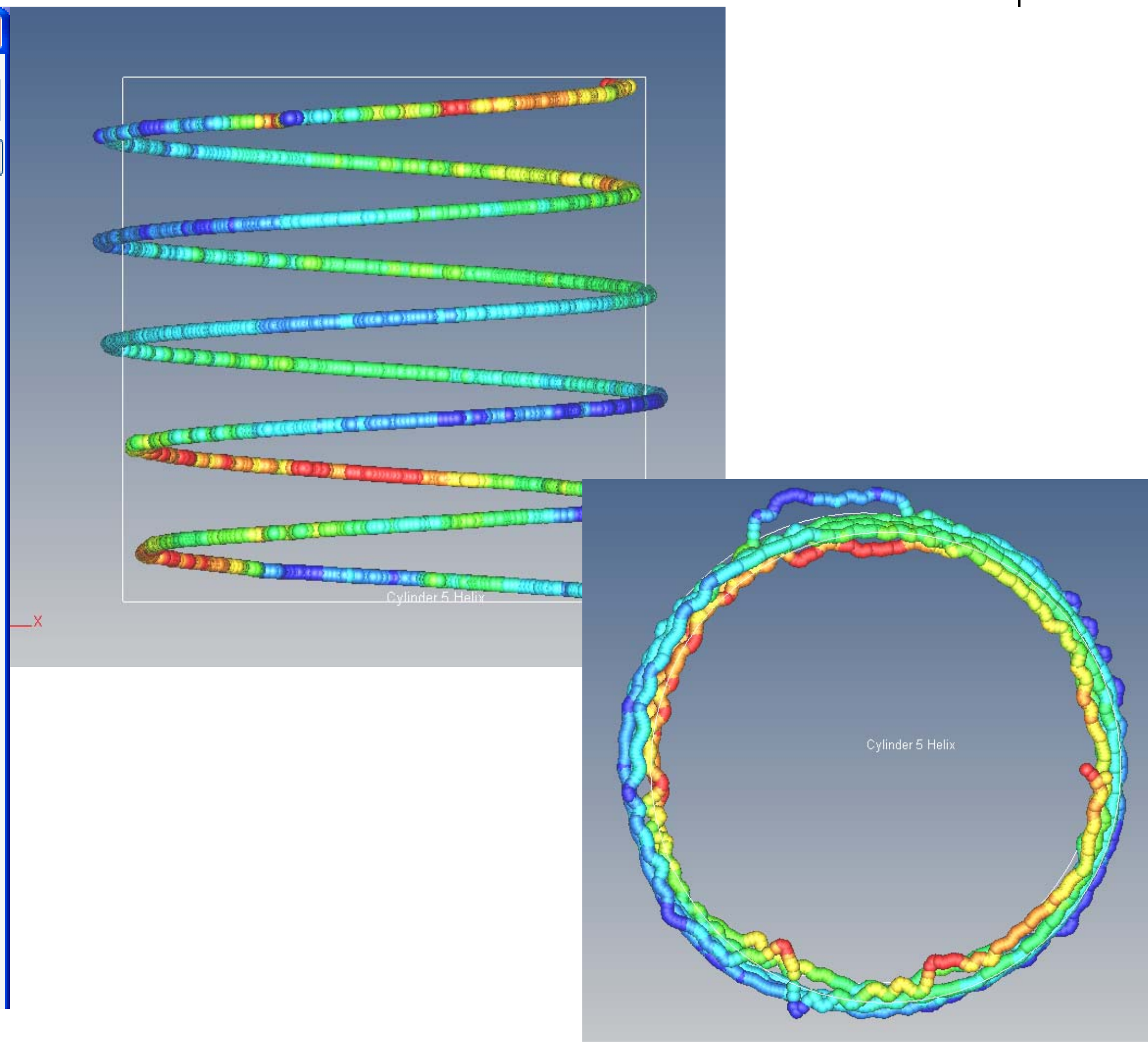

Measurement Strategy #8

Cylinder with double-pitch helix.

Concept: scan a lot on the thread – it will average out to the true center.

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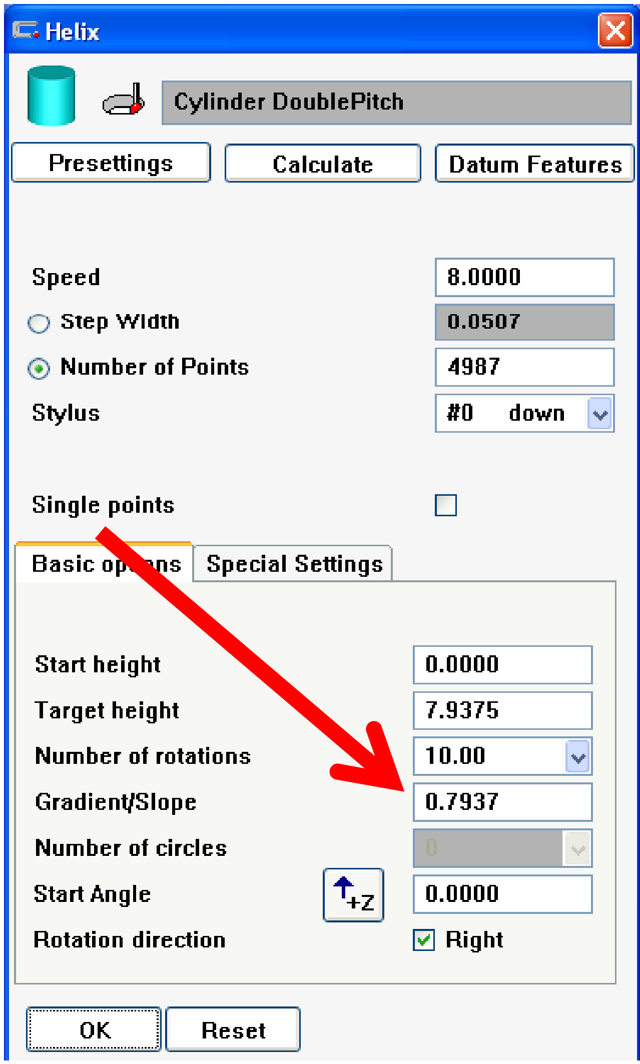

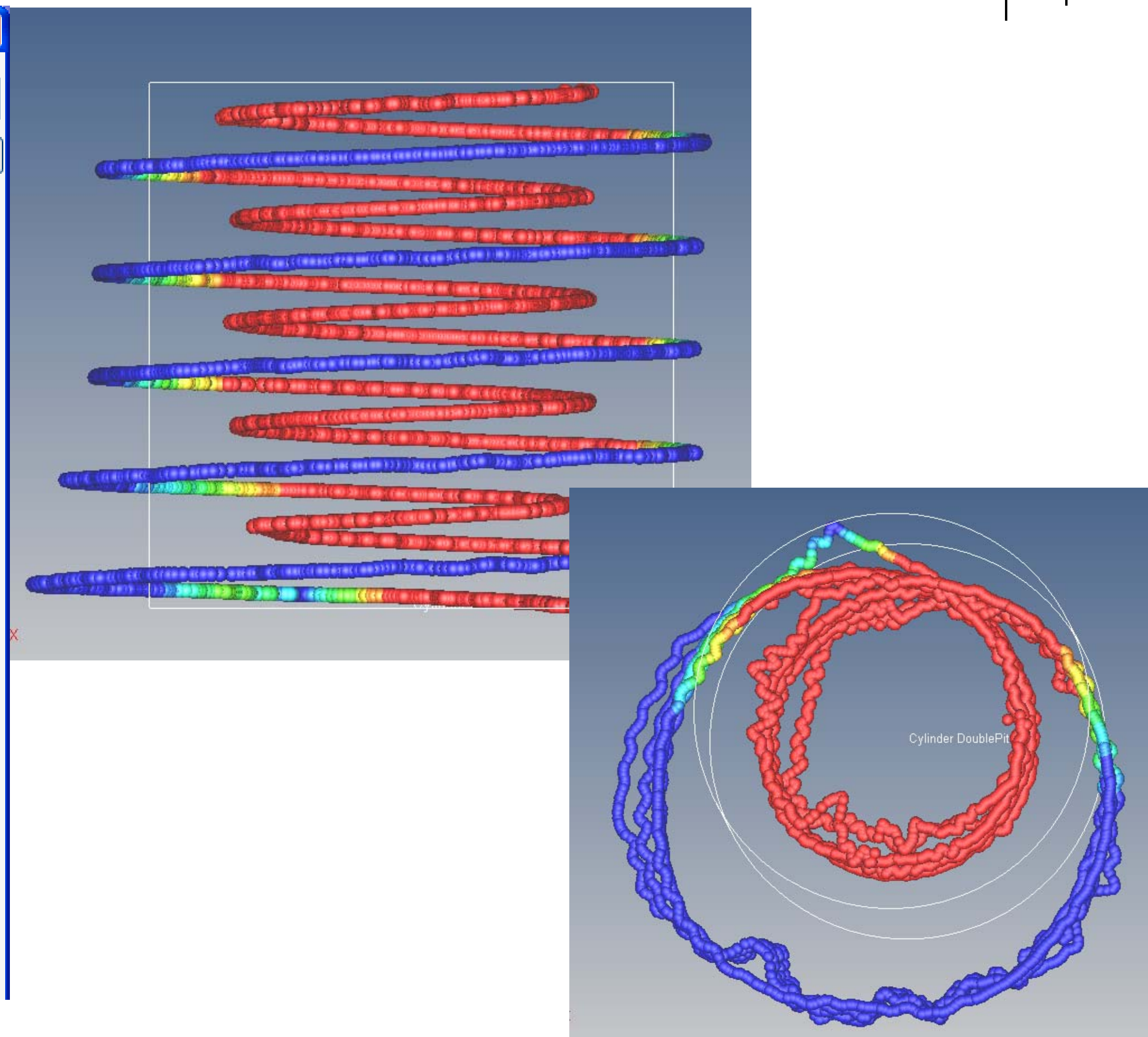

Measurement Strategy #9

Cylinder with Linear Paths.

Concept: scan a lot on the thread – it will average out to the true center.

