

## Verification Study

### Volumetric Feature Analysis Using 3D Laser Scan Data

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**Summary:** To meet Metron customer's requirements for the inspection of piston heads, Metron Systems has developed a process for determining the volume of the combustion bowl in a piston head using data from the MSG2 Laser Scanning System. In order to validate the performance of both the measurement system and the analysis procedure, Metron desired to know what level of measurement accuracy could be obtained when measuring a piston with a known volume. To answer this, Metron undertook a study to determine the accuracy and repeatability of this process by measuring a piston-like monument with a known volume. This was a whole system test where the data acquisition and the data analysis were treated as a single variable.

After conducting 10 measurement trials against a known volume of  $12.306 \text{ cm}^3$ , an average result of  $12.300 \text{ cm}^3$  with a standard deviation of  $0.008 \text{ cm}^3$  was obtained. The bias of  $0.006 \text{ cm}^3$  is within the standard deviation and both values are less than 0.1% of the measured value. The results of this test demonstrate that the measurement technique is both highly accurate and highly repeatable.

**Reference Volume:** A monument with a combustion bowl volume that mimics a piston was designed on a CAD system. The feature was deliberately kept simple so it could be easily measured and the volume validated. A high precision, flat and wide crown was employed to provide an un-ambiguous surface for determining a reference plane. The monument, shown on the left in Figure 1, was constructed out of aluminum, then measured on a CMM to determine the as-built geometry. The CAD model was modified to fit the actual geometry, as shown on the right in Figure 1. The CAD model was interrogated to determine that the actual (or expected) volume of the feature was  $12.306 \text{ cm}^3$ .

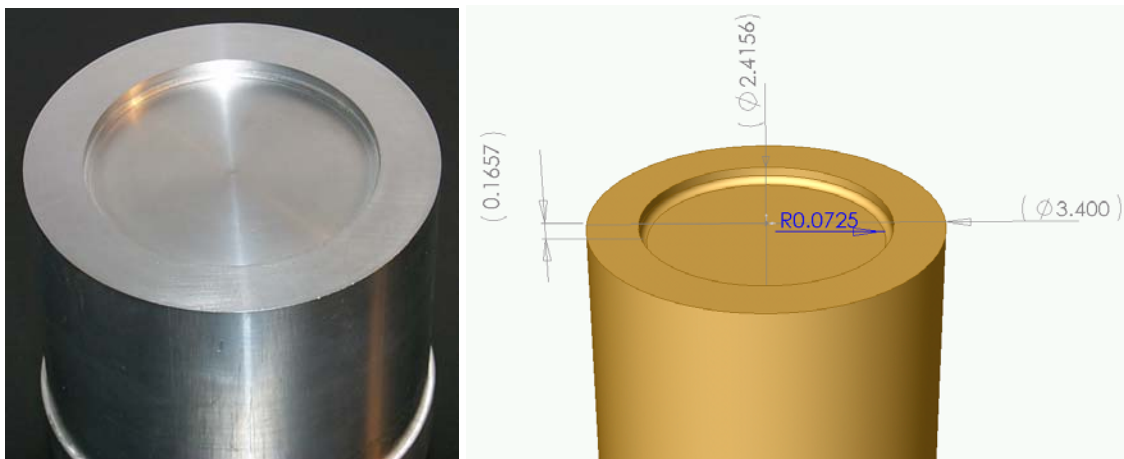
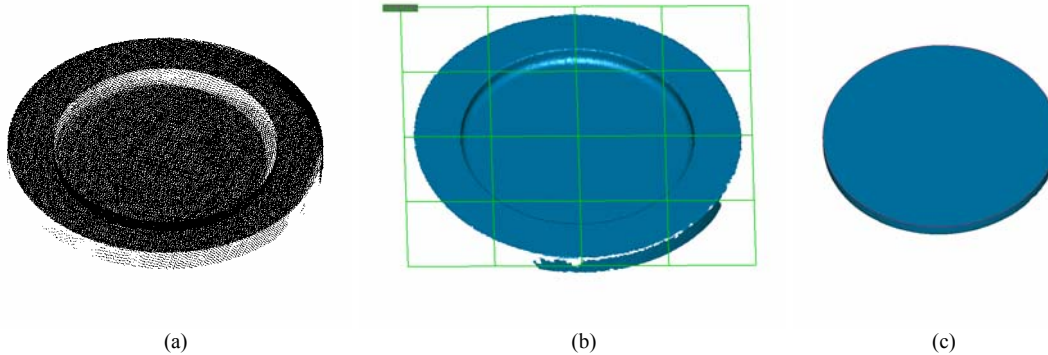


Figure 1. Piston-like reference monument and corresponding solid CAD model.

**Measurement Trials:** The monument was mounted on the MSG2 Laser Scanner and a comprehensive 3D point cloud of the monument feature was acquired, as shown in Figure 2(a). The point cloud was then converted to a polygon surface, as shown in Figure 2(b). A datum plane was established in the most non-subjective manner by simply fitting a plane to thousands of points obtained from the crown surface. The volume of the feature was then determined by analyzing the trapped volume bounded by this datum plane. The data acquisition and analysis procedure was repeated for 10 separate trials by a single operator, resulting in the data in Table 1.



**Figure 2.** 3D point cloud of the monument face (a), resulting surface with the datum plane shown (b) and solid model of the trapped volume on the face of the monument (c).

**Table 1. Volumetric Data and Statistical Analysis.**

Trial	Volume (cm <sup>3</sup> )	Variable		Volume (cm <sup>3</sup> )
1	12.304	Expected Value	$\mu$	12.306
2	12.287			
3	12.293	Average Measurement	$\chi$	12.300
4	12.295			
5	12.304	System Bias	$\mu - \chi$	0.006
6	12.298		$(\mu - \chi)/\mu$ %	0.046%
7	12.302	Standard Deviation	$\sigma$	0.008
8	12.316		$\sigma/\chi$ %	0.066%
9	12.298	Range	<b>R</b>	0.029
10	12.307			

**Conclusions:** Metron Systems has statistically demonstrated the accuracy and repeatability of using the MSG2 Laser Scanning System to measure the volume of a combustion bowl volume in a piston-like monument. The accuracy was found to be better than 0.05% of the expected value and repeatability was 0.07% of the average measured value. These tests show that the combined data acquisition system and analysis technique have accuracy and repeatability well within Metron customer's piston measurement requirements.