DETERMINATION OF STRAIGHTNESS ERROR USING AUTOCOLLIMATOR

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Principle: An autocollimator is an instrument which can measure small angles. They incorporate a collimating lens which is designed to transmit a parallel beam of light radiating from a source at its principal focus. A plane reflector placed in the path of the beam and normal to the geometric axis of the lens will reflect the light along the transmitted path to be refocused at the source (Fig.1). If the reflector is inclined at a small angle $\delta\theta$ to the normal, the beam is reflected at an angle equal to $2\delta\theta$ from its transmission path (Fig. 2). Any portion of the reflected beam passing through the lens will be refocused at the focal plane at a distance d from the principal focus. Consider that reflected ray which so happens to pass through the geometric centre of the lens. From the triangle made with this ray and the focal length f, $d=2f\delta\theta$. Thus the point at which the reflected beam is focused is independent of the distance of the reflector from the lens. However, as the angle increases, the amount of light that falls back onto the lens decreases and hence there is a limit to the distance that the reflector can be placed.

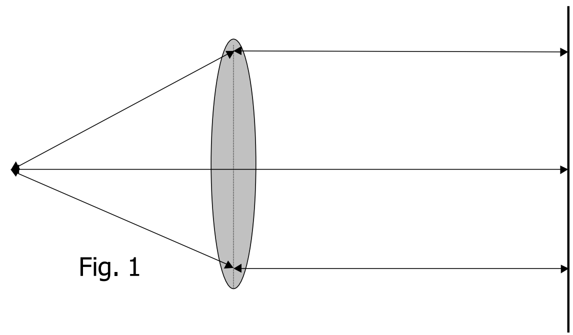

Fig. 1

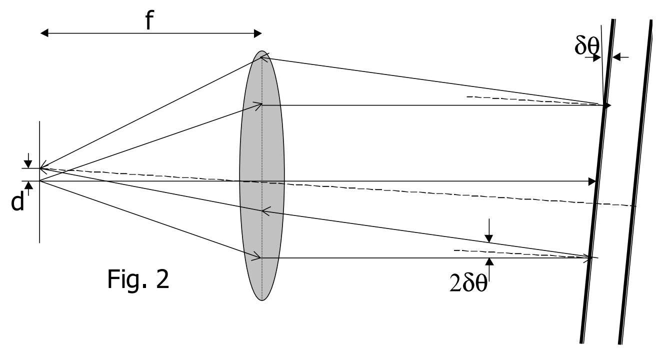

Fig. 2

An autocollimator is essentially a telescope permanently focused at infinity and fitted with means for illuminating an internal target graticule. There is also a micrometer eyepiece viewing system for measuring the displacement d of the image. A schematic diagram of the Microptic Visual Autocollimator is shown in Figure 3. The illuminated

