SEE-3D Report

Preliminary Technical Report
TR-355

Objective:

To summarize SEE-3D Surface analysis on 2/20/14 Engine Block

Report Prepared By:	Report Approved By:
Will Pisoni	Harold McCormick
Date: 2/25/14	Date: 2/26/14

16144 Westwoods Business Park

Ellisville, MO 63021

(636) 394-3331

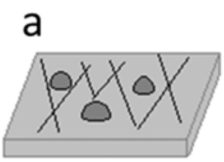
Table of Contents

Introduction

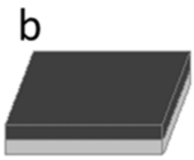
The CKE SEE-3D cylinder bore surface finish qualification system utilized in this study consists of three components. The first is the SEE-3D replicate head, which is a nondestructive cylinder bore replicating device utilizing a proprietary replicate material to create high resolution molds of the bore surface. The second component to the SEE-3D system is the white light interferometer used to map the surface of the mold in three dimensions. And the third is the customized SPIP software that quantifies up to thirty 2D and 3D surface characteristics. This system allows for quick, accurate and nondestructive cylinder bore surface finish analysis that can be used to control finishing processes and reduce wear and oil consumption in internal combustion engines. The four main steps of the process can be seen in the following images.

Replicate material is dispensed into replicate bar

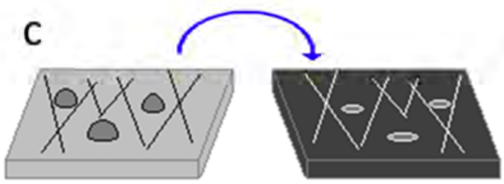
Replicator head is inserted into bore



Original honed surface

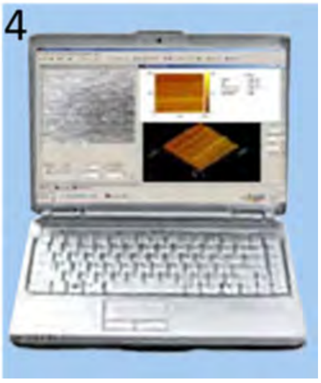


Replicate material cures



Replicate material is removed, producing a copy of the original surface

SEE-3D replicate is examined with interferometer



3D Images are processed using customized SPIP software to generate surface finish data

The customized SPIP software can quantify a variety 3D surface finish characteristics (See Table 1) as well as their 2D counterparts. From this large list, eight functional parameters that have been shown to have a strong correlation to oil consumption and wear in cast iron bores are examined and compared to CKE recommendations (See Table 2). These correlations were first determined through research conducted by Dana Corp. and Volvo Corp., detailed in "Cylinder Bore Finishes and Their Effect on Oil Consumption" (Hill, SAE 2001-01-3550, 2001) and "Advanced Techniques for Assessment Surface Topography" (Kogan Page Science, 2003). These correlations have since been validated by years of CKE experience in the field. Additionally, the SEE-3D system can quantify surface porosity size/distribution and surface finish with porosity removed with regards to sprayed coatings, as well as hard particle height/distribution for 390 Aluminum or Nikasil® bores.

Table 1: Possible Surface Finish Parameters Provided by the SEE-3D System

Sa	Sq	Ssk	Sku	Sy	St	Sz	S10z
Sz tph	Sds	Ssc	Sv	Sp	Smean	Sdq	Sdq6
Sdr	S2A	S3A	Sbi	Sci	Svi	Spk	Sk
Svk	Smr1	Smr2	Std	Stdi	Srw	Srwi	Shw
Sfd	Scl20	Str20	Scl37	Str37	Sdc0-5	Sdc5-10	Sdc10-50
Sdc50-95	TFM	X-hatch					

Table 2: 3D Functional Surface Finish Parameters Used to Characterize the Bore

CKE Recommended 3-D parameters	Optimal Parameter Range
S_{10z}: Ten Point Height	(Optimal range: 8-24 µm)
S_{vk}: Reduced Valley Depth	(Optimal range: 0.5-1.2 µm)
S_k: Core Roughness Depth	(Optimal range: 0.4-0.8 µm)
S_{pk}: Reduced Peak Height	(Optimal range: 0.4-1.5 µm)
S_{bi}: Surface Bearing Index	(Optimal range: 0.8-1.5)
S_{ci}: Core Fluid Retention Index	(Optimal range: 0.3-1.0)
TFM: Torn and Folded Material	(Optimal range ≥6, 1-10 scale)
X-Hatch: Hone Cross-hatch angle	(Optimal range: 25-35 Degrees)

Procedure

In this study the CKE SEE-3D system was utilized to quantify the surface characteristics at the top, middle and bottom of the bore in the cylinder and the two cycle engine Sleeve (See Figure 1). This was completed by first making replicates at Thrust°, 90°, 180° and 270° circumferential locations around the bores (See Figure 2) using the SEE-3D hardware. 3D mapped images were then taken at the Top, Mid and Bottom axial locations along each replicate utilizing the white light interferometer. Additional images were taken at an area of interest on the Sleeve that had a visually different finish than the surrounding areas. Finally, the mapped images were processed, quantifying critical surface characteristics at each location. The surface characteristics were then compared to the CKE recommended specifications.

