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Roundness Measurement Errors and Effects

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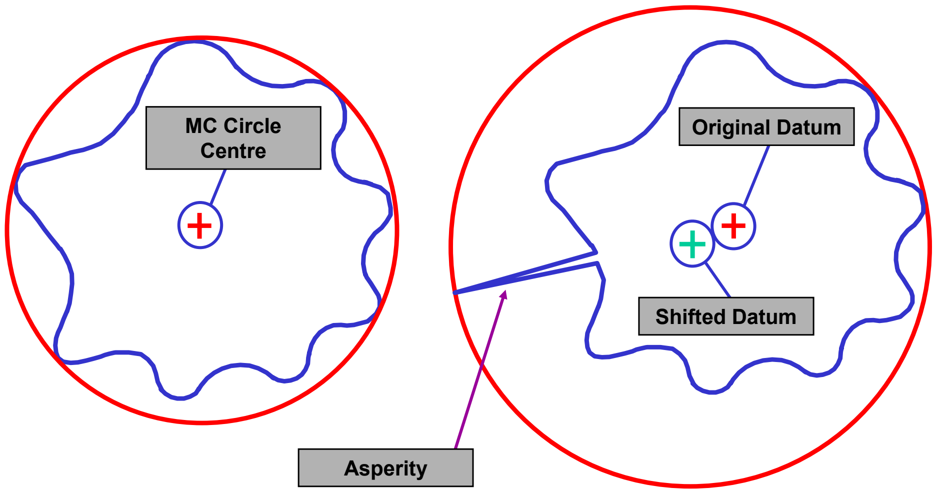
Contents

Asperity Effects on MC, MZ & MI Reference Circles



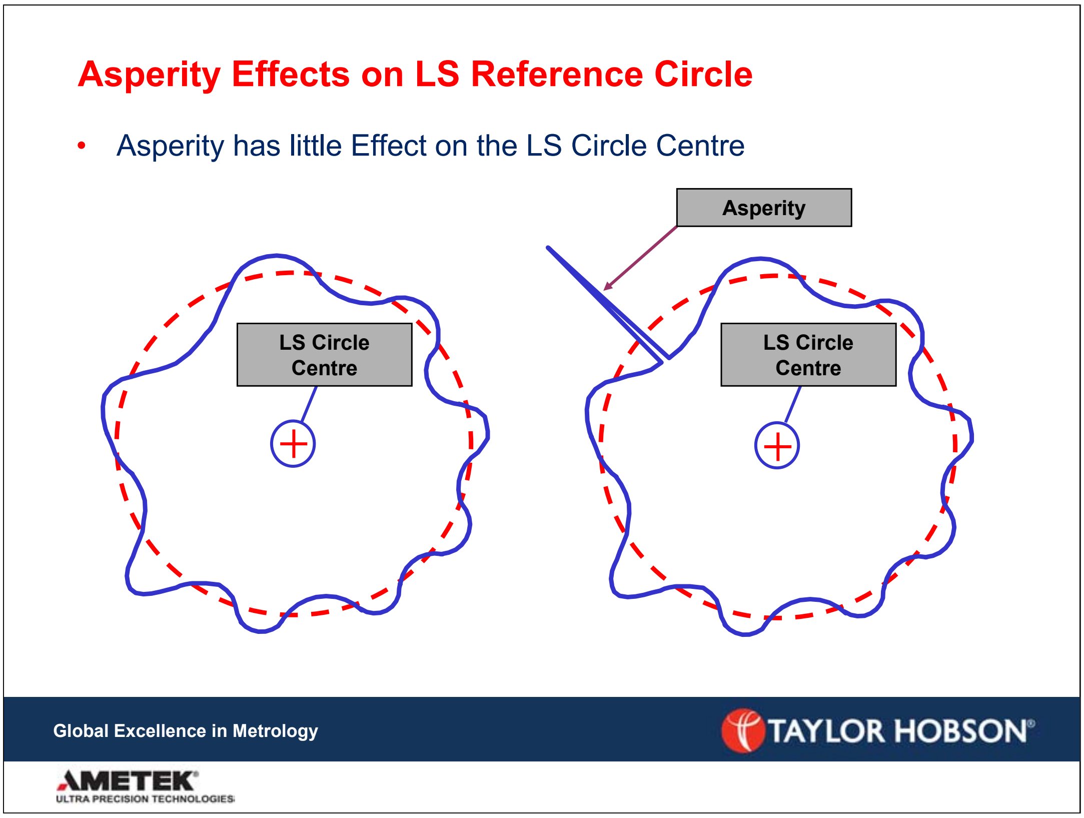
It is often necessary to use the centre of the measured component as a datum.

When using the MC MZ and MI reference circles care must be taken when setting a datum, if there is an asperity on the part then this may have a large effect on the centre of the reference circle.

As can be seen above the left hand drawing shows a part with no asperity.The MC reference circle is constructed to totally enclose the data, the centre of which is shown.

