3DCS GeoFactor Circular Distribution

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Abstract

The 3DCS development team has enhanced capability and simplified our Contributor analysis for Diametrical Tolerance Zones.

Enhancements include

1. Merge the traditional HLM Sensitivity analysis and GeoFactor analysis.
2. Match the GeoFactor coefficient to what a user would expect from a linear tolerance stack to our GeoFactor Equation Based Analysis.

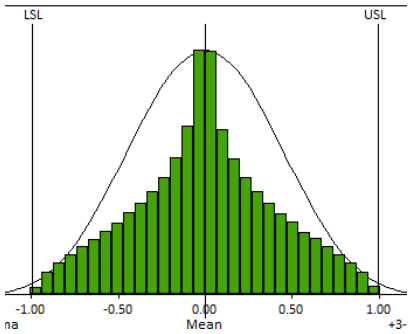
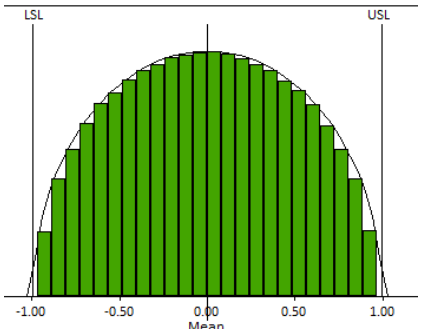
Problems With Previous Solution Methodology

Current versions of 3DCS correctly model the Normal 2D distribution.

If a user selects Uniform, Triangle or Trapezoidal distribution, then there is lower variation than expected due to the geometric effects of a circular tolerance zone.

For example, if a user selects a Uniform Distribution on the diameter, then the resulting distribution will be concentrated near the center of the diametrical zone.

Uniform Diametrical Distribution (measured in a direction perpendicular to the axis):

7.9.0.2 and earlier	**8.1.0.0**
	
6-Sigma: 1.225 * Range	6-Sigma: 1.5 * Range

Current Solution Methodology

Our strategy is consistent with the GeoFactor assumption of a linear model.

The new GeoFactor Analysis assumptions:

1. Linear model
2. Variation σ_{xi}^2 is additive.
3. GeoFactor is the geometric effect of geometry
4. $\sigma_y^2 = \Sigma\ GF_i * \sigma_{xi}^2$
5. σ_{xi} is the standard deviation of the distribution.

For GeoFactor analysis when the normal distribution is selected, the σ_{xi} = Tol/6. When non-normal distributions are selected, then σ_{xi}= f(Tol). For example, for a uniform distribution σ_x = 0.288675 Tol and for a Triangular distribution σ_x = 0.204124 Tol. And, the assumptions listed above are still true.

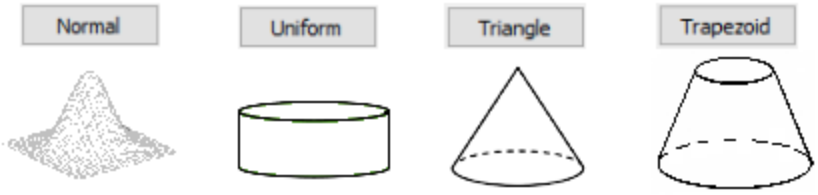
GeoFactor Analysis vs Monte Carlo Analysis

When using a circular tolerance zone and non-Normal distributions, the GeoFactor contribution will not match the Monte Carlo simulation. 3DCS will over-predict when compared to Monte Carlo Analysis due to 2D and 3D effects.

If a user would like Contributor analysis that is consistent with Monte Carlo analysis, we recommend users leverage the Simulation Based Sensitivity in the Advanced Analyzer and Optimizer (AAO) Add-on.

Future Enhancements for 3DCS Distributions

The 3DCS 8.1.0.0 release, ~Q2 2024, will have better support for GD&T with Diametrical Zones and non-normal distributions. 3DCS will simulate the correct 2D distribution for Normal,Uniform, Triangle and Trapezoid distributions.



