Study for the development of a photomask calibration procedure

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Abstract: In order to provide traceability for two-dimensional standards used in optical CMM calibration, this study was carry out testing the procedure for alignment, the image processing and analysis, mathematical model and the uncertainty evaluation in a measurement of a photomask of 300 mm x 300 mm. This paper describes all procedure development based on different bibliographic references and the image processing algorithm implemented to automatically detect the measurement points in the measurand.

Keywords: Image metrology, Computer vision, Dimensional metrology, Photomask.

1. INTRODUCTION

Lately, optical coordinate measuring machines (CMM) have been used in many applications in researches laboratories as well as in industry, due to their flexibility to measure lots of standards and mechanical parts such as scales, circular apertures, small gears and holes that can’t be measured by conventional instruments.

These measurements are possible by image processing techniques of the features of interest.

However, as in any measurement systems, optical CMM need traceability. At present, many National Metrology Institutes (NMI) are improving or developing systems for the calibration of two-dimensional optical standards used in optical CMM calibration to provide traceability.

Flügge et al [1] shows a procedure for optical 2D standards calibration. In this paper was described changes to be made on 1D, system already used in international comparisons as Nano3 [2] and L-K7 [3], to perform calibrations of 2D artefacts. Also in 2008, Mares et al [4] published a comparison using two optical measurement systems. The comparison was carried out with a commercial Optical CMM and a system develop by the laboratory. The standard used in this comparison was a 2D ball plate.

Weichert, 2009 [5] showed some modifications performed to a line scales calibration system to enable it to perform two-dimensional calibrations. The paper shows a virtual simulation for Y and Z measurements.

Others papers were recently published from NMI from different

Counties describing improvements and developments for two-dimensional standards calibration to be used in optical CMM calibration [6-9].

This paper describes an initial proposal for a procedure for a photomask calibration, using an optical probe developed by the Dimensional Laboratory from National Institute of Metrology, Quality and Technology.

2. MEASUREMENT PROCEDURE

The standard used in this study was a 300 x 300 mm glass plate from TESA. The standard is composed by vertical and horizontal lines marked with 10 mm intervals and 20 μm linewidth, as shown in figure 1.

The measurand are the distances from the center of each line intersection. The distances are measured using the 0 x 0 mm line as reference.

Following the procedure for this kind of standard described by Meli, et al [7], the plate was placed on the displacement table of the optical CMM and supported in three points (-140 mm/,-90 mm), (-140 mm,90) mm and (140 mm/,0 mm)) as indicated in figure 1.

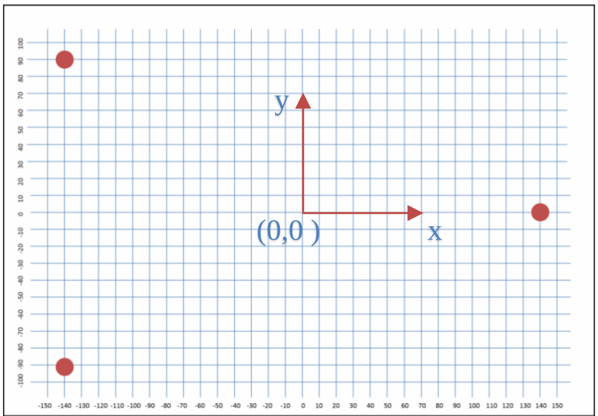

Figure 1 – Example of standard artifact

The procedure for alignment is based on two points in X axis (0 , 0) mm and (150,0) mm. Two temperature sensors were used for monitoring expansion effects. Is not possible to position the sensors on the artifact, so, small pieces of the same material were used to simulate the temperature of the standard during the measurement

After alignment, the measurement was carried out taking images from the crossover between horizontal and vertical lines. Each image was processed and analyzed in order to determine the center of all cross to be measured.

The image processing procedure was divided in following stages:

- Region of interest (Figure 2): The images were reduced from 752 x 480 to 140 x 140 pixels. The ROI analysis decrease number of calculations and increase speed of algorithm.

