Uncertainty Analysis with Inspection Shop Measurements

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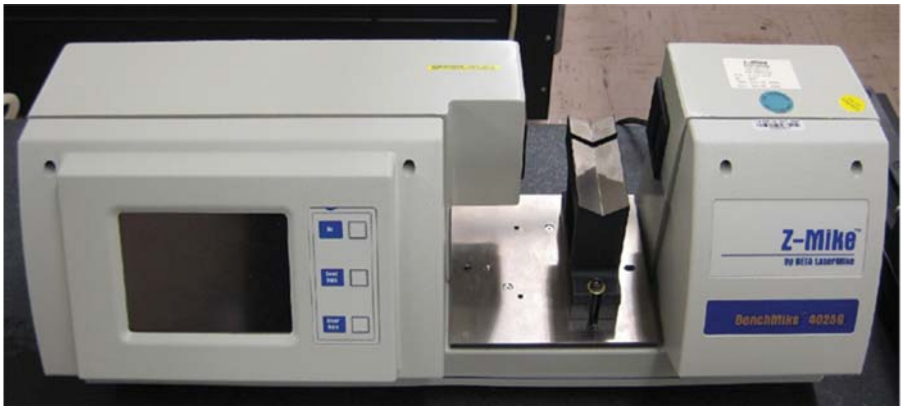

Figure 2. The Z-Mike measurement instrument, which uses a laser to measure diameters and lengths.

The LLNL inspection shop is chartered to make dimensional measurements of components for critical programmatic experiments. These measurements ensure that components are within tolerance, and provide geometric details that can be used to further refine simulations. For these measurements to be useful, they must be significantly more accurate than the tolerances that are being checked. For example, if a part has a specified dimension of 100 mm and a tolerance of 1 mm, then the precision and/or accuracy of the measurement should be less than 1 mm. Using the "10-to-1 gagemaker's rule of thumb," the desired precision of the measurement should be less than 100 µm. Currently, the process for associating measurement uncertainty with data is not standardized, nor is the uncertainty based on a thorough analysis.

The National Institute of Standards and Technology (NIST) has developed methods for analyzing measurement uncertainty. Figure 1 shows the key factors that influence measurement uncertainty. This project aims to augment the efforts within the LLNL inspection shop with a standardized and commensurately rigorous approach to determining and reporting uncertainty.

During FY2006, a fundamental understanding of inspection shop operations and equipment was gained so that measurement uncertainty analysis could proceed in FY2007.

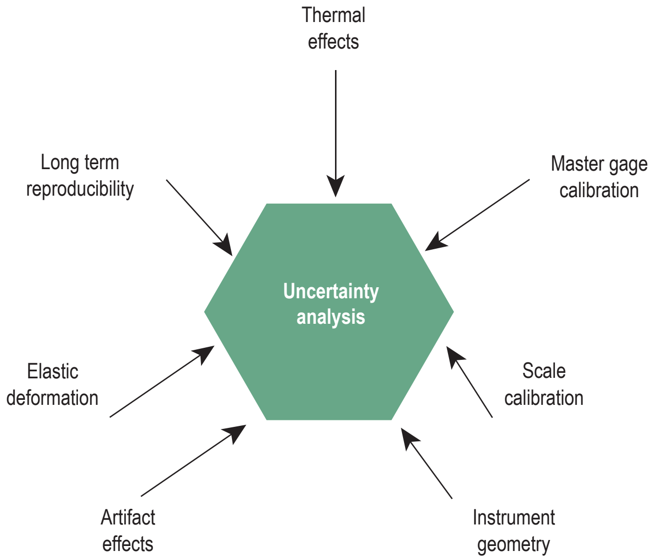

Figure 1. Schematic of the many factors that influence the uncertainty of a measurement.

Project Goals

The goal of this project is to begin providing measurement uncertainty statements with critical measurements performed in the inspection shop. To accomplish this task, comprehensive knowledge about the underlying sources of uncertainty for measurement instruments need to be understood and quantified. Moreover, measurements of elemental uncertainties for each physical source need to be combined in a meaningful way to obtain an overall measurement uncertainty.

Relevance to LLNL Mission

The measurements being made by the inspection shop are used to make decisions about accepting or rejecting critical parts. The inspection shop is widely used and the measurements are typically accepted as being "sufficiently" accurate. This assumption should be verified by a measurement uncertainty analysis, which is the accepted practice at all of the other NNSA sites. There is a significant risk to Laboratory programs if measurement data is in error, which could lead to the use of components in experiments that are outside of specifications.

FY2007 Accomplishments and Results

During FY2007, four milestones were met: the reports written in FY2006 were finalized; a tutorial on uncertainty analysis was given to the inspectors in the inspection shop; an uncertainty analysis was performed on the inspection shop's Z-Mike measurement instrument; and an uncertainty analysis was performed on the inspection shop's four Coordinate Measurement Machines (CMMs).

The Z-Mike measurement instrument (Fig. 2) is a new instrument in the inspection shop for measuring diameters and lengths using a laser. Reproducibility data was collected on the Z-Mike instrument; this data was analyzed and an uncertainty analysis was completed using the methods described in the references.

