

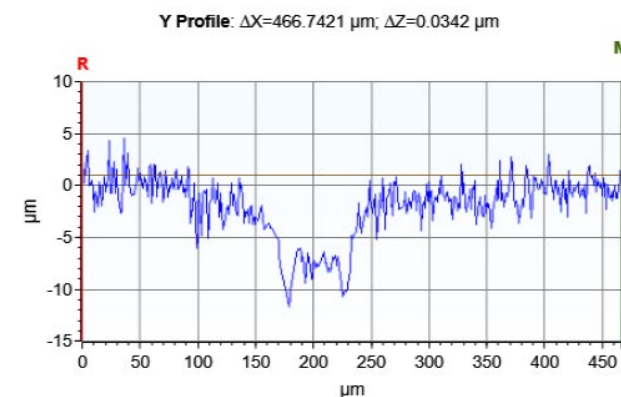
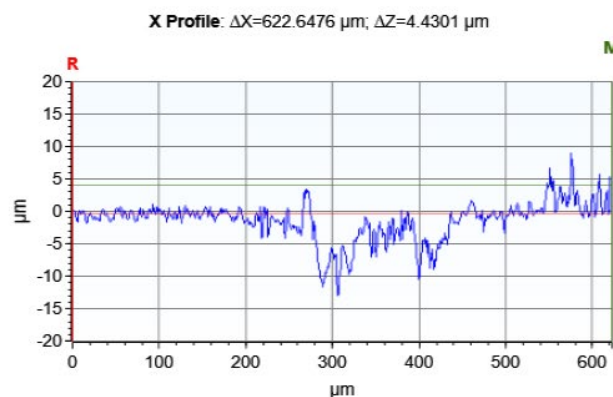
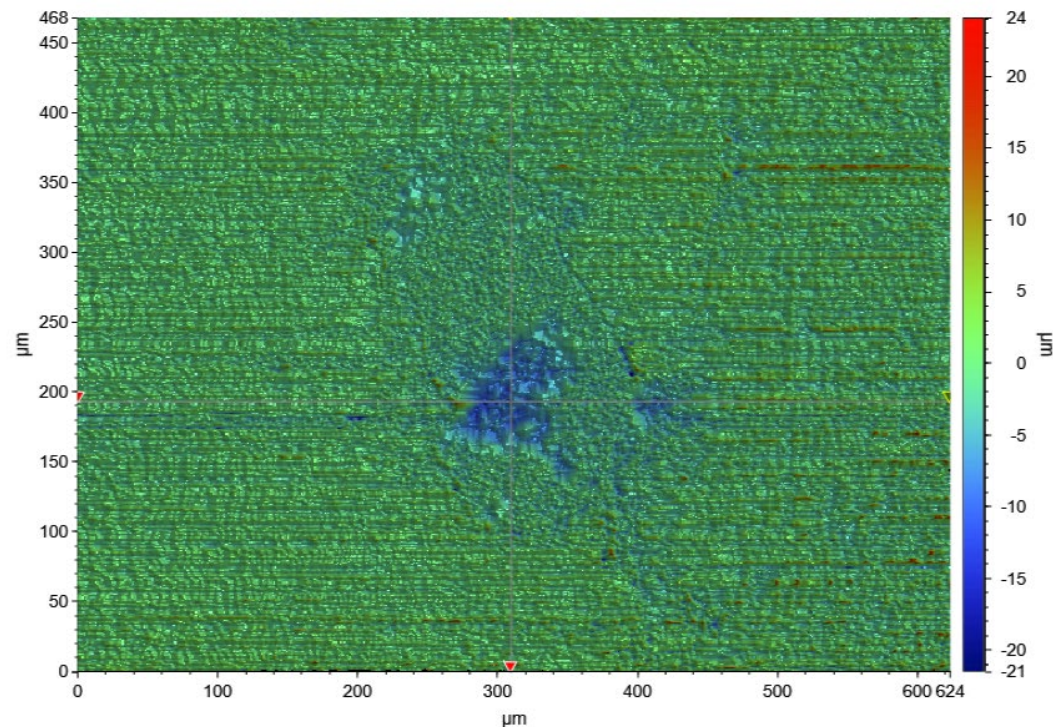
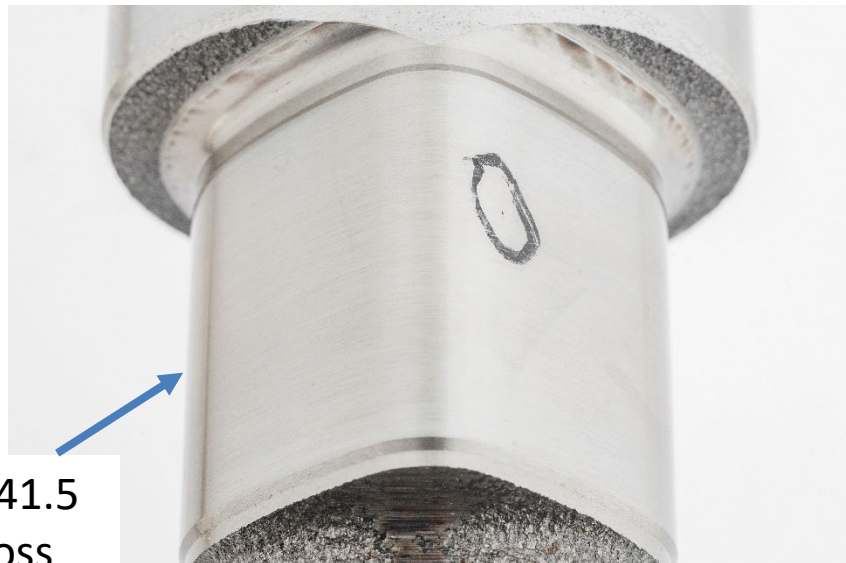
Pitted Batch O Camshaft Results

