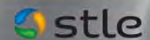


Mastering the Art of Honing

David Chobany
Wieslaw Grabon
Boris Zhmud

Sunnen Products
Politechnika Rzeszowska
Applied Nano Surfaces

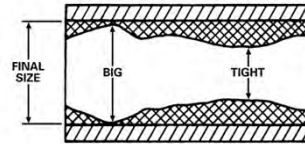


Topics of presentation

- **Honing: Definition and history**
- **Demands and trends in precision bore finishing**
- **Importance of honing oils**
- **Producing the ultimate in precision honed parts**
- **Diversity in market for precision honed parts**
- **Triboconditioning: Friction reduction and increased wear**
 - Improving the honed surface
 - Friction reduction testing
- **Conclusions**

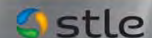


What is honing



- **Hone:** *“To perfect or maximize effectiveness”*

- A final abrasive machining process on inner diameter surfaces using precision tools loaded with expandable abrasives that are rotated and stroked within a part.
- Process designed to selectively remove excess stock created by bores that are out of round (OOR), not straight or cylindrical, have too rough a surface finish, or not sized precisely enough to fit and/or function in the end product.
- Process capable of producing bore size tolerances as small as 0.00002 inch (20 millionths of an inch, or one-half of 1 micron) and consistently hold extremely tight tolerances at sub-micron levels, even when running millions of parts.



Brief history of honing

- The idea of honing using a pre-determined grinding movement to create universal stock removal – began centuries ago. In the 1500's Leonardo da Vinci developed a tool for the machining of wooden tubes using a tool that used a motion of rotation and stroking and incorporated an abrasive grit.
- “Lots of details make perfection, but there is no detail in perfection”
- Perfect Circle



Brief history of honing

- Earlier versions of modern hone tools were developed at the beginning of the 20th century to improve components in the internal combustion engine.
- The first honing tools were wooden sticks with abrasive paper. Springs forced the sticks against the cylinder walls.
- In 1924 a five bladed stick honing tool with a universal joint and spring feed was patented.
- In the early 1930s, honing was first used in a high production application of stack honing of connecting rods.



Hone tool components and motion



- Custom designed to machine and application
- Durable body
- Spring retention
- Expanders and stones
- Feed cone and rod
- Rotation and reciprocation equal stroke
- Feed and speed generate crosshatch signature

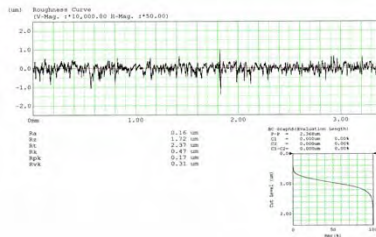
Animation credit to: <https://www.youtube.com/watch?v=Az-EI3QHSIE> Uploaded by ASTUD



Demand for high precision honing

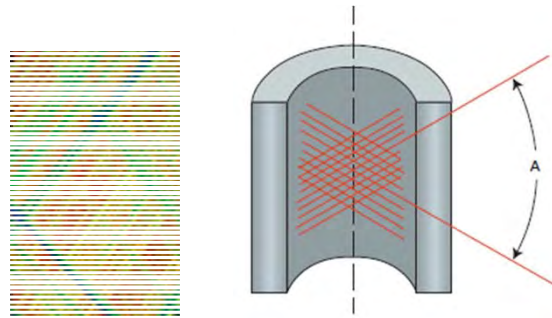
- **Surface Characteristics**

- Ra – down to 0,05µm (2µ")
- Rz – down to 0,4µm (16µ")
- Plateau finishes – Rpk, Rk, Rvk, mr1, mr2



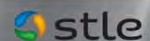
- **Crosshatch Angles**

- Oil retention grooves



Trends in precision bore finishing

- **Bore size and shape tolerance continue to shrink**
 - Microns to sub-microns
- **Statistical process controls requirements increase**
 - Cpk 1.33 * 1.67 * 2.0 and greater
- **Advancements in part materials**
 - CGI, spray bore, ceramics, exotics
- **Part design complexity**
 - Blind and tandem bore
 - Ports and reliefs
 - Varying wall thickness (thin to thick)



