



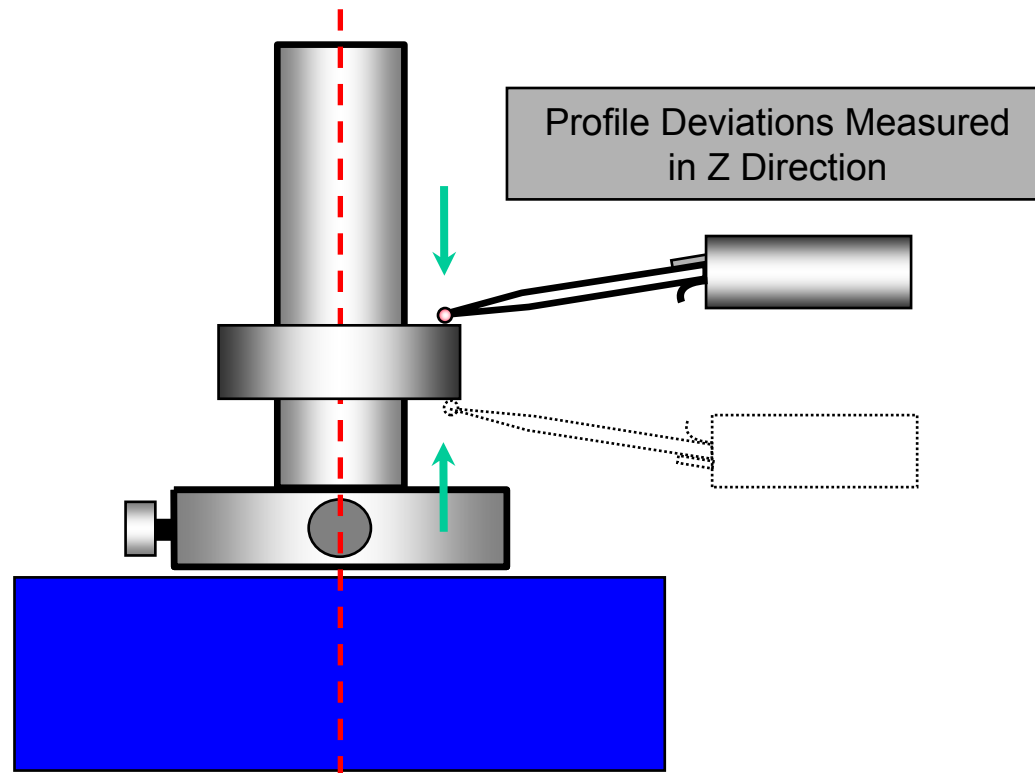
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Flatness and Squareness

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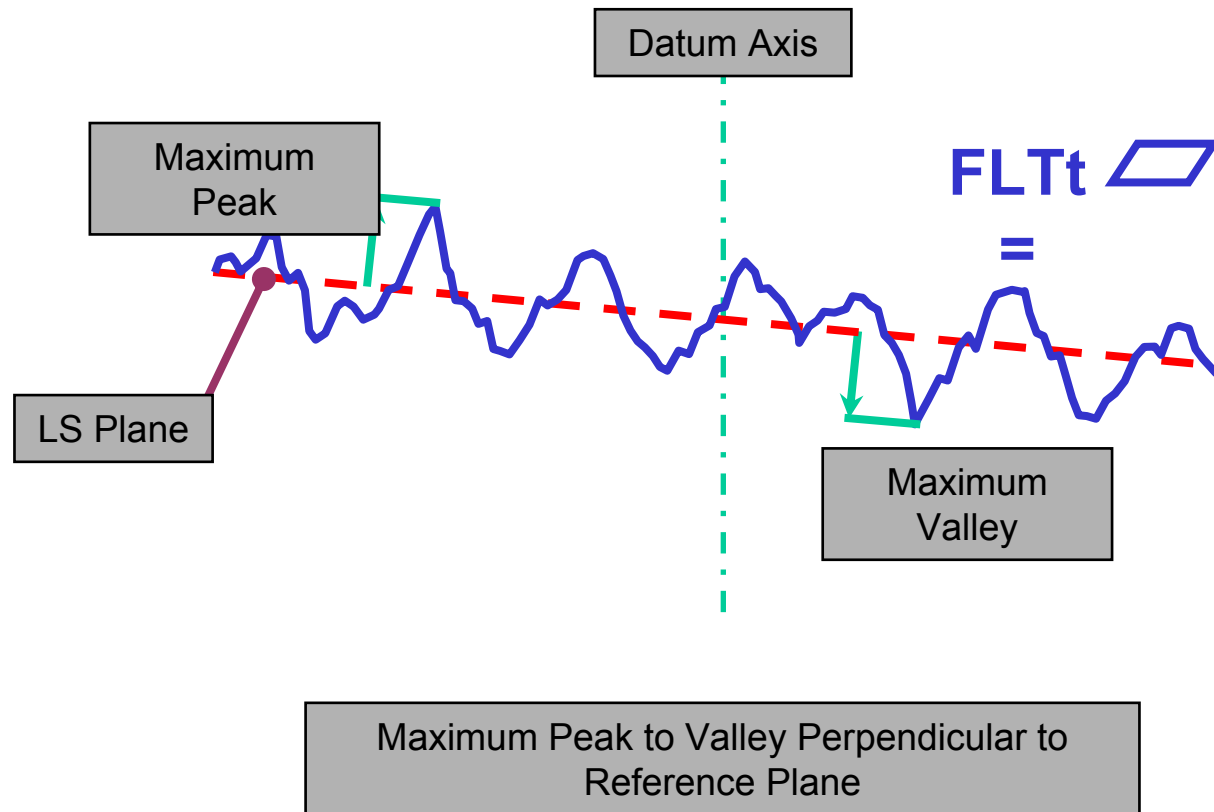
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Flatness Measurement Orientations



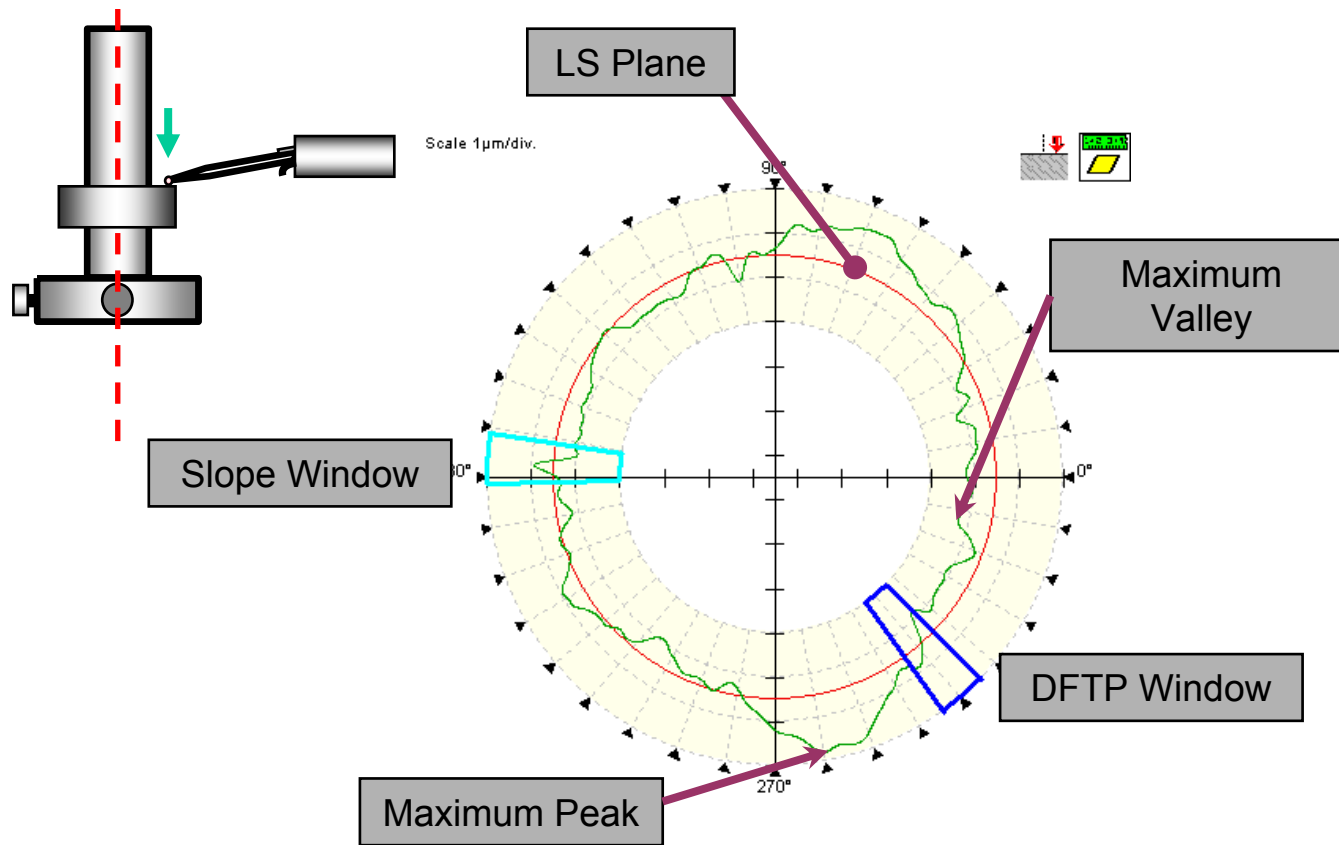
- On a lot of roundness systems it is possible to measure flatness, this is done by rotation of the gauge such that stylus deflection is in a vertical (Z) direction.
- This can apply equally for both upper and lower surfaces.
- All spindle movement and data collection methods are the same for that in roundness mode.

