Uncertainty of the Interferometric Radius Measurement in a Production Environment

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INTRODUCTION
The uncertainty evaluation of the interferometric radius measurement is well documented in literature [1-5]. Schmitz, et. al. [2], gave a partially through review of the evaluation the interferometric radius measurement uncertainty of a nominally 24.466 mm diameter sphere at NIST. Other work [3-5] showed full or partial uncertainty evaluations for measurements done at UNC Charlotte. In many cases, full uncertainty examples which follow the GUM (Guide to the Expression of Uncertainty in Measurement [6]) shown in literature are from single time measurements at national laboratories or academic environments. Applying the same principles to a production manufacturing environment will have complications and is not typically demonstrated in literature.

This paper will show how the uncertainty evaluation must be considered for a production manufacturing environment. This will focus on the changing conditions that require a new evaluation of the uncertainty. In addition, because measurements in a production environment at taken by many different people (who may have different skill levels), we must also have an easy to use tool that the operator can quickly and easily calculate the uncertainty of any specific measurement.

INTERFEROMETRIC RADIUS MEASUREMENT
Figure 1 shows a schematic of the interferometric radius measurement on a Fizeau type interferometer. The interferometer uses a transmission sphere (in black) to produce a converging spherical wavefront. The part, here concave, is first placed at confocal, where the test wavefront and part curvature match. The location of this position is recorded. Then, the part the moved to cat’s eye, at the test wavefront focus and this position is recorded. The difference between the two positions is the radius. The procedure is the same for a convex part; the confocal position is in the converging wavefront close to the interferometer.

FIGURE 1. Schematic of the interferometric radius measurement, a two part measurement.

The locations can be measured using various methods, which will contribute to the final uncertainty. In the production environment, DMI (displacement measuring interferometers are used).

THE PRODUCTION ENVIRONMENT
In the production environment, the following conditions can vary part to part, which sometimes means hour to hour.
- Part Radius
- Part Diameter
- Holding Conditions
- Transmission Sphere f/#
- Transmission Sphere Diameter
- Transmission Sphere Model Number
- Interferometer Model Number
  - Source Type
  - Camera Resolution
- DMI Model
- Environment
  - Temperature/Pressure/Humidity
- Measuring Procedure (Step through null or software correction)
- Operator, Shift
In addition to the aspects listed above, there are conditions that may change over time, such as error motions and alignments.

**UNCERTAINTY CONTRIBUTORS**

The uncertainty contributors that are considered are:
- Stage error motions
- Cosine error
- Abbe error
- Unsensed length due to temperature variations
- Deadpath error
- Uncertainty in environmental sensors
- Turbulence
- DMI system
- Fizeau transmission sphere error
- Surface figure error
- Viewing aperture
- Locating the null position
- Model used

**Additional Considerations for the Manufacturing Environment**

For some uncertainty contributors, we can regularly record values that can then later be used in uncertainty evaluations. These include measuring the stage error motions, the DMI cosine error, and the temperature / pressure / humidity sensor uncertainties. These are measured and recorded during regularity scheduled interferometer maintenance.

For the production environment, we must develop an easy to use tool for operators to evaluate the uncertainty on a case by case basis. This may be something as simple as an Excel file which does the calculations, or a specialty built software program which collects data from the interferometer maintenance and also calculates the uncertainty.

**REFERENCES**