Producing the ultimate precision parts

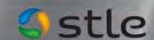
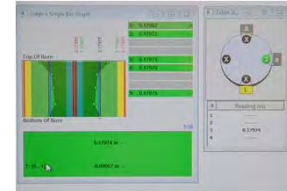
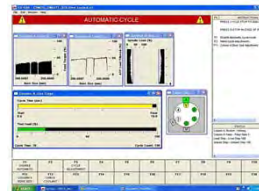
- **Machine Technology**

- Vertical or Horizontal
- Multi or single stroke technologies
- Servo-controlled tool expansion and stroke reciprocation process using precision ball-screws
- Single or multiple spindles
- Air gaging compliant
- Integration and automation



- **Control Technology**

- Windows® based PC
 - Configurable, user-friendly interface
 - In-house programming is flexible, supportable and easily updated
- Intuitive part processing
- Visual stroke and bore profiles



Producing the ultimate precision parts

- **Fixturing**

- Very critical to produce tight tolerance parts and cannot be overlooked. Honing is made to follow the existing bore and not to create or effect centerline
- Cardanic (technical float)
- Single or stacked parts
- Bladder
- Highly part customized (clams)



Single stroke honing option

- **Process Considerations**
 - Material
 - L/D ratio
 - Stock removal requirements
- **Interruptions or Tandem**
- **Chip and Burr Formation**
- **Surface texture and finish**
- **Bore geometry (rainbow)**



Producing the ultimate precision parts

- **Oil and Coolants**
 - Are critical to a successful honing process
 - Must provide for extreme lubricity under high honing pressures and harder abrasives
 - Formulation based on material being honed and tooling used
 - Choices include:
 - Petroleum or organic oils
 - Water based synthetics
 - Conformance to FDA, EC, etc. if required
 - Hi-performance surface active lubricity agents and anti-weld additives may be required to prevent welding of chip to part
 - Such as sulfur, chlorine and phosphorous
 - Proper oil allows for fast stock removal with low abrasive consumption, while still providing required surface finishes and accuracies at the lowest cost per part



Proper Oil – Coolant Selection



NEW: SHO-500 Honing Oil

SHO-500, a long-lived general-purpose honing fluid, is based on a renewable vegetable formulation that makes sustainable metalworking affordable and practical. **It is 100 percent vegetable-based**, therefore petroleum-free and without additives such as sulfur, chlorine and fluorine. This product is an ideal solution for honing applications where additives cannot be used, e.g. nuclear and some aerospace parts. SHO-500 joins Sunnen's two other planet friendly oils, MAN-863 and KG3X, which are listed as BioPreferred™ products by the U.S. Department of Agriculture.

MB-30 Honing Oil

MB-30 is Sunnen's multi-purpose industrial honing oil. High performance lubricity agents combined with sulfur extreme pressure additives prevent welding and tearing of the work piece and keep the abrasive clean. MB-30 delivers maximum cutting rates and abrasive life when honing difficult materials like stainless steel, and features a much higher level of surface active lubricity agent than other petroleum based machining oils. It works on virtually any metal from aluminum to zirconium.

MB-40 Honing Oil

MB-40 combines the best features of our industrial and automotive honing oils. It is specially formulated for use in severe applications that encounter problems such as pick up and galling. Formulated with extreme cutting additives, MB-40 works well in Single-Stroke Honing® Diamond Tooling, conventional and superabrasives honing as well as in KROSSGRINDING® applications. It has also proven useful when fine textures are desired.

LT9X Honing Oil Concentrate

LT9X can be used as a chlorine-free additive to boost performance or replace depleted additives in a wide variety of honing and cutting oils. Mixing LT9X in a one-to-one ratio with mineral oil makes a formulation similar to MB-30 Honing Oil. NOTE: Choose a mineral oil that is severely solvent refined or severely hydrotreated and has a viscosity of 50-100 sus. Avoid high wax content mineral oils.