The drawing on the right shows what happens to the centre of the reference circle when an asperity is present on the measured component. A new centre (datum) is calculated which in turn will lead to bad repeatability and instability in any subsequent concentricity, eccentricity or run-out results.

Therefore, care must be taken when constructing datums using reference circles that are calculated from peaks and valleys i.e. zonal type reference circles.



The Least Squares reference circle relies on area for calculation.

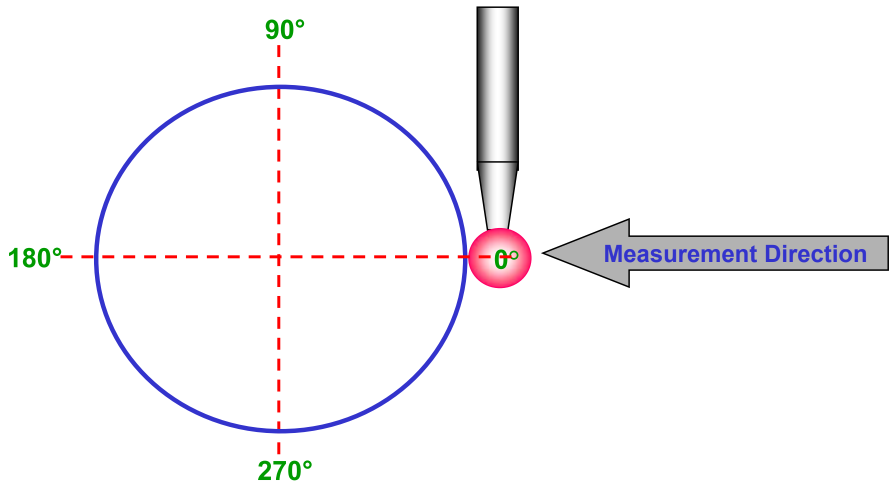
The asperity shown on the right hand drawing although large in amplitude is very small in terms of area and subsequently has little effect on the centre of the reference circle.

This makes the LS circle a more stable reference when constructing datums.

It should still be noted that good practice would be to ensure no asperities were present on any measurements.

Cosine Errors

- Stylus Centre and Component Centre Coincident

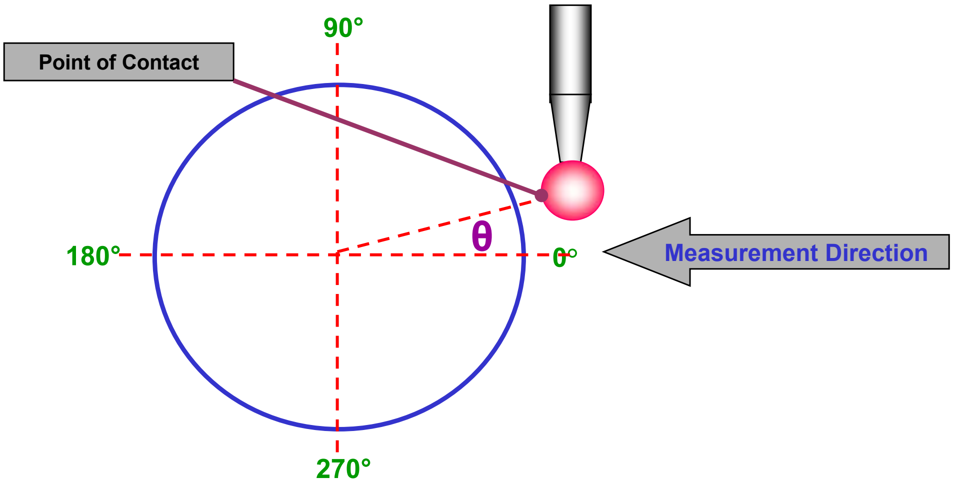


When measuring roundness the best possible means of measurement is when the stylus centre and the component centre coincide with the measuring direction.

If the stylus centre does not coincide with the component centre then this is a cresting error.

Cosine Errors

- Stylus Centre Out of Line with Component Centre



If we look at the situation here we can see that the stylus tip centre is not in line with the component centre along the measuring axis.

This means we have a cosine error in the measurement result.

Cosine errors cause a number of problems, as can be seen above the stylus is presumed to be measuring at the 0 degree position on the table whereas in actual fact the actual angular position is a few degrees off centre.

When trying to centre a component the eccentricity of the component needs to be measured and removed by adjustment. To do this it is often necessary to know the eccentricity position in terms of angle especially if the roundness instrument uses automatic means to calculate and remove eccentricity.