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FUELS & LUBRICANTS RESEARCH

What is a pit



Lobe 12 of CMIR-202553

Background and Results Summary

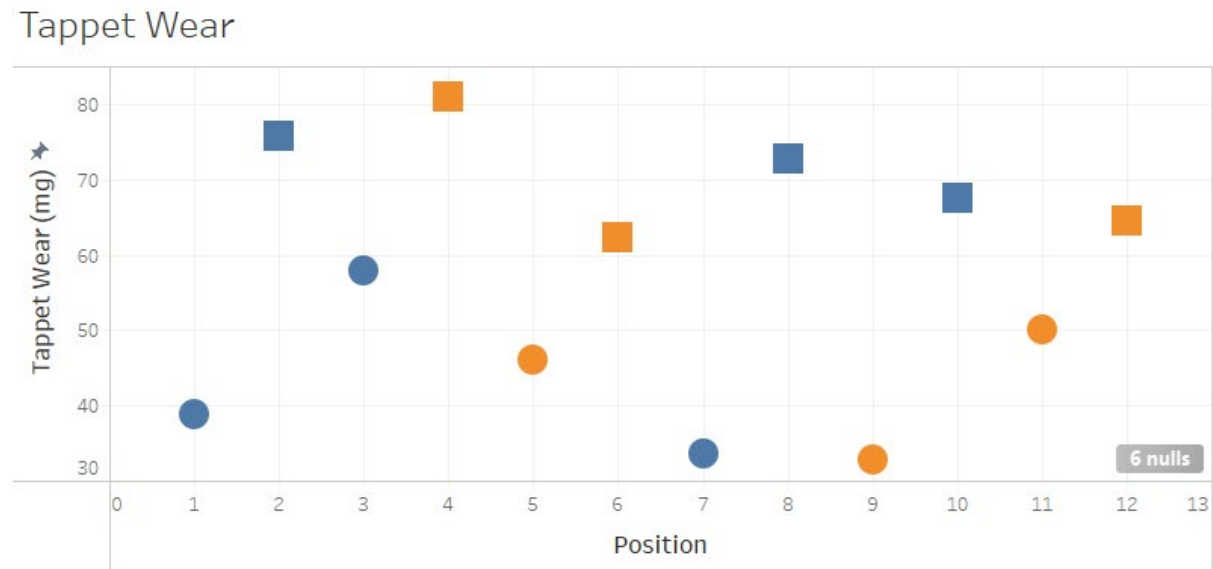
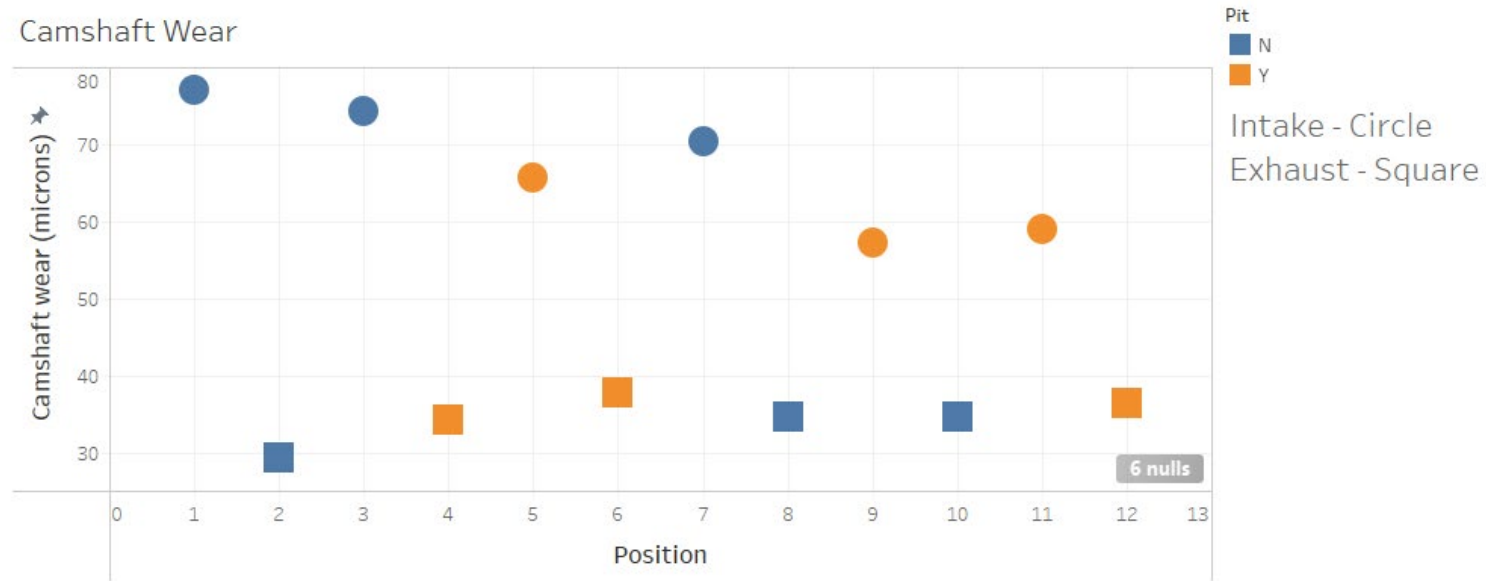
- TEI is out of unpitted cams
- All Testing shown here was run with RO 835 on Batch O camshaft kits at SwRI and
- “Pitted” cam donated by Cummins, 3 pitted intake lobes and 3 pitted exhaust lobes as identified by TEI; 3, 4, 5, 9, 11, 12
- Pitted run camshaft wear $Y_i = -0.017$; tappet wear $Y_i = -0.025$

Run #	Surface Pits?	Avg Cam Wear, μm	Outliers?	Avg Tappet Wear (Final), mg
LTMS Target	-	50.9	-	94.28
CMIR-195526	No	49.8	None	87.3
CMIR-195527	No	41.6	None	99.4
CMIR-196522*	No	45.2	Intake 5	103.2
CMIR-196523	No	37.5	None	96.2
CMIR-202553*	Yes, half	50.9	None	93.6

* Same stand

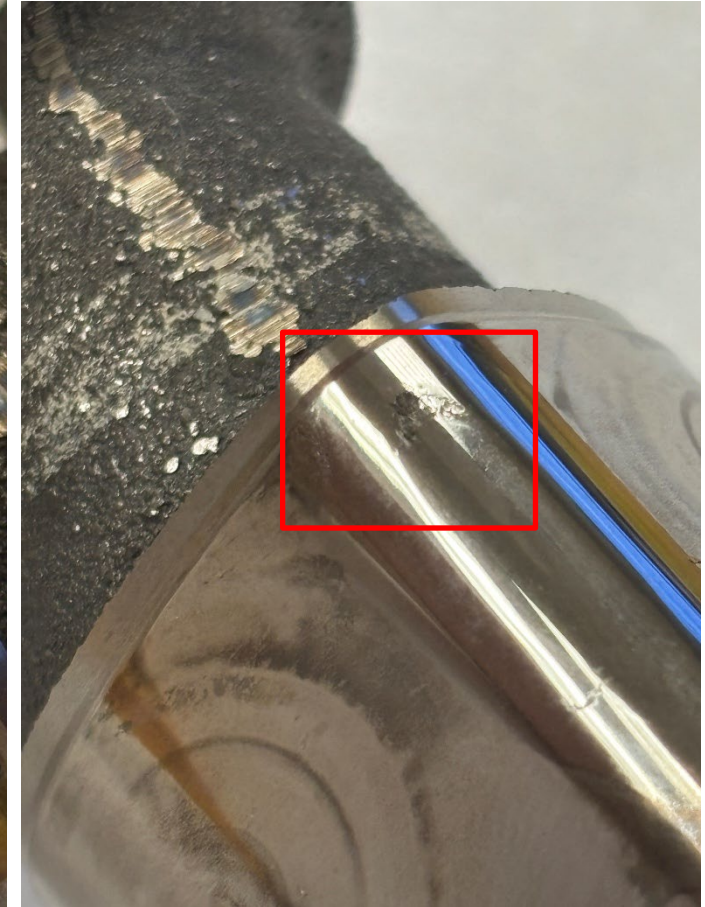
Pitted Cam Results

- Individual lobe averages
 - No corrections/transforms
- No evidence of increased wear on pitted cam lobes
- No evidence of increased wear on tappets with pitted cam lobes



Material Loss: Flaking

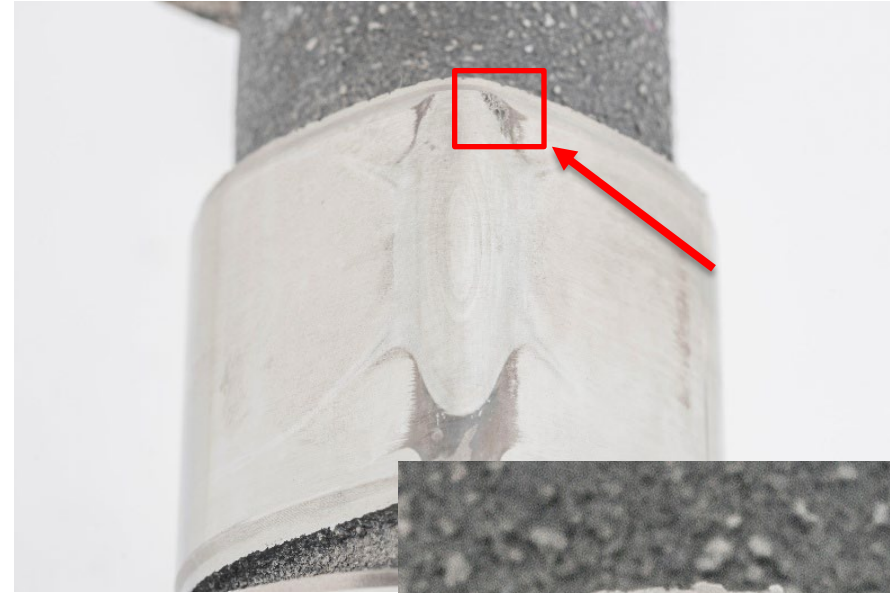
- Flaked off material is a common problem in previous, and current, batches
- Only 1 of the pitted lobes had any flaking
 - Not located at pit site



Lobe 2 of CMIR-195527
(non-pitted)

Pitted Cam Run vs Recent References

- Following slides show camshaft lobes with visible flakes called out by red arrows
- All prior tests are EOT only, pitted cam run has both BOT and EOT



Lobe 11 of CMIR-195527
(non-pitted)



