OPTICAL TOOLING APPLICATIONS

PART 2

BY ERIC HEILIMO

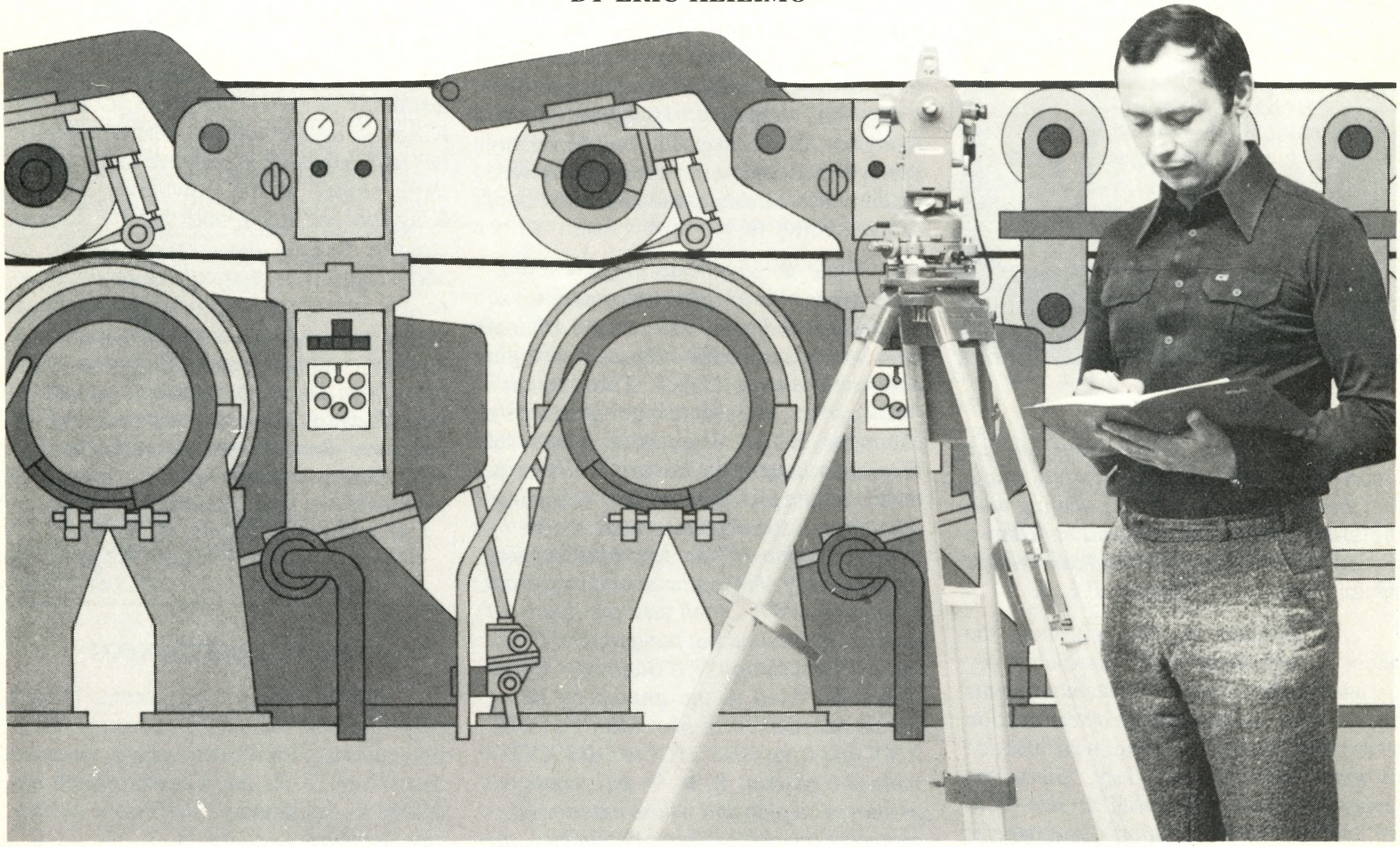


Figure 6

THE WILD GAP1 is suitable for many industrial applications such as transferring directions to different levels. One application (i.e. the checking of parallelism of rollers) will be given here. (See Figure 6)

Several applications have already been described using an autocollimation prism (Wild GAP1). The technique of autocollimation is used in numerous applications for checking and establishing perpendicularity, measuring small angular deviations, and for calibrating angle measuring devices such as rotary tables. One important application is the checking and monitoring of gyros, and gyro-stabilized platforms.

