Engine Liner Mapping

Next Generation Engine Liner Measurements for marine 2-stroke engines

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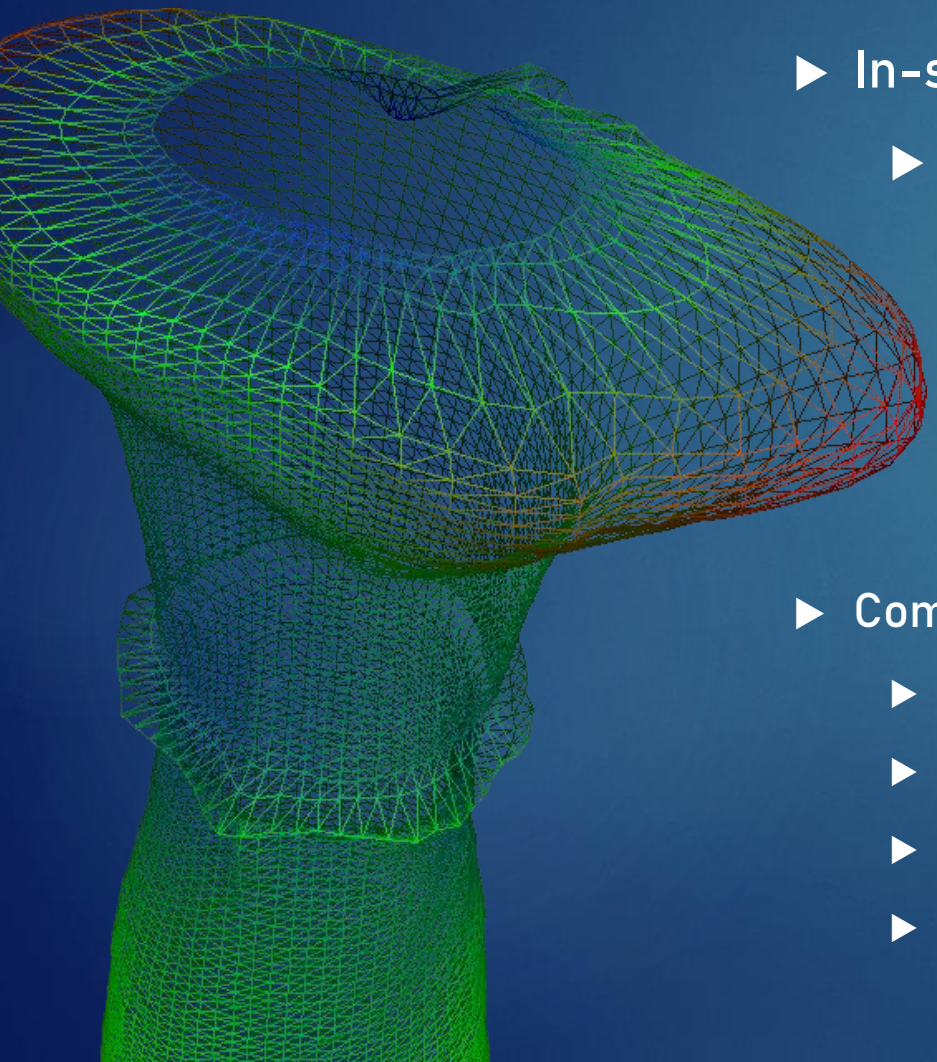
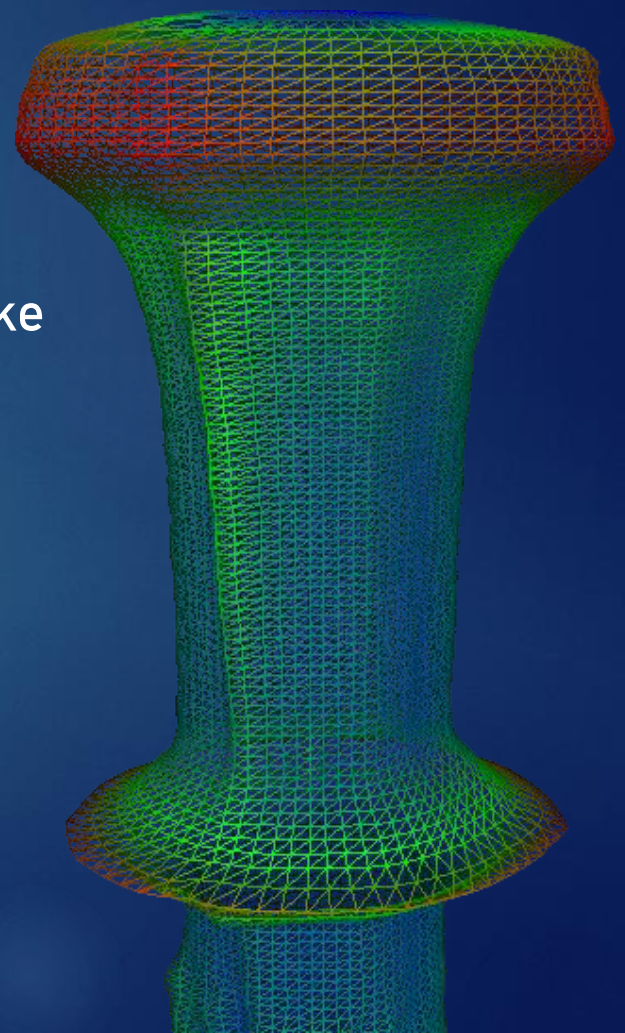
Presentation by
Birk Fleischer – CTO – Tenaro GmbH
Hamburg, Germany

TENARO

Engine Liner Mapping

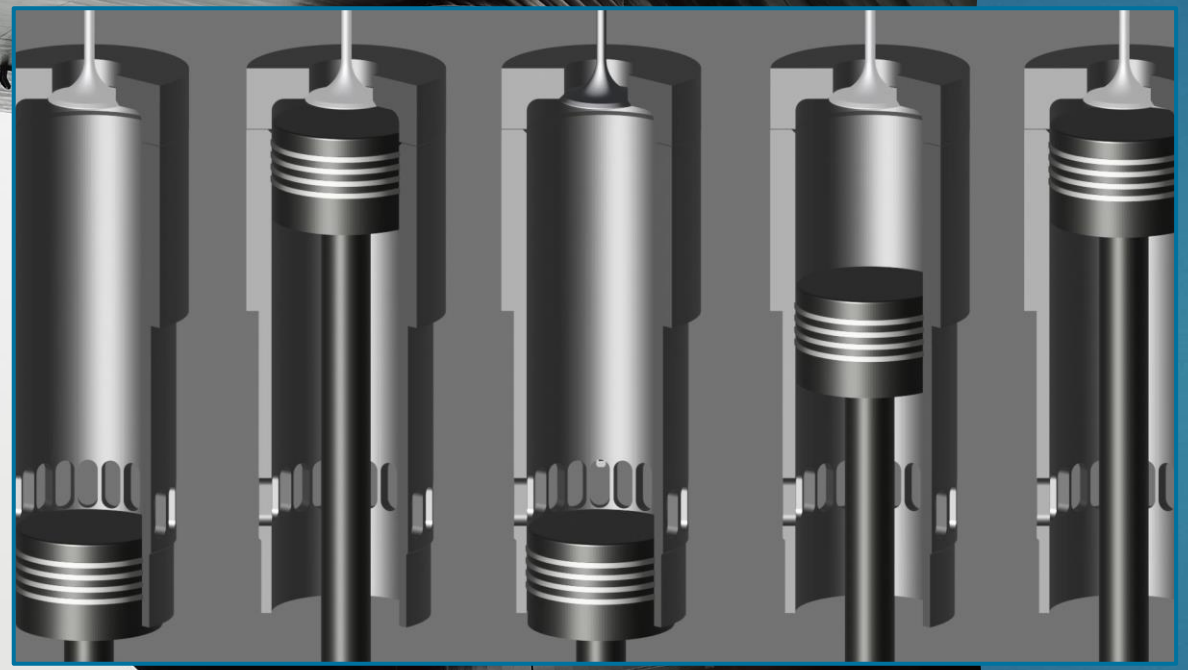
- Method for engine liner internal surface inspection
  - In-situ, hot engine „required“
    - 2-stroke – scav. ports required
      - 400+ mm bore size
      - Execution requires one engine stroke





- Combination of
  - On-site attendance and data gathering
  - Data verification
  - Data processing and post-processing
  - Reporting and recommendations

On-site work



- 4 tools:
  - Liner wear gauge system
  - Liner camera system
  - Piston ring coating thickness gauge
  - Piston ring camera system

- Use scavenge air ports only
- Move liner up & down – one time (~7min)
- No engine top side work
- Pre-heated engine
- Contactless, autonomous, precise, fast

Processing

- On-site result
  - Abt. 12.000 to 15.000 wear points per liner
  - Abt. 1700 MB of liner pictures
  - Abt 200 piston coating readings
  - Abt 300 MB of high-resolution ring pictures
- Initial data verification on-site
- Cross-referencing sensor data and calibration information for in-depth data check in office
- Correction for temperature