MAN-863 Honing Oil

MAN-863 was developed to answer the need for a non-hazardous, ecologically responsible, unregulated alternative to traditional honing oils. It is composed of natural surface active lubricity agents in combination with preservatives, a sulfur extreme pressure additive and metal deactivator to prevent staining of alloys containing copper. It is suitable for all materials including exotic metals. MAN-863 has a mild odor and is very gentle to the operator's skin.

MAN-852 Honing Oil

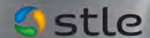
MAN-852 is a non-hazardous, ecologically responsible, unregulated honing oil composed entirely of natural surface active lubricity agents. Because this product does not use additives, it is ideally suited for applications where additives are restricted, such as the aerospace and nuclear industries. MAN-852 is approved by Boeing Aircraft Company and is used to hone critical parts where classic cutting oil additives such as sulfur or chlorine have been shown to cause microcorrosion, resulting in part failure.

KG3X Honing Oil

KG3X is a non-hazardous, ecologically responsible, unregulated honing oil. Like MAN-852, it is additive free and composed entirely of surface active lubricity agents, but formulated to a lower viscosity. Typically, this oil is used to hone critical parts where classic cutting oil additives such as sulfur or chlorine have been shown to cause microcorrosion, resulting in part failure. KG3X has a mild odor and is very gentle to the operator's skin. It is very popular with operators who are sensitive to additives used in cutting oils.

SCC Honing Coolant

SCC-605 and SCC-205 Honing Coolant Concentrates are formulated to meet the demands of the KROSSGRINDING® System, Single-Stroke Honing® and Metalbond Superabrasives Honing. They are far superior to conventional honing oils in reducing or eliminating workpiece temperature buildup. SCC Coolant is also suitable as a grinding coolant or general purpose metal working fluid for both ferrous and non-ferrous parts. It contains no dangerous nitrites, nitrates, PCB's, PTTBA, Mercurials, or Phenols.



Producing the ultimate precision parts

• Tooling

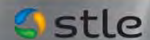
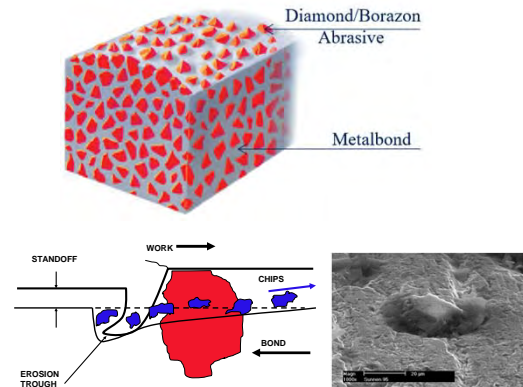
- Consists of driveshaft, tool head and feed connections. Proper tool component design and material specifications ensure long life and a quick return on initial investment.
- Each tool design is custom to the piece part and is optimized to achieve maximum tool and abrasive life while generating extreme tolerance bore geometries part after part with minimal operator input.
- Range 1.5mm – 1525mm
- Single stone with guides to multiple stone heads



Producing the ultimate precision parts

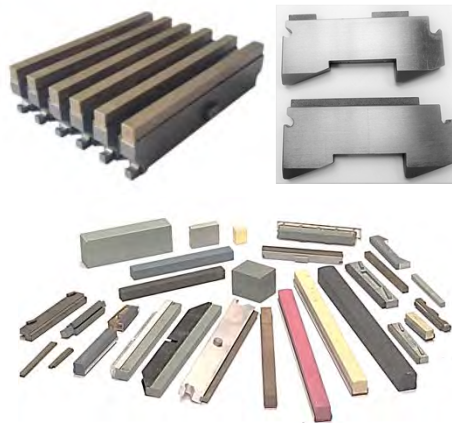
• Honing Superabrasives

- Sintered abrasive grit and bond tailored to application
 - Diamond used in cast iron, carbide, chrome, ceramics, glass
 - Borazon used in soft & hardened steel, Inconel, Stellite, stainless and other exotic/super alloys
 - Proprietary metal-bond technology
 - Stone machined to precise size
- Bond & Grit relationship is critical to process steady-state honing.
 - Erodability & Grit Retention