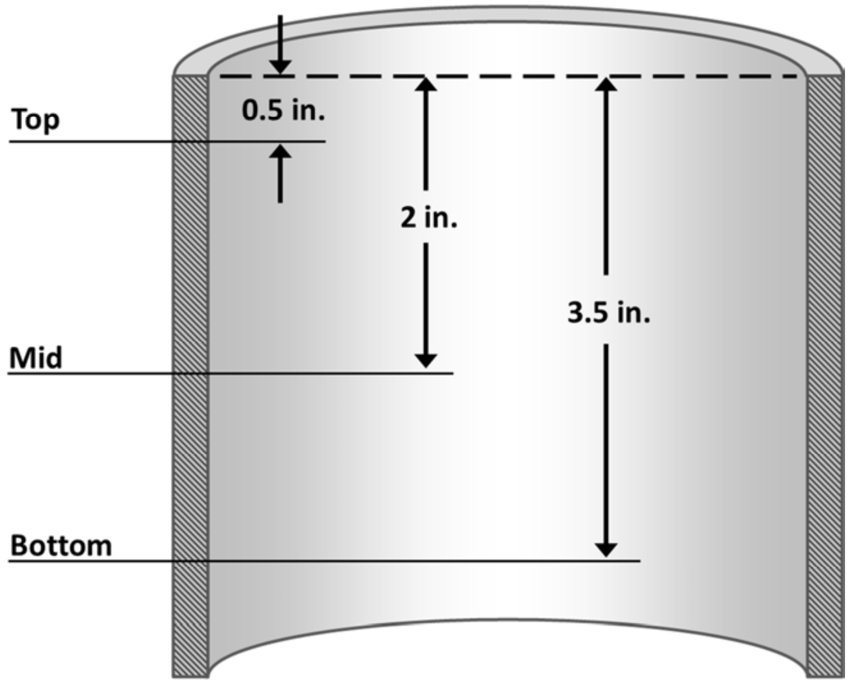


Figure 1: Cylinder/Sleeve Replicate Axial Locations

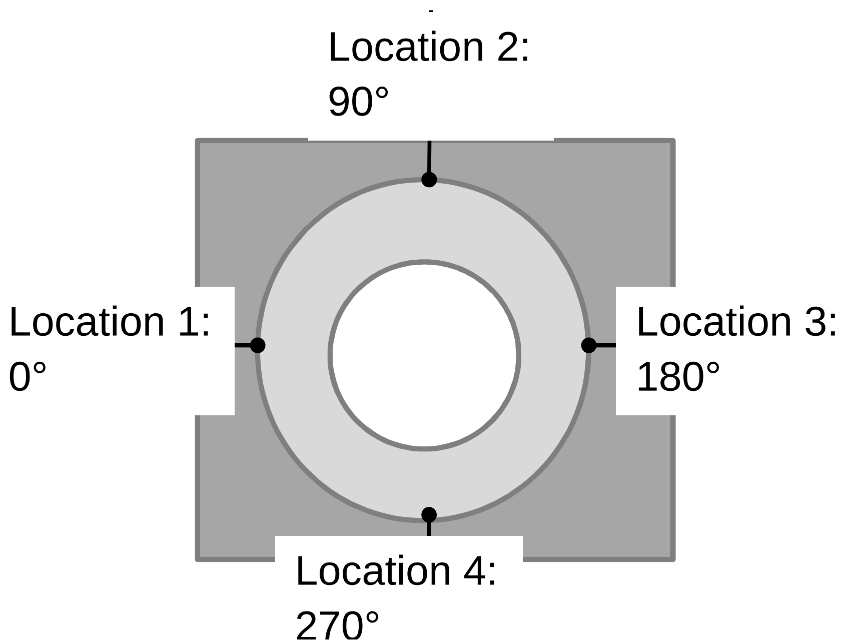


Figure 2: Cylinder/Sleeve Circumferential Replicate Locations

Results

1. Surface Finish Data (Values not meeting specifications are flagged in red)

1.1. Cylinder A (For complete data see Appendix 1)

When looking at the Cylinder A, some of the finish values at the axial locations indicate some parameters varying from CKE recommended specifications.

- Ten Point Height (S_{10z}) varies from the CKE recommended specifications for 3 of the axial locations.
- Reduced Valley Depth (S_{vk}) is near or within recommendations at half of the axial locations.
- Core Roughness (Sk) varies from the recommended values at all axial locations.
- Reduced Peak Height (S_{pk}) varies from the recommended values at many of the axial locations.
- Fluid Retention Index (S_{ci}) is above CKE recommendations at all but one axial location.
- Torn and Folded Material (TFM) exceeds acceptable levels.
- Cross Hatch Angle (X-Hatch) is inconsistent and varies from recommendations at many locations (See Figure 5).

Table 3: 3D Surface Finish of Cylinder A at Each Location

SEE-3D Surface Finish Data														
Cylinder	Axial Location	Radial Location	Image #	µm								n/a	1-10	Degree
				R_z	R_a	R_{vk}	R_k	S_{10z}	S_{vk}	S_k	S_{pk}	S_{ci}	TFM	X-Hatch
A	1	top	1	7.47	0.75	1.10	1.63	16.70	1.36	1.77	2.02	1.300	2.0	35.0
A	1	mid	1	6.37	0.68	1.25	1.49	19.29	1.76	1.33	3.57	1.652	2.0	60.0
A	1	bot	1	2.59	0.36	0.89	1.06	7.04	0.71	0.94	0.67	1.346	3.0	50.0
A	2	top	1	5.10	0.49	1.07	1.25	16.74	1.39	1.19	2.42	1.019	3.0	57.0
A	2	mid	1	4.91	0.47	0.83	1.11	13.28	1.00	1.32	1.67	1.300	2.0	50.0
A	2	bot	1	2.70	0.37	0.77	0.76	7.37	0.88	0.99	0.90	1.219	4.0	30.0
A	3	top	1	4.87	0.66	1.12	2.07	12.46	1.53	1.70	1.42	1.214	3.0	37.0
A	3	mid	1	5.13	0.53	1.50	1.10	19.10	1.36	1.28	1.77	0.981	4.0	60.0
A	3	bot	1	2.75	0.37	0.45	1.09	11.69	0.88	1.16	1.07	1.201	3.0	53.0
A	4	top	1	5.19	0.59	1.02	1.75	18.50	1.49	1.62	2.36	1.061	3.0	25.0
A	4	mid	1	3.57	0.50	1.07	0.93	13.85	0.93	1.05	1.68	1.046	3.0	60.0
A	4	bot	1	2.53	0.36	0.26	1.11	5.03	0.51	1.06	0.61	1.483	3.0	31.0

The surface porosity has been found to be less than 1.5% of the surface. As the cumulative area of the pores approaches 1.5% of the total area of the surface, oil consumption has been shown to increase. Background at CKE has found that porosity less than 1.5% has little to no effect on oil consumption

From the 3D surface images supplied in Appendix 1 (See Figures 3 & 4), it can be seen that the 5 cylinder has some torn and folded material content. Figure 4 shows a sample of areas, circled in yellow, from Cylinder A where torn and folded material is present. This material can disrupt proper sealing or even come loose from the surface and act as an abrasive that can lead to premature wear in the engine.

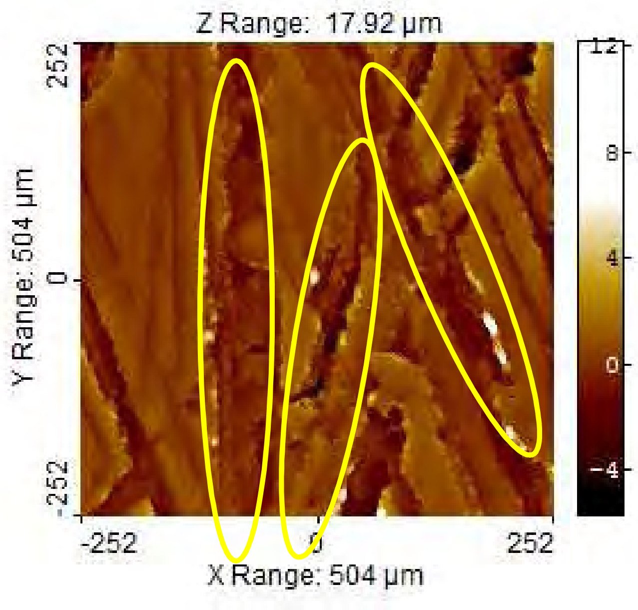


Figure 4: Cylinder A Torn and Folded Material Sample from Appendix 1

1.2. Cylinder B

When looking at the Cylinder B, some of the finish values at the axial locations vary from the CKE recommended specifications.