Lobe I – Intake

CMIR-196523: 44.0 μm



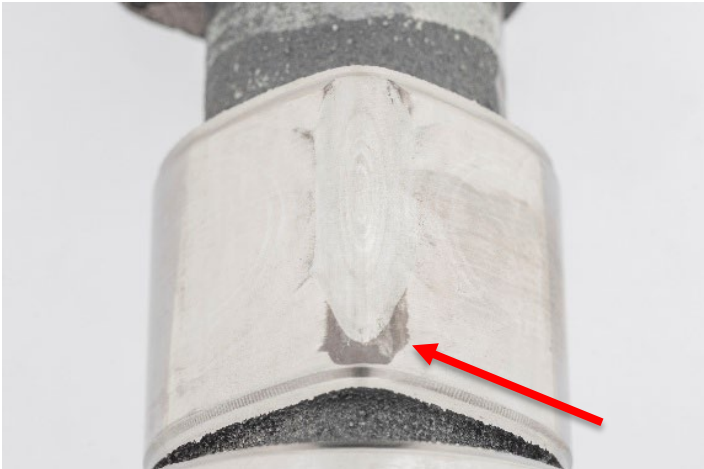
CMIR-196522: 48.7 μm



CMIR-195526: 51.0 μm



CMIR-195527: 39.0 μm



CMIR-202553 BOT

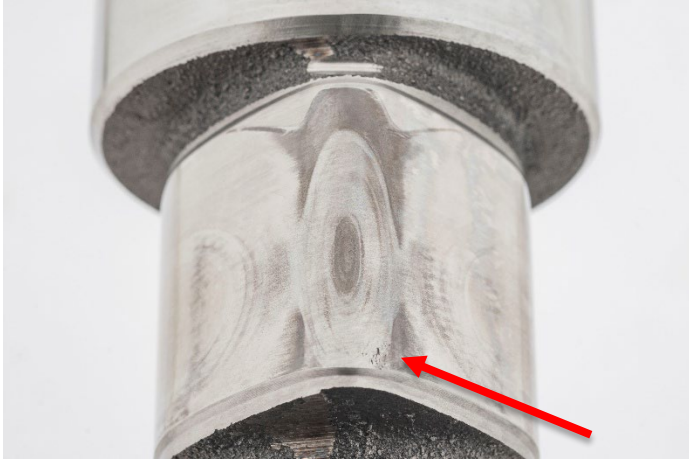


CMIR-202553 EOT: 77.0 μm



Lobe 2 - Exhaust

CMIR-196523: 26.3 μm



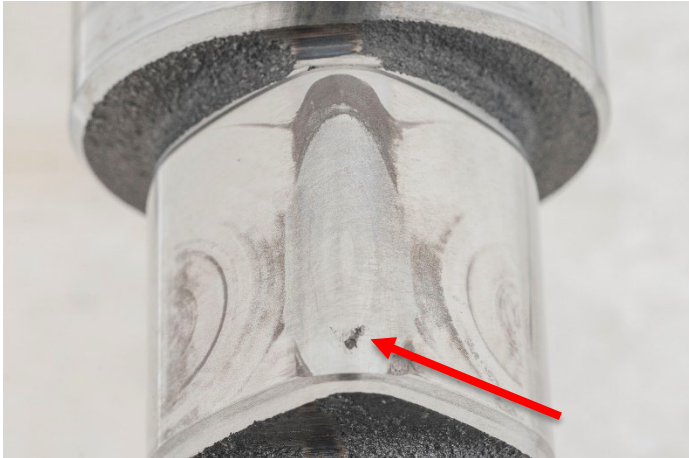
CMIR-196522: 45.7 μm



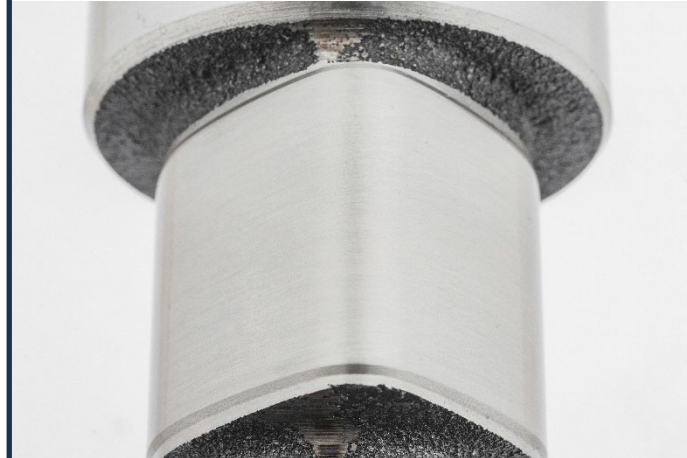
CMIR-195526: 71.3 μm



CMIR-195527: 44.0 μm



CMIR-202553 BOT



CMIR-202553 EOT: 29.3 μm

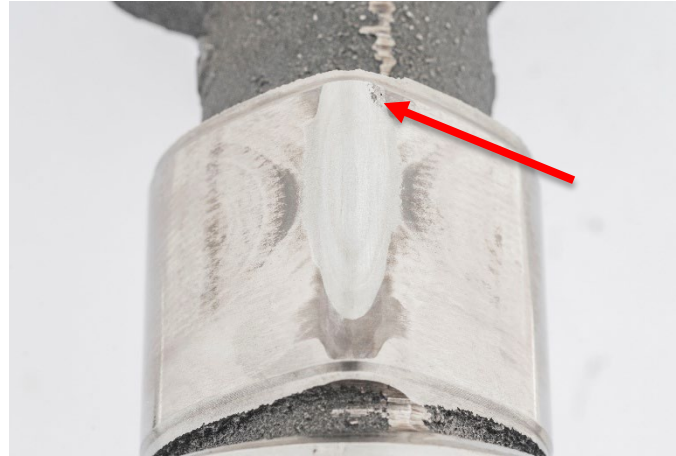


Lobe 3 - Intake

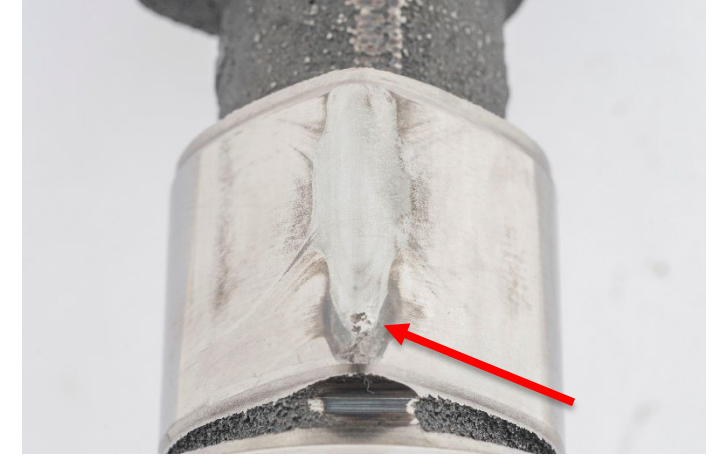
CMIR-196523: 44.7 μm



CMIR-196522: 48.0 μm



CMIR-195526: 64.3 μm



CMIR-195527: 56.3 μm



CMIR-202553 BOT



CMIR-202553 EOT: 74.3 μm



Lobe 4 - Exhaust

CMIR-196523: 34.0 μm



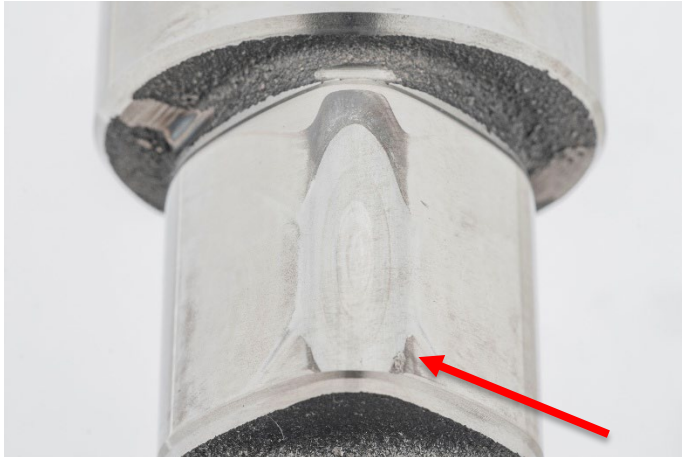
CMIR-196522: 52.7 μm



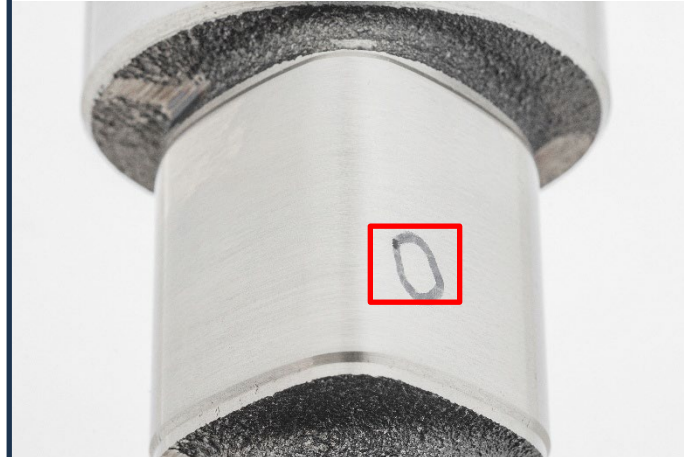
CMIR-195526: 56.0 μm



CMIR-195527: 35.0 μm



CMIR-202553 BOT



CMIR-202553 EOT: 34.3 μm

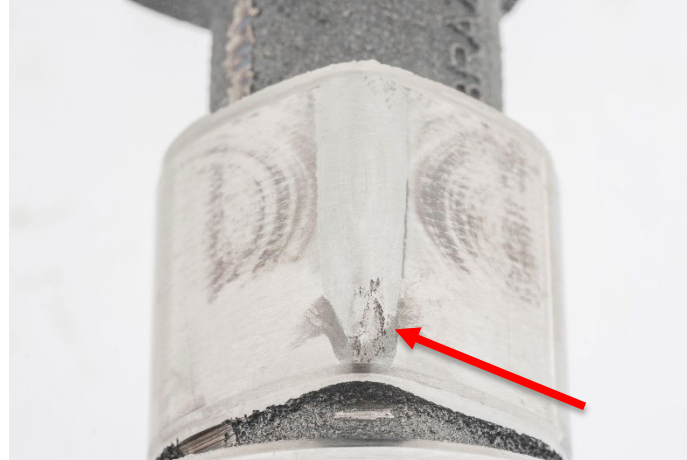


Lobe 5 - Intake

CMIR-196523: 43.7 μm



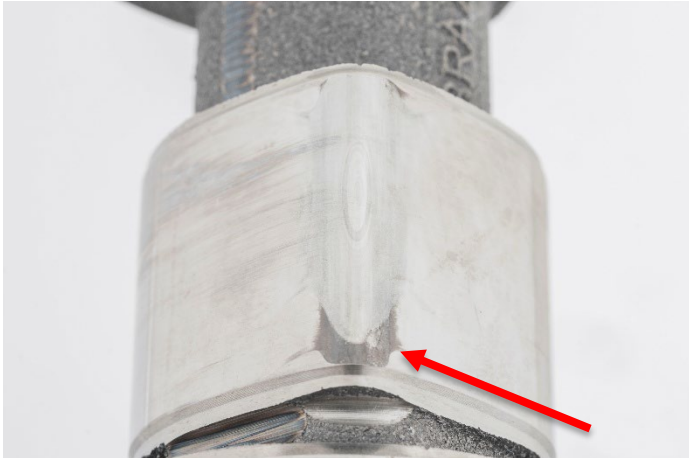