LEVELLING

Not too much will be said about levelling procedures as they are similar to those in surveying. A few points will be stressed dealing with the use of levelling in collimation and autocollimation.

As in higher order surveying, the corrections of atmospheric refraction and earth curvature should be applied to levelling measurements where applicable. It was mentioned that the Wild N3 and NA2 levels could be used as autocollimation instruments. If a mirror or an item fitted with a mirror is to be set precisely vertical, it can be done by first levelling the instrument and then adjusting the orientation of the mirror until autocollimation is obtained.

These levels, if in adjustment, can be used as horizontal collimators against which theodolites and other levels can be checked and adjusted.

WILD N3 PRECISION SPIRIT LEVEL

A complete section has been devoted for the explanation of this level because it was been specially designed for optical tooling, and its special features differ from other levels.

In optical tooling, spirit level instruments have advantages over automatic levels. Spirit levels are not sensitive to constant vibrations and strong permanent magnetic fields which are common occurrences in industry. On the other hand, automatic levels such as the Wild NA2, are affected by these factors and therefore are not capable of providing the same accuracy as spirit levels under these physical conditions.

The N3 level has a frictionless tilting axis, and a tilting screw which is accurately calibrated to permit the measurement of small changes in vertical angles. ''The tilting mechanism of the telescope is designed so that one interval of the tilting screw corresponds to a change in ele-

An example of the use of the autocollimation prism

Checking the parallelism of rollers

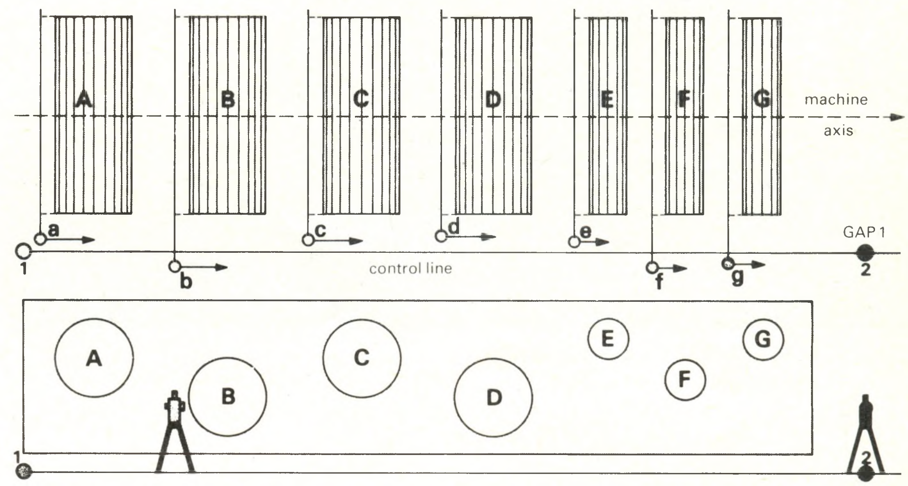
In rolling mills and with certain types of machinery, it is vital that rollers are aligned precisely. They must be exactly parallel to each other and at the correct height.

The rollers A, B, C . . . G have to be aligned. A control line with end points 1 and 2 is established on the factory floor parallel to the longitudinal axis of the machine. Centre the theodolite over point 1 and the autocollimation prism over point 2. Focus to and point to the ground point at 2 to align the telescope along the control line 1–2. Then focus to infinity, point to the autocollimation prism, and turn the prism until autocollimation with the vertical hair is achieved. The prism is now at 90° to the control line and can be used as a reference. It will define vertical planes parallel to the control line.