- Ten Point Height (S_{10z}) varies from the CKE recommended specifications at half of the axial locations.
- Reduced Valley Depth (S_{vk}) is near or within recommendations at most of the axial locations.
- Core Roughness (Sk) varies from the recommended values at all but one axial location.
- Reduced Peak Height (S_{pk}) varies from the recommended values at two of the axial locations.
- Fluid Retention Index (S_{ci}) is above CKE recommendations at all axial locations.
- Torn and Folded Material (TFM) exceeds acceptable levels.
- Cross Hatch Angle (X-Hatch) is inconsistent and varies from recommendations at all but one location (See Figure 5).

Table 4: 3D Surface Finish of Cylinder B at Each Location

SEE-3D Surface Finish Data														
Cylinder	Axial Location	Radial Location	Image #	µm								n/a	1-10	Degree
				R_z	R_a	R_{vk}	R_k	S_{10z}	S_{vk}	S_k	S_{pk}	S_{ci}	TFM	X-Hatch
B	1	top	1	6.08	0.71	1.00	2.17	13.52	1.59	1.69	1.92	1.052	3.0	64.0
B	1	mid	1	5.45	0.43	1.12	0.69	12.64	1.27	0.88	1.30	1.094	3.0	58.0
B	1	bot	1	4.07	0.35	0.75	0.91	10.68	0.91	0.90	1.15	0.992	3.0	46.0
B	2	top	1	5.50	0.61	1.03	1.41	6.69	0.90	1.45	0.85	1.343	3.0	61.0
B	2	mid	1	3.46	0.57	0.96	1.92	9.03	0.74	1.77	1.10	1.436	2.0	60.0
B	2	bot	1	2.48	0.27	0.37	0.76	4.53	0.66	0.89	0.59	1.262	4.0	56.0
B	3	top	1	3.31	0.42	0.49	1.32	6.27	0.64	1.06	0.68	1.345	3.0	60.0
B	3	mid	1	3.33	0.37	0.82	0.75	7.30	0.69	1.06	0.74	1.319	3.0	60.0
B	3	bot	1	3.48	0.55	0.93	1.43	7.52	0.83	1.13	0.79	1.226	4.0	45.0
B	4	top	1	9.30	1.07	1.51	2.32	19.16	2.46	2.62	3.31	1.185	2.0	27.0
B	4	mid	1	4.61	0.33	0.93	0.66	8.21	0.99	0.66	0.83	1.003	3.0	46.0
B	4	bot	1	4.04	0.42	0.83	1.22	11.20	1.05	1.15	1.17	1.199	3.0	38.0

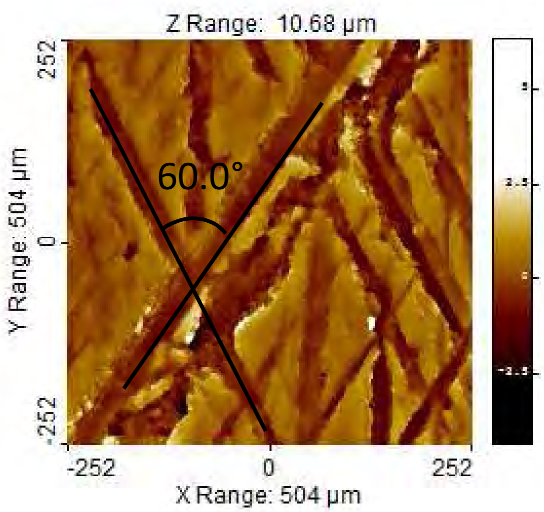


Figure 5: Cylinder b Cross Hatch Angle Example from Appendix 2

1.3. Surface Finish Comparison (Red bars bracket CKE recommended specification range on 3D parameters and Engine specification range on 2D parameters)

Most axial locations are within the recommendations. There are a few locations that are below the recommendations.

