University Of Jordan
Faculty of Engineering and Technology
Mechanical Engineering Department

Measurement Lab.

Experiment 1

Auto collimator

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Introduction

An autocollimator is an optical instrument that is used to measure small angles with very high sensitivity. As such, the autocollimator has a wide variety of applications including precision alignment, detection of angular movement, verification of angle standards, and angular monitoring over long periods.

Objectives:

- To measure straightness of a beam with the use of Auto-Collimator.
- To identify the principle of Auto-Collimator device.
- To be able to draw conclusions about straightness error using graphical methods and least square method.

Apparatus:

1) auto collimator
2) straight edge with 100mm marked intervals.

Theory:

Increasing demand for product reliability and efficiency has placed a corresponding emphasis on the geometric integrity of components and their assembly. In engineering applications, one often comes across the problems of measurement, of-geometrical parameters such as alignment, straightness, squareness, flatness, etc.

At many places it is required that the surfaces must be perfectly straight, e.g., in a lathe it is desired that tool must move in a straight path to generate perfect cylinder and it is possible .only when the controlling guideways are themselves straight. Also straight line or plane is the basis of most methods of measurements. The quality of straightness in precision engineering is represented by straight edge.

The fundamental principle about straightness measurement is given by Bryan. According to Bryan principle, a straightness measuring system should be in line with the functional point at which straightness is to be measured. If this is not possible, either the slideways that transfer the measurement must be free or angular motion or angular motion data must be used to calculate the consequences of the offset.

Definition of straightness of a line in two planes.

A line is said to be straight over a given length, if the variation of the distance of its points from two planes perpendicular to each other and parallel to the general direction of the line remains within the specified tolerance limits; the reference planes being so chosen that their intersection is parallel to the straight line joining two points suitably located on the line to be tested and the two points being close to the ends of the lengths to .be measured.

The tolerance on the straightness of a line is defined as the maximum deviation in relation to the reference straight line joining the two extremities of the line to be checked (Fig. 1).

Fig. 1: Profile of surface with respect to reference straight line.

It is the usual practice to state the range of measurement, i.e. the length to be checked; and the position of the tolerance in relation to the reference straight line. In most cases, the parts very close to the ends, which most often have local errors of no great importance, may be neglected.

Auto-collimators are sensitive and inherently very accurate optical instruments for the measurement of small angular deviations of a light reflecting flat surface. The auto- collimator has its own target which is projected by collimated light beams on a remotely placed surface and the reflected target image is observed in the ocular of the instrument.

The auto-collimator is stationed at the end of the bed with a rigid support base. The movement of the reflector along the bed will cause the reflected image of the target to deflect according to the angular error of the bed.

The autocollimator is a flat mirror mounted in a short tube made to fit a Newtonian telescope focuser, and set accurately perpendicular to the tube's axis. Centered in it is a small peephole or pupil that you look through.

Principles of operation

Tests for straightness can be carried out by using spirit level or auto-collimator. The straightness of any surface could be determined by either of these instruments by measuring the relative angular positions of number of adjacent sections of the surface to be tested.

So first a straight line is drawn on the surface whose straightness is to be tested.

Then it is divided into, a number of sections, the length of each section being equal to the length of spirit level base or the plane reflector's base in case of auto-collimator. Generally the bases of the spirit level block or reflector are fitted with two feet so that only feet have line contact with the surface and whole of the surface of base does not touch the surface to be tested. This ensures that angular deviation obtained is between the specified two points. In this case length of each section must be equal to distance between the centre lines of two feet. The spirit level can be used only for the measurement of straightness of horizontal surfaces while auto-collimator method can be used on surfaces in any plane.

In case of spirit level, the block is moved along the line on the surface to be tested in steps equal to the pitch distance between the centre lines of the feet and the angular variations of the direction of block are measured by the sensitive level on it.

Angular variation can be correlated in terms of the difference of height between two points by knowing the least count of level and length of the base.

In case of measurement by auto-collimator, the instrument is placed at a distance of 0.5 to 0.75 meter from the surface to be tested on any rigid support which is independent of the surface to be tested.

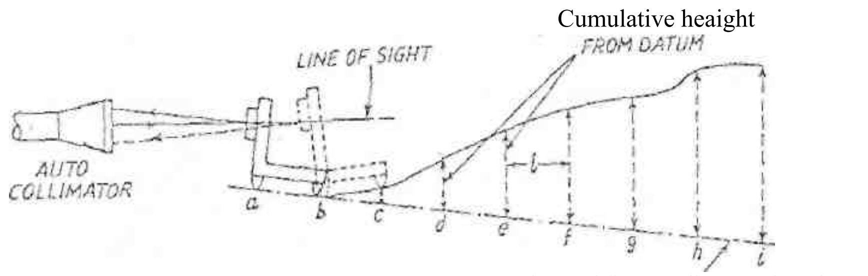


Fig. 2: Steps of taking the readings.