To check roller A: Set up the theodolite at a. Note that centring to within 2 or 3 cm of the control line is all that is required. Autocollimate to the prism (if required, the offset of the theodolite, left or right of the control line, can be read on the prism's mm-scale) and turn off 90°. Hold a scale against each end of the roller in turn and check the alignment. Note that for measurements to the roller to 0.05 mm/0.002 inch, a Wild parallel plate micrometer can be fitted to the theodolite telescope.

The other rollers are checked in the same manner. The advantages of the method are that centring is unimportant, and therefore errors due to centring cannot occur, and that the theodolite can be set to the different heights of the rollers as autocollimation with the vertical hair is always achieved.

The height and horizontality of the rollers are normally checked with a precision level, such as the Wild N3 or the Wild NA2 with GMP3 Parallel Plate Micrometer.



Many tasks can be solved in a similar manner. Whenever a precise reference is required for alignment or horizontal angle measurement in optical tooling, choose

The Wild GAP 1 Autocollimation Prism.

Figure 7

vation of the line of sight of 2.06″; i.e. 0.01 mm. per 1 m. (1:100000).''

The telescope has several unique features. It has an extremely short focusing distance which is helpful in optical tooling. ''A scale or target only 30 cm. (12 inches) in front of the objective can be brought into perfect focus.

To complement this extremely short minimum distance, focussing produces a zoom effect.'' In other words, at short sighting distances the magnification decreases and the field of view increases; and at far distances, the reverse takes place. ''When focusing to 2 m., the field of view is twice as wide as that of a comparable conventional telescope.''

The N3 telescope also has a very stable focusing mechanism, in that the line of sight will not deviate much over the entire focusing range. ''On changing focus from infinity to 2 m., the line of sight will not vary by more than 2 seconds, and as any change in the line of sight is really only at short distances - from infinity to 20 m., the change will never be more than 0.5 seconds - the effect on measurements is negligible.''

A built-in parallel plate micrometer increases the accuracy of taking readings from a rod. ''The micrometer reads directly to 0.1 mm. Estimation to 0.01 mm. is possible.''

APPLICATION

The N3 can be used as an autocollimation instrument for checking the flatness of such surfaces as plates, rails and benches. An autocollimation mirror is mounted on a base and this is positioned at each of the points being measured. Readings are taken on the graduated tilting screw. ''As an interval is 2″, readings to 1″ of arc are easily taken. If the base of the mirror is 200 mm. in length, a change in inclination of 1″ corresponds to a height difference of only 1 micron between the points on which the base rests.'' This example illustrates the obtainable accuracy in levelling procedures.

PROCEDURE FOR MEASURING THE ROTATIONAL ACCURACY OF THE SHOP LATHE

First the diameter of the chuck was measured with reasonable accuracy in order to obtain a measurement for the circumferance. The diameter was measured with vernier calipers. The circumference was calculated from c = π x diameter. It appeared that 24 measurements, 15° apart were sufficient to accurately determine the motion of the mirror and axis. The arc distance between each 15° position was calculated from Arc = $c/24$. Each of these 15° positions were marked out on the circumference of the chuck beginning at any arbitrary position.