Results – wear liner & ring coating

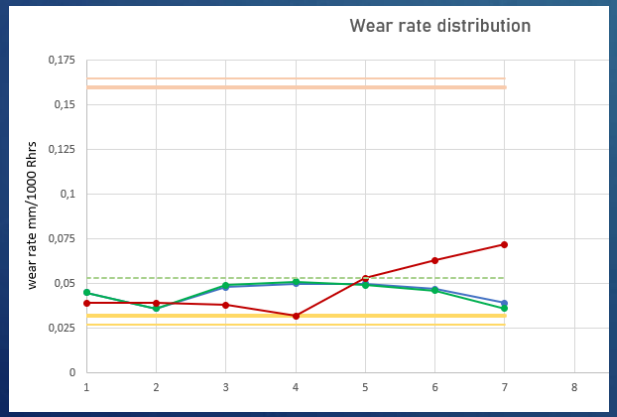
Quantitative results -2D – sections & graphs

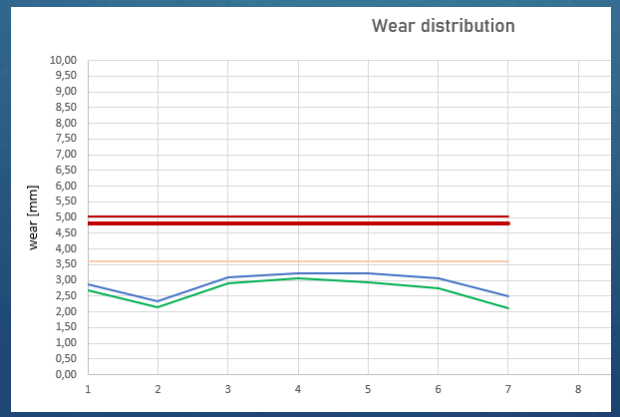
Cylinder Unit ID		1	2	3	4	5	6	7	8	9	10	11	12
	R-hrs	64.790	64.790	64.790	64.790	64.790	64.790	64.790					
LINER DATA	Direction	liner wear [mm]											
	0°	1,38	1,06	1,66	1,47	1,45	1,31	1,12					
	90°	1,42	1,29	1,54	1,69	1,75	1,69	1,40					
	180°	1,47	1,05	1,59	1,58	1,48	1,40	1,17					
	270°	1,49	1,28	1,42	1,72	1,74	1,74	1,32					
	F-A	2,85	2,11	3,25	3,05	2,93	2,71	2,29					
	E-M	2,92	2,57	2,96	3,41	3,50	3,44	2,73					
	Ovality	-0,07	-0,46	0,29	-0,36	-0,57	-0,73	-0,44					
		Wear rate [mm/1000 hrs] - Lifetime in Rhrs											
	W-Rate	0,045	0,036	0,048	0,050	0,050	0,047	0,039					
	remain. lifetime	43.000	68.000	35.000	31.000	32.000	37.000	59.000					
	total lifetime	108.000	133.000	100.000	96.000	97.000	102.000	124.000					
	Status												
RING DATA	Position	coating thickness [µm]											
	T	0	0	23	10	0	0	0					
	MT	0	0	0	0	0	0	0					
	MB	0	33	0	0	0	0	0					
	B	0	51	0	0	0	0	0					

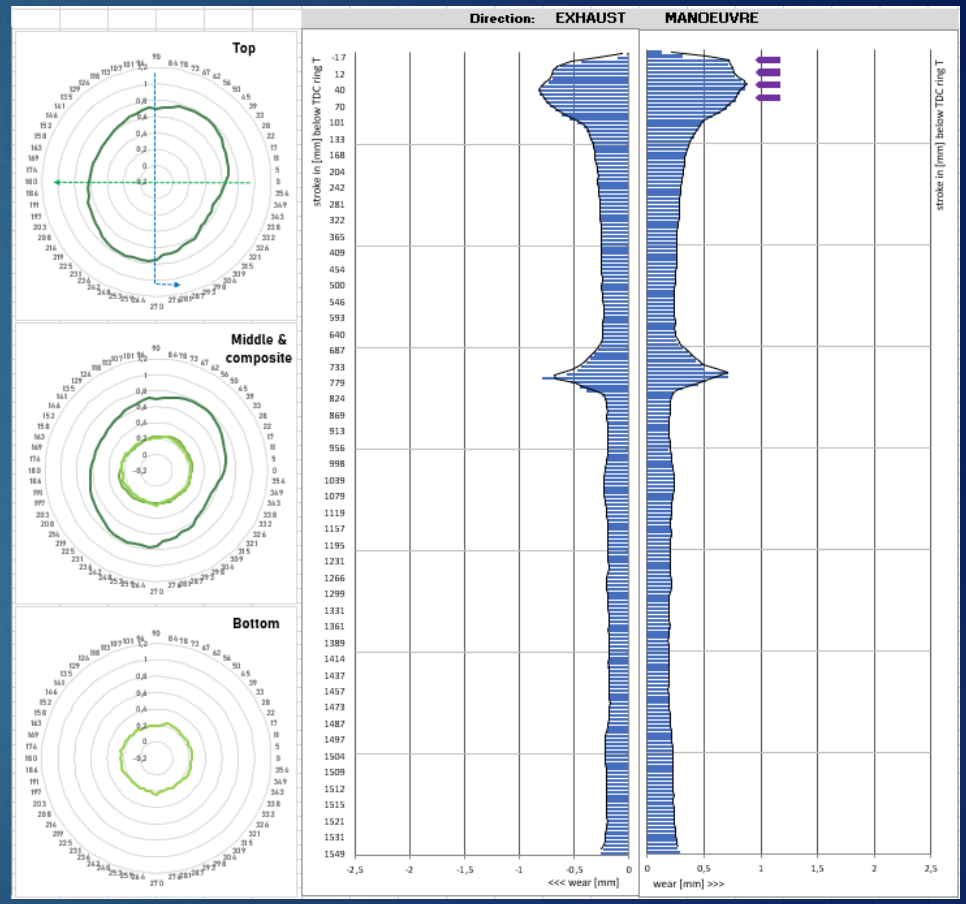
Recommended liner limits & colour code			
Max wear [0,8% D]	4,80	mm	75% of max
Max. ovality [0,1% D]	0,60	mm	
High wear rate warning	0,160	mm per 1000Rhrs	
Low wear rate warning	0,032	mm per 1000Rhrs	
Target wear rate (+/- 0.01)	0,053	mm per 1000Rhrs	
Target Rhrs 90.000	Min. Rhrs 30.000	Max. Rhrs 150.000	

Piston ring colour code	
>275µm	like new
100<>275	normal
<100 µm	worn
<12 µm	no coating
this colour	likely broken

