

# OPTICAL POLYGON CALIBRATION USING ONLY ONE AUTOCOLLIMATOR

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## ABSTRACT

In this paper we present a new measuring method to obtain the angular variations of the faces of an optical polygon using only one autocollimator. The method requires additionally an external beam splitter to divide the light from autocollimator and a flat mirror for second autocollimator emulation. The method can be used for polygons of any number of faces. In this case we present calibration results of a twelve faces polygon.

## 1. INTRODUCTION

Polygon mirrors are used as angle standards for angular calibrations, for example to determine the angular displacement accuracy of machine tool rotary tables. There are two well-known methods for polygon mirror calibration stated in the industrial standards [1] [2]. One of them uses two optical polygons with the same number of faces (or at least an integer multiple) and one autocollimator. This method compares errors between both polygons; from this comparison it is possible to separately determine errors of each. The other method uses only one polygon but two autocollimators. In this case, the angle between every adjacent pair of faces of the polygon is compared to the angle formed by the two autocollimators.

The main problem we found for the calibration of the polygon is concerned to our restricted resources; we just have one polygon and one autocollimator. So we need to develop a method adequate to these resources.

In “ASPE 1996 Annual Meeting” [3] we proposed a method that uses a He-Ne LASER beam, a beam splitter, a mirror, a lens, a knife-edge and a photodetector. Besides, it requires a previous calibration of photodetector response correlation between beam intensity and angular displacement for two beam trajectories and was not precise enough for our calibration.

In this paper we present a different method to overcome the above mentioned problems. The calibration procedure uses only one autocollimator for calibrating only one polygon at a time, in this case the optical setup is similar as that in ref. [3]. It can be used to measure any kind of optical polygon with flatness of  $\lambda/10$  or better on the reflective faces.

## 2. METHOD

### 2.1 Experimental set up

The optical polygon is placed on a flat plate with a spindle or on a turntable, in order to let free turn of polygon. An autocollimator is aligned over the face  $0^\circ$ . After that, a beam splitter is

placed between both devices obtaining “A” and “B” beams. One of them, A, goes directly towards the 0 degree face of polygon, while the other, the beam B, is directed towards an adjacent face aided through a flat mirror as showing in Fig. 1a).

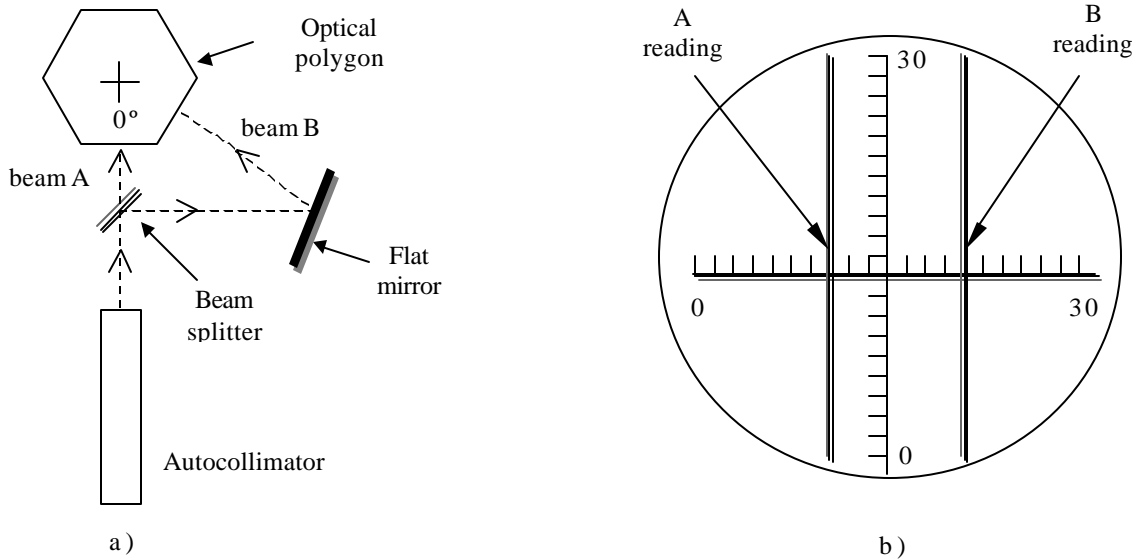


Figure 1-. a) Optical device showing divided beams “A” and “B”. b) View inside of autocollimator, position of “A” and “B” readings.

Now, as showing in Fig. 1b), inside of autocollimator we have two readings, one from each beam. It is convenient to have low readings for beam A and high readings for beam B to effect of avoid confusion with both readings. In the case of electronic autocollimators, it is possible to block the beams in alternative way in order to read each separately.

