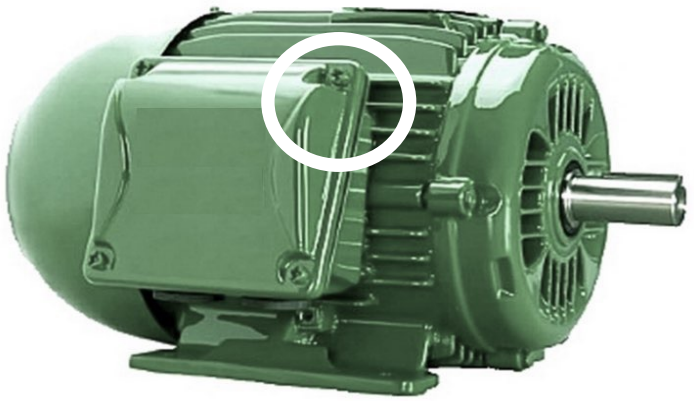
SOLVING AN INDUSTRIAL PROBLEM USING ADVANCED STATISTICAL TOOLS

Matheus Luchese Sguissardi

Discovery Summit Americas 2021

PROBLEM DESCRIPTION



When the customer receives the motor, he needs to open the connection cover and connect the cables to his own machine. After connecting it, he needs to close the box again, screwing it.

By specification, the screw has to withstand at least 10 times the process of opening and closing the cover.

However, when closing the box, the aluminum hole was stripped, so the screw was turning false, generating a customer complaint.

HYPOTHESIS

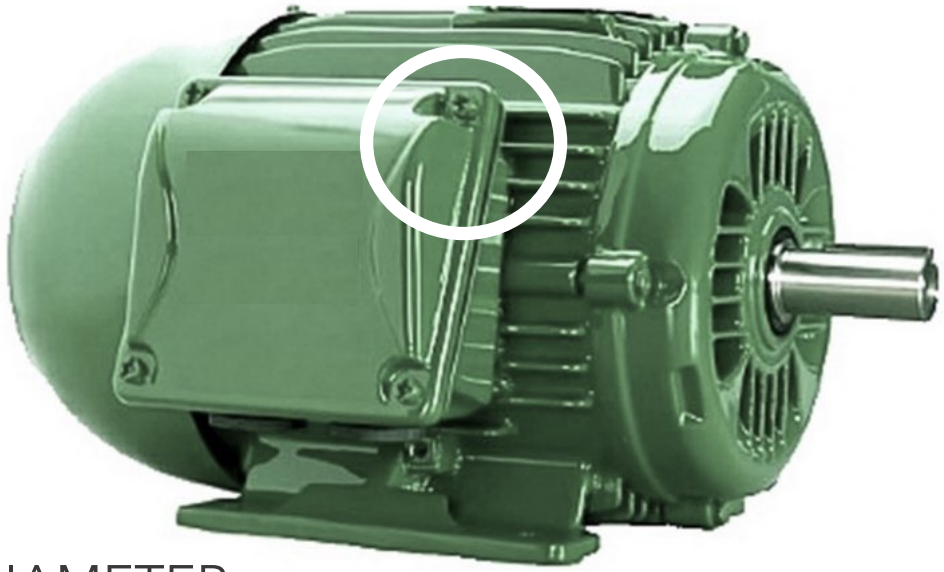
Which hypothesis could help us to understand the failure?

DESIGN ERRORS
PRODUCT ENGINEERING

HIGH SCREWING MACHINE TORQUE
ASEEMBLY LINE

REDUCED SCREW DIAMETER
SUPPLY

FITTING ALUMINUM HOLE WITH OPENED DIAMETER
INJECTION PROCESS



HYPOTHESIS

Which hypothesis could help us to understand the failure?

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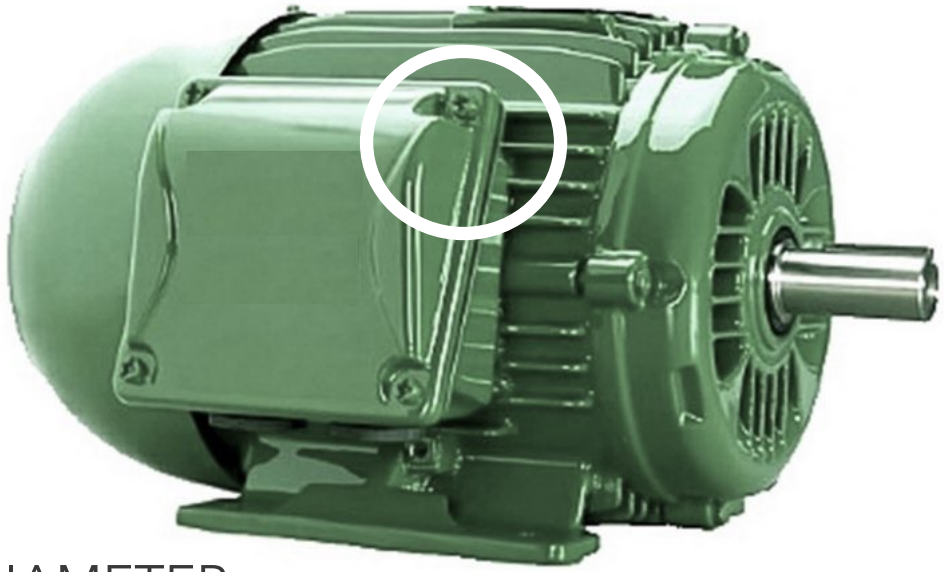
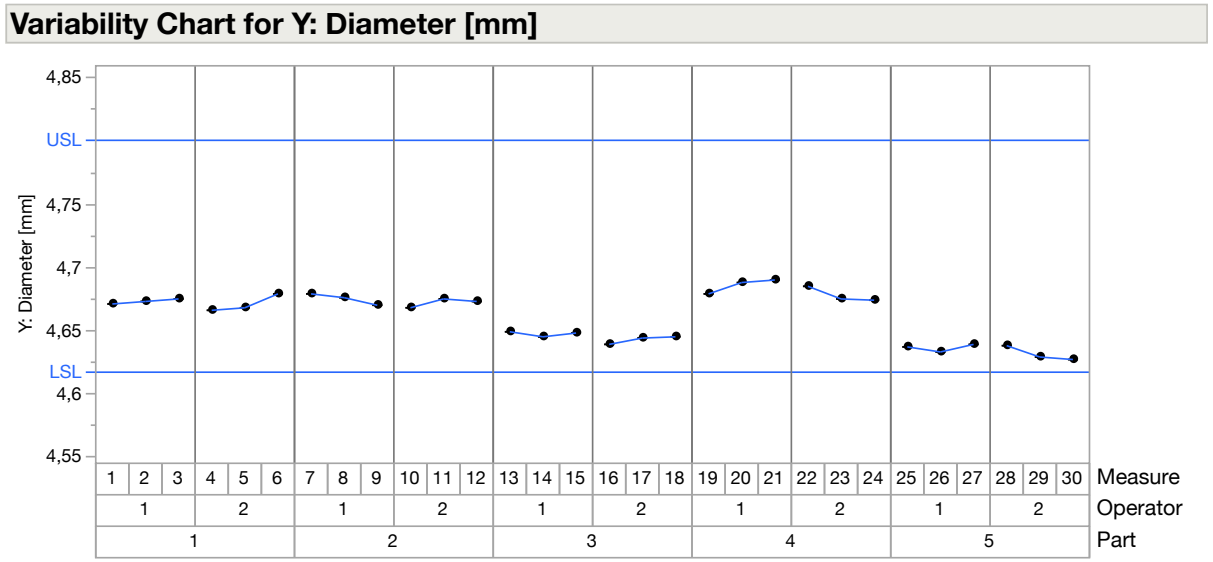


HYPOTHESIS – REDUCED SCREW DIAMETER

Before start measuring the screws in the factory, we need to be sure that the measurement system is approved.

SCREW DIAMETER



Variance Components

Component	Var Component	% of Total	20 40 60 80	Sqrt(Var Comp)
Total	0,00045098	100,0		0,02124
Part	0,00042305	93,8		0,02057
Measure	0,00001923	4,3		0,00439
Operator	0,00000869	1,9		0,00295
Part*Operator	0,00000000	0,0		0,00000
Part*Measure	0,00000000	0,0		0,00000
Operator*Measure	0,00000000	0,0		0,00000
Part*Operator*Measure	0,00000000	0,0		0,00000
Within	0,00000000	0,0		0,00000

APPROVED

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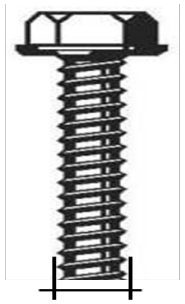
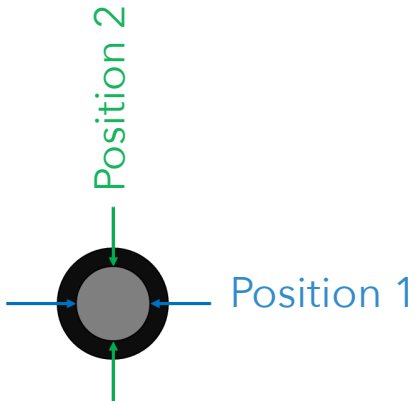
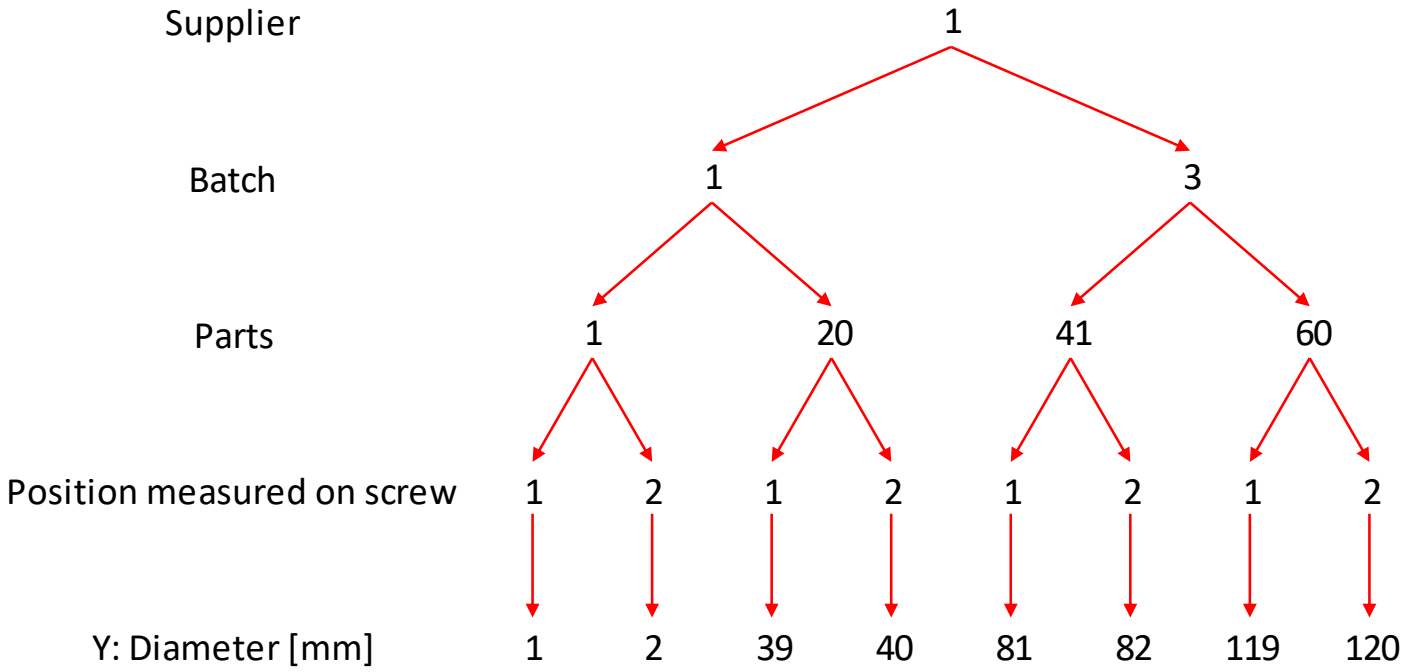
HYPOTHESIS – REDUCED SCREW DIAMETER

Voice of the Process (VOP)