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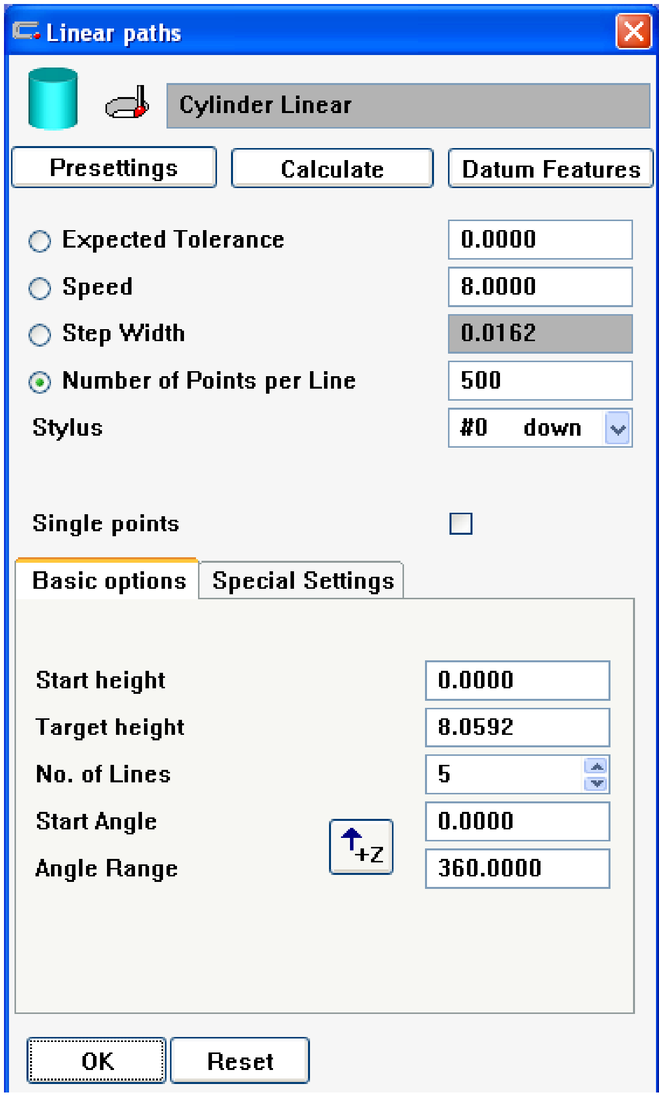

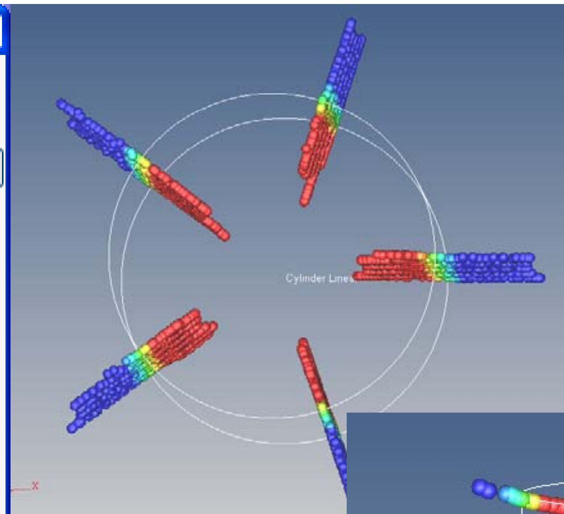

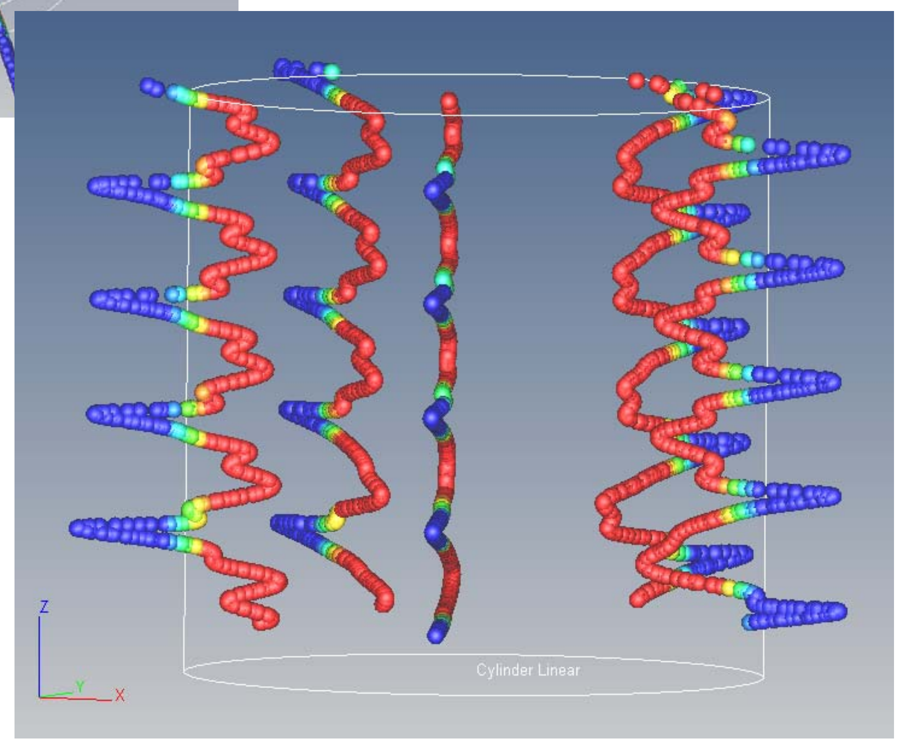

Measurement Strategy #10

Cylinder with reverse Helix.

Concept: scan a lot on the thread – it will average out to the true center.

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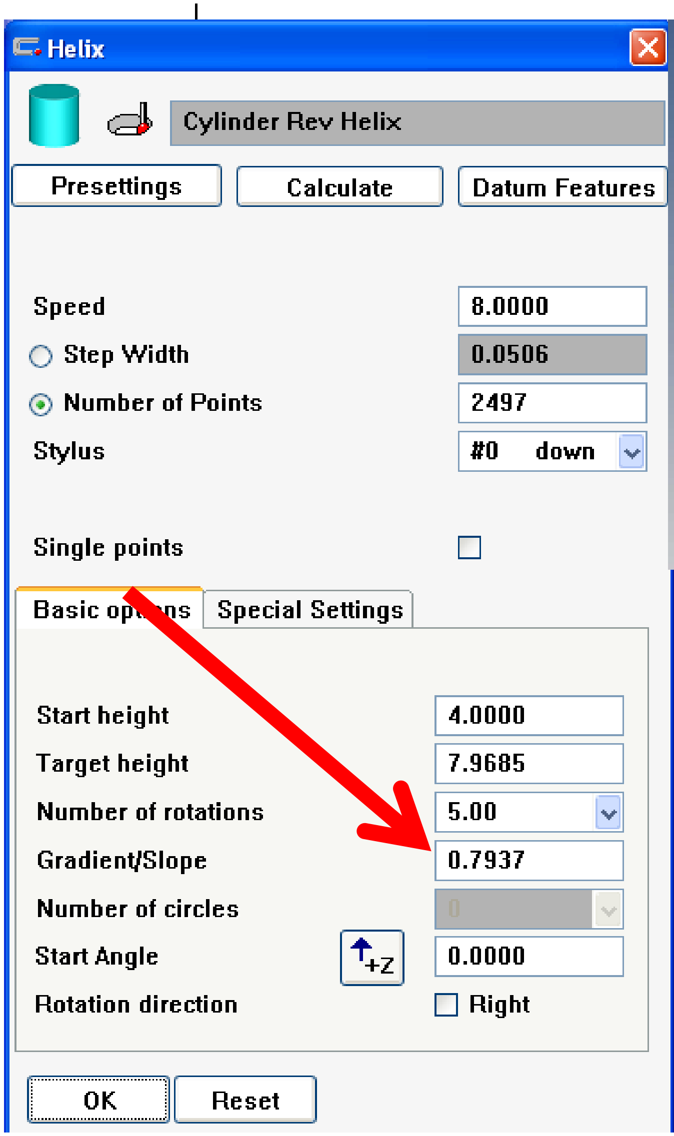