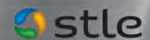
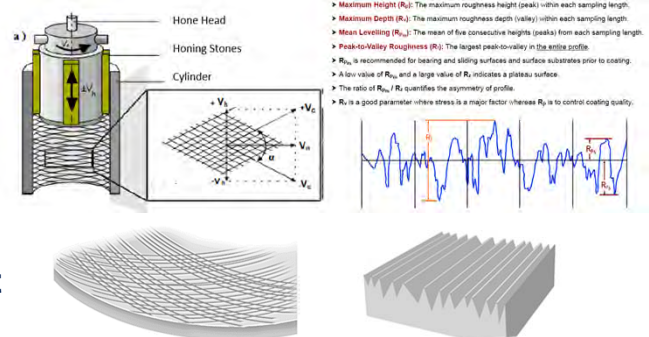
Honing stone design considerations

- **Pre-hone bore condition**
 - Size
 - Geometry (Taper, Ovality, etc)
 - Surface roughness
- **Bore characteristics**
 - Diameter to length ratio
 - Interruptions (grooves, cross-holes, cut-outs, etc)
 - Material and hardness
- **Honing fluid**
- **Process feed and speed**



A quality honed surface is dependent on client functional objectives

- **Shape**
 - Perfecting bore shape/ geometry
- **Surface texture**
 - Support of tribologically stressed contact surfaces
 - Creation of defined oil retention valleys and cross hatch
 - Bearing surface creation
 - Smooth, near polish
- **Minimization of residual part stress**

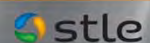


Precision honing machine technology designed for use in ...

Small job shops

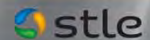


Highly regulated industries



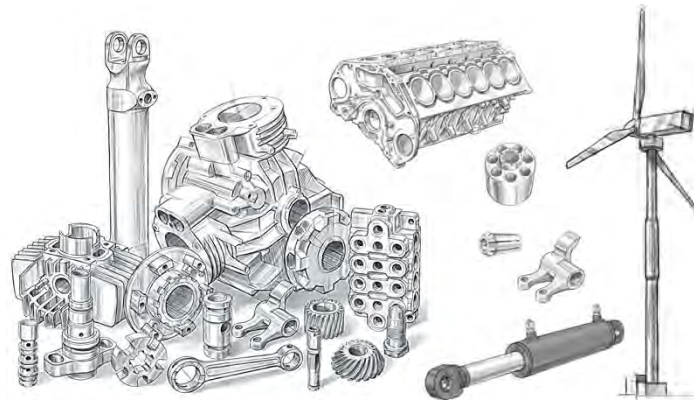
High precision requires a total solutions provider

- Machines and Controls
- Tooling
- Abrasives
- Fixtures
- Gages
- Oils/Coolants
- R&D Laboratory
- Global manufacturing and support
- Internal-External Expertise



Overall market for precision honed parts

- Engine Powertrain
- Gears
- Hydraulic
- Medical
- Energy
- Military
- Machine Components



Honed parts - Automotive industry

- **Typical Car & Engine Components**

- Motor Blocks, Small Engines, Injectors, Turbo Charger Housings, Common Rail Parts, Servo Steering Components, Brake Drums, Liners, Gears, Rocker Arms, Connecting Rods.

- **Sample processing requirements**

- Liners: Surface roughness parameters, Constant Crosshatch Angle
- Small Engines: Nikasil & Chromium plated, blind-bores
- Injectors: Tolerances < 0.001 mm, $R_z < 1$
- Brake Drums: Constant Surface Texture, ovality < 0.015 mm, blind-bore
- Gears: $< 0.003 - 0.004$ mm, surface finish $R_a 0.2 - 0.3$, Perpendicularity
- Connecting Rods: Bore Parallelism, Roundness, Surface