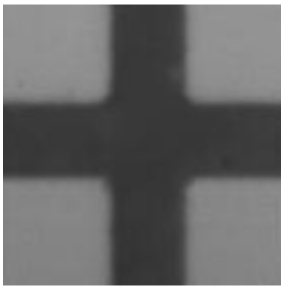

Figure 2 – Region of interest (ROI)

- Image segmentation: was performed using Otsu method for image segmentation [10]. In this step the image is changed to a binary image (Figure 3).Center determination: The measurement point is calculated by the average of all middle points in vertical and horizontal directions (Figure 3).

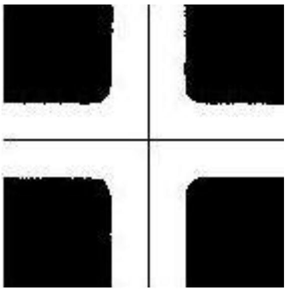

Figure 3 – Image segmentation and center point determination.

For each point measured on the plate the same procedure was performed, and each point consists in an ordered pair representing the cross center. In total, 89 points were measured. The choice of points was made according to the previous certificate of the standard calibrated by Metas, from Switzerland.

In the analysis of the results, after all corrections of the environmental conditions, the measurements referring to points, (0, 0) mm and (+150, 0) mm should be zero error deviation from nominal values. Due the procedure recommend that the alignment of the machine coordinate system is performed through these points as a reference. However, the corrected results presented a deviation of +2.2 µm in the coordinate referring to the Y axis at +150 mm / 0 mm. This deviation can be considered as a plate misalignment, and represents 4 pixels on the image, this value is a limit for visual alignment.

The alignment error was corrected mathematically by a rotation for all measured points (Equation 1).

$$\begin{pmatrix} X' \\ Y' \end{pmatrix} = \begin{pmatrix} \cos(\theta) & \mathrm{sen}(\theta) \\ -\mathrm{sen}(\theta) & \cos(\theta) \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \end{pmatrix} \qquad (1)$$

The X´ and Y´ values are the measurement result.

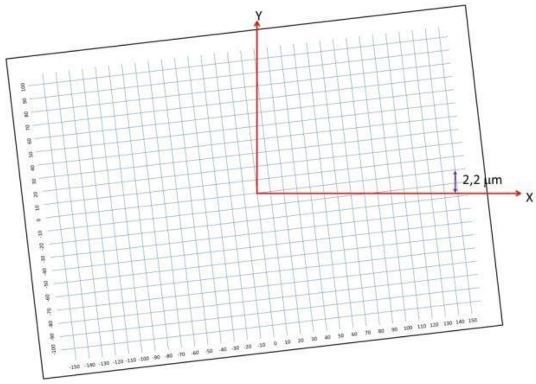

Figure 4 – Example of alignment and mensurand correction.

3. RESULTS

Analyzing the results from 3 runs of measurements, were considered as input quantity for uncertainty evaluation the air and material temperature, humidity, air pressure, uncertainty from laser certificate, pixel length, edge detection, alignments deviations and type A uncertainty.

Following the GUM method the expanded uncertainty were about 13 µm for the presented procedure. In order to compare this results with standard certificate was calculated the normalized error, where maximum value obtained was 0.7, proving the results compatibility.

However, this measurement procedure still requires further study regarding its feasibility. Changes must be made in the system in order to improve its repeatability. In this study presented here the greatest contribution was the standard deviation of the measurement, which should be reduced so that the uncertainties compatible with those required for this type of standard.

4. CONCLUSIONS

The aim of this paper was to establish a measurement procedure for the measurement of photomask standards, in order to provide traceability for this type of standard.

The described procedure proved to be efficient to obtain the results for the measurand, with results compatible with certificate of the standard.

The next steps of this development will be carried out in order to reduce the uncertainty of this method. The expect uncertainty for this standard is about 1 mm, so that the uncertainties provided by the inmetro can be compatible with the other national metrology institutes.

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