SCREW DIAMETER

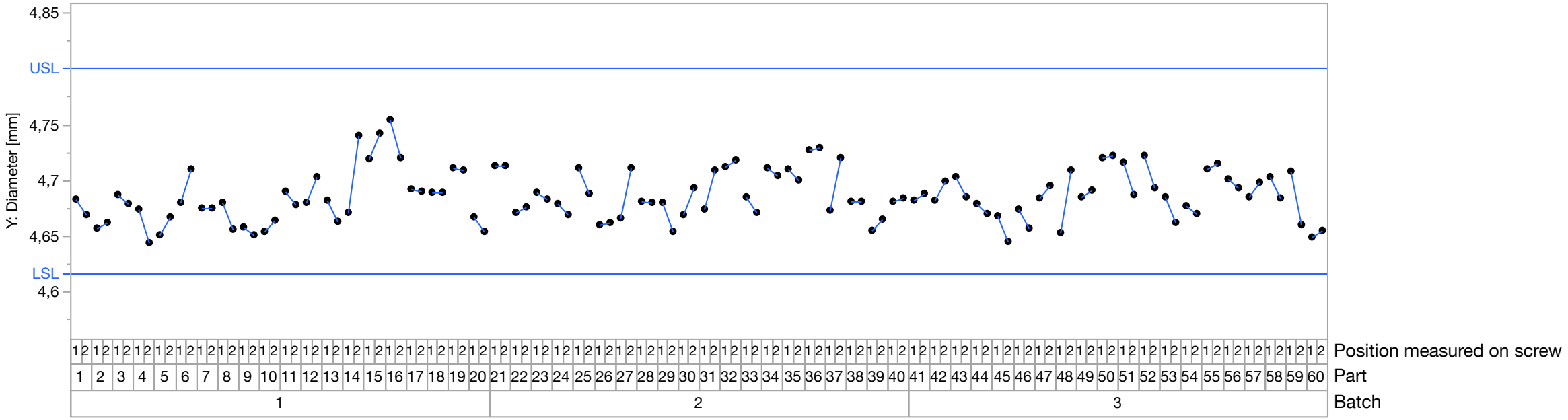




HYPOTHESIS – REDUCED SCREW DIAMETER

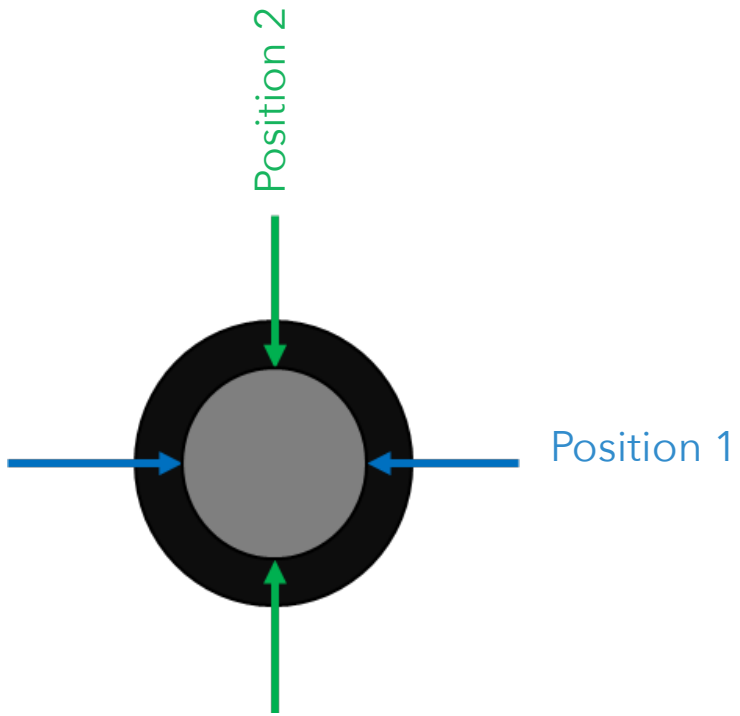
Practical Analysis

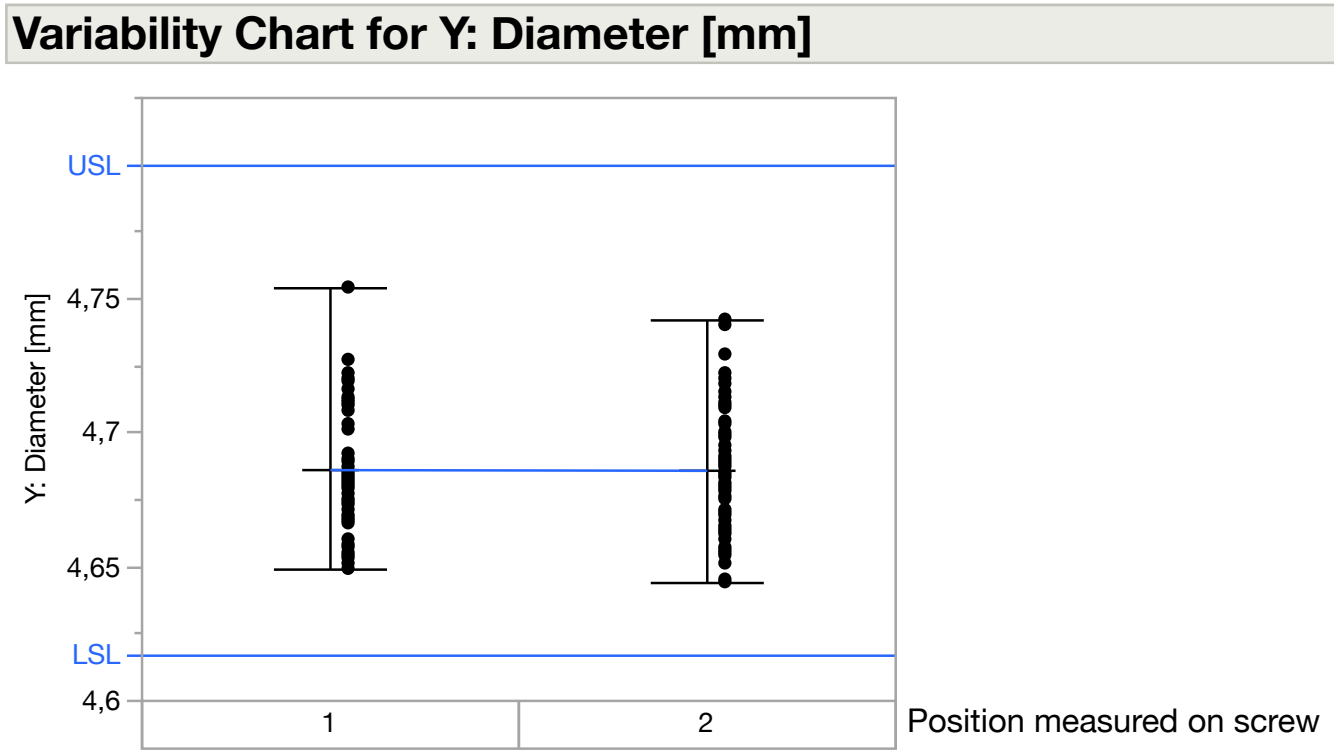
Variability Chart for Y: Diameter [mm]



HYPOTHESIS – REDUCED SCREW DIAMETER

Graphical Analysis





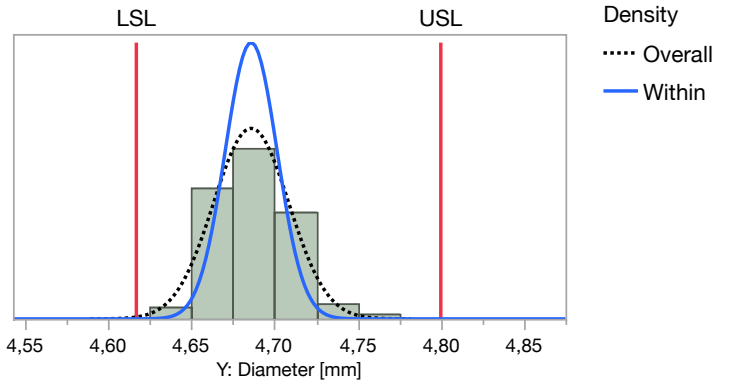
There is no circularity errors on the screws

HYPOTHESIS – REDUCED SCREW DIAMETER

Quantitative Analysis

Y: Diameter [mm] Capability

Histogram



Process Summary

LSL	4,617
USL	4,8
N	120
Sample Mean	4,686008
Within Sigma	0,015624
Overall Sigma	0,022674
Stability Index	1,451214

Within sigma estimated by average moving range.

Within Sigma Capability

Index	Estimate
Cpk	1,472
Cpl	1,472
Cpu	2,432
Cp	1,952

Overall Sigma Capability

Index	Estimate
Ppk	1,014
Ppl	1,014
Ppu	1,676
Pp	1,345

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	5,0109175	1169,3954
Above USL	1,4855e-7	0,248664
Total Outside	5,0109177	1169,6441

Considering an ideal Ppk as 1.33, we could assume that the screws could affect the problem in a long-term basis.

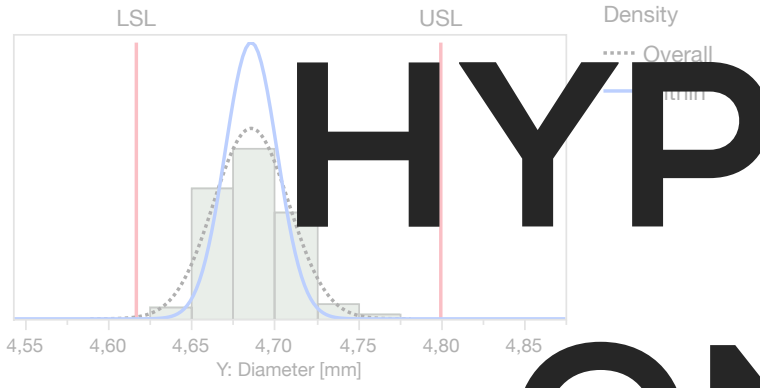
Although, before blame the suppliers we need to understand the injection process.

HYPOTHESIS – REDUCED SCREW DIAMETER

Analysis

Y: Diameter [mm] Capability

Histogram



Process Summary

LSL	4,617
USL	4,8
N	
Sample Mean	4,6860
Within Sigma	0,0156
Overall Sigma	0,0226
Stability Index	1,4512

Within estimated by average moving range.

Within Sigma Capability

Index	Estimate
Cpk	1,472
Cpl	1,472
Cpu	2,432
Cp	1,952

Overall Sigma Capability

Index	Estimate
Ppk	1,014
Ppl	1,014
Ppu	1,676
Pp	1,345

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	5,0109175	1169,3954
Above USL	1,4855e-7	0,248664
Total Outside	5,0109177	1169,6441

HYPOTHESIS ON HOLD

Considering an ideal Cpk as 1.33, we could assume that the [illegible] in the problem even when they are inside the specification limits. Although, before blame suppliers we need to understand our injection process.

HYPOTHESIS

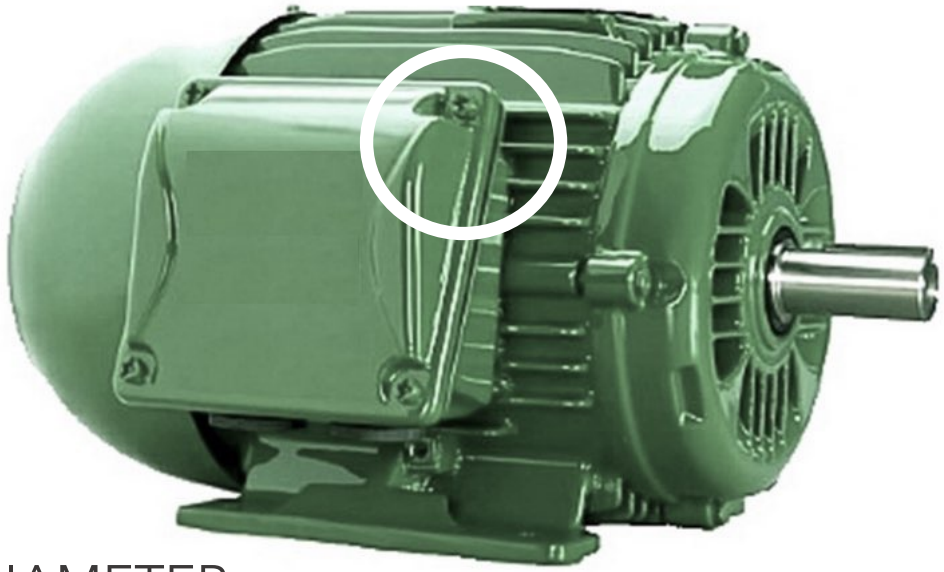
Which hypothesis could help us to understand the failure?