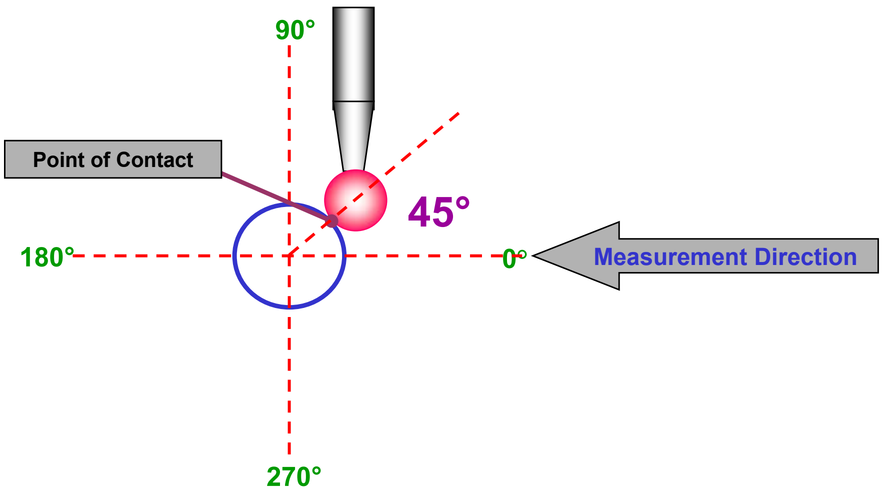
If there is a cresting error then it will become more difficult to centre the component.

Although it is good practice to remove all of the eccentricity by mechanical means this is not always possible, residual eccentricity is usually removed by mathematical means.

If there is a large cresting error these calculations will also be wrong.

Cosine Errors

- Smaller Diameter Component, Larger Angular Error

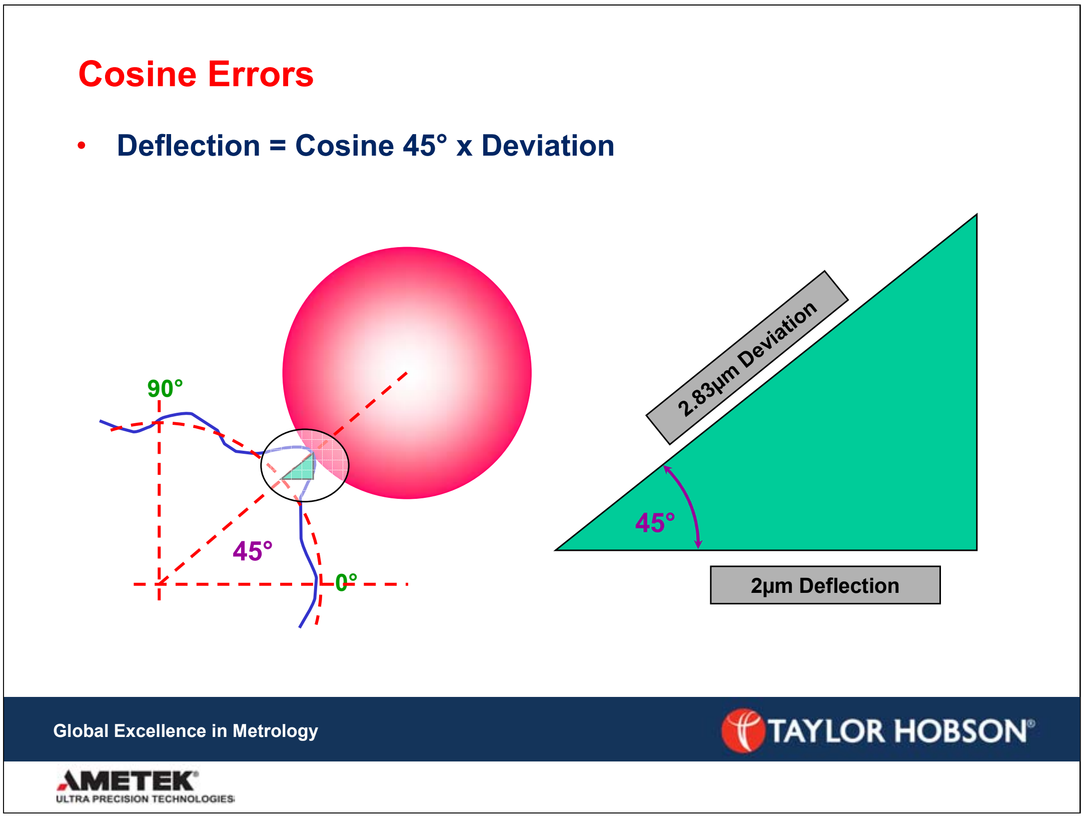


As can be seen above the smaller the component the larger the angular error in terms of cresting.

So the larger the component the less the effect.

Another error that will occur due to bad cresting is the actual measurement amplitude, if the cresting is off by 45° as in the above diagram, then for a given deviation on the component there will be a smaller deflection on of the stylus in the measuring direction.

This sort of effect can be particularly bad on fuel injector nozzles especially at the seating face where the diameter is extremely narrow.



