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Form Measurement

AMETEK
ULTRA PRECISION TECHNOLOGIES

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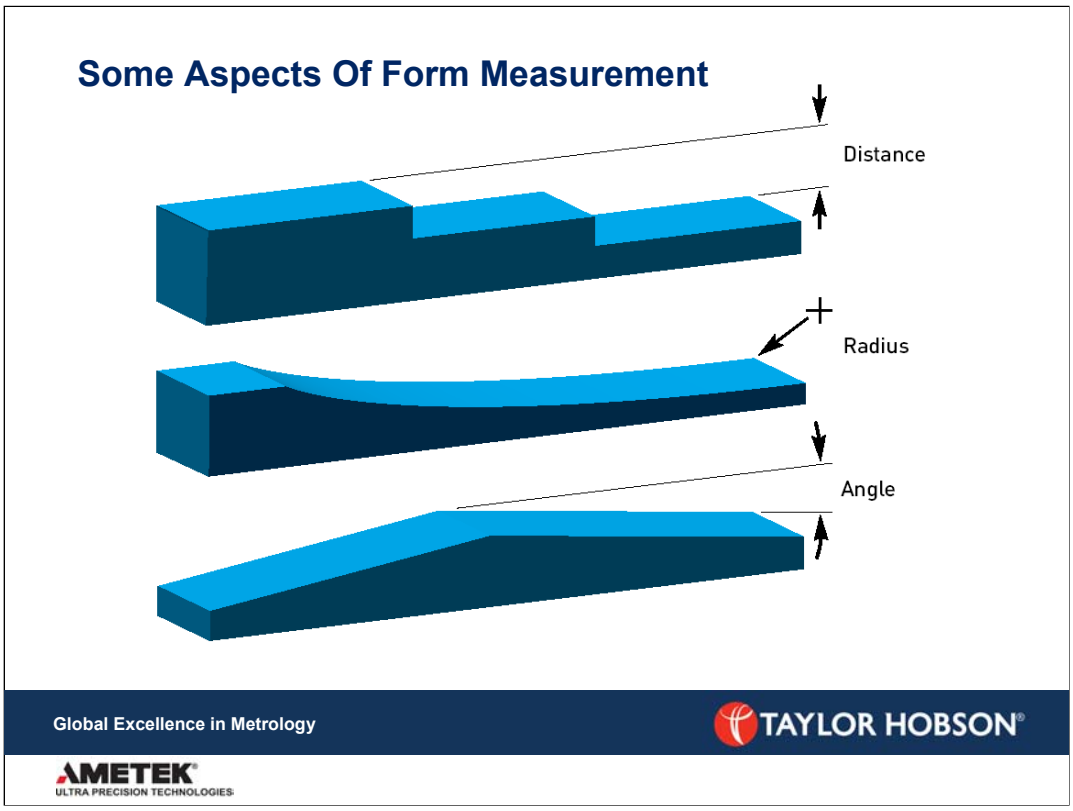


Gauge Range, Resolution and Linearity are important for Form Measurement.

Often, a large range and excellent resolution are required.
This means that the calibration method is very important.

Some considerations are:

a)Gauge range , Resolution and Linearity

b)Calibration Method / Ball Radius

c)Stylus Type & ensure Stylus tip is suitable

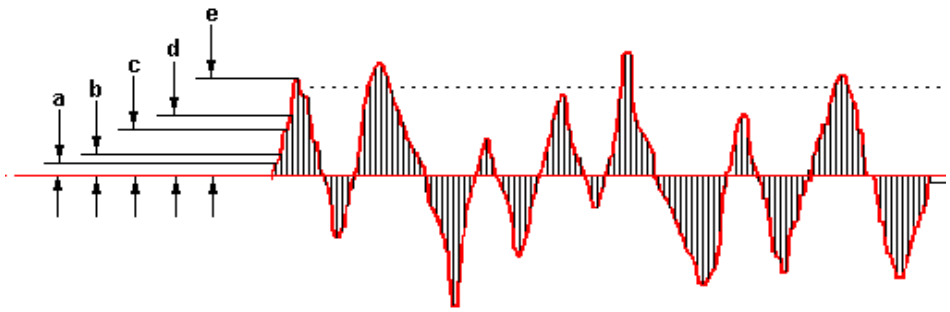
d)Ensure measurement is within the calibrated range

e)Ensure part does not contact the stylus tip at a position which was not covered by the calibration. This means that the stylus length, the stylus tip radius and the calibration ball radius must be considered.

f)Ensure stylus does not 'flank'

g)Component alignment and fixturing.