LS Flatness Definition



- Flatness can be analyzed by quantifying deviations from a least squares reference plane.
- A least squares reference plane is a plane where the areas above and below the plane are equal and are kept to a minimum separation.
- Flatness is calculated as the highest peak to valley normal to this reference plane.

LS Flatness Polar Result

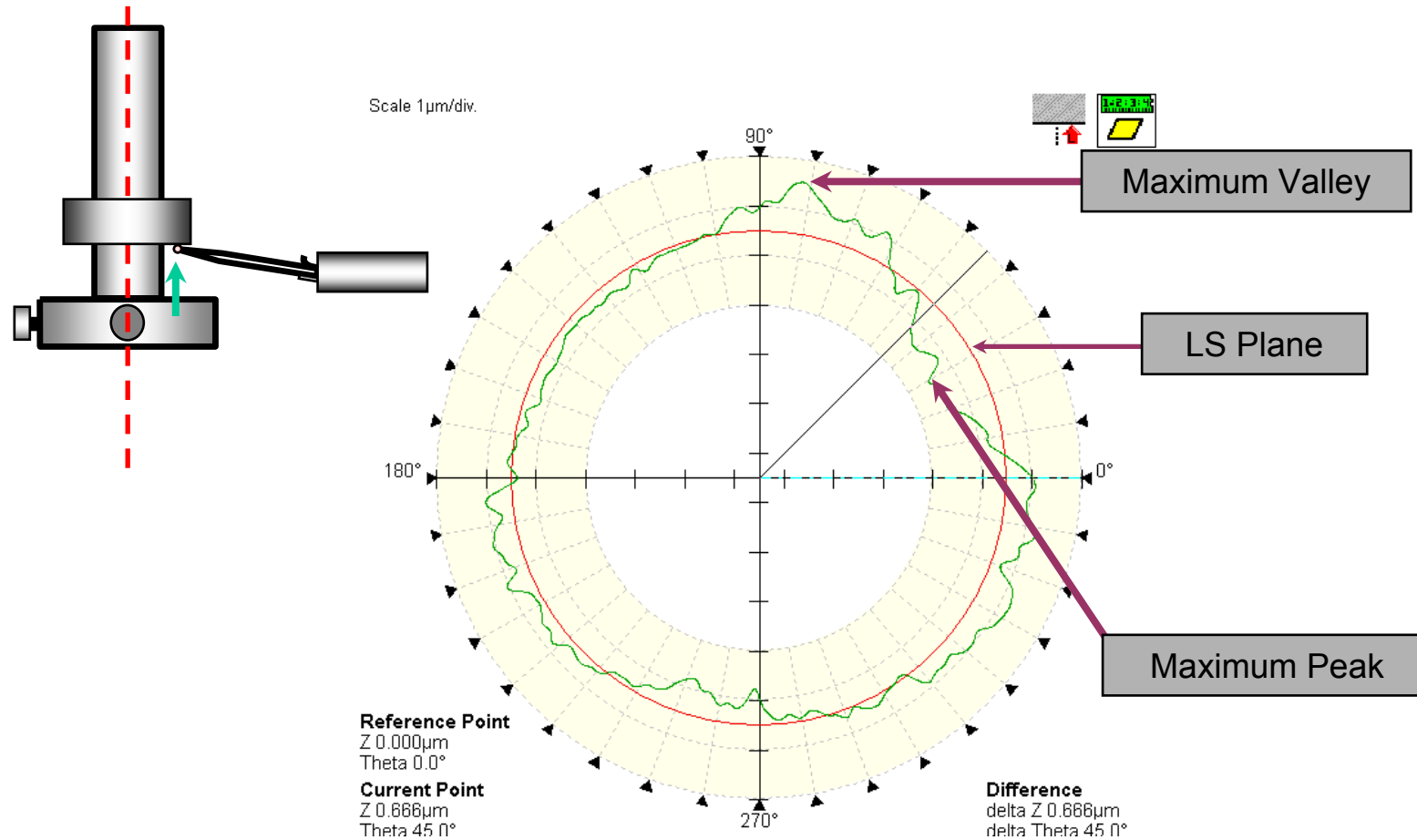


- When the flatness measurement has been analysed we get a plot with the 1st harmonic removed, hence the profile is concentric to the paper.
- Because we are using a polar profile to view a flatness measurement, deviations outside of the LS plane represent peaks and deviations on the inside represent valleys.
- This is only the case for flatness measurements made with the stylus contacting downwards onto the surface.

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LS Flatness Polar Result



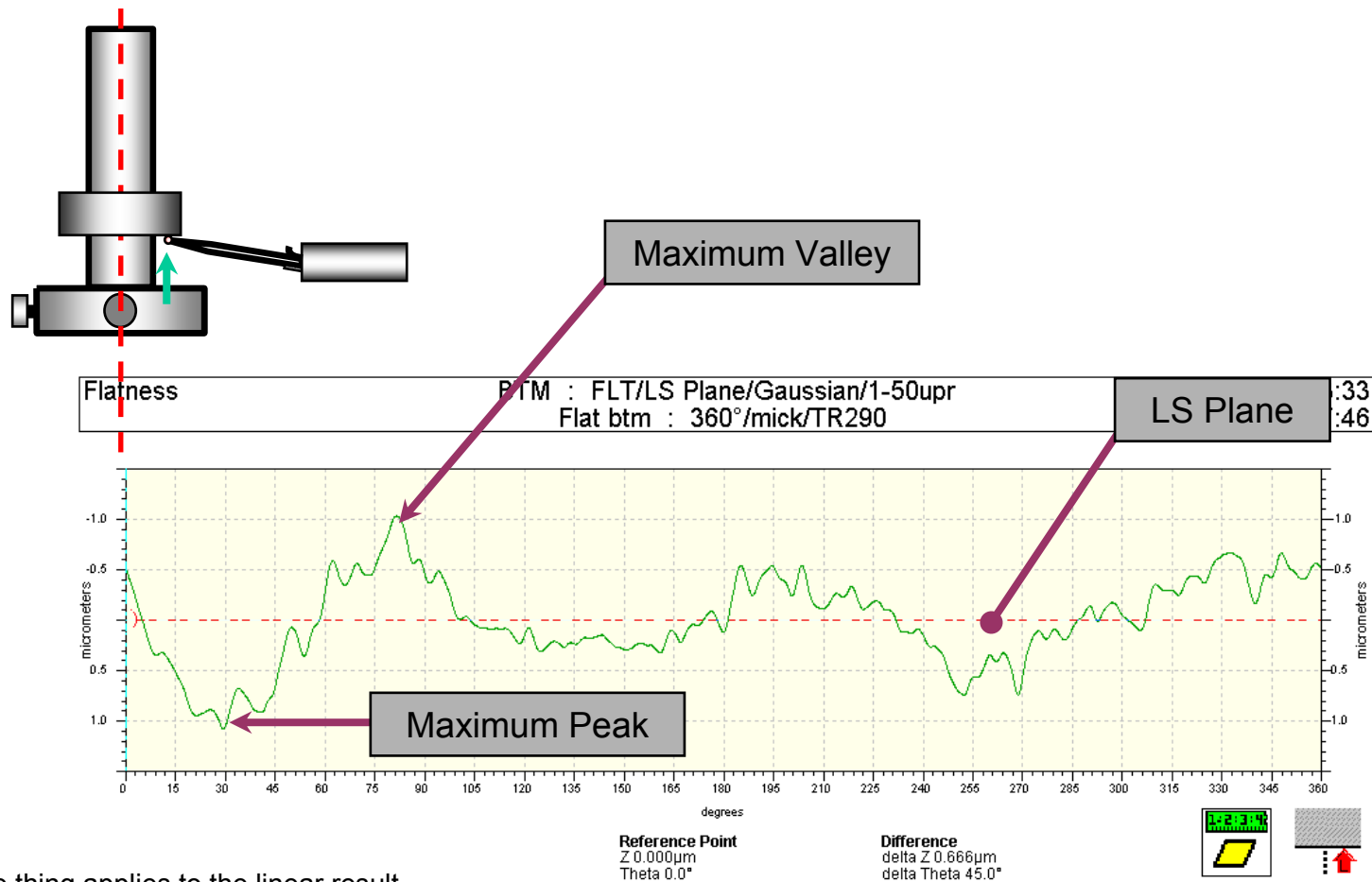
Now when we analyse flatness because the surface is upside down (stylus contact direction up) then deviations on the outside of the LS plane are valleys and deviations on the inside of the plane are peaks.

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LS Flatness Linear Result



The same thing applies to the linear result.