If we look at the measured deviation above we can calculate the actual deflection of the stylus.

$$\text{Cosine } 45^\circ = \frac{\text{deflection}}{\text{deviation}}$$

Therefore:

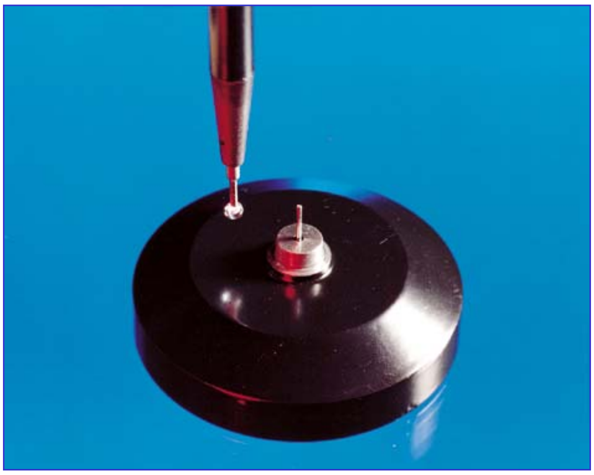
Deflection = Cosine 45° x Deviation

From this calculation we can calculate that if the stylus deflects by 2µm then the actual deviation of the component is 2.83µm almost 1µm difference. In certain circumstances this error may be quite significant, particularly when measuring roundness and concentricity on a cone, such as an injector valve or body seat.

Although this is an extreme case it does show the importance of correct set up and cresting.

Cosine Errors - Cresting

- Stylus Cresting Pin



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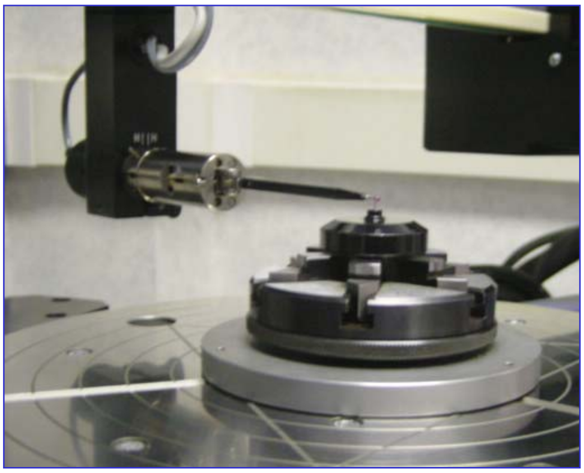
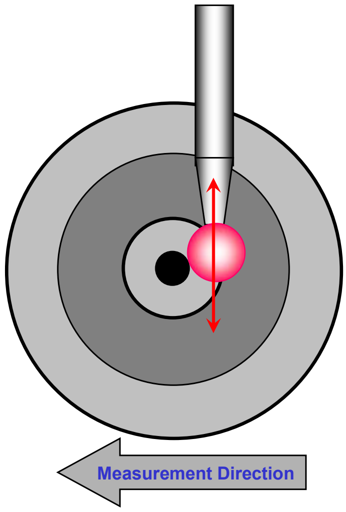
There are a number of ways of setting the stylus to remove any cresting errors, it is possible to use the component itself especially if the part is a pin or consists of a small diameter.

However if the part is has large diameter cresting is not so easy, in these cases a cresting standard can be used.

An example of a cresting standard is shown in the diagram, this standard consists of a small pin sitting on a stand, ideally this stand will have three feet to enable the user to place on the roundness instrument without any rocking.

Cosine Errors - Cresting





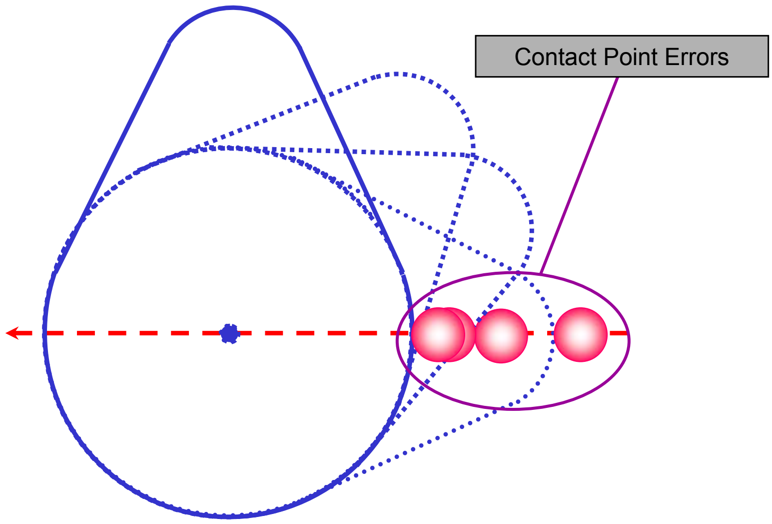
The standard is placed central on the table of the roundness measuring instrument and centered.

Once the part is centered it is usually possible to see the cresting error by viewing from above, if there is an error the operator can make the necessary adjustment by moving the stylus in a plane orthogonal to the measuring direction.

If it is not possible to see the actual error then the gauge reading on the instrument can be used, the operator will find the position of maximum deflection on the gauge, this will be the crest position.

