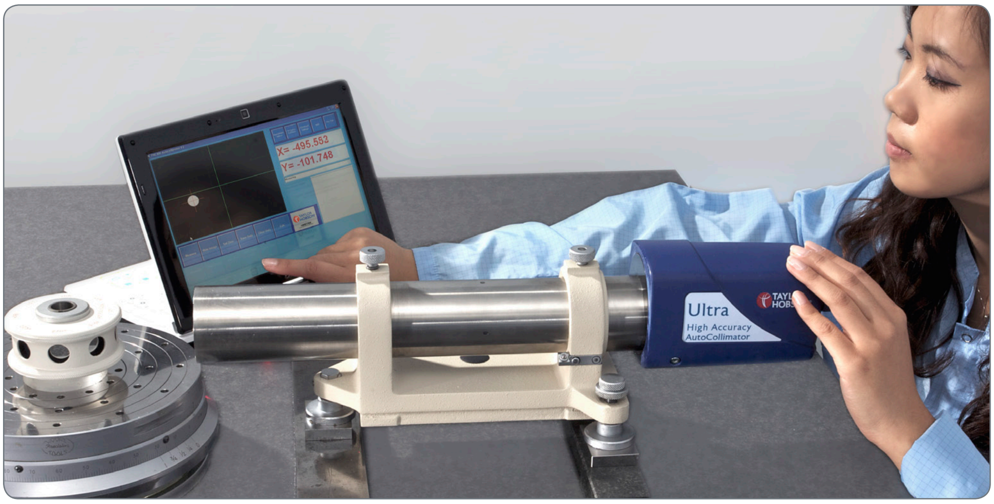
Ultra Autocollimator

Measuring angular errors of polygons, indexing & rotary tables with the wide range, high accuracy Ultra Autocollimator



Modern machining systems use rotary tables for tilting and indexing the part. The rotary table's positioning accuracy is an integral part of system accuracy. If the rotary table is out of position by as little as 10 arc seconds and the part to be machined has a radius of 20 cm (8"), the table can contribute 0.01 mm (0.0004") error to a feature location.

A similar situation exists when a rotary table is used for inspection. When the table is located on a CMM, its accuracy is a strong contributor to the system accuracy. To ensure system accuracy, it is prudent to verify rotary table angular errors during machine qualification trials.

To quantify errors of machine tools and CMMs an autocollimator is a very useful economical tool. It is capable of checking positioning and encoder errors.

Autocollimator

An autocollimator is an optical device designed to provide high-resolution, high-accuracy measurement of angles. Easy-to-operate devices, autocollimators are used with angle masters such as polygons to measure deviation from nominal angle. Support software packages apply polygon calibration deviations and plot results.

When used to measure angular errors of rotary tables an autocollimator measures the deviation from nominal angle determined by the angular master. The angular master is usually a precision polygon mirror or an index table.

When either is placed on the table to be measured it must be concentric with the axis of rotation within 0.5 mm (0.02 inch). Both have a reference diameter that can be centred using an electronic indicator. The masters must be parallel to the axis of rotation within 120 seconds or better. The autocollimator can be used to measure the parallelism deviation.

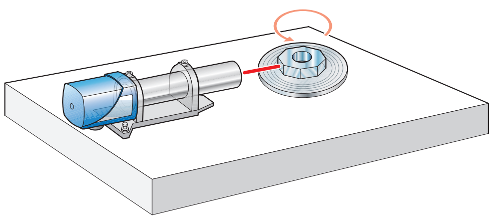
Polygon

Although polygons are available with as many as 72 faces, those used for rotary tables typically have 8, 12, or 16 faces. The polygons are regular; that is the angle between the faces is equal. Since polygons are not perfectly regular a list of deviations is supplied in the form of a calibration chart. Typical calibration accuracy of these masters is 0.2 second.

To ensure proper alignment, the polygon is mounted on the rotary table using an inside diameter as a reference. The inside diameter centre line is parallel to the faces and square to the base. After alignment, one of the mirror faces on the polygon is rotated toward the autocollimator and zeroed; then the rotary table readout is zeroed.

During inspection the table is rotated until its readout is the nominal angle of the polygon (45 degree increments for an eight-sided polygon). The next face should be aligned to the autocollimator. If it isn't, the error can be read on the autocollimator. The table should be rotated to each face of the polygon until all positions are inspected. At zero degrees, the table should return to zero deviation.

Principle of checking an indexing table with Ultra Autocollimator



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Index table

An alternative to the polygon is the precision indexing table. The typical angular accuracy of an index table is 0.25 second. A 360 position indexing table yields one degree resolution. Indexing tables are available in any number of positions per revolution.