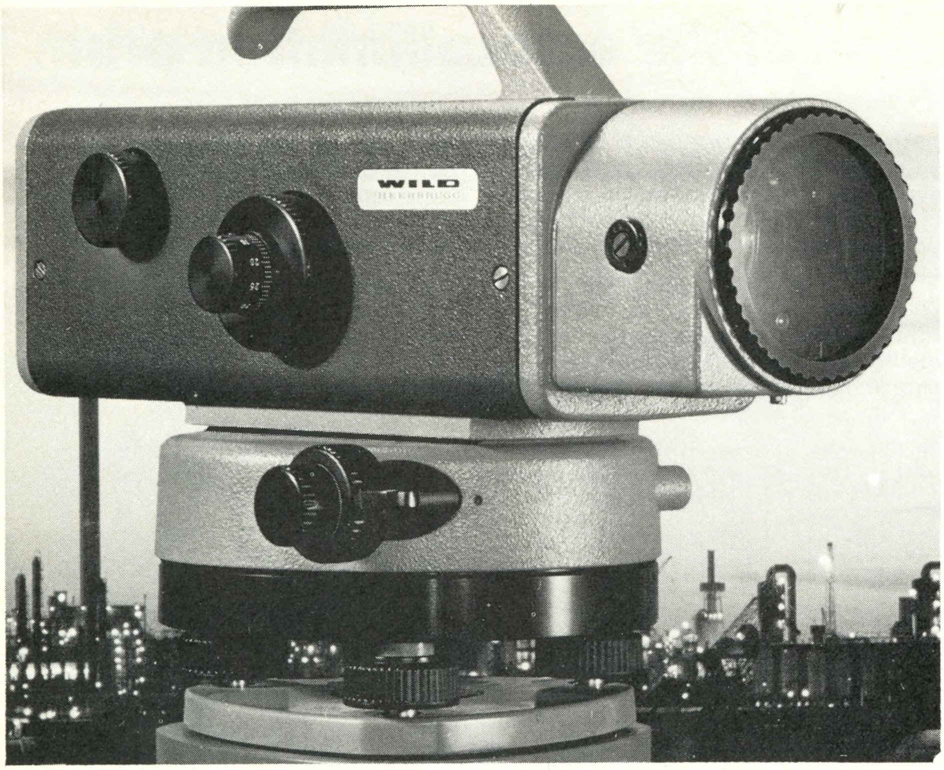


Figure 8

A front surface mirror was obtained, whose diameter was larger than the diameter of the T3 objective. It is advantageous to have the mirror larger than the objective so that a strong reflected image is obtained (this has been discussed earlier). The mirror was positioned in the chuck so that it was roughly in the centre of the axis of rotation, (it is not required to be exactly centred). The autocollimation theodolite (T3) was set up in front of the mirror (i.e. distance was 1.12 m.) approximately in line with the lathe axis and at the height of the mirror. The theodolite was then levelled, focused to infinity, and the telescope was pointed to the mirror to obtain autocollimation. The mirror, or chuck was then rotated through 180°. Autocollimation was not obtained as the reflected ray had been deflected though too large an angle. (This is illustrated in Figure 10.) This meant that the mirror was probably not close to being perpendicular with the axis of rotation. The tilt of the mirror therefore had to be adjusted to make it closer to 90° with the axis. (It should not be set exactly at 90° but fairly close, because it is desirable to get a roughly circular plot from the measurements. If the mirror is exactly perpendicular, then a plot may not be obtained as the variation in the angular values will be small and possibly zero if there is no wobble in the axis.) Once the mirror had been adjusted, autocollimation was obtained; however the line of sight was close to the edge of the mirror, and as a result the reflected image was weak. (See Figure 11). The theodolite was shifted in position slightly on the head of the tripod, to bring the line of sight closer to the centre of the mirror. The angle between the axis of rotation and the mirror was now close to 90° (i.e. 90° ±1°) and therefore the line of sight of the theodolite at autocollimation was close to being parallel with the rotational axis.

A T1 theodolite was set up on the opposite side of the lathe as shown in Figure 9, facing the T3, and in such a way that the markings on the chuck would be viewed. Using the principle of collimation, the lines of sight of the two instruments were made collinear. It is not important to line up the instruments exactly, since the T1 is used only to set up a vertical reference plane which is used when turning the chuck accurately through each 15° division. In other words, each of the 24 markings on the chuck are brought into coincidence with the line of sight from the T1. Beginning with the first point, the motion of the axis was measured as follows; with the first point on line with the reference plane, autocollimation was obtained with the T3 in the direct position. Both the horizontal and vertical circles were read. The chuck was rotated so that the next marking was brought into coincidence with the line of sight of the T1. The reflected image of the crosshairs of the T3 were again brought into coincidence with the actual crosshairs, and both circle readings were recorded. This procedure was repeated until horizontal and vertical circle readings had been taken at all positions through a 360° rotation of the chuck. (See Figure 12) The telescope of the T3 was then transitted into the reverse position. The entire procedure was repeated taking a second set of readings for all 24 positions.

