Engine Expo 2010, Stuttgart

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The successful use of Plasma Spray Cylinder Coatings in a NASCAR application to achieve friction reduction and cost benefits

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NASCAR Engines: Background

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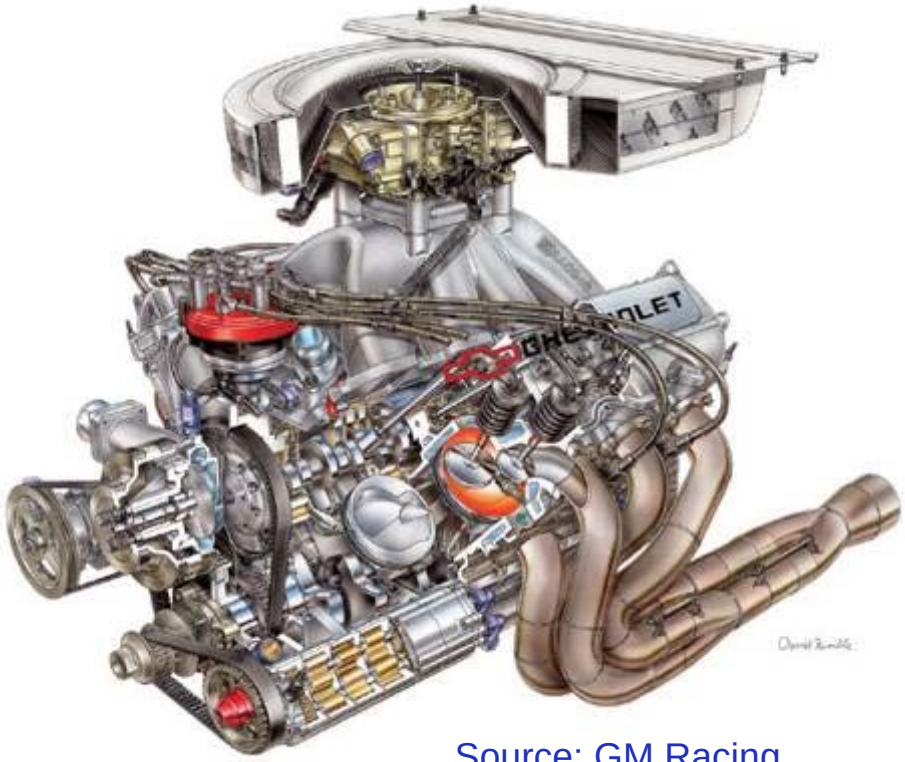
- Displacement: 5.8 liters
- Maximum Bore size: 106.3 mm
- Minimum Stroke: 82.63 mm
- n_{max}: 9800 rpm
- Single 60 mm cam in block
- 2 Valves per cylinder
- Iron cylinder case
- Aluminum cylinder heads
- The following major engine components must be submitted by the OEM and approved by NASCAR:
  - Cylinder Case
  - Cylinder Heads
  - Intake Manifold



Source: GM Racing

NASCAR Engines: Background Continued

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- Flat tappet (non-roller) cam follower
- 2 plane crankshaft
- Main and rod minimum bearing sizes are regulated
- Power: > 875 BHP
- One engine per race weekend
- Engine life is approximately 2 $^{x}10^{6}$ cycles
- Engine materials are regulated
- Piston minimum weight 400 grams
- Connecting rod minimum weight 325 grams
- Piston pin minimum weight 70 grams
- Carburetion is mandated
  - Fuel injection will be introduced 2011

Source: TRD

Source: Ford

NASCAR Engines: Cylinder cases

- Cylinder cases are either gray iron or CGI.
- Engines are completely rebuilt after each use
- Typically: engines are honed and the bore size is increased with each rebuild
  - This procedure requires a large inventory of pistons and rings
- Once the cylinder case exceeds the maximum bore size than the block may no longer be used in competition
- Fully machined and prepared cylinder cases can exceed $20,000 US in replacement cost

Source: GM Racing

NASCAR Engines: Cylinder kit friction development with plasma sprayed bore coatings

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- Friction reduction is one of the key areas for improvement of engine performance
- With relatively high engine speeds and a long stroke the cylinder kit is a major target for friction reduction
- SUME*Bore*® coatings were evaluated as a potential source of friction reduction
  - Low alloyed carbon steel with Molybdenum
  - Cr_3C_2 25 (Ni 20Cr)
  - TiO_2
- Appropriate honing techniques were used for each coating
  - Plateau honing is traditionally used with iron bores
  - A smooth honing near mirror finish was used with the coated bores
- Top rings were changed to be compatible with the coated bore surface
  - A CrN-PVD face coated ring was used for the coated bore
- No change was made to the second ring
- Oil ring tension was reduced by 50% with the coated bore without a significant increase in oil consumption

