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Title: Coordinate Measuring Machine Pit Artifact Inspection Procedure

Author(s): Montano, Joshua D.

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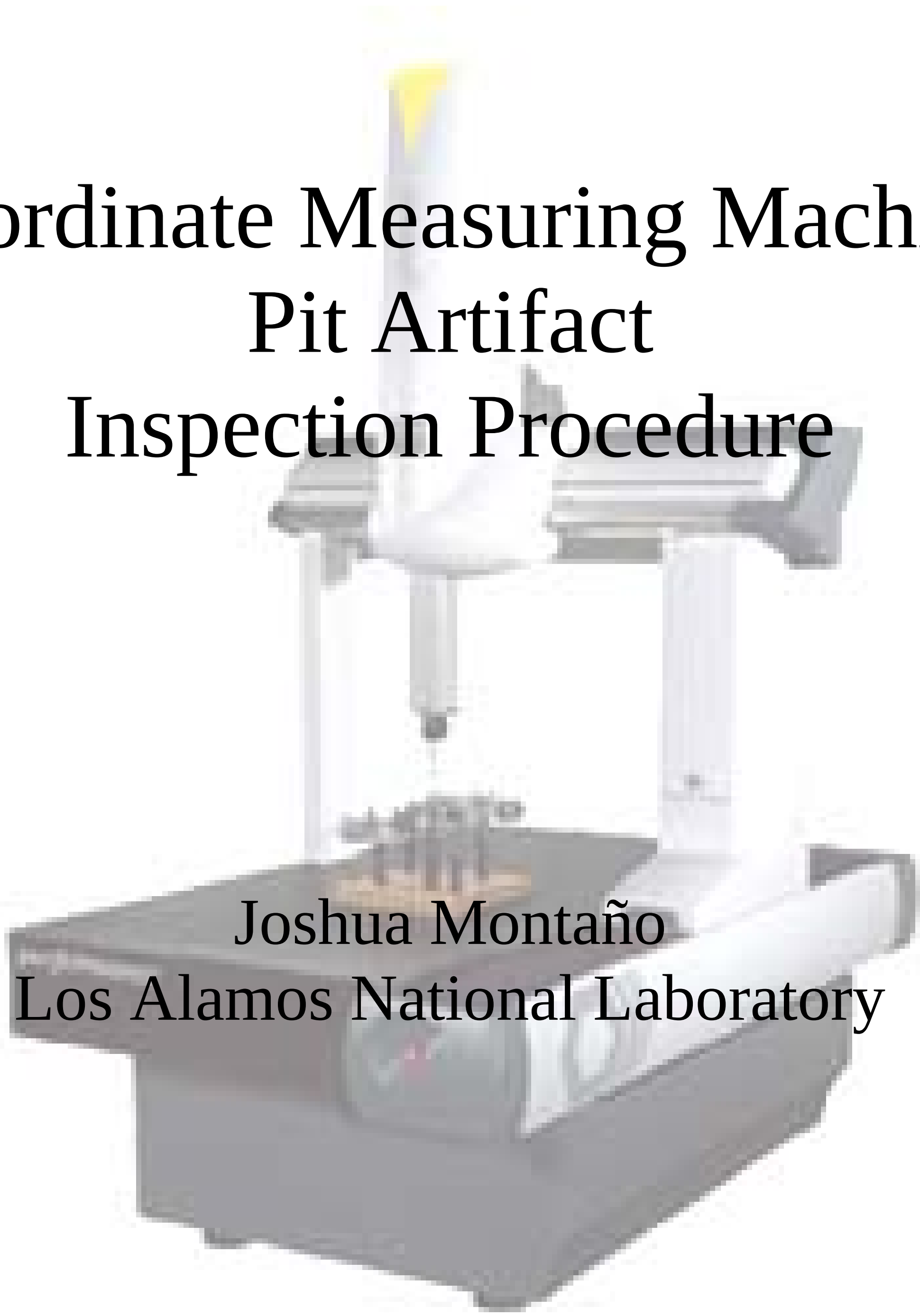
Coordinate Measuring Machine
Pit Artifact
Inspection Procedure



Joshua Montaño
Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Abstract

The goal of this document is to outline a procedure for dimensional measurement of Los Alamos National Laboratory's CMM Pit Artifact. This procedure will be used by the Manufacturing Practice's Inspection Technology Subgroup of the Interagency Manufacturing Operations Group and Joint Operations Weapon Operations Group (IMOG/JOWOG 39) round robin participants. The intent is to assess the state of industry within the Nuclear Weapons Complex for measurements made on this type of part and find which current measurement strategies and techniques produce the best results.