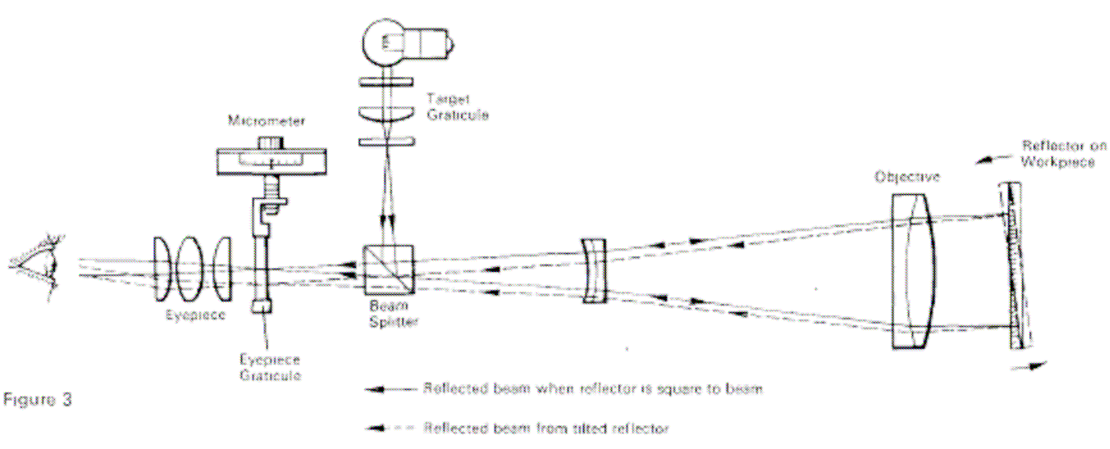

Figure 3

target graticule is situated in the principal focal plane of the objective and the emergent beam is directed along the axis of the telescope by a beam splitter. The reflected beam, passing straight through the beam splitter, is brought to a focus on the eyepiece graticule and both the graticule and the image are viewed simultaneously through the eyepiece. The eyepiece graticule lines can be moved across the field of view by means of the micrometer, until they coincide with the reflected target image, thus enabling its displacement to be measured. The micrometer is graduated in angular units corresponding to the angular displacement of the reflector.

Measurement of straightness:

See the annexure for definition of straightness error. The principle employed for measurement is illustrated in Figure 4. The reflector is mounted on a carriage which is moved step by step from its initial position AB at one end of the slideway to successive positions BC, CD etc. along the surface. The distances between adjacent points A, B, C, D ... are equal to the nominal span of the carriage (50 mm). Any lack of straightness of the slideway will cause the carriage to tilt slightly. The angles of tilt are measured by the autocollimator and the difference in height of the two feet of the carriage can then be calculated for each position.

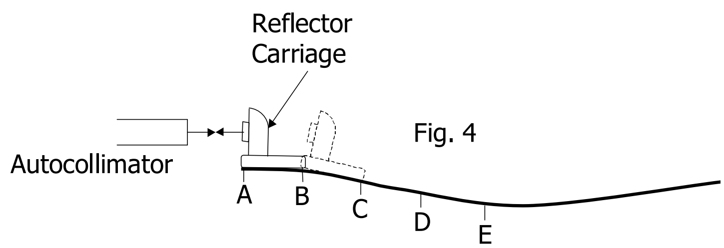

Fig. 4

Procedure:

1. Position the micrometer of the autocollimator to measure displacements in the vertical plane. Place the carriage at the nearest position AB and adjust the autocollimator base until the reflected image of the target crosslines is near the centre of the field of view.
2. Move the carriage to the other end of the bed and check that the reflected image is still within the range of measurement. If it is not, make fine levelling or rotational adjustments to the autocollimator.
3. Return the reflector carriage to position AB. Take an autocollimator reading and record it
4. Move the carriage along to its second position (BC) and take another reading. Continue thus until the carriage is at the end.
5. Repeat the readings as the carriage is moved in the reverse direction, towards the autocollimator. Take the average of the readings at each position as the measurement result.

Calculation:

1. See table next page. The "difference from first reading" column is obtained by subtracting the reading at AB (=20 in this example) from the readings at other positions. This is the variation in tilt of the reflector compared with its attitude at position AB.
2. The "rise or fall" column is the angular deviation in previous column converted into linear displacement. $1 \text{ second} = \frac{1}{3600} * \frac{\pi}{180} radians \;\; = \frac{1}{3600} * \frac{\pi}{180} * 50{,}000 \mu m$ $\cong 0.25 \mu m$. Add a zero at the top of the column to represent the height of point A (regarded as the datum).

Position	Autocollimator Mean Reading	Difference from first reading	Rise or fall over 50mm baselength	Cumulative Rise or Fall	Adjustment required	Error
mm	seconds	seconds	µm	µm	µm	µm
0			0	0	0	0
0-50	20	0	0	0	1	1
50-100	18	-2	-0.5	-0.5	2	1.5
100-150	16	-4	-1	-1.5	3	1.5
150-200	10	-10	-2.5	-4	4	0
200-250	14	-6	-1.5	-5.5	5	-0.5
250-300	24	4	1	-4.5	6	1.5
300-350	22	2	0.5	-4	7	3
350-400	18	-2	-0.5	-4.5	8	3.5
400-450	10	-10	-2.5	-7	9	2
450-500	8	-12	-3	-10	10	0

3. The cumulative rise or fall column, gives the amount by which the end of each segment is displaced from zero datum line AB. When these values are plotted, the graph obtained is shown in Figure 5.

