PURDUE UNIVERSITY

School of Materials Engineering

# Characterization of “Wide Peening Cleaning” Die Surfaces for Automotive Applications

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**Abstract:** This study aims to **assess the effectiveness of Wide Peening Cleaning (WPC) treatment in enhancing the mechanical properties and wear characteristics** of automotive-grade steel commonly used in dies. The baseline steel, SUS440C was selected for initial evaluation and is representative of materials prevalent in automotive dies. Test coupons of the SUS440C steel underwent comprehensive analyses including **surface stress, hardness, roughness, and sliding wear tests**, serving as benchmarks for comparison. Subsequently, additional steel samples were subjected to either traditional shot peening or the advanced WPC treatment. These treated samples underwent identical testing protocols as the untreated baseline samples to evaluate the impact of each treatment method on material properties and wear resistance.

This work is sponsored by Toyo Seiko, South Bend, IN

## Project Background

Wide Peening Cleaning (WPC) is a process currently localized in Japan. The process involves a combination of bombarding the surface of the metal with titanium powder and heating and cooling cycles to treat the metal. Toyo Seiko wishes to see the results of various **mechanical testing on both Shot Peened (SP) and Wide Peening Cleaned (WPC) samples compared to baseline samples.**

| [number of samples] Sample Types ↓ | *Testing* | | | |
|---|---|---|---|---|
| | Sliding Wear | Surface Hardness (Rockwell + ≥ 3 Vickers) | Surface Imaging (Optical & Roughness) | Surface Residual Stress (Pulse-Tec) |
| “Baseline” | 2 | 2 | 2 | 2 |
| Baseline + “shot peening” | 2 | 2 | 2 | 2 |
| Baseline + “WPC” | 2 | 2 | 2 | 2 |

Table of testing regiments


## Experimental Design

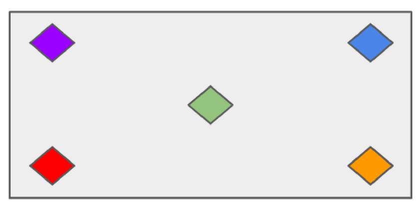
### Material Choice

| Steel Grade | Chemical Composition (%) | Hardness (HRC) | Density ($kg/m^3$) | Corrosion Resistance |
|---|---|---|---|---|
| SUS440C | C: 0.95 - 1.2; Mn: <1; S: <0.03; Cr: 16-18; Fe: remainder; Si: <1; P: <0.04; Ni: <0.6; N: <0.75 | 58 | 7780 | Fresh water, steam, crude oil, gasoline, perspiration, and alcohol |

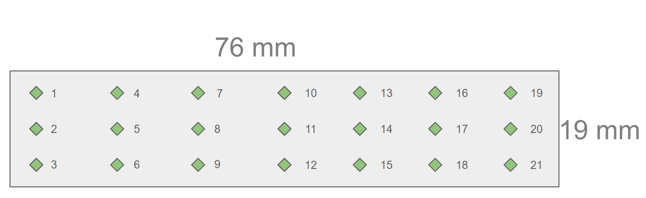
Two sample thicknesses were used: **1/8” and 1/16”** to determine if the thickness affected the extent of the processing method.
All samples were heat treated to a **Rockwell hardness of 57**.
Shot peening and WPC treatment were performed on several samples

### Hardness Testing

Surface hardness testing was a crucial aspect of our investigation to the effects of shot peening and WPC. To ensure comprehensive evaluation, we conducted five-point testing on each sample. These points were strategically selected, located on the corners and center of the rectangular samples. Using a **Rockwell indenter on the C scale** with a **1500 kg load**, we measured hardness at these designated points and subsequently averaged the results to provide a comprehensive representation of surface hardness across the samples.

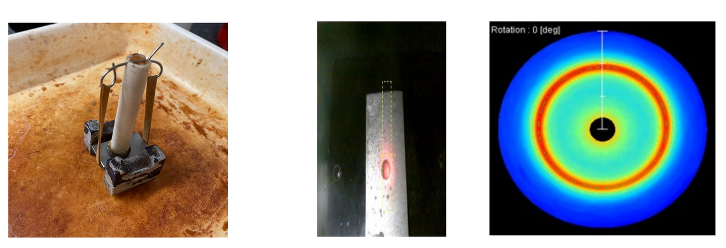


To assess the impact of shot peening on **hardness through the material depth**, we conducted **Vickers testing** on cross-sectional samples. The indentations were placed at different depths with 21 indentations in a 7x3 matrix using a 10gf load.



