A characterization of a CrN multi-layer coating was completed on behalf of Cummins Fuel Systems. Three samples, each subjected to a different post-grind polishing method, were examined. The following properties were tested in each sample: residual stress, hardness, elastic modulus, surface roughness, and adhesion. Based on adhesive performance, sample 12 proved superior to samples 4 and 8, because less cracking and no delamination occurred. Greater variation in residual stresses present in the coatings are likely what resulted in more extensive cracking and delamination in samples 4 and 8. A large variation in hardness and elastic modulus values, similar to the variation for the residual stress, was seen in samples 4 and 8.

**Objective:** Perform a comprehensive characterization to identify why coated hardware is performing worse than uncoated hardware.

**Materials**
- All samples had the following characteristics:
  - H13 substrate
  - Vacuum core hardened with gas quench
  - Gas nitrided at 450°C for 10 hours
  - 50 µm of surface removed during grinding

**Sample Post-grinding Polishing**
- 4: None
- 8: Plasma Electrolytic Polishing
- 12: Tape Polishing

**Residual Stress**

**Results**

**Residual Stress**

The surface measurements shown indicate the level of internal stresses in the steel substrate just below the multi-layer coating. Missing portions of each circle correspond to areas that were removed for hardness and modulus gradient measurements.

**Hardness and Elastic Modulus**

For a 95% confidence interval, microscale (<50µm) scratch and surface roughness is indistinguishable in all samples. Microscale roughness for 4 and 8 were comparable, while 12 was larger than both. At the macroscale, 8 was the smoothest, followed by 12 and then 4.

**Discussion**

Sample 12 exhibited the least variation and greatest uniformity in property measurements. A single conclusion or average value for each property was more easily converged upon for sample 12 than for samples 4 and 8.

Residual stress in samples 4 and 8 have regions of both high tension and high stress. Such variation effects adhesion and crack behavior across the surface. Areas of the coating in tension are more susceptible to film fissure and areas in compression are more likely to experience delamination.

**Recommendations**

- Tape polishing correlates with uniform property measurements, and should be used as the preferred post-grind polishing method.
- Residual stress mapping should be used to predict coating fracture behavior.