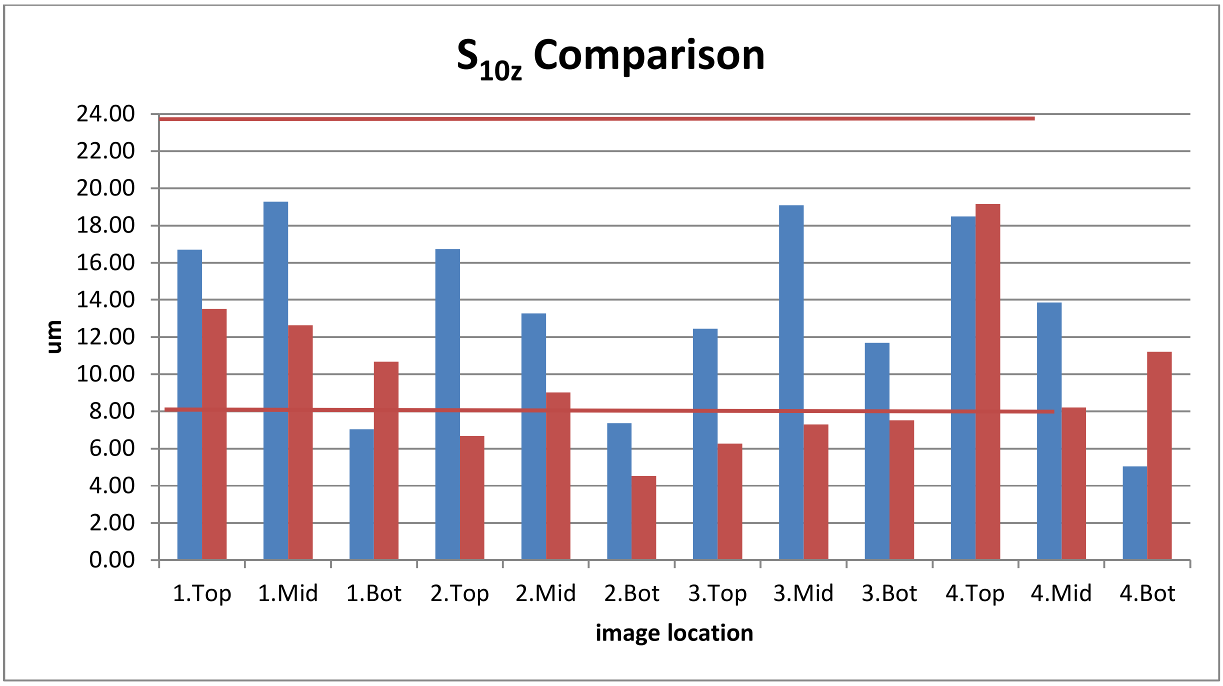


Figure 6: Comparison of S_{10z} between the two bores

Most axial locations are within or near recommendations

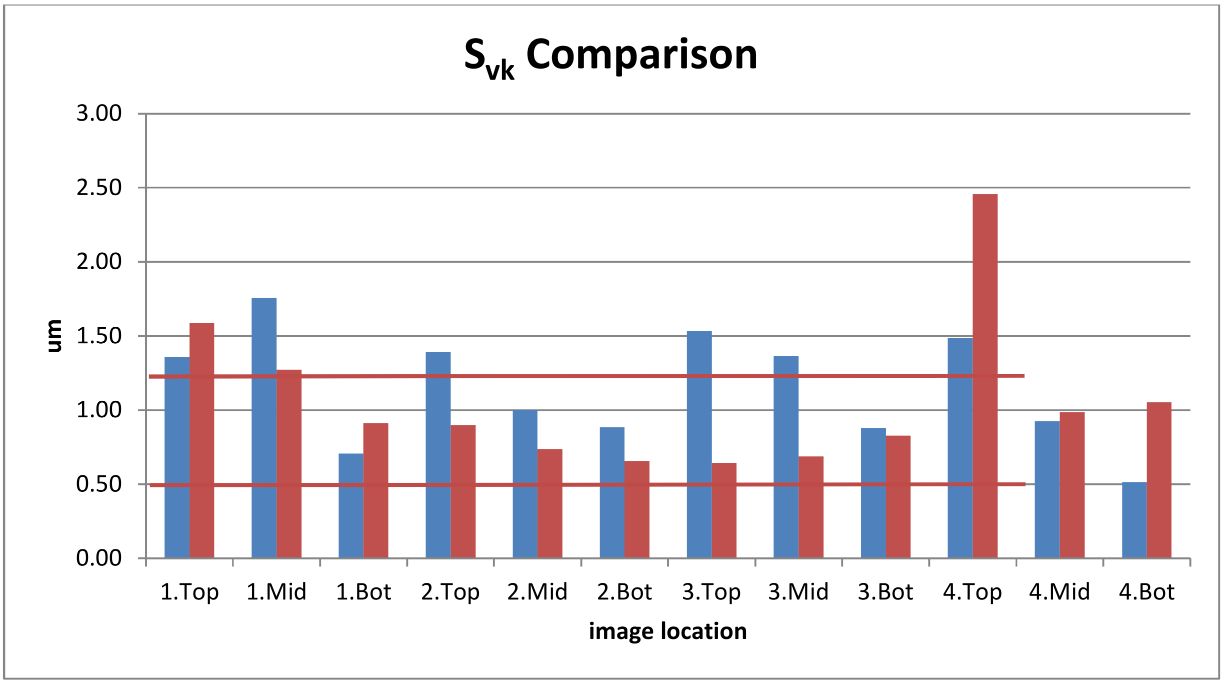


Figure 7.1: Comparison of S_{vk} between the two bores

Red bars show Spec

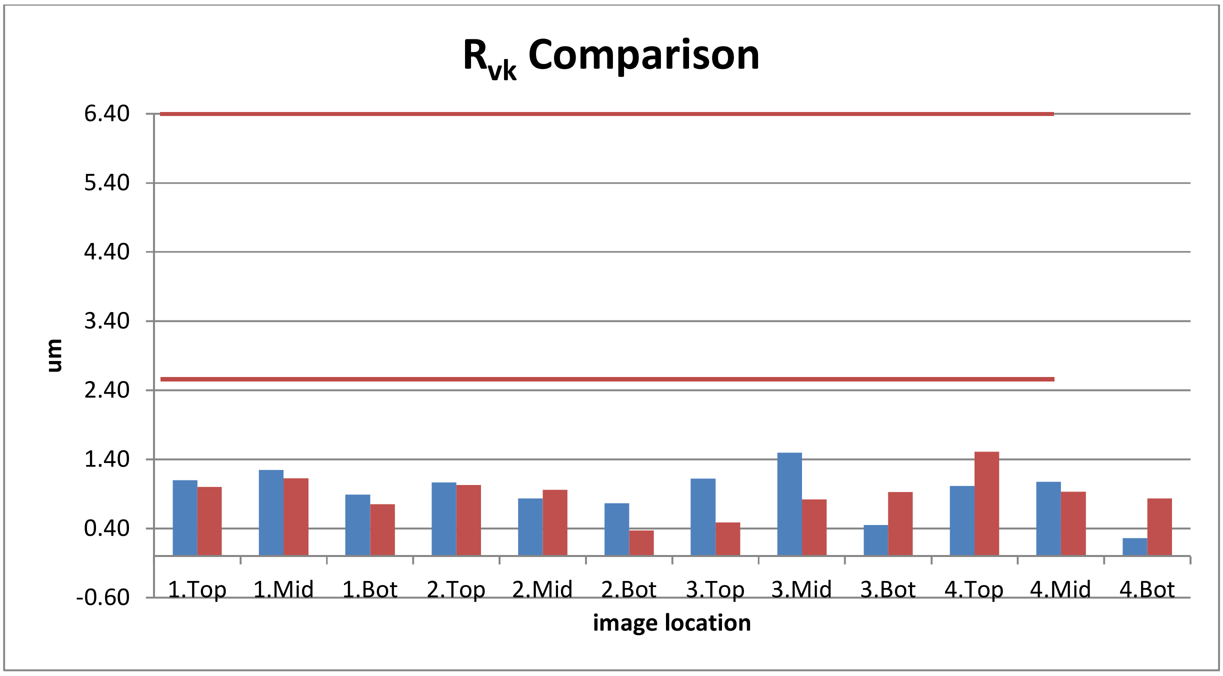


Figure 7.2: Comparison of R_{vk} between the two bores

Most of the values are above the recommendations.