Form Fit : Least Squares Line



$a^2 + b^2 + c^2 + d^2 \ldots. = \text{minimum}$

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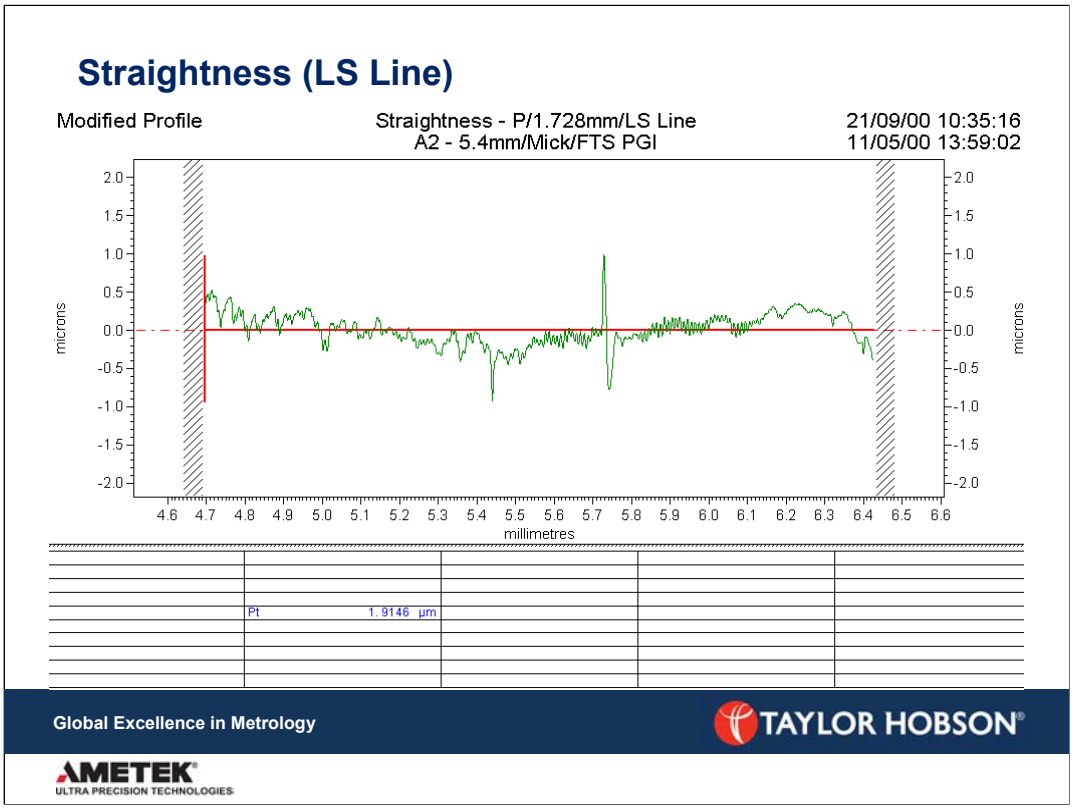
Parameters such as peak to valley need to be related to a reference line or mean line.