CMIR-196522: 70.3 μm



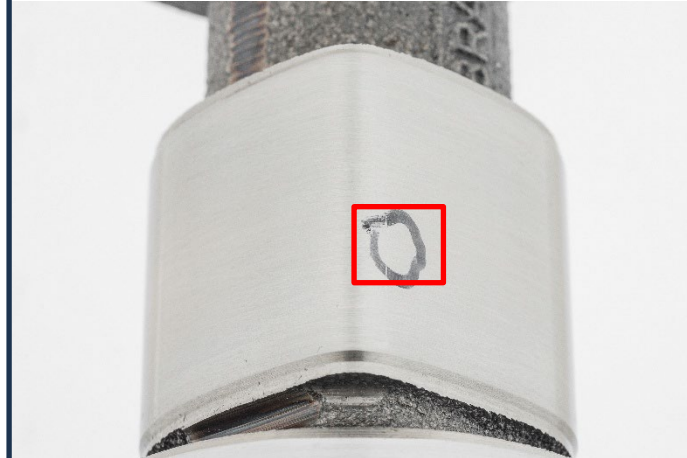
CMIR-195526: 45.7 μm



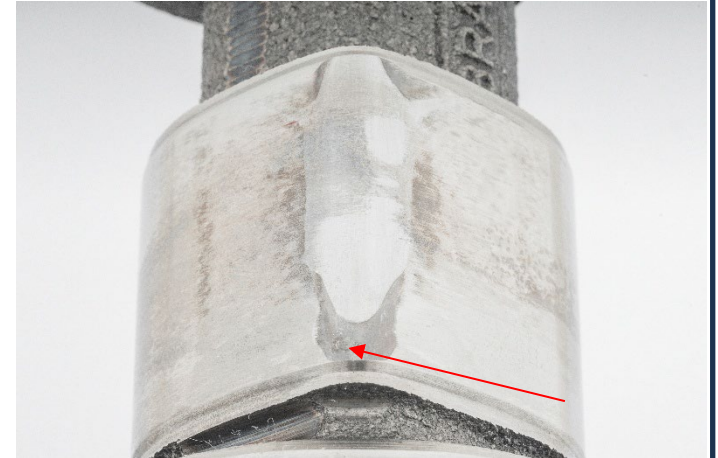
CMIR-195527: 38.0 μm



CMIR-202553 BOT



CMIR-202553 EOT: 65.7 μm



Lobe 6 - Exhaust

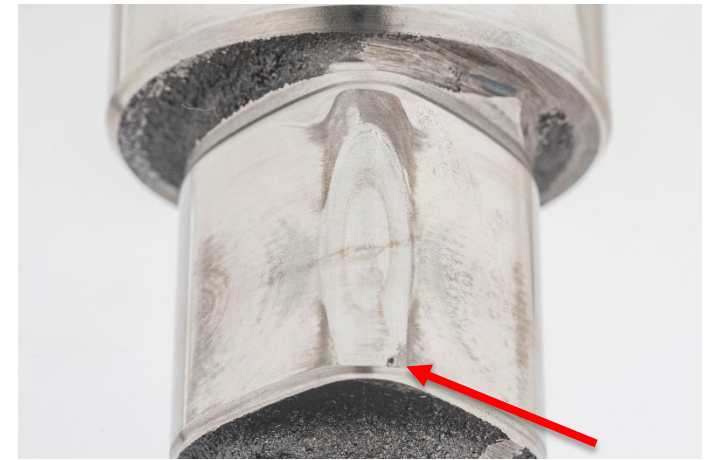
CMIR-196523: 29.3 μm



CMIR-196522: 38.0 μm



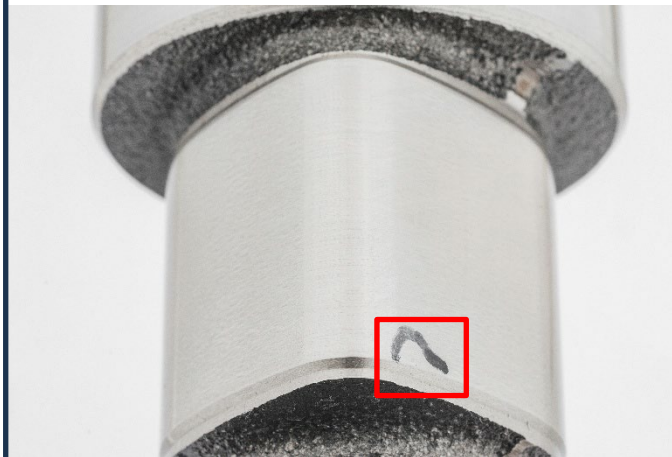
CMIR-195526: 38.3 μm



CMIR-195527: 39.3 μm



CMIR-202553 BOT



CMIR-202553 EOT: 37.7 μm



Lobe 7 - Intake

CMIR-196523: 41.3 μm



CMIR-196522: 46.3 μm



CMIR-195526: 41.7 μm



CMIR-195527: 44.0 μm



CMIR-202553 BOT



CMIR-202553 EOT: 70.3 μm

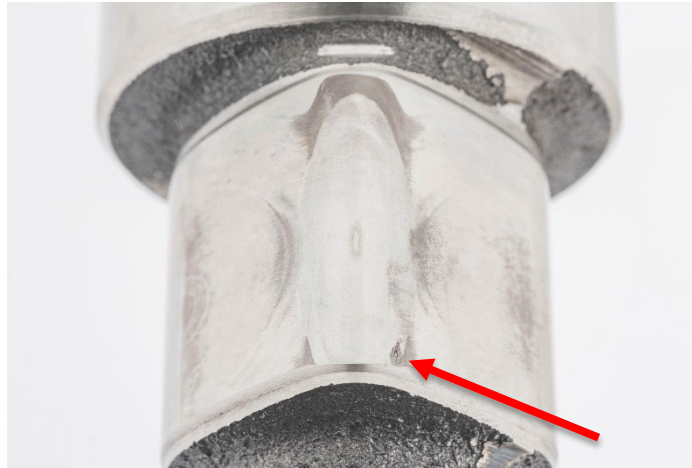


Lobe 8 - Exhaust

CMIR-196523: 40.0 μm



CMIR-196522: 41.0 μm



CMIR-195526: 41.3 μm



CMIR-195527: 44.3 μm



CMIR-202553 BOT



CMIR-202553 EOT: 34.7 μm



Lobe 9 - Intake

CMIR-196523: 39.7 μm



CMIR-196522: 48.0 μm



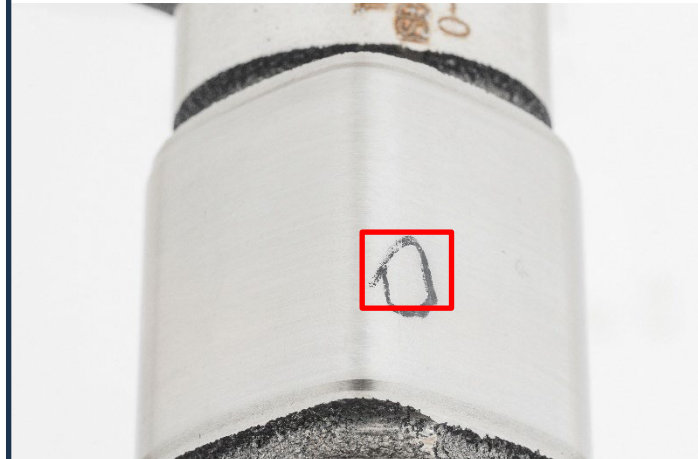
CMIR-195526: 36.3 μm



CMIR-195527: 47.7 μm



CMIR-202553 BOT



CMIR-202553 EOT: 57.3 μm



Lobe 10 - Exhaust

CMIR-196523: 33.3 μm



CMIR-196522: 39.3 μm



