Technology Brief: Carbide-Reinforced Amorphous Carbon or Diamondlike Carbon Protective Coatings

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Technology Overview

Engineered Coatings, Inc. (ECI) is developing thin-film wear coatings that offer a unique combination of high-hardness, high-toughness, sliding-wear and fretting-wear resistance, and low friction. These net-shape, low-deposition-temperature physical vapor deposited (PVD) coatings offer protective surfaces for gears, bearings, and other components of moving mechanical assemblies. Low friction surfaces reduce induced temperatures and also reduce material removal from wear processes. Increased surface durability and component lifetime will result by application of these unique PVD coatings.

Coating designs include the co-deposition of hard transition-metal carbides (e.g., TiC, SiC) for superior mechanical properties and amorphous carbon (a-C) additions that provide low-friction surfaces. Gradients in composition during coating growth control residual stress, which results in exceptional adhesion and coating/substrate interfacial toughness. Key features of the coating design, attributes, applications, and benefits are shown below.

Transition Metal Carbides
- High Temperature Capability
- High Elastic Modulus
- High Hardness
- Wear Resistance
- Corrosion Resistance

Carbon/Graphite
- Solid Lubricant With Low Friction
- Transfer Film Formation
- Low-Moderate Elastic Modulus; Compliant

Co-Deposition by Unbalanced Magnetron Sputtering (UBMS)
- Graded Composition
  - Ø Residual Stress Control
  - Ø Good Adhesion, Toughness

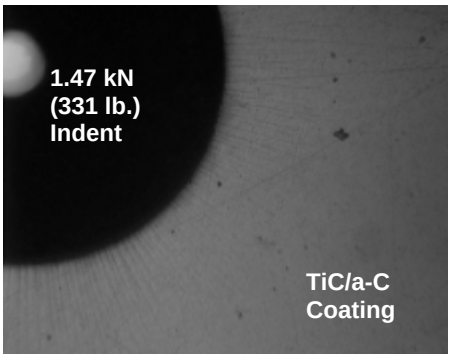
Key Attributes
- Net-Shape, No Part Growth
- Smooth Surface Finish
- Low-Deposition Temperature; Will Not Temper or Distort Parts

Applications
- Gear, Bearing Surfaces
- Shafts
- Tools

Benefits
- Increased Durability, Life
- Reduced Maintenance
- Reduced Costs / Increased Profits

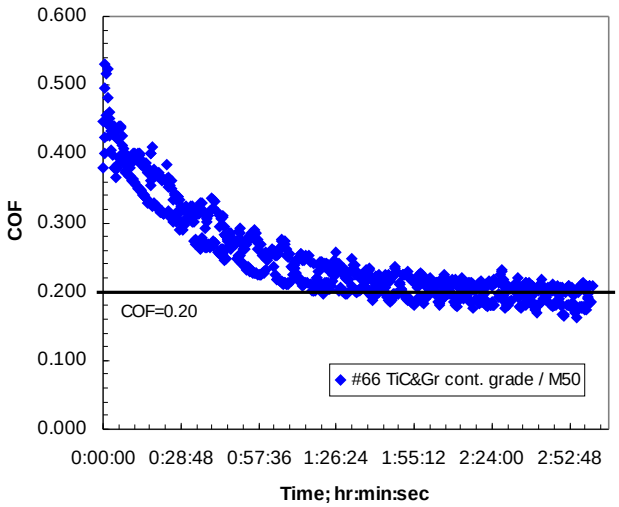
Performance Results

Optimization of coating deposition protocols has resulted in excellent coating adhesion and coating/substrate interfacial toughness, as shown by below as no flaking from a high load (1.47 kN (331 lb)) indentation with a conical indenter.



Excellent Adhesion of TiC/a-C Coating on 52100 Steel After High-Load Indentation

Mechanical property tests on these coatings have shown: 1) high hardness (e.g., 20-35 GPa vs. 11 GPa for non-coated bearing steel), 2) a low (<0.2) dry coefficient of friction (COF), which reduces with time (see below), 3) very low wear factors, and 4) fretting-wear resistance vs. Al alloy (see data on pg. 2).



Continual Reduction in COF vs. Time for TiC/a-C Coating on M50 Steel

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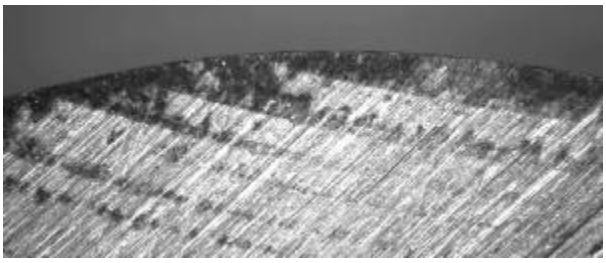
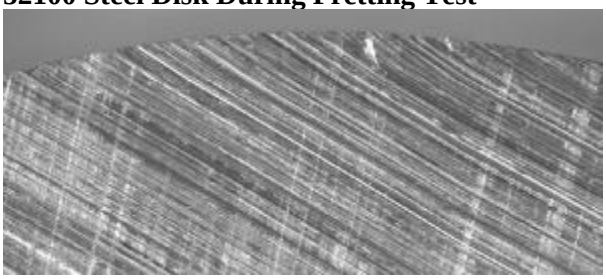
Fretting wear resistance of 52100 and M50 steels vs. A357Al alloy is required to reduce material transfer from the softer Al surface to the harder steel. Debris transfer can serve as sites for fatigue crack initiation and eventual part failure. Shown below are simulated fretting-wear test results on bare and TiC/a-C coated 52100 steel, which includes nearly complete elimination of Al transfer to the coated steel surface.



Black Al Debris Transferred to Non-coated 52100 Steel Disk During Fretting Test



Elimination of Al Debris on TiC/a-C Coated 52100 Steel Disk During Fretting Test

Technology Status

The carbide/solid lubricant coating technology is currently under development by ECI under Phase II of a U.S. Navy Small Business Innovative Research (SBIR) Program. Optimization of coating processing parameters and deposition protocols is being conducted along with process scaling to a larger deposition chamber, which will be used to coat larger parts and larger quantity of parts. Engineered Coatings has entered into a Cooperative Research and Development Agreement (CRADA) with the Air Force Research Laboratory (AFRL) to enable property comparison of films fabricated by our method with a pulsed laser/sputter-deposition method.

Engineered Coatings is also developing (under a Phase I SBIR program) diamondlike-carbon (DLC) composite coatings with the incorporation of H-containing gas during deposition, which will further reduce coefficient of friction exhibited by a-C matrix coatings.

Industry tests/evaluations of the carbide/solid lubricant a-C coating technology are being conducted by a coating toll service vendor and a major proprotor/aircraft systems integrator. The proprotor manufacturer is conducting subsystem-level shaker table tests of non-coated and ECI-coated bearing components vs. a cast Al housing part to simulate operational conditions in the rotorcraft proprotor.

Technology Evaluation Opportunities

Engineered Coatings welcomes and encourages mechanical system designers, developers, and integrators to consider evaluation of this unique carbide/solid lubricant coating technology that ECI is developing. Our materials scientists/engineers and thin-film experts will assist in coating materials recommendations and processing approaches to solve your surface-related problems.

Engineered Coatings routinely conducts small-scale coating feasibility trials for customers. If required, we can also perform coating screening tests; including ball-on-disk adhesion/wear, galling, and simulated fretting-wear evaluations.

For further information, please contact:
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