

Effects of Lighting on Performance of CMM Video Probes

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Abstract

CMMs equipped with non-contact probes, such as video probes, are becoming popular for a variety of 2-D or 2.5-D objects. The advantages of a video (or vision) probe include the ability to measure features which are either too small or too delicate for a touch probe. Unfortunately, vision-based probing systems do not have the same measurement accuracy as touch probe equipped machines. For example, a Moore M48 coordinate measurement machine has an expected measurement uncertainty of 0.2 μm (plus a scale dependent term) when using a touch probe (the actual repeatability is on the order of 0.03 μm). When the probe is changed to a Leitz LS1 vision system, the expected measurement uncertainty is 1.2 μm plus a scale dependent term. The decreased accuracy is due entirely to the change in probing method. Components of the error budget include environmental effects, choice of lighting, lens distortions, and stage 2-D accuracy. Lighting is a major contributor to the measurement error budget, especially when a bidirectional measurement needs to be made (for example, the width of a line, rather than the center location of a line). We report on the effect of the sensitivity of vision probing on an OGP Avant Apex 200 to different lighting conditions, both for unidirectional and bidirectional measurements.

Introduction

Coordinate measuring machines are well established for inspection of machined mechanical parts. For some applications, such as miniature gears or electrical connectors, a CMM touch probe is too large to probe the desired features on a small part. While CMM touch probe stylus balls are available as small as 0.3 mm, most users use styluses of several millimeter diameters. For smaller features, a video inspection machine is frequently used, or a video probe is attached to a CMM and used as a 2-D system. Other applications for a video inspection system are parts which are strictly 2-D in nature, such as apertures or windows, or delicate parts. Figure 1 shows a typical part which might be used with a video inspection system.¹

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Figure 1. LIGA fabricated part for inspection by video system. This part is typically 10 mm wide by 1.5 mm tall. (From ref. [1]).

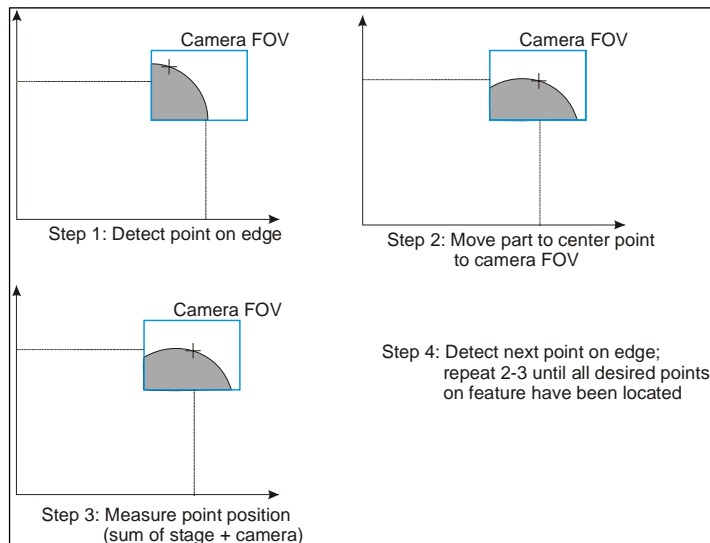


Figure 2. Point coordinate detection with a video probe.

imperfect geometry of the feature (feature does not have a perfectly defined edge, or has topography), and also because of imperfect lighting. Figure 3 illustrates some of these possible difficulties.

Manufacturers of video inspection systems include Brown and Sharpe, Mahr, Mitutoyo, OGP, View Engineering. For example, the published manufacturer specifications for the OGP Avant Apex 200 is $E_{xy}=(1.2+L/500) \mu\text{m}$, where E_{xy} is the measurement uncertainty in x or y , and L is the measured dimension in millimeters.²

The manufacturers' vision software evaluates 2-D geometrical features, such as circle diameter, roundness, and location. They do this by detecting points on the edge of the feature and then using numerical fitting algorithms to evaluate the geometry. Figure 2 shows an example process for measuring a circular feature. What, then, are possible errors in the measuring process? There are possible errors in the fitting algorithms, and possible errors in locating geometric points. We will focus on possible errors in locating geometric points. In a 2-D Cartesian measurement of a point, the point location is determined by summing the stage position with the point location within the camera field of view. Assuming Gaussian probability density functions for the measurement error for the stage position and the camera position field of view, the combined point location error variance is the sum of the individual position variances. Stage measurements are typically done with glass scales with resolutions of $0.1 \mu\text{m}$ or better. The dominant term in the measurement uncertainty in x - y is due to the optical point location. There is measurement uncertainty due to

