

MEASUREMENT OF STRAIGHTNESS ERROR OF MACHINE GUIDEWAYS USING AUTOCOLLIMATOR

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Abstract: This paper shows the straightness error measurement method of guideways of various machines. A short description of straightness measurement method using Autocollimator and result of straightness error for 4.75 feet (1448mm) long guide way of engine lathe. This method is also use for the measurement of straightness error of the guideways of large scale machine tools. The purpose of the work is to identify the straightness error of guide ways and get result of error with best possible accuracy.

Index Terms - machine, straightness measurement, machine guide ways, autocollimator

I. INTRODUCTION

For large machines with long guide ways, it is important to align the guide ways both in the vertical direction and horizontal direction. So for the proper alignment of the guideways it is necessary to check the straightness error of the guideways along its length.

Definition of straightness:

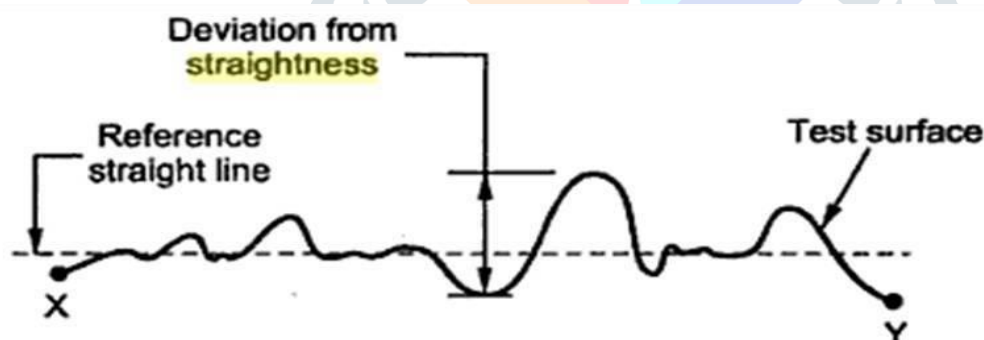


Fig.1 Profile of test surface

“The linear uniformity of work surface measured from the external reference line is known as straightness.”

Or

“A straightness error is defined as the deviation perpendicular to the direction of travel as shown in Fig. 1. Assuming the ideal travel path is a straight line; any deviation from the straight line in the horizontal plane is called horizontal straightness and in the vertical plane is called vertical straightness.”

II. LITERATURE REVIEW

The methods of straightness measurement:

There are two group of methods are use for the straightness measurement based on following manner.

- measuring the length
- measuring the angle

In the group based on length measurement the different methods used are as following.

- Wedge method
- precise ruler and gauge
- string and microscope

In the group based on angle measurement the different methods used are as following.

- Autocollimator method

- Precession level method

Autocollimator:

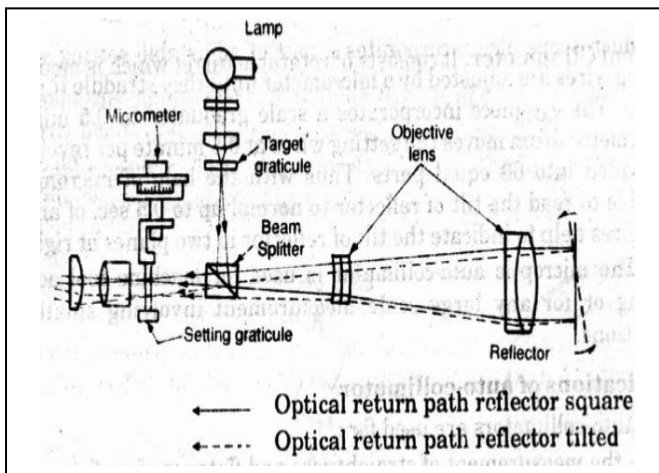


Fig.2 Line diagram of autocollimator



Fig.3 Autocollimator

Autocollimator is a device which is use to measure the readings of angular deviation. It is use to measure very small angular deviation. Here Fig.2 shows the line diagram of autocollimator.