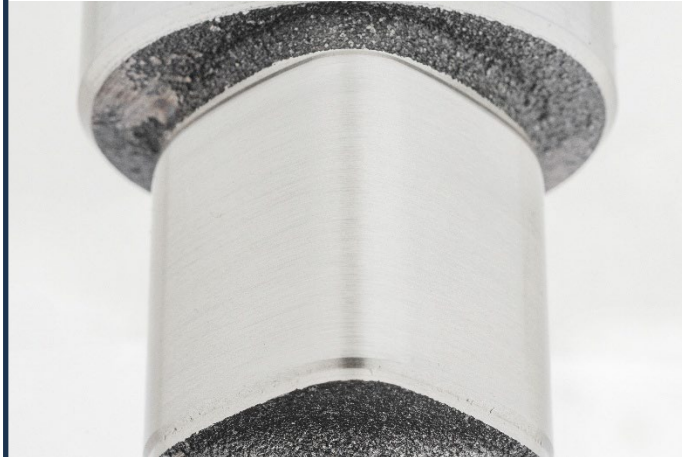
CMIR-195526: 51.7 μm



CMIR-195527: 43.3 μm



CMIR-202553 BOT



CMIR-202553 EOT: 34.7 μm



Lobe II - Intake

CMIR-196523: 37.0 μm



CMIR-196522: 44.7 μm



CMIR-195526: 39.3 μm



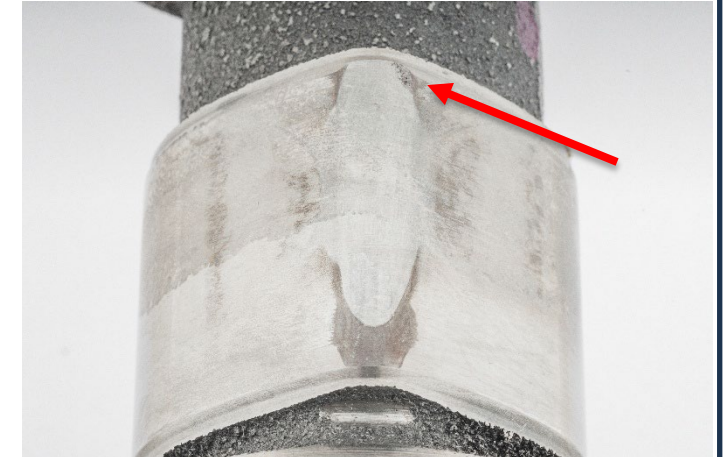
CMIR-195527: 47.3 μm



CMIR-202553 BOT



CMIR-202553 EOT: 59.0 μm



Lobe 12 - Exhaust

CMIR-196523: 37.0 μm



CMIR-196522: 43.3 μm



CMIR-195526: 60.3 μm



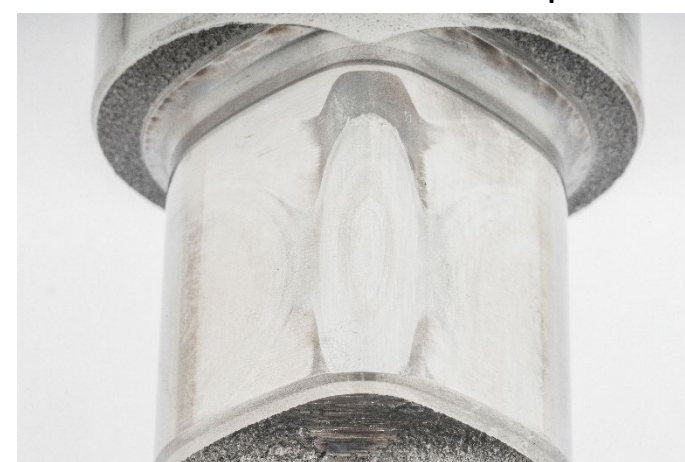
CMIR-195527: 20.7 μm



CMIR-202553 BOT



CMIR-202553 EOT: 36.3 μm



Summary

- A pitted cam produced what would be a passing reference
- Pitted camshaft lobes did not show a shift in severity vs non-pitted lobes
- Tappet wear was consistent across pitted vs non-pitted lobes

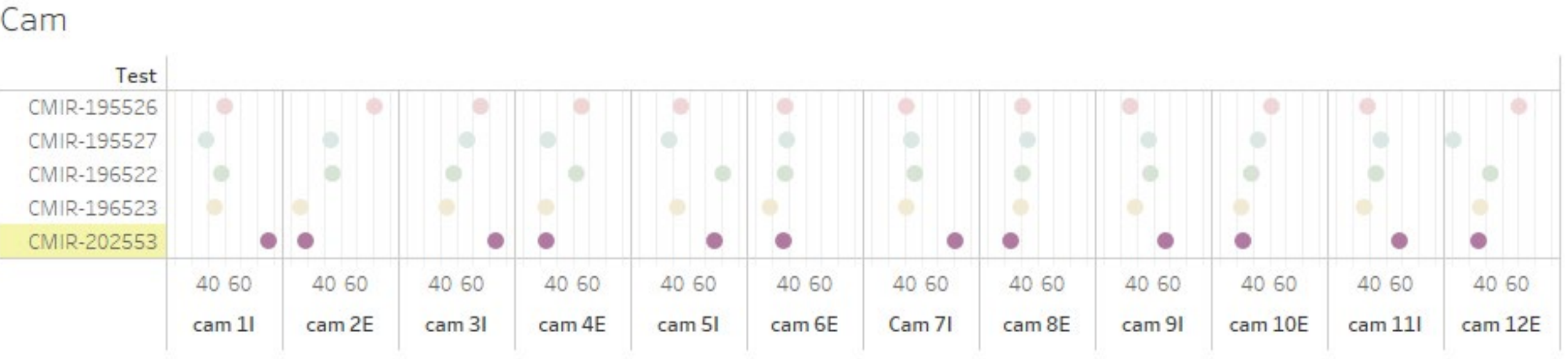


Motion

- The panel directs TEI to allow the distribution, for labs willing to accept them, of kits with camshafts containing up to one intake lobe and one exhaust lobe with a visible “pit” as a rolling change. Test reports are to include identification of pitted lobes noted in the comment section.