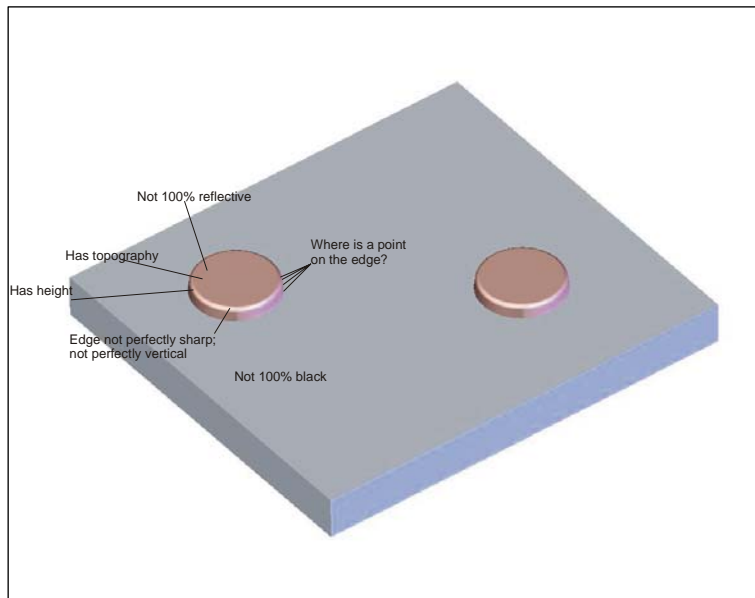


Figure 3. Lighting can exacerbate measurement problems with imperfect target geometries.

Some evaluations of a geometric feature, such as the center location of a circle, are insensitive to biases in the edge point location, as the biases cancel each other in a symmetric fashion. Other evaluations, such as the diameter of a circle, are sensitive to surface and lighting. There are no ISO or ANSI standards for evaluating the performance of vision probing systems.³ Draft standards of vision probing (also called video probing) systems, such as ISO10360-7 and ANSI B89.4.18 recognize the problem of possible bias due to lighting conditions, and specify bidirectional probing (such as the width of a line) in addition to

unidirectional probing (such as the center location of a line) in performance tests, but the drafts do not address evaluating the effects of lighting. The drafts recommend using the manufacturer's recommended lighting settings.

We therefore decided to evaluate the sensitivity of lighting on the evaluation of circle diameters.

Experimental Results

An OGP Avant Apex 200 system in the Sandia National Laboratories Mechanical Calibration Laboratory⁴ was used.[‡] Ring lighting, through lighting, and top lighting can be used with this system. Figure 4 shows a typical evaluation screen.

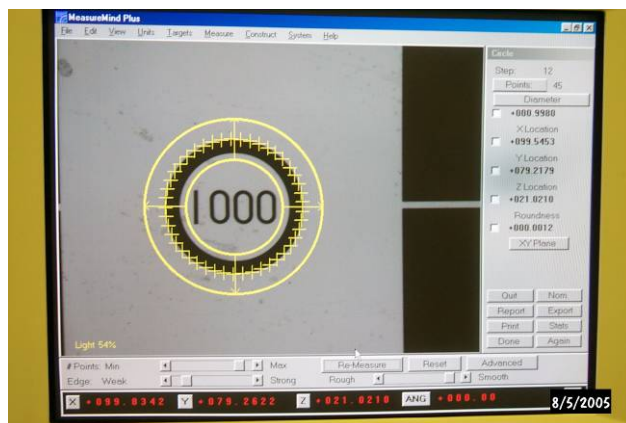


Figure 4. Measurement and evaluation screen on OGP Avant Apex 200 system.

The annular target is black film on glass. The user chooses the lighting, then, when the measurement program is recalled, the measurement system also recalls the lighting setup for the feature or point being probed. For best results, the manufacturer recommends lighting such that the camera is 50% saturated.