Engine performance comparison with TiO_2 cylinder bore coating vs gray cast iron

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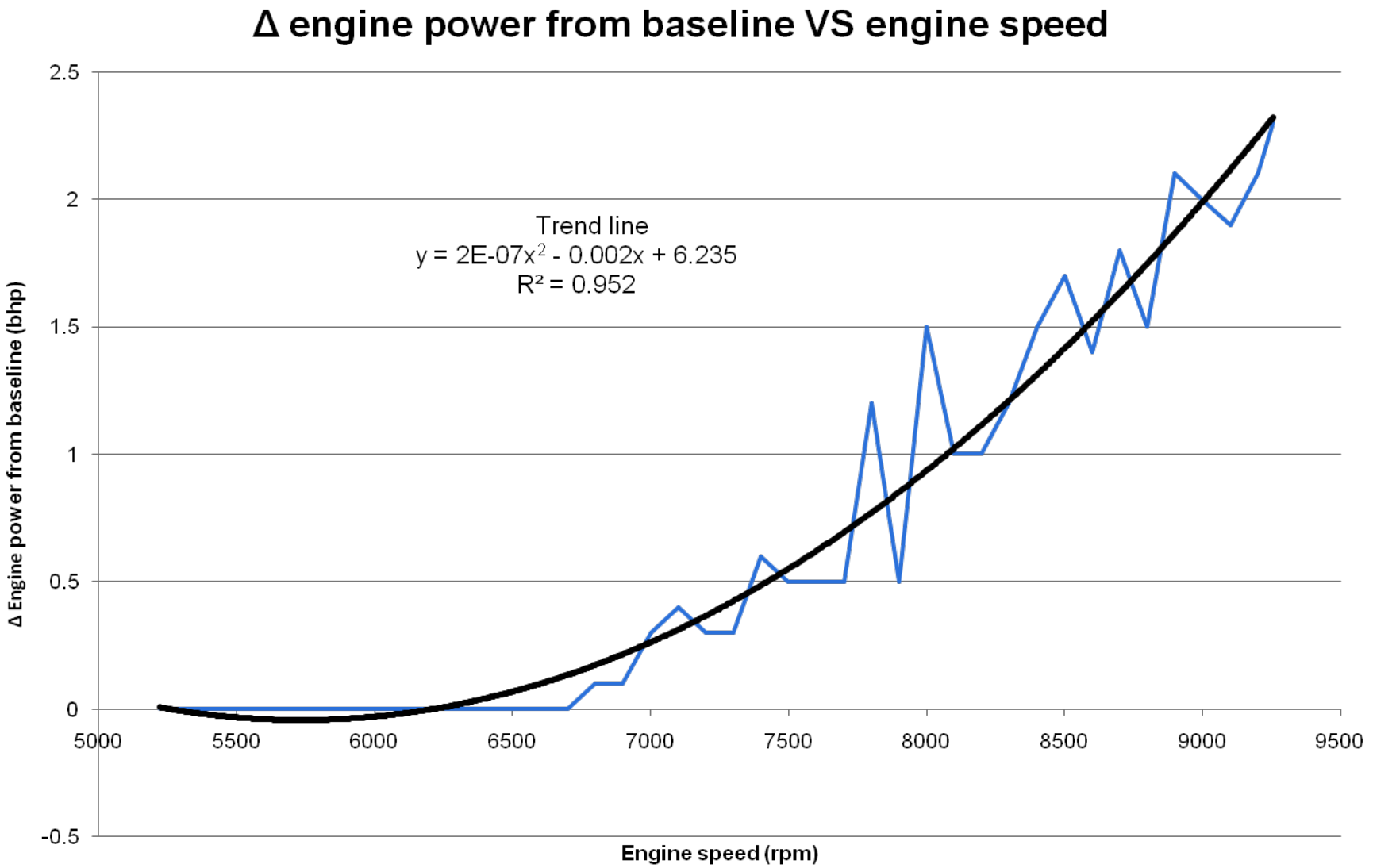

Results of testing and observations

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- A power gain was observed when the cylinder kit was modified as a system with both the Cr_3C_2 25 (Ni 20Cr) and the TiO_2 plasma sprayed bore coatings
  - The TiO_2 coating indicates a greater magnitude of friction reduction
- The results are not statistically significant
  - The population was to small
- Additional testing continues
- Piston to bore clearances were increased by 0.013 mm with the coated bores
- The TiO_2 coating is sensitive to oil ring configuration
- The Cr_3C_2 25 (Ni 20Cr) coating is robust with outstanding wear characteristics but is more difficult to hone optimally
- The key to obtaining friction reduction is to optimize all of the variables in the system
  - Bore coating and honing technique
  - Piston skirt profile and clearances
  - Ring pack

"The blue coating„ TiO_2 as used in the NASCAR trials (in the "as sprayed" condition)

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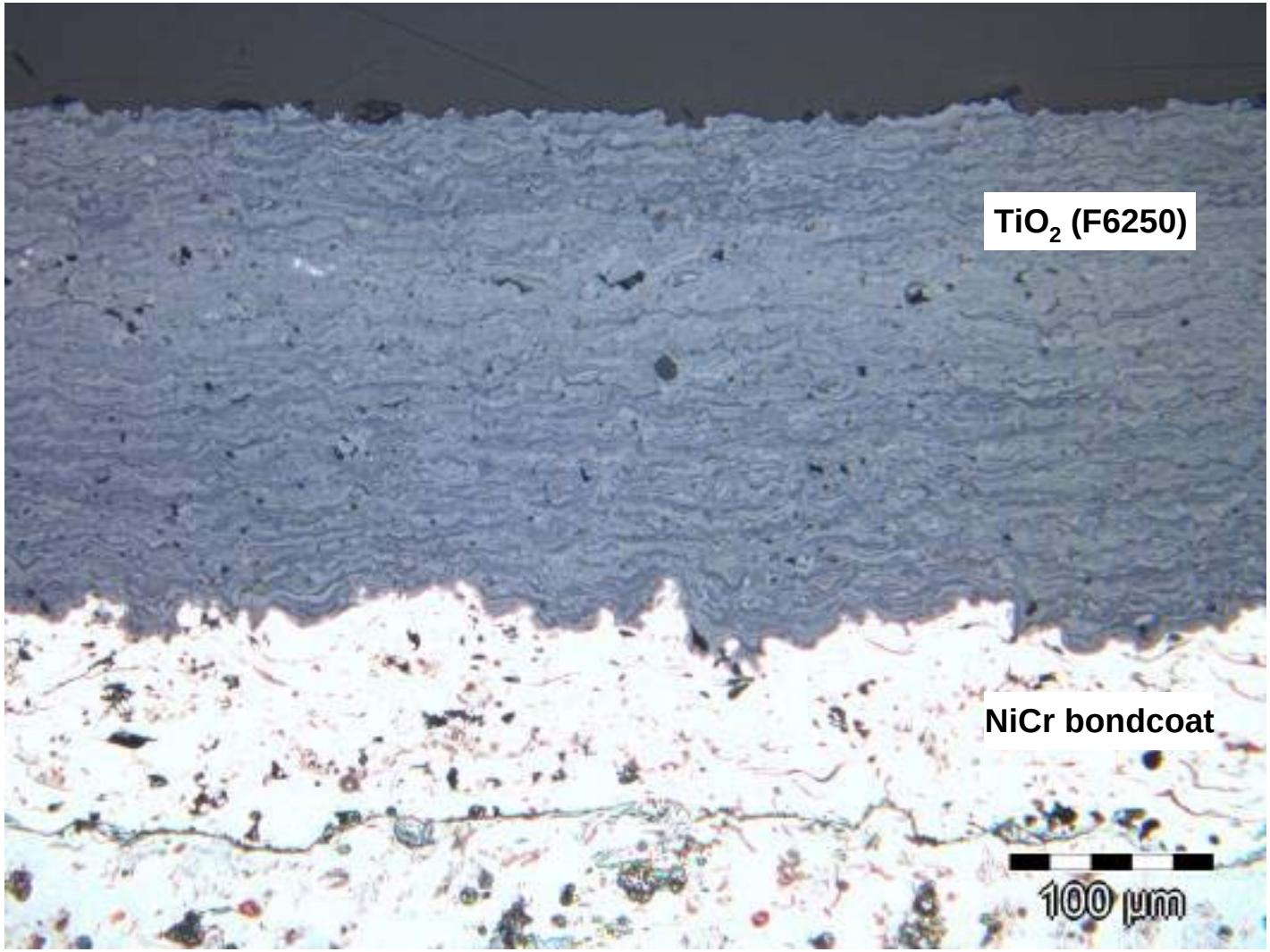