analysis rev60



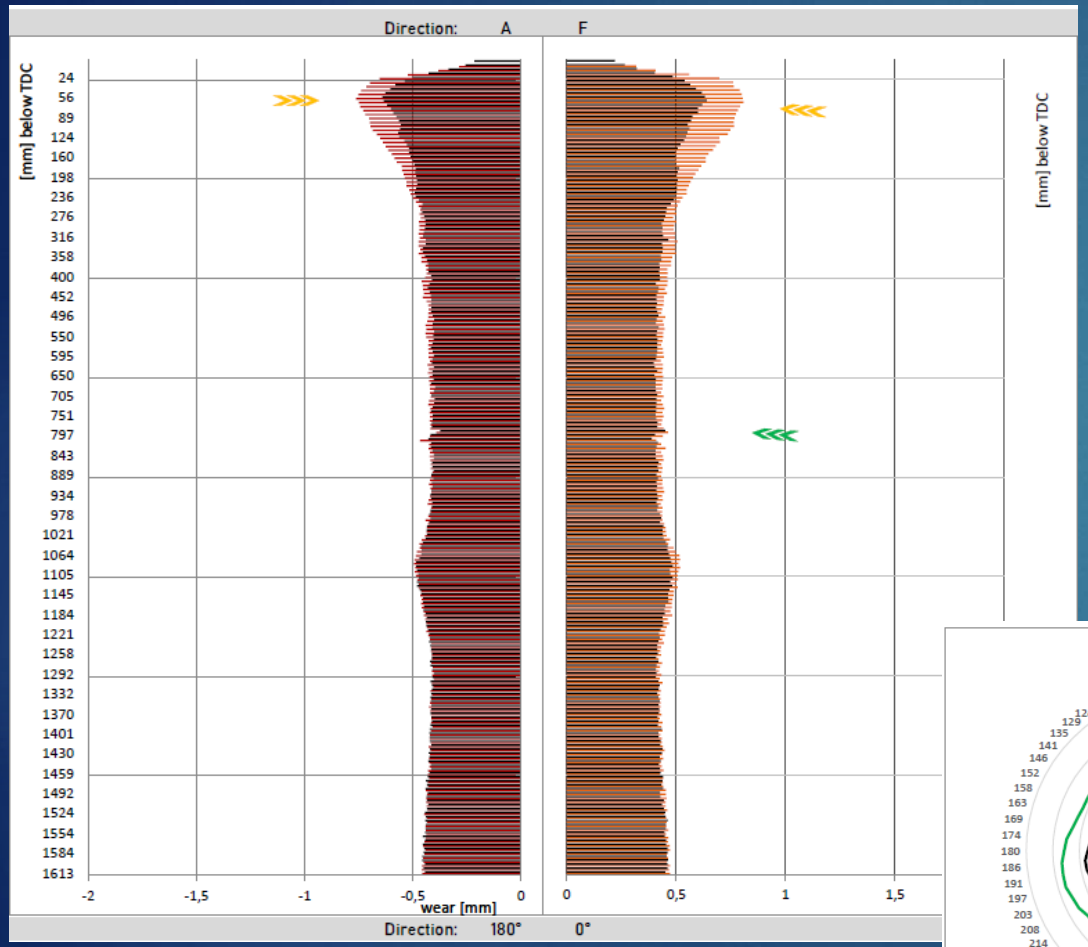


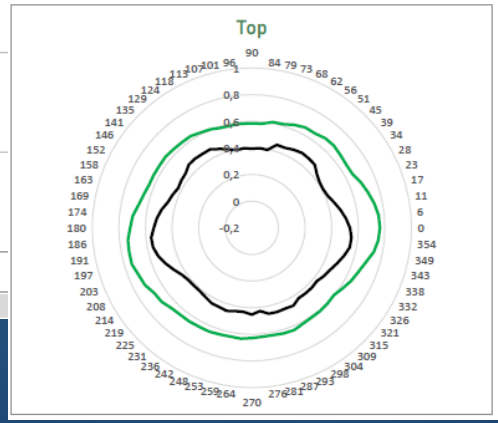


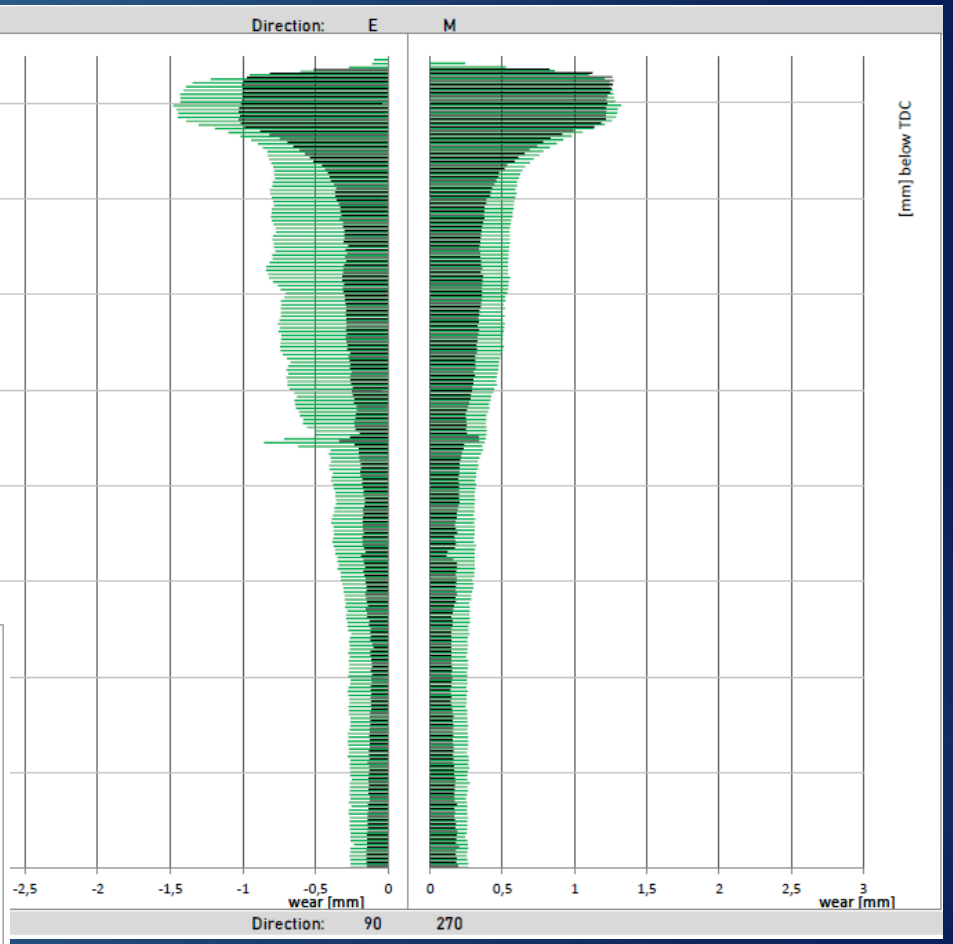
System resolution 0.01mm
System precision +/- 0.03mm