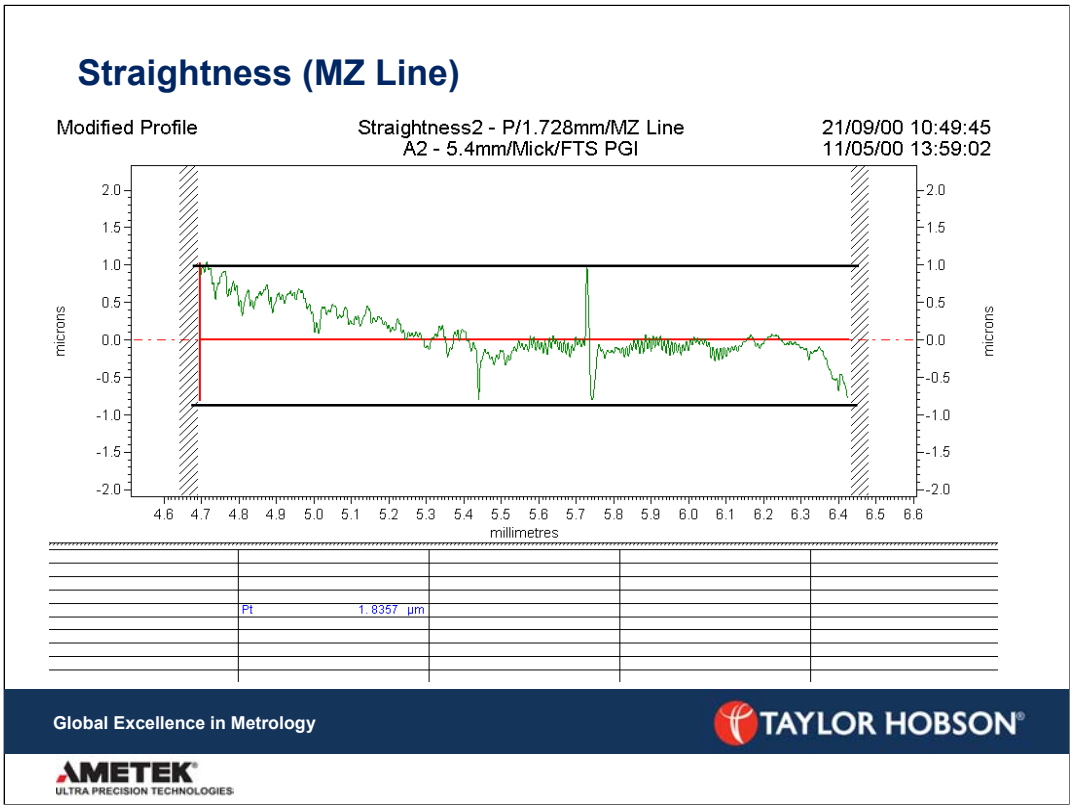
The least squares line is a line which bisects the profile such that the areas above and below this line are equal and are kept to a minimum.

This is shown in the formula:

$a^2+b^2+c^2+d^2+\ldots..$ Is at a minimum.