Cost benefits of plasma sprayed bore coatings in NASCAR applications

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- With plasma sprayed bore coatings a cylinder case will only be honed when required from operation such as with debris ingestion
  - The need for a bore hone with each rebuild will be eliminated
  - This significantly reduces labor cost for the rebuild as well as the turn around time
- Most significantly, the number of piston and ring sizes maintained in inventory will be drastically reduced
- Expensive cylinder cases will never be scrapped from reaching the bore limit
- Small imprecations which may otherwise have scrapped the cylinder case may be repaired with the coating
- The inventory of cylinder cases may be reduced

know how transfer into non-race engines

SUME*Bore*® - the process overview

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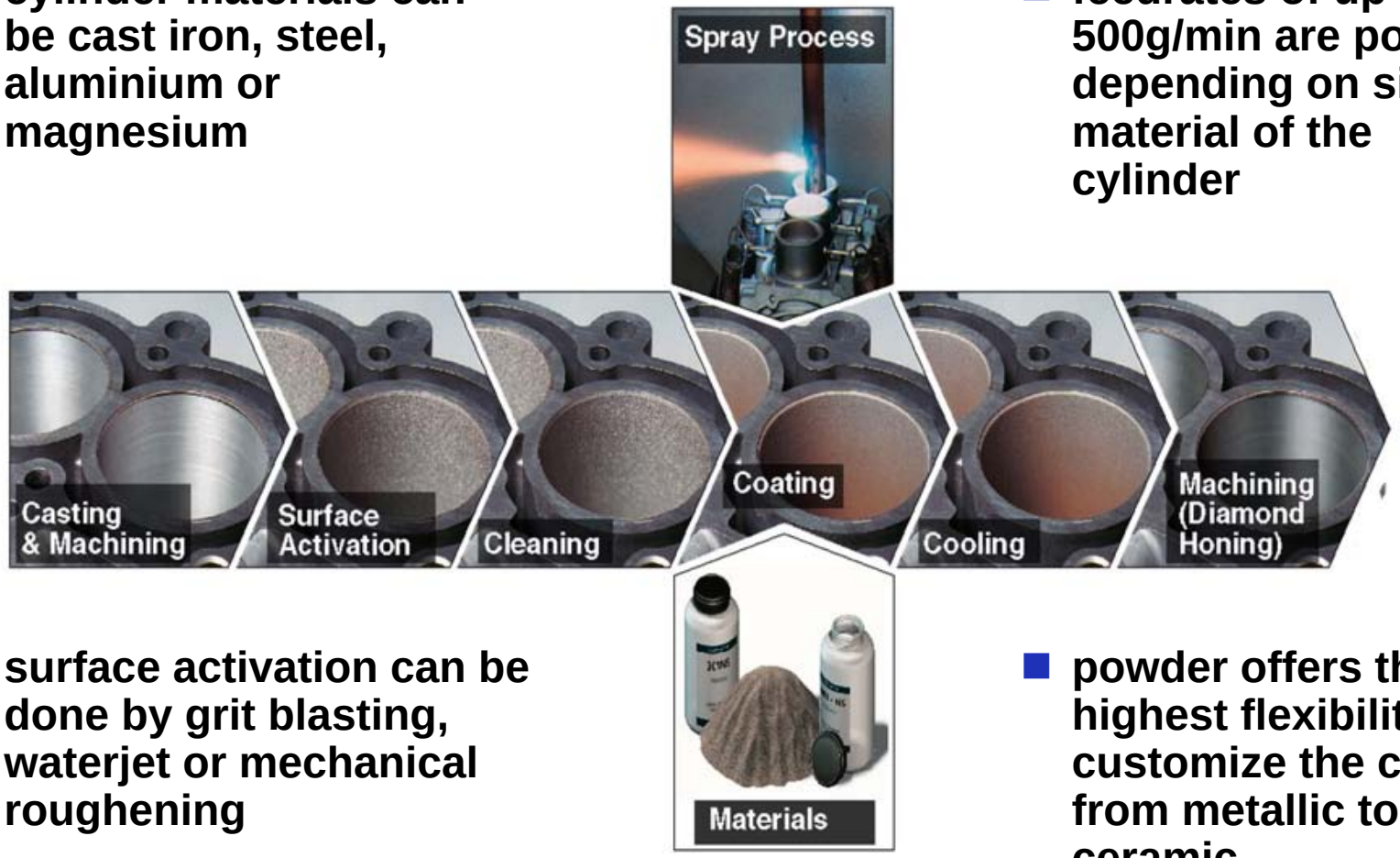
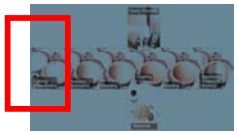
- cylinder materials can be cast iron, steel, aluminium or magnesium