Results - wear

Quantitative results -2D – Trends





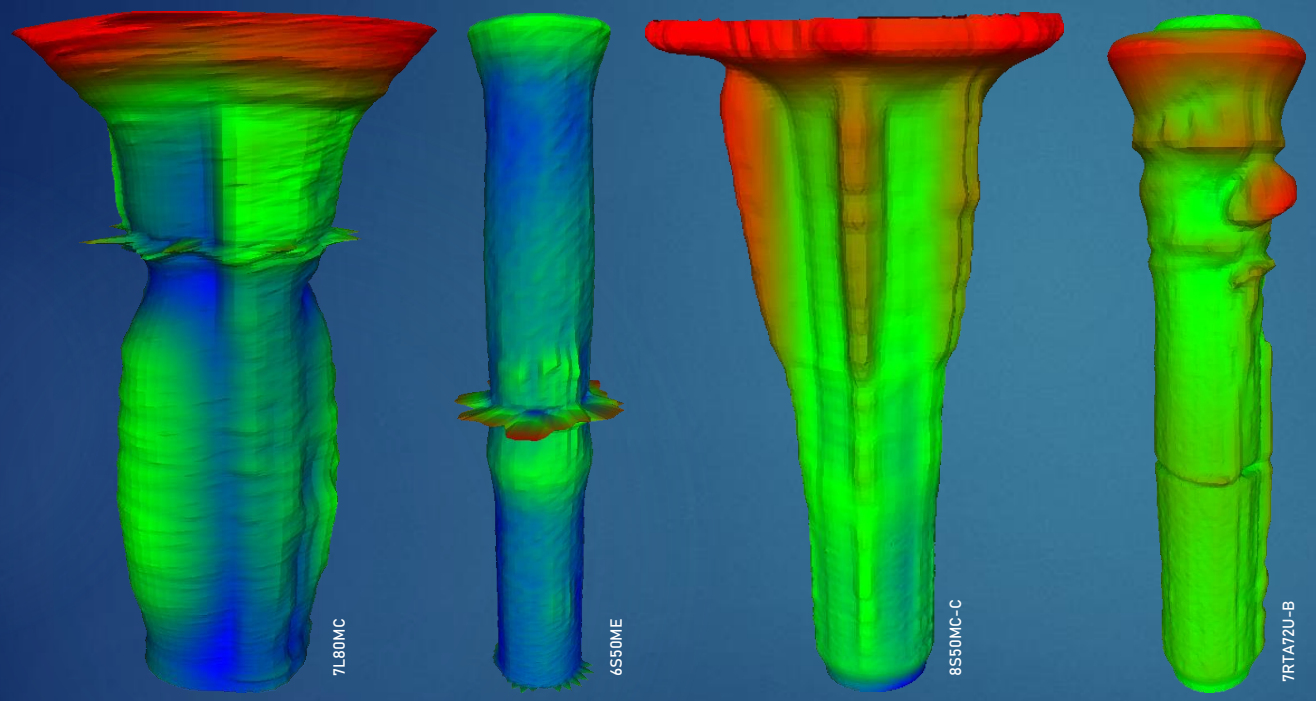


Track wear change over full stroke

Track wear change in full circumference

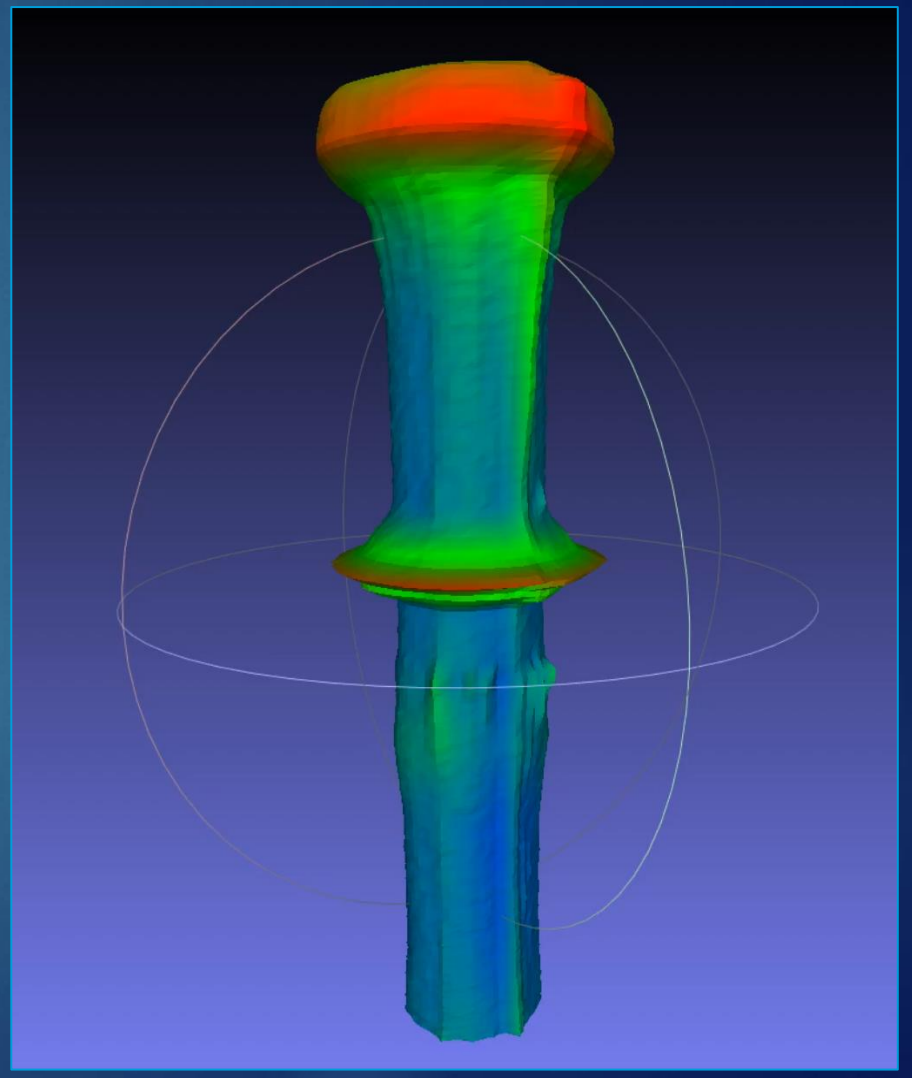
Results – wear

Qualitative results - full surface



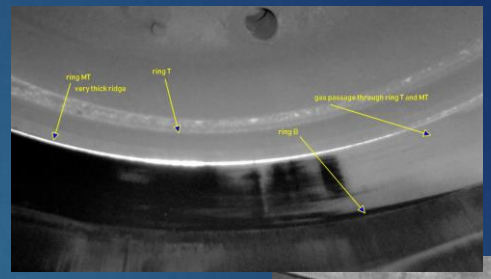
Full surface 3D models of liner wear

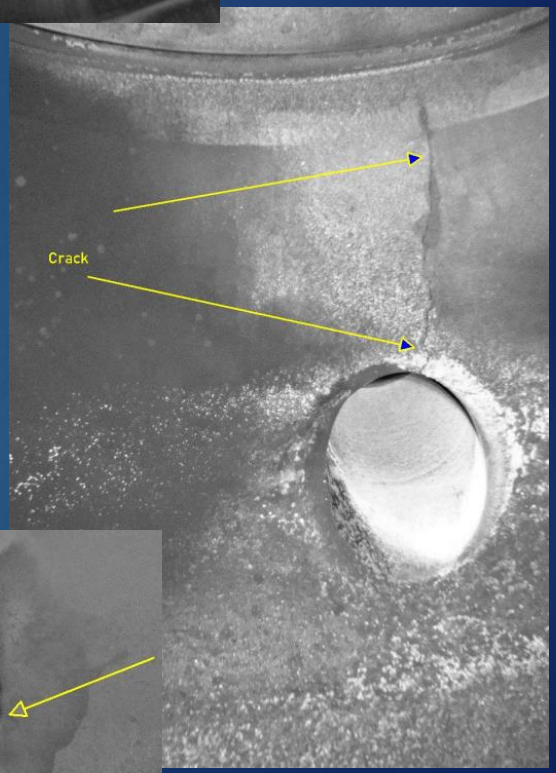
find issues, analyse, understand

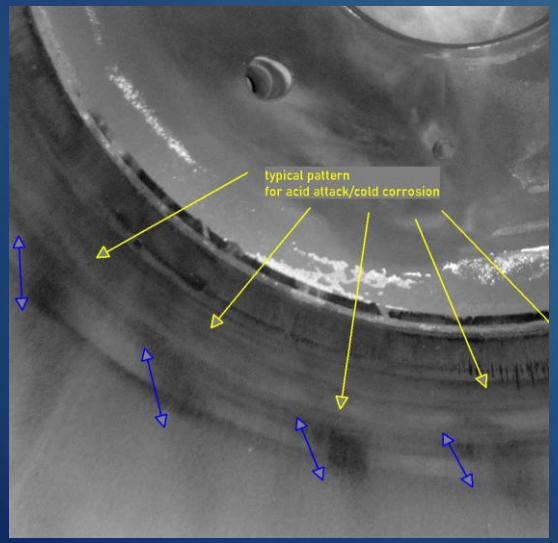


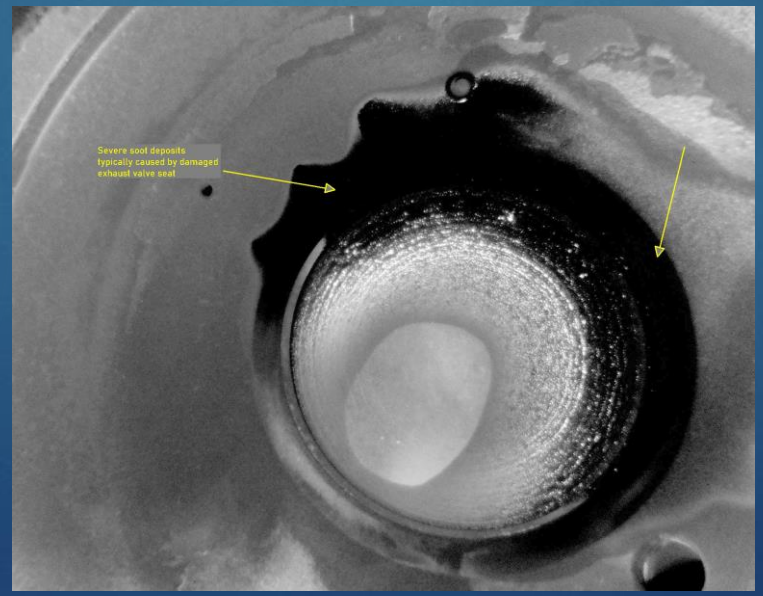
Results – liner camera

- Liner: abt 40 pictures per liner
- Detailed pictures of
  - liner wall, lub oil injection area
  - Cylinder cover, Exhaust valves, Fuel injectors
  - Surface coverage with soot/deposits
  - Starting air valve