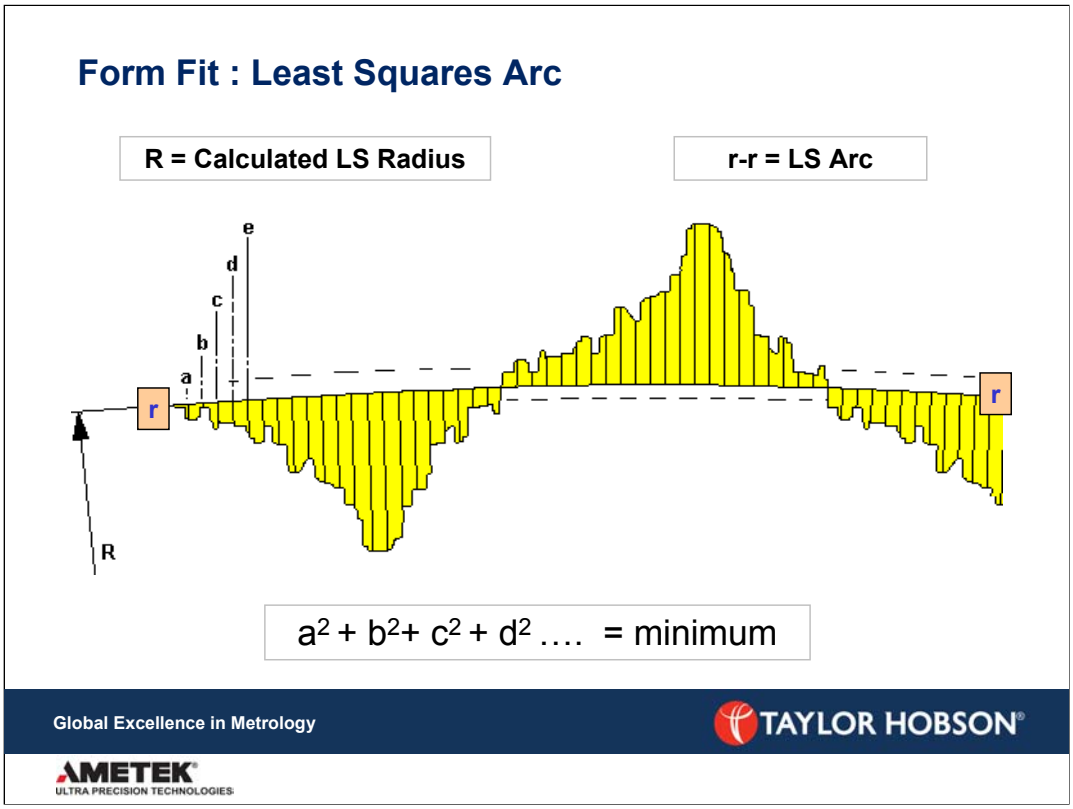


For a straightness result the measured data can be fitted to an LS line the resultant Pt value is the maximum deviation from the LS line i.e the component straightness error.



The measured data can also be fitted to an MZ (minimum zone) reference. The minimum zone reference is defined by a pair of straight, parallel lines which just enclose the entire profile such that the distance between the lines (the zone) is a minimum. The displayed reference line is the mean position between these two lines and to which all parameter calculations are referenced. The Pt value displayed is the straightness error. Usually the MZ result will give a smaller straightness error than the LS result over the same profile.

It must be said that using an MZ reference is not as stable as an LS reference due to its susceptibility to random peaks and spikes.



The radius of a measured surface can be determined by fitting an arc to the measurement data. This is positioned such that the sum of the squares of the deviations of the profile from the line of the arc is a minimum, shown as:

$a^2+b^2+c^2+d^2+e^2$…..

The radius of this arc is then calculated.

The principles used are similar to those employed in the calculation of the Least squares Line.

Accuracy of Radius Measurement

Factors Affecting Radius Accuracy

Component Related	Instrument Related
Surface Finish of Component	Accuracy of Calibration
Form Error of Component	Condition of Stylus
Traverse Length / Included Angle	Traverse Datum Straightness

- Specify Form Error (Pt) as well as Radius
- Always Measure within Calibrated Gauge Range

