



Carl Zeiss Industrial Metrology



Carl Zeiss IMT Algorithms





Carl Zeiss IMT Why Least Squares ?





Carl Zeiss IMT Why Maximum Inscribed ?



- Provides the correct result for
 - Size
 - Location
- On *internal* diameters
- When used with enough data density
- However it is not as stable as Least Squares because..
 - It fits on extreme points



Carl Zeiss IMT Why Minimum Circumscribed ?



- Provides the correct result for
 - Size
 - Location
- On external diameters
- When used with enough data density
- However it is not as stable as Least Squares because..
 - It fits on extreme points



Carl Zeiss IMT Why Minimum Zone ?



- Provides the correct result for
 - Form

- When used with enough data density
- However it is not as stable as Least Squares because..
 - It fits on extreme points





• What's the difference between Outer Tangential and Maximum Inscribed on an *internal* diameter ?







• What's the difference between Outer Tangential and Minimum Circumscribed on an <u>external</u> diameter ?







- What's the difference between Inner Tangential and Minimum Circumscribed on an *internal* diameter ?
- Nothing !
 Nothing !
 Is this a functional mating size fit?
 No !
 When might you use it ?
- To determine if there is enough material on a casting so that it will cleanup during machining, to evaluate the maximum size, or to evaluate wall thickness



- What about Inner and Outer Tangential ?
 What's the difference between Inner Tangential a
 - What's the difference between Inner Tangential and Maximum Inscribed on an <u>external</u> diameter ?
 - Nothing !

Carl Zeiss IMT

- Is this functional mating size fit?
- No !
- When might you use it ?





Maximum

Carl Zeiss IMT So why do we have Inner and Outer Tangential ?



We make it visible.

 Because it is more descriptive for Planes and Lines



Carl Zeiss IMT So lets generalize the math



- We have Gaussian Least Squares fits which minimize the square root of the sum of the squared errors
 - In this type of fit all data points have the same weight in determining the fit
 - There is *absolutely nothing functional* about this type of fit





- We have <u>extrema</u> fits (Inner and Outer Tangential, Max Inscribed, Min Circumscribed) which fit on the high points of the feature
 - In this type of fit only the high points have any weight in determining the fit
 - This is <u>absolutely functional</u> fitting for size and location like when mating a plane against a granite surface plate, or finding the slip fit pin that just fits into a bore <u>Maximum</u>

Inscribed Circle





- We have <u>minimum zone</u> fits which equally balance the high and low point of the feature
 - In this type of fit only the high point and low point have any weight in determining the fit
 - This is *absolutely functional* fitting for form analysis



Carl Zeiss IMT Summary



- Know the basic best math of each algorithm
- Understand the potential difference (pros and cons) each algorithm can provide
- Apply the algorithm that meets the needs of the application accordingly
- There is no one simple rule that can define what to use and when, as a CMM programmer, you must help decide what is best on a case-by-case basis



Carl Zeiss IMT Summary



- You need to consider
 - Data density
 - Purpose of the measurement
 - Accept / Reject
 - Process control
 - Correlation concerns





We make it visible.

- LSQ –2D Best Fit
 - Textbook math (Gauss) that minimizes the square root of the sum of the squared deviations
 - In certain cases it can reject a good part
 - Best use is for understanding the process, not for accept/reject analysis

	Best Fit3						
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• L1 – 2D Best Fit

- Zeiss math that tries to show the worst case error more clearly
- In certain cases it can reject a good part, and will do so more than LSQ
- Best use is for understanding the process, not for accept/reject analysis, and it does this better than LSQ at showing the process problem
- The geometric element is determined in such a way to minimize the sum of the deviation values.
- This best fit is insensitive against outliers and leads to a clear result with low computational effort.

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We make it visible.

- Minimum –2D Best Fit
 - Textbook math (Tschebychev) that minimizes the maximum deviation
 - Will at times reject a good part, but less frequently than LSQ
 - Best use is for accept/reject analysis

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We make it visible.

- Tolerance 2D Best Fit
 - Zeiss math that iteratively tries to accept the part like you would with a hard gage
 - Will accept the maximum number of parts
 - Best use is for accept/reject analysis and does a better job than Minimum

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	Best Fit3					<u></u>	
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Questions