The first pointing with circle readings Hz1 and V1 was taken to be the reference point. Hz1 and V1 were subtracted from the subsequent readings to obtain differ-

Figure 9 Instrumental Setup for Lab Project

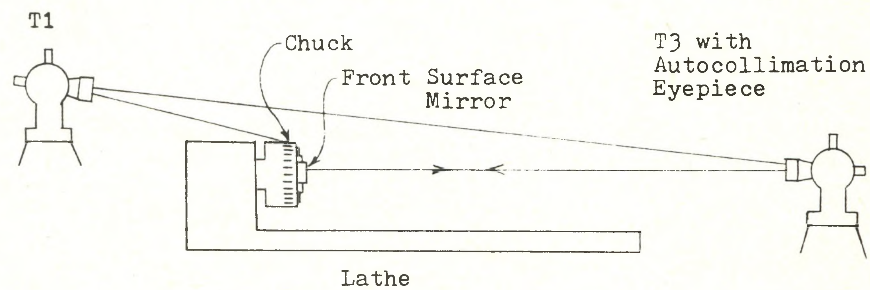


Figure 10

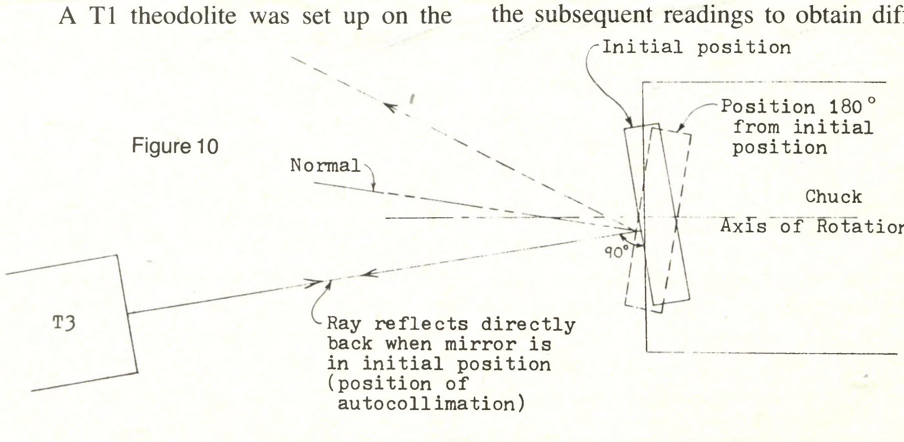
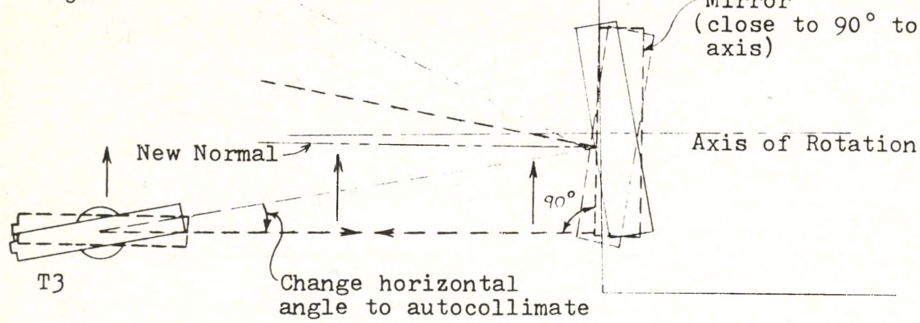


Figure 11



ences in horizontal and vertical circle readings, ΔHz and ΔV. ΔHz was then plotted against Δto give a graphical representation of how the mirror moved through a 360°rotation.