We used through-only illumination to evaluate the diameter of a nominal 1000 μm diameter circular annulus. Plotting the illumination setting from 1 (minimum) to 10 (maximum),

[‡] We gratefully acknowledge the assistance of Barbara Allison and Margaret Baca in making measurements, and Tony Bryce in obtaining measurement artifacts.

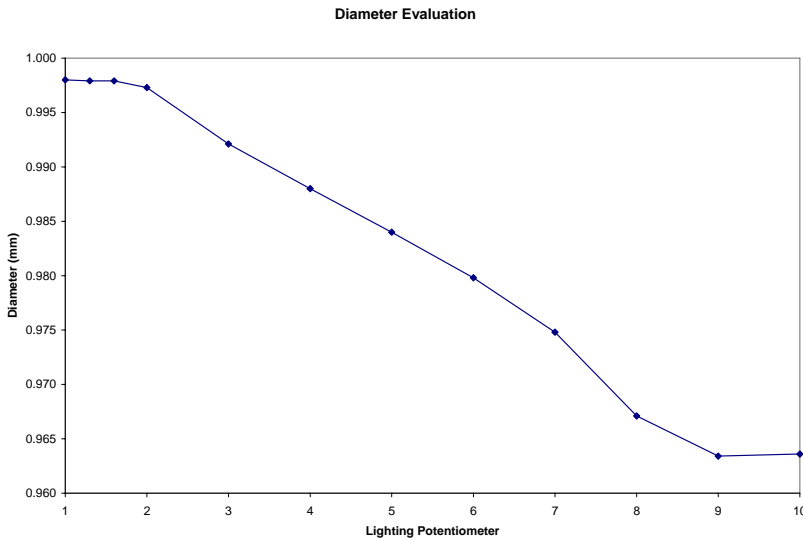


Figure 5. Evaluation of diameter as function of lighting setting.

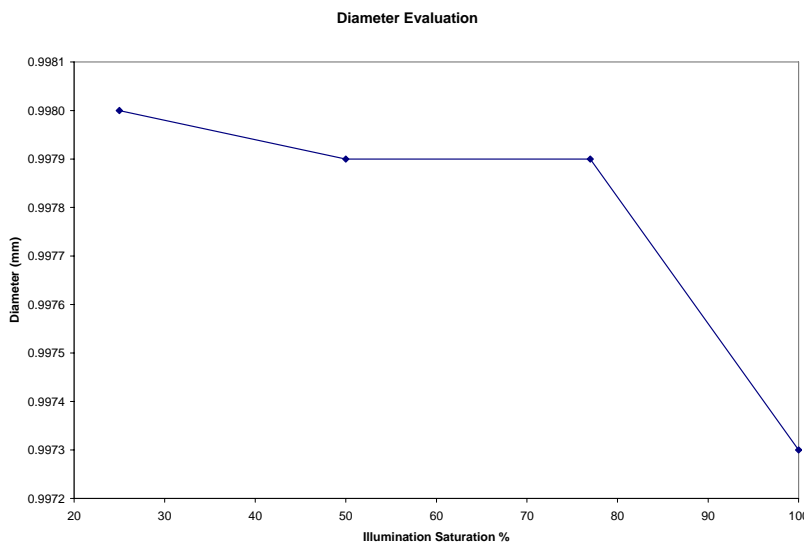


Figure 6. Diameter as a function of illumination saturation.

the evaluated diameters range from 998.0 μm to 963.6 μm . This is shown in Figure 5.

This variation in measured diameter of approximately 35 μm greatly exaggerates the actual sensitivity due to illumination. Since the recommendation of the manufacturer is for 50% saturation, we plot the bright illumination versus measured diameter (50% is achieved at an illumination potentiometer setting of about 1.5). This is shown in Figure 6.

The variation in measured diameter is now about 1 μm as the lighting saturation in the bright region goes from 25% to 100%.

Discussion

The reproducibility of the diameter evaluations is well at the submicron level. However, the question of what is the true diameter of the annulus really depends on what is the true location of the edge points. This depends on lighting. Even

using the recommended illumination settings, there is no assurance that the system is measuring the circle diameter. We believe that it is necessary to use a hybrid artifact which can be measured with multiple probing schemes to assure that bidirectional vision probing is accurate.

References

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