Specialized engine honing techniques

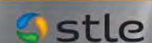
- **Torque Plate Honing**

- Honed with block or liner under bolted load to represent head installation



- **Hot Honing of NASCAR block**

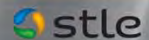
- Block honed with elevated oil temperature to replicate operating temperature



Honed Parts – Hydraulic Industry

• Typical Hydraulic Applications

- **Axial Piston Pumps**
 - Multiple bore piston pumps: tolerance: ± 0.01 (mm), ovality 0.002, cylindricity 0.004 (mm), roughness: Ra 0.2 - 0.4 (μm)
 - Improve life time, greater efficiency (smaller leaks)
- **Hydraulic Manifold Blocks and Valves**
 - Manifolds, valves, control sleeves: tolerance: ± 0.001 (mm), ovality: 0.001 (mm), cylindricity: 0.002 - 0.003 (mm), roughness: Ra 0.2 - 0.4 (μm)
 - Higher pressure operation / efficiency due to high precision, no leakage
- **Cylinders**
 - Tolerance H7 / H8, ovality: 0.01 - 0.03 (mm), roughness: Ra 0.32 (μm)
 - High precision, long seal life



Honed parts – Specialized industry

• Aviation Applications


- Landing gear, control shafts, pressure reservoirs
 - H7/H8 tolerances, blind holes, thin-walled parts, hard to machine materials

• Energy Applications

- Oil and gas drilling and sampling components, wind power generation gears, turbines
 - H7/H8 tolerances, Ra 0.2 - 0.4, direct honing of cold drawn, plasmas and coated tubes

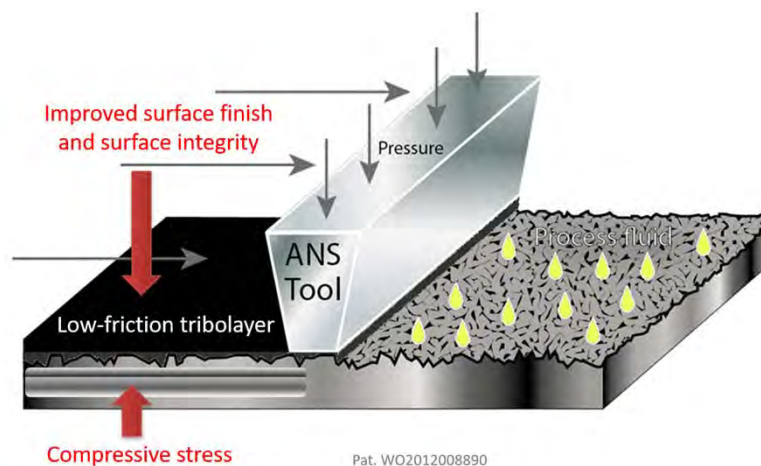


Triboconditioning®. A preferred solution to improve plateau honed surfaces and to answer the need for Friction Reduction and increased Wear Resistance

- What is Triboconditioning®  In short:
 - A mechanochemical surface finishing process, a variant of tribofinishing
 - Combines mechanical burnishing in combination with a tribochemical solid lubricant deposition
 - Applied using existing production Hone Machinery
 - Allows in-manufacture running-in
 - Allows per-component process optimization