RESULTS

After each set of readings was taken (24 points), the first point in each set was repeated to obtain an angular misclosure on the results. The largest misclosure was 6.2″ which could have resulted from not being able to set the markings exactly coincident with the reference line from the T1. (It was determined that an error in the positioning of the chuck, of a fraction of a millimetre, caused an angular error of several seconds.) However, the magnitude of this misclosure is insignificant due to the fact that if it was distributed over the 24 readings, the correction at each point would only be 0.25 second. Also, the scale of the plot is such that a difference in readings of ½ second is about the finest that can be easily distinguished.

For the reverse vertical angle readings, the actual zenith angle is given by 180° - Observed Vertical Angle. This meant that the signs had to be reversed on all the ΔVertical angles.

To get a suitable scale at which to plot the observations, it was necessary to reduce all Δangle values by a factor of 20. This in effect caused the differences between the direct and reverse readings to be reduced also by a factor of 20. This resulted in the differences being so small that they could not be plotted (i.e. the maximum difference was only about 0.8″). Therefore only one set of readings had to be plotted (i.e. Direct readings) as opposed to plotting both direct and reverse and then taking the mean values.

The final plot was an ellipse which contains both mirror misorientation and the motion or ''wobble'' of the axis.

If no wobble exists in an axis, the resulting measurements would show a plot of a circle, the radius of the circle being a measure of the inclination of the mirror. The proof for this is as follows; assuming for simplicity, the mirror is tilted by an angle ∝ from the vertical.

Therefore this means that for a mirror inclination of ∝ from the vertical, the range in vertical angle to obtain autocollimation in both positions of the mirror (0° and 180°) is 2∝. The radius of the circle is equal to the inclination of the mirror (∝). This is true irrespective of where the horizontal line through the telescope intersects with the mirror. It does not have to intersect at the axis of rotation of the mirror (as shown in the diagram). The instrument height can be changed up or down and this does not alter the angular relationships. The diagram can also be viewed in plan, and in this case the angle ∝ represents an inclination of the mirror in the horizontal plane. The angle 2∝ is now the range in horizontal angle required for autocollimation in both positions of the mirror (0° and 180°). It can be noted that a horizontal displacement of the line of sight has no effect on the angular relationships with the mirror. The same process applies for a combined horizontal and vertical inclination of the mirror. Therefore, any inclination of the mirror in the horizontal and vertical planes will result in a circular plot when the mirror is rotated through 360°. The radius of the circle will be equal to the total inclination of the mirror.

Since the measurements in the experiment produced an ellipse and not a circle, then this means that there is a definite wobble in the lathe axis. Due to the symmetry of the plot, this wobble must be symmetrical about the axis of rotation.