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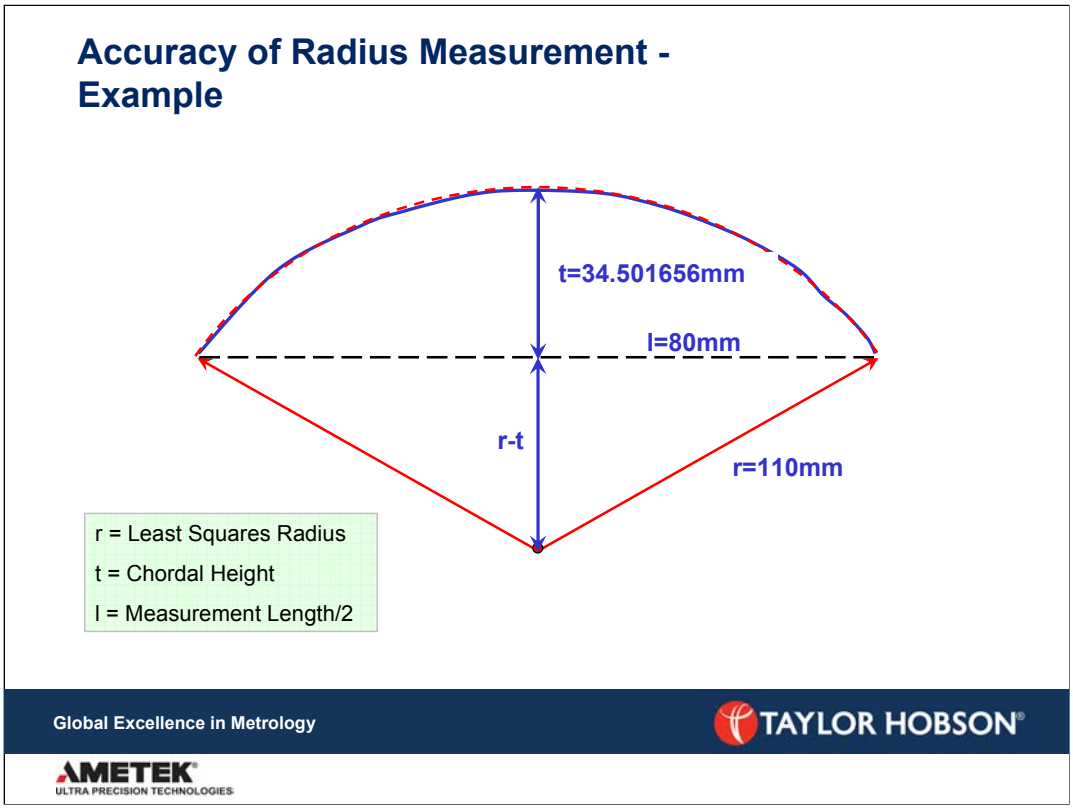
When measuring small radii, the surface roughness of the component and the value of the included angle have a major influence on the accuracy

For larger radii the accuracy depends more on the accuracy of calibration and traverse.

Always specify Pt as well as Radius.