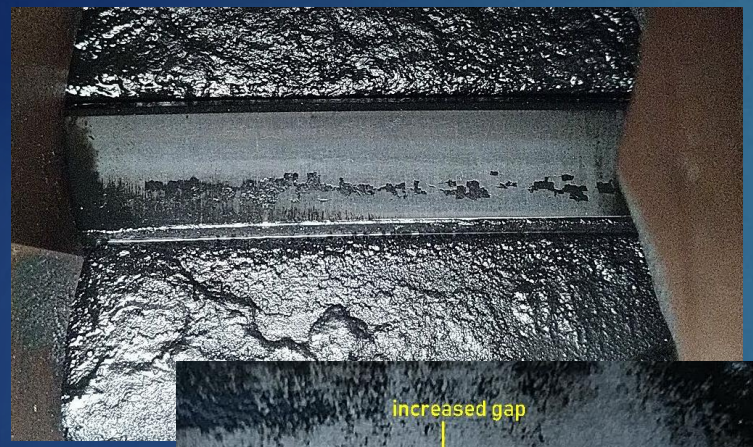


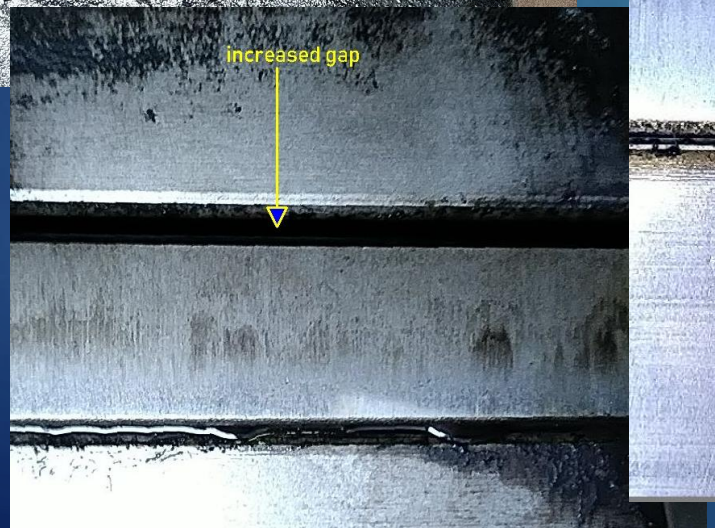


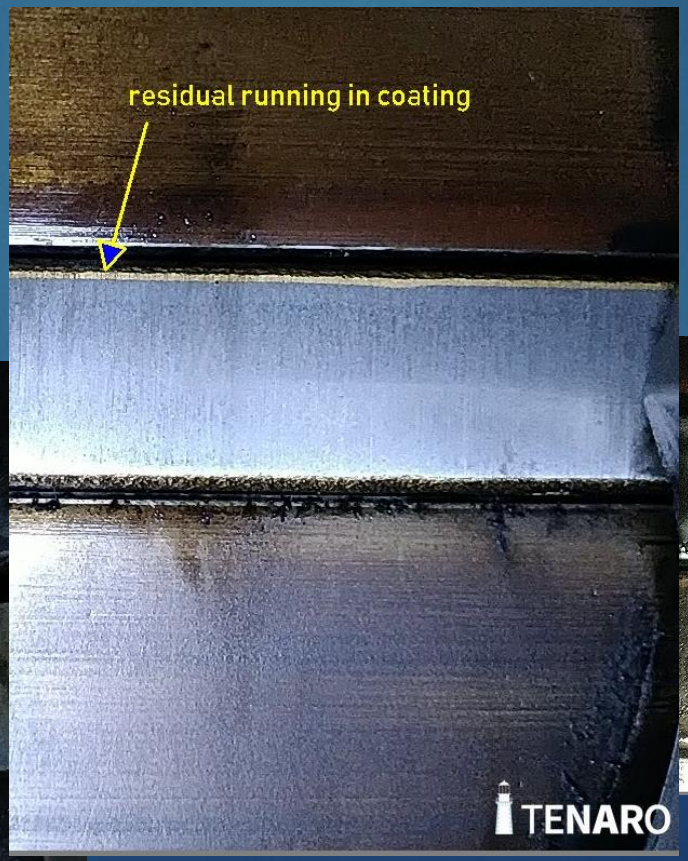


Results – ring pictures

- Piston rings: abt 12 pictures per piston (3 per ring)
- Surface structure, coating, crown gap
- Crown deposits, optional skirt condition

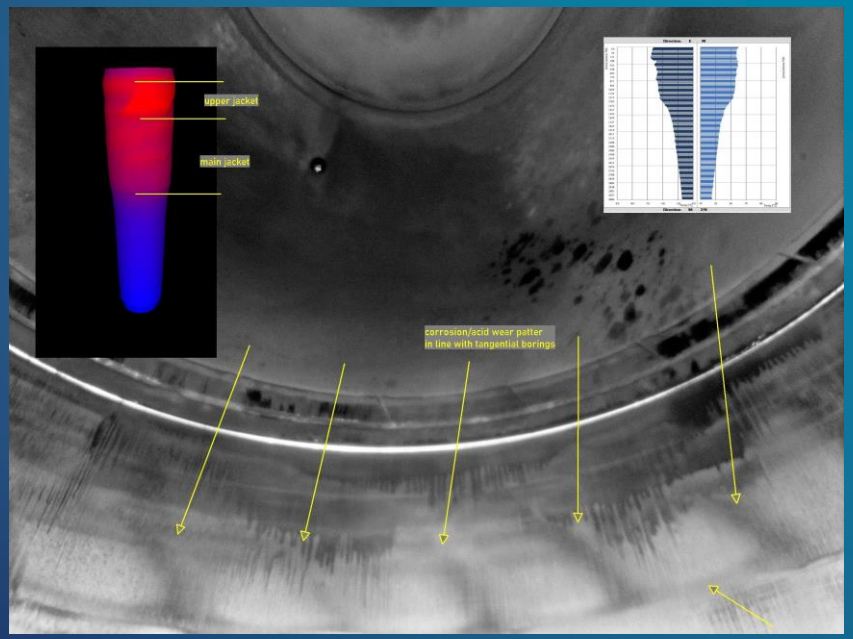


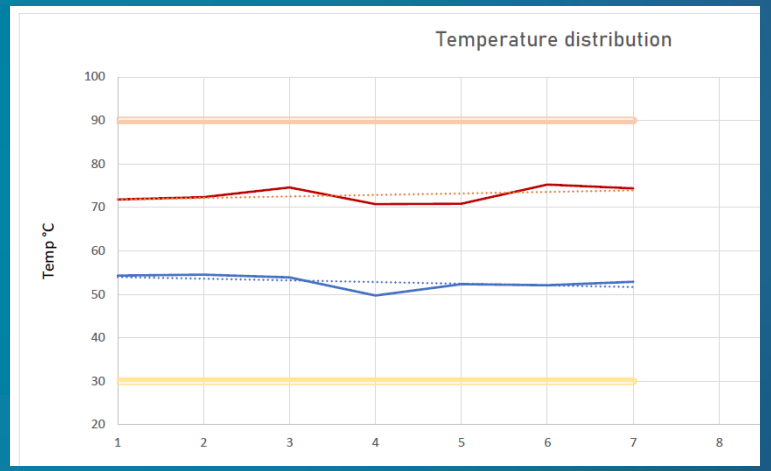


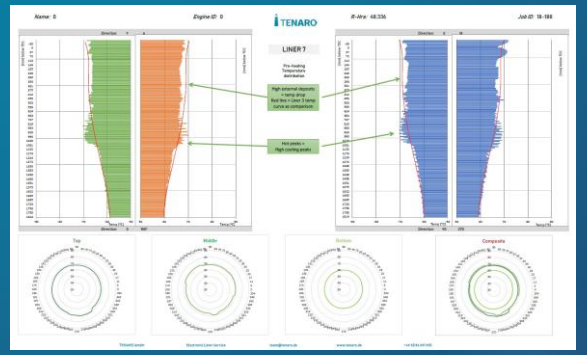


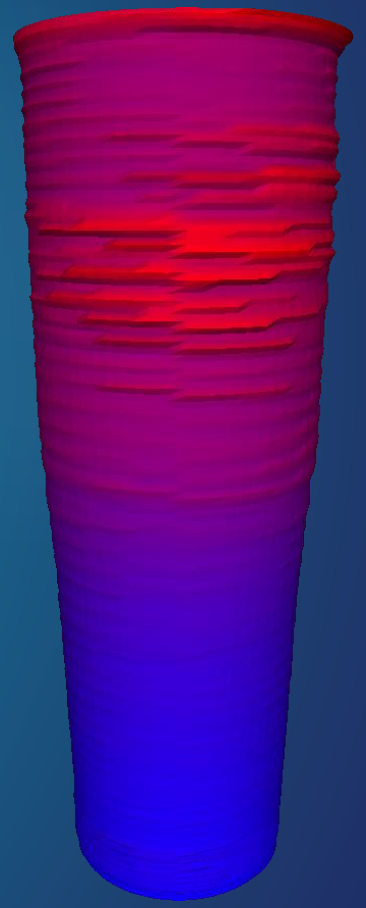
Results – thermal analysis

- Review of preheating distribution
- Reverse engineering for cooling water distribution
- Predictions on:
  - Liner in-service cooling behaviour
  - Fouling of liners on water side
  - Deposits in upper/lower water jacket