DESIGN ERRORS
PRODUCT ENGINEERING

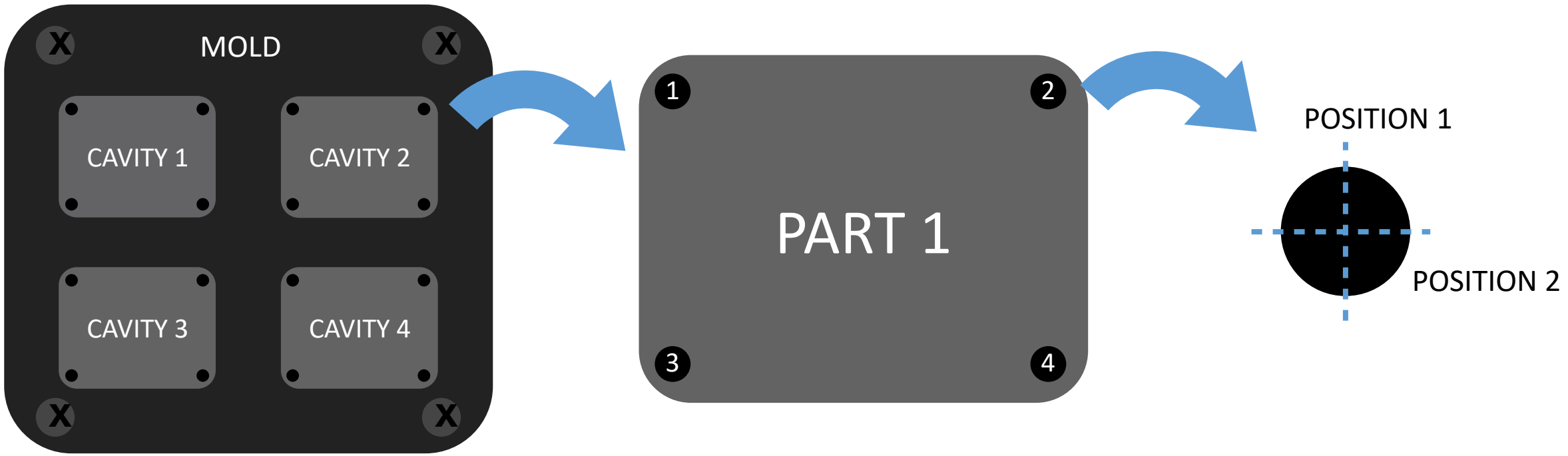
HIGH SCREWING MACHINE TORQUE
ASEEMBLY LINE

REDUCED SCREW DIAMETER
SUPPLY

FITTING ALUMINUM HOLE WITH OPENED DIAMETER
INJECTION PROCESS

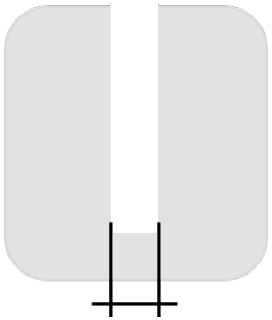


HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

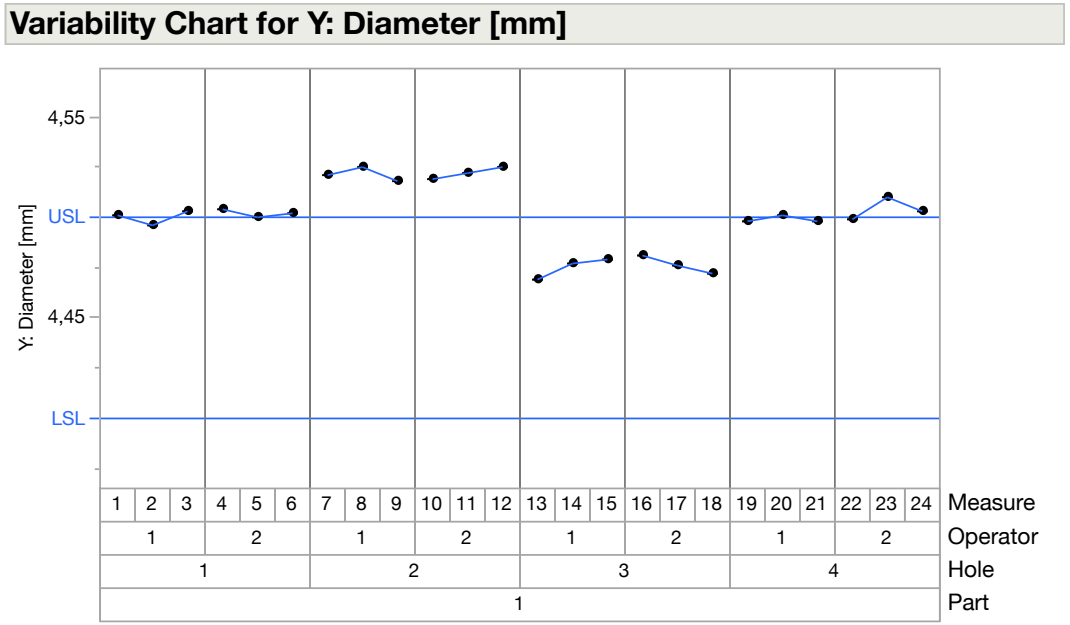


HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

Before start measuring the injected parts in the factory, we need to be sure that the measurement system is approved.



Hole Diameter



Variance Components

Component	Var Component	% of Total	20 40 60 80	Sqrt(Var Comp)
Total	0,00036764	100,0		0,01917
Hole	0,00035267	95,9		0,01878
Measure	0,00001357	3,7		0,00368
Operator	0,00000140	0,381		0,00118
Part	0,00000000	0,0		0,00000
Part*Hole	0,00000000	0,0		0,00000
Part*Operator	0,00000000	0,0		0,00000
Hole*Operator	0,00000000	0,0		0,00000
Part*Hole*Operator	0,00000000	0,0		0,00000
Part*Measure	0,00000000	0,0		0,00000
Hole*Measure	0,00000000	0,0		0,00000
Part*Hole*Measure	0,00000000	0,0		0,00000
Operator*Measure	0,00000000	0,0		0,00000
Part*Operator*Measure	0,00000000	0,0		0,00000
Hole*Operator*Measure	0,00000000	0,0		0,00000
Part*Hole*Operator*Measure	0,00000000	0,0		0,00000
Within	0,00000000	0,0		0,00000

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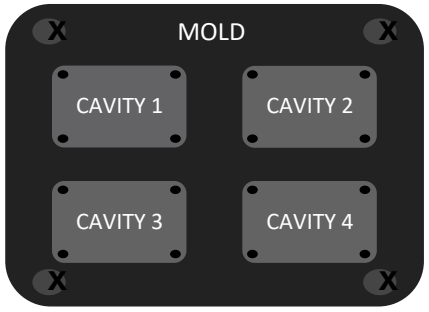
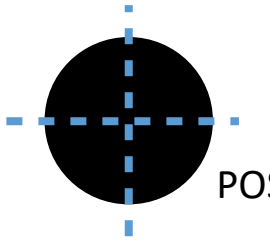
HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

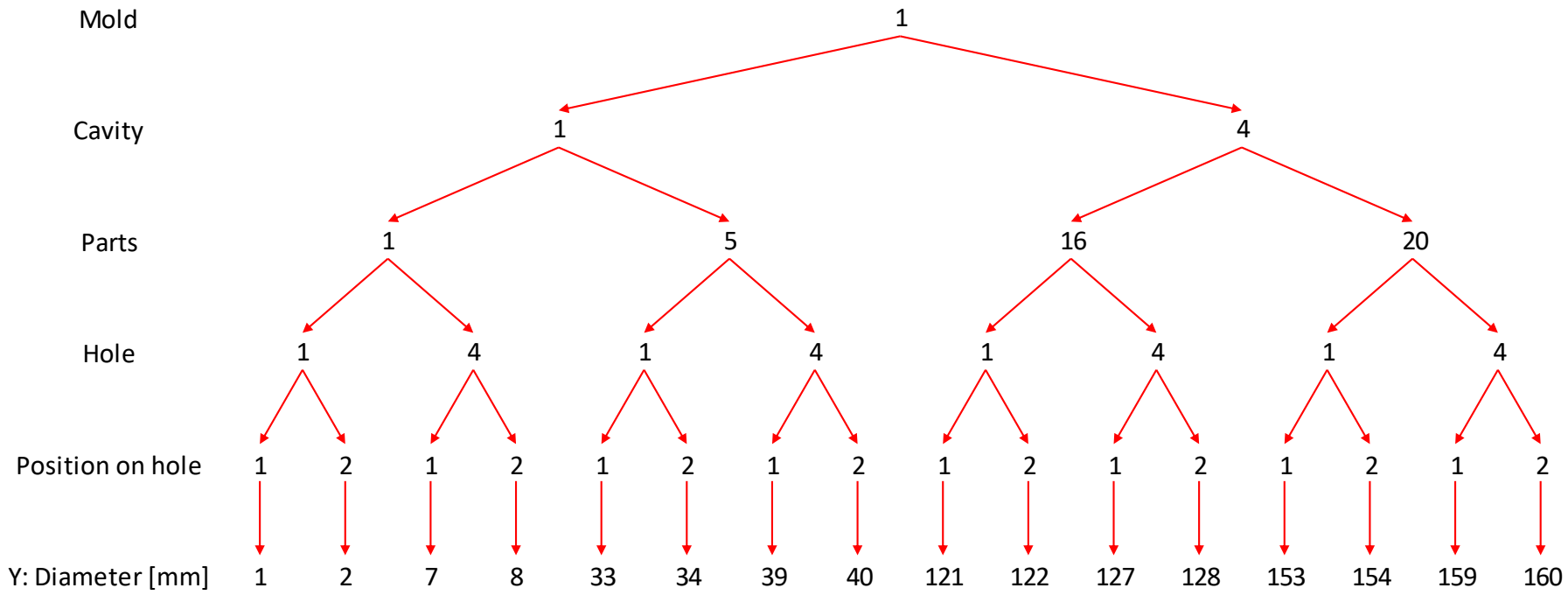
Sample Strategy



POSITION 1

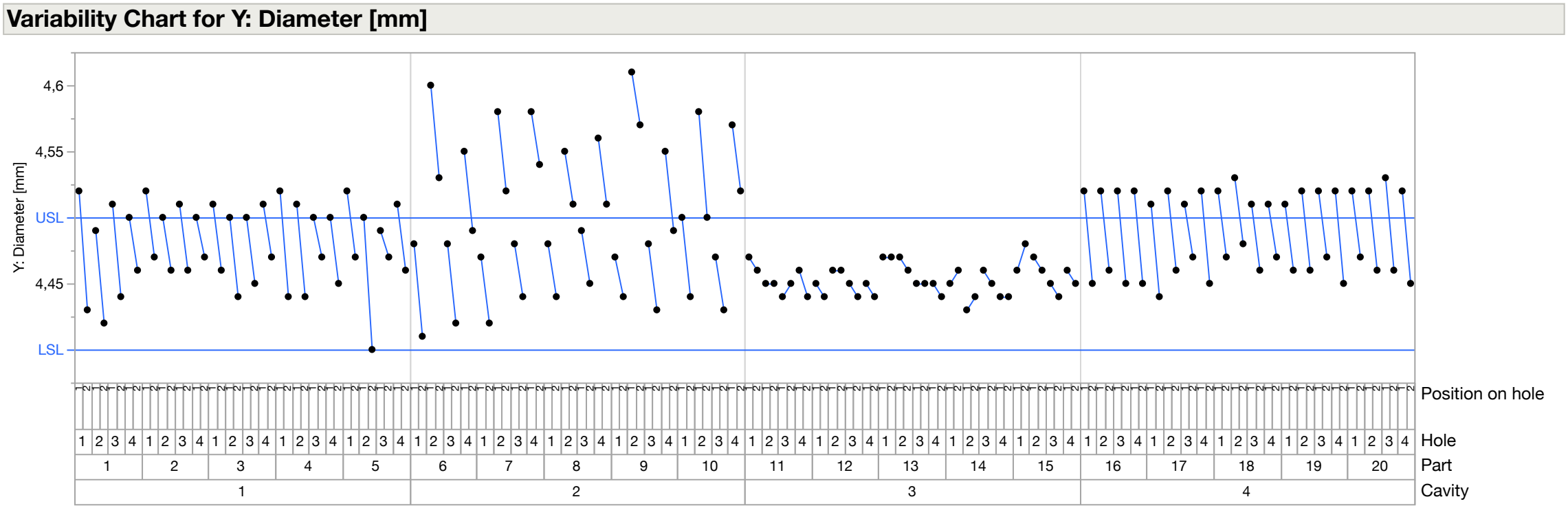


POSITION 2



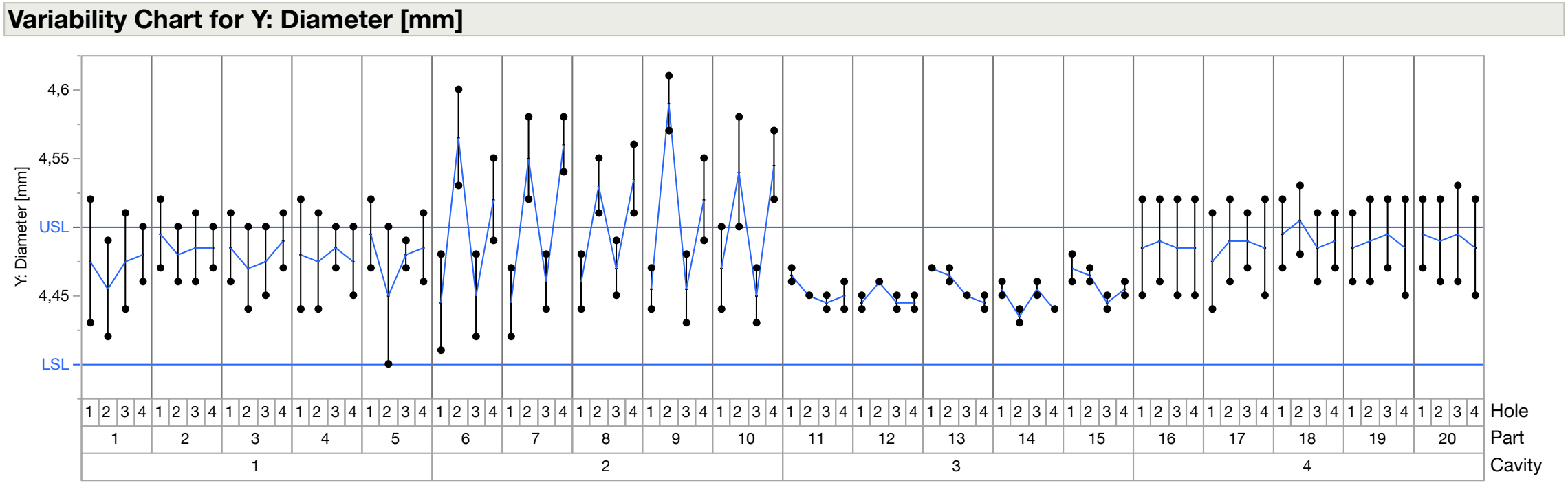
HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