Working principle of autocollimator:

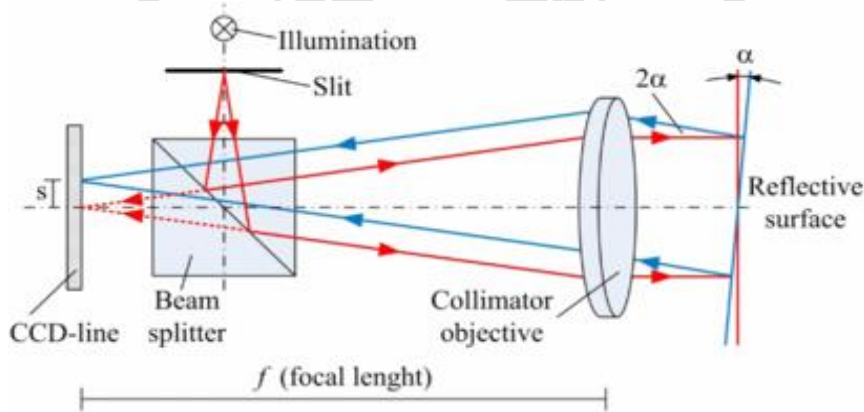


Fig.4 Principle of Autocollimator

Above fig.4 shows the working principle of autocollimator. A plane reflector is placed in the path of the beam and normal to the to the geometric axis of the lens which is indicated by red colour plane in above fig. It will reflect the light along the transmitted path (red colour beam) and to be refocused at the source.

If the reflector is inclined at a small angle α to the normal which is indicated by blue colour plane in above figure, the beam is reflected at an angle to 2α (blur colour beam).The reflected beam will refocused at the focal plane at a distance S from the principle focus. From the triangle made with this ray and the focal length f , $S=2f\alpha$.By using this equation the reading of angular deviation will be calculated.

Guideways:

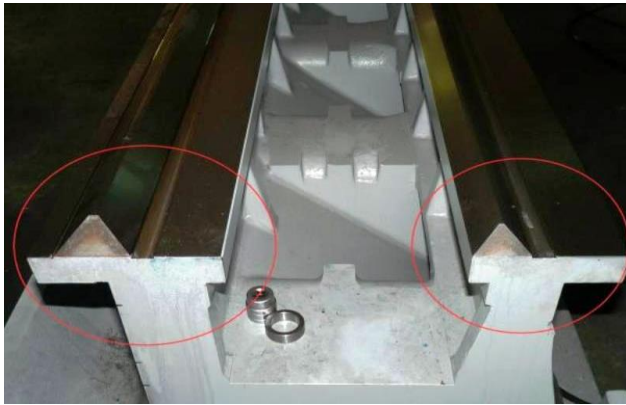


Fig.4 Guideways

The Guideway is one of the important elements of machine tool. The main function of the guideway is to make sure that the cutting tool or machine tool operative element moves along predetermined path. The Linear Motion Guideways provide a smooth and linear motion in machine tools, due to which higher accuracy and precision can be obtained.

III. INVESTIGATION AND RESULT OF STRAIGHTNESS ERROR OF GUIDEWAYS USING AUTOCOLLIMATOR

This investigation is carried out on the Guideways of engine lathe. The length of the guide way is 4.75feet (1448mm).The list of instruments required for this investigation are listed below.

List of instruments:

- Autocollimator for measurement of angular deviations
- Reflector stand of 100mm base length
- Measuring steel ruler to make divisions on guideway.

Investigation procedure:



Fig.5 Guideway under investigation

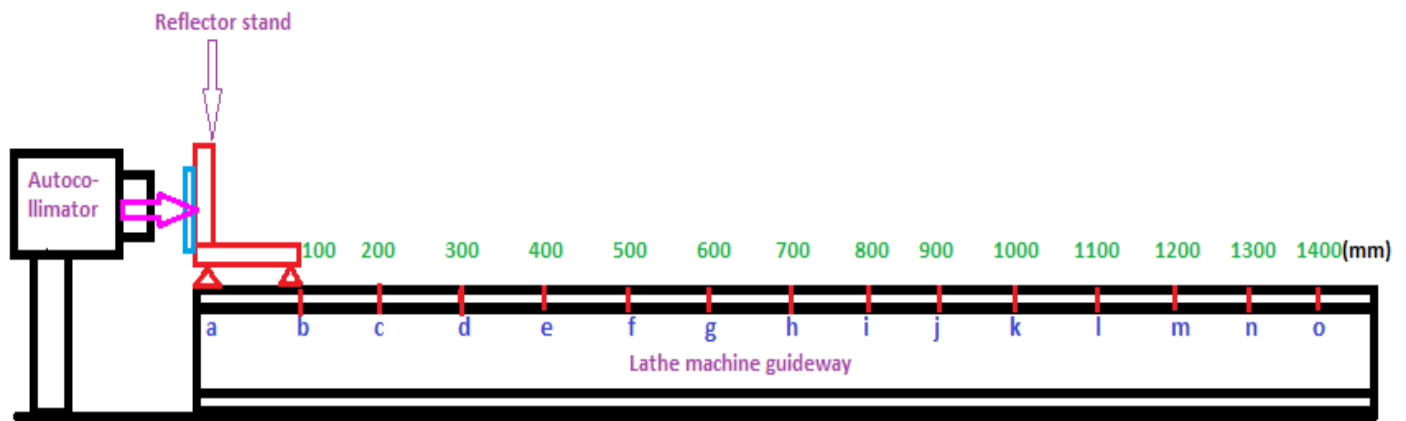


Fig.6 Setup for straightness error measurement

Here above fig.6 shows the setup for the straightness measurement by using the autocollimator. The procedure of measuring straightness error of the engine lathe Guideways is given below. Here the length of Guideways is divided into equal parts as shown in fig.6. The length of the each part is equal to the distance between the feet of the reflector stand. Here each part is of 100mm.

Procedure:

- (I) Position the micrometer of the autocollimator to measure displacements in vertical plane. Place the reflector stand 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.
- (II) Move the reflector stand 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 adjustments to the autocollimator.
- (III) Return the reflector stand to position AB. Take an autocollimator reading and record it.
- (IV) Move the carriage along to its second position (BC) and take another reading. Continue this process and move the reflector stand along the guideway to successive positions CD,DE,EF,FG,GH,HI,IJ,JK,KL,LM,MN,NO and take the readings of angular deviation of each part.
- (V) Repeat the readings as the reflector stand is moved in the reverse direction, towards the autocollimator. Take the average of the readings at each position as measurement result.

Calculation:

Table 1:- Calculation table

1 Position	2 Autocollimator reading	3 Difference from first reading	4 Rise or fall over 100 mm base length $(\frac{1}{3600} \times \frac{\pi}{180} \times 100000) \approx 0.50$ μm	5 Cumulative rise or fall	6 Adjustment to bring both ends to zero	7 Error = [(6)+(5)]
mm	Sec	Seconds	μm	μm	μm	μm
0			0	0	0	0
0-100(AB)	30''	0	0	0	-L/n=-5	-5
100-200(BC)	42''	12	6	6	-2L/n=-10	-4
200-300(CD)	36''	6	3	9	-3L/n=-15	-6
300-400(DE)	50''	20	10	19	-4L/n=-20	-1
400-500(EF)	32''	2	1	20	-5L/n=-25	-5

500-600(FG)	38''	8	4	24	-6L/n=-30	-6
600-700(GH)	40''	10	5	29	-7L/n=-35	-6
700-800(HI)	36''	6	3	32	-8L/n=-40	-8
800-900(IJ)	48''	18	9	41	-9L/n=-45	-4
900-1000(JK)	36''	6	3	44	-10L/n=-50	-6
1000-1100(KL)	60''	30	15	59	-11L/n=-55	4
1100-1200(LM)	34''	4	2	61	-12L/n=-60	1
1200-1300(MN)	38''	8	4	65	-13L/n=-65	0
1300-1400(NO)	40''	10	5	70=L	-14L/n=-70	0

- (I) See above table for calculation. The “difference from first reading” column is obtained by subtracting the reading at AB (=30'' in above readings.) from the readings at other positions. This is the variation in tilt of reflector compare it at position AB.
- (II) The “rise and fall” column is the angular deviation in previous column converted into linear displacement using the relation $1 \text{ second} = \left(\frac{1}{3600} \times \frac{\pi}{180} \times 100000\right) \approx 0.50 \mu\text{m}$. Add a zero at the top of the column to represent the height of point A (regard as the datum)
- (III) The cumulative rise and fall column gives the amount by which the end of each part is displaced from zero datum line AB. The value of last segment gives the total cumulative rise or fall L (here L=70). These readings are plotted and graph is obtained as shown in fig.7 below.