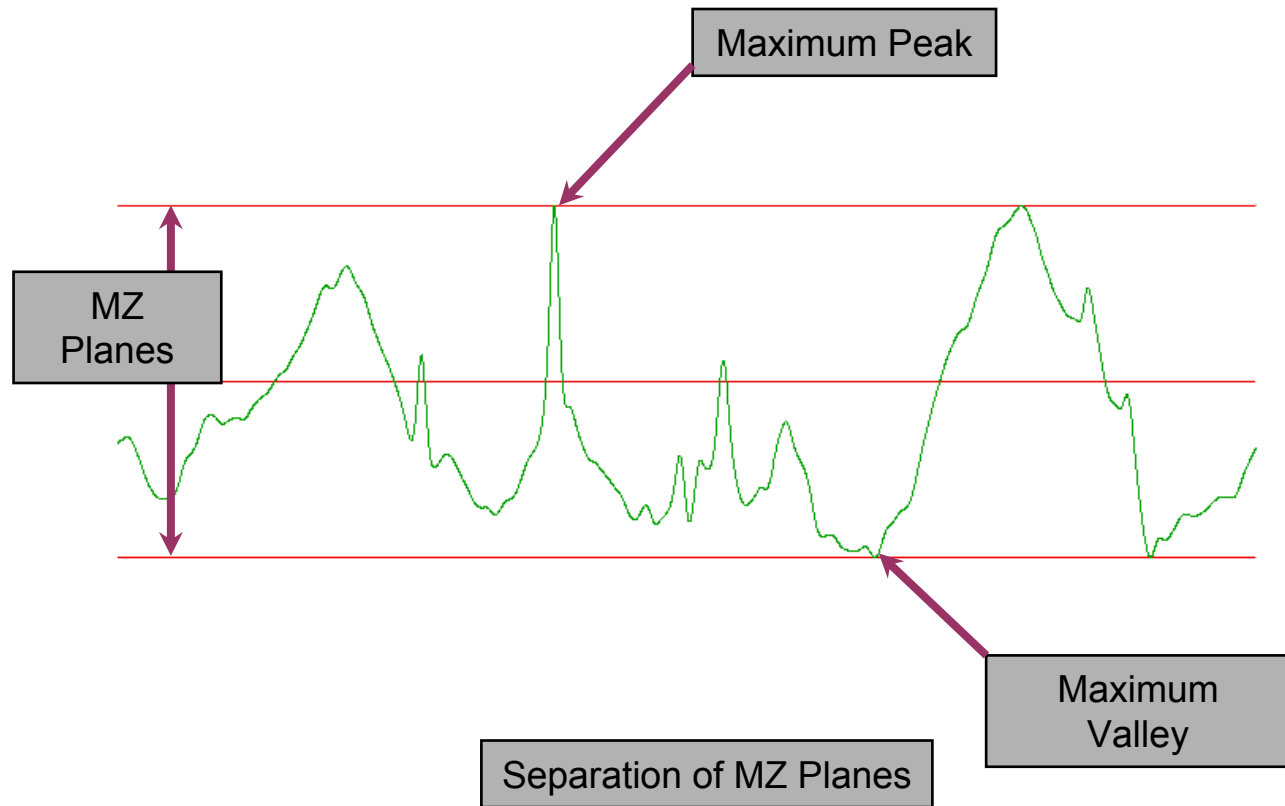
Measuring the same sample as in the previous slide, the same surface again upside down (stylus contact direction up) now the deviations above the LS plane are valleys and deviations below the plane are peaks. So basically we've taken the polar plot and stretched it out to show in a Linear format.

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MZ Flatness Definition



- Flatness can also be analysed by a minimum zone calculation, defined as two parallel planes that totally enclose the data and are kept to a minimum separation.
- The flatness error can be defined as the separation of the two planes.
- Generally the MZ flatness value will give a smaller result than the LS flatness due to the zone type of fit to the data.

Flatness Analysis Options

- Filter Options

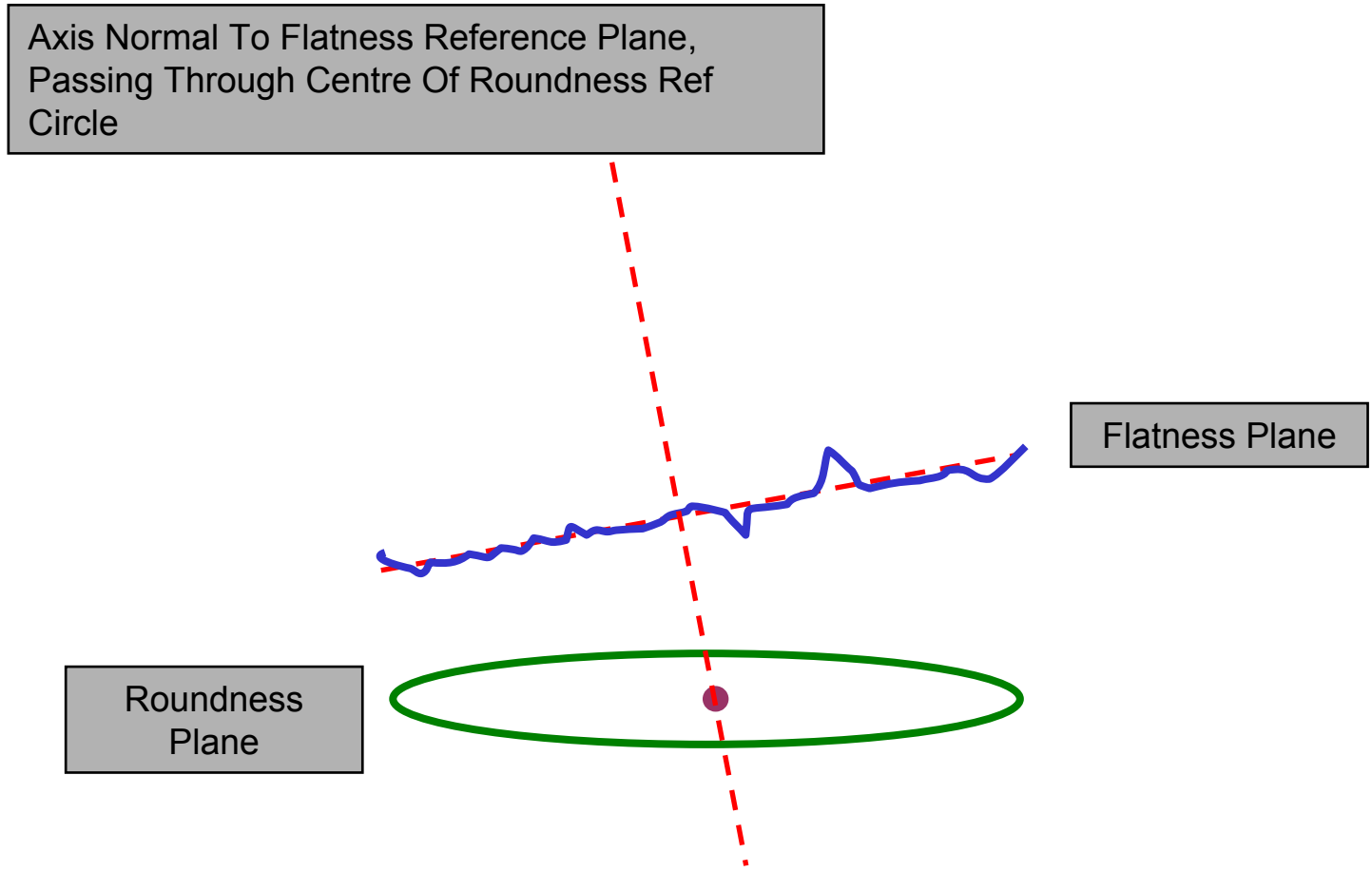
— Gaussian	}	1-15	UPR
— 2CR		1-50	UPR
		1-150	UPR
		1-500	UPR

- Parameters

- Harmonics
- DTFP (Departure from True Plane)
- Max / Average Slope

- The analysis options used in Flatness measurement are essentially the same as those used for roundness. The same filter types and values are available.
- The harmonics and slope calculations are also the same as for roundness.
- DTFP (Departure From True Plane) replaces the roundness, DFTC (Departure From True Circle). The same method of window settings can be applied to the data.