- feedrates of up to 500g/min are possible, depending on size and material of the cylinder
- surface activation can be done by grit blasting, waterjet or mechanical roughening
- powder offers the highest flexibility to customize the coating, from metallic to fully ceramic

Surface activation prior to SUME*Bore* plasma coating application



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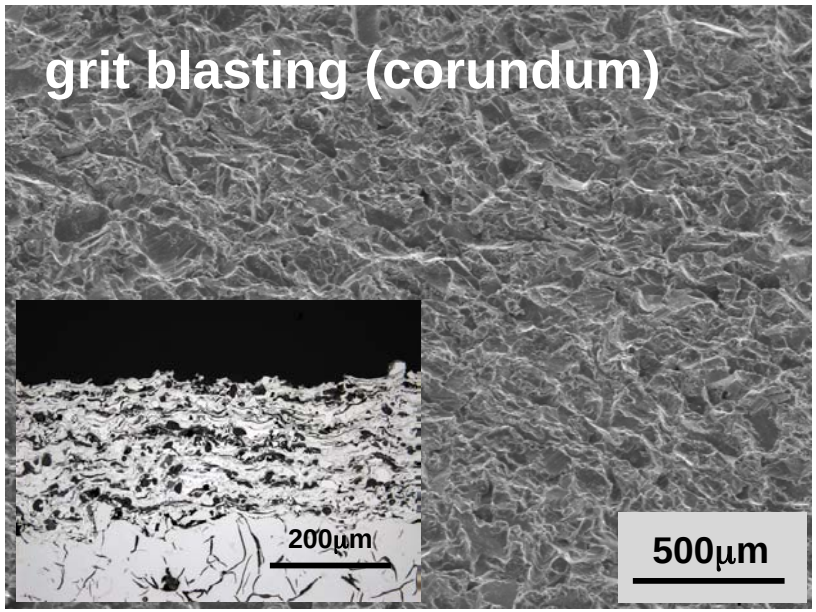

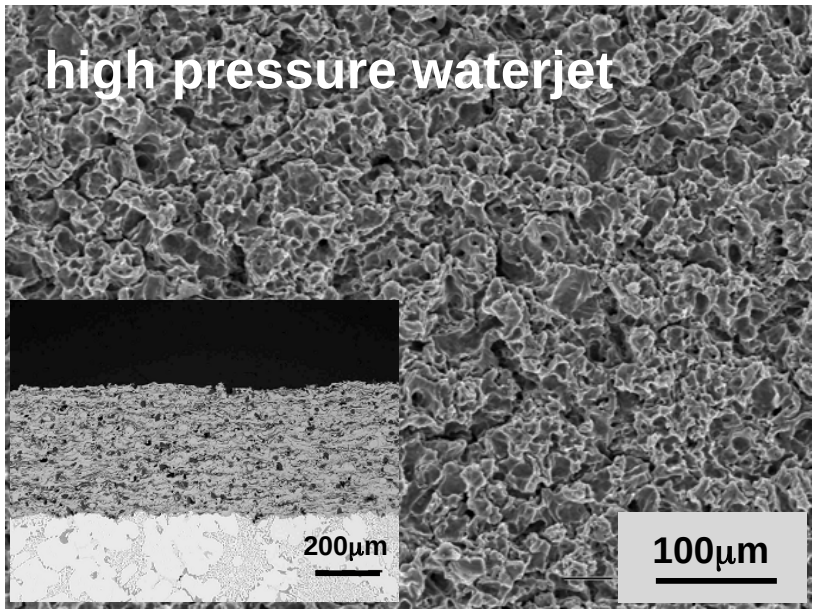

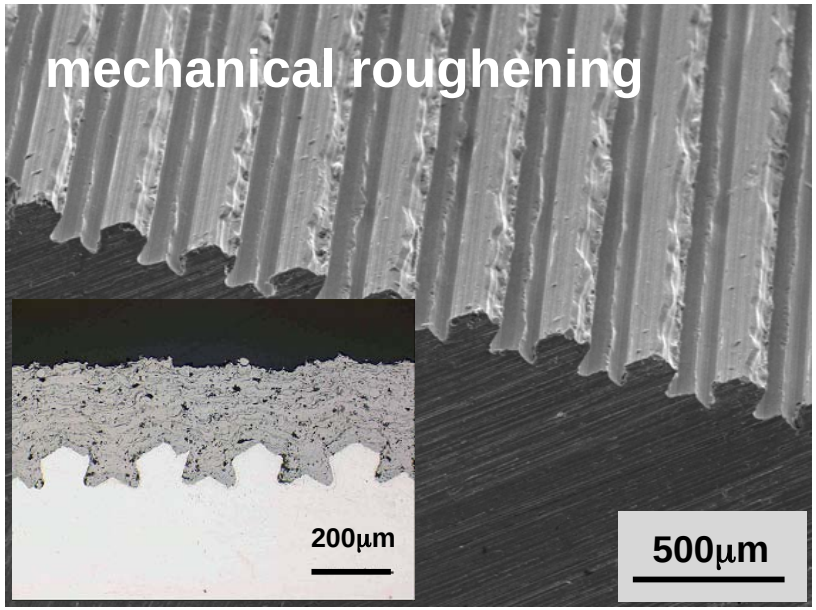

- All currently applied surface activation techniques work well with the SUME*Bore*® plasma coating process of Sulzer Metco.
- The "as sprayed" surface is very smooth on all differently activated surfaces.

