Fine Media Peening Effects on Corrosion Resistance of Diesel Engine Materials

PURDUE UNIVERSITY
School of Materials Engineering

Student Team: Allison Hirzel, Zoe Johnson, Jacob Fish, Noah Wheeler
Faculty Advisors: Dr. Paul Mort, Dr. Mark Gruninger
Industrial Sponsors: Cummins, Progressive Surface, Ervin Industries, Electronics Inc

Fine media peening has recently become more widely used in numerous emerging technologies within automotive, diesel engine and aerospace applications. This work characterizes fine media shot samples and qualitatively correlates the surface topography and residual stress profiles of peened samples to corrosion resistance. This process was done using both hardened S70 on steel grades 4140 and 52100. A second round was done used courser CCW32 shot media on Almen strips (steel grade 1070).

This work is sponsored by:
Cummins, Progressive Surface,
Ervin Industries, & Electronics Inc.

Motivation

Diesel engines are made of select high-strength steels to **withstand cyclic fatigue and corrosion.**

Shot Peening is primarily used to **increase** fatigue strength by imparting compressive residual stresses on a surface.

While shot peening benefits fatigue, its effect on corrosion resistance is not fully understood.

Corrosion Resistance

Corrosion resistance is *highly influenced* by **composition.** **Chromium and Aluminum improves corrosion resistance**, but at the tradeoff of strength

Evaluating shot peening for its effect on corrosion resistance will clarify whether it can be used to avoid such a tradeoff for diesel engines

Table 1: Nominal Composition (wt%) of Sample Alloys

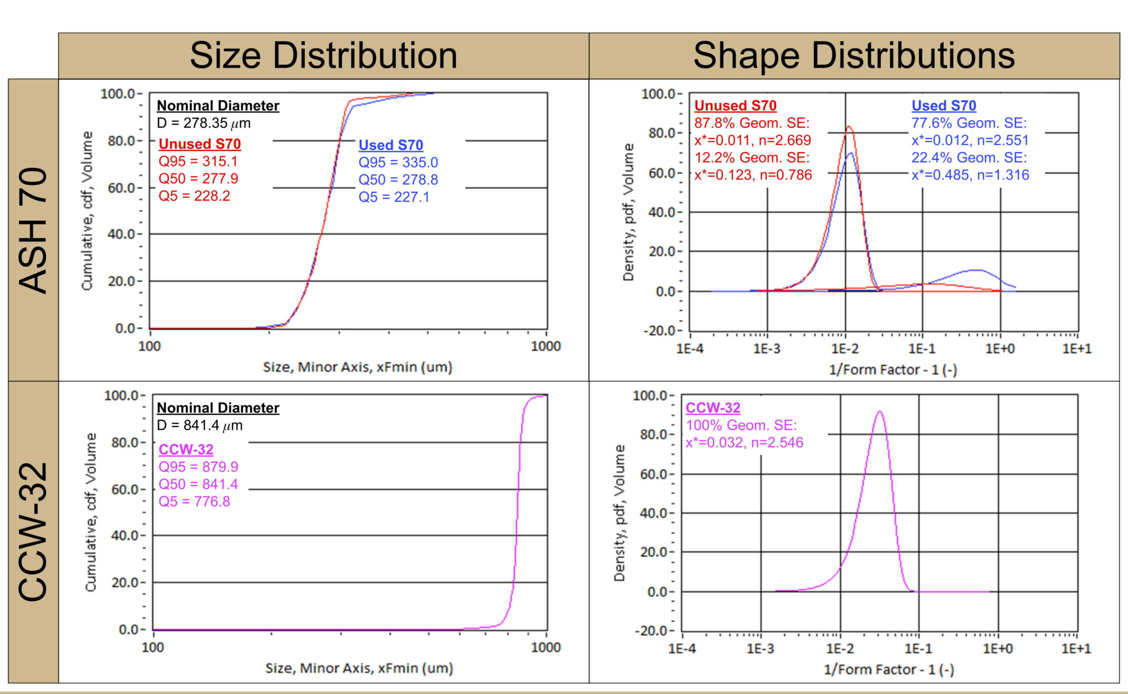
Element	4140	52100	1070
Carbon	0.405	1.040	0.700
Chromium	0.950	1.450	-
Manganese	0.875	0.350	0.750
Molybdenum	0.200	-	-
Silicon	0.225	0.225	-
Phosphorus	≤ 0.035	≤ 0.025	≤ 0.040
Sulfur	≤ 0.040	≤ 0.025	≤ 0.050
Iron	Balance	Balance	Balance

