Operation of the SmartScope FOV Video Measurement System

1 Introduction

The SmartScope FOV (Optical Gaging Products, Inc.) is a video measuring microscope system that uses calibrated optics and a high precision linear translation table to produce non-contact, dimensional measurements of objects. The instrument produces measurements in three dimensions which are both more accurate and more precise than those obtainable using standard mechanical devices such as micrometers and calipers.

2 Scope

This document applies to caseworking personnel who perform metallurgy analyses. The SmartScope FOV video measurement system is used for measuring physical dimensions and surface features of a wide variety of objects.

3 Principle

The instrument determines planar dimensions by reference to a highly accurate and precise linear translating stage on which the object being measured is placed. Calibrated lenses and software algorithms permit accurate measurement of planar spacing and height differential between selected points or features. Although lenses of various magnifying capacity are available to provide different image areas (fields of view), the selected points to be measured do not have to be within a single field of view (FOV). Illumination options provide the user the ability to control the intensity, direction and incidence angle of light and optimize the image for measurement. The software algorithms use the calibrated magnification factors to determine the size of the region within the instrument FOV at a given magnification. Physical measurements are made by selecting two or more points on a feature of interest and comparing the relative distance between them to the known dimensions of the FOV and the difference in lens height at optimal focus. Distances greater than the FOV are determined by reference to it and to the stage displacement. Edge detection and automated focusing routines permit highly reproducible feature selection.

4 Specimens

Imageable features of solid objects that are small enough to fit between the sample stage and lens apparatus can be analyzed by this method. The features to be measured must be perpendicular to the optical axis. Rough surfaces and irregular edges can affect measurement accuracy. Specimens should be free of any loose debris where in contact with the stage and at all measurement points.

5 Equipment/Materials/Reagents

a. Certified microrule

b. Calibrated grade B-standard thickness block set

c. Microsoft Excel, MINITAB software or other statistical calculating tool

6 Standards and Controls

The instrument contains a built-in, NIST (National Institute of Standards and Technology) traceable, optical reference filar. The instrument determines its magnification factor automatically by reference to this filar. This internal calibration process is verified by reference to measurements made on a cerified microrule and/or grade B-standard thickness blocks.

7 Calibration and Verification

The system is calibrated annually by a certified and licensed service provider that meets the FBI Laboratory Operations Manual (LOM) requirements. During normal operation, the lens magnification is auto-calibrated by the instrument within its measurement routine. Prior to the first use of a particular lens to make a significant measurement on a given day, the user will verify the calibration and enter the verification results in the instrument log book. Thickness reference standards are used to verify height differential, and a certified microrule is used to verify planar distance.

8 Sampling

Sampling of items examined under this protocol is determined by the nature of the evidence and can consist of multiple items or one or multiple regions of interest on one item. If large numbers of physically indistinguishable items are received for testing, a sampling plan may be employed. If the sampling plan will be used to make an inference about the entire set of items, then the plan will be based on a statistically valid approach. Every item may be tested at the examiner’s discretion. Any sampling plan and corresponding procedure used will be documented in case notes.

9 Procedure

a. Select the appropriate lens. Image the feature of interest (FOI) on the sample (or reference material) using the MeasureMind 3D MultiSensor software tools. Adjust the magnification as needed using the joystick or software controls.

b. Adjust the lighting to optimize the image using the appropriate light source. Available light sources include coaxial lighting from above, a ring light with selectable lighting directions and incidence angles, or transmitted light from below. Adequate brightness and contrast can typically be achieved by adjusting the light level to approximately 40 - 65%.

c. Focus the image using the joystick or select the focus tool that is appropriate for the FOI from the Toolbox icons.

d. To set the stage reference position, move an appropriate point of the FOI to the screen centerline, focus and zero the X, Y and Z values.

e. Select the measurement mode and a measurement tool from the Toolbox icons. (The specific function of each icon can be determined by hovering over the icon with the cursor.)