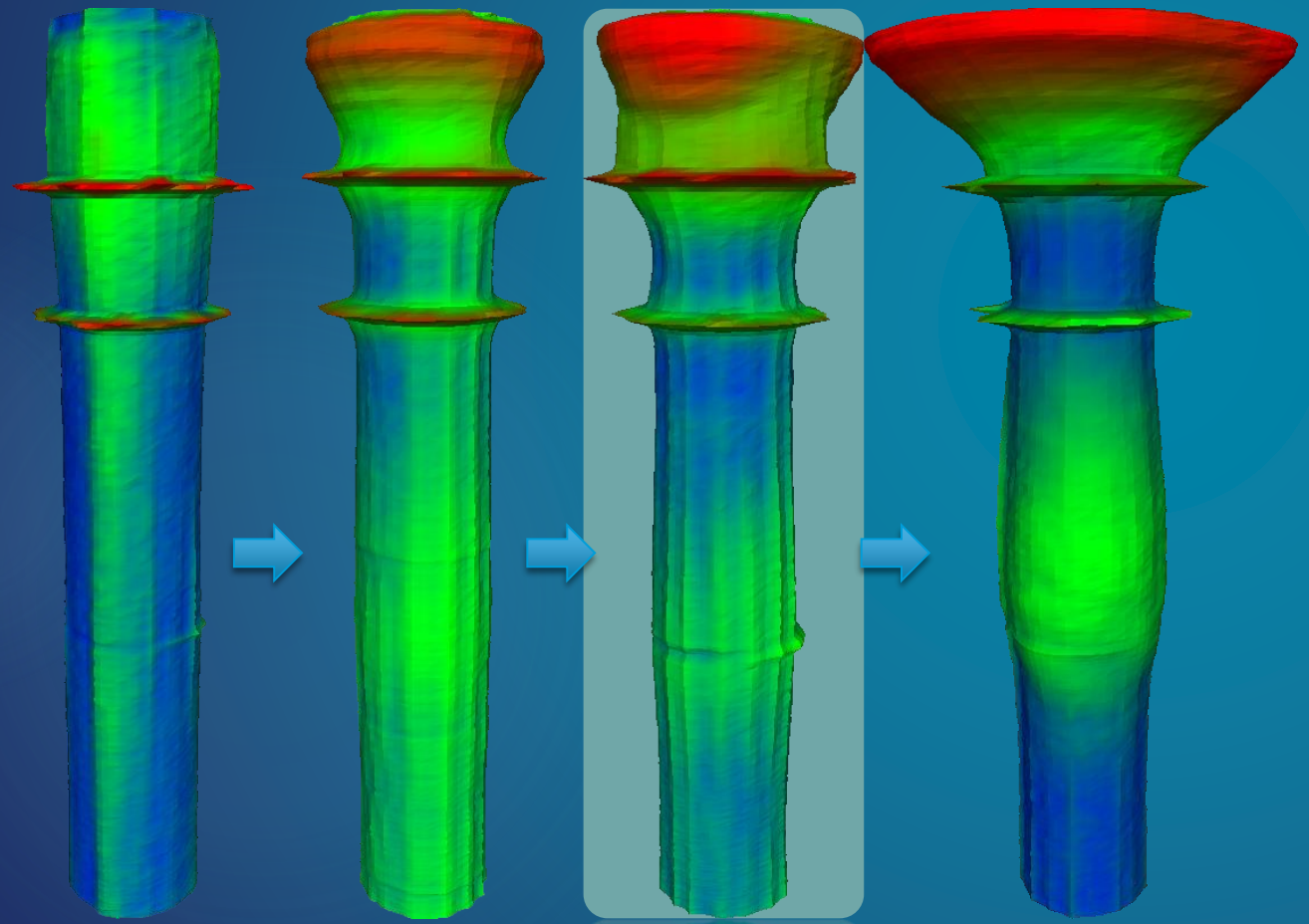




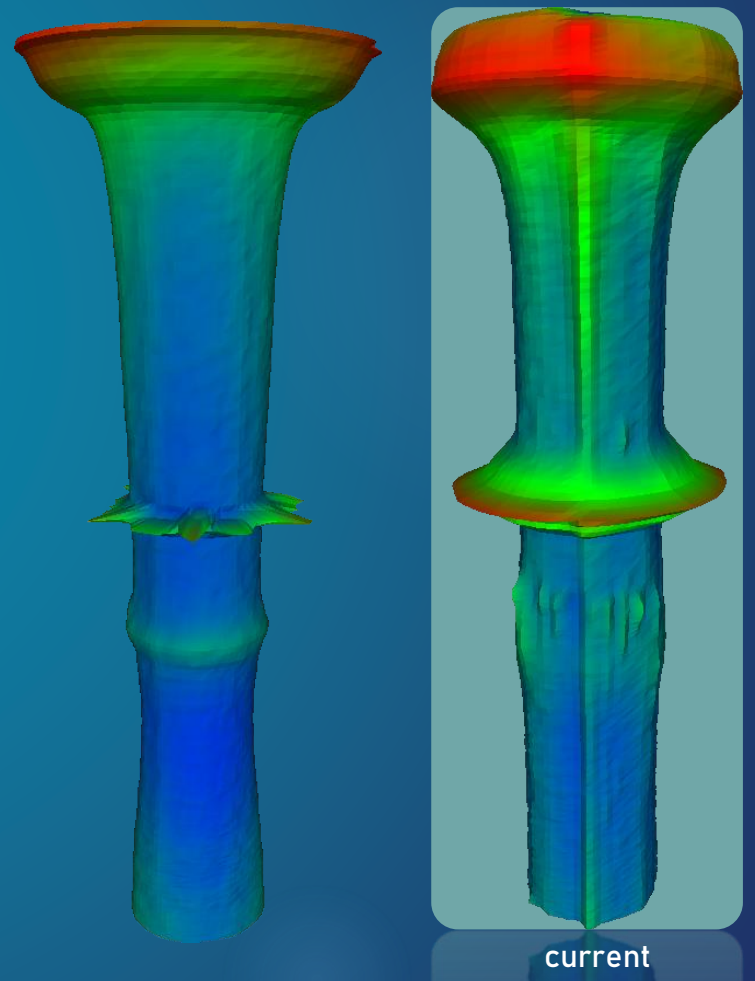
Liner mapping review

More details mean better understanding of wear behaviour

- Historical data vs current



- Standard vs current



Reporting & Recommendations

- comprehensive report for all measurements and inspections
- Traffic light system for easy overview
- Clear recommendations

	Cylinder Unit ID	1	2	3	4	5	6	7	8	9
	R-hrs	50.978	50.978	50.978	50.978	50.978	50.978	50.978	50.978	
LINER DATA	Direction	liner wear [mm]								
	0°	1,09	1,35	1,50	1,23	1,99	1,94	2,63	2,10	
	90°	0,91	0,91	0,99	1,01	1,62	2,12	1,94	1,73	
	180°	0,99	1,15	1,28	0,99	1,81	1,73	2,23	1,78	
	270°	0,97	1,11	1,31	1,25	1,78	1,80	2,22	1,84	
	F-A	2,08	2,49	2,78	2,22	3,79	3,66	4,87	3,88	
	E-M	1,88	2,02	2,30	2,25	3,40	3,91	4,16	3,57	
	Ovality	0,20	0,47	0,48	-0,03	0,39	-0,25	0,71	0,31	
		Wear rate [mm/1000 hrs] - Lifetime in Rhrs								
	W-Rate	0,039	0,044	0,050	0,044	0,071	0,074	0,089	0,073	
	Lifetime	150.000	127.000	106.000	127.000	60.000	55.000	37.000	56.000	
RING DATA	Position	coating thickness [µm]								
	T	58	2	90	470	352	62	271	26	
	MT	0	0	0	189	84	0	0	0	
	MB	2	8	0	194	132	0	10	0	
	B	147	146	197	378	257	216	262	184	

~ liner 1
The liners show typical wear pattern of a new liner with increased wear in the lower stroke area (yellow arrow). The wear is well within limits. Top stroke area shows local ovality and partial gas leakage. We recommend check the lubrication timing, material and injector function and to monitor the development more closely.

~ liner L2, L4, L6 & L7
The wear is notably beyond recommended limits, the liners show full gas passage at top piston rings and wear has developed over full stroke. We recommend to exchange the liners soonest.

~ liner L3
The liner shows wear pattern of a new liner but of slightly irregular shape (green arrow). Wear rate is well within limits, normal monitoring recommended.