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1.0 Introduction

One of the Inspection Technology Subgroup's objectives is to assess measurement practices. The Inspection Technology Subgroup has performed round robin activities in the past but those efforts have focused on shell measurement [1]. In 2009 Los Alamos National Laboratory (LANL) worked with the Kansas City Plant (KCP) to design and build a pit intended as a round robin artifact. The artifact was fabricated at KCP and delivered to LANL in early 2011.

2.0 Methodology

The idea behind this round robin is two fold. First it will provide two data sets for assessment calculations (controlled and experimental measurement). Second it will help bound the limits of accuracy and precision (see Figure 1). Questions about accuracy can sometimes arise when the artifact is not calibrated. Calibration of LANL's CMM Pit Artifact is not possible. In cases like these, credit is given to the National Institute of Standards and Technology (NIST) traceable equipment, professionals doing the inspections considering both their expertise and experience, and any secondary tests that may be used to increase the confidence level of measurement data provided.

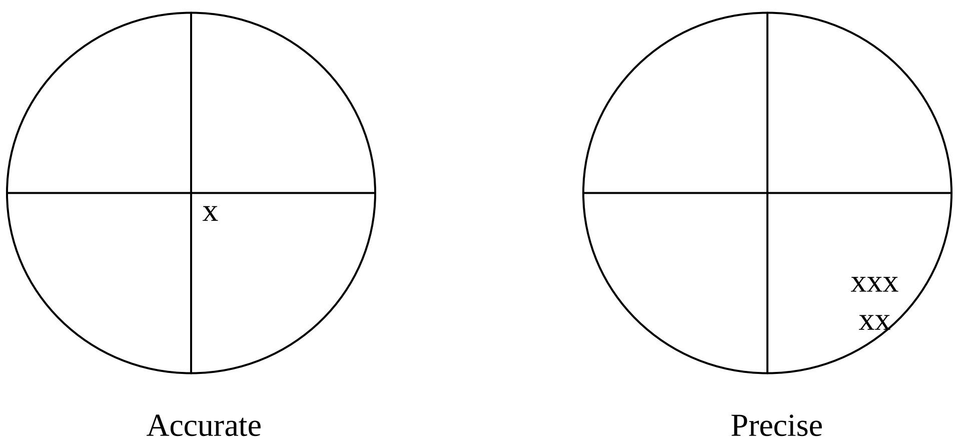

Figure 1. Accuracy and precision.

Given the considerations above, and by doing inspections at different sites with different participants and equipment, the assumption is that the data collected will be both accurate and precise.

2.1 Parameters

Since different sites have different equipment, different capabilities, and different inspection techniques, it is critical that as many parameters as possible be recorded to help understand variability in the measurement data.

Parameters to be recorded but not limited to:

A. Machine
   i. Brand (Brown & Sharpe, Ziess, etc.)
   ii. Controller (B3C-LC, etc.)
   iii. Controller firmware version
   iv. Size (x, y, and z)
   v. Accuracy (x, y, z, probing, scanning)
   vi. Calibration (ISO/B89 – include current calibration results)
B. Equipment
   i. Probes (SP600M, SP25, Revo, etc.)
   ii. Styli ball material (ruby, SiN, etc.)
   iii. Styli shank material (ceramic, steel, etc.)
   iv. Styli size and length (6 x 75 mm)
   v. Extensions and configuration
   vi. Rotary table (brand, size, and accuracy – include current calibration results)
C. Software
   i. Operating system and version
   ii. Measuring software and version
D. Probing
   i. Undefined path scanning, defined path scanning, point to point
   ii. Speed
   iii. Force
E. Environment
   i. Temperature (room, part, temp gradient, correction, compensation)
   ii. Humidity

2.2 Setup

Part setup is also important to understanding measurement data. Again, it is critical that as many parameters as possible be recorded to help understand variability in the measurement data.

Parameters to be recorded but not limited to:

A. Part orientation relative to the CMM (sketch strongly preferred)
B. Tools
C. Fixtures
D. Adhesives
E. Impression material

2.3 Measurement

Measurement approach is the third significant part to the data gathering process. Each round robin participant should provide a thorough explanation of the approach and mathematical algorithms used.