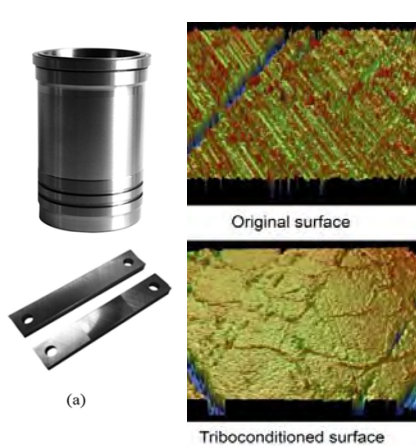
The Triboconditioning® mechanism



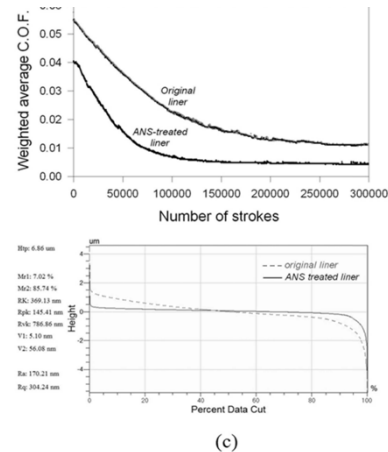
28



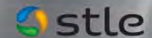
Triboconditioning effect on HDD liners



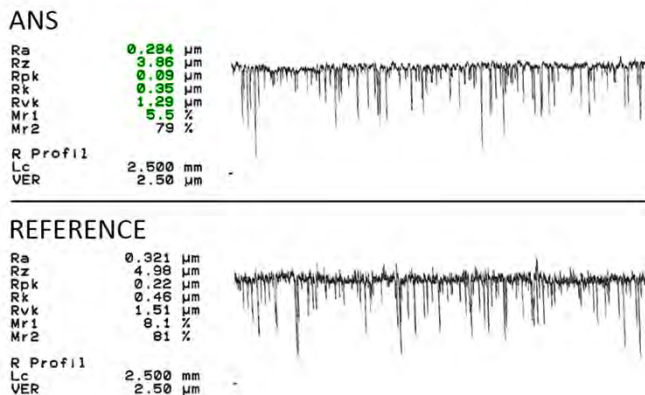
Ref: B. Zmud, E. Tomanik, F.-A. Xavier, *Tribology, Surface Chemistry and Morphology of WS₂ Tribofilms Generated by the ANS Triboconditioning Process*, *Lubrication Science* 2013.



2



Surface roughness profile



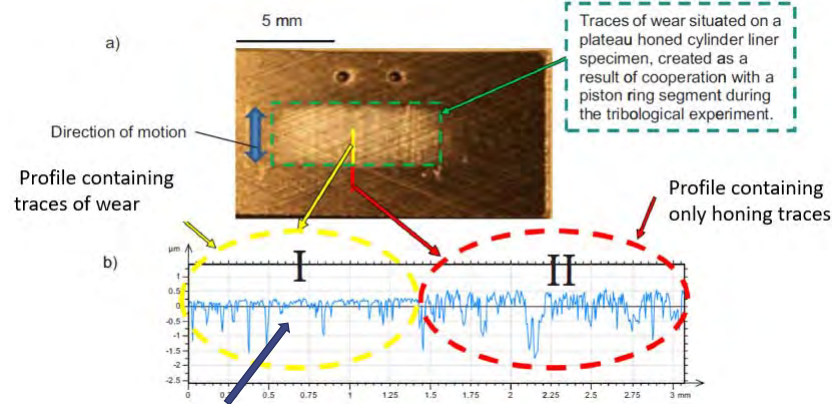
A plateaued surface similar to a helical slide honed one, but chemically enhanced



30



Cylinder liner: Running-in process analysis



Benefits for select applications

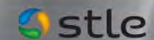
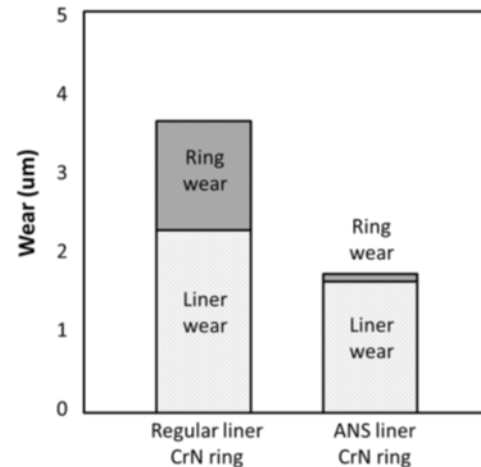
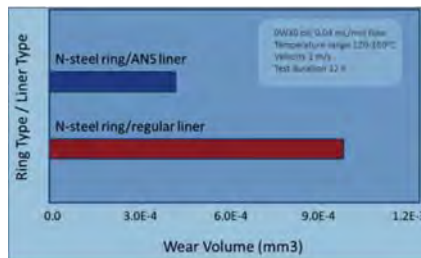