Media Characterization

Minor Axis: minimum diameter of a media particle. Used in the size distribution plots due to its correlation to sieving.

Form Factor: overall roundness of an imaged media particle. Inverted form factor plots place **rounder media closer to zero**, less round media further from zero.

Media Used: Hardened S70 (ASH70) and Cut Wire (CCW32)



Shot Peening Systems

Progressive Surface

3/8” Long Venturi nozzle

ASH70 media (60+ HRC).

Peened at Almen A *intensities of 4, 7, and 10* (based on industry peening standards)

Sentenso at Purdue MMRL

1/4“ Straight Bore nozzle

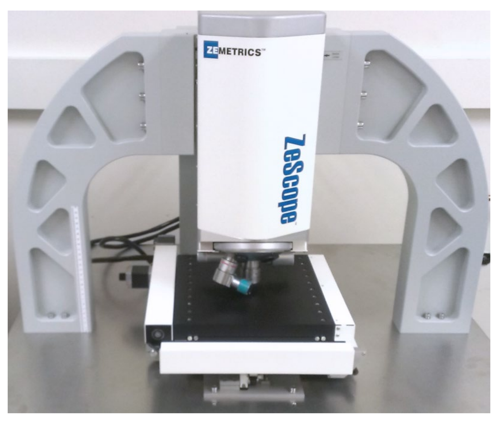
CCW32 media (63 HRC).

Single and triple coverage conditions peened at Almen A intensity of 7.5

Table 2: Summary of Shot Peening Parameters

Peening Media	Workpiece Material	Workpiece Thickness (in.)	Air Pressure (psi)	Media Flow Rate (lb/min)	Impingement Angle (deg.)	Almen A Arc Height (1/1000 in.)	Exposure Time (s)
ASH 70 (60+ HRC)	4140 Steel 52100 Steel	0.25	18	10	45	3.9	0.756
			56	5	45	6.9	0.612
			41	3	90	10	0.864
CCW-32 (63 HRC)	Almen A Strip (1070)	0.051	14.5	5.08	45	7.48	16
			14.5	5.08	45	8.39	48
	Almen C Strip (1070)	0.094	14.5	5.08	45	2.03	16
			14.5	5.08	45	2.69	48

Characterization Methods



Residual Stress

Pulse-Tec u-X360

- Uses radiation to determine residual stress of surface
- Electro-etch samples to achieve different depths
- Use 9.8V and 0.5Amps for 2 min to achieve 0.01mm additional depth

Surface Topography

Zygo ZeScope Optical Profilometer

- Place samples under microscope lens and image at 5x magnification
- The scan area is 900μm x 900μm.
- The average roughness (S_a) is provided to create quantifiable comparisons