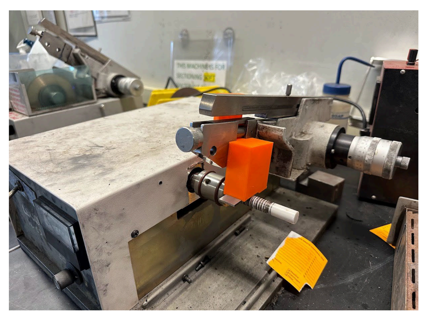

### Residual Stress Testing

A residual stress profile was created to compare the difference between SP, WPC and test coupons without any peening treatment (as heated). Residual stress correlates to the strengthening and toughness of the material after the material is processed through peening. The test coupons were electro-etched with a 72 A current for approximately 1 minute to create a 1 mm depth which was measured by a dial indicator. Afterwards, the coupon was placed in a PulsTec XRD with a chromium tube at 35° to gather the residual stress data through the position of the Debye-Scherrer ring, and this process was repeated until a depth of 8 mm was reached.



### Sliding Wear Test

A sliding wear test was run on each sample to analyze how the processed surfaces could resist imposed wear. Each sample was subjected to 2 hours of rotation under a 10N load at 130 revolutions per minute, which equated to 620 meters of distance worn. At each 30-minute mark, the wear groove width was measured and converted to groove depth and volume removed.



Each sample was compared to the others to determine which processing method resists the most wear. No lubricants were used for this test.

### Optical Profilometry

- Zygo profilometer
  - Utilized bands of light to image a topographical surface of 160 x 220 µm.
- Also analyzed the surface range values (Spv), Surface average (Sa), and Surface root mean square average (Sq)