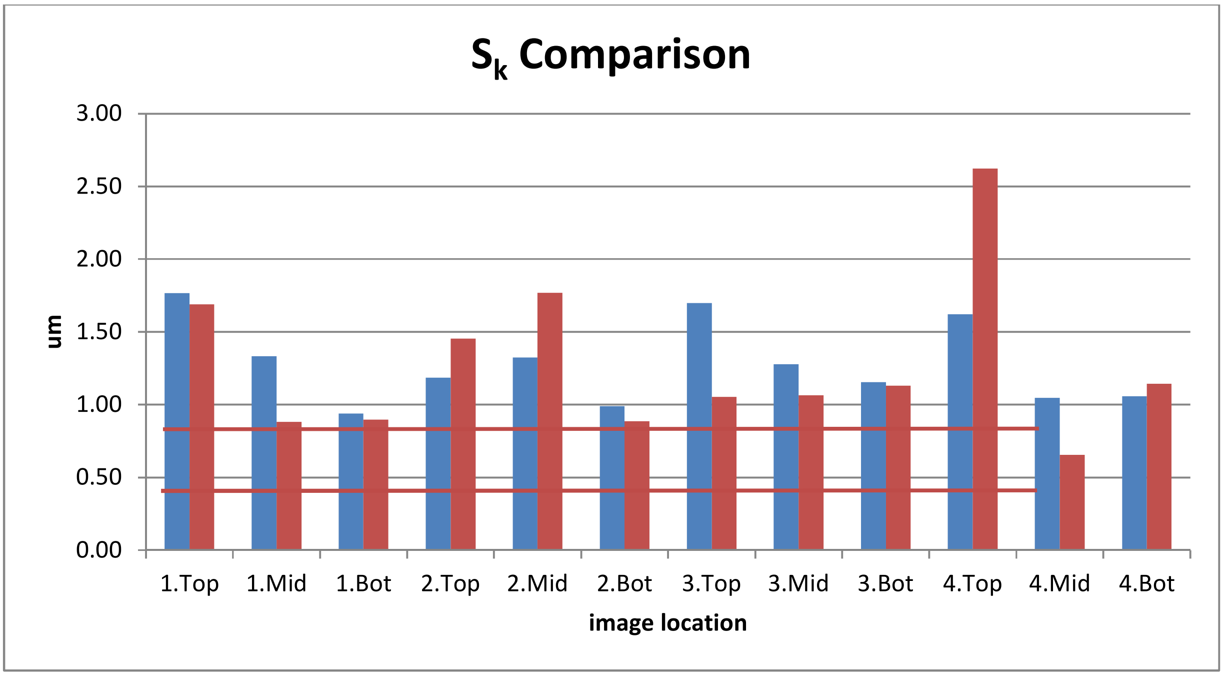


Figure 8.1: Comparison of S_k between the two bores

Red bars show spec.

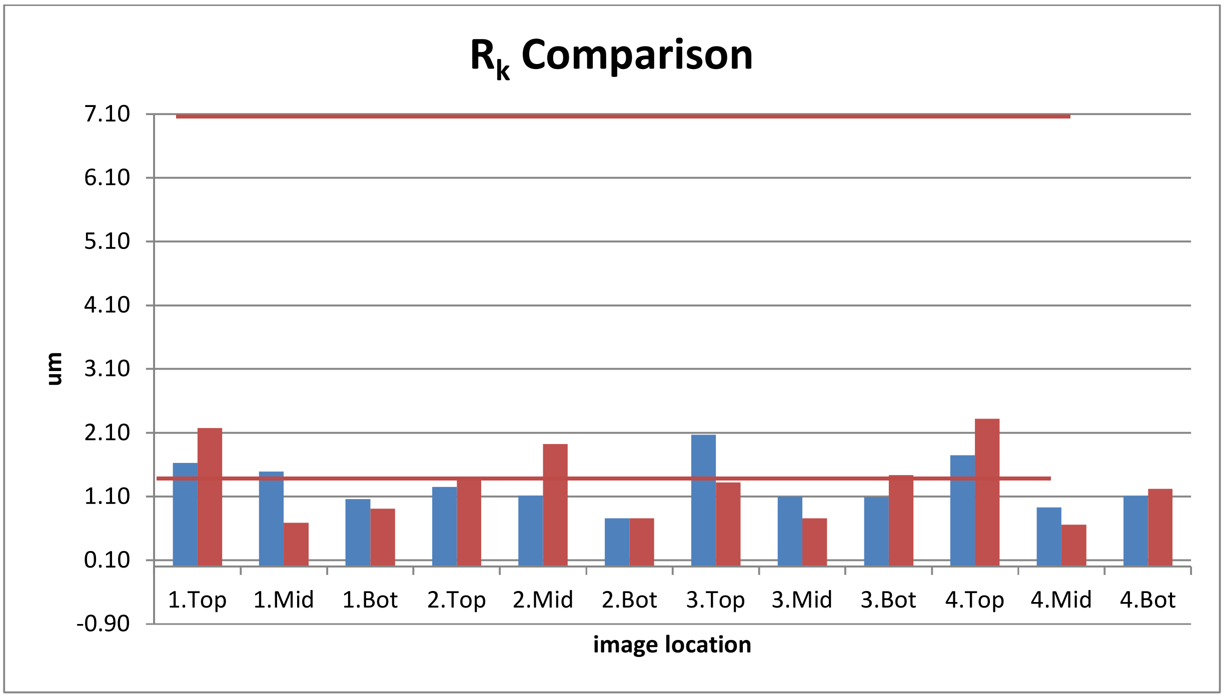


Figure 8.2: Comparison of R_k between the two bores

Cylinder B is mostly within the recommendations while Cylinder A varies from the recommendations at half of the locations

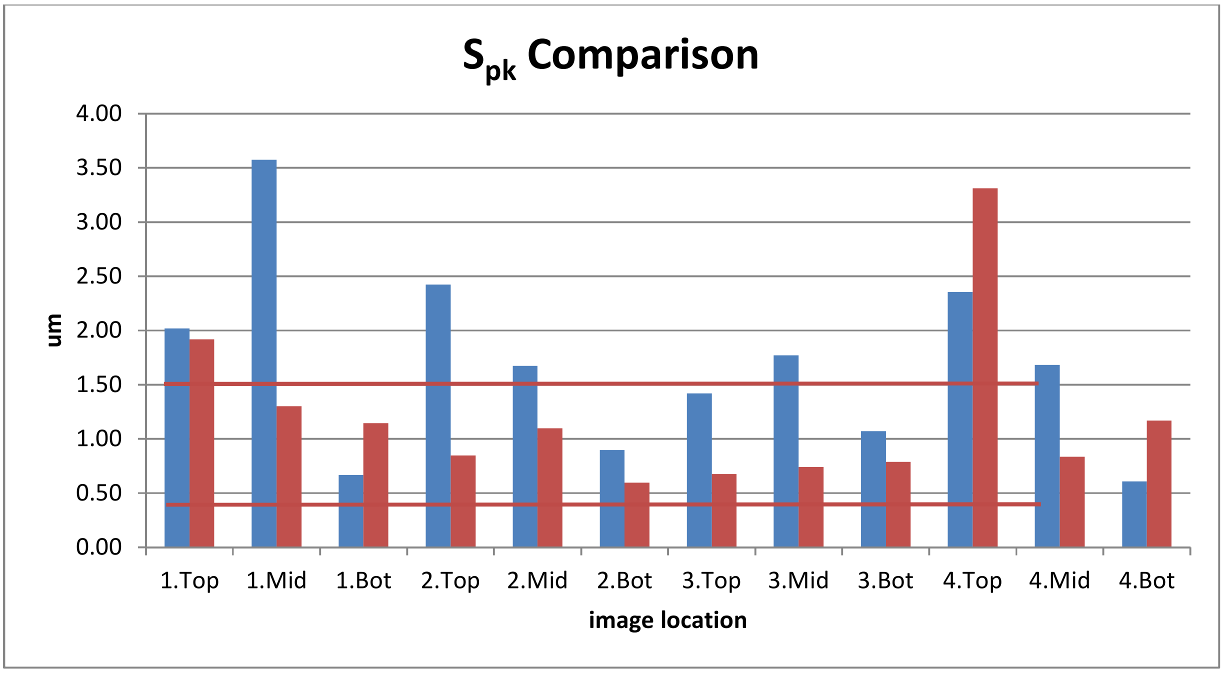


Figure 9.2: Comparison of S_{pk} between the two bores

Red bars show spec.