Cosine Errors - Caused by Component Shape

- **Measurement with Stylus** Vertical



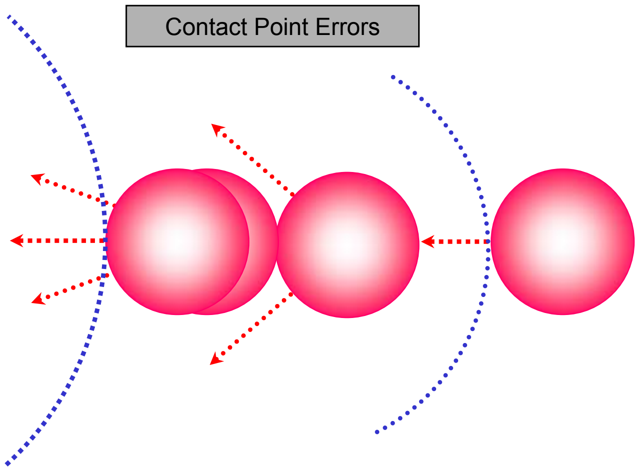
Sometimes the component shape can cause cresting or contact point errors.

If we take an extreme case as shown here the component is rotating about a point, similar to that of a cam.

As the lobe of the cam comes round the contact point on the ball will change from that of the round area of the cam.

Cosine Errors - Caused by Component Shape

- **Measurement with Stylus** Vertical



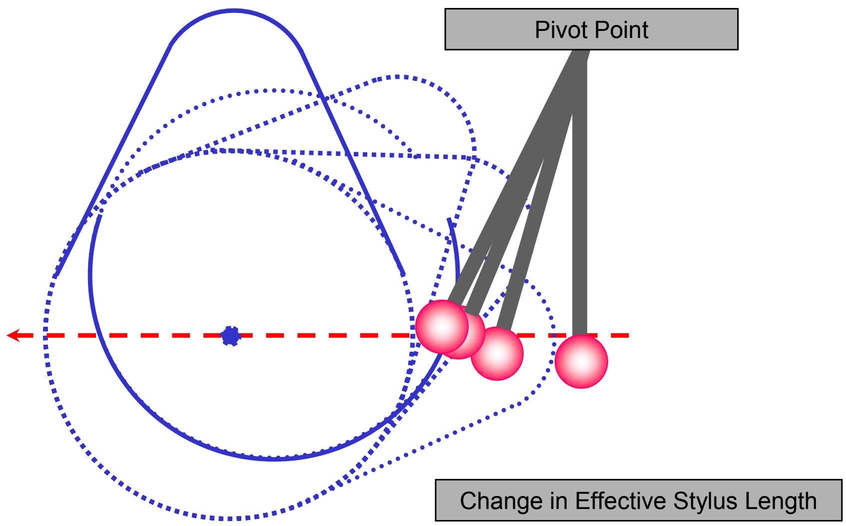
As can be seen above the arrows indicate the change in contact position of the stylus ball, in actual fact as the lobe passes through zero, contact will be made on the opposite side of the ball.

It is also noticeable that the cresting is correct, the measuring direction of the stylus is in line with the component axis. The stylus in this case is held in a vertical attitude.

The effect of this is similar to that of the cresting error discussed on previous pages.

Cosine Errors - Caused by Component Shape

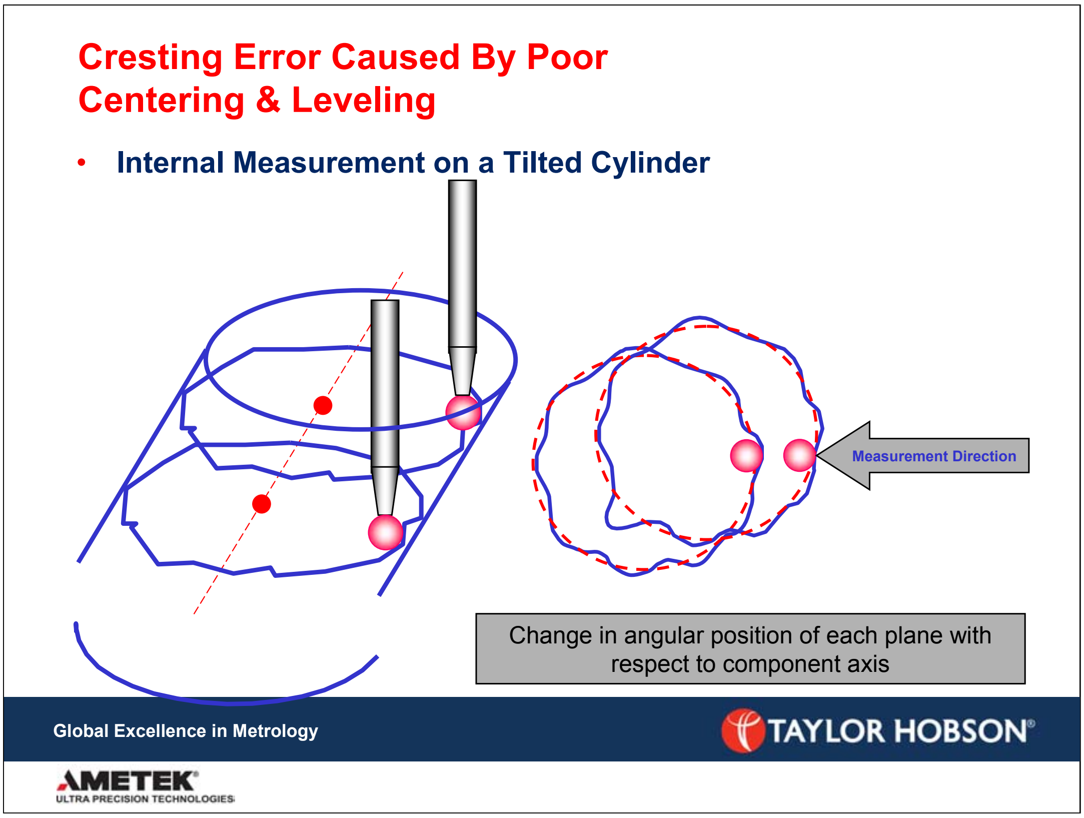
- **Measurement with Stylus** Horizontal