COV Practical Analysis



HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

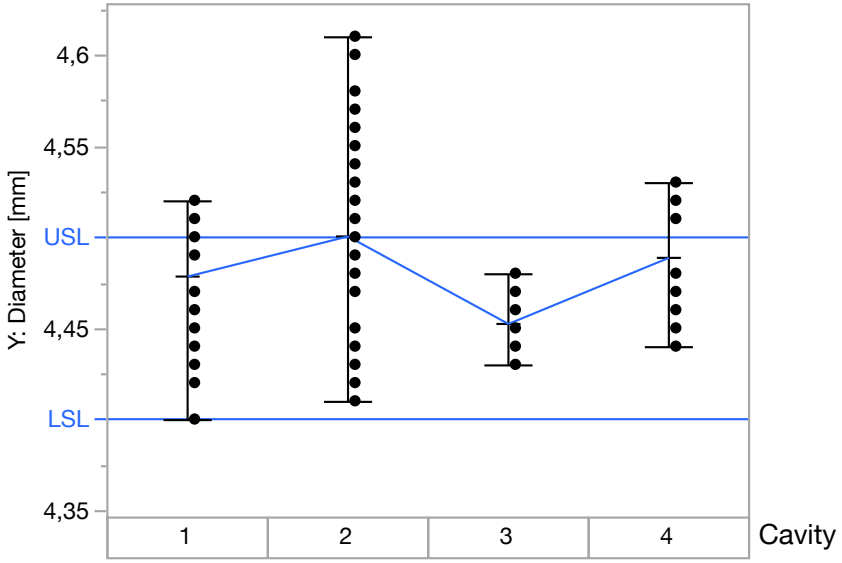
COV Graphical Analysis



HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

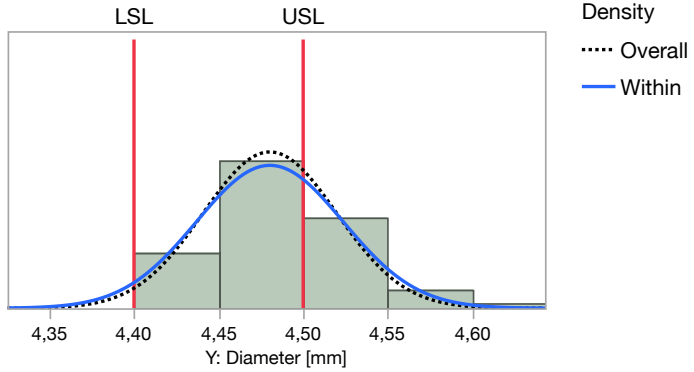
COV Quantitative Analysis

Variability Chart for Y: Diameter [mm]



Y: Diameter [mm] Capability

Histogram



Process Summary

LSL	4,4
USL	4,5
N	160
Sample Mean	4,480313
Within Sigma	0,043308
Overall Sigma	0,039596
Stability Index	0,914282

Within sigma estimated by average moving range.

Within Sigma Capability

Index	Estimate
Cpk	0,152
Cpl	0,618
Cpu	0,152
Cp	0,385

Overall Sigma Capability

Index	Estimate
Ppk	0,166
Ppl	0,676
Ppu	0,166
Pp	0,421

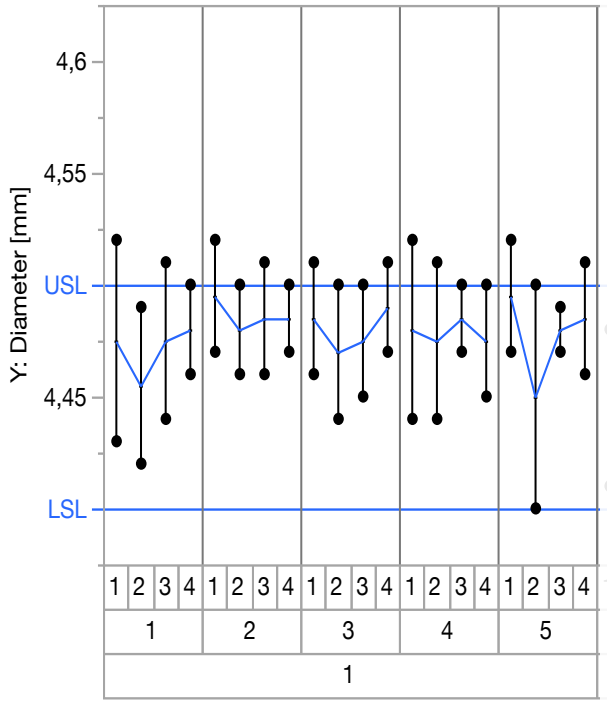
Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	31837,653	21264,346
Above USL	324701,42	309519,78
Total Outside	356539,07	330784,13

HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

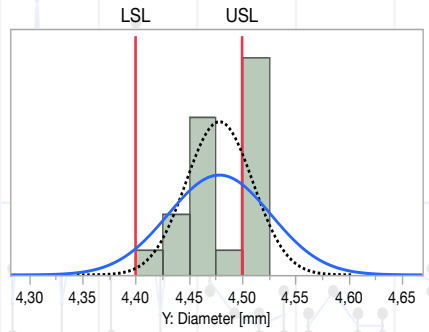
COV Quantitative Analysis

Variability Chart for Y: Diameter [mm]



Y: Diameter [mm] Capability - Cavity 1

Histogram



Process Summary

LSL	4,4
USL	4,5
N	40
Sample Mean	4,47875
Within Sigma	0,048174
Overall Sigma	0,031394
Stability Index	0,651672

Within sigma estimated by average moving range.

Within Sigma Capability

Index	Estimate
Cpk	0,147
Cpl	0,545
Cpu	0,147
Cp	0,346

Overall Sigma Capability

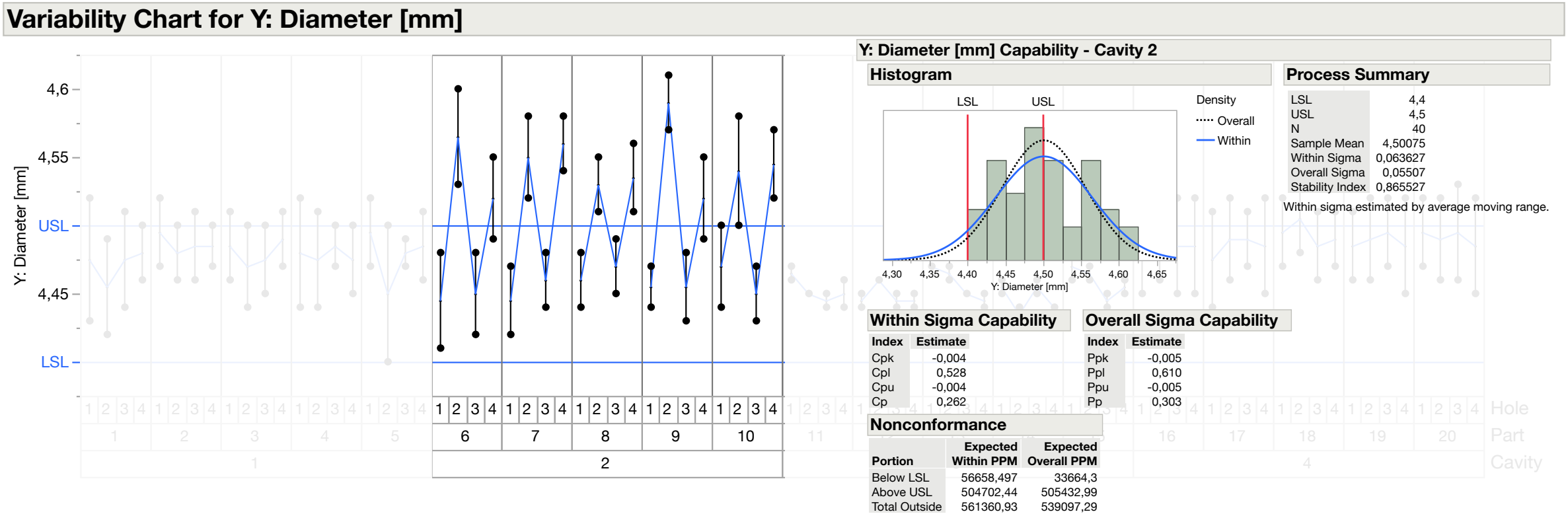
Index	Estimate
Ppk	0,226
Ppl	0,836
Ppu	0,226
Pp	0,531

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	51057,435	6063,1212
Above USL	329568,21	249240,06
Total Outside	380625,65	255303,18

HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

COV Quantitative Analysis



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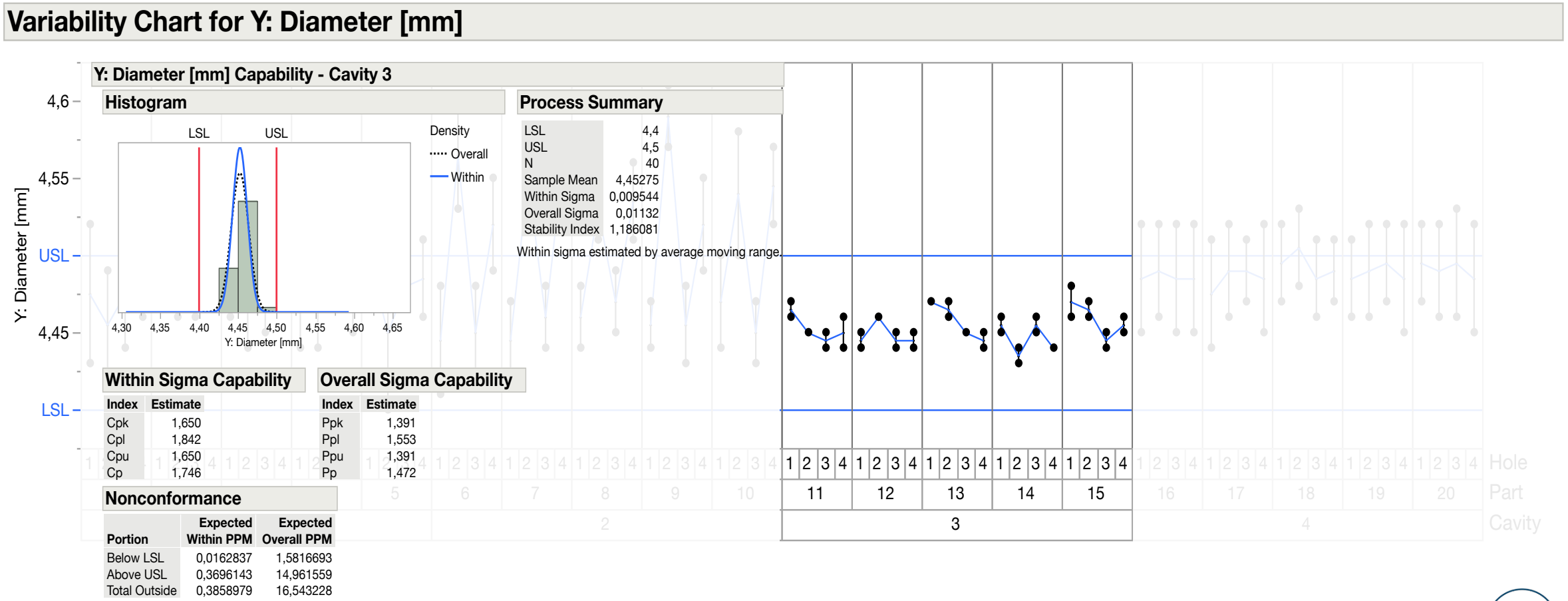