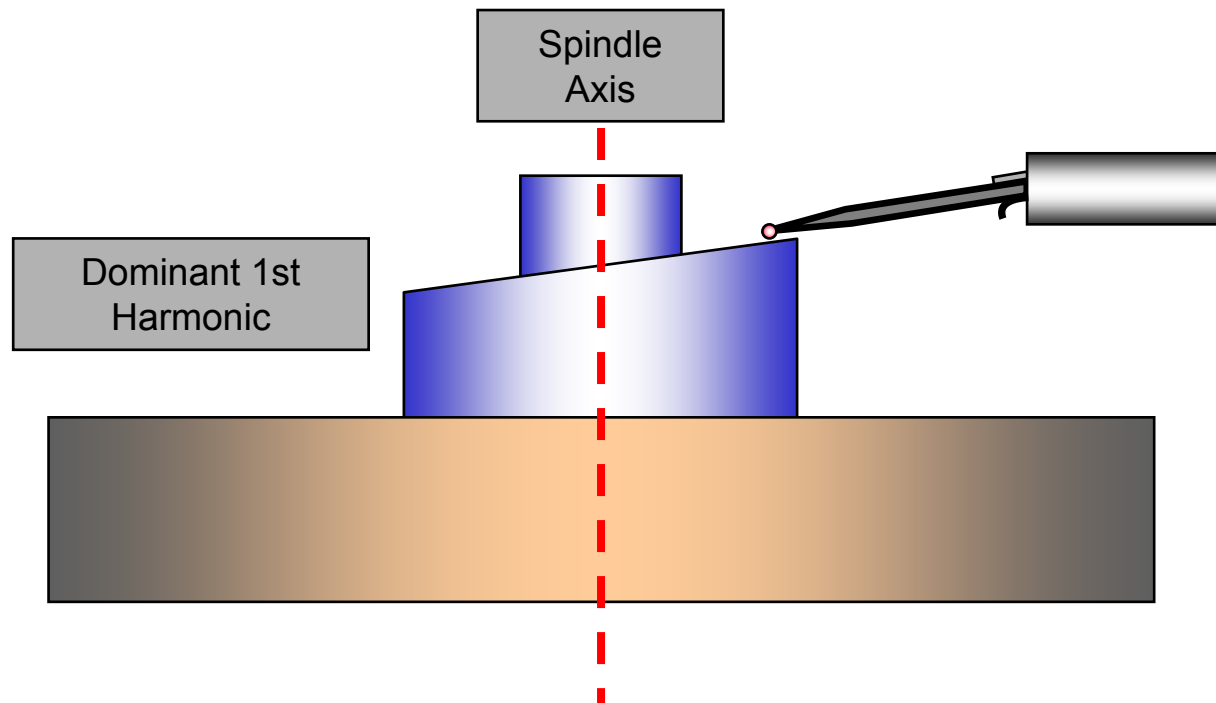
Roundness / Flatness Axis



The above diagram shows the description of a roundness/flatness axis generated from a single roundness and flatness measurement.

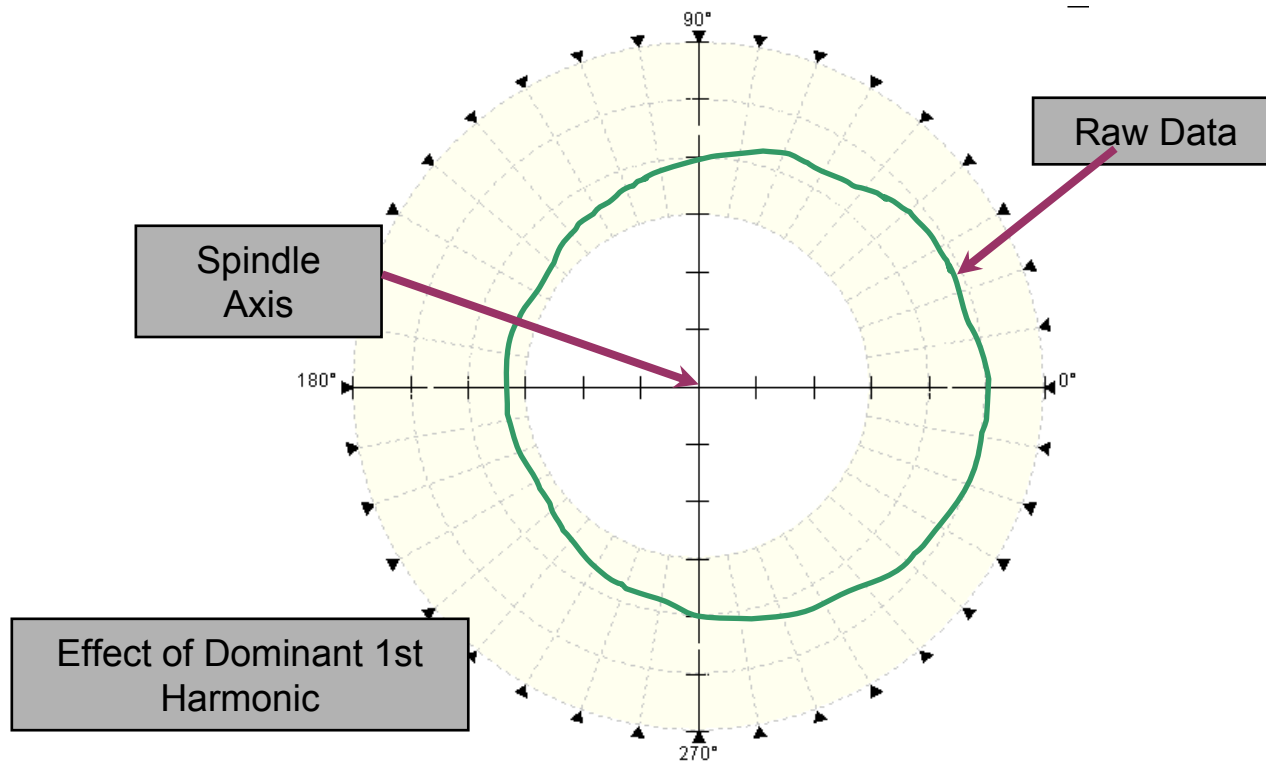
This type of datum is particularly useful for setting the axis of a large diameter, thin component as a datum.

Flatness on a Tilted Surface



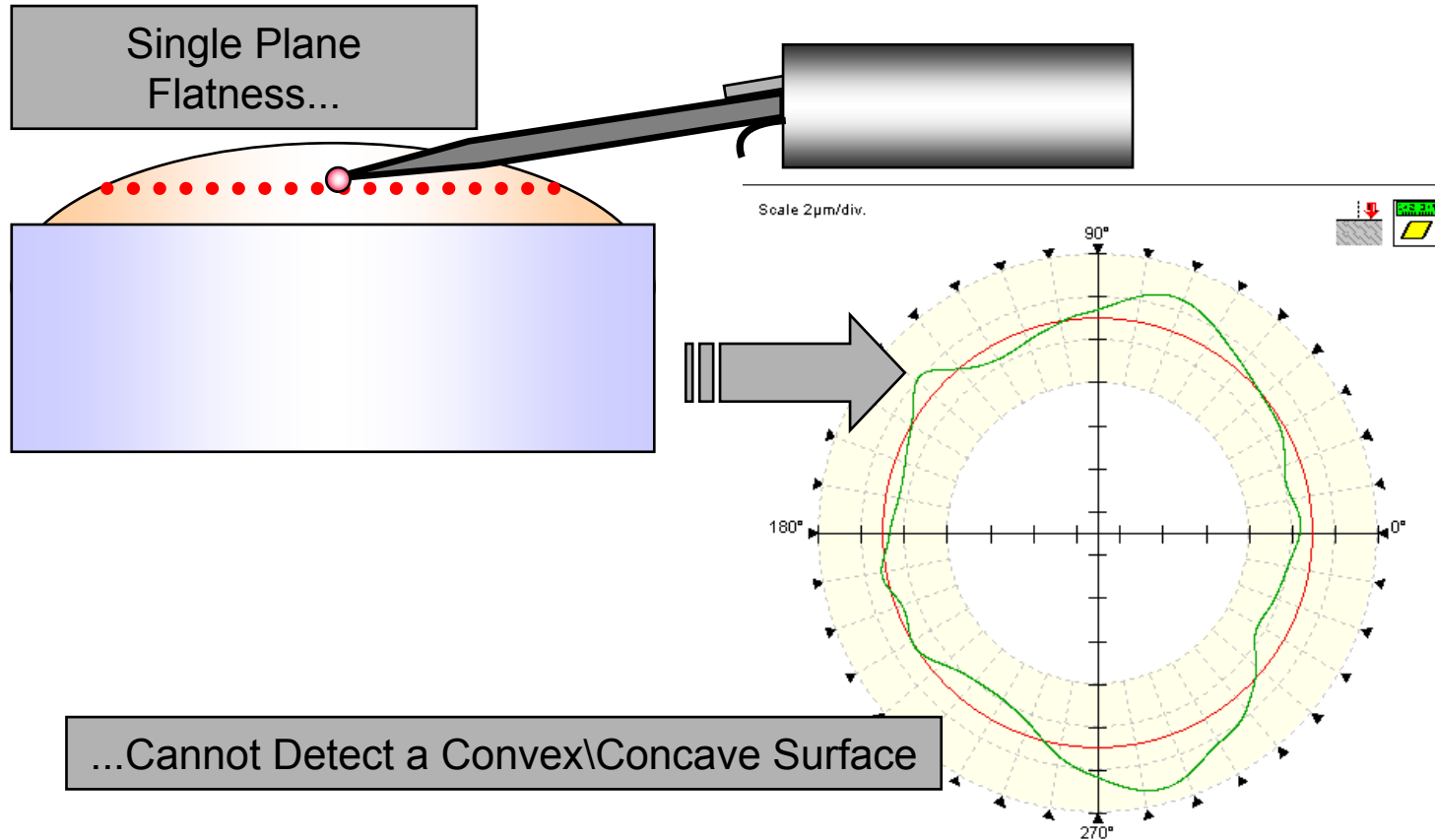
- Measurements made for flatness on tilted surfaces will induce a large 1st harmonic much the same as a roundness measurement with a large eccentricity.
- This 1st harmonic is the out of squareness of the surface with respect to the selected datum, which in the above example is the spindle axis. Therefore, it is important to ensure that, prior to performing a flatness measurement, the component is sufficiently levelled to reduce any possible effects on the flatness analysis.
- The levelling of the component should be performed at the farthest radial position from the spindle axis as possible.

Flatness on a Tilted Surface



On some types of instrument it is possible to see the effects of this 1st harmonic. In the case above we can see that the plot of the flatness measurement is not concentric to the graph, this is the 1st harmonic. It should be noted that the measurement displayed above has not been filtered and is the raw data only, no Least squares plane fit has been made.