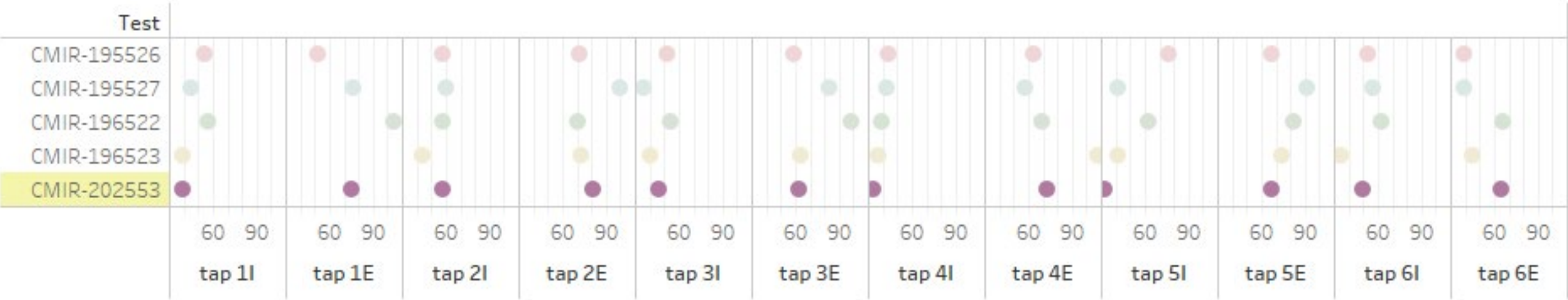
Appendix

Camshaft Lobe Averages by Test

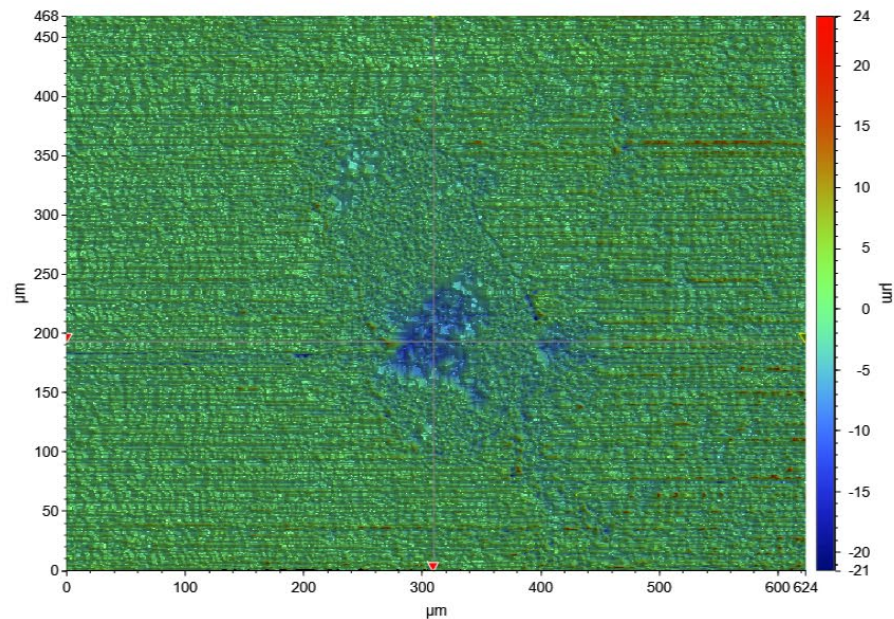


Tappet Averages by Test

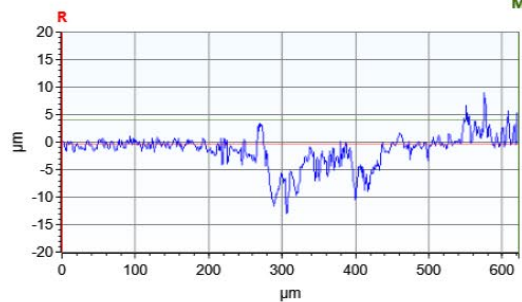
Tappet



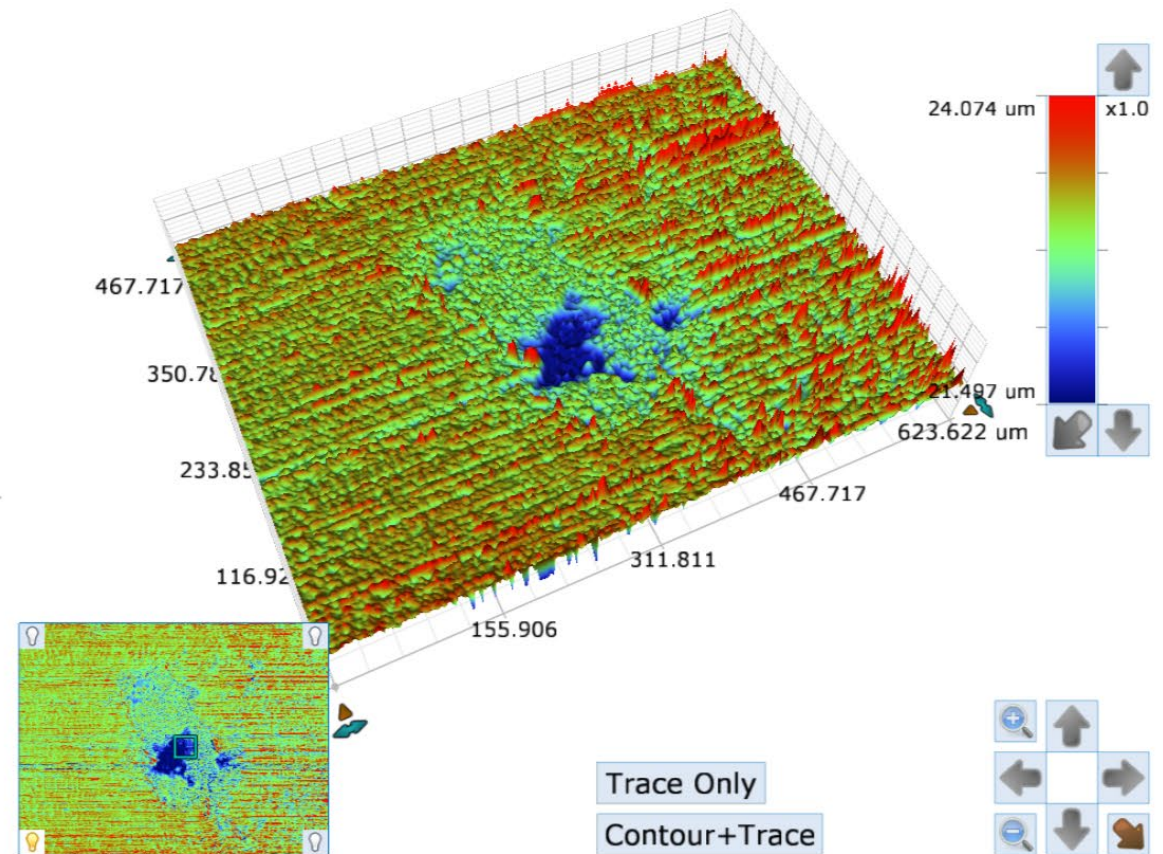
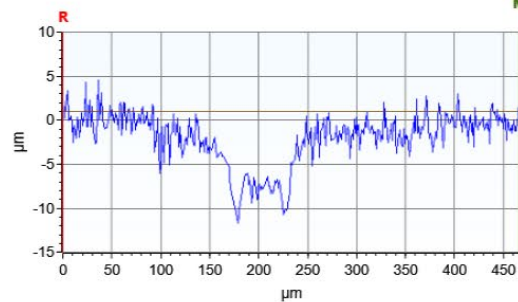
Bruker Images – Pit on Lobe I2