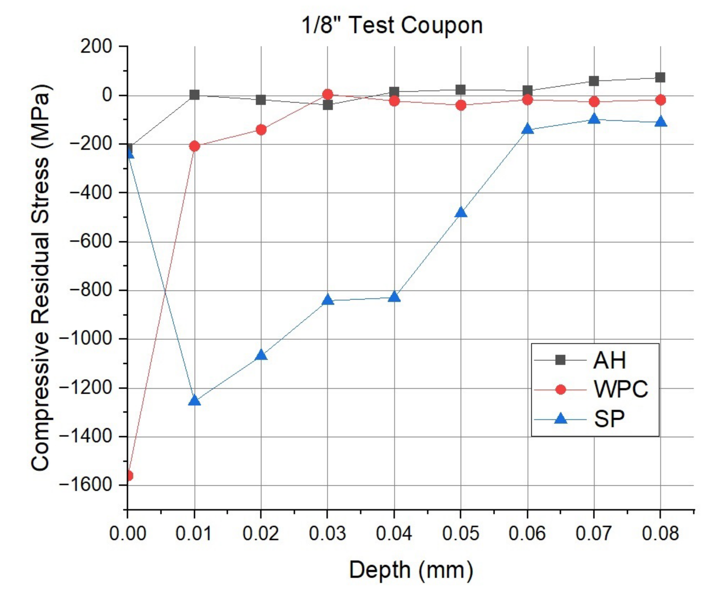
## Results & Discussion

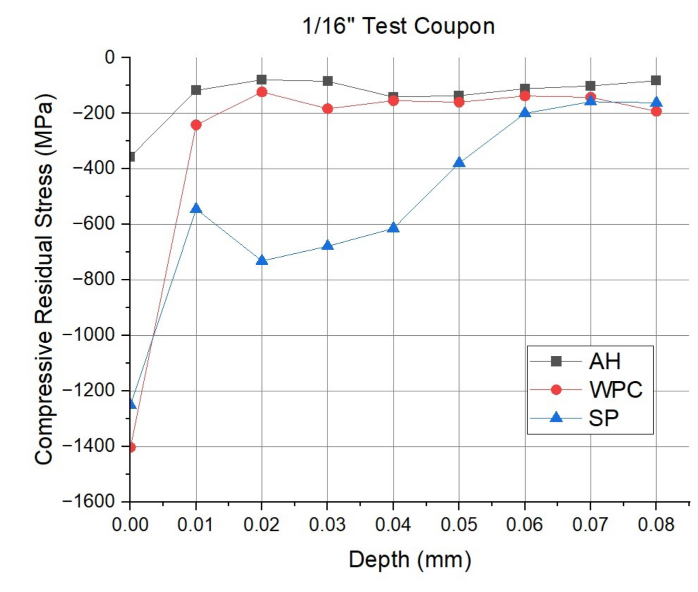
### Hardness Testing

| | Surface Hardness | | | | Through Material Hardness | |
|---|---|---|---|---|---|---|
| | 1/16 Sample 1 | 1/16 Sample 2 | 1/8 Sample 1 | 1/8 Sample 2 | 1/16 | 1/8 |
| As heated | 57.5 ± 0.7 | 35.4 ± 4.8 | 55.1 ± 2.0 | 34.5 ± 11.4 | 58.2 ± 2.8 | 57.4 ± 2.7 |
| Shot Peened | 57.2 ± 1.3 | 42.8 ±10.8 | 27.0 ±3.6 | 36.0 ± 10.4 | 60.3 ± 1.4 | 57.1 ± 1.6 |
| WPC | 30.2 ± 10.0 | 39.1 ± 5.0 | 34.2 ± 9.0 | 29.5 ±4.9 | 61.8 ± 4.0 | 58.6 ± 2.9 |

- Most of the samples retained their heat treated hardness of about 57, with the exception of some unusually low hardness measurements.
- The low hardness data exhibited far greater variability and inasmuch is difficult to explain and/or substantiate.

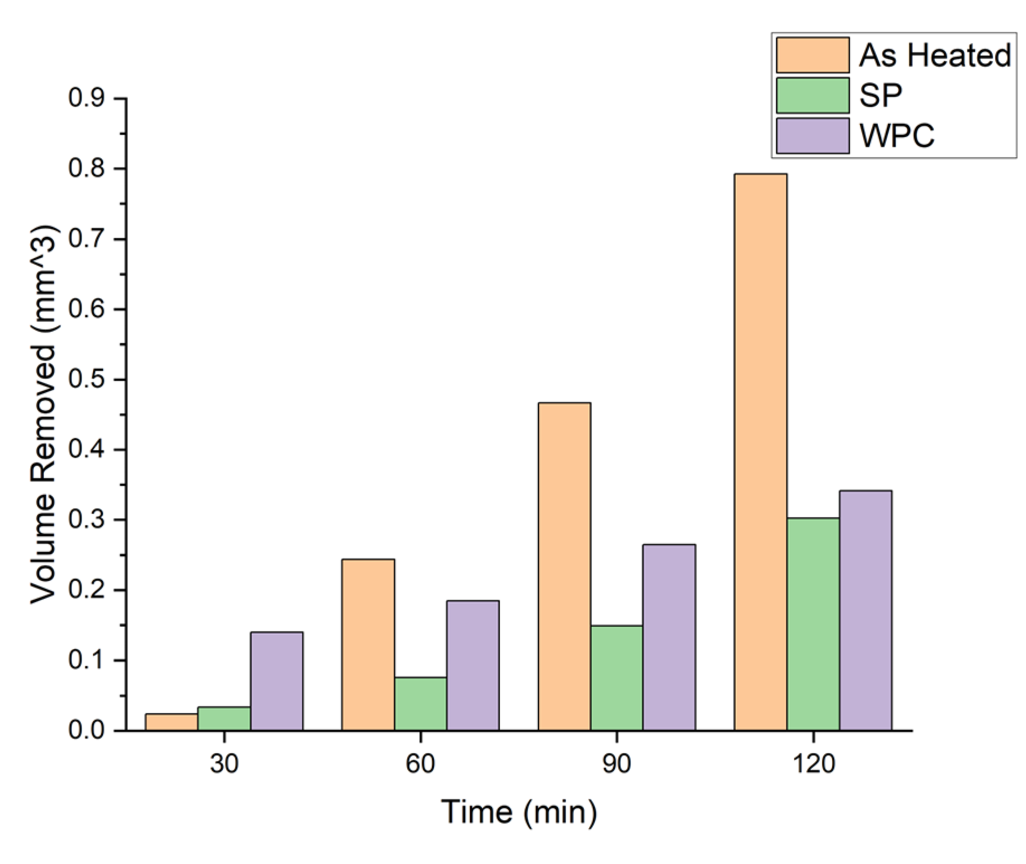
### Residual Stress Testing




- Compressive residual stress for both WPC coupon thicknesses is **higher than** the stress for SP test coupons at the surface (0.00 mm)
- Indicates that peening **successfully induced hardness** into the material.