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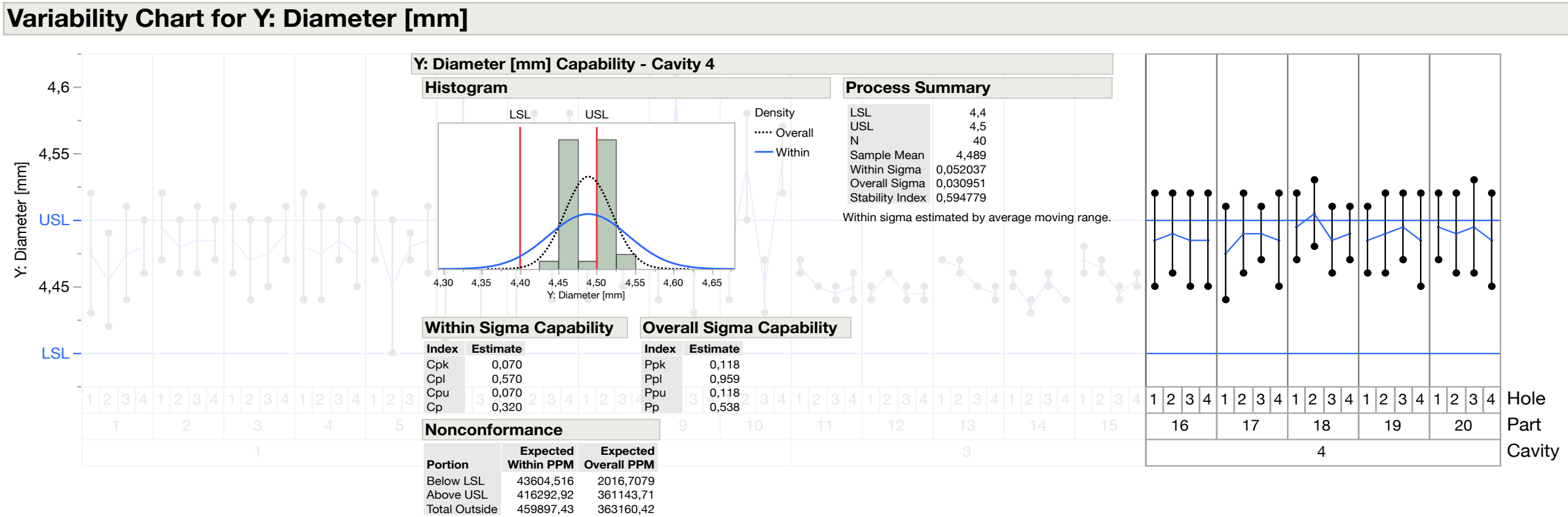
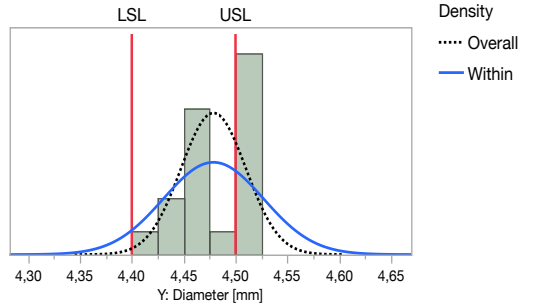


HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

COV Quantitative Analysis

Y: Diameter [mm] Capability - Cavity 1

Histogram



Within Sigma Capability

Index	Estimate
Cpk	0,147
Cpl	0,545
Cpu	0,147
Cp	0,346

Overall Sigma Capability

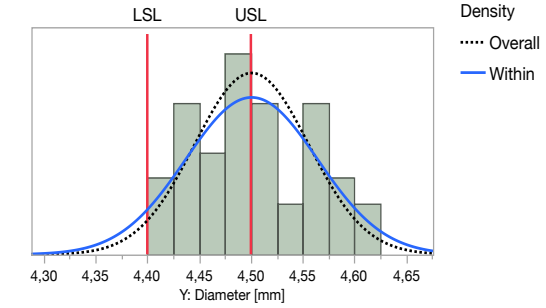
Index	Estimate
Ppk	0,226
Ppl	0,836
Ppu	0,226
Pp	0,531

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	51057,435	6063,1212
Above USL	329568,21	249240,06
Total Outside	380625,65	255303,18

Y: Diameter [mm] Capability - Cavity 2

Histogram



Within Sigma Capability

Index	Estimate
Cpk	-0,004
Cpl	0,528
Cpu	-0,004
Cp	0,262

Overall Sigma Capability

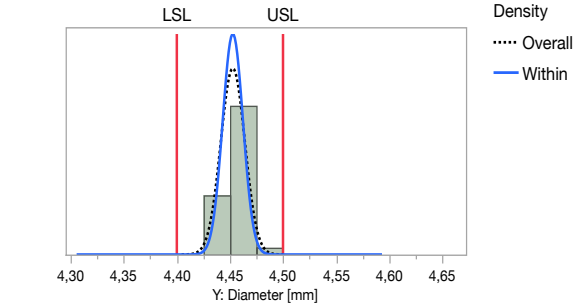
Index	Estimate
Ppk	-0,005
Ppl	0,610
Ppu	-0,005
Pp	0,303

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	56658,497	33664,3
Above USL	504702,44	505432,99
Total Outside	561360,93	539097,29

Y: Diameter [mm] Capability - Cavity 3

Histogram



Within Sigma Capability

Index	Estimate
Cpk	1,650
Cpl	1,842
Cpu	1,650
Cp	1,746

Overall Sigma Capability

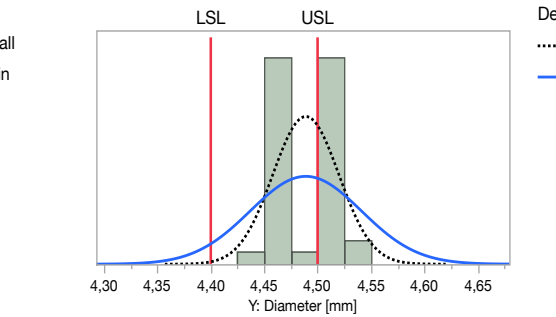
Index	Estimate
Ppk	1,391
Ppl	1,553
Ppu	1,391
Pp	1,472

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	0,0162837	1,5816693
Above USL	0,3696143	14,961559
Total Outside	0,3858979	16,543228

Y: Diameter [mm] Capability - Cavity 4

Histogram



Within Sigma Capability

Index	Estimate
Cpk	0,070
Cpl	0,570
Cpu	0,070
Cp	0,320

Overall Sigma Capability

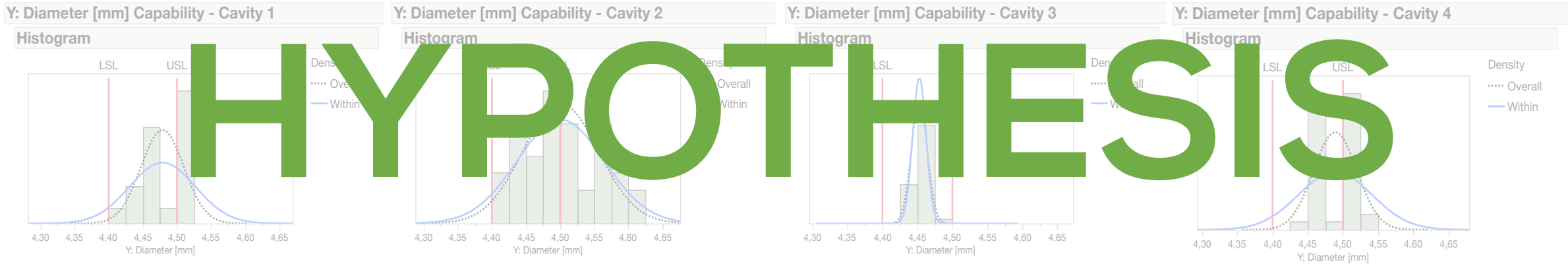
Index	Estimate
Ppk	0,118
Ppl	0,959
Ppu	0,118
Pp	0,538

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	43604,516	2016,7079
Above USL	416292,92	361143,71
Total Outside	459897,43	363160,42

HYPOTHESIS – FITTING HOLE WITH OPENED DIAMETER

COV Analysis



HYPOTHESIS VALIDATED

Within Sigma Capability

Index	Estimate
Cpk	0,147
Cpl	0,545
Cpu	0,147
Cp	0,346

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	51057,435	6063,1212
Above USL	329568,21	249240,06
Total Outside	380625,65	255303,18

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	56658,497	33664,3
Above USL	504702,44	505432,99
Total Outside	561360,93	539097,29

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	0,0162837	1,5816693
Above USL	0,3696143	14,961559
Total Outside	0,3858979	16,543228

Overall Sigma Capability

Index	Estimate
Ppk	0,118
Ppl	0,959
Ppu	0,118
Pp	0,538

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	43604,516	2016,7079
Above USL	416292,92	361143,71
Total Outside	459897,43	363160,42

HYPOTHESIS

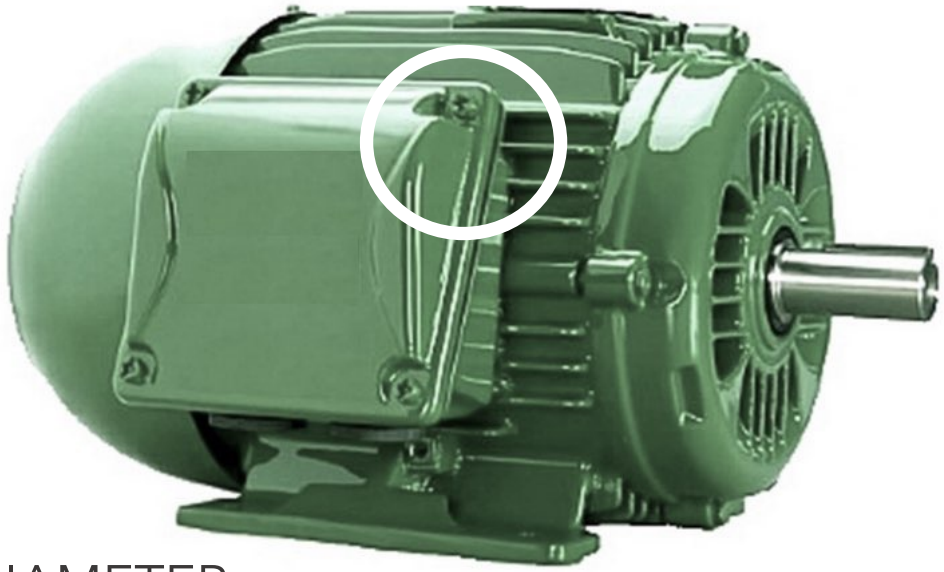
Which hypothesis could help us to understand the failure?

DESIGN ERRORS
PRODUCT ENGINEERING

HIGH SCREWING MACHINE TORQUE
ASEEMBLY LINE

REDUCED SCREW DIAMETER
SUPPLY

FITTING ALUMINUM HOLE WITH OPENED DIAMETER
INJECTION PROCESS



HYPOTHESIS

Which hypothesis could help us to understand the failure?

DESIGN ERRORS
PRODUCT ENGINEERING

HIGH SCREWING MACHINE TORQUE
ASEEMBLY LINE

REDUCED SCREW DIAMETER
SUPPLY

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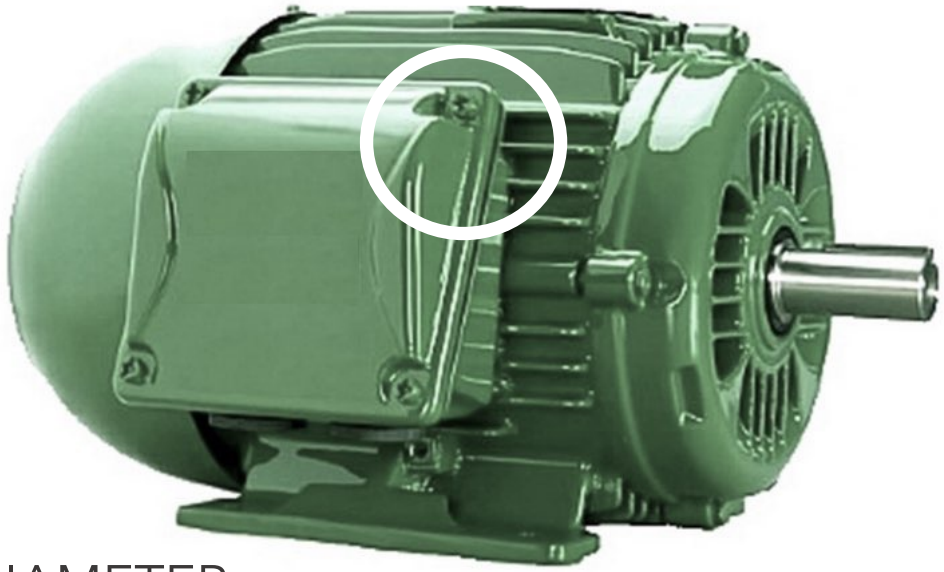
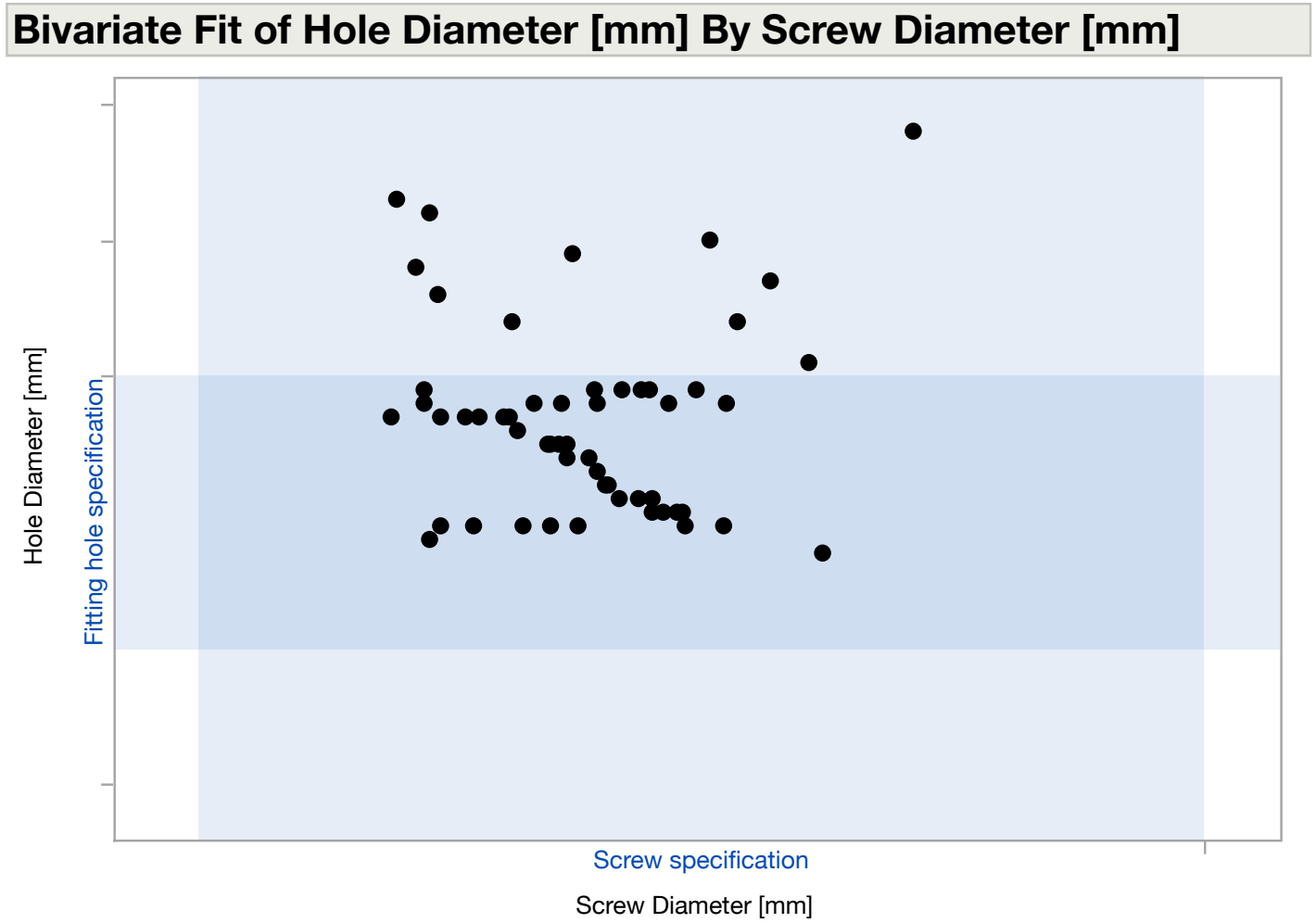