Sample Characterization

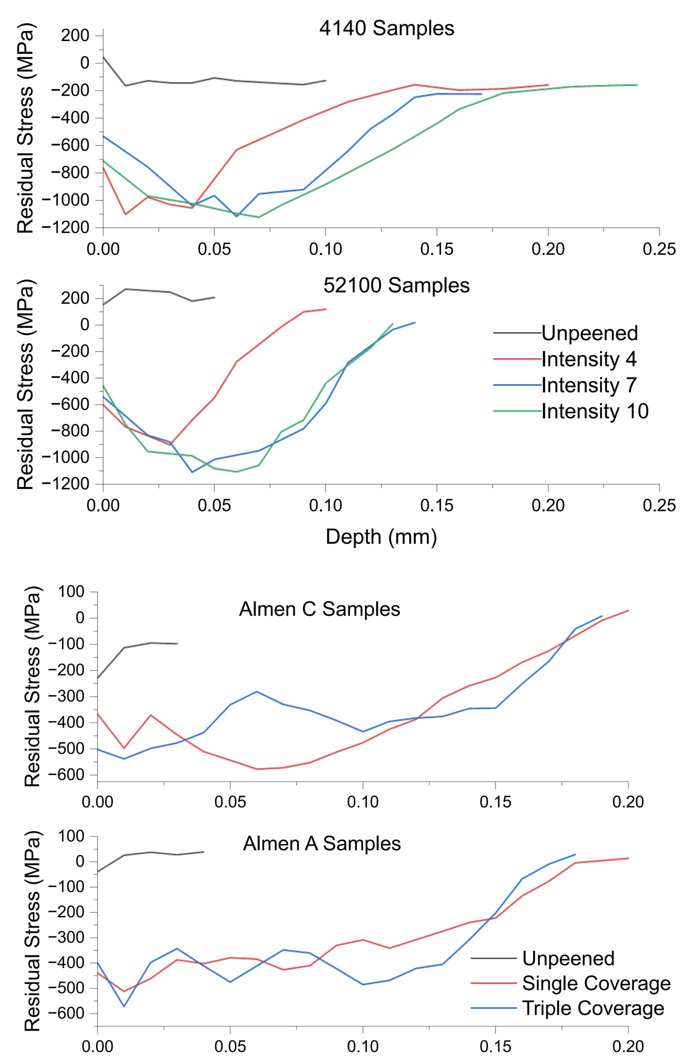
Residual Stress

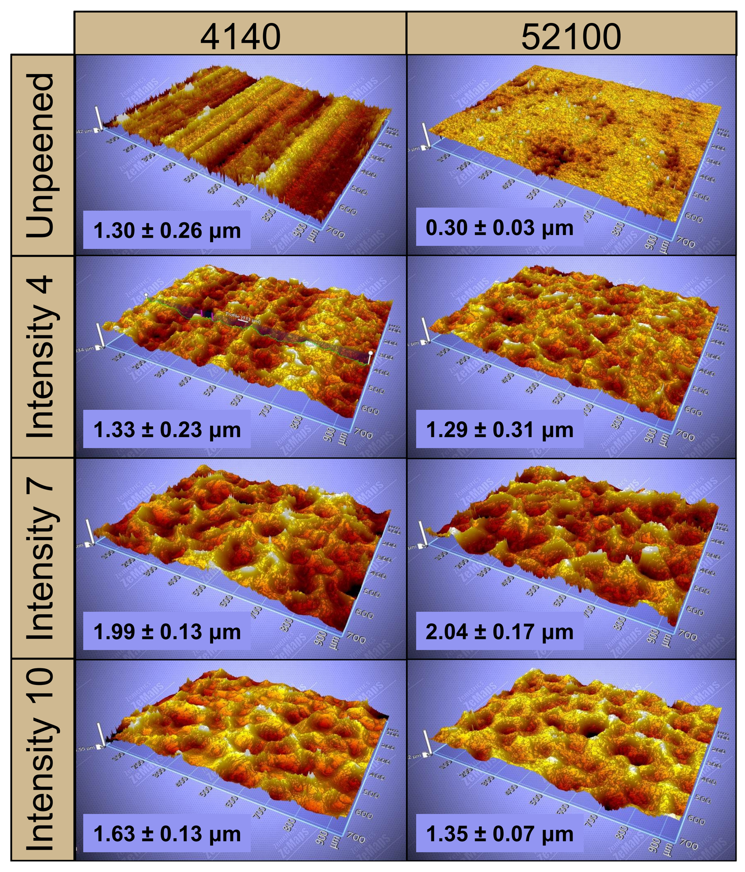
The stress profile in the graphs to the left show the compressive residual stress that is within the sample as the intensity of peening increases.