To use an indexing table, a plane mirror is placed on the centre of rotation and parallel to the axis of rotation. The indexing table is aligned in the same manner as a polygon. During inspection the rotary table is rotated to 23 degrees, for example, and the indexing table is counter-rotated 23 degrees. If the mirror isn't aligned, again, the error can be read on the autocollimator.

A similar technique using a high accuracy clinometer such as the Taylor Hobson TB100 instead of a precision indexing table can also be used.

Optical encoders

Optical encoders are mounted on the axis of rotation of most machine tool rotary tables. Optical encoders are very accurate devices; their principal source of error is the eccentricity and tilt of the grating to the axis of rotation and typically not the lines on the grating. Both of these errors are sinusoidal in shape. To verify accuracy, an 8- or 12-sided polygon could be considered.

A second example is a rotary table driven by a gear and worm with an optical encoder on the worm shaft. The error pattern is a product of the gear errors plus the worm errors plus the encoder errors.

If the pitch on the ring gear is 2 degrees we can explore the periodic (repetitive in a fixed increment) worm and encoder errors by testing the table in eight places 15 minutes apart. The ring can then be checked in increments of 2 degrees. The error, when the table is in use, is the sum of the worm and ring errors.

Inductosyn scales

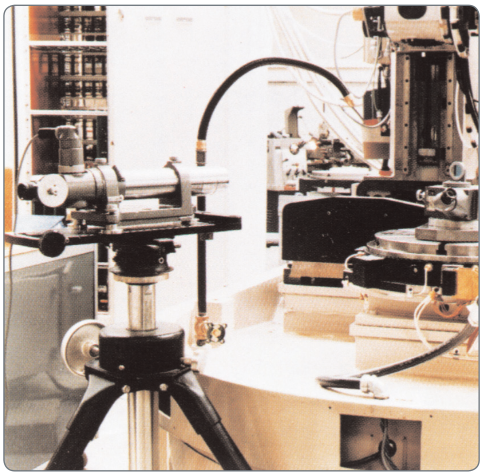
The Inductosyn rotary scale exhibits two types of periodic error. The first is caused by tilt and/or eccentricity of the scales to the axis of rotation. Similar to errors occurring with optical encoders, these errors occur once per revolution and can be seen by testing eight or more points. The second type of error is periodic in one pole of the Inductosyn scale. There are 180, 360, or 720 poles per revolution. Accordingly, the scale must be tested at least at eight points in one pole.

An index table can be used to qualify Inductosyn scales by stacking a 360 position table and a 375 position table. Using counter rotation, we can go forward by one degree on one table and then backward 0.96 degree (360/375) on the other, generating multiples of 144 seconds.

Tilt motions

The procedures discussed work equally well for tilting tables. A polygon or index table can be used to verify the accuracy of tilt motion of the main axis. Use caution if there is an offset between the point of inspection of a tilt axis and the point of use. Since no structure has infinite stiffness the offset may be a source of error. Using a precision clinometer to verify the angle of the worktable with part and fixture in place may be desirable.

Checking a machine tool indexing head using a Taylor Hobson TB clinometer on its back, with a small reflector to enable any position from 0–360° to be measured.



This application note demonstrates just one of the applications for the Taylor Hobson electro-optical metrology range.

Contact Spectrum Metrology to discuss your own measurement requirements.

Spectrum Metrology Ltd
Unit 8 Ireton Avenue
Leicester, LE4 9EU

Tel: (44)(0)116 276 6262,
Fax (44)(0)116 276 6868
Email: sales@spectrum-metrology.co.uk
www.spectrum-metrology.co.uk

Taylor Hobson UK
(Global Headquarters)
PO Box 36, 2 New Star Road
Leicester, LE4 9JD, England

Tel: +44 116 276 3771
taylor-hobson.sales@ametek.com

Taylor Hobson France
Tel: +33 130 68 89 30
taylor-hobson.france@ametek.com

Taylor Hobson Germany
Tel: +49 611 973040
taylor-hobson.germany@ametek.com

Taylor Hobson India
Tel: +91 80 67823200
taylor-hobson.india@ametek.com

Taylor Hobson Italy
Tel: +39 02 946 93401
taylor-hobson.italy@ametek.com

Taylor Hobson Japan
Tel: +81 36809 2406
taylor-hobson.japan@ametek.com

Taylor Hobson Korea
Tel: +82 31 888 5255
taylor-hobson.korea@ametek.com

Taylor Hobson China Beijing Office
Tel: +86 10 8526 2111
taylor-hobson.beijing@ametek.com

Taylor Hobson China Shanghai Office
Tel: +86 21 58685111-110
taylor-hobson.shanghai@ametek.com

Taylor Hobson Singapore
Tel: +65 6484 2388 Ext 120
taylor-hobson.singapore@ametek.com

Taylor Hobson USA
Tel: +1 630 621 3099
taylor-hobson.usa@ametek.com

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