Multi-plane Flatness

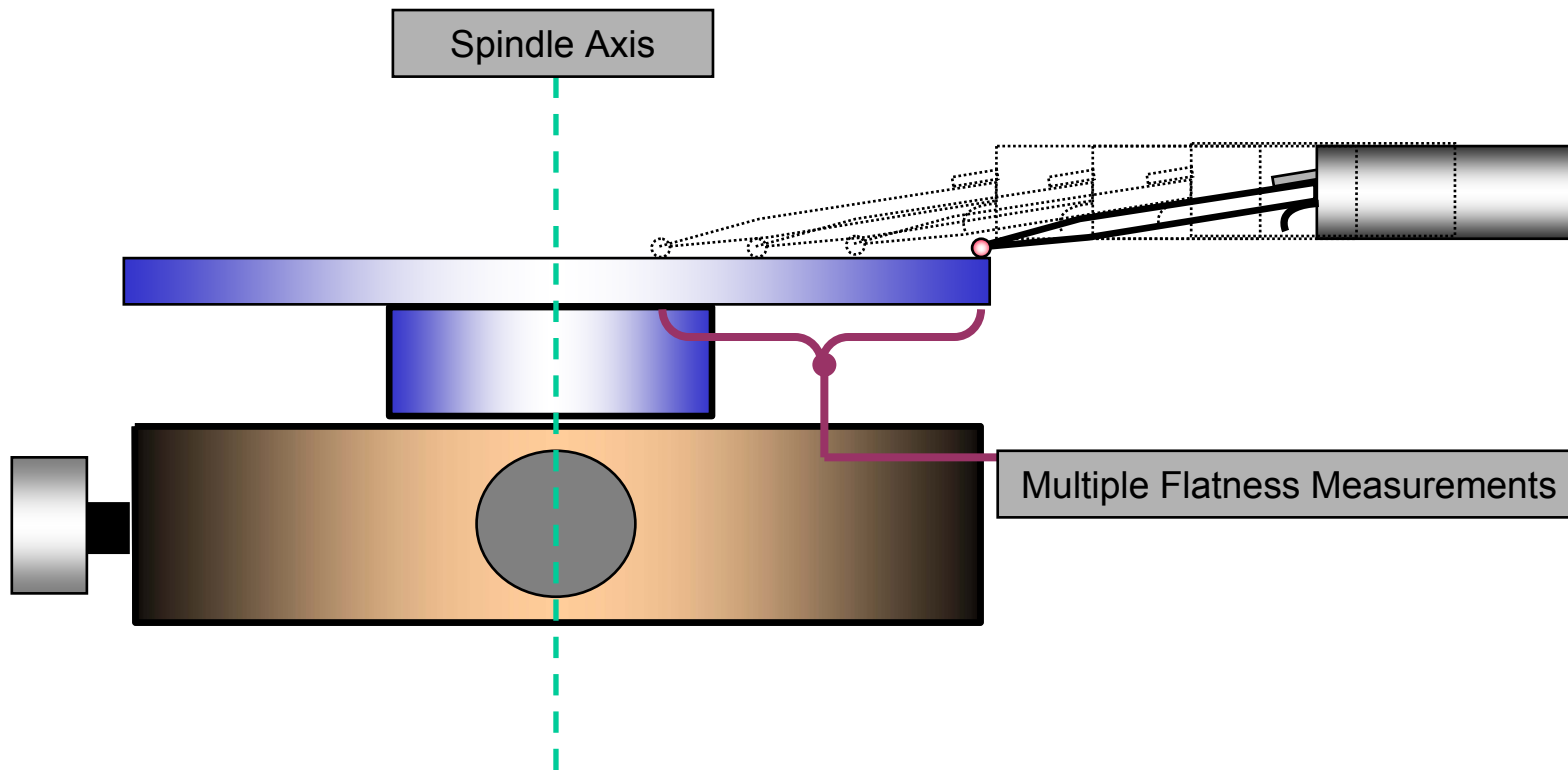


A single plane flatness measurement is usually sufficient on most components. However, a single flatness plane will not be able to show if the component surface has a convex or concave form. To obtain this type of information the operator needs to consider performing a multiplane flatness measurement.

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Multi-plane Flatness

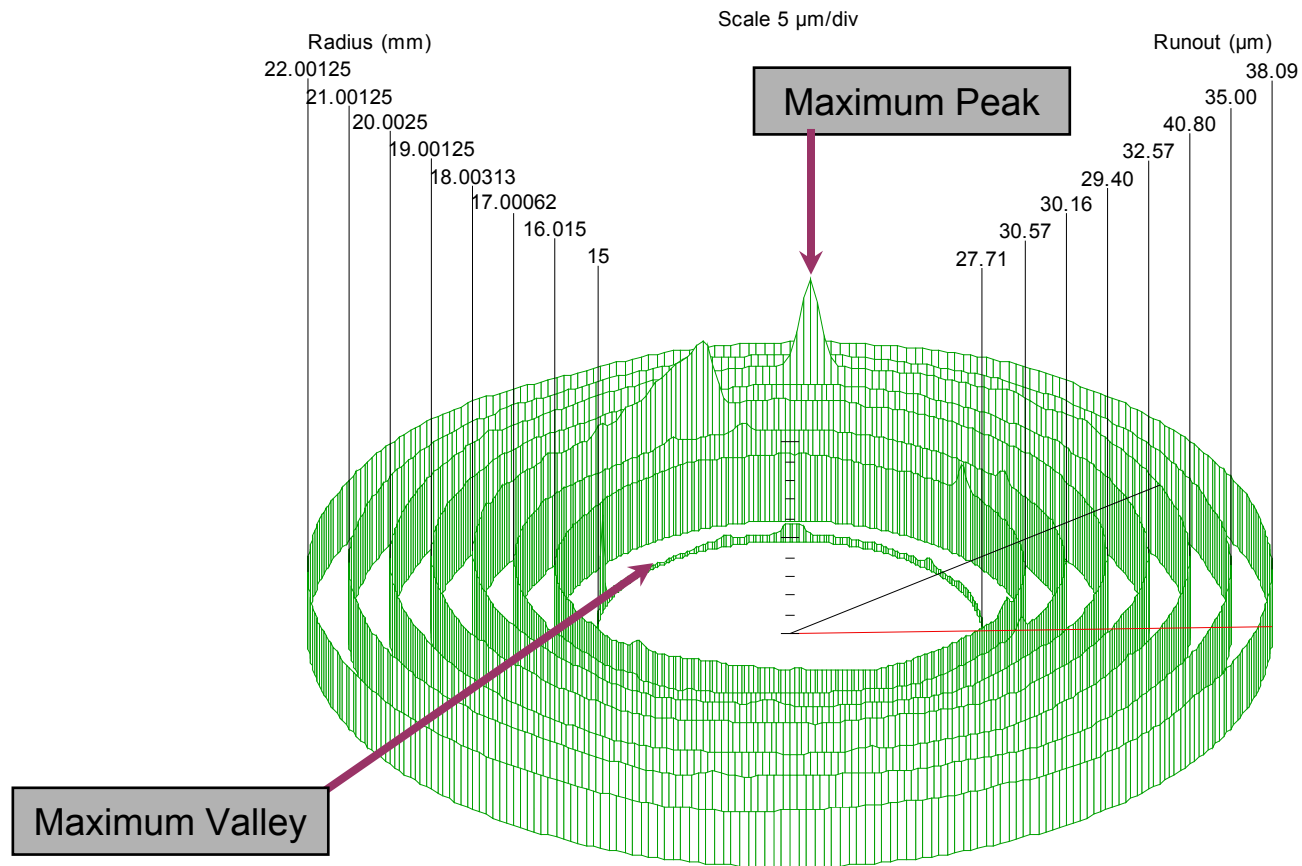


In order to measure multiplane flatness the measuring instrument should have a radial straightness unit (RSU).

If the instrument has a horizontal datum (RSU) then any radial movement of the stylus will be of a linear motion. This means that any multiple flatness measurements can be compared because their radial and height relationships are compatible for analysis.

The accuracy of the multiplane flatness measurement is dictated by the straightness accuracy of the RSU, therefore it is important that the gauge remains in contact with the component surface when traversing from radial plane to the next. If the gauge is re-contacted between measurements the accuracy of the flatness measurement will be dictated by the positional accuracy of the column.

Multi-plane Flatness Result



On a lot of flatness measuring systems it is possible to combine the results of a flatness measurements.