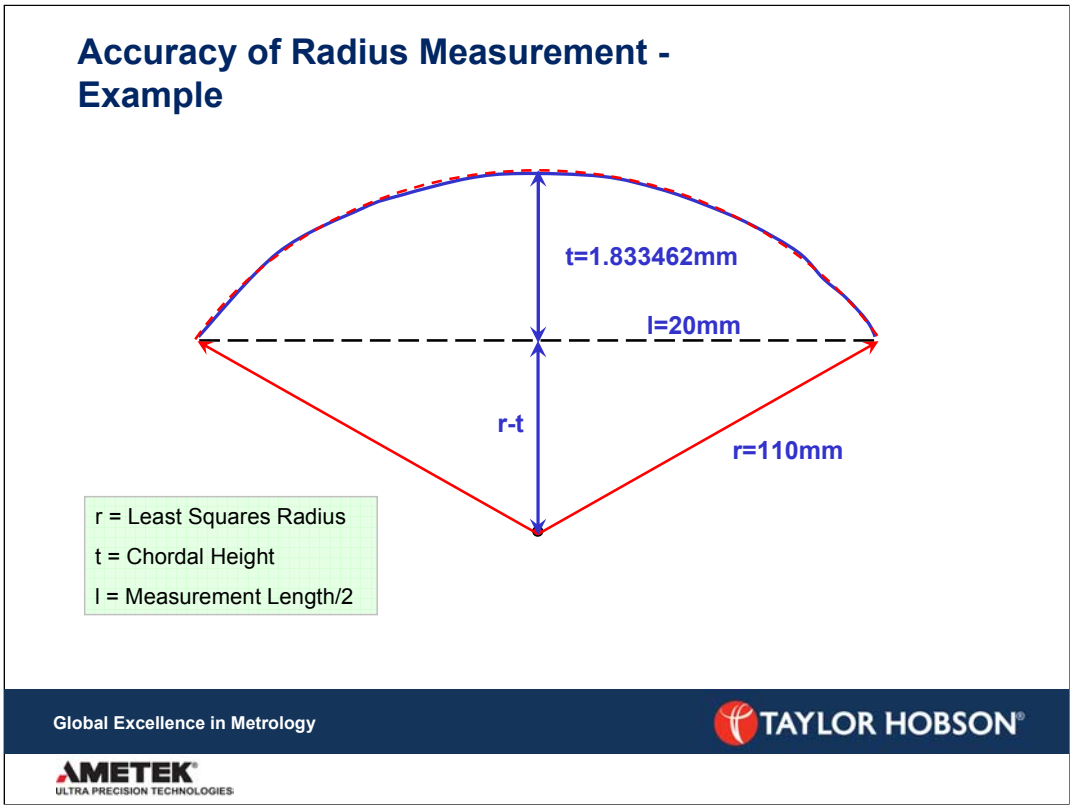


With reference to the diagram above can see a profile (coloured blue) with a slight form error, fitted through this profile is the least squares arc, shown here as a red dotted line.

Using the intersecting chords of a circle theorem we can say that :

So for example a measurement made over a radius of 110mm and a measurement length of 160mm will give a value for **t** as follows.

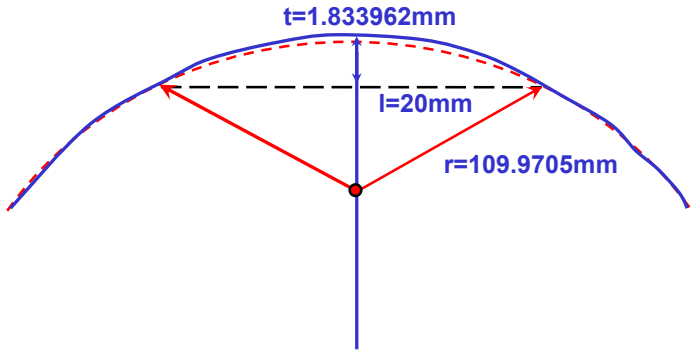
This will make the value for **t**= 34.501656mm.



If we now reduce the measurement or assessment length to 40mm for the same least squares arc of the same radius then we can say that:

This will make the value for **t**= 1.833462mm.

Accuracy of Radius Measurement - Example



r = Least Squares Radius
t = Chordal Height
l = Measurement Length/2

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The profile of this component like all components is not perfect, as we can see from the diagram above, there is an error in form. If we were to calculate a new least squares arc based on the area shown above then the value of **t** will change from the calculation in the previous slide which shows the calculation for a true arc.If the value of **t** is increased by 0.5µm to represent the new least squares arc calculation based on the form error in the profile, the value for **t** will now be changed from 1.833462mm to 1.833962mm.

Substituting this new value in the calculation will give:

$$r = \frac{20^2 + 1.833962^2}{2\,(1.833962)} \qquad r = 109.9705 \text{ mm}$$

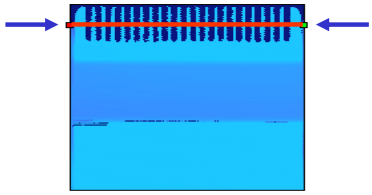
In conclusion care must be taken when trying to assess instrument accuracy based on small measurement lengths, the case above is not an error but the true radius at the assessed area. Over small measurement lengths the value of **t** has larger effects on radius calculation. Because of these factors when measuring radius and verifying instrument capability it is important to understand that the calibration standards are measured for radius based on the whole or majority of the surface. Standards with slight form errors will have different radius values at different parts of the profile.

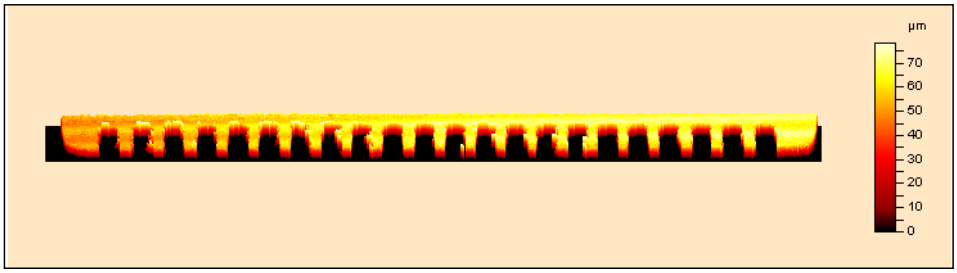
Form Exclusions

- Analysis of Interruptions in Radius (LS Arc)
- Straightness Analysis – Excluding Holes (LS Line)
- Software Levelling