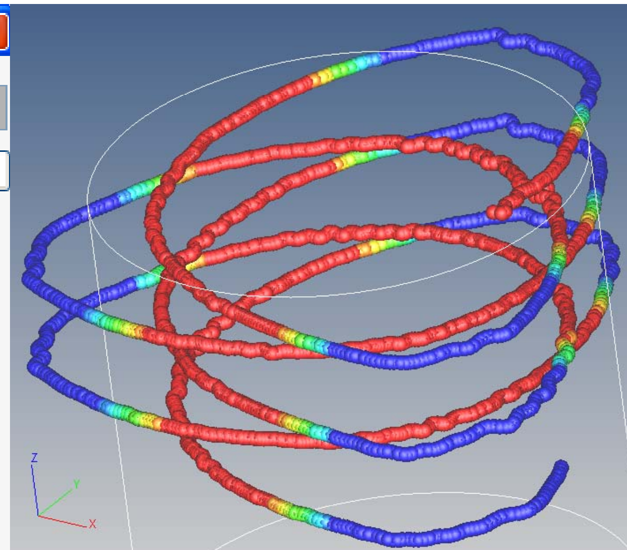

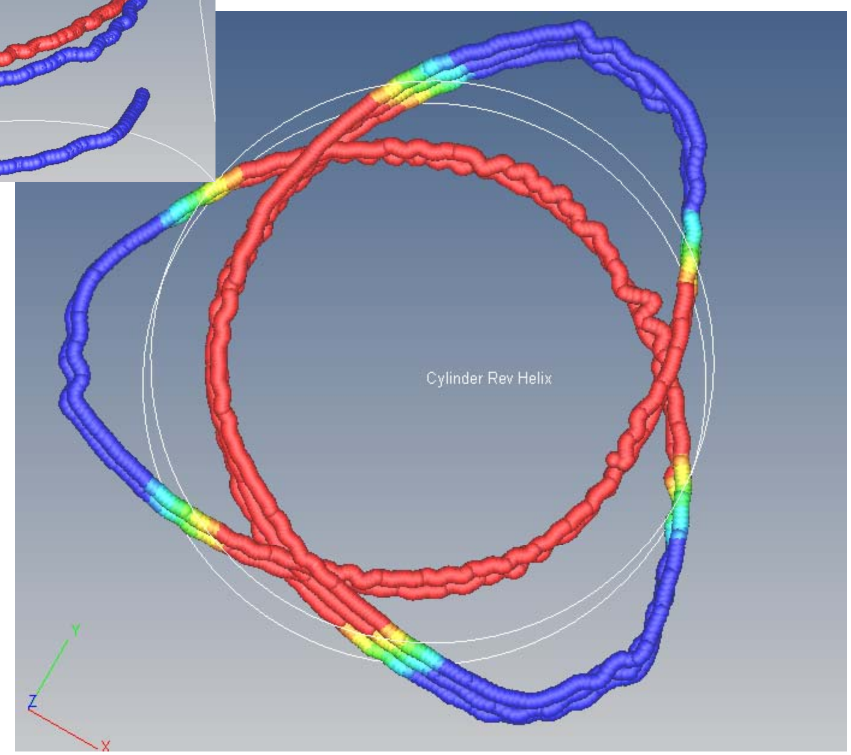

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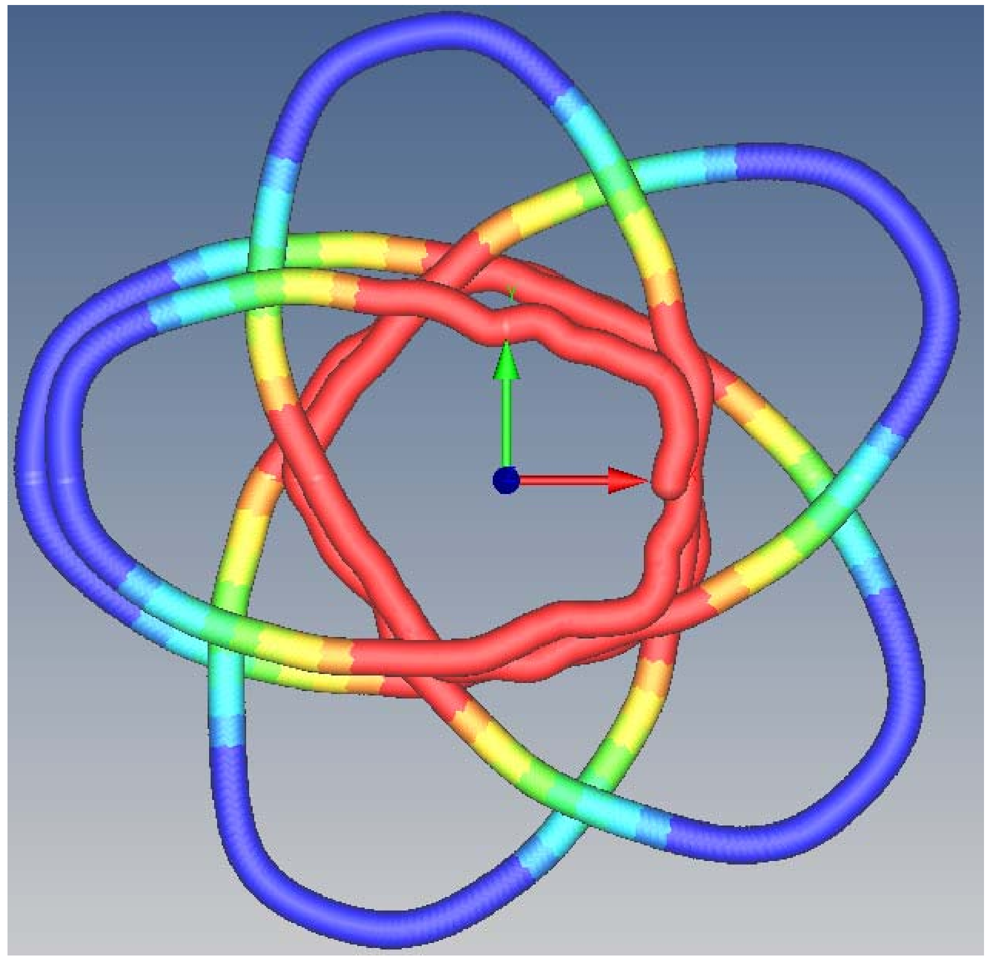
¼ Pitch Helix Gradient



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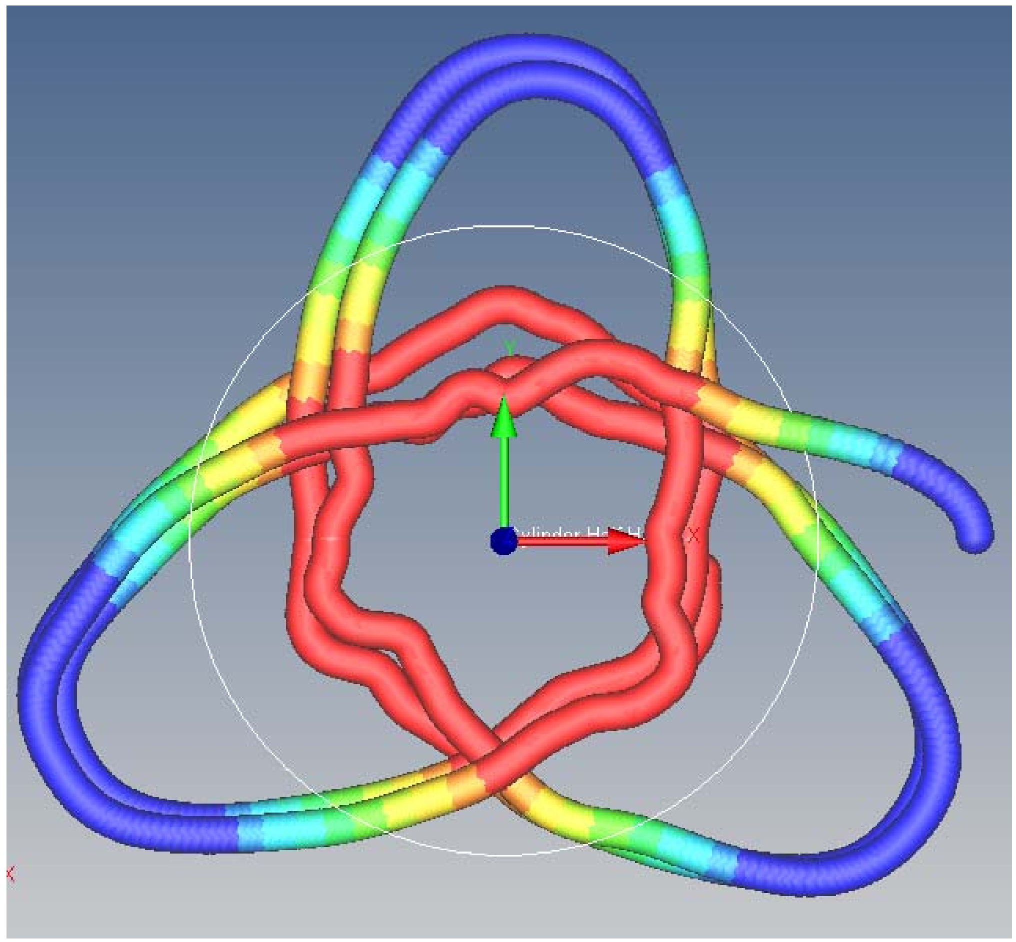
½ Pitch Helix Gradient



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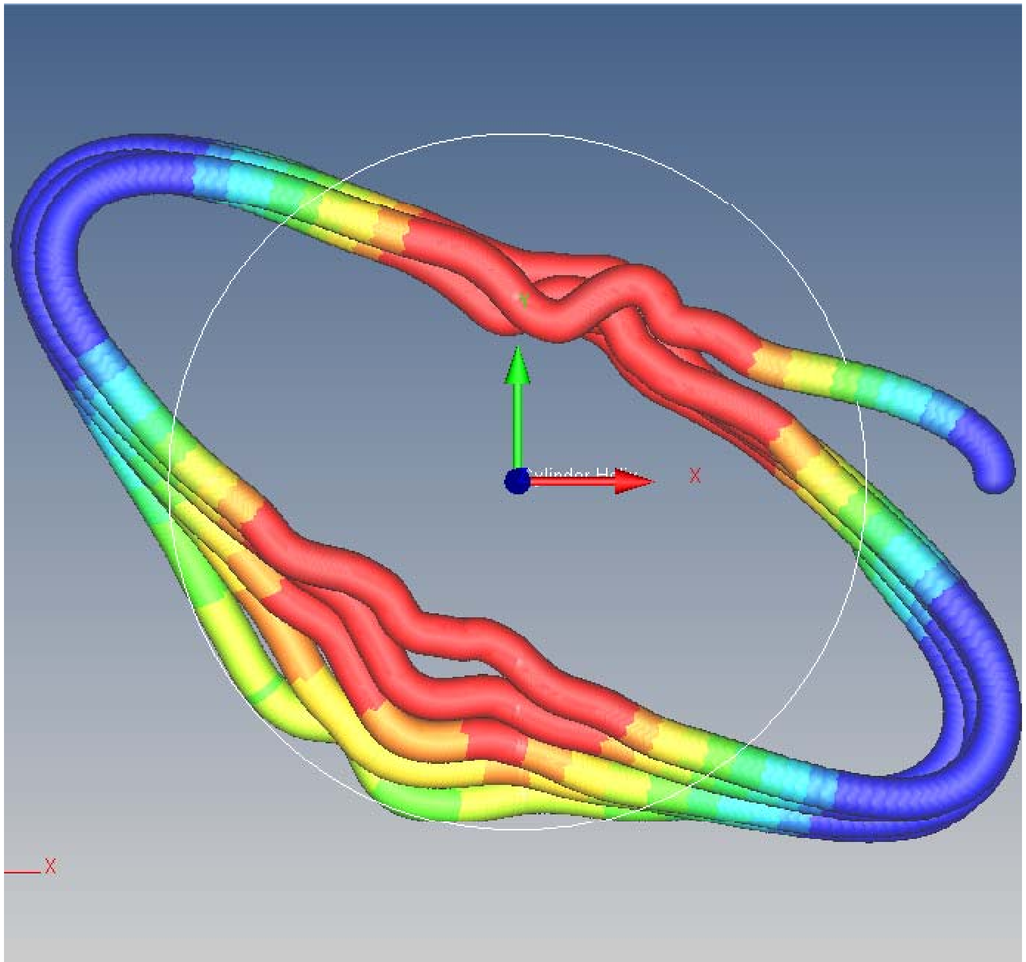
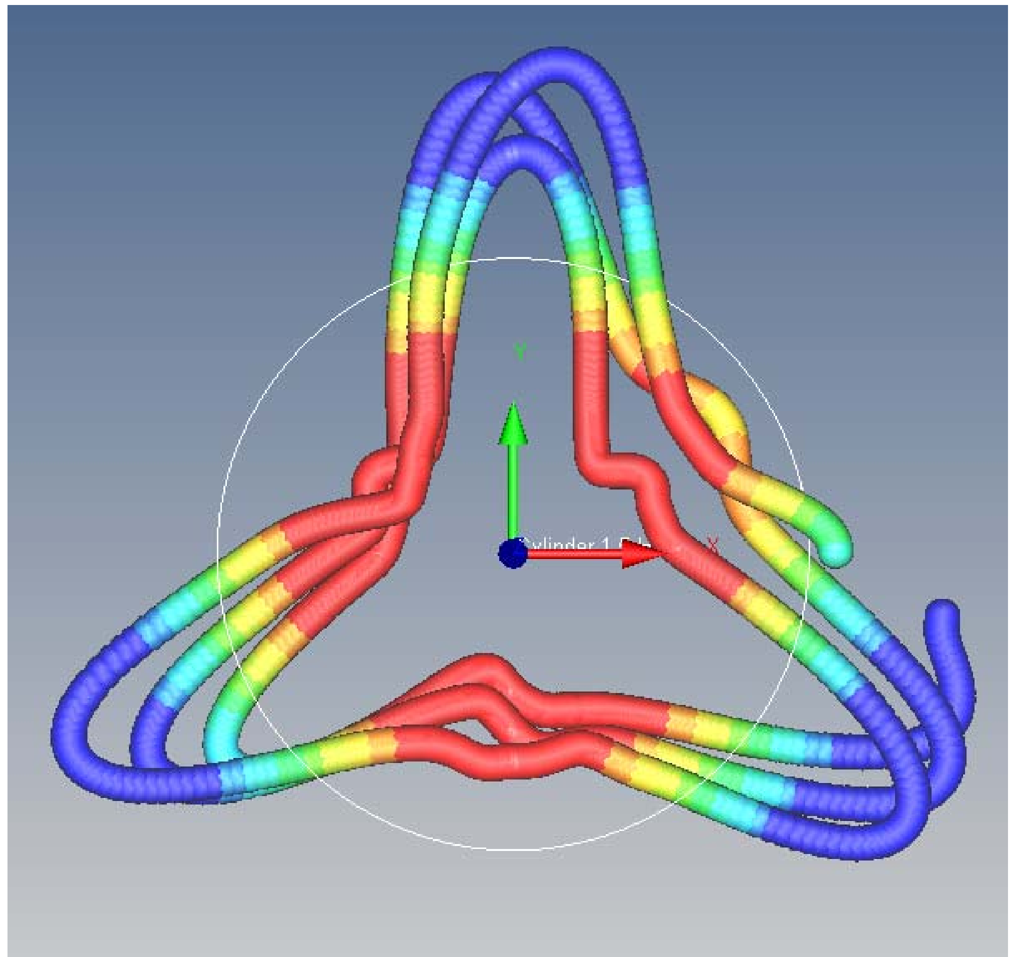
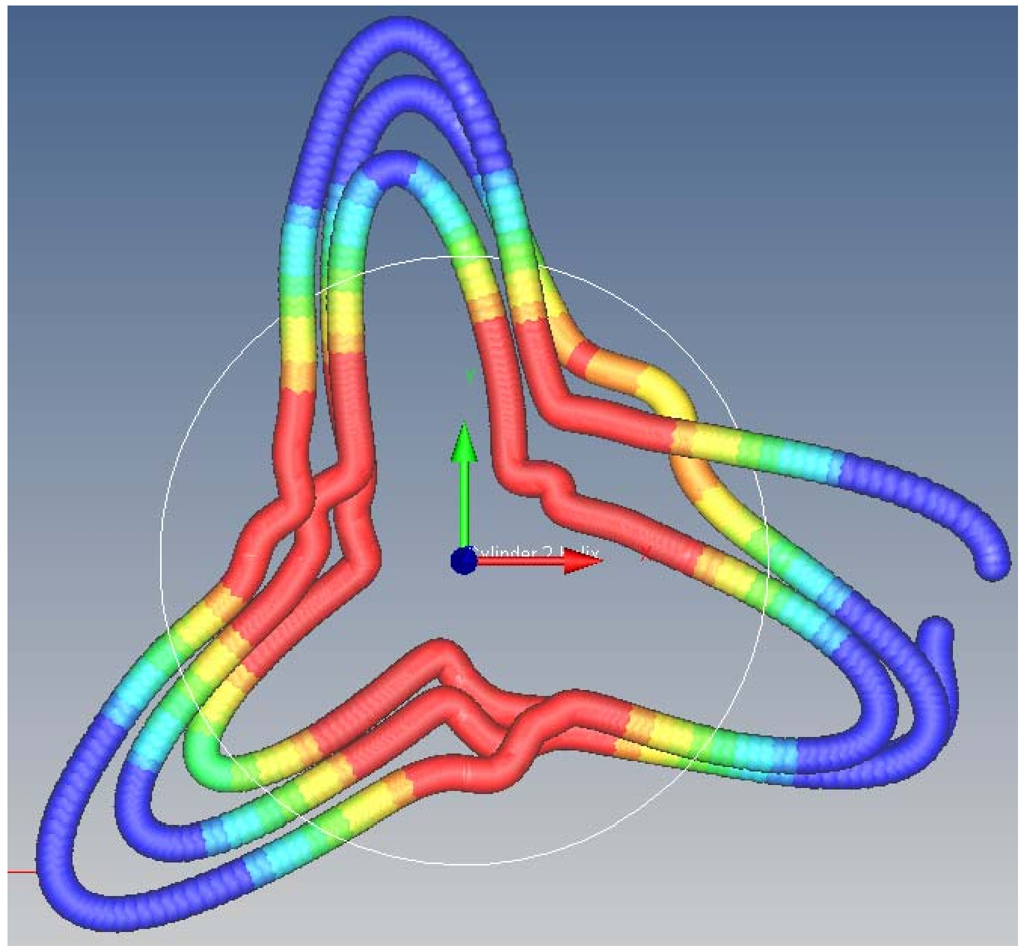
1 Pitch Helix Gradient