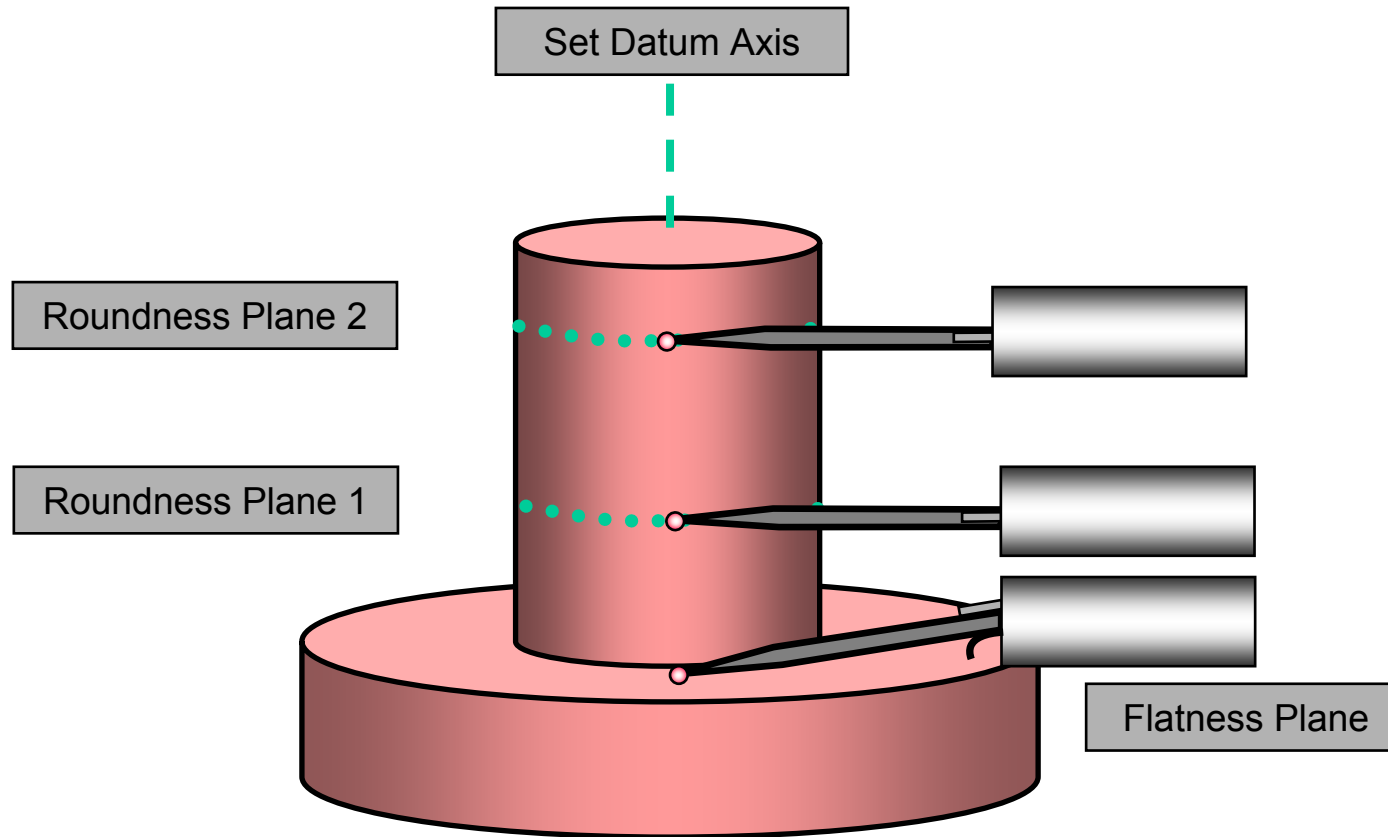
In the case above 7 flatness planes have been measured, the overall flatness is calculated by fitting a Least squares or Minimum zone flatness plane through all of the data.

The flatness value would be the highest peak to lowest valley when measured normal to the reference plane.

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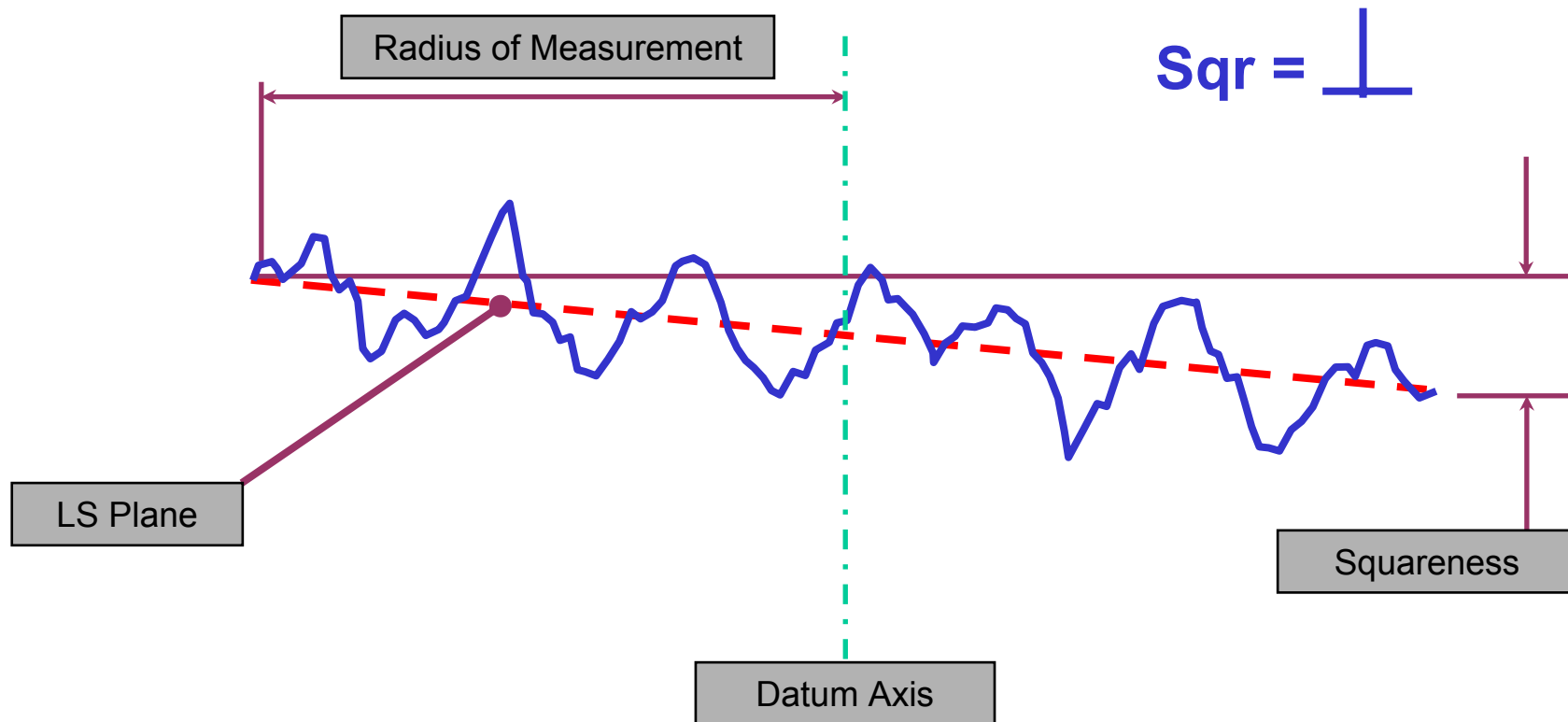


Squareness



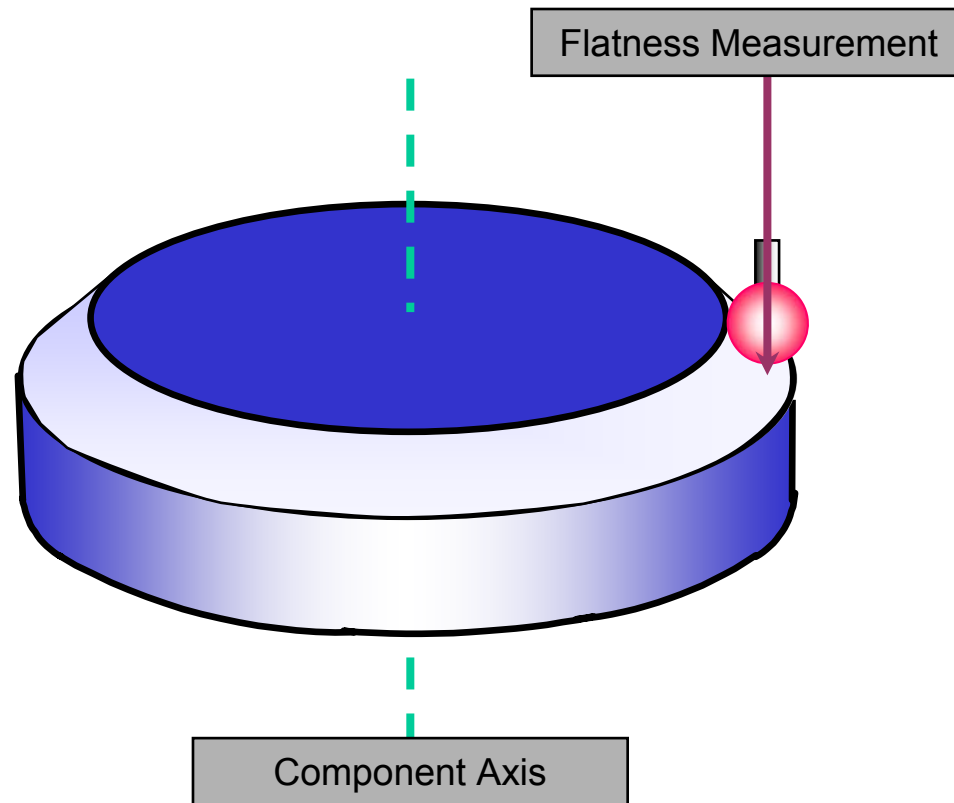
The above slide shows the method of analysing the squareness of a flatness plane with respect to a pre defined datum axis, in this case an axis created from two roundness planes.