If the stylus is placed in a horizontal attitude we have a further error in that the effective stylus length is lengthening and shortening with respect to the component axis due to its pivotal movement.

This will cause a continual change in cresting.

Again it should be noticed that this is an extreme case but it does highlight the effect, a good example where this may have some effect is on piston measurement where the ovality of the piston is quite large.

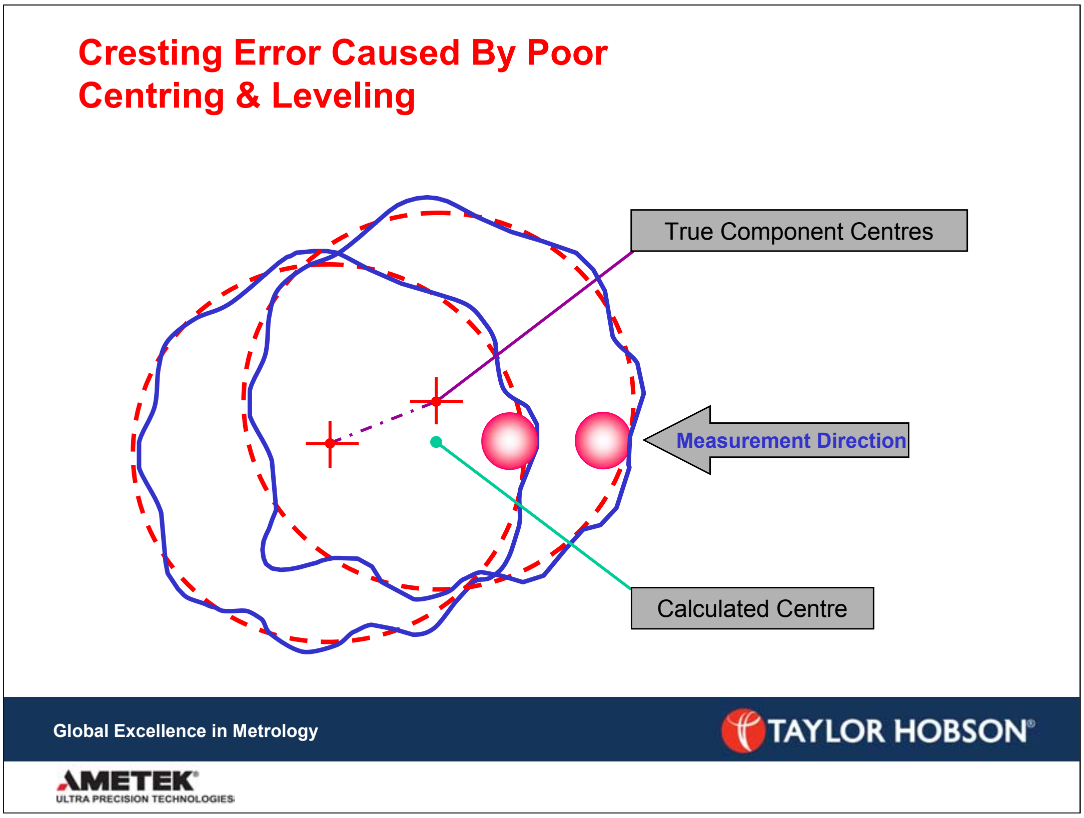


Other sources of error can be caused by bad centering and leveling of components.

If we look at the above the internal bore of this cylinder is being measured at two planes.