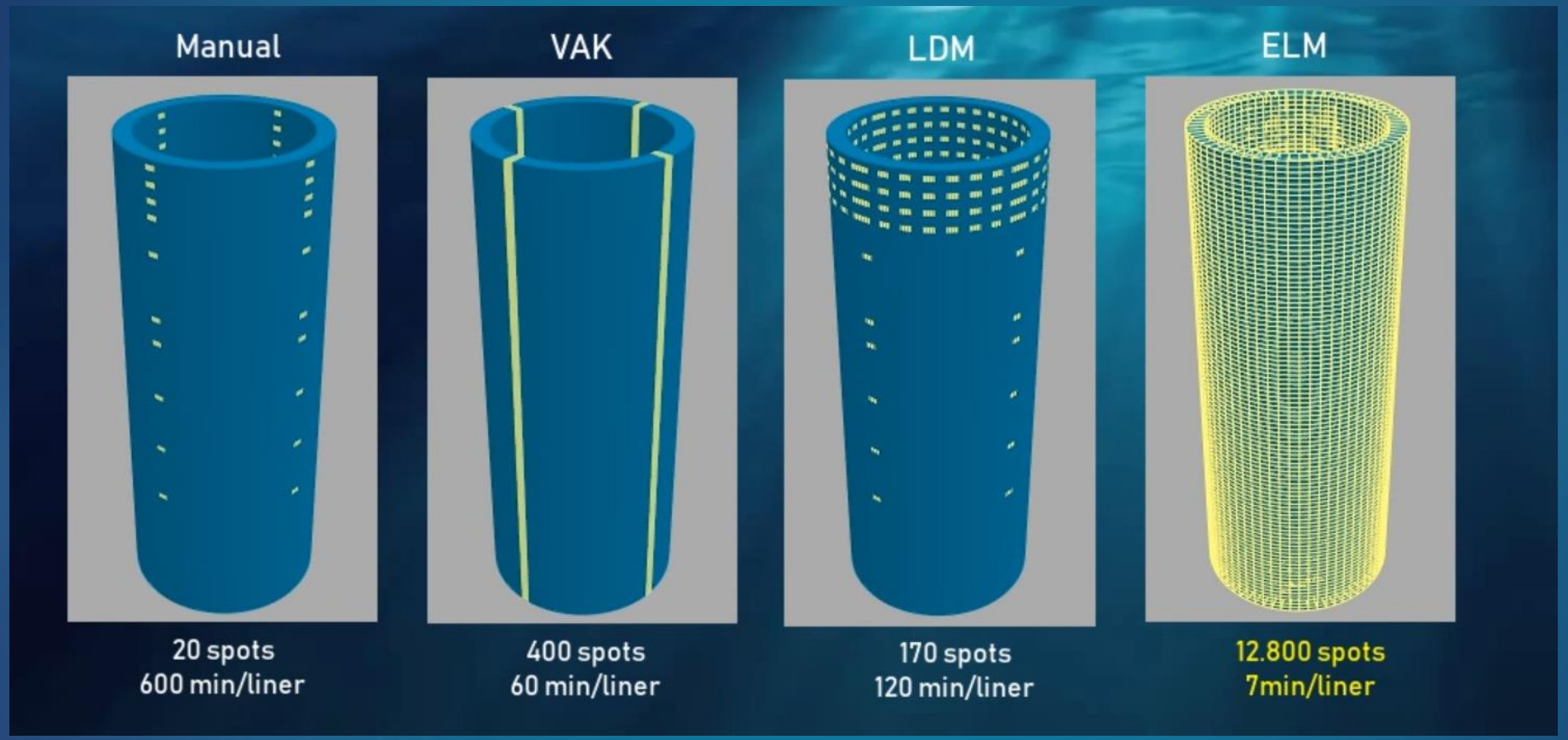
~ general impression / summary

Soot deposits:	high
Carbon deposits:	medium
Lubricator grooves & injectors:	clear & intact
Starting air valve:	clear, no cracks
Exhaust valves:	medium deposits, intact, no pitting
Exhaust valve seats:	not visible
Fuel injectors:	all covered in soot & leaking – overhaul recommended
Wave cut/honing pattern:	none

6. Visual summary

Unit	ELM	ELM Trend	PR	PR Trend	CBI-L	CBI-R	Temp
1		New		--			
2		--		--			
3		--		--			
4		--		--			
5		--		--			
6		--		--			

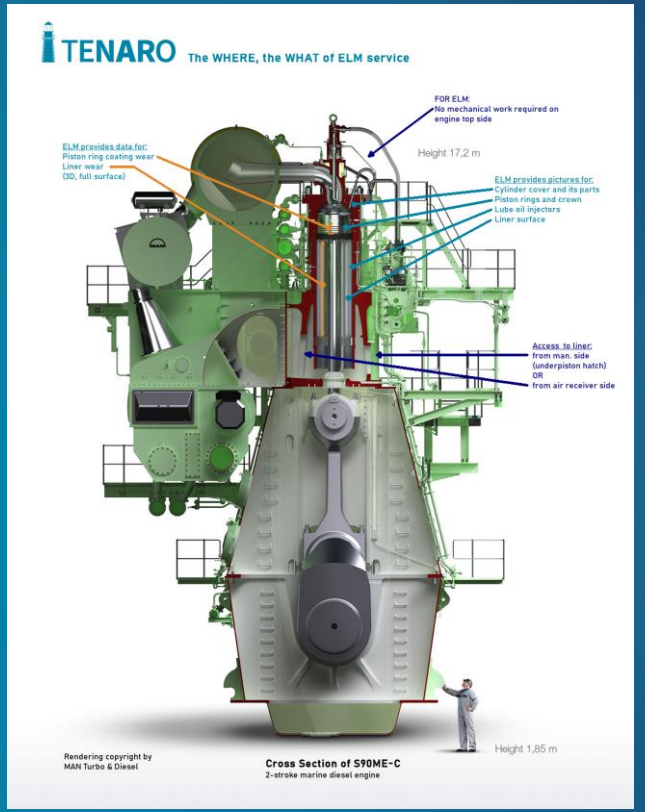
Alternatives ?

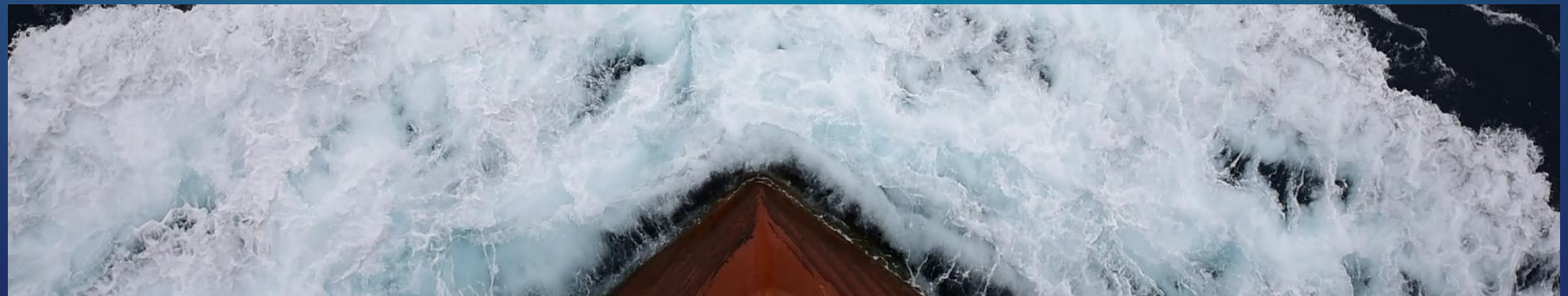


- Other methods are slower, less precise and ignore 90% of liner surface

Used when ?

- Maintenance planning (truely condition based)
- Engine budget planning
- Pre-Dock inspections (budgets/work)
- Post purchase inspection
- Engine Problems





Where ?

- World wide service also during COVID19

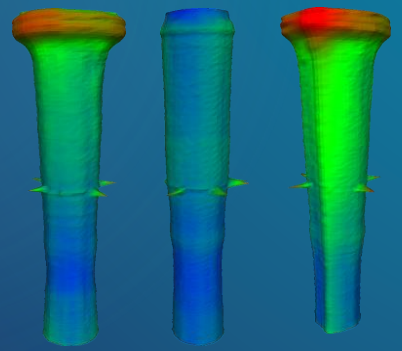
- Local stations:
  - China (Shanghai)
  - Singapore
  - Hamburg (Germany)
  - ARA Region
  - Gdansk (Poland)
  - USA (Los Angeles)

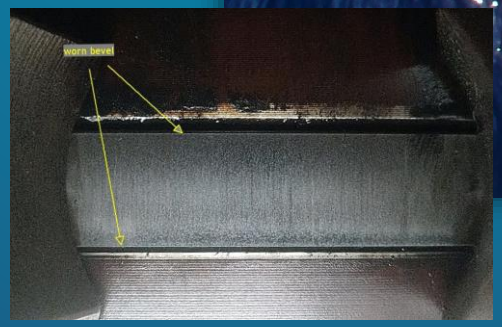
- Clustered service:
  - Europe
  - UAE/Arabia
  - Panama
  - Houston (US)

Why Tenaro ?

- Maker independent
- Engine service independent
- No selling of spares/overhauls

- Unique cutting edge technology
- Unmatched detail and speed
- Truly world wide service
- Cost effective, low overhead





Engine Liner Mapping (ELM)

Fully electronic system – low on-site work - fast – contactless
objective – high precision – high detail – 2D – 3D