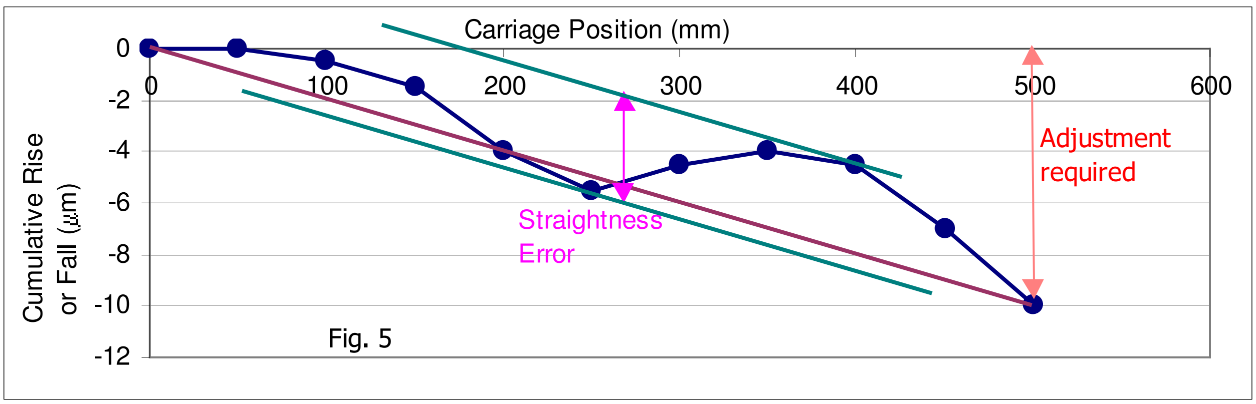

Fig. 5

4. In order to determine the errors with respect to the end-point line, we need to rotate the right end so that the error there becomes zero. Thus, the adjustment required at the last point is negative of the cumulative rise or fall at that point. This total adjustment has to be reduced proportionate to the distance from the first point to get the required adjustments at the intermediate points. The adjustment at the first point will be zero.
5. Add the adjustment required at each point to the cumulative rise or fall. The straightness error along the line is the maximum error – minimum error= (3.5--0.5)=4.0 in this case. See Fig. 5.

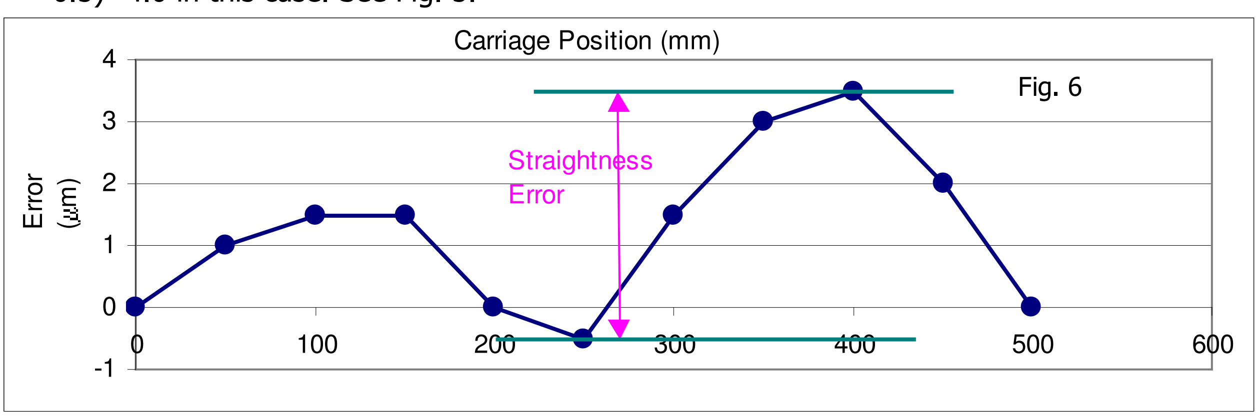

Fig. 6