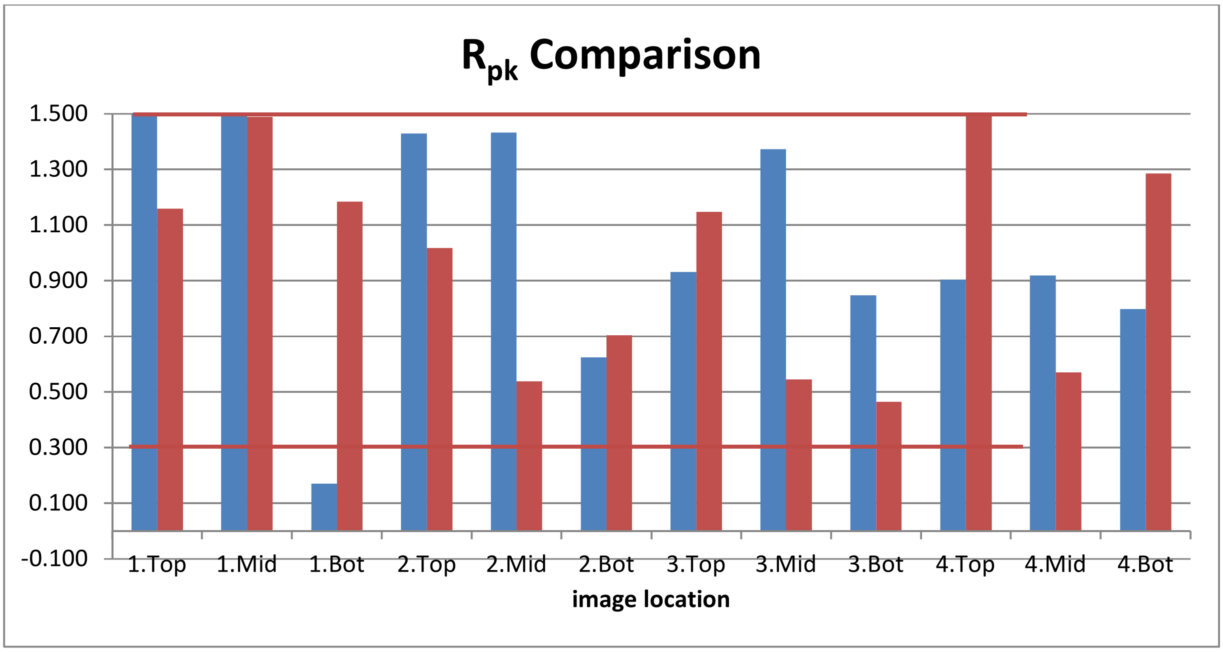


Figure 9.2: Comparison of R_{pk} between the two bores

Most of the locations have values that are higher than the recommendations

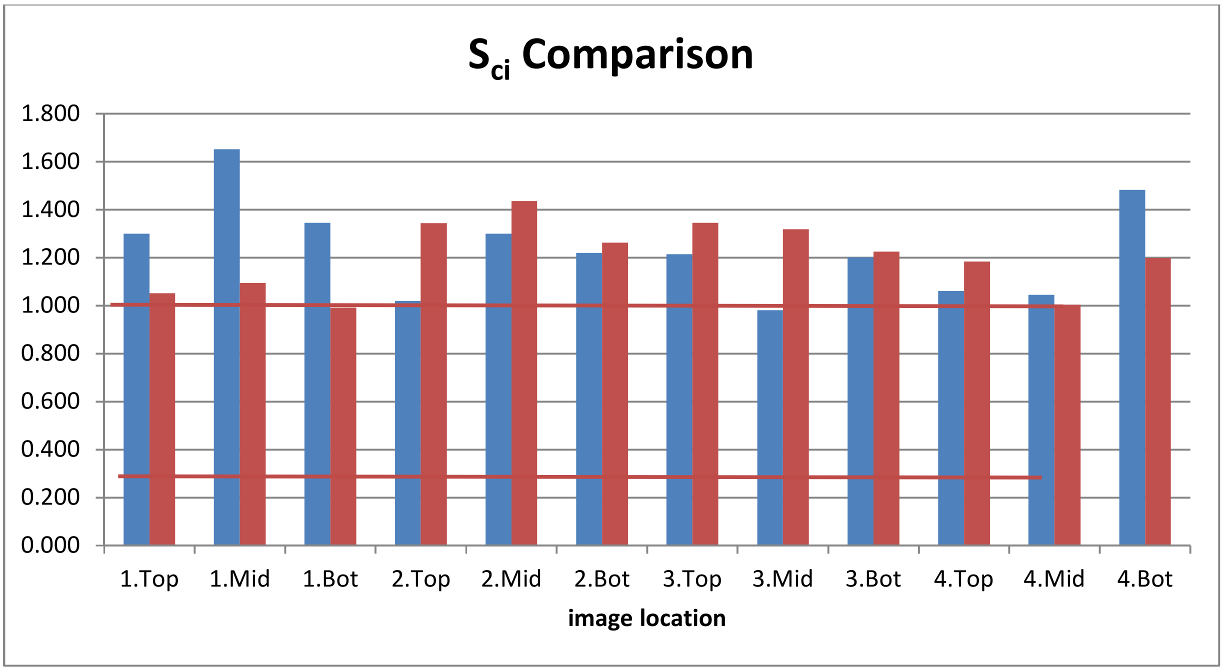


Figure 11: Comparison of S_{ci} between the two bores

Both cylinders have values that are below the recommendations