Parameters to be recorded but not limited to:

A. Manual points taken (location and quantity)
B. Direct computer control (DCC – location and quantity)
C. Alignment techniques (best fit, iterative, etc.)

3.0 Experimental Evaluation

The program(s) used to complete sections 3.1 and 3.2 should be well commented and attached to measurement results.

3.1 Using Defined Features (Controlled Measurement)

Round robin participants are encouraged to first inspect the part using defined features (tooling balls) for coordinate system position and orientation. This will serve as the "controlled" measurement as provide the best opportunity to compare with other participants.

A plane through the center of all three tooling balls is to be used as Z = -12.7 mm. Note that 12.7 mm linear and positive translation is required to achieve the part center. Perpendicular to this plane is the Z axis. Using the right hand rule and the two tooling balls that are 90° apart, the X and Y axis can be defined providing a fully constrained coordinate system. Note that a 7.5° rotation is required for the 0° azimuthal angle. See Figure 2, 3, and 4 below.

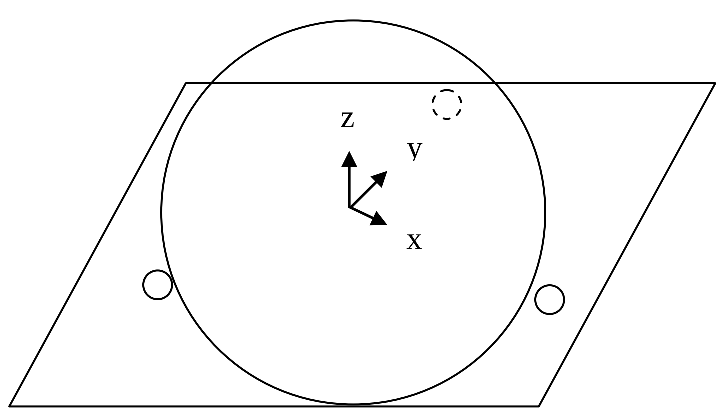

Figure 2. CMM Pit Artifact - part coordinate system placement

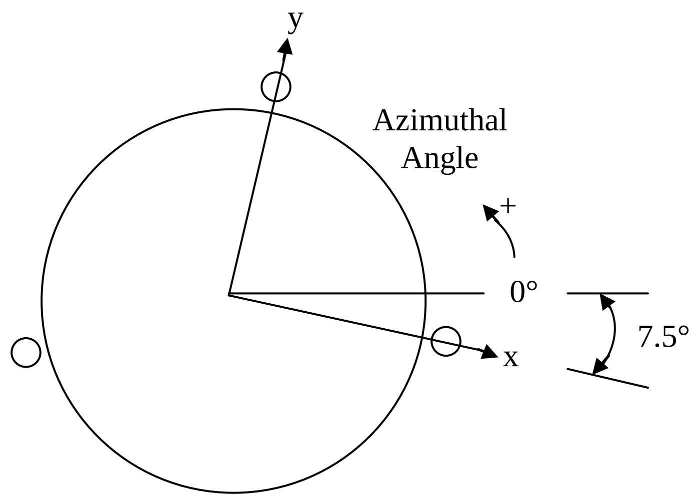

Figure 3. CMM Pit Artifact - top view

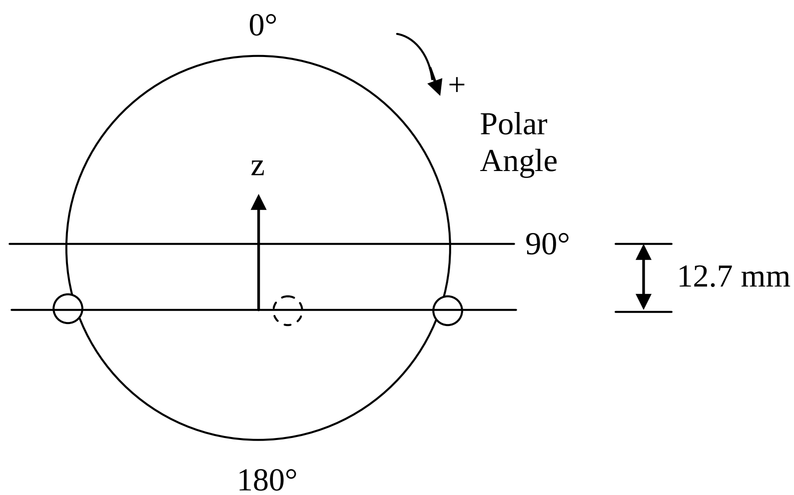

Figure 4. CMM Pit Artifact - front view

3.2 No Defined Features (Experimental Measurement)

Round robin participants are also expected to measure the part without the use of defined features. This will probably require the use of one or more alignment techniques such as best fit, iterative, etc. to locate and orient the part coordinate system. A measurement plan with the exception of the sample pattern is left to the discretion of the participant.