The parallel beam from the instrument is projected along the length of the surface to be tested.

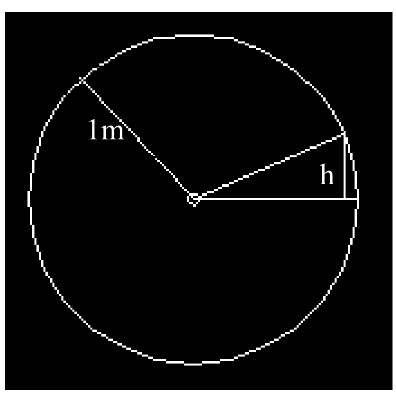
A block fixed on two feet and fitted with a plane vertical reflector is placed on the surface and the reflector face is facing the instrument.

The reflector and the instrument are set such that the image of the cross wires of the collimator appears nearer the centre of the field and for the complete movement of reflector along the surface straight line, the image of cross-wires will appear in the field of eyepiece, the reflector is then moved to the other end of the surface in steps equal to the centre distance between the feet and the tilt of the reflector is noted down in second from the eyepiece.

The autocollimator projects a beam of collimated light. An external reflector reflects all or part of the beam back into the instrument where the beam is focused and detected by a photodetector. The autocollimator measures the deviation between the emitted beam and the reflected beam. Because the autocollimator uses light to measure angles, it never comes into contact with the test surface.

Visual autocollimators rely on the operator's eye to act as the photodetector. Micro-Radian visual autocollimators project a pinhole image. The operator views the reflected pinhole images through an eyepiece. Because the human eye acts as the photodetector, resolution will vary among operators. Typically, people can resolve from 3 to 5 arc-seconds. Because the human eye is able to discern mutiple images simultaneously, visual autocollimators are suitable for measuring multiple surfaces simultaneously. This makes them ideal alignment instruments in applications like aligning laser rod ends or checking parallelism among optics. Visual autocollimators can also be equipped with an eyepiece reticle for aid in lining up test optics to a master reference.

To calculate Tilt of 1 sec of Arc of the Reflector:



$\tan\theta = h /$ radius
$\theta = 1$ sec of arc
h=tan 1 sec x Radius
$h = 4.848 \times 10^{-6}$ meter
h = 5 micrometer / meter approximately
h = 0.5 micrometer / 10^{-3} mm

PROCEDURE

1. Clean the surface plate or table.

2. Position the auto-collimator in line with the reflector. Switch on the lamp in the autocollimator, the alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to make certain that the target graticule is contained within the eyepiece field.

3. Fix a guide strip to control the horizontal displacement of the reflector and minimise the movement of the target graticule.

4. Mark off the positions along the surface plate equal to the pitch positions on the reflector base (in this case 100 mm). Column 1 should indicate this position.

5. At the initial position takes the reading and tabulates (column 2)
6. Move the carriage (reflector) to the next position and again tabulate the reading.

7. This method is to continue until the final outward position is recorded.

To improve on the accuracy and ensure no errors have been introduced, readings should also be taken on the inward run. If this exercise is followed then the average of the two readings is to be shown in column 2.

8. The remainder of the table should be filled by adopting the following procedure:
   - Column 3 This is the variations of the tilt occurring between the position at which the reading is taken and the original position.
   - Column 4 The angular position in column 3 is converted into a linear measure (1 second = 0.5 micro m). Insert a zero at the top of the column to represent the datum.
   - Column 5 This is the cumulative algebraic sum of the displacements. Calculate the mean displacement this is the amount by which the displacement must be adjusted to relate them to the zero datum.
   - Plot the values of column 5 versus column 1.

Observed Data:

Table (1): Variation of rise/fall angle along surface.

1	2	3	4	5
Position of reflector	Auto-coll. Reading	Difference From 1st Reading	Rise (-) or Fall (+) per 100 mm	Cumulative Rise or fall
mm	seconds	seconds	µm	µm
0			0	0
0 – 100				
100 – 200				
200 – 300				
300 – 400				
400 – 500				
500 – 600				
600 – 700				
700 – 800				
800 – 900				
900 – 1000				

Discussion and review Question:

›› Explain the principle of the Auto-collimator.

›› Are the existence of burrs or dust on the surface plate affect your result.

›› Auto collimator works on the principle light reflection, it concerned with the idea that flat surface will reflect light at ------------- angle.

›› The main scale is divided into ---------- divisions each reads ------- min.

›› The accuracy of the device is ----------

›› The alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to --------------

›› Determine the maximum straightness error with respect to

a) A line joining end points
b) The least square line.

›› Discuss and compare your results.

- Which method is more accurate , why?