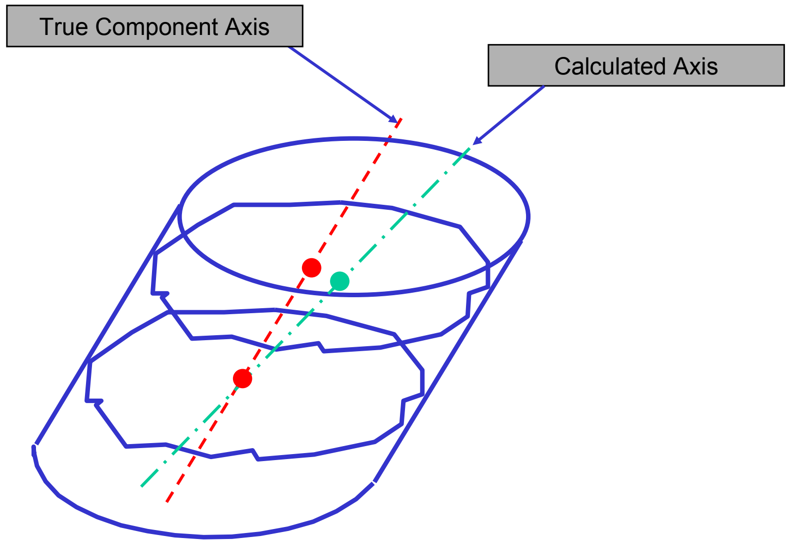
Due to the tilt of the cylinder the angular position of each plane with respect to the component axis will shift as the stylus is moved up vertically through the bore.

These errors will cause miscalculation of the cylinder axis and its position in terms of tilt.



The above diagram shows the real centre of each component plane along with the assumed centre.

Cresting Error Caused By Poor Centring & Leveling

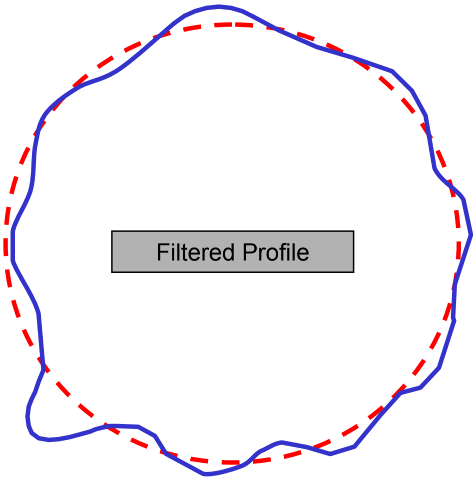


These incorrect centres will cause incorrect calculation of the position and tilt of the cylinder.

It should be noted that these effects are again greater on smaller bores, when small and highly accurate measurements are to be made on fuel injectors for example, the best possible centering and leveling should be obtained.

Effects of Stylus Force

- **Excessive Stylus Force Can Cause High Frequency Errors**



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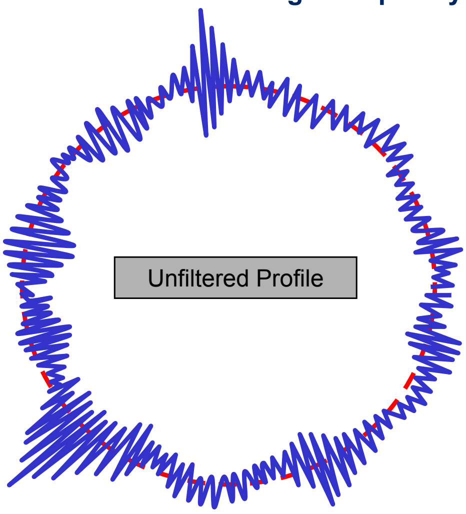
On measurements of fine surfaces or high precision surfaces a strong stylus force can cause high frequency errors.

These errors are not always obvious especially where high frequency filtering is used.

Effects of Stylus Force

- Excessive Stylus Force Can Cause High Frequency Errors



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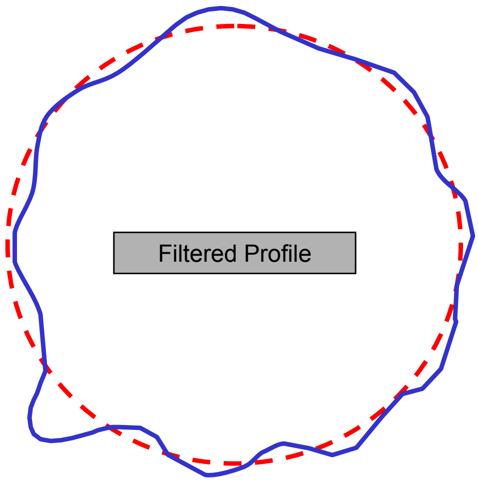
The errors shown here are due to the fact that both the stylus ball and the component are very smooth this causes a high frequency resonance.

However after filtering the high frequency component on the surface will not be apparent.

Effects of Stylus Force

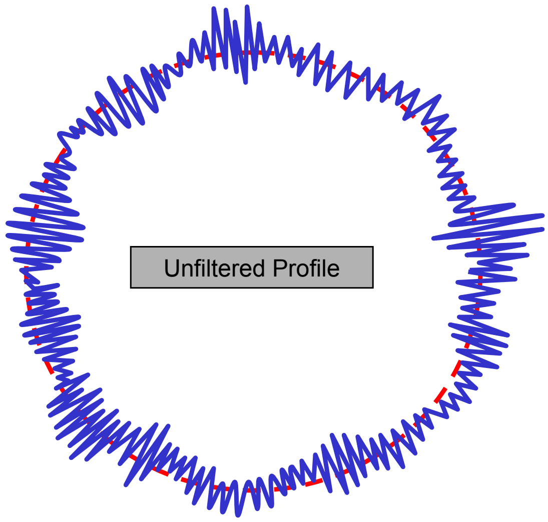
- **Profile Changes Shape After Repeat Measurement**



If the same component is measured again the shape will appear to change, this is because the effect is not repeatable and will appear at random on the surface.