HYPOTHESIS – INTERACTION BETWEEN SCREW & FITTING HOLE



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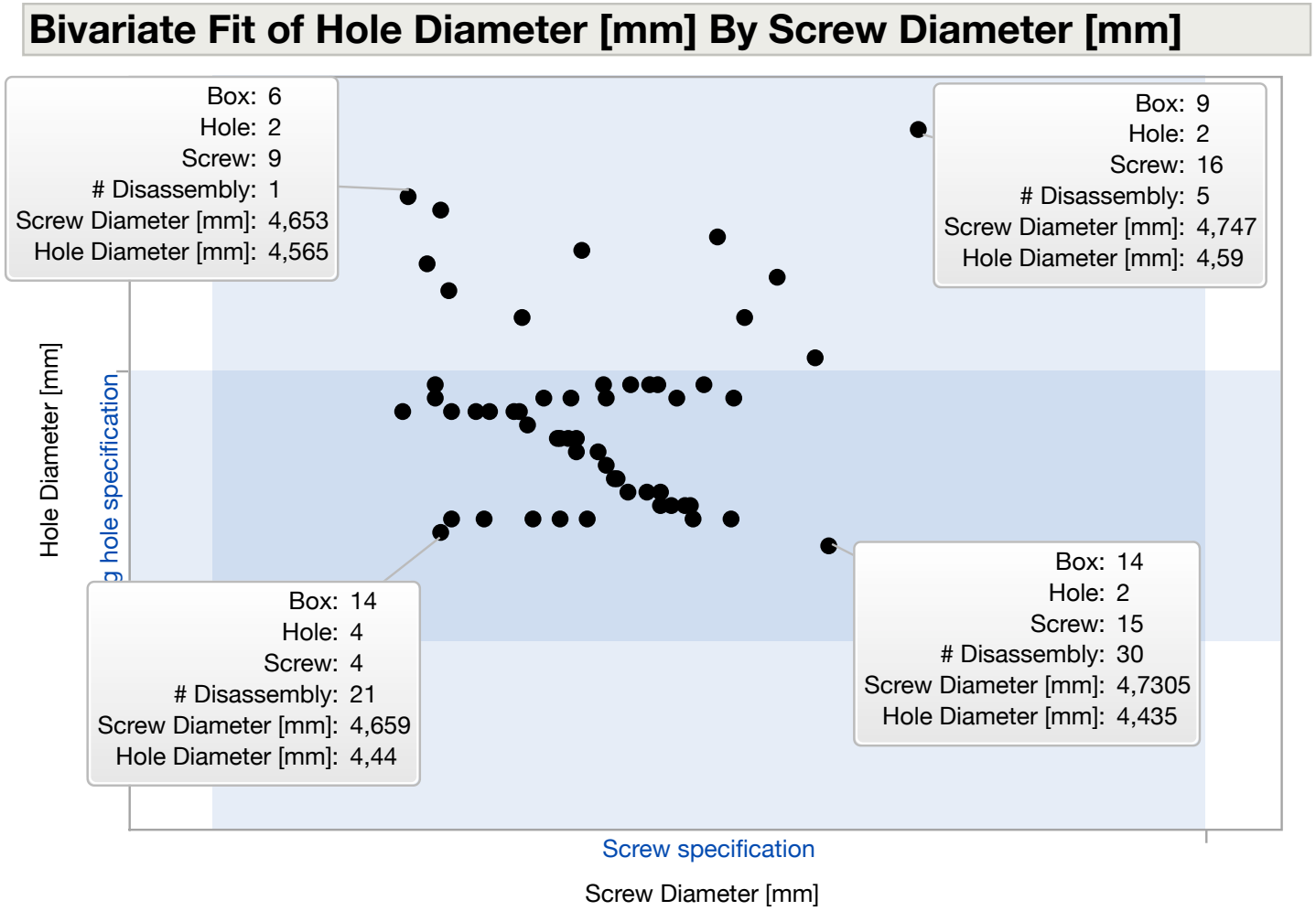
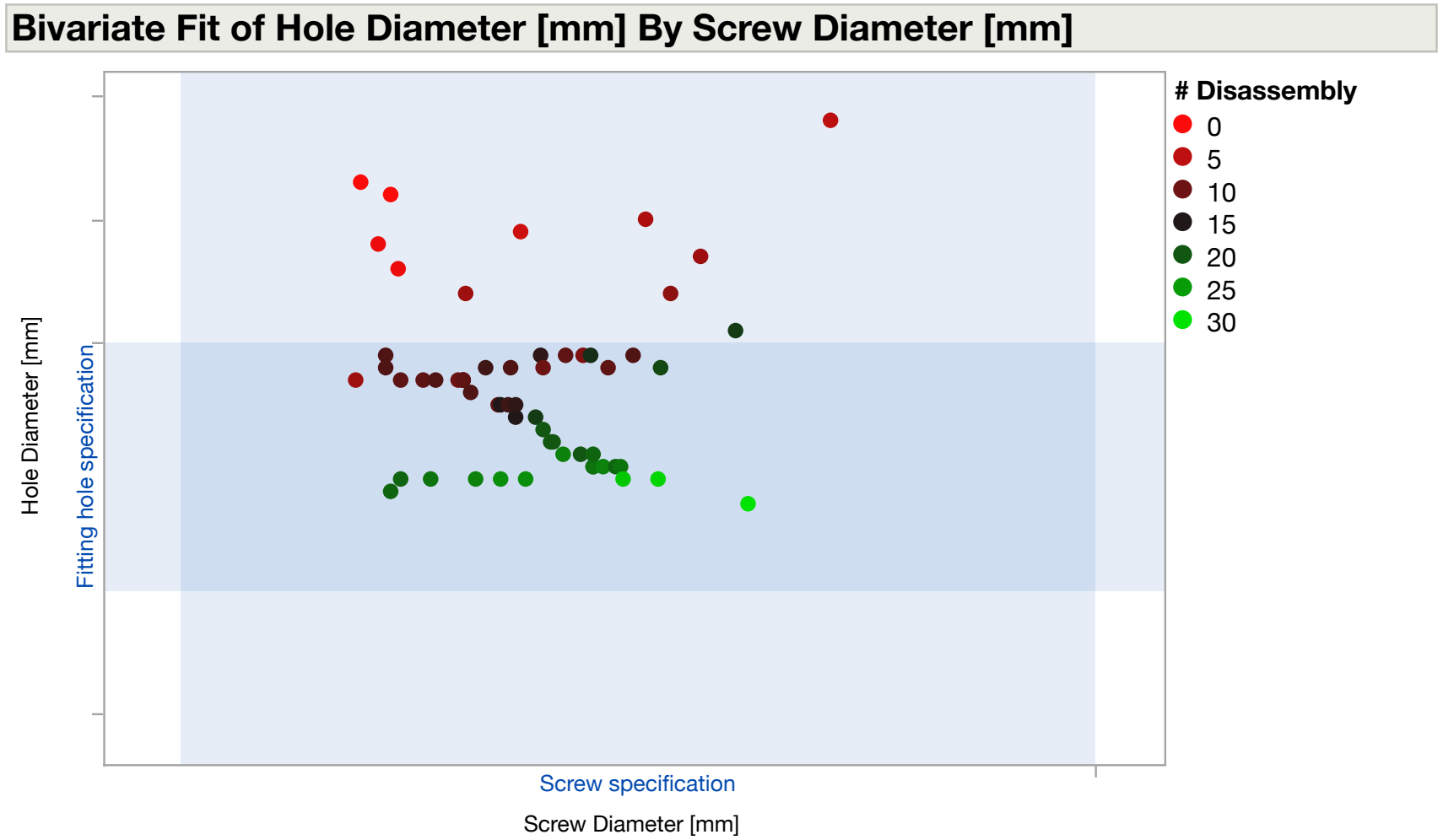
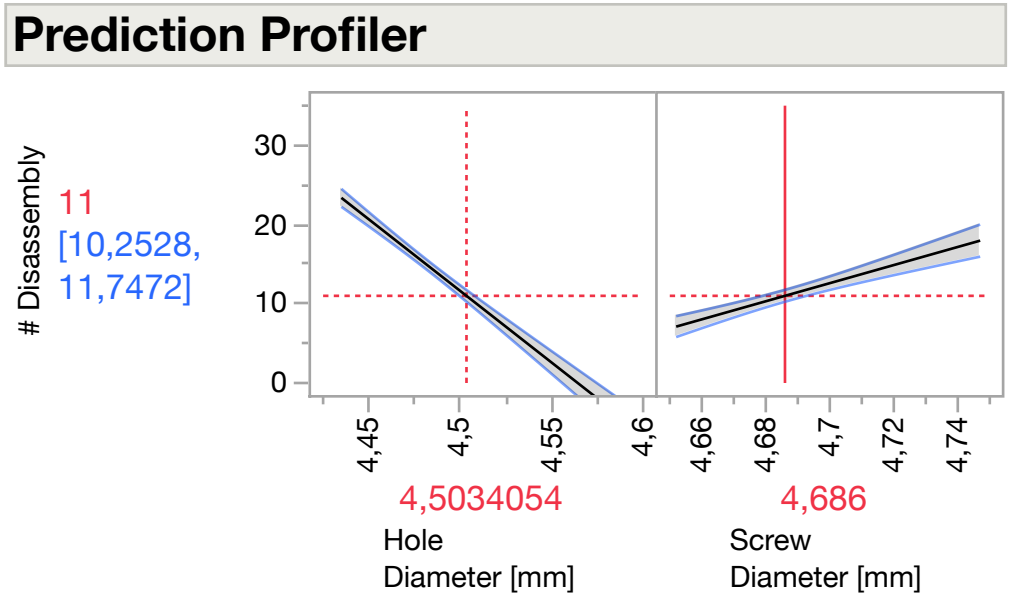


HYPOTHESIS – INTERACTION BETWEEN SCREW & FITTING HOLE



SIMULATOR – INTERACTION BETWEEN SCREW & FITTING HOLE

What should be the fitting hole´s diameter measure to guarantee the quality with the actual screw provided by the supplier with a mean equal to 4,686?