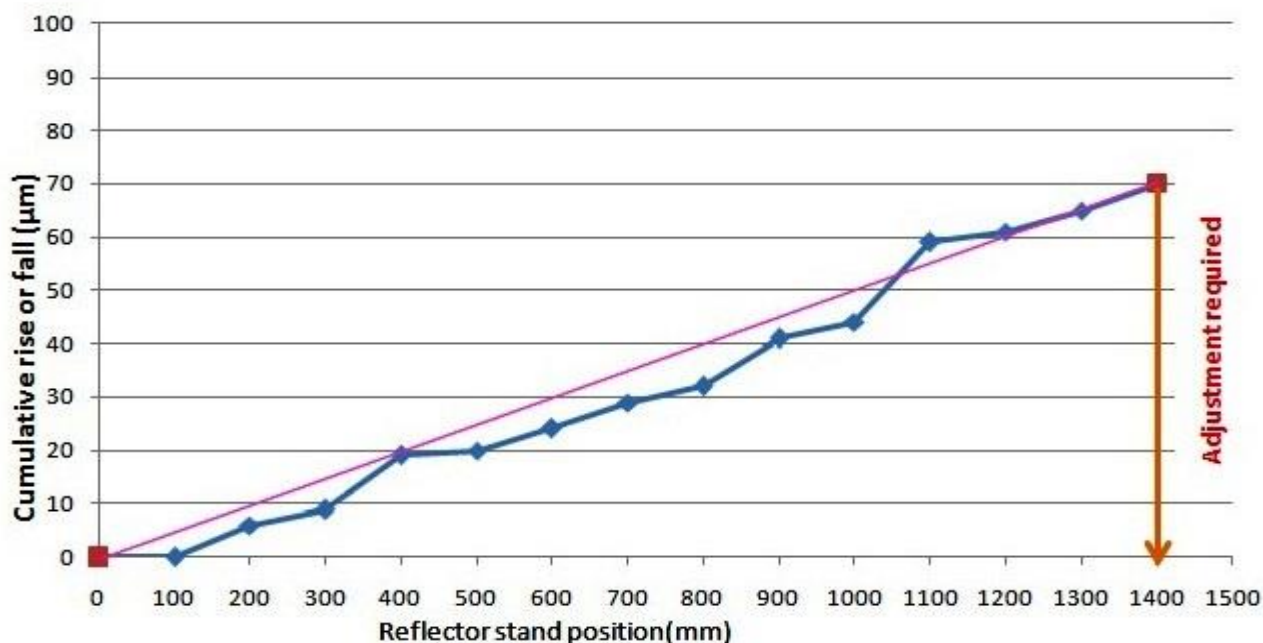


Fig.7

- (IV) 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 and fall at that point. The required adjustment at intermediate points can be calculated as per the column 6 in above table-1. The adjustment at first point will be zero.
- (V) Add the adjustment required at each point to the cumulative rise or fall and find the error of each point as per the column 7 in above table-1. Now these readings are plotted and graph is obtained as shown in fig.8 below.

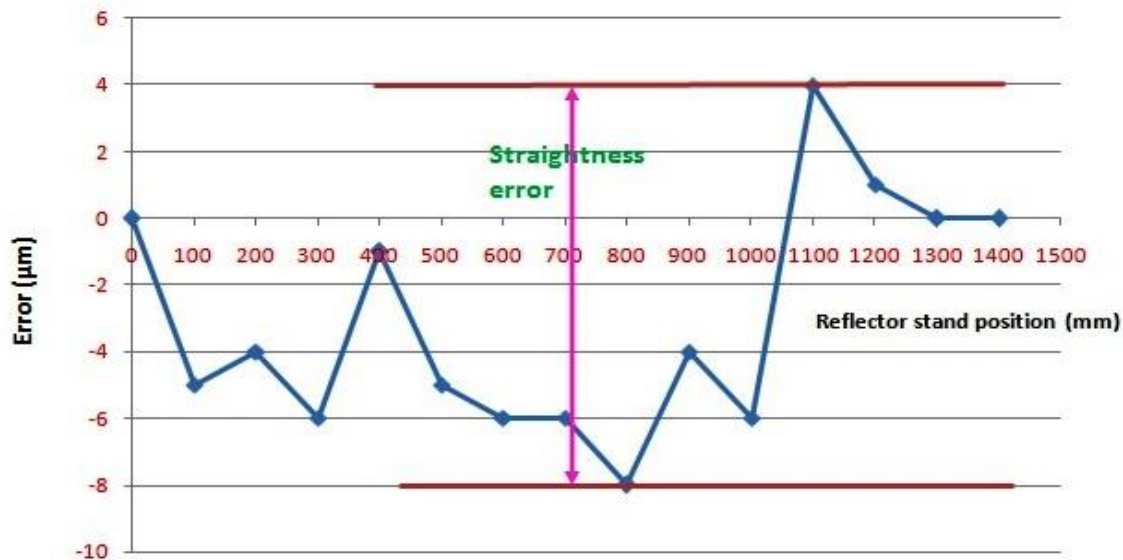


Fig.8

Result of straightness error:

The straightness error along the guideway is the (maximum error – minimum error) = $[4 - (-8)] = 12 \mu\text{m}$ in this investigation.

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