For *4140* and *52100* grade steel, *intensity 10* had a **maximum** compressive stress (1100-1200 MPa) **deeper** into the sample.

For *Almen C and A* strips, *single coverage* and *triple coverage* are essentially the **same**.

Single coverage **work hardens** the material, while *triple coverage* ensures **maximum stress** is reached.

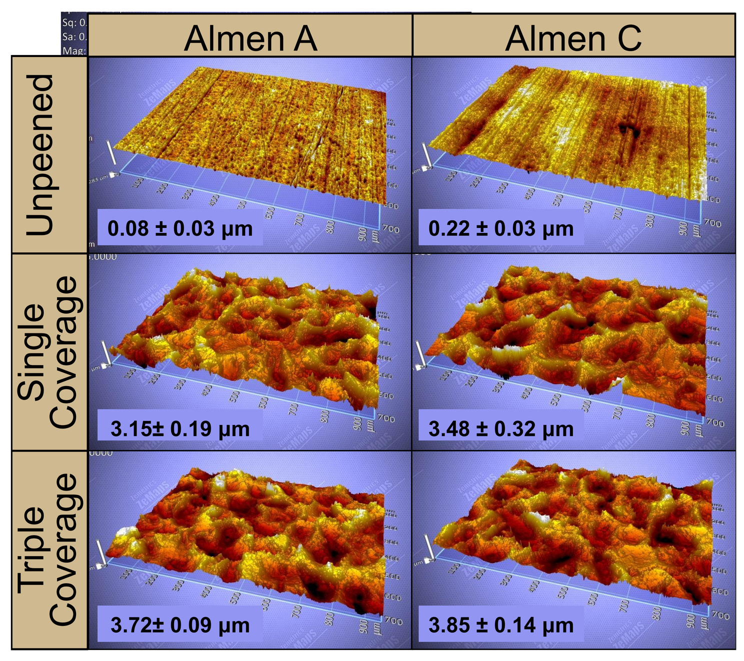




Surface Topography

An optical profilometer was used to measure the surface topography before and after peeing was completed. The **average roughness (S_a)** is provided to create a meaningful connection between peening and surface topography.

For *4140* and *52100* grade steel the average roughness of the material **increased** at *intensity 7* and **decreased later** when increasing the intensity of shot peening.



Almen A and C strips show that in *triple coverage* the dimples are more prominent. Due to the **increase** in media size as well as an **increase** in peening duration time.

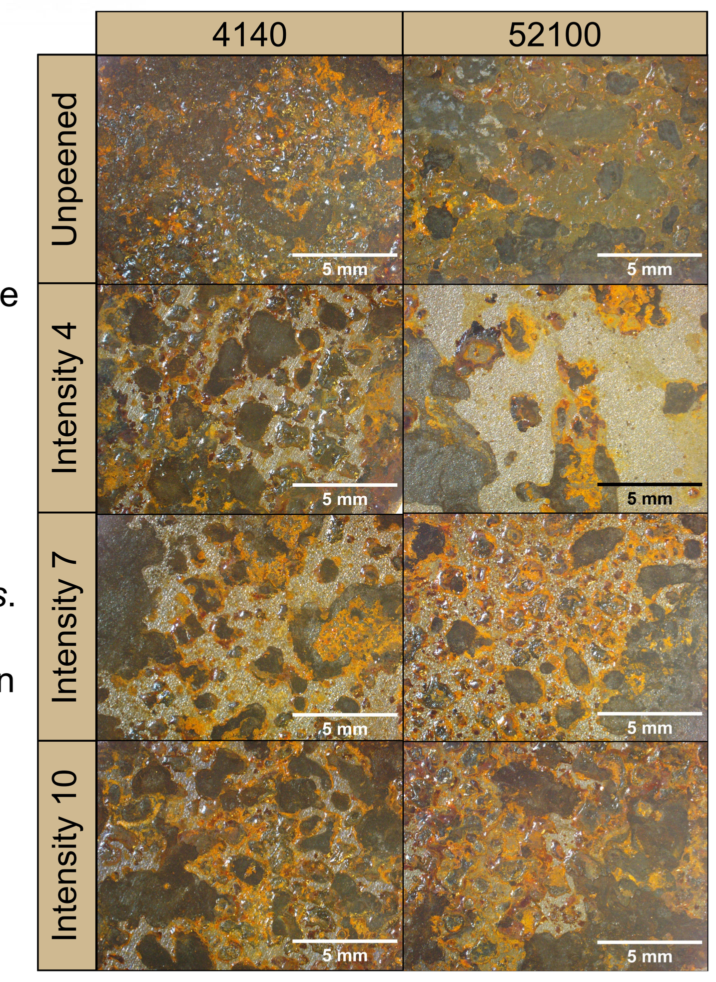
The average roughness was very similar from single to triple coverage.