Figure 12

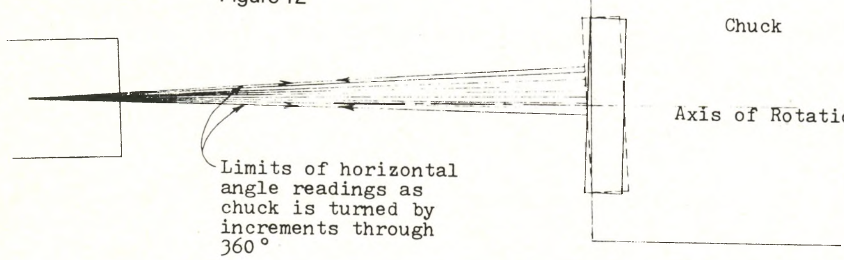


Figure 13

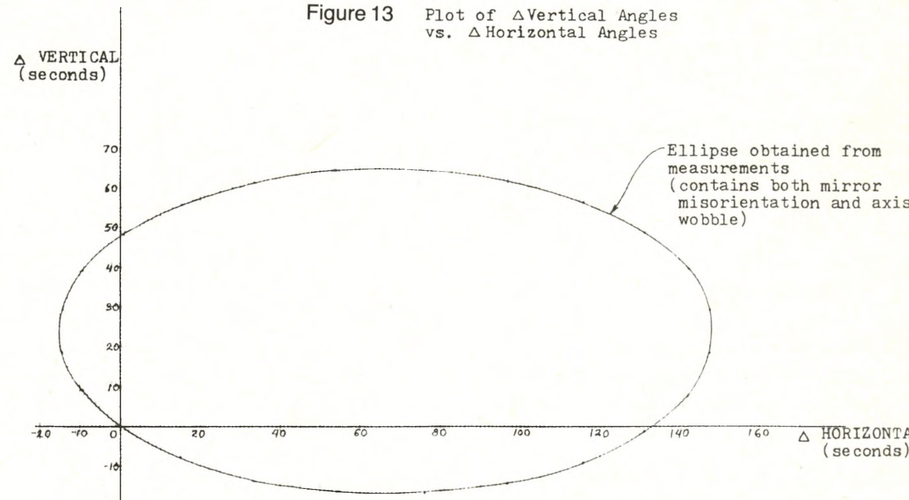
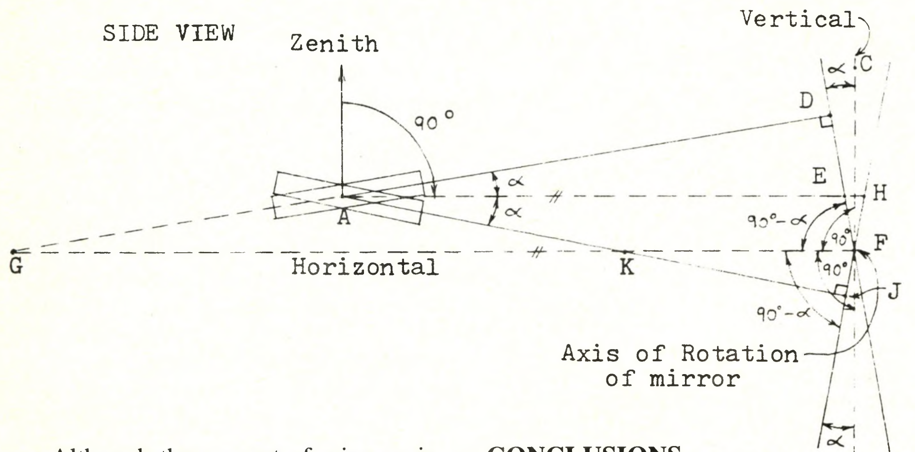
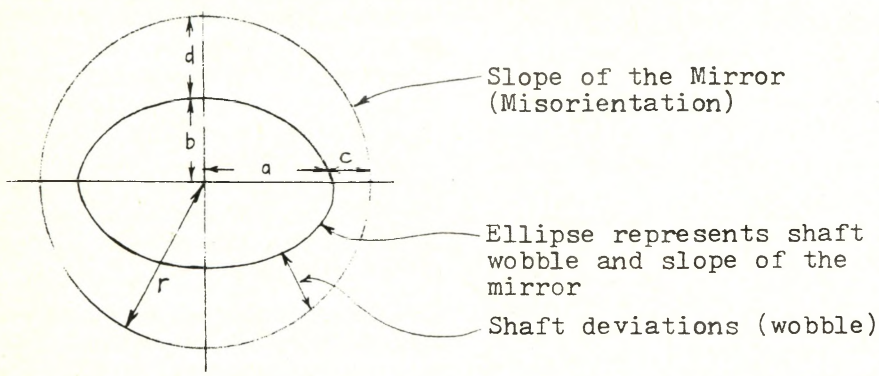


Figure 14 Angular Relationship between a Mirror Tilt and the Radius of the Circular Plot



Although the amount of mirror misorientation with respect to the axis could not be determined numerically by measurements, it can be illustrated in general terms by the following diagram.

Figure 15 Mirror Misorientation and Wobble



In this case $r = a + c = b + d$.