Squareness Definition



The squareness value is the minimum separation of two parallel planes normal to the reference axis that totally enclose the reference plane.

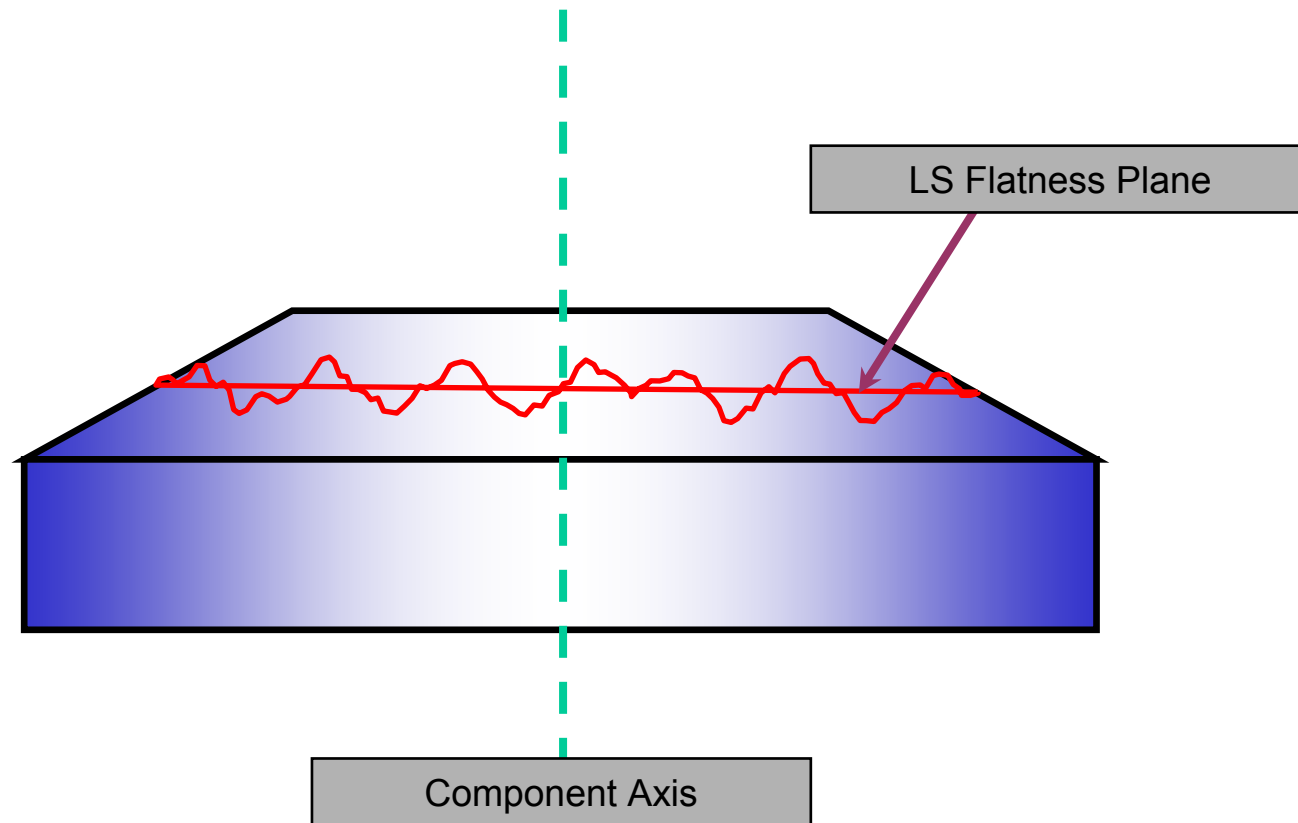
Squareness on a Cone



Although it is possible to measure the flatness of a cone along a single trace, squareness is not possible. In this example an axis is constructed through the base of the component and saved as a datum. A flatness measurement is now made around the conical area of the part.

Squareness on a Cone

Result Shows Flatness Plane Square to Axis



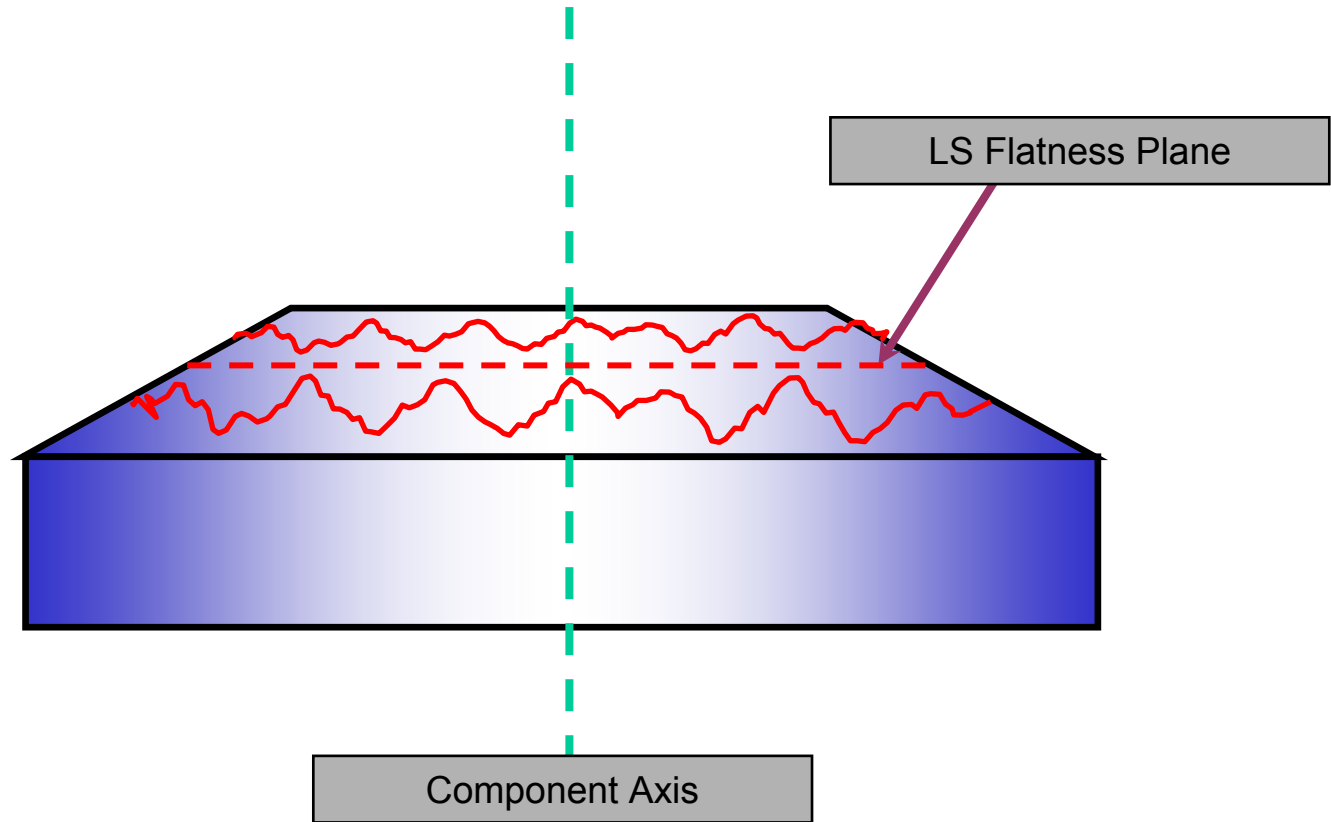
If squareness is now asked for, based on the flatness measurement to the constructed axis, then the result may show good squareness. However it is quite obvious in this instance that the measured surface is not square to the datum axis.