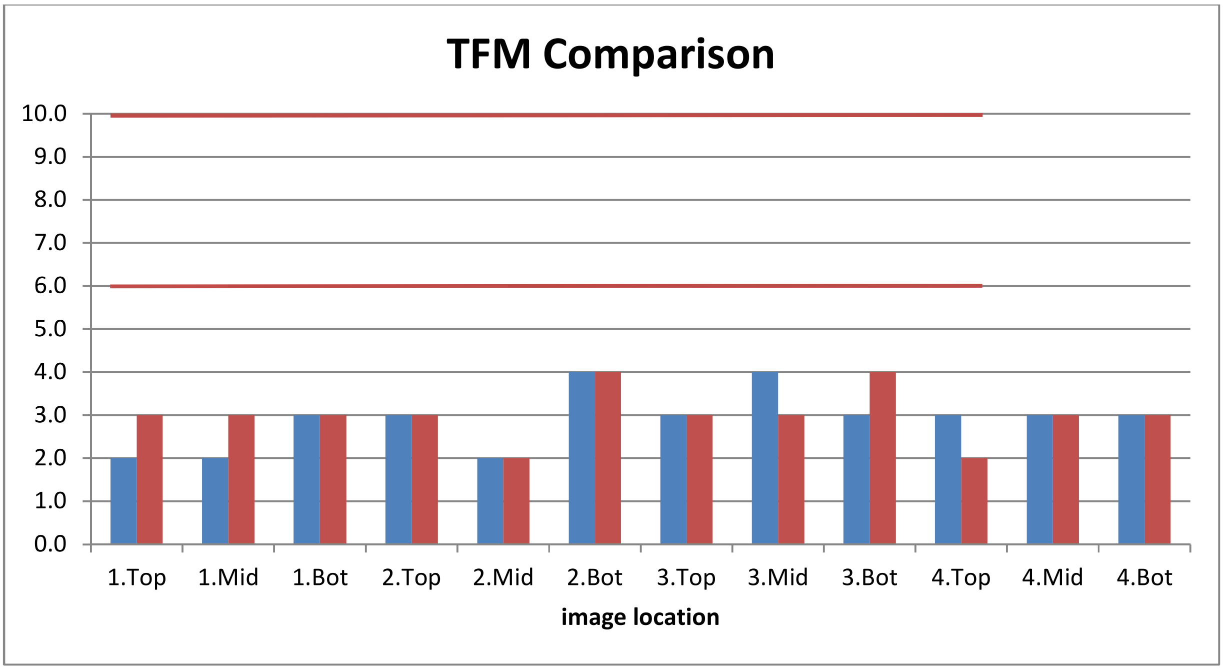


Figure 12: Comparison of TFM between the two bores

Most locations vary from CKE recommendations.

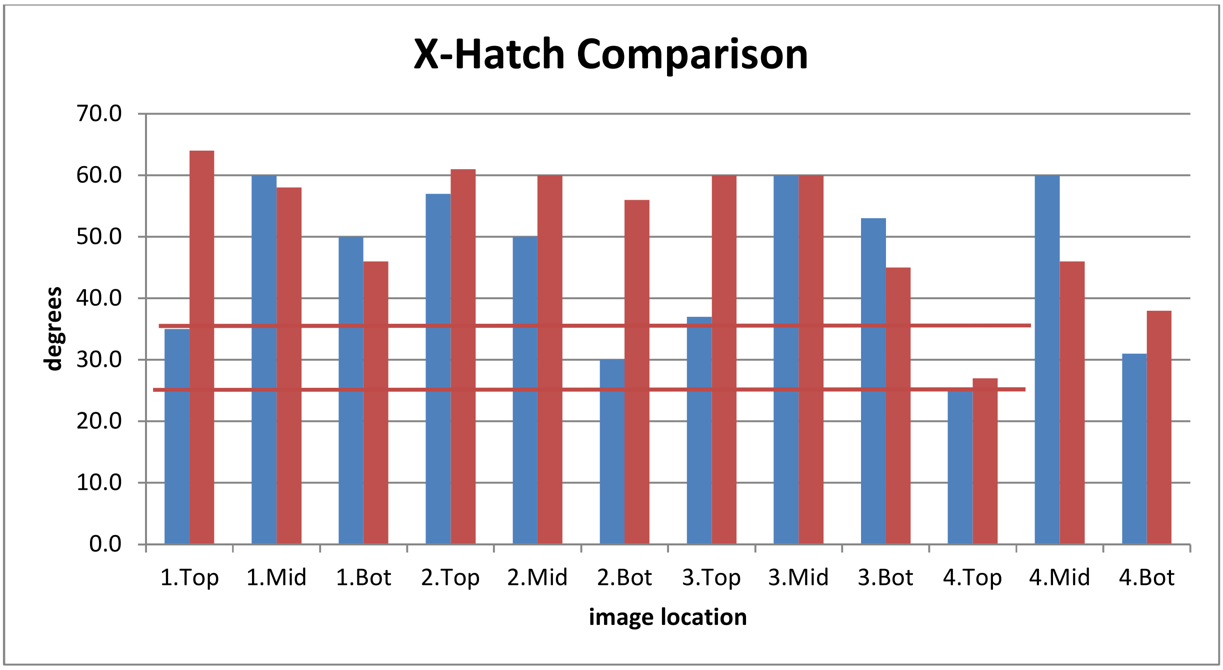


Figure 13: Comparison of X-Hatch between the two bores

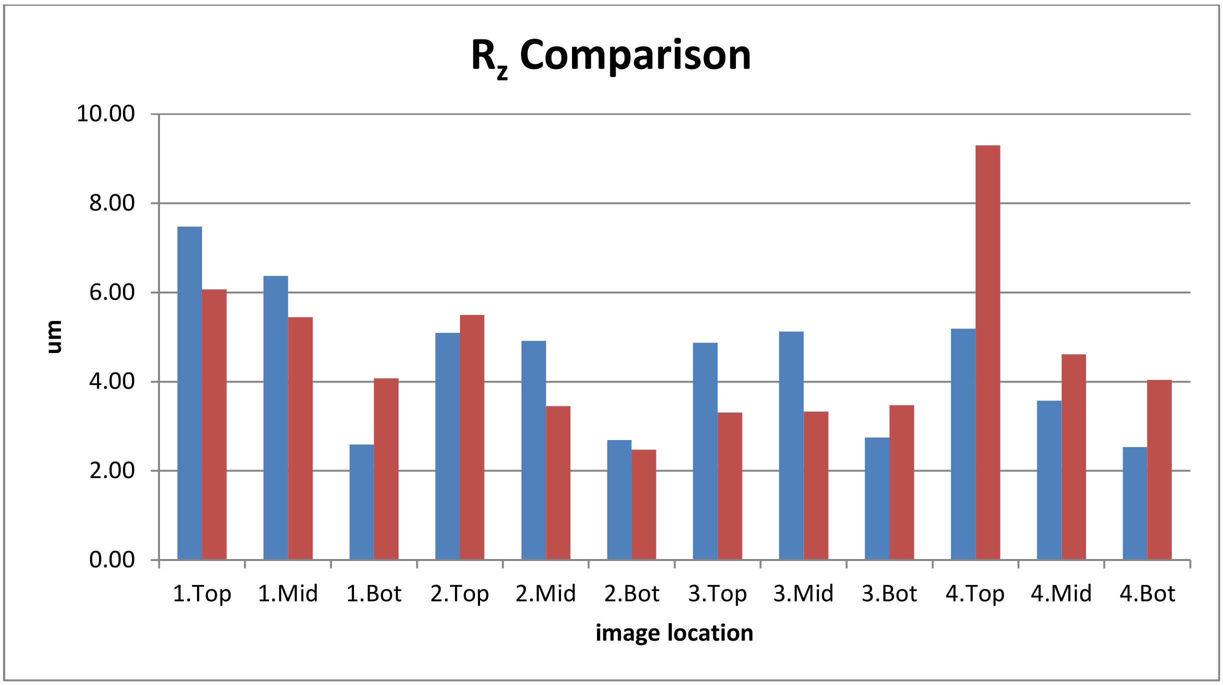


Figure 14: Comparison of R_z between the two bores

Red bars show spec.