### Sliding Wear Test

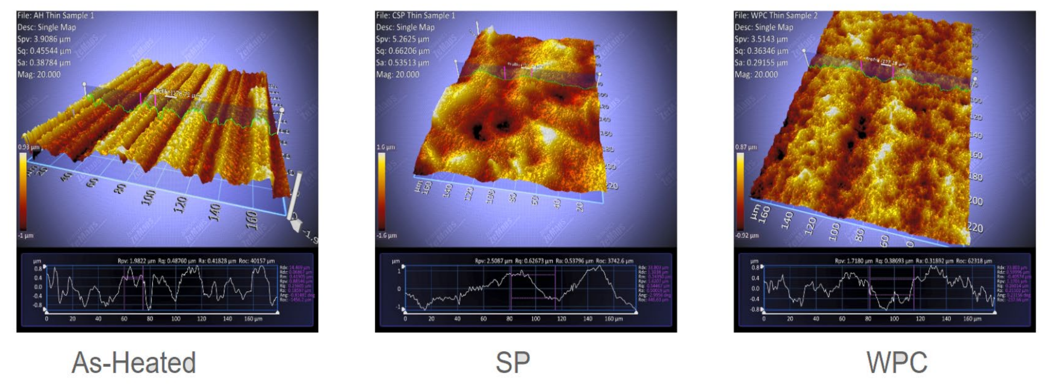



Typical developed wear groove.

- Both the SP and WPC operations significantly improved the wear resistance of the samples compared to their as heated condition
- The SP and WPC specimens experienced 62% and 57% decreases in wear respectively

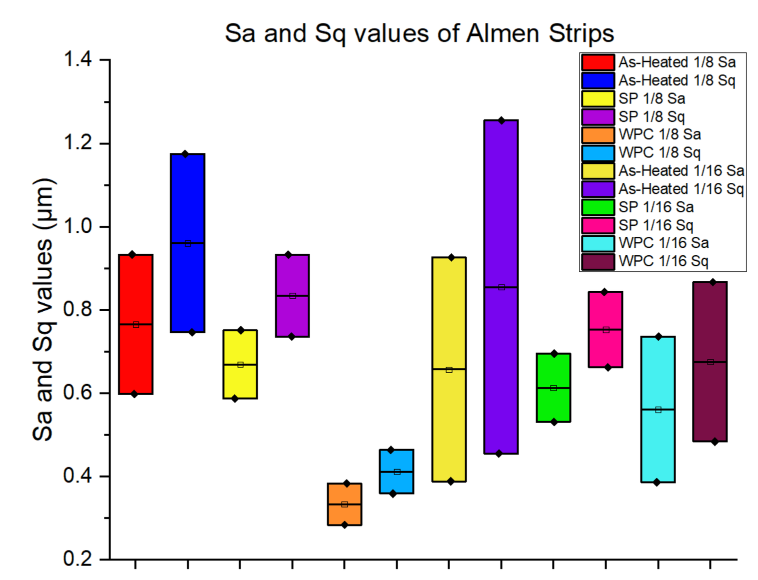
## Results & Discussion Cont.

### Optical Profilometry




- As-heated sample shows **evidence of rolling**
- SP sample shows indent of shot medium and **little to no evidence of rolling**
- WPC sample shows **evidence of titanium powder** impacting surface
- WPC sample also shows that it **does not fully remove evidence of rolling**

### Surface Roughness




- **As-heated samples are the roughest**
- As-heated samples also show **highest variance** in roughness
- SP is rougher than WPC

## Conclusions & Future Work

- With the exception of some unusually and difficult to explain low hardness measurements, neither shot peening or WPC significantly changed sample hardness.
- While hardness did not appear to be changed by shot peening or WPC, other measurements also demonstrated “classic benefits” associated with “peening” The surface residual stresses of the WPC and SP specimens significantly exceed those of the as-heated specimens
- In wear testing, the SP and WPC specimens both surpass the resistance of the as-heated specimens, with a 62% and 57% decrease in wear respectively
- According to the surface roughness data, **the WPC parts are smoother than the SP parts**, but roughness will differ on a case-by-case basis
- Overall, **both WPC and shot peening produce surfaces with improved mechanical characteristics over the baseline.**
- Future work considerations include a **corrosion testing series** especially for automotive components
- Additionally, development of a **Finite Element Analysis (FEA)** model to simulate mechanical behavior of parts in use

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