ELM allows full understanding of engine condition

	Cylinder Unit ID	1	2	3	4	5	6	7	8	9
	R-hrs	50.978	50.978	50.978	50.978	50.978	50.978	50.978	50.978	
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	270°	0.97	1.11	1.31	1.25	1.78	1.80	2.22	1.84	
	F-A	2.08	2.49	2.78	2.22	3.79	3.66	4.87	3.88	
	E-M	1.88	2.02	2.30	2.25	3.40	3.91	4.16	3.57	
	Ovality	0.20	0.47	0.48	-0.03	0.39	-0.25	0.71	0.31	
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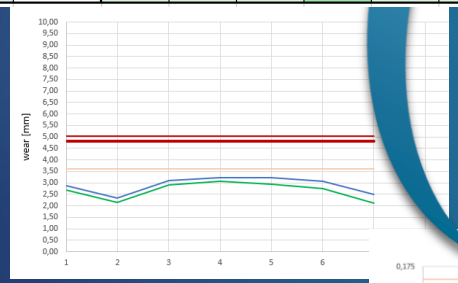
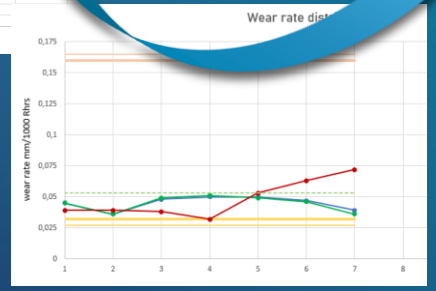
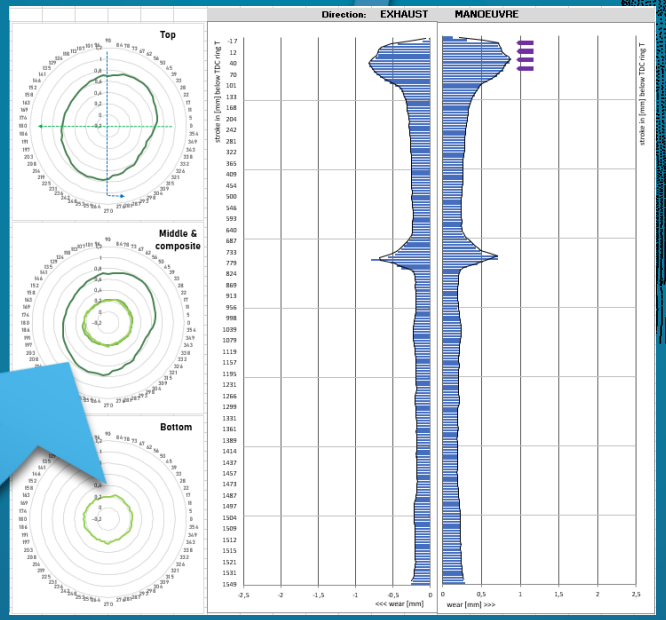
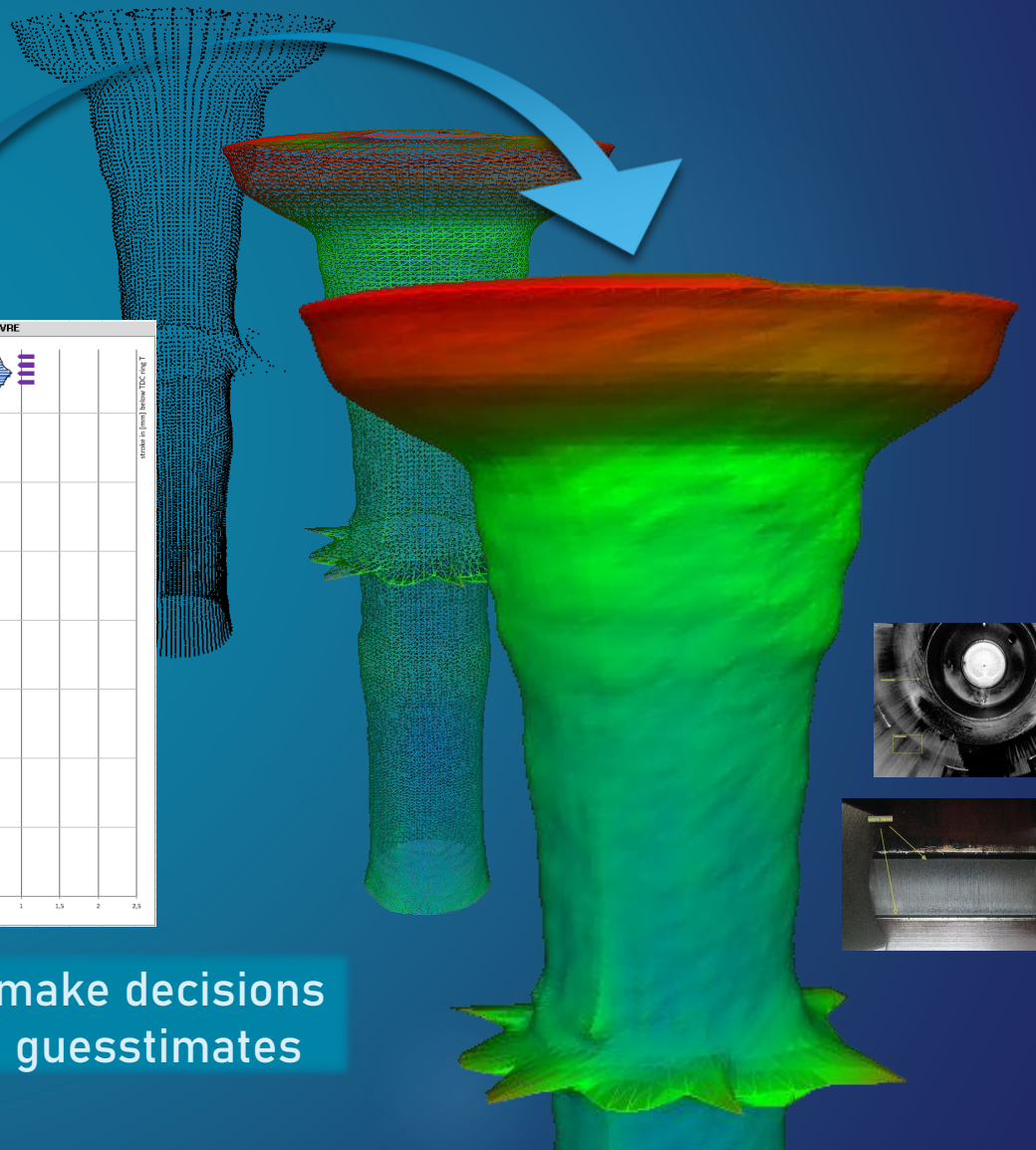




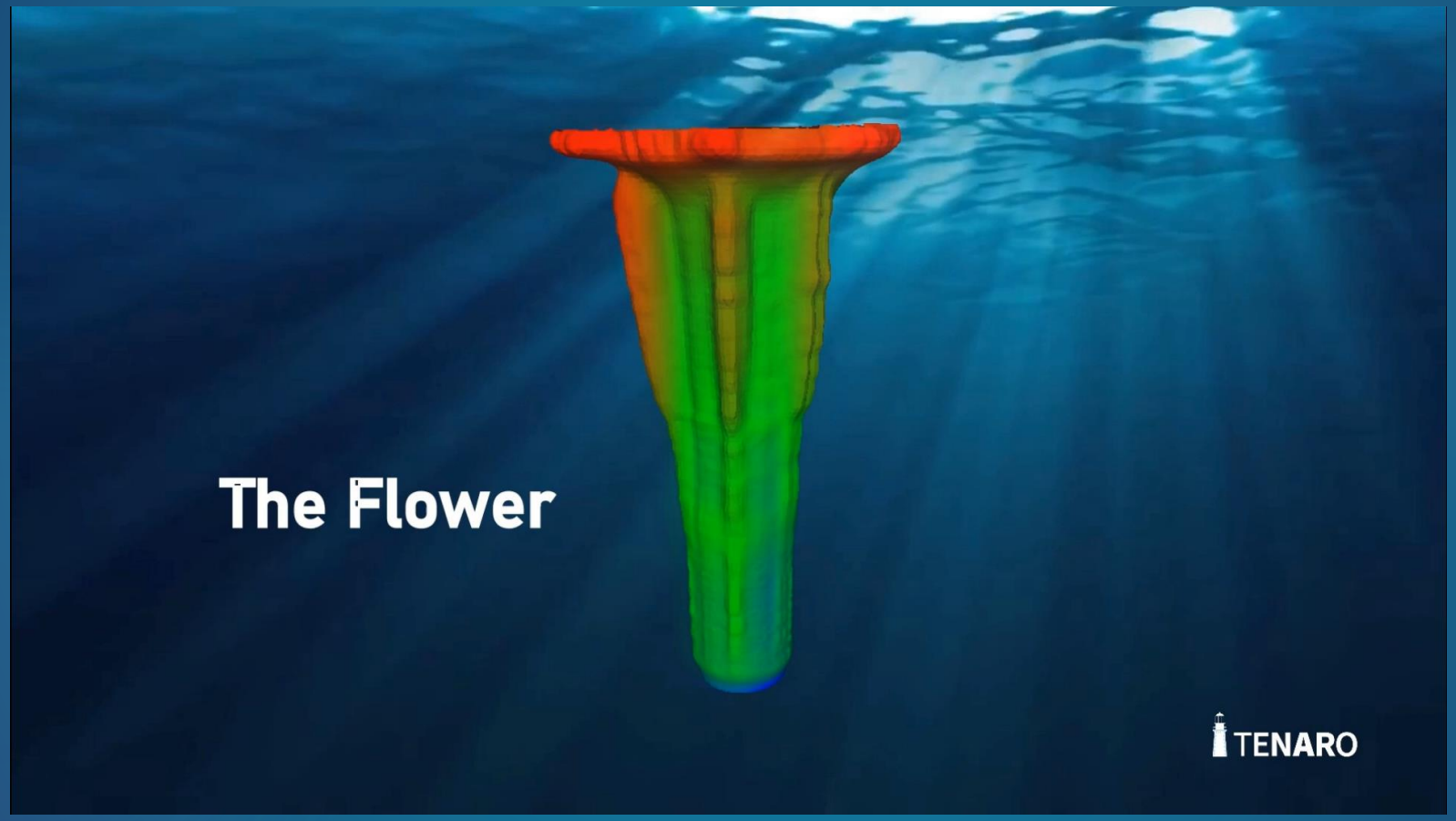




ELM – a service to make decisions
based on facts not guesstimates

Engine Liner Mapping

Next Generation engine liner measurements for marine 2-stroke engines



https://www.youtube.com/watch?v=zmaKOpKPrks

Thank you for joining !

Presented by
Birk Fleischer CTO/MD

www.tenaro.de
team@tenaro.de
+49 40 822 153 291 (24/7)