SUMEBore® Technology

Diamond honed plasma coating – "mirror finished"

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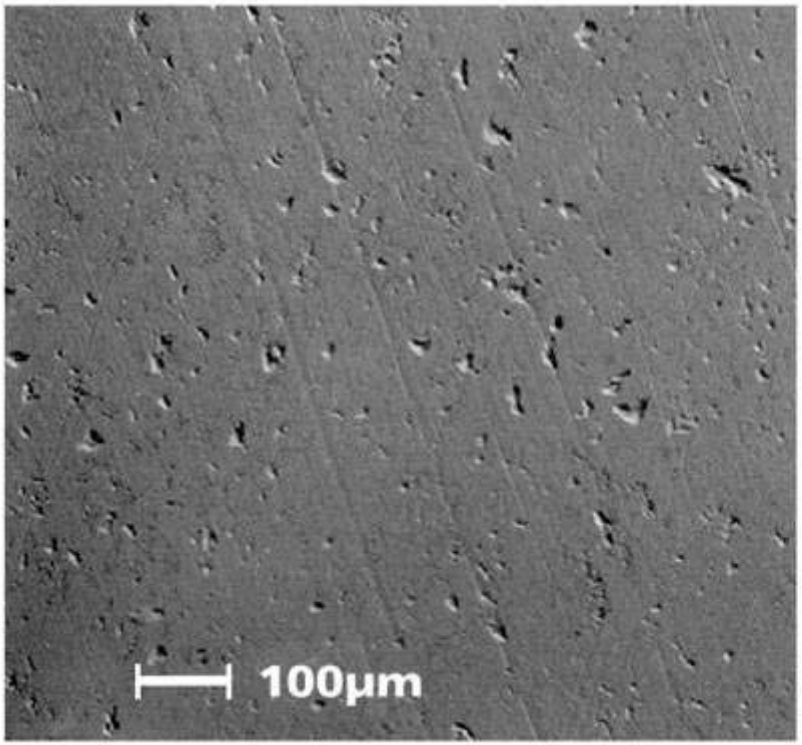
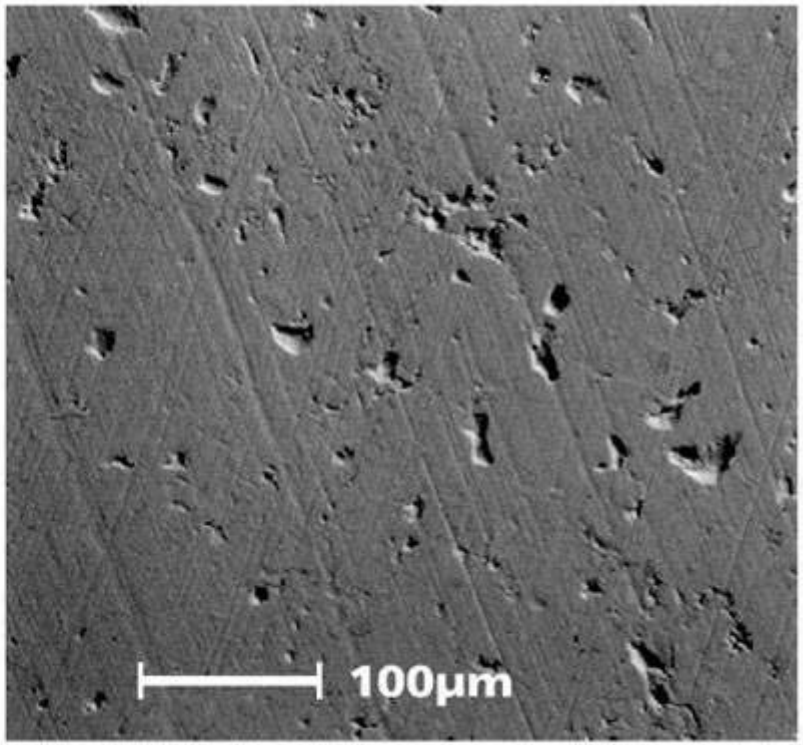
Smooth honing (mirror finishing), recommended for the SM plasma coating
Typical topography after honing with diamond tool
Low alloyed carbon steel XPT512 ($HV_{0.3}$ = 450)





SUME*Bore*® - our "materials box"

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			XPT 512	F 4301	F 2056	XPT 627	F 2071	F 4375	Ceramics
Reduced friction		Low alloyed carbon steel	●	●	●	●	●	●	●
Additional requirements	Scuffing	Steel / molybdenum compos-ite for increasing of the scuffing resistance		●					●
	Corrosion I	Modified base material: Cr-Mo stainless steel for bio-fuel compatibility				●	●	●	●
	Corrosion II	Highest corrosion resistance with superferrite composition						●	●
	Wear	Material Matrix Composite MMC with “soft” ceramics to im-prove wear			●		●		●
SUME*Bore*® Powders									

Automotive Venture – SUME*Bore* cell in Wohlen

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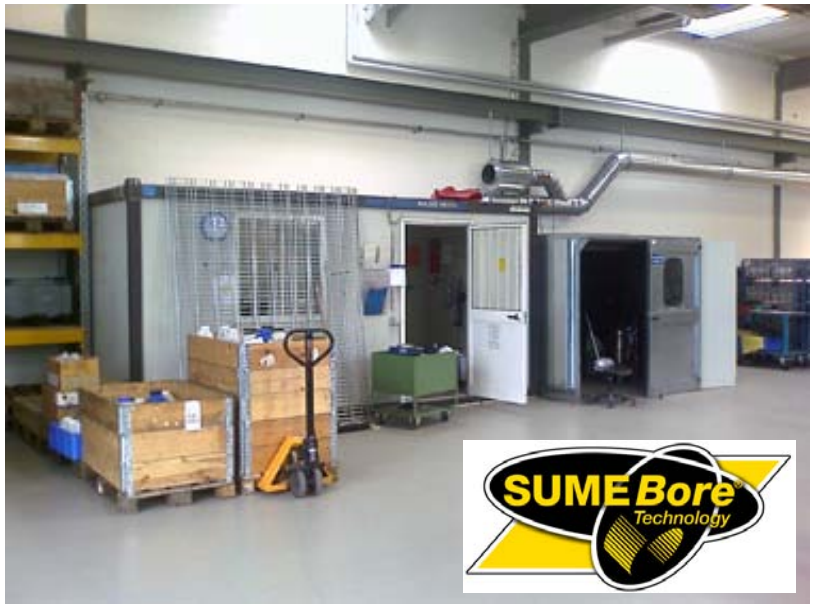

- recently moved SUME*Bore* activities into new facility
- ability to coat prototype blocks/liners and small series production
- close to 20'000 engines and 2'000 truck liners coated so far for a large number of clients

Automotive Venture – SUME*Bore*® cell in Westbury

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Experience Sulzer Metco in Mass Production