## 2.2 Experimental procedure

Once the devices have been aligned as described above, both readings are taken, *i.e.*, A reading from 0° face and B reading from adjacent face. For this particular case, we have a twelve faces optical polygon, so B reading comes from 30° face.

After that, the optical polygon is revolved until beam A aims to 30° face and beam B towards 60°. A and B readings are taken again. This procedure is repeated until all other pairs of adjacent faces are measured.

## 2.3 Formulas for computing the angular variation of the polygon faces

Having the angles  $q_1, q_2 \dots q_N$  for each face of the polygon, all of them measured from 0° face, the differences between adjacent faces are computed as

$$D(N) = q_N - q_{N+1}$$

where  $N = 1, 2, \dots, 12$  and, for the twelve faces polygon, we have:  $q_{l3} = q_l$ . Then, the angular error of each face referred to the nominal value is given by:

$$E(N) = D(N) - \frac{1}{n} \sum_{N=1}^n D(N),$$

where  $n = 12$  for our case.

### 3. EXPERIMENTAL RESULTS

The experimental set up depicted in Fig. 1 was built. In order to avoid multiple secondary reflections, a pellicle beam splitter was used. Due to the minimum division of our autocollimator (0,5 arc seconds), several series of measurements were done to minimize the standard deviation and uncertainty values, this last one was of  $\pm 1,0$  arc-sec. Table 1 shows the errors of a polygon obtained with the proposed method as well as the data obtained with the two autocollimators method.

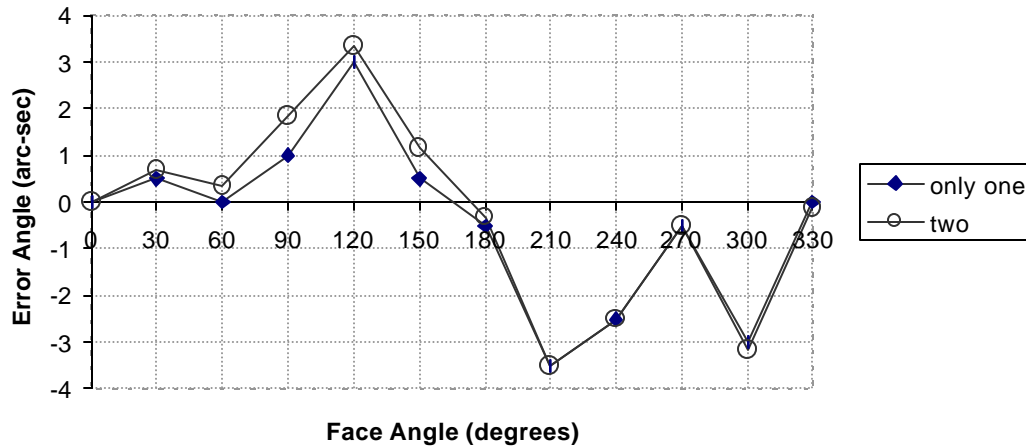
NOMINAL ANGLE [degrees]	ERROR (average) [arc-sec]	
	Only one	two
0	0	0,0
30	+0,7	+0,5
60	+0,3	+0,0
90	+1,8	+1,0
120	+3,3	+3,0
150	+1,2	+0,5
180	-0,3	-0,5
210	-3,5	-3,5
240	-2,5	-2,5
270	-0,5	-0,5
300	-3,2	-3,0
330	-0,1	0,0

Table 1. Comparative errors obtained from only one and two autocollimators

The uncertainty of two autocollimators method was  $\pm 1,3$  arc-sec while the other was  $\pm 1,0$  arc-sec. From Fig. 2 we can appreciate that the plots of the measured polygon errors are very similar.

#### 4. DISCUSSION AND CONCLUSIONS

We have presented a method for measuring the error angles for one optical polygon with only one autocollimator. In comparison with the other methods, the experimental set up is very simple and reliable. Also, aligning and measuring take a little time. As an additional advantage, we use the same formulation described by Nava [4] to obtain the polygon errors. The experimental results obtained with the proposed method as well as those obtained by using two autocollimators were also presented confirming the performance of the method.



Graphic 1. Comparison of errors obtained from methods employing only one and two autocollimators.

#### 5. REFERENCES

- [1]. K. J. Hume, *Metrology with Autocollimators*. Higler & Watts Ltd. (London, England, 1965).
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- [4]. R. Nava, *Calibración de un Polígono Óptico de 12 Caras Mediante Dos Autocolimadores (Calibration of a Twelve Faces Optical Polygon with Two Autocollimators)*. Technical Report. CIUNAM, (México, 1992). In Spanish.