Form Exclusions - Example

Straightness On Interrupted Surface





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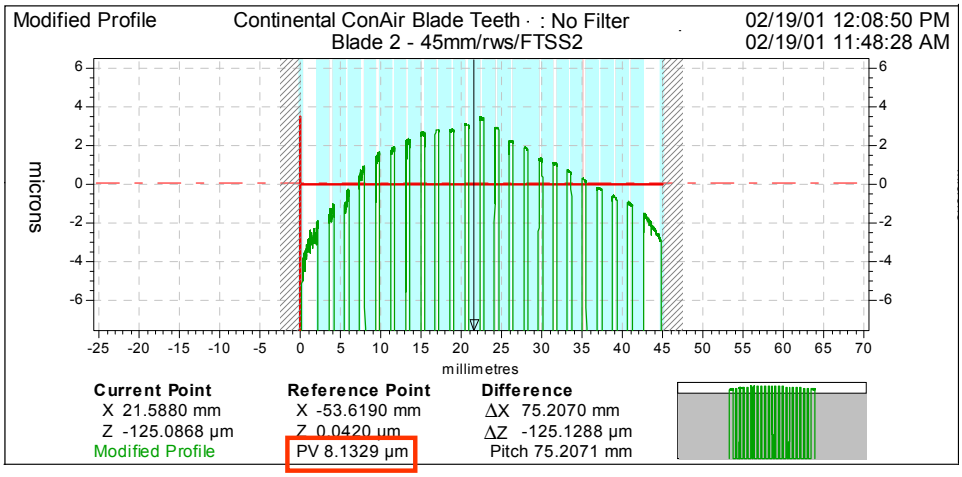
Note use of form fit exclusions (and auto-scale exclusions) to find the straightness of the blade teeth - many interruptions.

Straightness (PV) is 8.13microns.

Form Exclusions - Example



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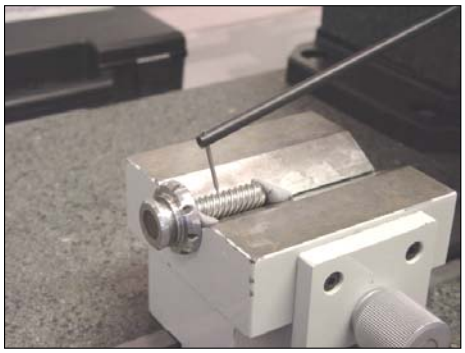
Note use of form fit exclusions (and auto-scale exclusions) to find the straightness of the blade teeth - many interruptions.

Straightness (PV) is 8.13microns.

Dimensional Measurement

- Angles Between Straight Surfaces
- Pitch, dx and dz between Radius Centres
- Intersections of lines / arcs
- Step Height & Distance Measurement

Dimensional Measurement - Example



- Profile
- Angle
- Radius

Summary

- Gauge Range, Resolution and Linearity are important for Form Measurement.
- Parameters such as peak to valley need to be related to a reference line or mean line.
- For a straightness result the measured data can be fitted to an LS line the resultant Pt value is the maximum deviation from the LS line
- The measured data can also be fitted to an MZ (minimum zone) reference.
  - using an MZ reference is not as stable as an LS reference due to its susceptibility to random peaks and spikes
- The radius of a measured surface can be determined by fitting an arc to the measurement data.
  - When measuring small radii, the surface roughness of the component and the value of the included angle have a major influence on the accuracy.
- Form fit exclusions (and auto-scale exclusions) can be used to find the straightness of a surface with interruptions.
- Dimensional Measurements can also be made including distance, step height and angle.

Contact us

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