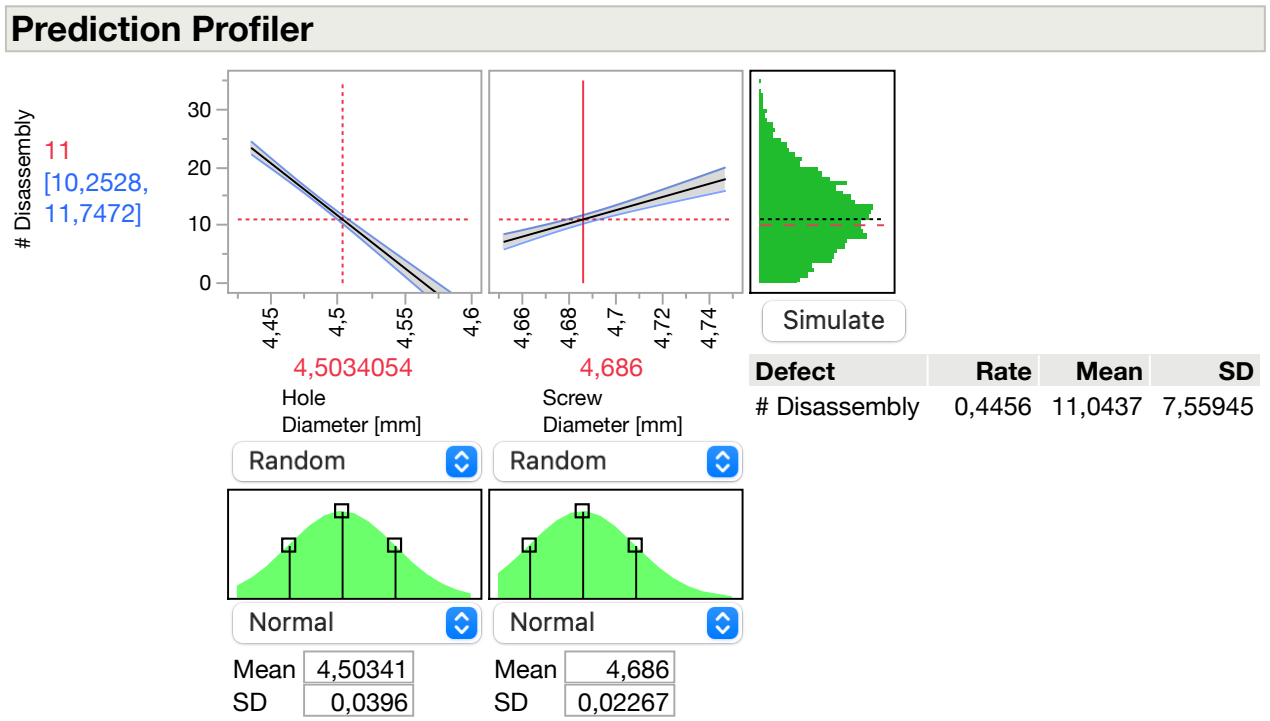


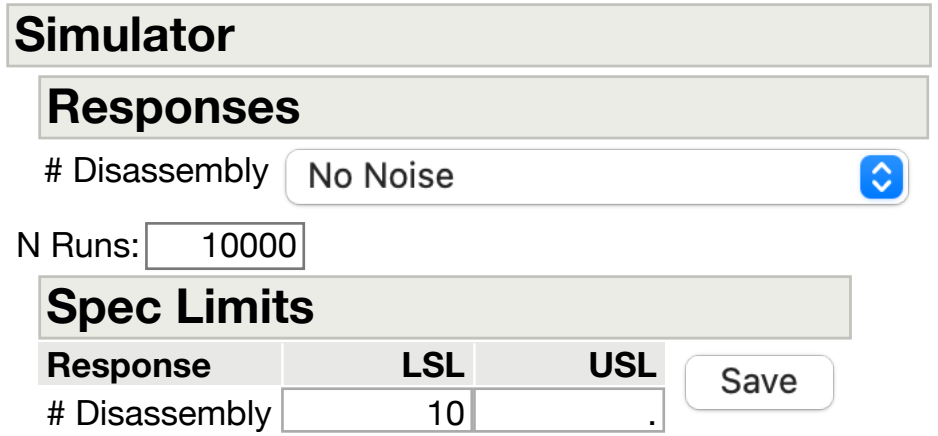
Summary of Fit	
RSquare	0,886882
RSquare Adj	0,880822
Root Mean Square Error	2,46398
Mean of Response	14,8
Observations (or Sum Wgts)	60

What about the process variation?

SIMULATOR – INTERACTION BETWEEN SCREW & FITTING HOLE

When the current process variation is added, we start seeing a big % of probability off having the disassembly problem

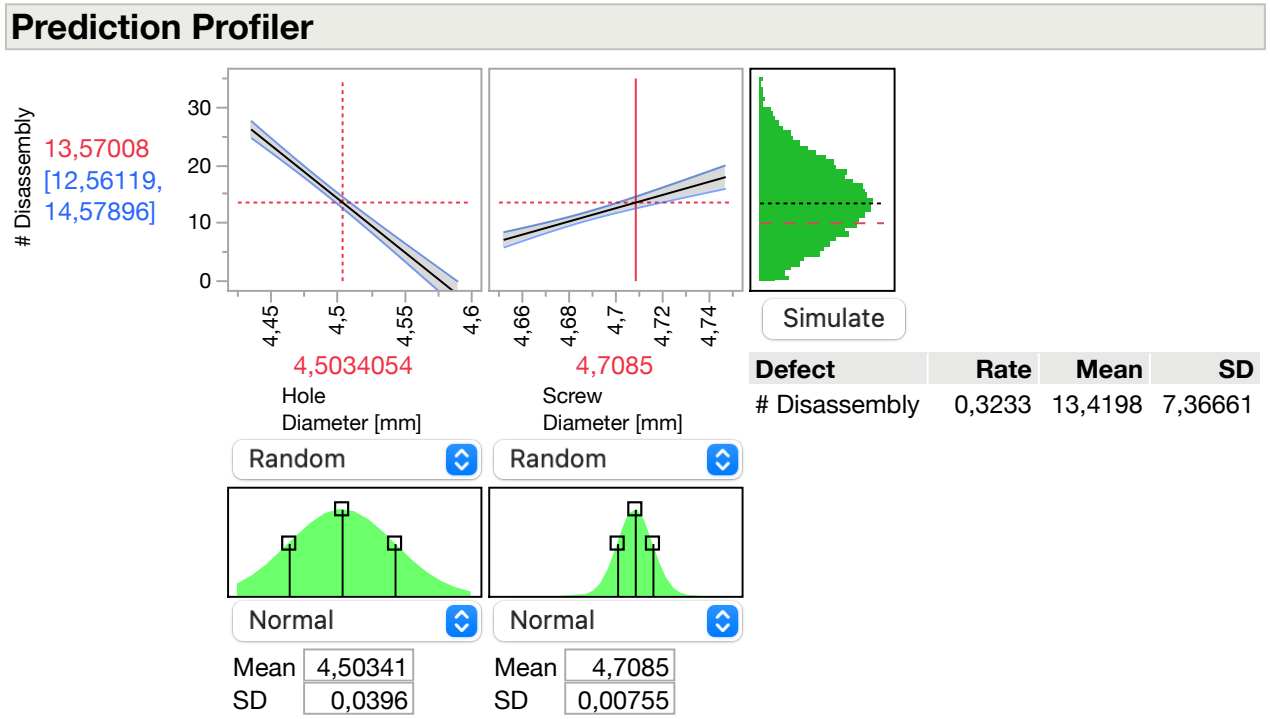


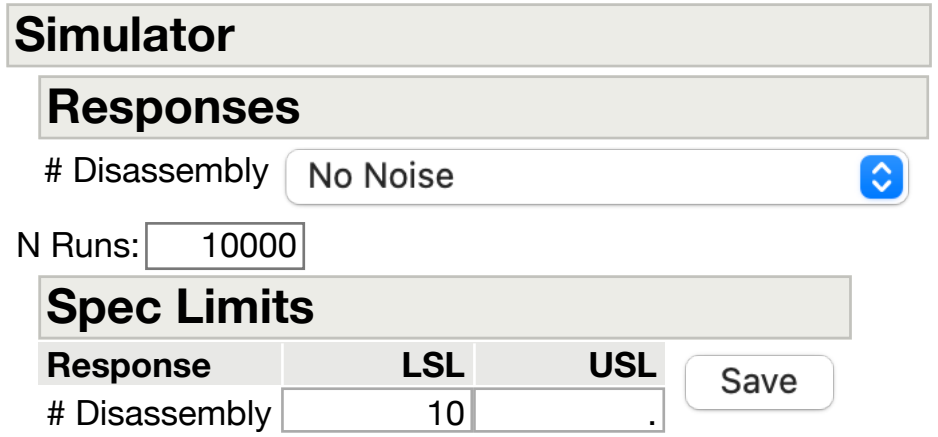


What happen if we ask the screw supplier to work in the nominal of the specification and reduce the variation of his process?

SIMULATOR – INTERACTION BETWEEN SCREW & FITTING HOLE

Scenario 1 – Doing nothing in the process and ask the screw supplier to deliver the mean in the nominal and to reduce the variation

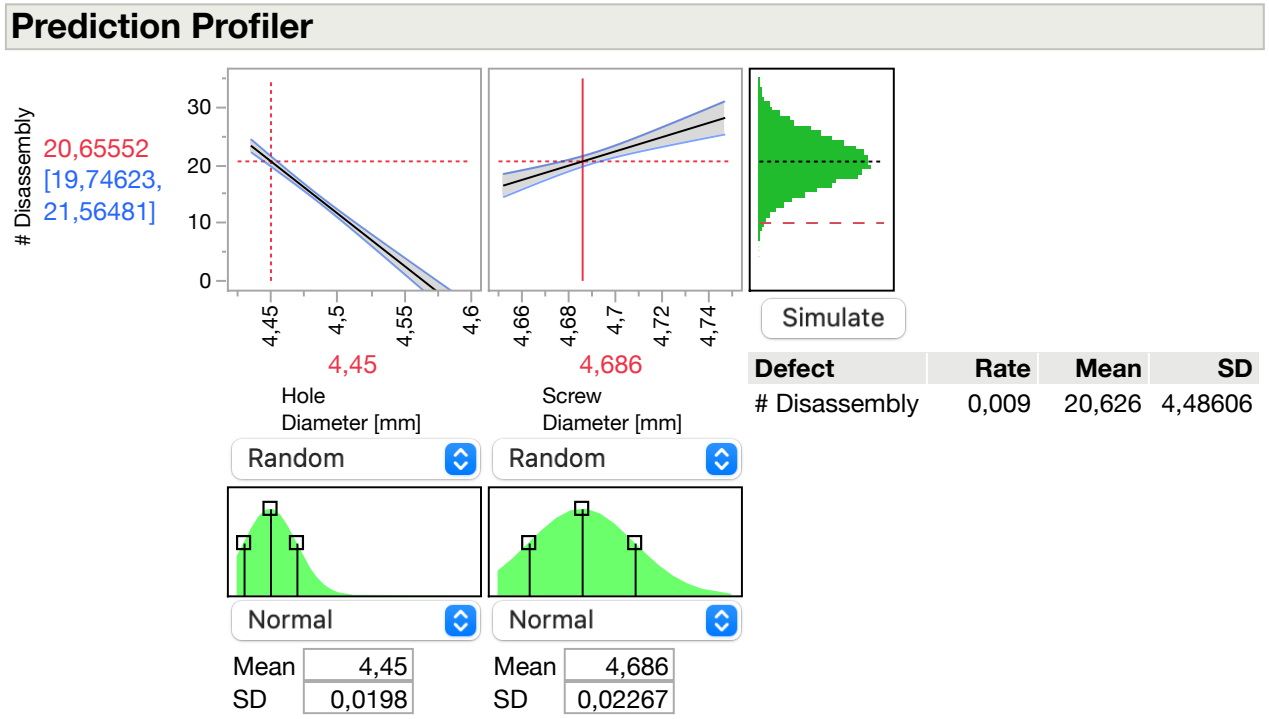


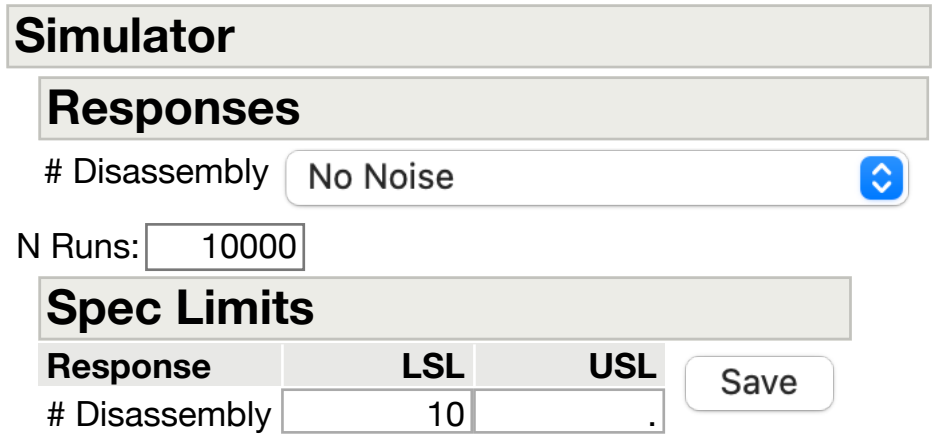


Little benefit and too much effort. What happen if we work in our process?

SIMULATOR – INTERACTION BETWEEN SCREW & FITTING HOLE

Scenario 2 – Reducing the fitting holes diameters mean and variation.





Even with the screw variation, the process would work with a mean of 21 disassembly, and the worst scenario would be 10 disassembly.