1 ½ x Pitch
Helix Gradient



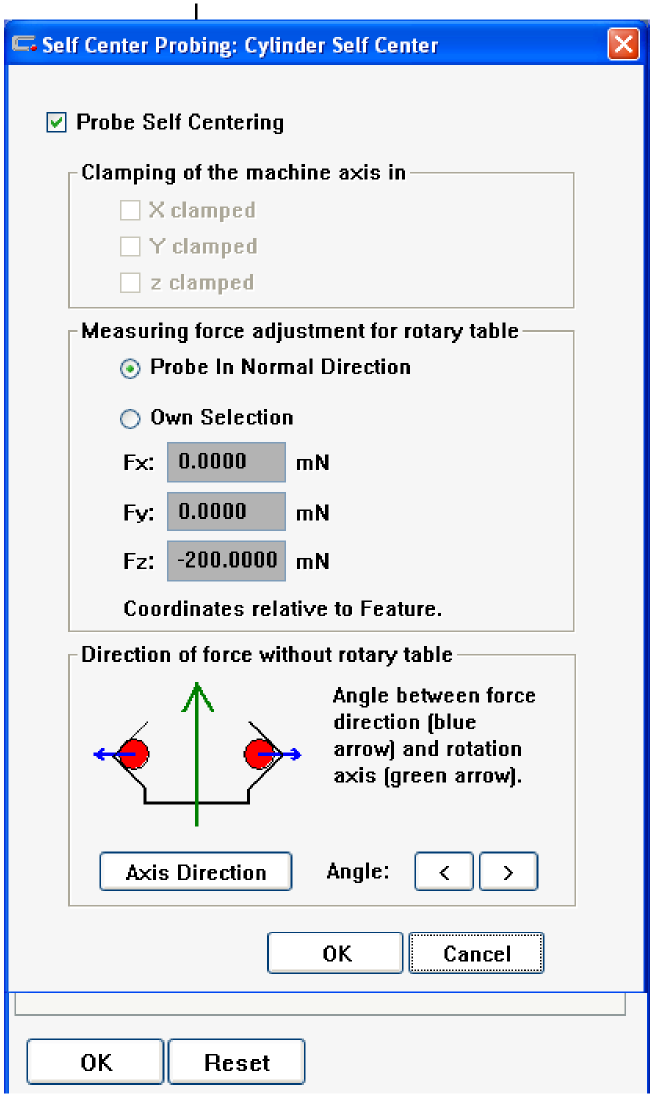
2 x Pitch Helix Gradient

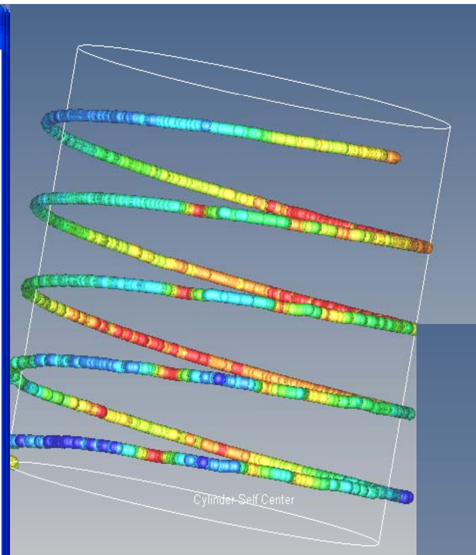


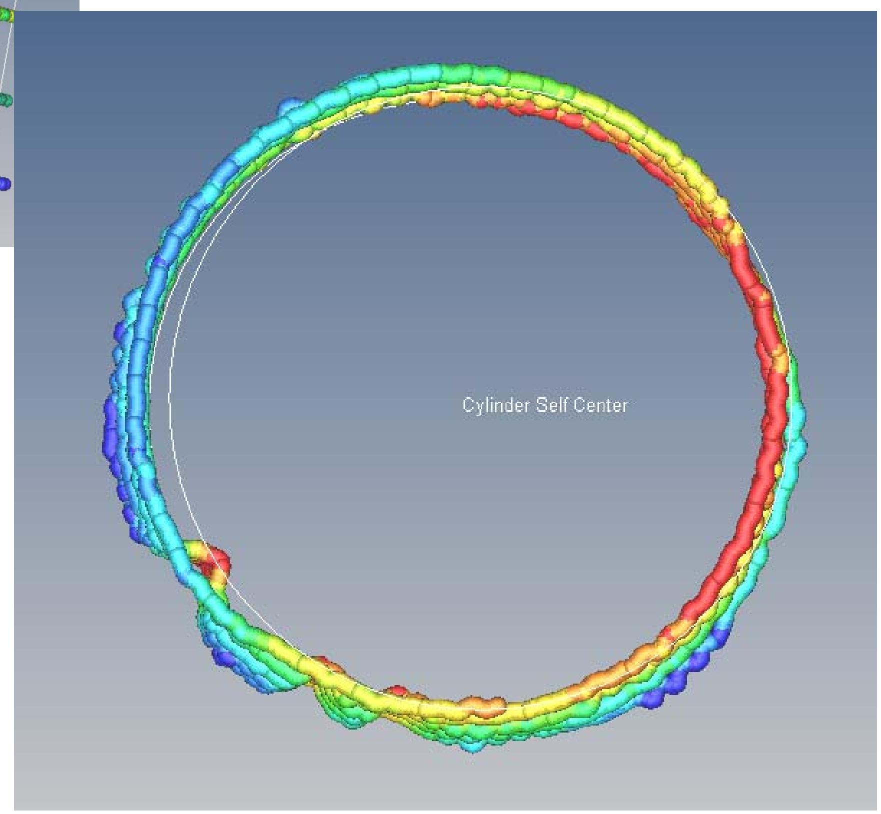
Measurement Strategy #11

Cylinder with self-center Helix.

Concept: stylus will push into the tread, close to pitch diameter.