X Profile: $\Delta X=622.6476 \mu\text{m}$; $\Delta Z=4.4301 \mu\text{m}$



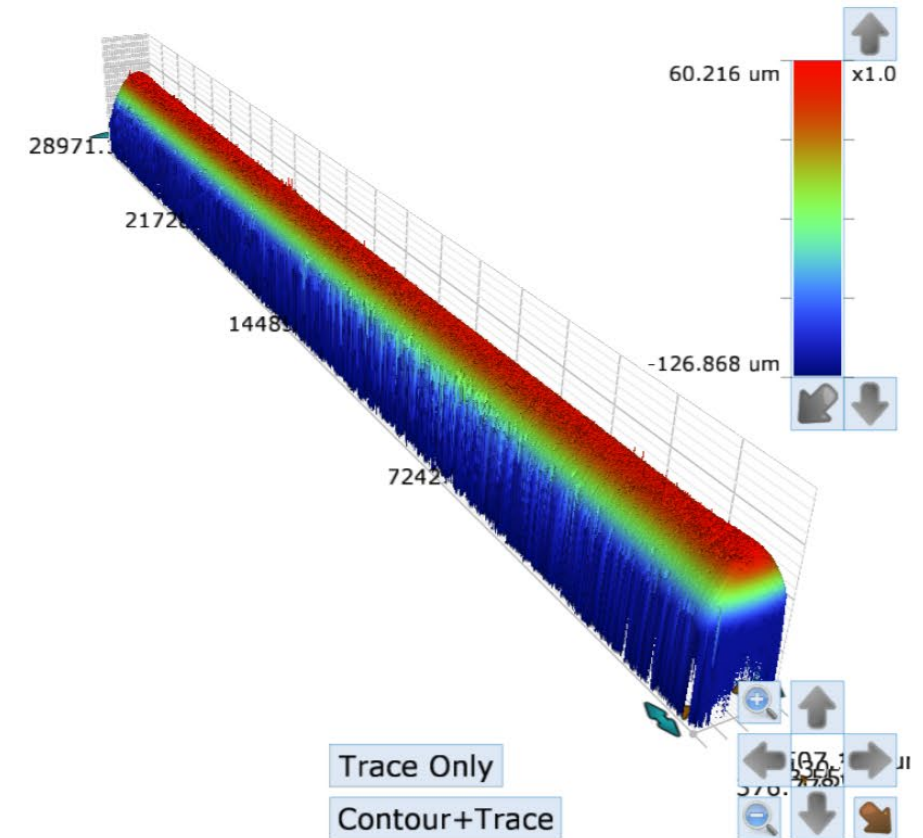
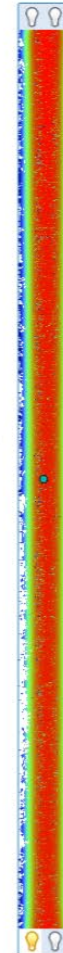
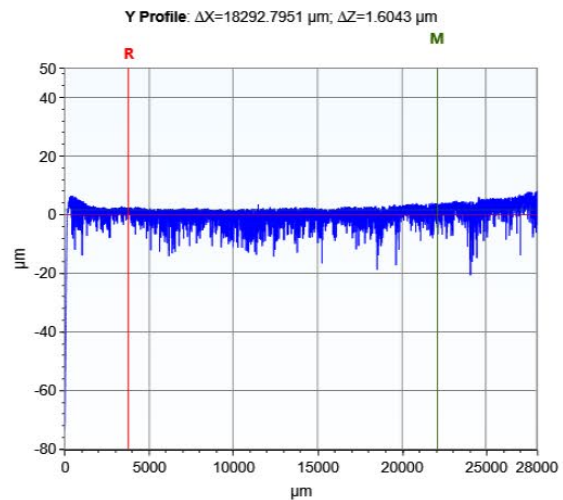
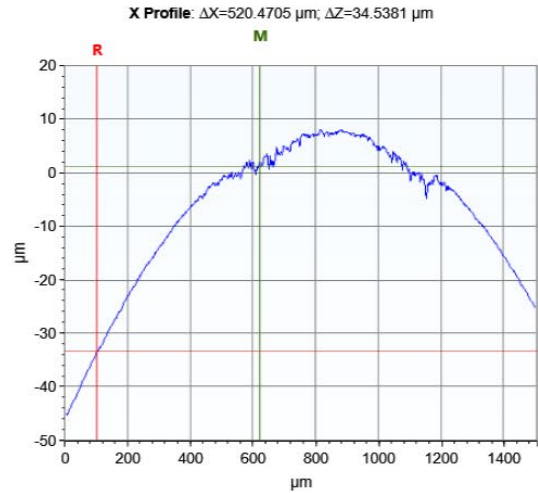
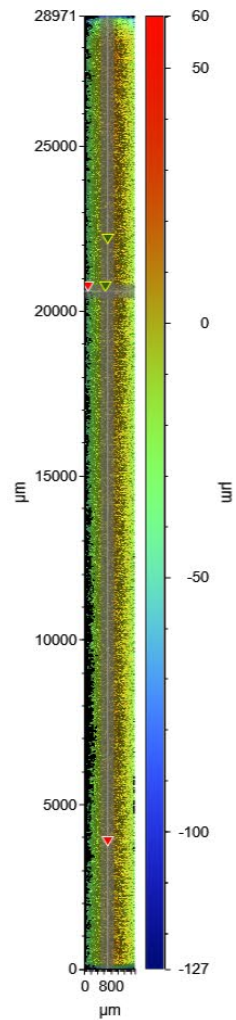
Y Profile: $\Delta X=466.7421 \mu\text{m}$; $\Delta Z=0.0342 \mu\text{m}$



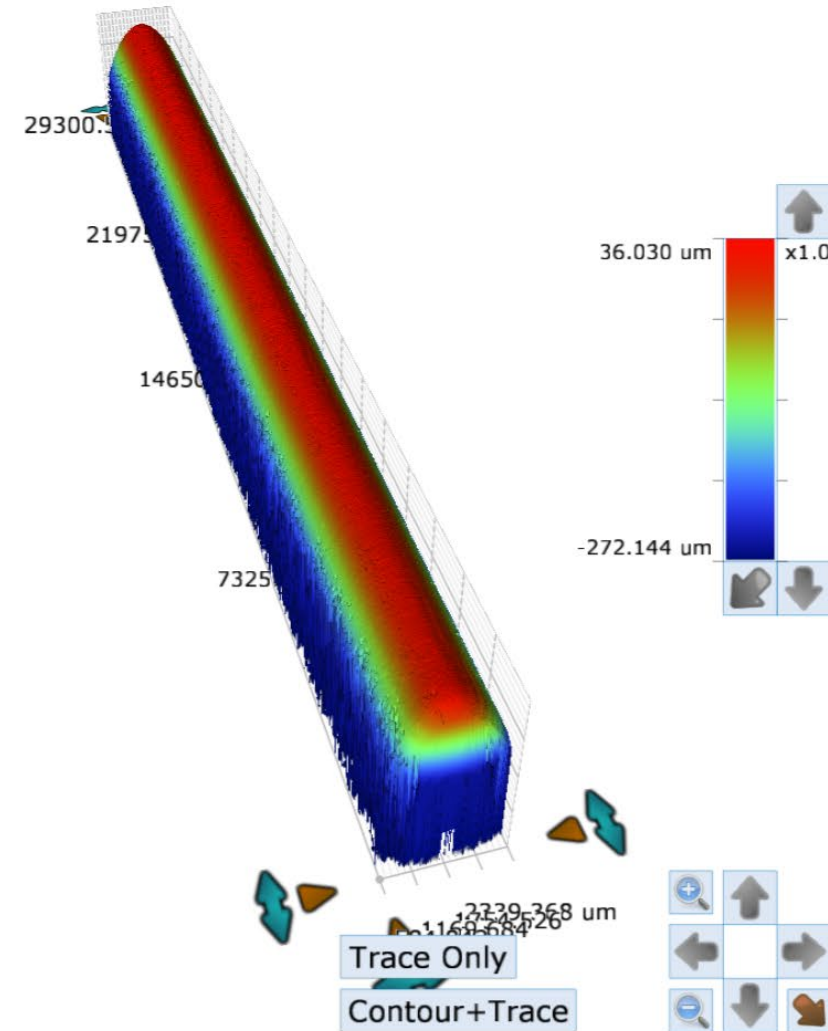
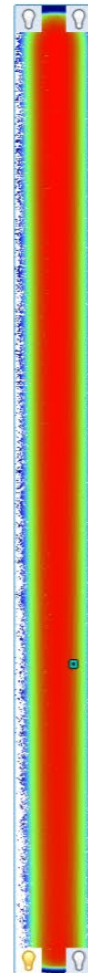
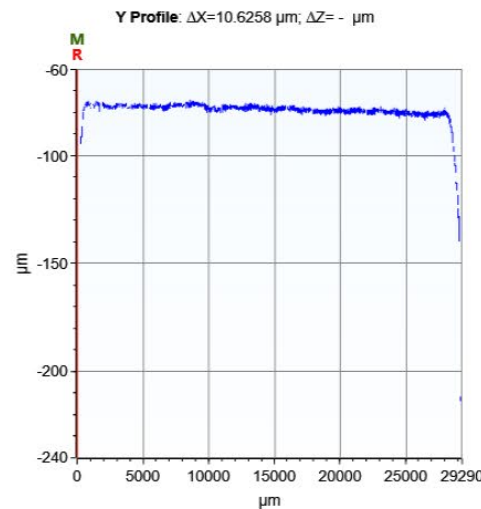
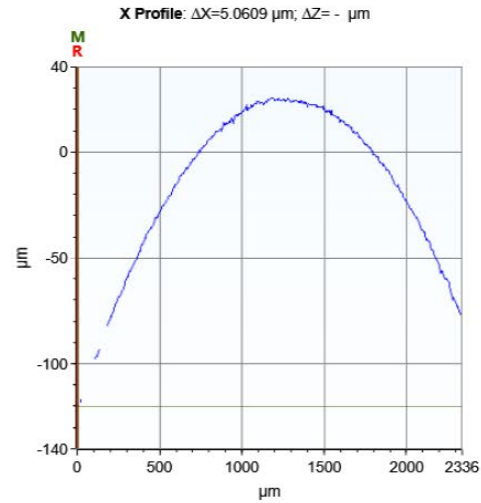
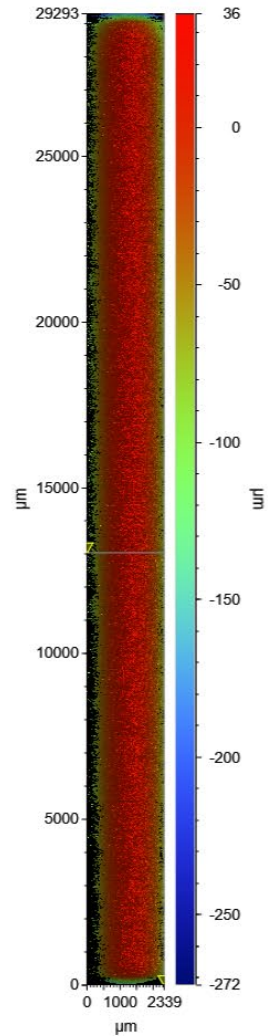
Trace Only