Effects of Stylus Force

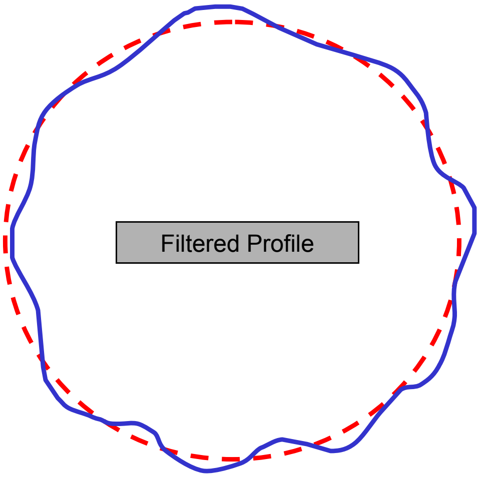
- **After Repeat Measurement - High Frequencies have shifted**



Here is the same component measured again this time the high frequency element has shifted.

Effects of Stylus Force

- **After Filtering - Shape Changes**



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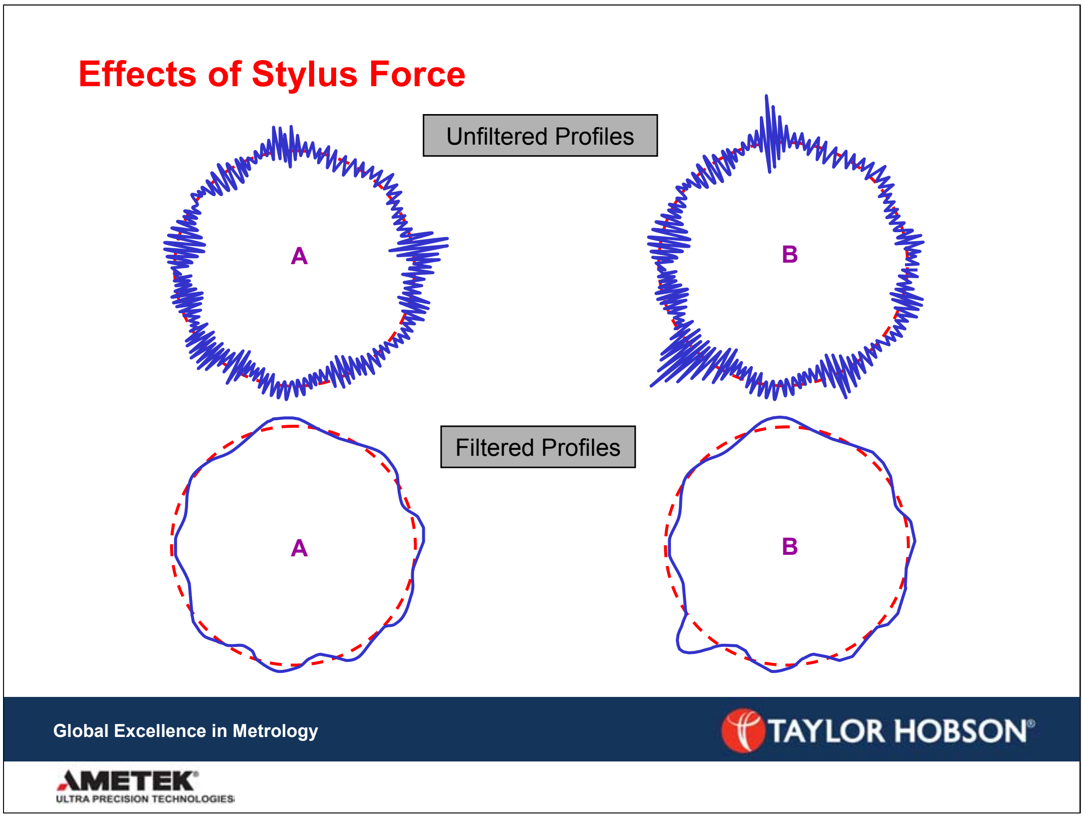
Consequently the shape appears to have changed after filtering.



A good example of where this error may occur is on fuel injector bores where the surfaces are very fine, to remove this effect it is often best to reduce the stylus force to the minimum force possible.

Summary

- Clean components are a must
  - For consistency and compatibility it is important that the correct reference circle is chosen dependant on the application and study being performed, any asperities can seriously effect repeatability and undermine R&R results.

- Accurately crest styli
  - Initially checking that styli are crested accurately prior to measurements will produce more accurate results and help towards producing better repeatability.

- Ensure components are centred and levelled to a level acceptable for the application
  - Thus reducing set up cresting errors

- Set/verify stylus force
  - Set styli force using a corex gauge (or similar) to reduce the effect of high frequencies noise or ringing on the surface, again to aid in repeatability and accuracy.

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