Self Center Probing: Cylinder Self Center
Probe Self Centering
Clamping of the machine axis in
X clamped
Y clamped
z clamped
Measuring force adjustment for rotary table
Probe In Normal Direction
Own Selection
Fx: 0.0000 mN
Fy: 0.0000 mN
Fz: -200.0000 mN
Coordinates relative to Feature.
Direction of force without rotary table
Angle between force direction (blue arrow) and rotation axis (green arrow).
Axis Direction
Angle: < >
OK
Cancel
OK
Reset


Cylinder Self Center


Cylinder Self Center

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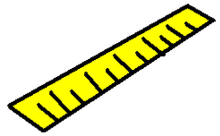

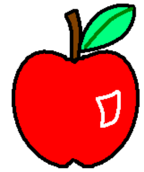

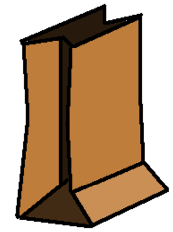

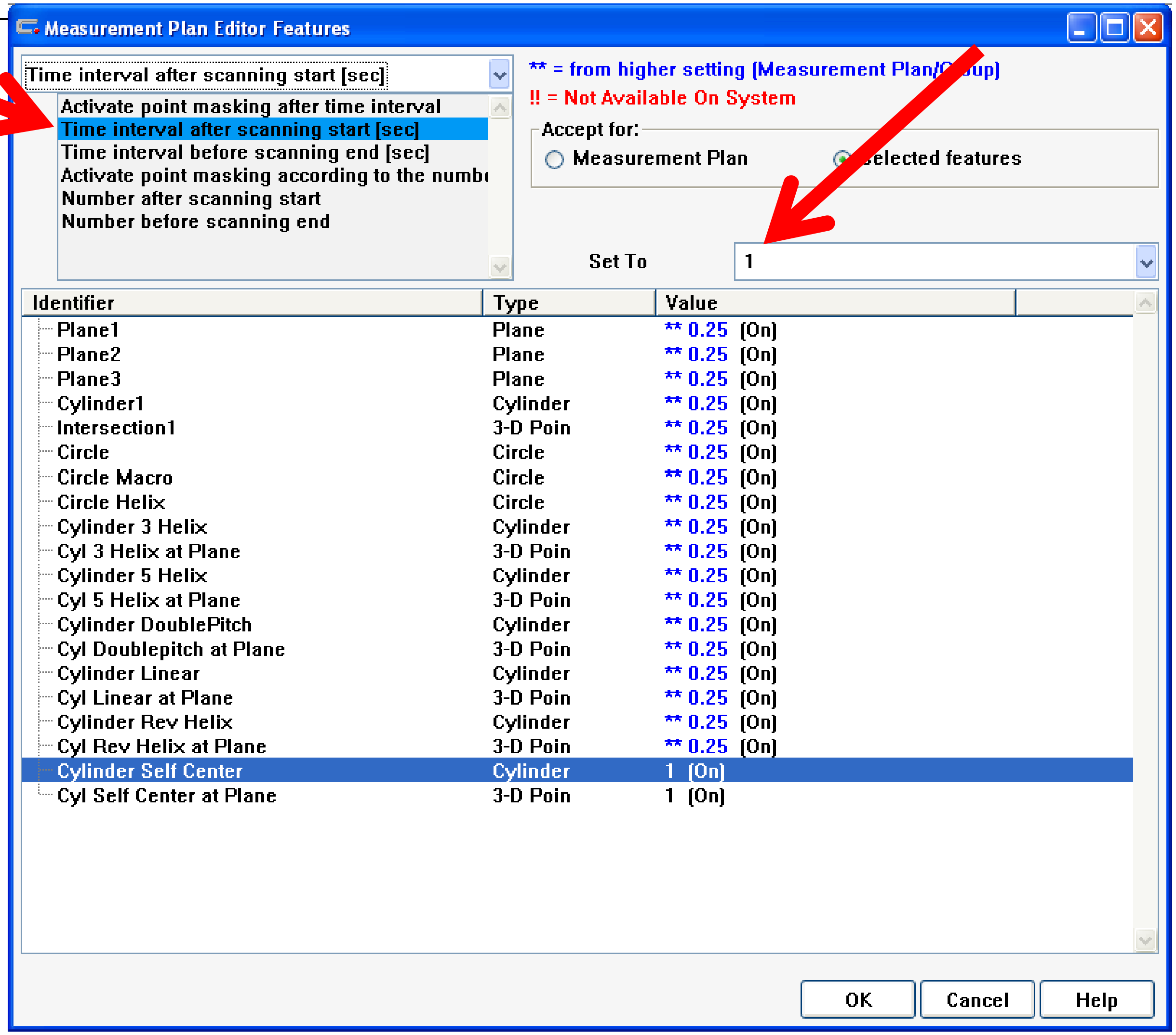

More testing!

remove/replace plug.
5 runs, 5mm stylus
5 runs, 3mm stylus

Plug Average is nominal.
Try 3 different parts.

(Accura, 0.200mm tol)

Part 1:

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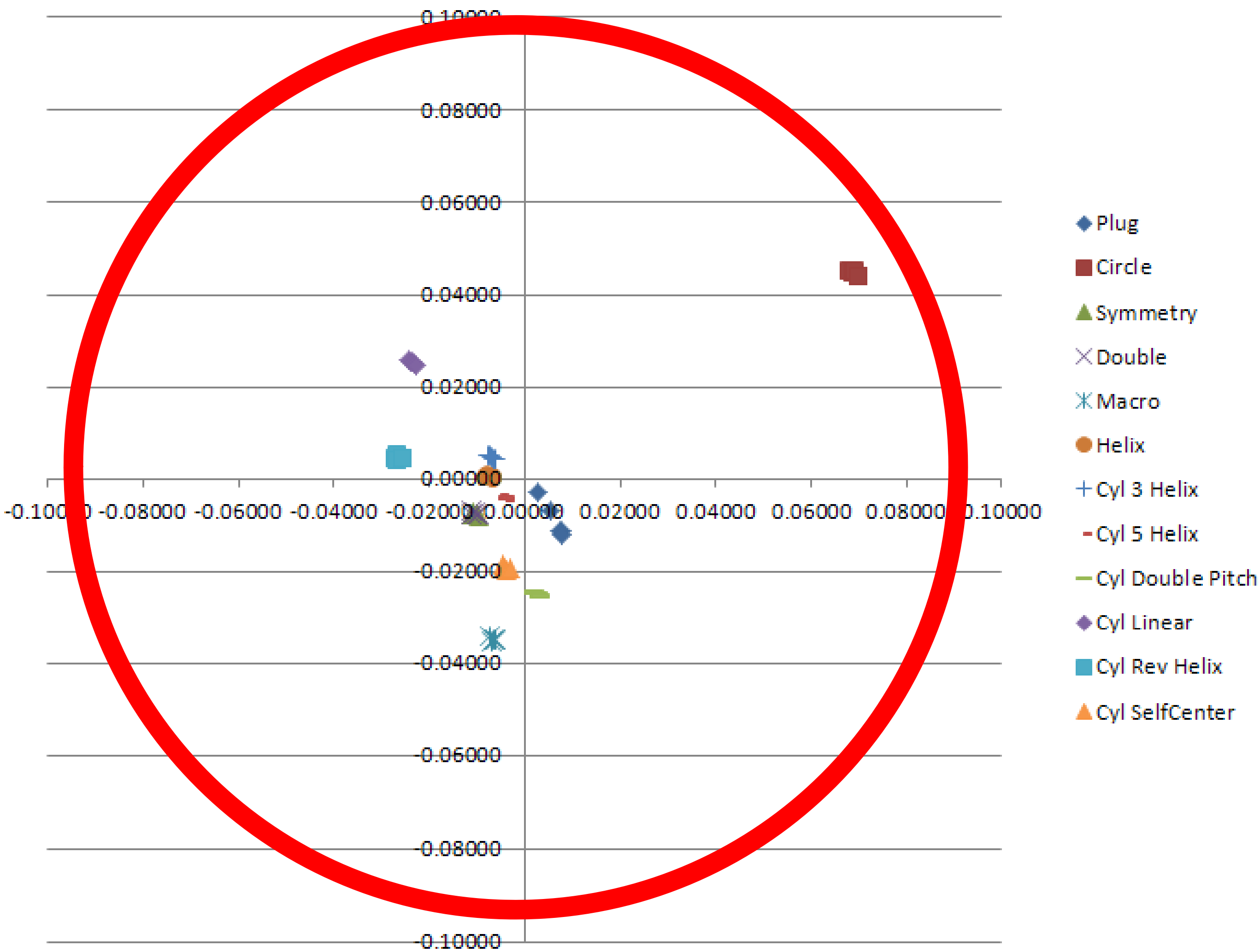
3mm stylus



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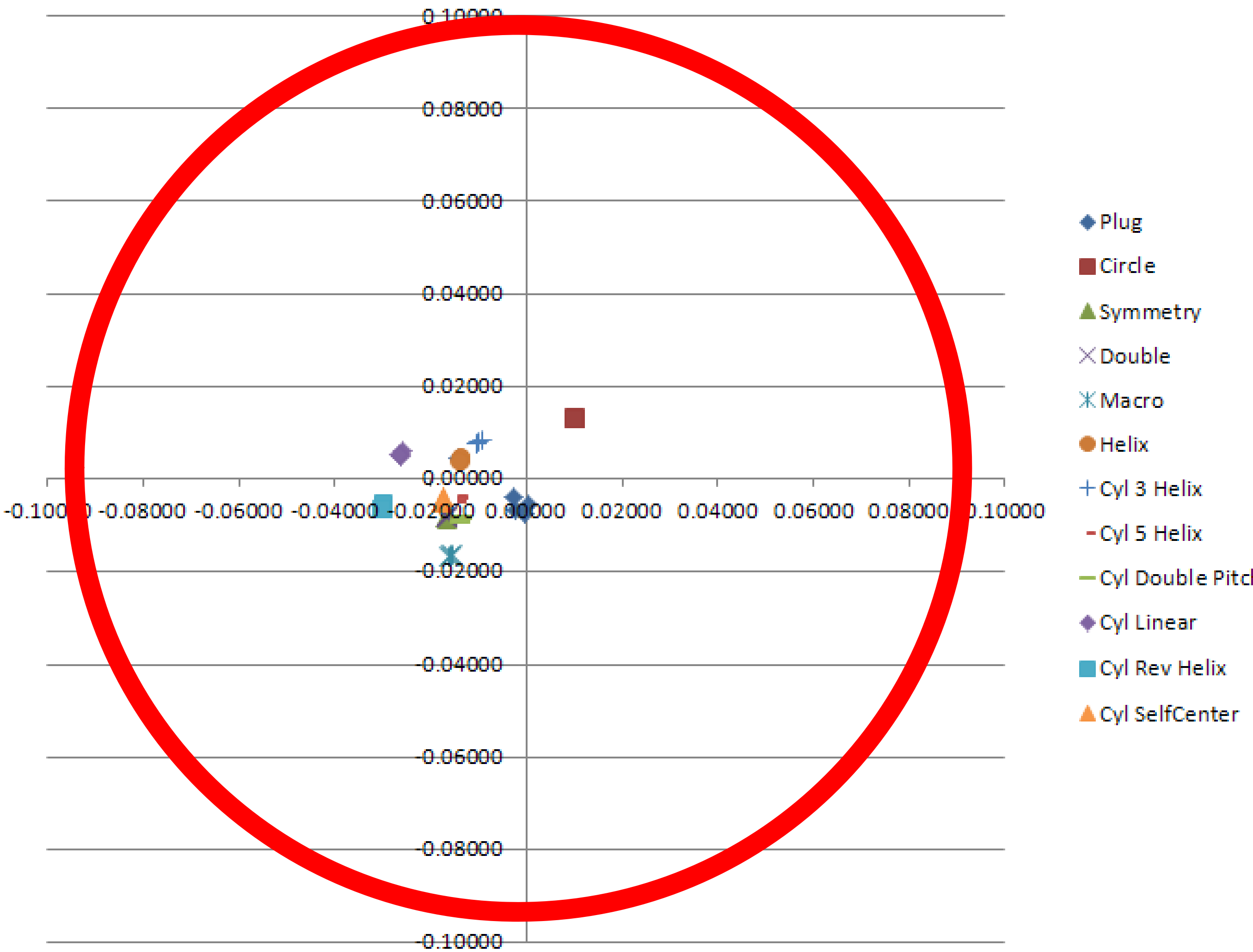
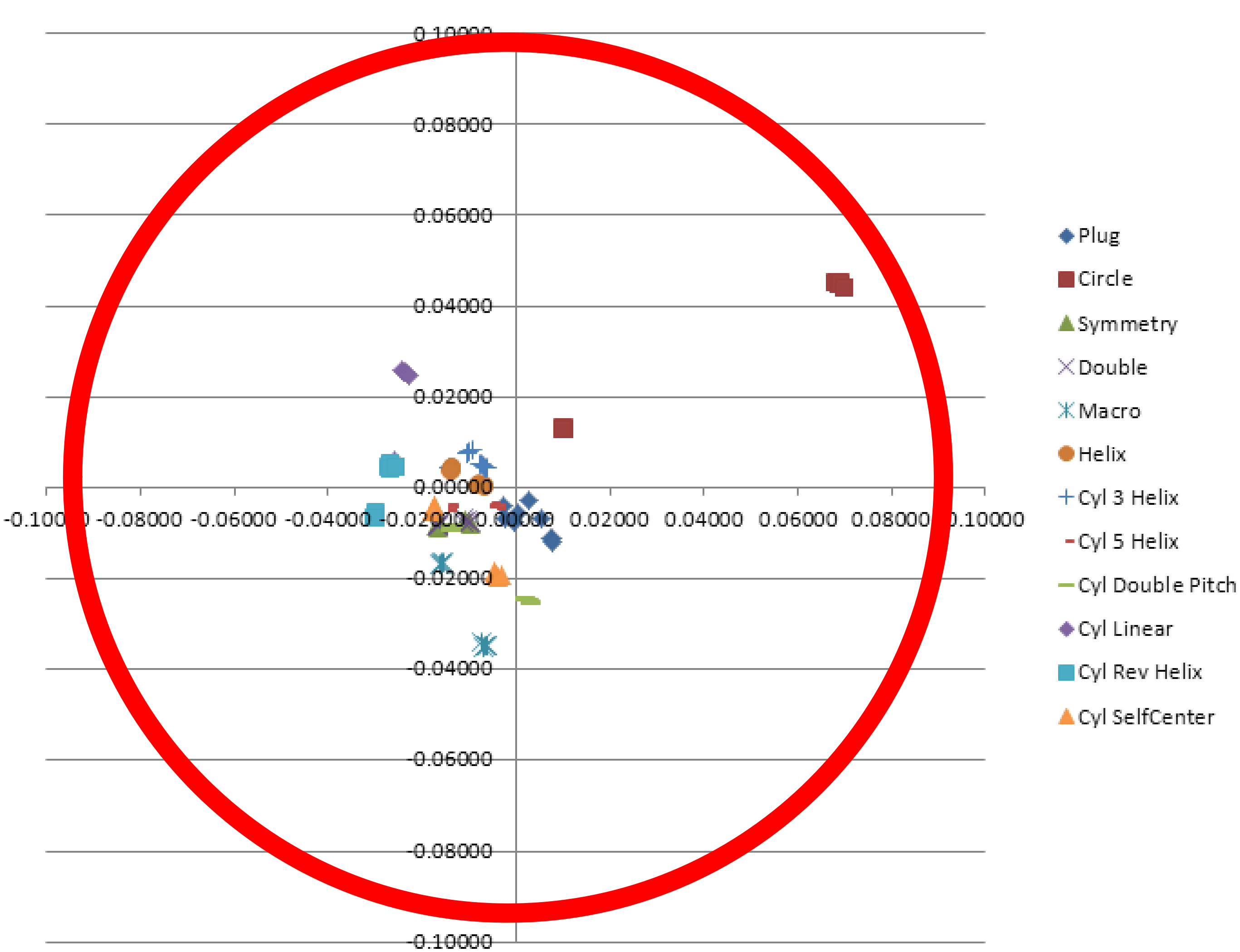
5mm stylus