- **TC of camshafts reduces cam and lifter wear**
 - test conditions similar to ASTM D6891)
- **TC of crankshafts reduce bearing wear**
 - test conditions similar to ASTM D6709)
- **TC of cylinder bores reduced bore scuffing**
 - ASTM D6750, CEC L-101-08) top ring wear (ASTM D7484, ASTM 6483))
- **The benefits are the greatest when using low-SAPS low-viscosity motor oils**



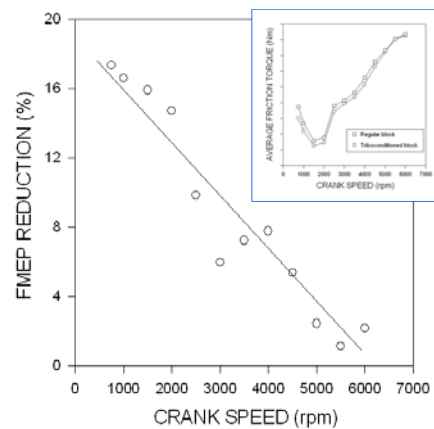
Ring and liner wear reduction

- Significantly reduced piston ring and liner wear
- Patented technology (jointly with Mahle)



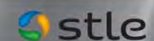
Friction reduction: Motored engine test

- **Ford 1.6L i4 GTDI engine**
 - Measured:
 - total crank torque (→ BMEP)
 - in-cylinder gas pressure (→ IMEP)
 - $FMEP = BMEP - IMEP$



Reduction in FMEP due to Tribocoating®

34.4



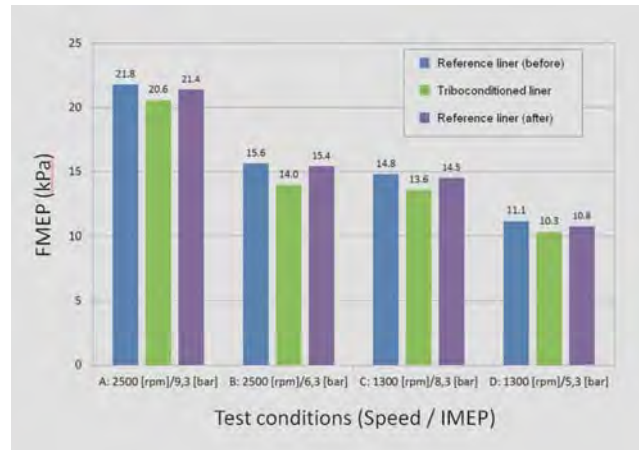
Friction reduction: FLE test

- **Reduction in FMEP**

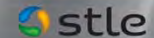
- 5 to 15%

- **Fuel economy**

- $\sim \Delta \text{FMEP} / \text{IMEP}$
- $\sim 0.1\text{-}0.5\%$



35



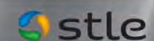
Overall system approach

- System approach is a must: ring tension, ring width, ring material, oil and engine operation conditions (speed, peak pressure, etc.) all play a role
 - One-sided component-level “optimization” can be very misleading
 - Compression ring: smoother surface => lower friction
 - Oil ring: smoother surface => higher friction



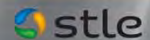
- ← Compression ring
- ← Wiper ring
- ← Oil ring

36



Conclusions

- Honing machinery and intuitive control technology continue to evolve to address new application challenges (materials, GD&T requirements, etc.)
- Mechanochemical surface finishing allows additional improvement in the tribological properties
- Timely developments given demand for higher energy efficiency and lower emissions
- Triboconditioning improves lubrication at low speed/high load enabling the use of lower viscosity oils, start-stop and boosting



Society of Tribologists and Lubrication Engineers



Thank you for your attendance during this presentation supported through the “Society of Tribologists and Lubrication Engineers”.

I am available to answer any questions that may arise in the future regarding precision honing and Tribo-conditioning.

David Chobany

Phone: 314-782-2100 x 2428

Email: dchobany@sunnen.com