Contour+Trace

Bruker Images – Lobe 12



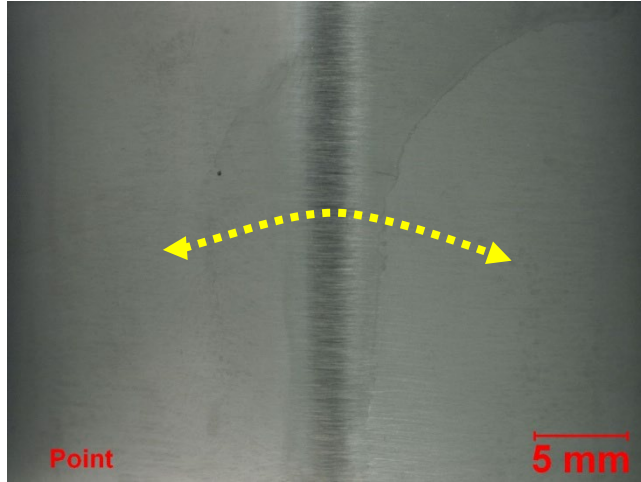
Bruker Images – Lobe 7



Analytical Results		
Label	Value	Units
Natural Volume	2118548586.496	μm^3
Negative Volume	1150532452.352	μm^3
Net Missing Volume	661534474.24	μm^3
Normal Volume	22.247	μm^3
Positive Volume	488997912.576	μm^3
Total Displaced Volume	1639530364.928	μm^3

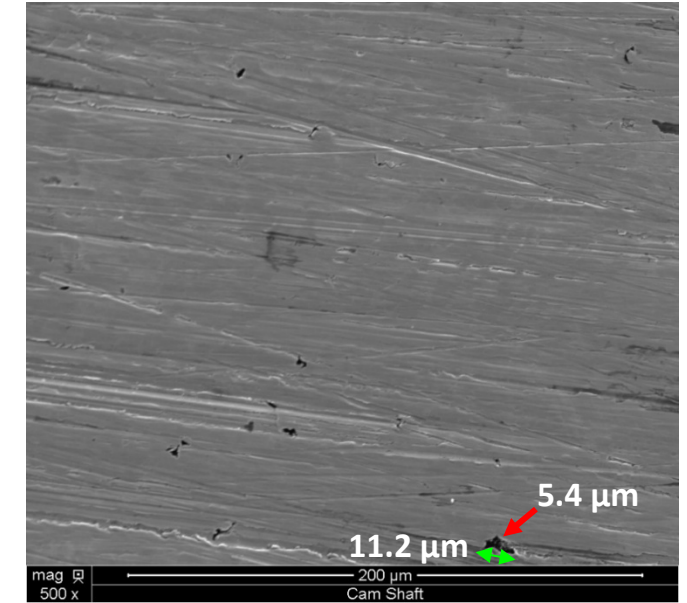
SEM of Lobe Tip

Stereoscope image of Lobe Tip

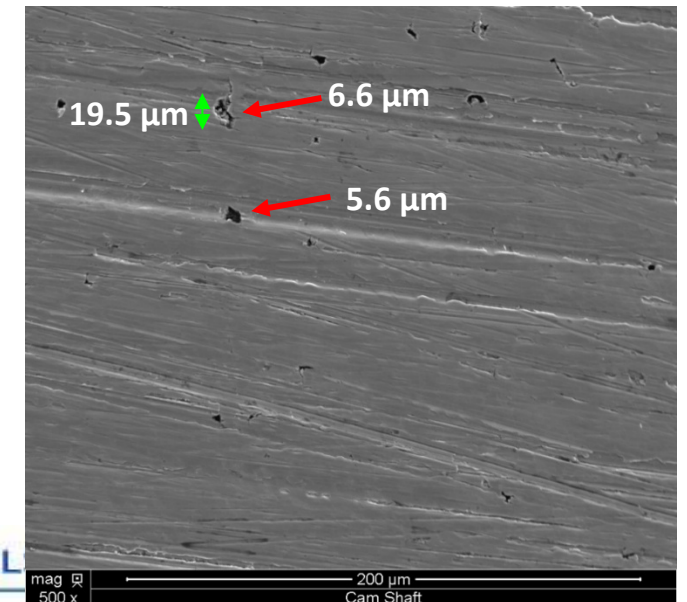
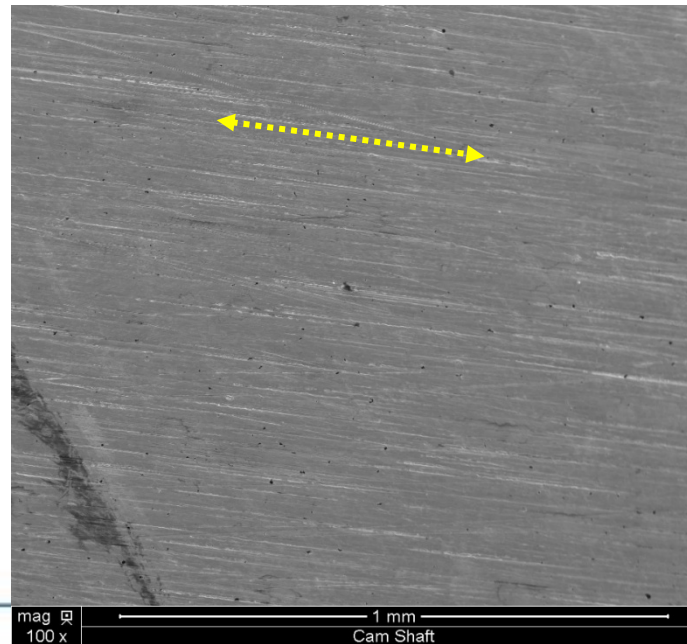


- The lobe tip was examined by scanning electron microscopy (SEM)
- SEM images demonstrated typical wear features
- Linear scratches were present and oriented parallel to the yellow arrow over the stereoscope image
- Discrete pits over the surface exhibited obvious scratches as material was removed and dragged over the surface
- Discrete pits exhibited maximum opening between 5-7 μm (0.0002"); maximum elongation was measured in the range of 10-20 μm (0.0004-0.0008")

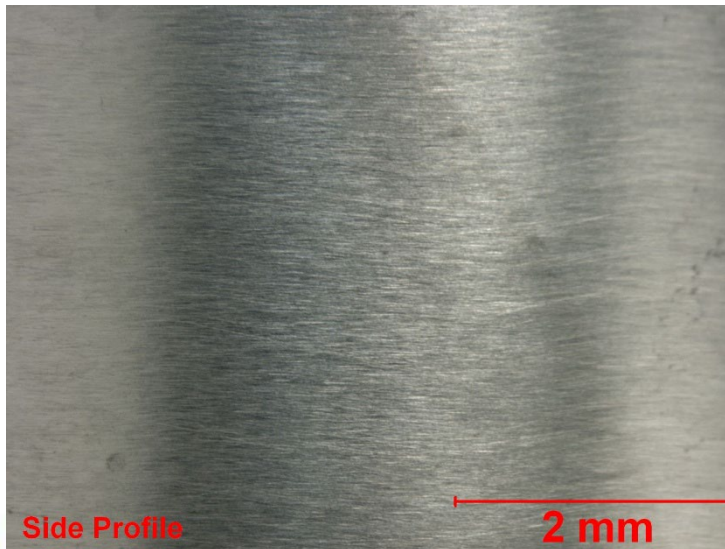
SEM images of surface topography:



SEM image of the lobe wear surface:



Stereoscope image of the wear surface



FUEL

Microstructural Evaluation

- The etched micrographs demonstrated a chilled cast iron microstructure
- Chilled cast iron constituents consisted of pearlite (dark), and interdendritic carbide (white)

Stereoscope image of the polished cross-section

- Areas examined correspond to numerical annotations

