Introduction to Abradable Powder Coatings

June, 2017
Company Background

- We introduced Abradable Powder Coatings in 2000 (automotive)
  - Low cost geometric refinement and efficiency improvement for powertrain components (fit and sealing)
  - ISO 9001-2008 Registered, Global, Tier 2 Automotive Supplier
  - Over 16 million powertrain components to date. Zero defects
  - Located in Clarkston, MI

- Two Patents in USA & other key global locations

- We offer a “Rainbow of Black Coatings” – proven in various applications

- Expertise in formulation, prototyping and high volume application
APC is ‘rough / fuzzy’ as applied. Wears in to the shape of the mating surface upon initial operation. Lasting geometric refinements of components improve fit, efficiency and durability. Applications – lubricated/dry, hot/cold, sacrificial/permanent

Prior to Break-In

After Break-In

Initially- surface texture provides quick wear-in, followed by asymptotic decline in wear rate

Long term - ideal tribological surface has:
polished plateaus (Low RpK)
random crevices (High RvK)
Value Fundamentals of APC - “A Perfect Fit Every Time”

- Improves efficiency

- Lifelong geometric improvement to components (typical thickness 20µ to 200+µ)
  - Build devices tight – causing light interference fit
  - Final geometry laps in during initial operation

- Eases challenges - tolerancing, stack-up, thermal expansion

- Reduces clearances

- Cuts NOISE

- Reduces friction - stabilizes oil film

- Eliminates scuffing

- Economical, scalable powder coating process

- Environmentally friendly
Holset HD Diesel Turbocharger

- Rotor cuts perfect seal shape during operation
- Improves fuel economy
- Economical retrofit

Photos after 150K miles

Observations

A. THE TREATMENT TO THE PREVIOUS TURBO DEFINITELY INCREASED ITS RESPONSE TO CHANGES IN NEEDED POWER.

B. A FUEL MILEAGE INCREASE WAS DEFINITELY AQUIRED AS HIGH 6s AND LOW 7s WERE THE NORM, ABOUT ½ MILE FURTHER.

C. NO MECHANICAL PROBLEMS WERE ENCOUNTERED DURING THE USE OF THIS TURBO.

THIS TURBO WAS USED WHEN I PURCHASED IT, SENT IT TO YOU, INSTALLED IT AND NOW HAS ALMOST 280,000 MILES ON IT AND IS JUST WORN OUT.

I HOPE THIS NEW UNIT GIVES AS GOOD SERVICE.
Throttle Response - Abradable Seal Photos

- 150,000 miles on coating
- Driver perceived better throttle response
- Driver reported significant mpg savings on known route & load over 1.5 years
- All tips evenly polished
- Rotor ‘bedded’ into thick coating
- Convenient retrofit improvement
Pumps

- Higher pressure at low RPM
- Lower friction
- Debris tolerant
- Longer life
- Manufacturability
- Remanufacturing
- Restoration
Blowers/Compressors

- Improve volumetric efficiency
- Reduce friction and heating
- Extends peak performance
- Refurbish / retrofit
APC has been a ‘Huge’ success on Pistons

- Race market > 3300 Engine Jobs to date.
  - 30-40% annual growth for 5 years via word of mouth
  - Drag race, circle track, endurance, tractor pull
  - Gas, alcohol, diesel, JP8, nitromethane

- Remanufacturing

- Licensed UEM & USC & L2LSE

- Advanced engine development
  - Next Gen Combat, Small Engines, Stationary Power
  - Specified in drones, passenger aircraft

- Restoration of used pistons – Not a band aid – Better performance and durability
LSX Corvette 800 hp ‘drift’ race engine
- After 1 year ~ 400 hours @ 7000+ rpm
- Unexpected excellent skirt condition
- Unexpected excellent ring condition
- Rod bearings also surprisingly great
- Former Don Garlitz and Roush NASCAR engine builder

1600 hp alcohol truck pull Nat. Champ
- After Dyno + 25 pulls (piston cracked)
- Unexpected excellent condition
- Best ever pan vacuum
- Unexpected excellent skirt condition
- Unexpected excellent ring condition
How it works on Pistons

**Improved Fit**
- Build it too tight
- APC hones piston to the ideal fit *for EACH bore*
- Reduces secondary motions in rotating group
- Improves ring flutter, seal & life
- Reduces slap, noise
- Permanent geometric refinement

**Improved Friction**
- Creates optimum, stable oil film across entire skirt
- Break-in event seeks minimum friction per Strubeck diagram
- Enlarges contact area to spread load & lengthen oil leak path
- Tolerates foreign debris
- Stays- long term scuff resistance
Secondary motion of pistons is critical for piston ring longevity

- Rock causes rings to work harder, flutter more, seal less.
- Rock requires larger crevice volume
- Rock can pump oil around the rings
- APC Stabilizes Piston, Keeps rings square to bore
- APC enables reduced ring tension for lower piston assembly friction
- APC reduces volume of oil rings must handle
New formulations far exceed oil temperature range

High Temperature Tolerance

- Slick+
- Armor
- EXMD9
- EXMD9A

Surface Temperature (°C)

Load: 650 psi, 500 Cycles at each Temp.
New formulations for lower friction on boundary lubrication conditions
Thank you for your interest

‘Bonus’ slides on Pistons follow
In an operating engine APC will find and preserve the lowest friction piston geometry for each bore

1. Build tight across entire skirt. At start-up, rapid, friendly wear-in

2. Self fitting - Oil film forms and wear rate asymptotically declines

3. Locked-in geometry - When there is just enough room for a stable oil film, the wear stops

4. APC Piston has: a) minimized secondary motion  
   b) minimum oil film thickness for lowest friction  
   c) no boundary lubrication

Final shape is determined at temperature, under load. Friction, wear, and secondary motions of the rotating assembly are minimized. **Engine efficiency and durability are enhanced.**

APC plateaus are polished, so a VERY THIN oil film can prevent asperity contact.
Reduces Peak Loads and Prevents Scuffing

- Enables stiff architecture to achieve the perfect fit
- …with no risk of scuffing

APC redistributes load to adjacent areas

Outlaw 358 Sprint Engines

Scuffing Epidemic Cured

After duty cycle, highly loaded, scuff prone area is visible
Rotating Group Benefit - Bearing Life

Visual Engine Parts Comparison After 2500 Miles Racing

- **OEM Liquid Coated Engine**
- **APC Coated Engine**

- **Typical Failure Mode**
- **Delayed Onset**

**Reduced Shock Loads Preserve Bearings**
14.7L Cummins Diesel Engine – over 400k miles and still low oil consumption

- NTC-300 855 CI (14.7 L) Cummins Gen III 400HP diesel
- Over 400k miles on in frame rebuild using coated pistons and fresh liners.
- After rebuild oil consumption reduced by 50%

"Coating the piston skirts also. This engine still does not need oil added between oil changes. I have not removed a piston to check wear as it is not called for at this time."
APC In A Chain Saw Engine - Vibration

Vibration Comparison

- Uncoated Piston
- Coated Piston

Chainsaw: Shiniawa 695
Factory Piston Clearance
High RPM, No Load
Normal Operating Temp.
B&K Type 2270 Analyzer
Same Day, Same Conditions

Horizontal Vibration (g)

Frequency (Hz)
APC In A Chain Saw Engine - Noise

Noise Comparison

- Uncoated Piston
- Coated Piston

Chainsaw: Shiniawa 695
Factory Piston Clearance
High RPM, No Load
Normal Operating Temp.
B&K Type 2270 Analyzer
Same Day, Same Conditions