Example 1: Cylinder bore coating system for VW

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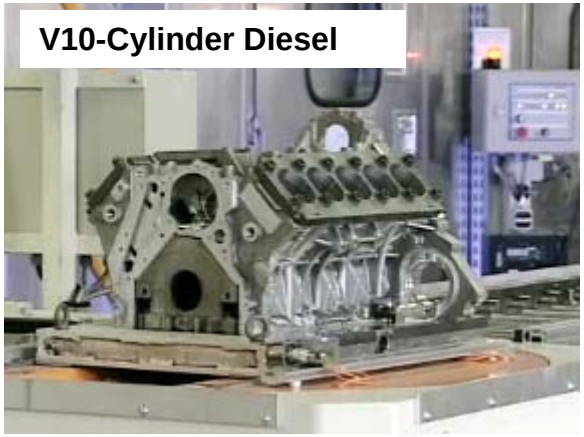
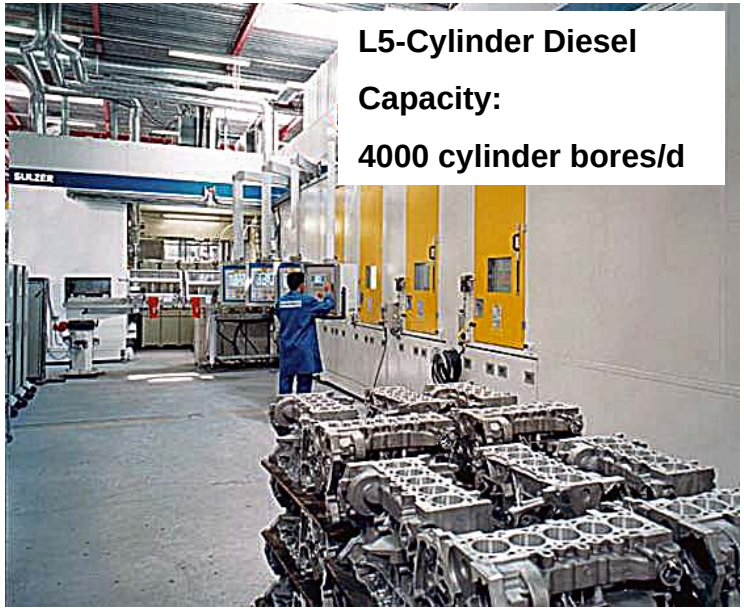


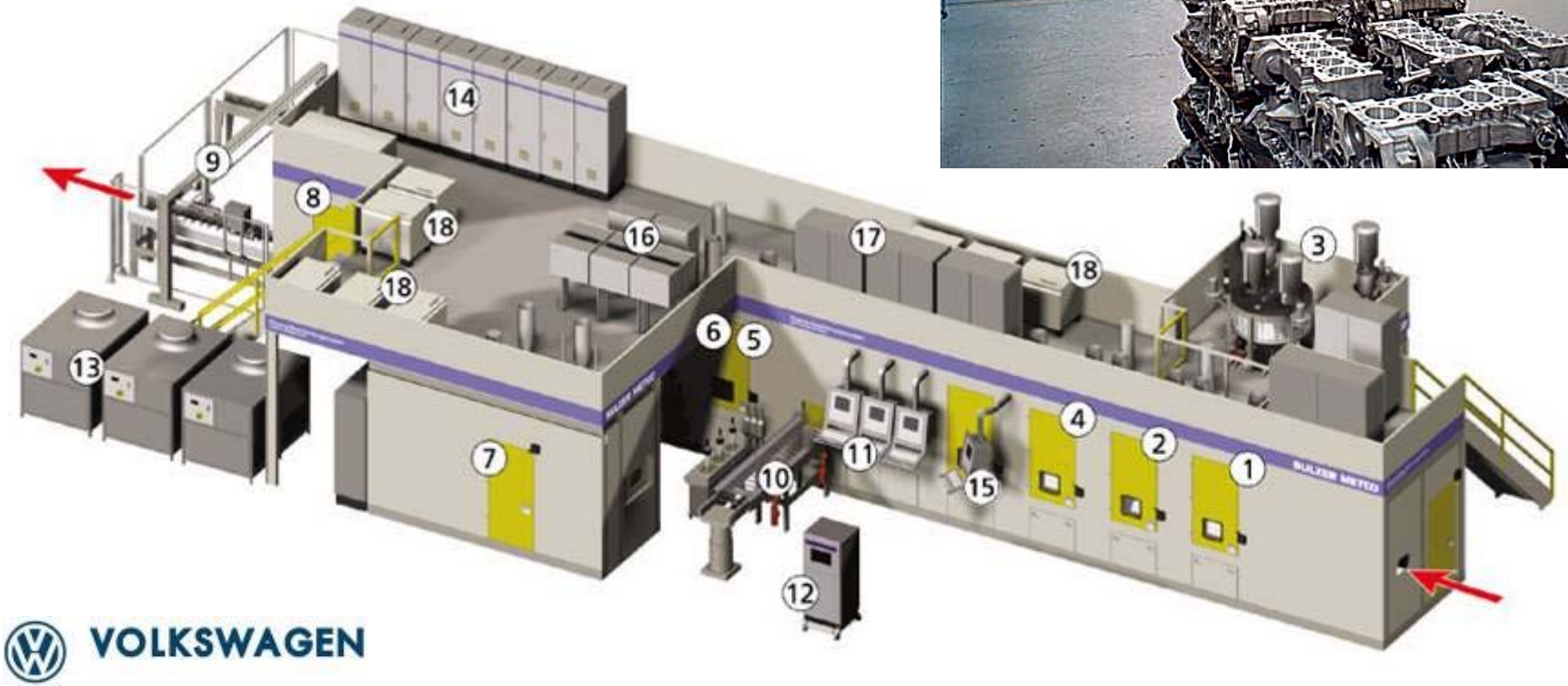
V10-Cylinder Diesel



L5-Cylinder Diesel

Capacity:

4000 cylinder bores/d



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Example 2: Cylinder bore coating system for outboard