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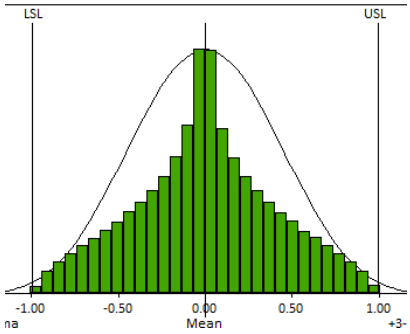
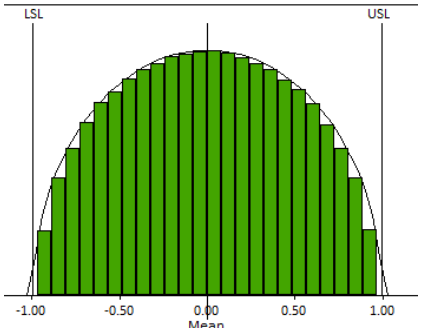
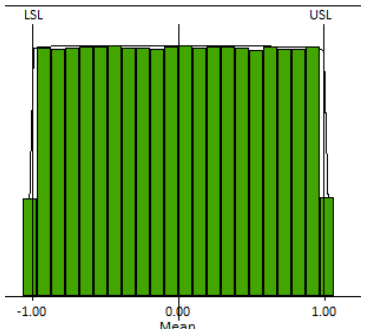
For example, if a user selects a Uniform Distribution on the diameter, then the resulting distribution will be concentrated near the center of the diametrical zone.

Uniform Diametrical Distribution (measured in a direction perpendicular to the axis):

7.9.0.2 and earlier	**8.1.0.0**
	
6-Sigma: 1.225 * Range	6-Sigma: 1.5 * Range

We will still slightly overpredict with the GeoFactor Analysis relative to the Monte Carlo analysis but that is because of the small difference between a “hockey puck” distribution and an actual linear Uniform distribution.
Here is an example for Uniform distribution:

<u>Not changing</u>
Uniform Linear Distribution (measured in variation direction):

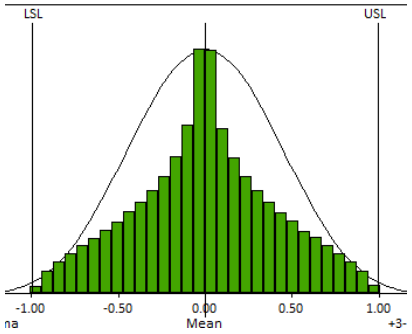


6-Sigma: 1.732 * Range

Changing

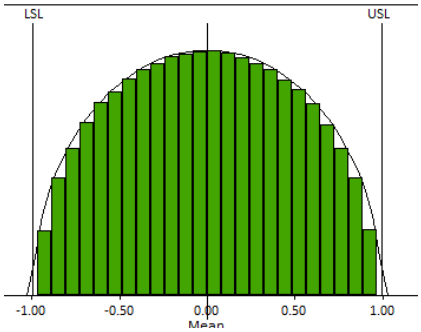
Uniform Diametrical Distribution (measured in a direction perpendicular to the axis):

7.9.0.2 and earlier



6-Sigma: 1.225 * Range

8.1.0.0



6-Sigma: 1.5 * Range

We have found that user expectation is that a Uniform distribution for a Diametrical Zone is equivalent to a Uniform distribution for a Linear Zone. This isn't exactly the case since the area of the circle is not consistent when measuring along a vector perpendicular to the axis of the circle. But users want to replace their 1D stacks with our GeoFactor Equation-Based Analysis tool and in order to make them more confident in their results we had to apply the scaling factor of 1.732 for Diametrical Zones.

The major drawback to making this change is that we have now decoupled the Contributor Analysis from accurately predicting where the variation comes from, in the Monte Carlo analysis. For example, any Uniform distribution (with Diametrical Zone) will see its predicted variation overstated by a factor of 1.732 (the Linear coefficient) / 1.5 (the Diametrical coefficient).

The DCS technical team asserts the Contributor Analysis is an estimate of how much variation is coming from each contributor.

In the 8.0 release the 3DCS software will have the new distributions (Normal, Uniform, Triangle, Trapezoid, etc.) and the legacy distributions (how we currently do it). The legacy distributions can go back to using the old coefficients that will perfectly (or near perfectly) line up with their expectations. The new distributions can then be the ones that used our preferred approach.