All 10 results



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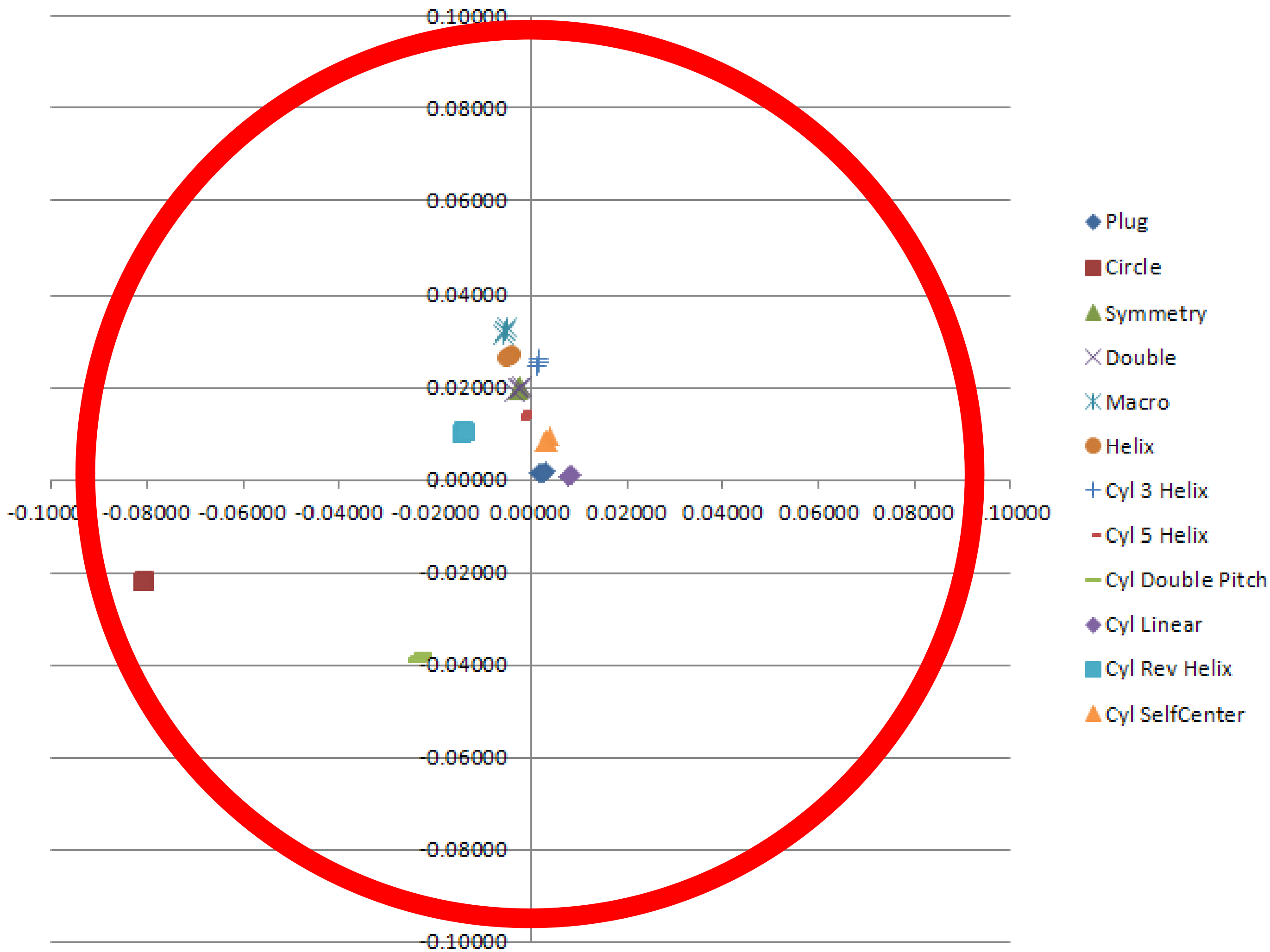
	Nominal	Upper Tol	Range	Average
True Position Pin	0.000	0.200	0.021	0.000
True Position Cyl 5 Helix at Plane	0.000	0.200	0.019	0.021
True Position Cyl Doublepitch at Plane	0.000	0.200	0.020	0.025
True Position Cyl Self Center at Plane	0.000	0.200	0.005	0.026
True Position Circle Helix	0.000	0.200	0.016	0.029
True Position Symmetry	0.000	0.200	0.013	0.030
True Position Double	0.000	0.200	0.013	0.030
True Position Cyl 3 Helix at Plane	0.000	0.200	0.011	0.032
True Position Circle Macro	0.000	0.200	0.026	0.046
True Position Cyl Rev Helix at Plane	0.000	0.200	0.010	0.060
True Position Cyl Linear at Plane	0.000	0.200	0.018	0.068
True Position Circle	0.000	0.200	0.133	0.104

Part 2 :

3mm stylus


0.10000
0.08000
0.06000
0.04000
0.02000
0.00000
-0.02000
-0.04000
-0.06000
-0.08000
-0.10000
-0.1000 -0.08000 -0.06000 -0.04000 -0.02000 0.00000 0.02000 0.04000 0.06000 0.08000 0.10000
Plug
Circle
Symmetry
Double
Macro
Helix
Cyl 3 Helix
Cyl 5 Helix
Cyl Double Pitch
Cyl Linear
Cyl Rev Helix
Cyl SelfCenter

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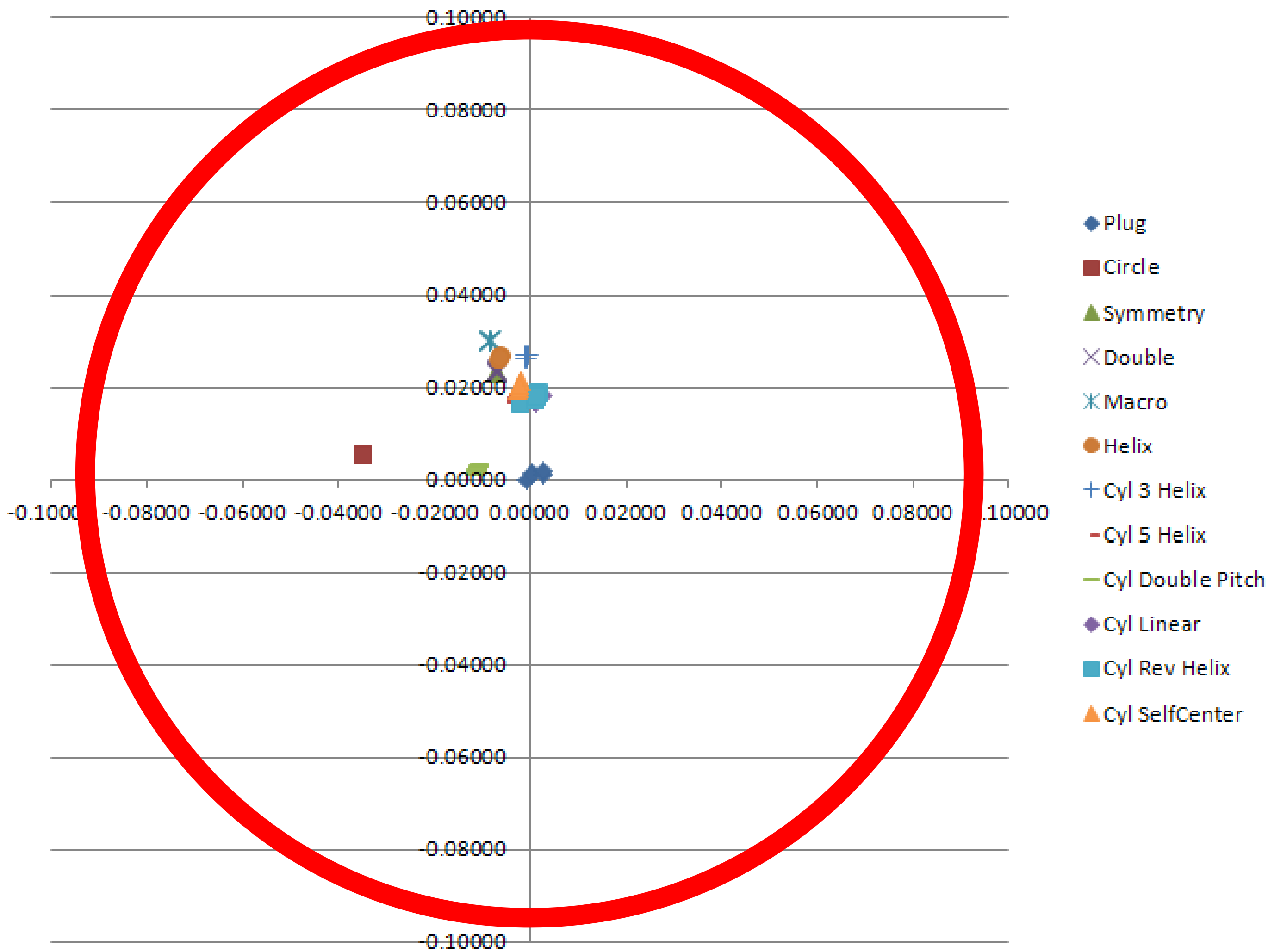
5mm stylus