Applying this same analysis method to the four CMMs in the inspection shop would be extremely cumbersome; hence, a different method was used. A commercial vendor has created a CMM program that uses algorithms developed at NIST to analyze the measurement uncertainties associated with the measurement of specific part features/geometries. Using this program, a generic part with common geometric features was input into the program along with the inspection shop's CMM calibration data, probe data, and temperature data. Using the data, the program created uncertainty reports for each part feature (Fig. 3). The analysis shows that the performance of the four CMMs in the inspection shop varies considerably (Fig. 4). This result is not a surprise, but it does show the importance of choosing the correct metrology tool when making a critical measurement.

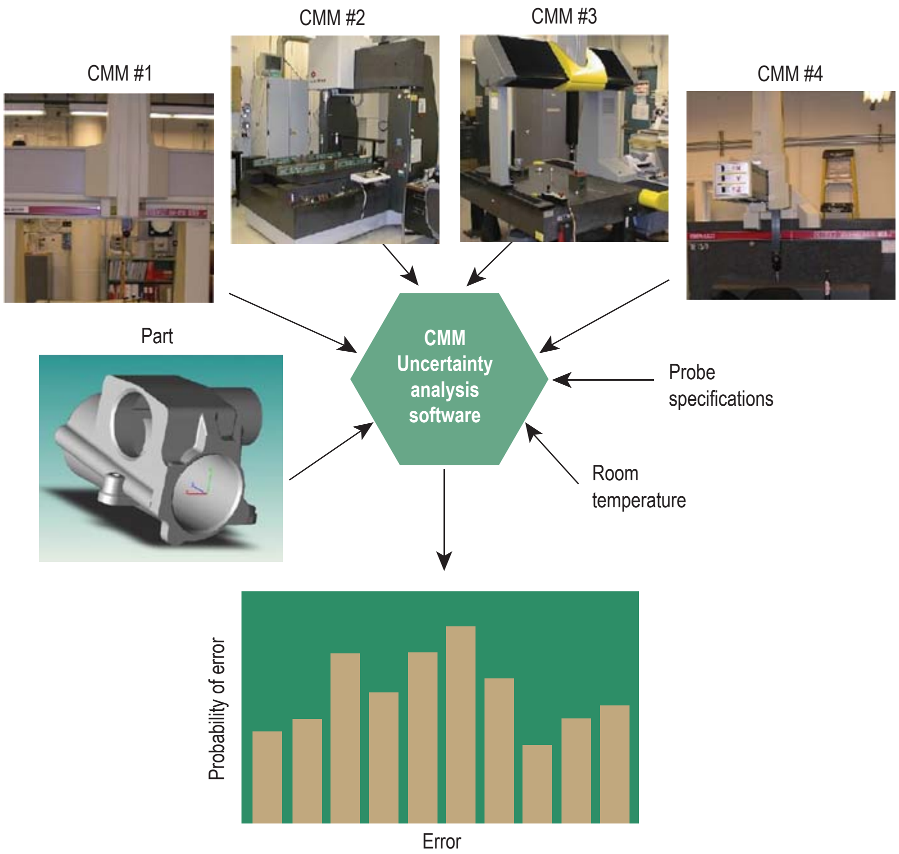

Figure 3. Performance analysis of CMMs. The software creates a report detailing the uncertainty of each feature measurement on each part for each CMM.

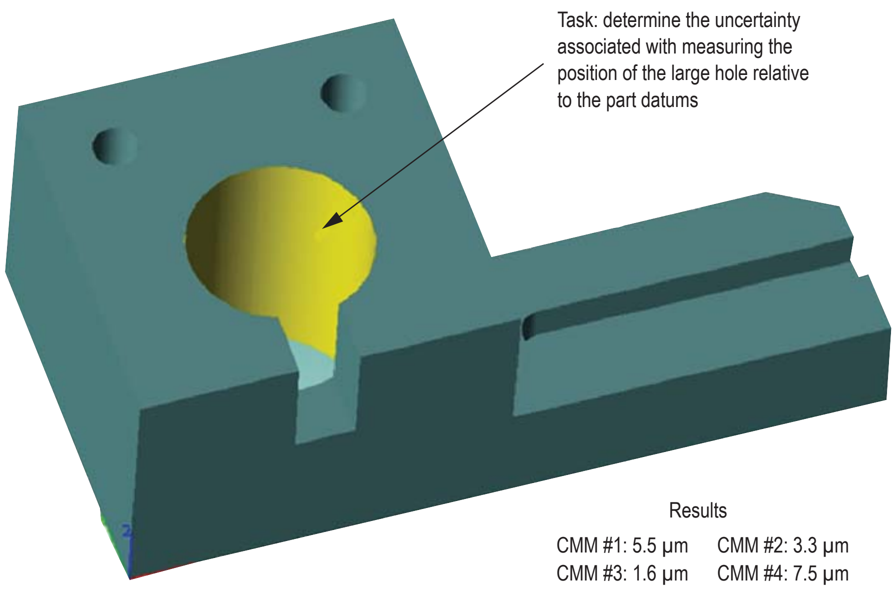

Figure 4. Uncertainty results for the four inspection shop CMMs when measuring the position of a hole using the uncertainty analysis software.

Related References

1. Doiron, T., and J. Stoup, "Uncertainty and Dimensional Calibrations," *Journal of Research of the National Institute of Standards and Technology*, **120**, 6, pp. 647-676, 1997.
2. Taylor, B. N., and C. E. Kuyatt, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," *National Institute of Standards and Technology, Technical Note 1297*, 1994.