The wobble is always represented by the difference between the mirror misorientation and the final result (the ellipse). In the sketched case the wobble in the vertical direction (d) is greater than the wobble in the horizontal direction (c). (Note that r has not been determined.)

Where the wobble is the same in both horizontal and vertical directions, then

$$a - r = r - b$$
or $$a = 2r - b$$
$$2r = a + b$$
or $$r = \frac{a + b}{2}$$

Therefore, when $r > \frac{a+b}{2}$, the wobble in the vertical becomes larger than the wobble in the horizontal, as in the diagram. When $r < \frac{a+b}{2}$, the reverse is true.

Therefore the magnitude of wobble in both horizontal and vertical directions if different, requires the determination of the mirror misorientation (r), before individual wobbles can be determined.

CONCLUSIONS

On the basis of the investigation carried out, the following conclusions were made:

It is evident from the graphical representation of the measurements, that there is a definite wobble in the lathe axis. This is due to the fact that an ellipse was obtained instead of a circle. Since the plot was symmetrical, it indicated that the wobble of the axis is also symmetrical about the axis of rotation. The amount of wobble in an axis is always the difference between the mirror misorientation and the final plot which contains both mirror misorientation and wobble. Depending on the relative size of the plots (i.e. the circle with respect to the ellipse, if such is the case), it can be determined whether the wobble in the horizontal direction is larger than that in the vertical or vice versa.

The exact amount of wobble could not be numerically derived from the measured data. In order to determine it, the exact angular relationship between the mirror and the axis of rotation in an initial position must be known. In other words, the total amount of mirror inclination, must be known, before the amount of wobble can be calculated. This could not be done feasibly in the experiment. ●

Articles from Periodicals

The Canadian Surveyor. The Canadian Institute of Surveying. Volume 36, No. 4, December, 1982.

"From Compass to Satellite." W. D. Stretton. pp 11-346.
Volume 37, No. 1, Spring, 1983.

"A Study of the Effect of Standard Laboratory Processing on Speed and Resolution of Three Black and White Aerial Films." E. A. Fleming, M. Landreville and E. Nagy. pp 3-10.

"The Ultimate Trespass." J. F. Doig. pp 11-17

Survey Review. The Ministry of Overseas Development. Volume 27, No. 207, January, 1983.

"Some tests of Retro-reflective Materials for Electro Optical Distance Measurements." T. J. M. Kennie. pp 3-12.

"Beating the Bounds." A. C. McEwen. pp 13-19.

"Determination of the Secular Movements of the Axis of the Civic Tower at Modena." P. Russo. pp 21-38.

"Surveying with Non-levelled Theodolites." S. A. Kyle. pp 39-42.

Volume 27, No. 208, April, 1983.

"Some Tests of of Retro-reflective Materials for Electro-optical Distance Measurements (cont.)." T. J. M. Kennie. pp 51-61.

"A Computer Method for A Priori Investigation of the Electro-optical Distance Meter Additive Constant Error due to Infra-red Source Inhomogeneities." M. Rezulski and A. Zakrzewski. pp 63-74.

"Astronomic Determinations of Deflection of the Vertical." V. Achilli, P. Baldi and S. Zerbini. pp 75-80.

"Innovative Cartography in Palestine of 1917-1918." D. Gavish and C. Biger. pp 81-91.

Surveying and Mapping. The American Congress on Surveying and Mapping. Volume 43, No. 2, June, 1983.

"Surveying - A Career You Can Learn in 72 Weeks or Less." Donald E. Bender pp 111-114.

"The Use of Tidal Datums in the Law." John Briscoe. pp 115-121.

"The Correction for Levelling Refraction and its Impact on Definition of the North American Vertical Datum." Sanford R. Holdahl. pp 123-140.

"Houston's Metropolitan Common Digital Base: Four Years Later." Francis L. Hanigan. pp 141-151.

"Surveying and Mapping (S & M) in China." Dr. A. J. Brandenberger. pp 153-160.

"The Kiket Island Nuclear Power Generation Site Survey." Daniel E. Beardslee. pp 161-173.