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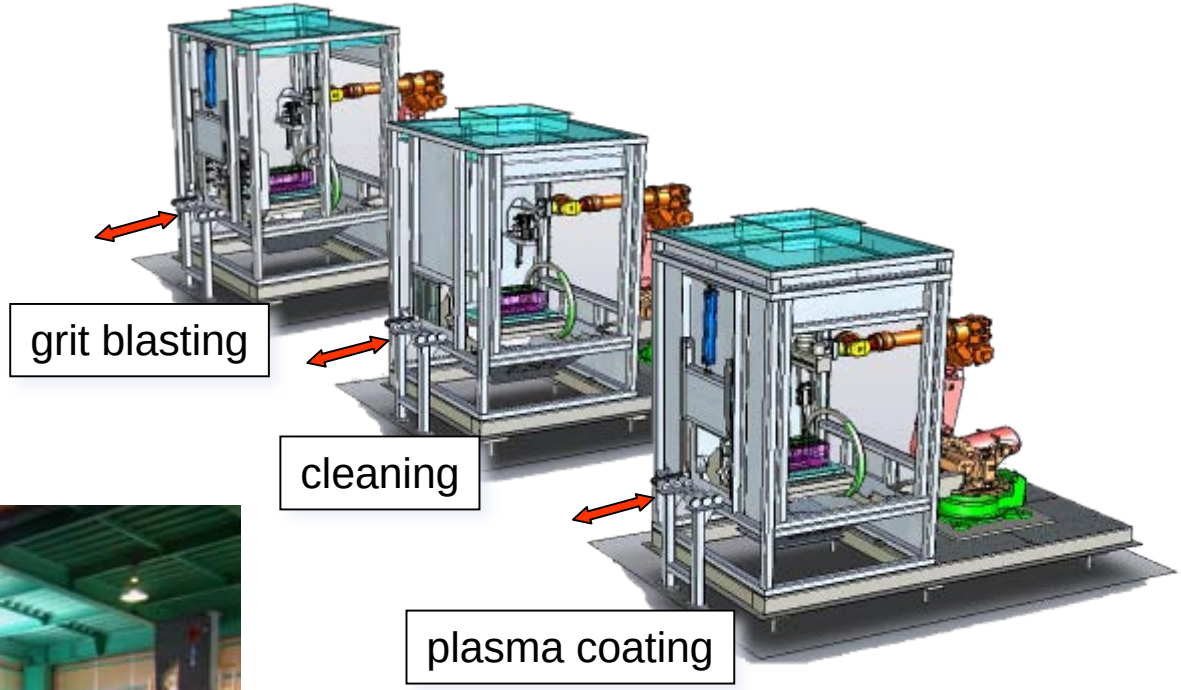
V6-Cylinder Engines

Capacity:

300 cylinder bores/d



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Example 3: Scaleable production cell for truck liners

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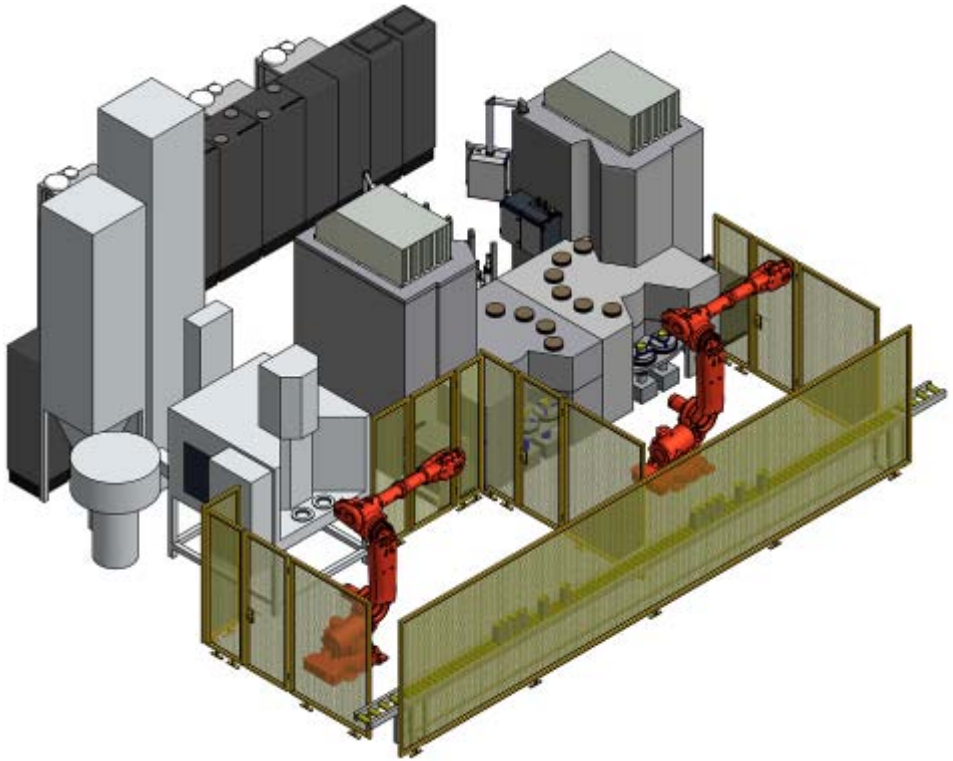
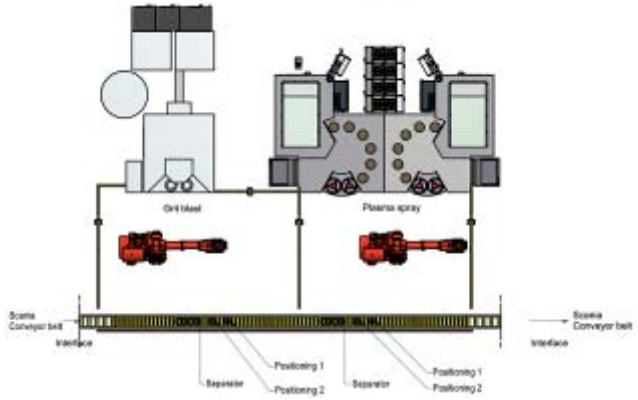
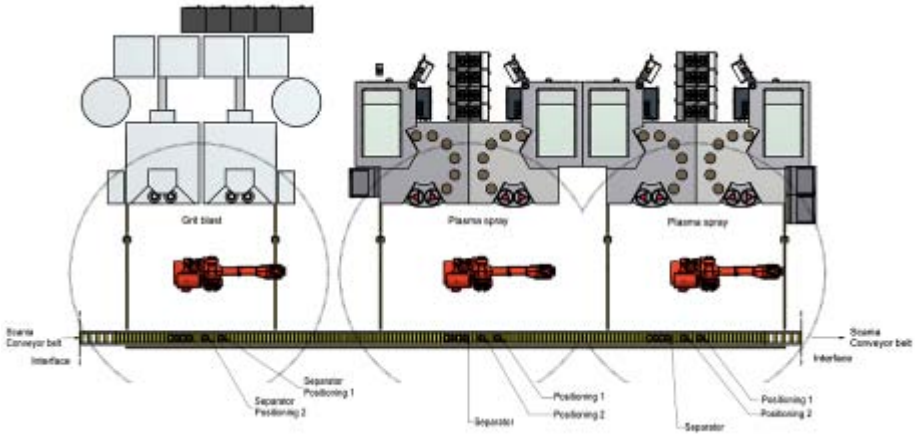