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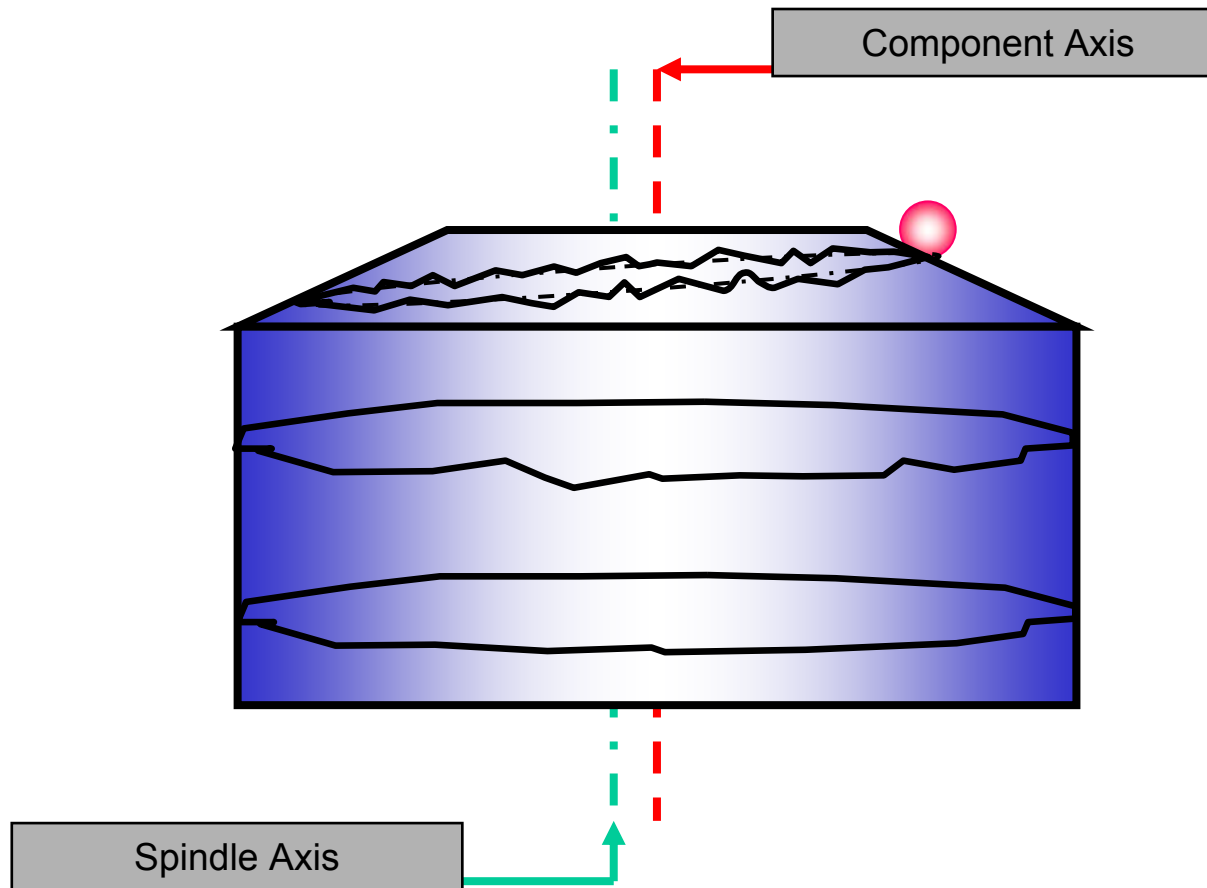
Squareness on a Cone

Same Problem with Two Flatness Planes...



Even if the operator chooses to measure using multiplane flatness the results will still show good squareness. This is because if more than one flatness planes is measured then an average plane is fitted to all measured data, the result will again indicate good squareness.

Squareness Error Due to Eccentricity



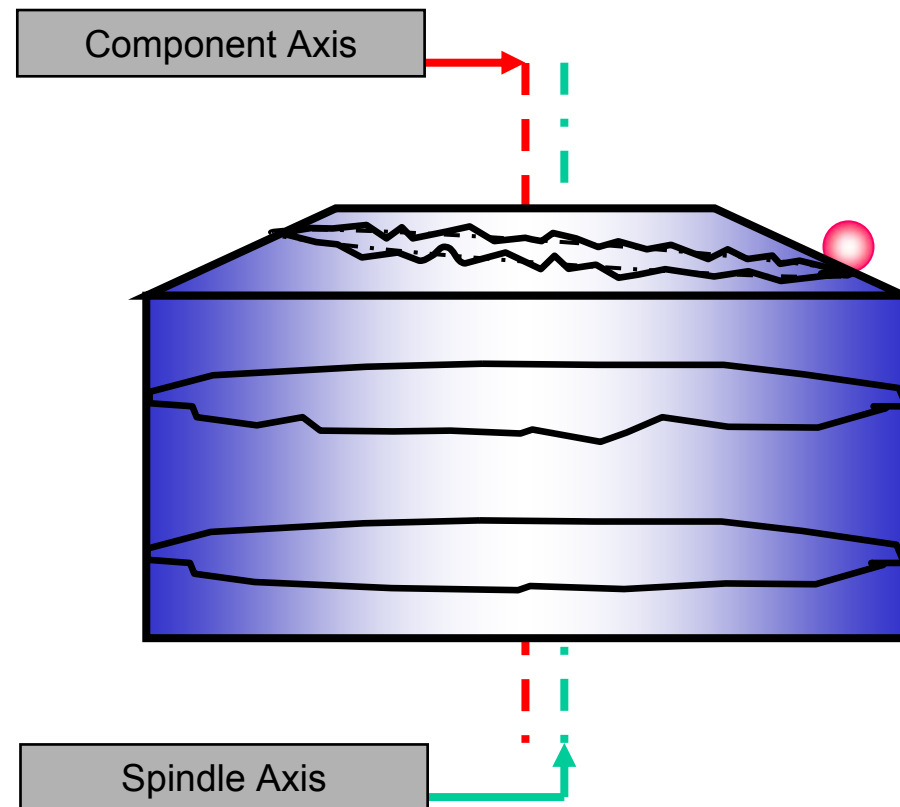
In this diagram we can see that two roundness measurements have been made in order to construct an axis. A flatness measurement is then made in order to assess squareness to the created axis.

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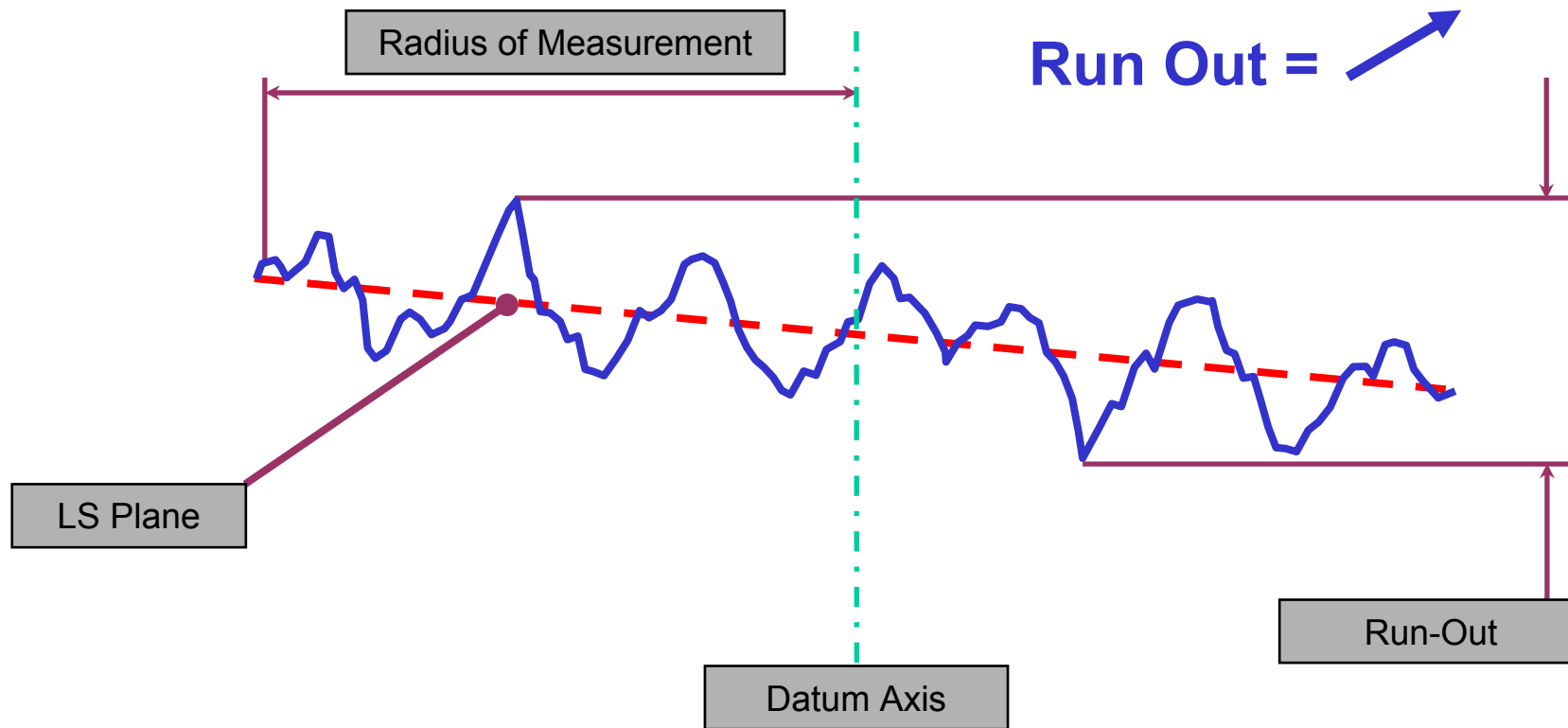
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Squareness Error Due to Eccentricity



Because of the eccentricity of the component to the created axis there will be an induced error in the squareness. This is due to the stylus ball rising up and down the slope of the taper causing an apparent angular error. It should be noted that if this part was perfect and there was no eccentricity then the result would show good flatness, even though the part is not flat but tapered.

Run Out Definition



Run-out is the minimum separation of two axial planes normal to the datum axis which totally enclose the profile.

Summary

Flatness

- By rotation of a Talysron gauge to the correct orientation Flatness measurements can be made using the same data collection methods as those used for roundness.
- Flatness Analysis can be polar or linear and fitted to a least squares plane or Minimum Zone fit.
- A Multiplane flatness measurement using a Radial Straightness Unit (RSU) can be taken to give an overall form analysis of the surface.

Squareness

- Squareness can be measured of a flatness plane with respect to a predefined datum axis, normally an axis created from a minimum of two roundness planes.
- Squareness errors can occur on coned or slightly angled surfaces if the datum axis has not been optimised.
- The parameter Runout when associated with flatness measurement is a combination of both the flatness error on the surface and the out of squareness.

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