Corrosion Testing

Corrosion testing was done in a **Q-Fog CCT chamber** at Cummins.

Samples placed in humidity chamber for 24 hours at 100ºF with water fog.

Centers of samples are displayed



Both *unpeened 4140* and *52100* samples had the **most** corrosion.

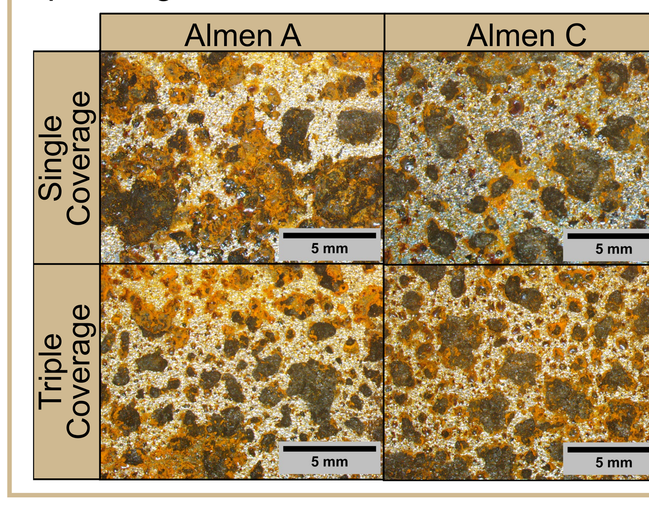
The *4140 intensity 7* sample had the **least** amount of corrosion out of *all 4140* samples.

The *52100 intensity 4* had the **least** amount of corrosion out of *all samples.*

The corrosion **decreased** in severity after peening.

There is an **increase** in severity as intensity **increases**.

Both *Almen A and C* samples have **similar** levels of corrosion for each peening condition.



Slightly less corrosion on single coverage Almen C compared to single coverage Almen A due to increased thickness.

The *triple coverage* samples have spots of corrosion are **smaller**, but more evenly spread compared to the *single coverage*.

Discussion & Conclusion

Fine media peening of *4140* and *52100* show:

- **Increased** corrosion resistance with shot peening
- **'Sweet spots'** between intensity of peening and corrosion resistance
  - *Intensity 7* for 4140
  - *Intensity 4* for 52100
- **Overpeening** effects at *intensity 10* for both steel grades

Coarse media peening of *Almen strips* show:

- **Increased** number of corrosion nucleation sites with *triple coverage*
- Slight **decrease** in corrosion amount as thickness **increases**

Overall:

- A link **does** exist between shot peening and corrosion resistance
- Intensity **'Sweet spots'** exist providing maximum corrosion resistance
- **Overpeening** causes **lowered** corrosion resistance
- Surface topography and compressive residual stresses may not be the dominant mechanisms controlling corrosion resistance

References

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3. Mort, P., Feltner, L., “Characterization of Shot Size and Shape Distribution”, *Science Update*, 23, p. 52-54, 2022.

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