Cylinder liners for trucks

Capacity single cell:

250’000 liners / year (bottom left)
500'000 liners / year (bottom right)





Concept Sulzer Metco for mass production

Example 4: Production cell for large liners

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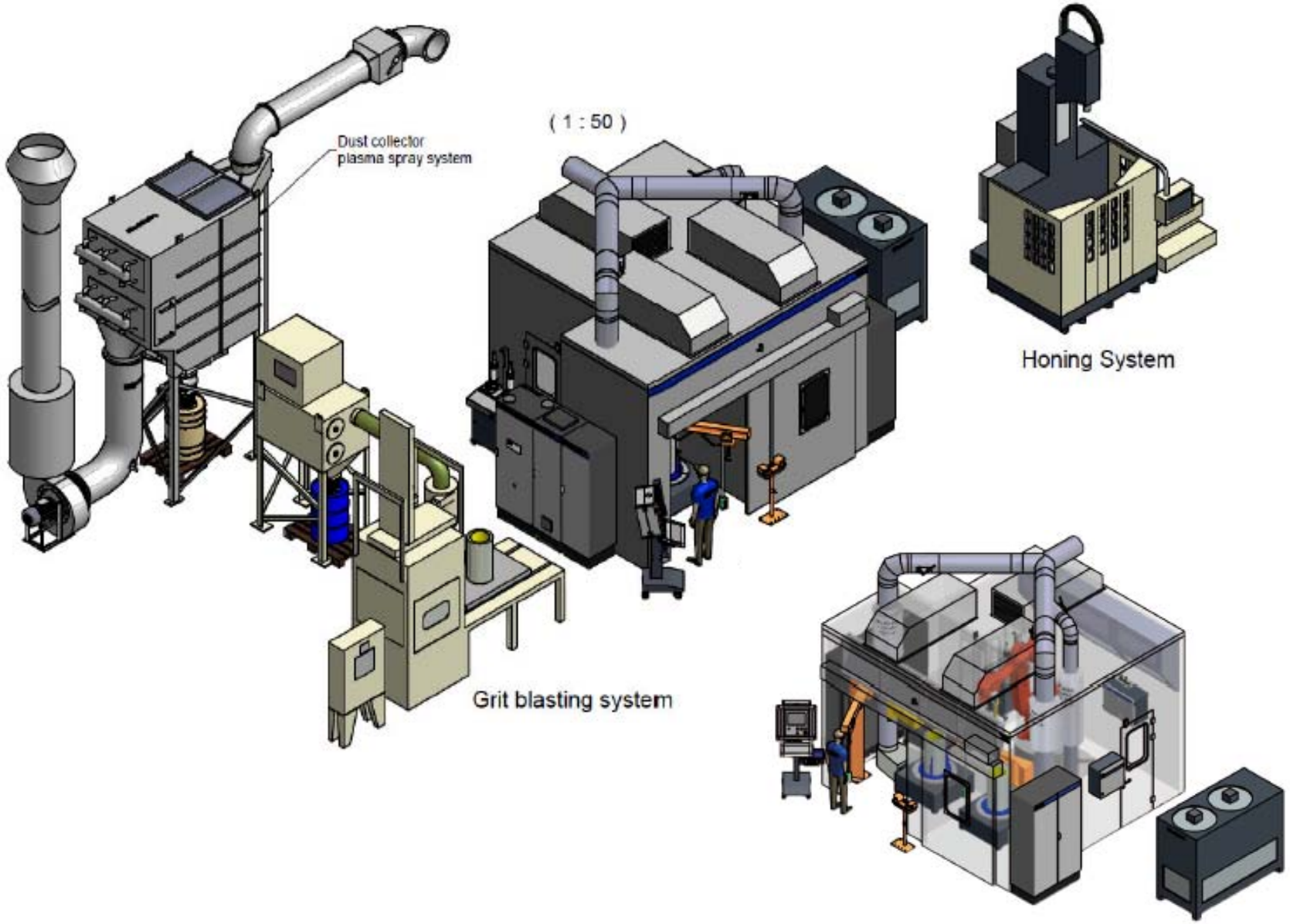

Conclusions

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- In a limited trail an optimized cylinder kit showed a performance increase with the SUME*Bore*® plasma sprayed bore coatings in a NASCAR engine application
- While the population size was not large enough to provide statistically significnat results the trend continues to show that the system is directionally correct for the reduction of cylinder kit friction
- TheSUME*Bore*® plasma sprayed bore coatings also offer operational benefits:
  - Elimination of routine honing operations (Reduced labor costs & Improved turnaround)
  - Reduction in cylinder case, piston and ring inventory

- **The results can be transferred into the non-racing engine business with similar advantages and:**
  - **emission reduction**
  - **reduction in oil and fuel consumption**
  - **capability for engine remanufacturing**
- **Additional performance gains are likely with continued development**