HYPOTHESIS

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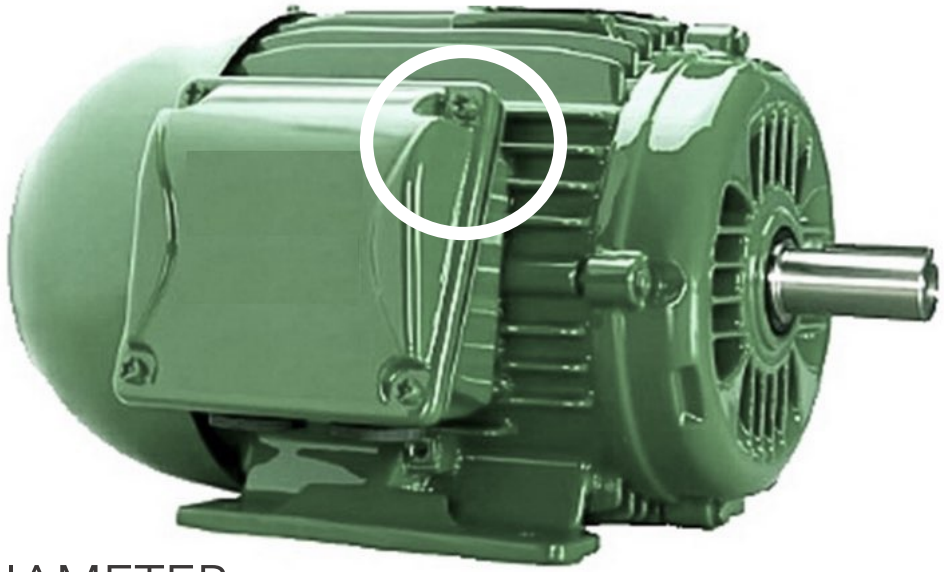


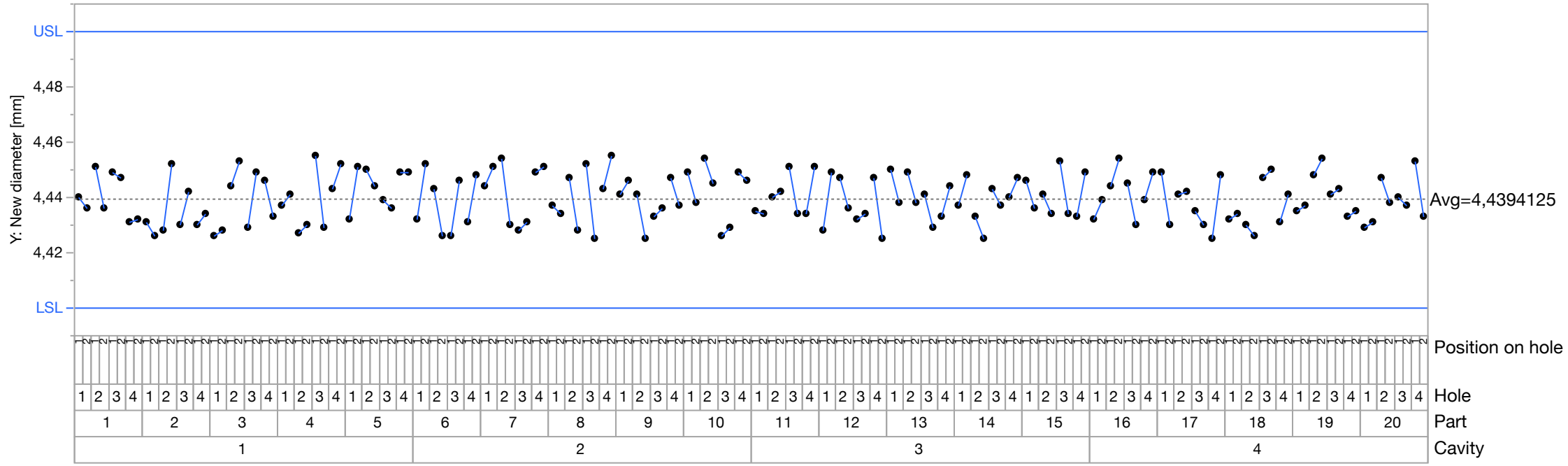
ACTION PLAN

After sharing the results and predictions to the leadership, actions have been taken in the aluminum injection mold. The pin used to create the fitting hole was replaced.

The modified mold delivered the following results for validation.

VALIDATION

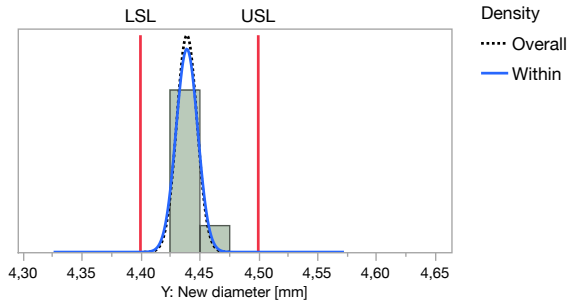
Variability Chart for Y: New diameter [mm]



VALIDATION

Y: New diameter [mm] Capability

Histogram



Process Summary

LSL	4,4
USL	4,5
N	160
Sample Mean	4,439412
Within Sigma	0,009158
Overall Sigma	0,008576
Stability Index	0,936429

Within sigma estimated by average moving range.

Within Sigma Capability

Index	Estimate
Cpk	1,435
Cpl	1,435
Cpu	2,205
Cp	1,820

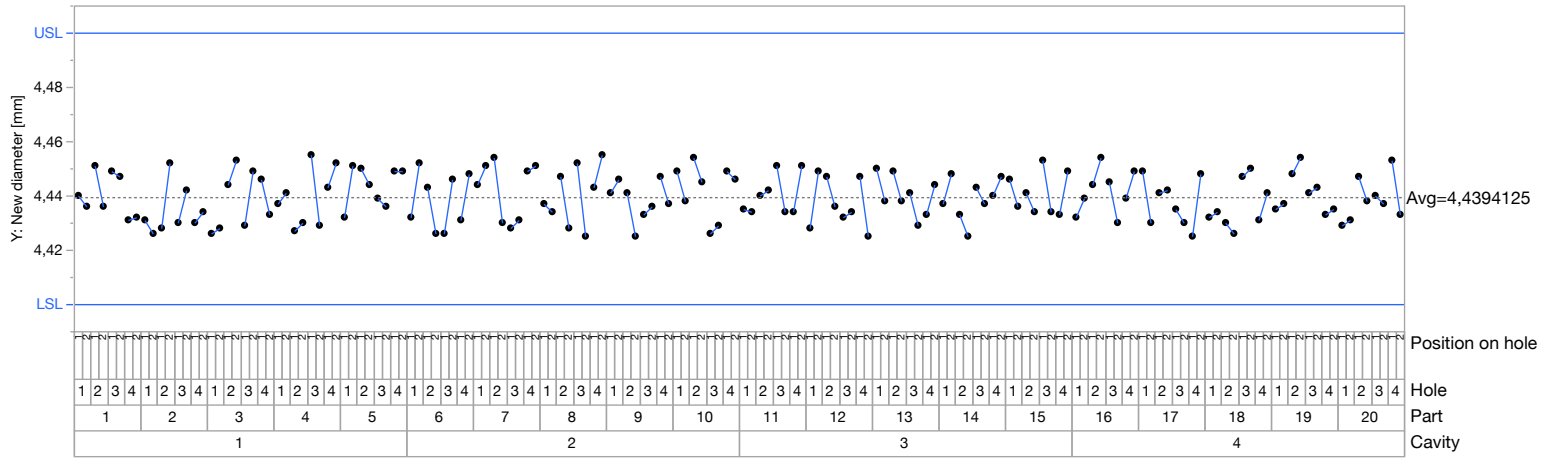
Overall Sigma Capability

Index	Estimate
Ppk	1,532
Ppl	1,532
Ppu	2,355
Pp	1,944

Nonconformance

Portion	Expected Within PPM	Expected Overall PPM
Below LSL	8,3959684	2,154079
Above USL	1,8448e-5	8,0203e-7
Total Outside	8,3959868	2,1540798

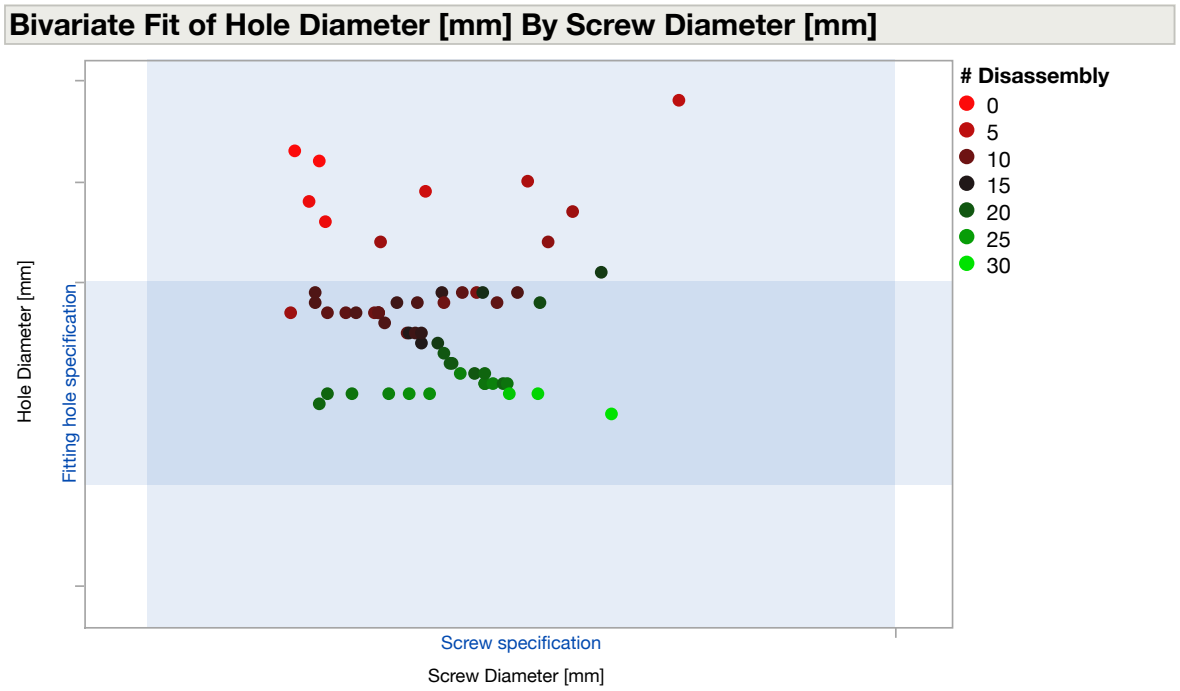
Variability Chart for Y: New diameter [mm]



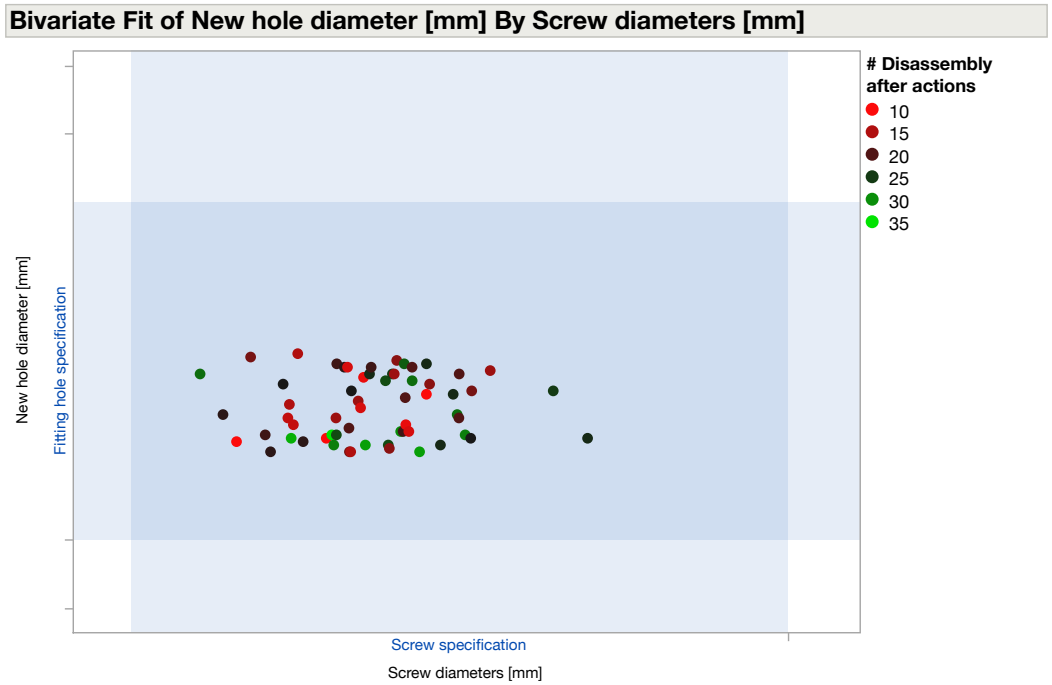
VALIDATION

Before and after actions comparison

BEFORE



AFTER



Matheus Luchese Sguissardi
Lean Six Sigma Master Black Belt
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PROBLEM
SOLVED

MATHEUS LUCHESE SGUISSARDI

Mechanical Engineer, MBA in Project Management and Lean Six Sigma Master Black Belt certified by Six Sigma Academy & Company – UK.

10 years of experience with Six Sigma Programs in Multinational Companies, founder of the Plana Consulting & Trainings in Brazil and professor of Six Sigma topics at a Mexican University and a Brazilian Institution of Postgraduate Courses.

thank you