f. Move the stage to the first point to be recorded. (The software contains edge finder functions which allow optimal selection of the feature edge being measured). Record the point using the “Enter” button on the joystick platform. Relocate the stage to the next point of interest and record the next point until the feature is represented.

g. When the correct number of points has been entered, the software will automatically display the result. For example, if three points are entered along the edge of a circle, the software will fit a curve through the points and generate a diameter measurement. To collect an additional measurement of the same FOI, select “Again”.

h. To measure planar (X-Y) dimensions, no refocusing is required between point acquisitions. For Z (height) measurements, use the autofocus function to focus on the surface at each height of interest.

i. Record the measurement values in the case notes.

10 Instrumental Conditions

The principal instrumental condition to be set is the lighting level. Multiple lighting sources are present on the instrument (see section 9 Procedure). The one which gives the best FOI image should be used in a given situation. A light level between approximately 40 and 65% typically produces adequate contrast for the autofocus and edge finder routines to properly function. The light level is displayed on screen and can be adjusted in live time.

11 Decision Criteria

The instrument is considered to be functioning correctly if the mean value of five or more measurements generated on a standard gauge block falls within the 99.7% confidence interval for its certified values or 0.0001 inches, whichever is larger. If the measured values do not agree adequately, a second series of five measurements will be taken. If these also do not agree within the specified tolerance, the instrument will be serviced and recalibrated by a certified and licensed service provider that meets the LOM requirements.

12 Calculations

12.1 Quantitative Analysis

a. Feature characteristics (such as diameter, line length, or radius of curvature) are automatically calculated by the instrument software from the position of the stage and lens at each of the points entered for that feature. These readings, and their associated measurement uncertainty, may be used to report a range or series of measurements.

b. To report averaged measurements, collect at least five values. Calculate and report the mean and expanded measurement uncertainty.

Mean is calculated as: $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, where $\sum_{i=1}^{n} x_i$ is the sum of the measurements, n is the number of measurements and $\bar{x}$ is the mean dimension.

12.2 Comparative Analysis

Where quantitative data from two specimens are being compared, a pooled, two-tailed Student-t test statistic of the sample means is typically used for the comparison. Two samples are deemed to be "indistinguishable" in the property under consideration if the two samples differ by less than the preselected critical t value ($t_{critical}$). The critical t value is typically chosen so that a value of $\alpha = 0.05$ can be achieved for the analysis and is determined by the degrees of freedom associated with the measurements. An $\alpha = 0.05$ means that there is a 5.0% chance of incorrectly rejecting a match between two samples when one actually exists.

To perform this test, the sample means and sample variances of each sample are determined as follows:

The mean value: $\bar{x}_a = \frac{\sum_{i=1}^{n_a} x_i}{n_a}$ where $\bar{x}_a$ is the average value of the measurement on sample "a",

$\sum x_i$ is the sum of the individual measurements and n_a is the number of measurements made on that sample. he variance of the individual measurement values from sample "a" is given by:

$$s_a^2 = \frac{\sum_{i=1}^{n_a}(x_i - \bar{x})^2}{n_a - 1}$$

The mean and variance of the sample "b" data are calculated in an analogous manner.

The pooled sample variance is then calculated as: $s_p^2 = \frac{(n_a - 1)s_a^2 + (n_b - 1)s_b^2}{(n_a + n_b - 2)}$

A standard two-tailed statistical test of the two sample means is performed.

If $\left| \frac{\left(\bar{x}_a - \bar{x}_b\right)}{\left(\sqrt{s_p^2\left(\frac{1}{n_a} + \frac{1}{n_b}\right)}\right)} \right| > t_{critical}$, the samples have a statistically significant difference. If not, the samples are deemed to be indistinguishable.