3.3 Measurement Locations

Each round robin participant will be required to report deviations (in mm) from nominal design definition at the locations documented in Table 1 for both measurement processes described in sections 3.1 and 3.2.

Table 1. Required measurement locations

		Azimuthal Angle						
		0	30	60	…	270	300	330
Polar Angle	0							
	2							
	4							
	…							
	176							
	178							
	180							

The artifact was designed to also accommodate 24 evenly spaced azimuthal angles and may be used. This collection strategy is preferable but in the interest of time and money, remains optional. See Table 2 below.

Table 2. Optional measurement locations

		Azimuthal Angle						
		0	15	30	…	315	330	345
Polar Angle	0							
	2							
	4							
	…							
	176							
	178							
	180							

3.4 Data Analysis

The data gathered will be analyzed on a point to point basis. For example the result from 30 degrees azimuthal, 32 degrees polar will only be compared to the same result point from other participants at that location. A three dimensional standard deviation plot will be created using each point location independently using equation 1 below [2].

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \qquad (1)$$

3.5 Uncertainty

Pit measurements at LANL, although common have not been fully evaluated for uncertainty. Past and current measurements follow the Test Accuracy Ratio as stated by 9900000 specification, "test accuracy ratios of 4:1 or greater are maintained or when the product definition specifies the measuring equipment to be used, the resulting values can be directly compared to the specified limits" [3]. In layman terms, if a measurement of an object 10 ± 1 mm was needed, the measurement would require a calibrated instrument with an accuracy of 0.25 mm.

Uncertainty statements generated by an uncertainty budget typically include Type A and B sources such as the CMM calibration certificate, gauge repeatability and reproducibility (GR&R) results, etc. Because of time and budget constraints uncertainty statements while encouraged, are considered optional and not required. For two or more participants that do supply uncertainty statements, E_n values using equation 2 below will be used to test for satisfactory/unsatisfactory performance. Equation 2 (taken from ISO 17043) is often used by NIST for laboratory to laboratory comparisons. Calculations will be on a point to point basis similar to the analysis above [4].

$$E_n = \left| \frac{x - X_{ref}}{\sqrt{U^2 + U_{ref}^2}} \right| \qquad (2)$$

Where,

$E_n \leq 1.0$ indicates "satisfactory" performance and generates no signal

$E_n > 1.0$ indicates "unsatisfactory" performance and generates an action signal

4.0 Conclusions

The approach of dictating parameters rather than documenting them was purposely not taken. While it does start to bound some of the data gathered it also runs the risk of eliminating potential participants from the round robin. For example if the part was to be inspected vertically then some sites may not be able to participate because of lack of machine volume. This is a similar case for parameters such as probe force and scan speed. Different machines with different controllers may produce better data using different parameters. Varying parameters are considered part of the measurement process under evaluation.

Similar to the round robin performed by NIST, multiple machines within one site may be used as long as measurements are independently reported [5].

5.0 Future Work Recommendations

For the initial round robin exercise participants may inspect the artifact the best way they see fit and provide data sets following instructions given in this procedure. In order to reduce variability and possibly uncertainty in data, subsequent round robin exercises may include the dictation of some parameters and elimination of some participants based on those parameters.

6.0 References

[1] Gould, J., *"Report on the UK/US Collaborative Programme to Evaluate Shell Measurement Comparability"*, AWE/CMD/T/009/00, Atomic Weapons Establishment, March 2000

[2] D. Moore, G. McCabe, "*Introduction to the Practice of Statistics"*, 1993

[3] Boehning, C. et al., *"General Requirements (U)"*, 9900000, January 2005 https://prp.sandia.gov/GeneralSpecs/9900000.pdf

[4] *"Conformity Assessment – General Requirements for Proficiency Testing"*, ISO 17043, International Organization for Standardization, 2010

[5] Caskey, G., Phillips, S., Borchardt, B., *"Results of the NIST National Ball Plate Round Robin"*, Journal of Research of the National Institute of Standards and Technology, Vol. 102, No. 1, January-February 1997

7.0 Attachments

Drawing # MS045254-001