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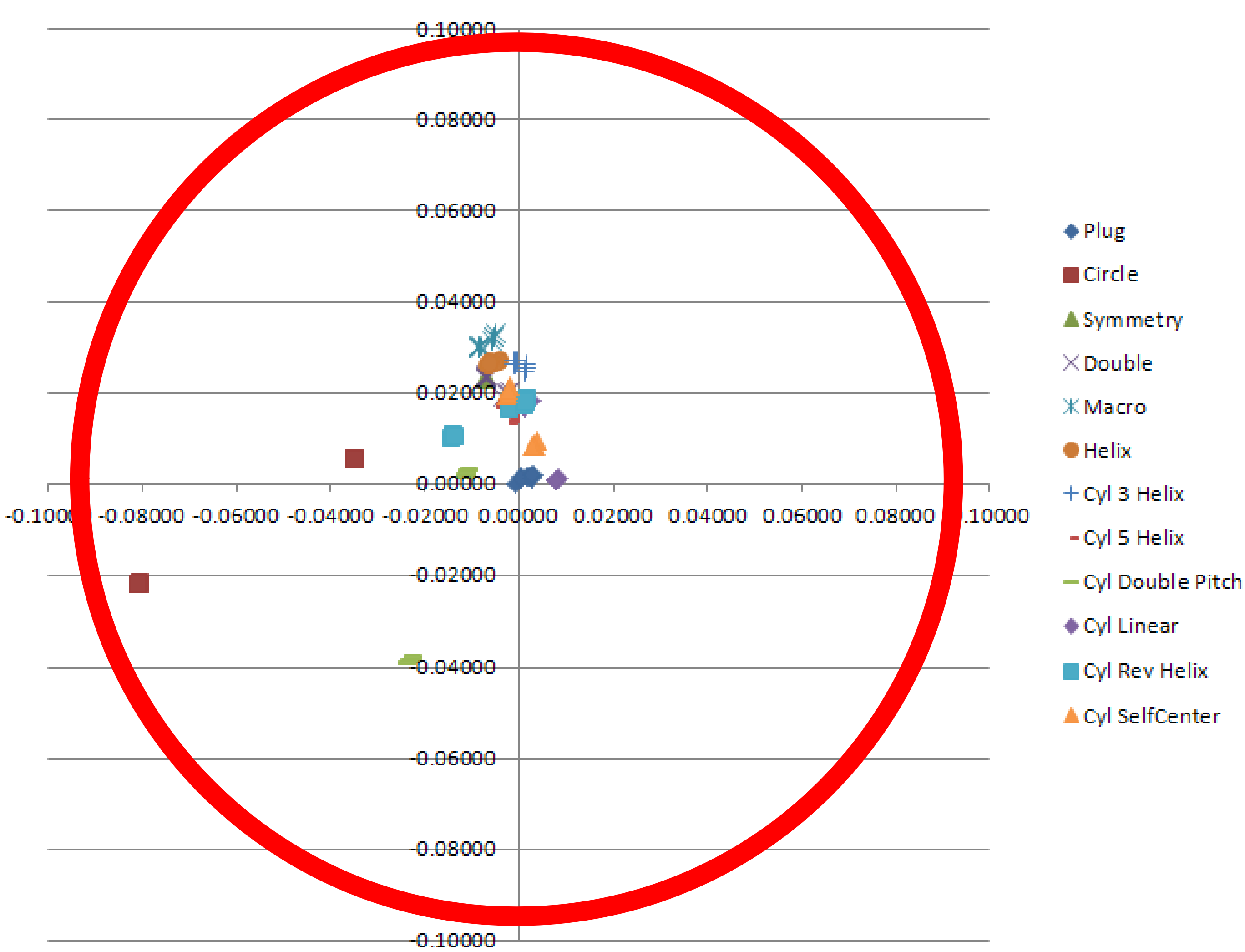
All 10 results



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	Nominal	Upper Tol	Range	Average
True Position Pin	0.000	0.200	0.005	0.000
True Position Cyl Linear at Plane	0.000	0.200	0.022	0.017
True Position Cyl Self Center at Plane	0.000	0.200	0.026	0.027
True Position Cyl Rev Helix at Plane	0.000	0.200	0.005	0.030
True Position Cyl 5 Helix at Plane	0.000	0.200	0.010	0.031
True Position Double	0.000	0.200	0.010	0.042
True Position Symmetry	0.000	0.200	0.010	0.043
True Position Cyl 3 Helix at Plane	0.000	0.200	0.005	0.050
True Position Circle Helix	0.000	0.200	0.002	0.052
True Position Cyl Doublepitch at Plane	0.000	0.200	0.069	0.053
True Position Circle Macro	0.000	0.200	0.005	0.062
True Position Circle	0.000	0.200	0.098	0.120

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Part 3 :

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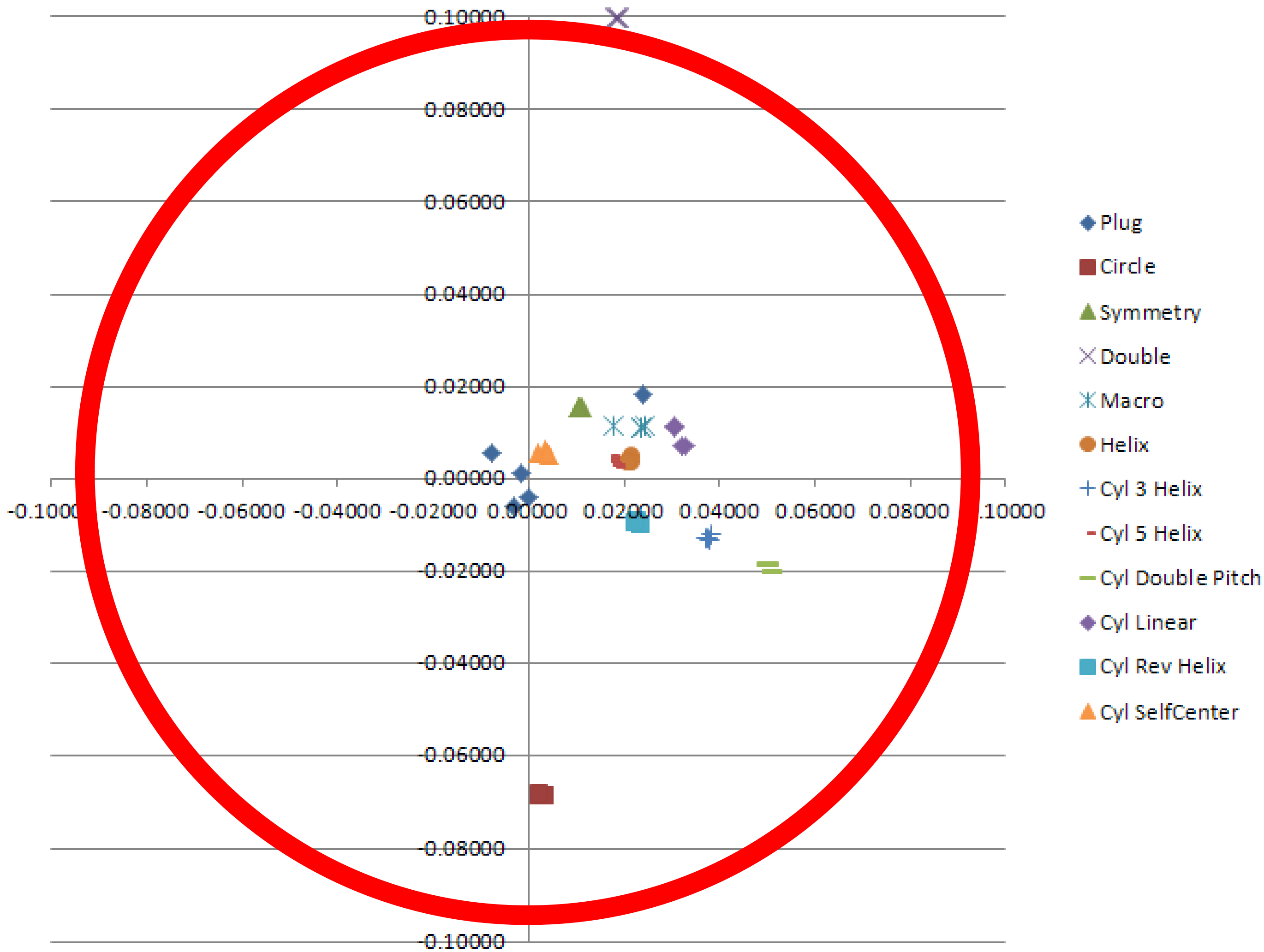