In general, the number of individual measurements required per sample is determined by the population data distribution. If the sample populations are known to be, or can reasonably be assumed to be, normally distributed (Gaussian), as few as three measurements per sample can be used to compare the results. However, an increased number of measurements will provide an improved measurement standard deviation estimate. Typically physical dimension measurements are normally distributed.

In the majority of instances where the measurement populations are not normally distributed, 5-10 measurements per sample will result in sample means that are approximately normal and will be adequate for the comparison outlined above. For heavily skewed population distributions, a minimum of 30 measurements per sample may be required to achieve this. Heavily skewed data distributions will normally be detectable on inspection of the sample data. Statistical tests also exist for determining whether data are Gaussian or non-Gaussian and can be employed as they are needed. Commonly, a normal probability plot is constructed for this purpose using statistical software packages such as MINITAB.

13 Measurement Uncertainty

Quantitative data from this procedure are typically used for comparative purposes. Expanded uncertainty should not be used for these inter-comparisons because it increases the probability two samples will appear to be analytically indistinguishable and therefore increases the likelihood of type II errors (false inclusion). Should quantitative reporting be required, the measurement uncertainty will be estimated in accordance with the *Chemistry Unit Procedures for Estimating Measurement Uncertainty* in the CU QAM.

14 Limitations

Since measurement relies on imaging the specimen, the instrument cannot measure internal cavities. In order for a feature to be measured accurately, it must be perpendicular to the objective lens. Accurate height (Z) measurements require surfaces that respond well to the autofocus software routine.

15 Safety

Standard safety precautions, such as wearing protective gloves, should be observed when handling evidentiary materials. Electrical or mechanical hazards may require special precautions.

This instrument SOP has the following specific safety requirements:

- The motorized stage is computer-driven. Ties and other loose clothing should not be worn when operating it, and long hair should be tied back. If entanglement occurs, a red panic button labeled “STOP” can be used to interrupt the instrument power and halt the stage motion.

- The halogen sample illumination lamps are extremely hot when operating and should never be touched unless adequate time has been allowed for cooling.

16 References

MeasureMind Graphical Measurement Software Reference Guide, Part No. 790040, 5th Printing, Optical Gaging Products, 850 Hudson Ave., Rochester, NY 14621-4896

MeasureMind 3D MultiSensor Software Fast Start Guide, Part No. 790321, Optical Gaging Products, 850 Hudson Ave., Rochester, NY 14621-4896

SmartRing Service and Maintenance Guide, Part No. 790136, Optical Gaging Products, 850 Hudson Ave., Rochester, NY 14621-4896

Chemistry Unit Quality Assurance and Operations Manual, Federal Bureau of Investigation, Laboratory Division, most recent revision

FBI Laboratory Operations Manual, Federal Bureau of Investigation, Laboratory Division, most recent revision

FBI Laboratory Quality Assurance Manual, Federal Bureau of Investigation, Laboratory Division, most recent version

Rev. #	Issue Date	History
3	04/24/2014	Minor grammatical changes made to sections 3, 7 and 12. Language in section 6 updated. Service interval in section 7 changed from 6 months to annually. Calculation for sample standard deviation simplified in section 12. Corrections made to the remaining equations in section 12. Section 13 has been rewritten to reflect updated measurement uncertainty requirements. References updated in section 16.
4	12/21/2018	Renumbered Metallurgy SOP Manual documents; this document was formerly Metal 13 and is now designated Metal 302. Added personnel to section 2. Made minor editorial corrections throughout document. Updated section 7 to include verification. Added requirements for sampling plan in section 8. Revised measurement steps in section 9. Updated confidence interval and service requirements in section 11. Updated measurement uncertainty policy in section 13. Revised sections 4, 5, 14 and 15. Added additional references to section 16.

Redacted - Signatures on File

Approval

Metallurgy Technical Leader Date: 12/20/2018

Chemistry Unit Chief Date: 12/20/2018

QA Approval

Quality Manager Date: 12/20/2018