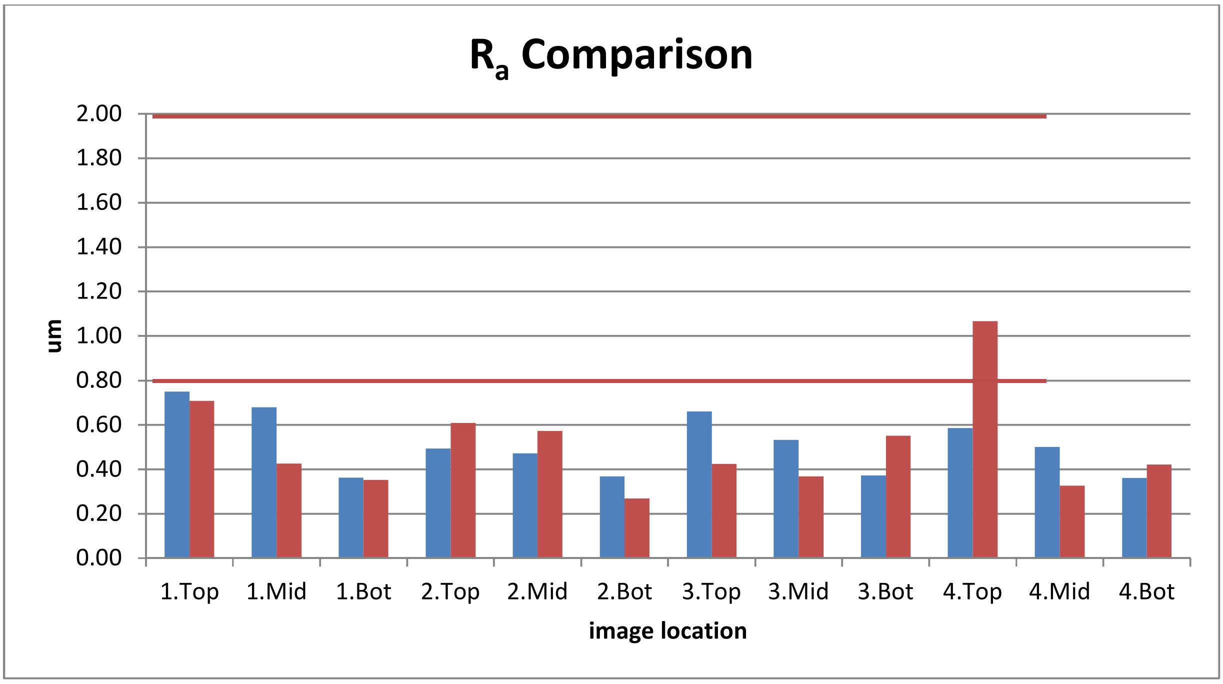


Figure 15: Comparison of R_a between the two bores

Figures 16 and 17 show typical 2D traces from Cylinders A and B.

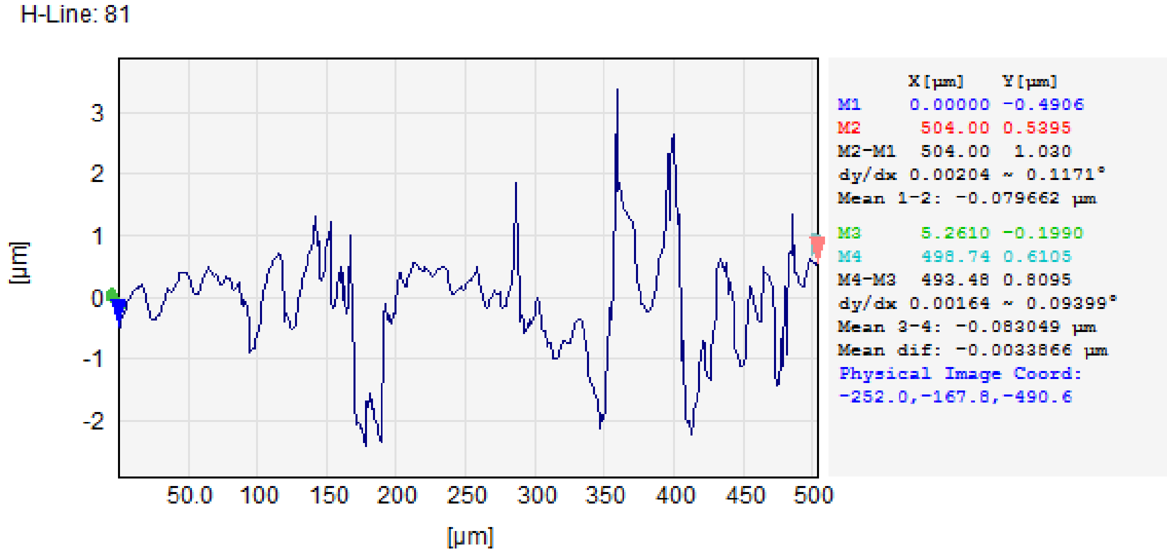


Figure 14: Cylinder A Surface Roughness Trace Example from Appendix I

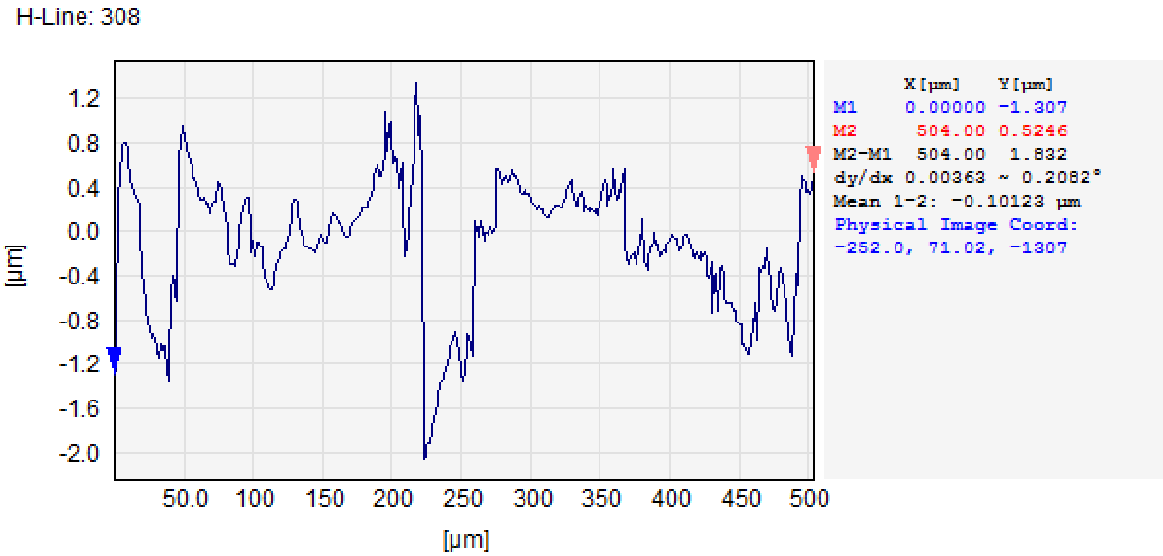


Figure 15: Cylinder B Surface Roughness Trace Example from Appendix II