3mm stylus

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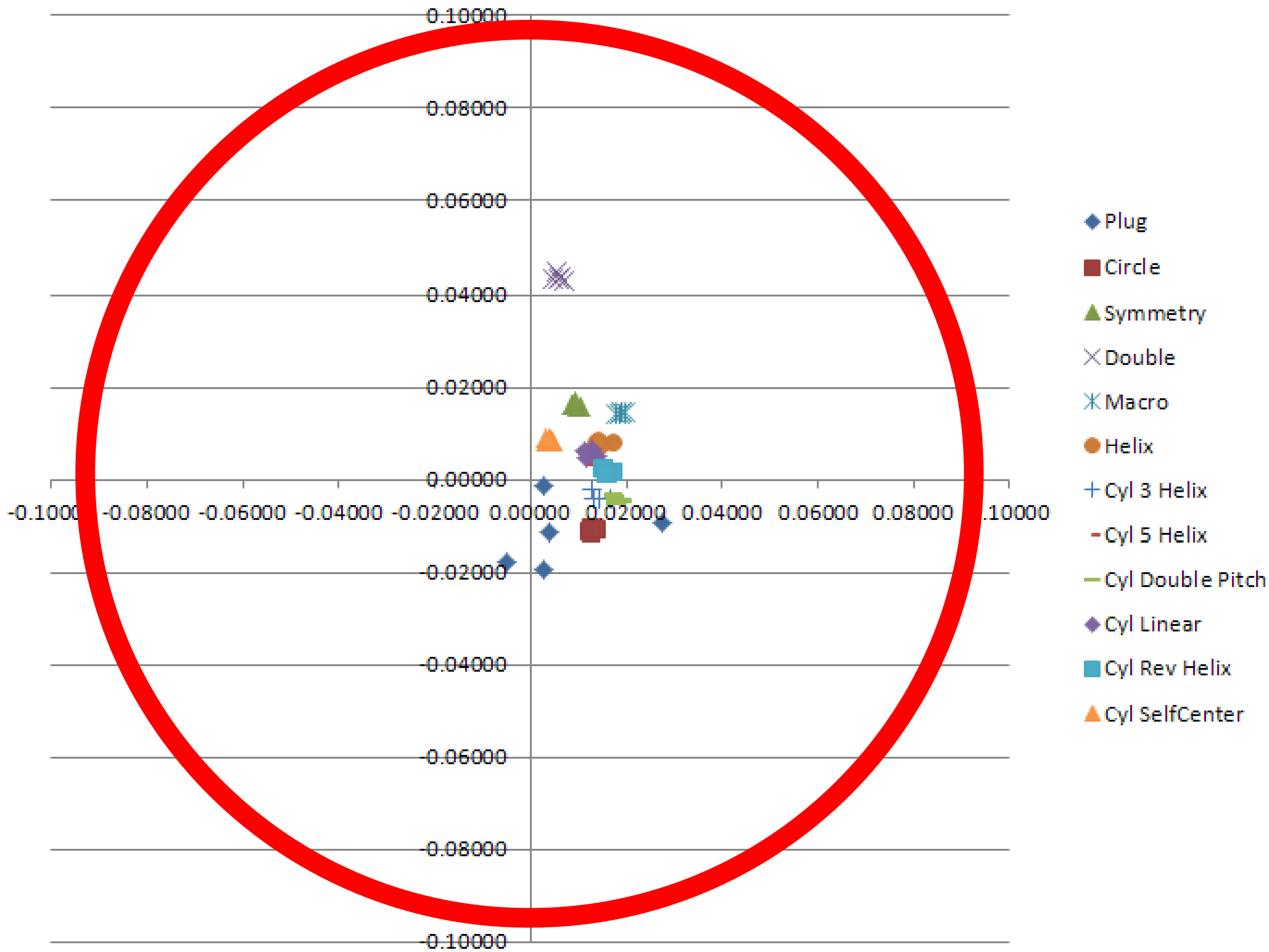
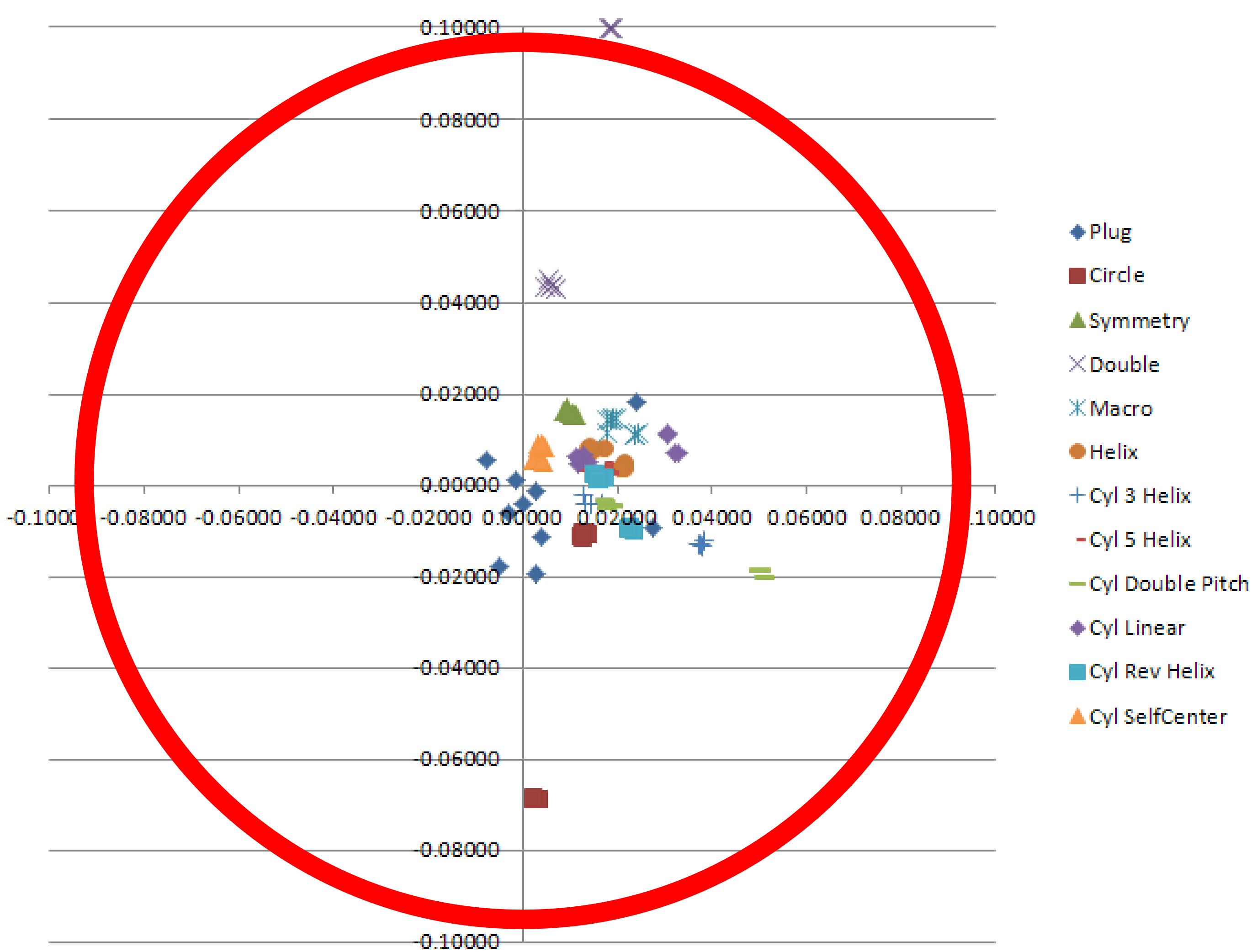
5mm stylus



All 10 results



	Nominal	Upper Tol	Range	Average
True Position Pin	0.000	0.200	0.057	0.000
True Position Cyl Self Center at Plane	0.000	0.200	0.008	0.023
True Position Cyl 5 Helix at Plane	0.000	0.200	0.013	0.027
True Position Cyl Rev Helix at Plane	0.000	0.200	0.021	0.031
True Position Circle Helix	0.000	0.200	0.012	0.035
True Position Symmetry	0.000	0.200	0.002	0.042
True Position Cyl Linear at Plane	0.000	0.200	0.042	0.043
True Position Cyl 3 Helix at Plane	0.000	0.200	0.055	0.044
True Position Circle Macro	0.000	0.200	0.012	0.048
True Position Cyl Doublepitch at Plane	0.000	0.200	0.075	0.062
True Position Circle	0.000	0.200	0.105	0.071
True Position Double	0.000	0.200	0.117	0.154

Now, you are thinking to yourself…

"I just sat through 105 slides – what is the conclusion?"

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What’s Important to You and your company?

- “Accuracy” compared to Flex Plug?
- Repeatability?
- TIME?

Location Deviation (all Tests)

	Average Avg
True Position Pin	0.000
True Position Cyl Self Center at Plane	0.025
True Position Cyl 5 Helix at Plane	0.026
True Position Symmetry	0.038
True Position Circle Helix	0.039
True Position Cyl Rev Helix at Plane	0.040
True Position Cyl 3 Helix at Plane	0.042
True Position Cyl Linear at Plane	0.042
True Position Cyl Doublepitch at Plane	0.047
True Position Circle Macro	0.052
True Position Double	0.075
True Position Circle	0.099

Repeatability (all Tests)

	Range Avg
True Position Symmetry	0.008
True Position Circle Helix	0.010
True Position Cyl Rev Helix at Plane	0.012
True Position Cyl Self Center at Plane	0.013
True Position Cyl 5 Helix at Plane	0.014
True Position Circle Macro	0.014
True Position Cyl 3 Helix at Plane	0.024
True Position Cyl Linear at Plane	0.027
True Position Pin	0.028
True Position Double	0.046
True Position Cyl Doublepitch at Plane	0.055
True Position Circle	0.112

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Inspection Time per Hole

	Time (sec)
True Position Circle Helix	4.000
True Position Circle	4.000
True Position Circle Macro	5.000
True Position Cyl 3 Helix at Plane	7.000
True Position Symmetry	9.000
True Position Double	9.000
True Position Cyl 5 Helix at Plane	10.000
True Position Cyl Rev Helix at Plane	10.000
True Position Cyl Self Center at Plane	14.000
True Position Cyl Linear at Plane	17.000
True Position Cyl Doublepitch at Plane	18.000
True Position Pin	30.000

Notes:

Use LSQ fitting to eliminate the effect of "junky" threads

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Notes:

Use of the Flex Plug "wore" the thread geometry to some degree – shavings on the plug were evident after use, especially with aluminum parts

Conclusion:

There is no “Perfect” solution to gaging the location of threaded holes on a CMM.

Conclusion:

If you have the time and money and can afford repeatability issues, use the flex plug.
It's the only way to theoretically measure location based on thread face Surfaces

Conclusion:

If you have the time, the best way to match a flex plug is self-center scan a helical cylinder up the thread with at least 5 revolutions.

Conclusion:

If cycle time is important, just measure a circle with one revolution with a helix with the gradient of the pitch.

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Conclusion:

Use as large a stylus as possible. Measurements “converged” closer to the target center when a larger tip was used, regardless of measurement method.

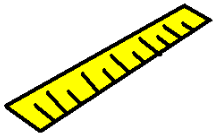
Conclusion:

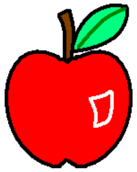
Repeatability of ANY method on the CMM (with any one stylus size) is always better then repeatability of a flex plug.

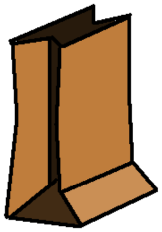
Disclaimer:

The conclusions displayed here are representative of the data gathered in this testing.

Before choosing a method of inspecting threads, it is recommended to test and verify your results on your parts.







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You’ve got Questions, We have answers.

Measuring Threaded Holes