

This project focuses on developing **optimal shot peening parameters**, including Almen A arc height settings, for induction-hardened steel shafts to **improve fatigue performance by enhancing compressive residual stress for axle applications**. At the spline transition region of a shaft, the surface structure and properties factor significantly into tribological effects. **Residual stress and topography characterization** are used to evaluate the efficacy of the developed shot peening parameters with DCCW 20 shot media at **Purdue's Manufacturing & Materials Research Lab (MMRL)**. Modeling of the peening effects is completed using an existing simulation program and the experimentally developed parameters.

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Background

Induction-hardened 1050 steel shafts manufactured by AAM feature a **spline transition region** where the radius decreases from the shaft to the spline, as outlined in red. Shot peening parameters for the Progressive Peener at MMRL are optimized for this region to **improve resistance to fatigue**.



Project Objectives

Process Development: Establish shot peening settings that achieve the desired Almen A intensity.

Residual Stress Characterization: Measure and document residual stresses at both 100 and 200% coverage at specified depths.

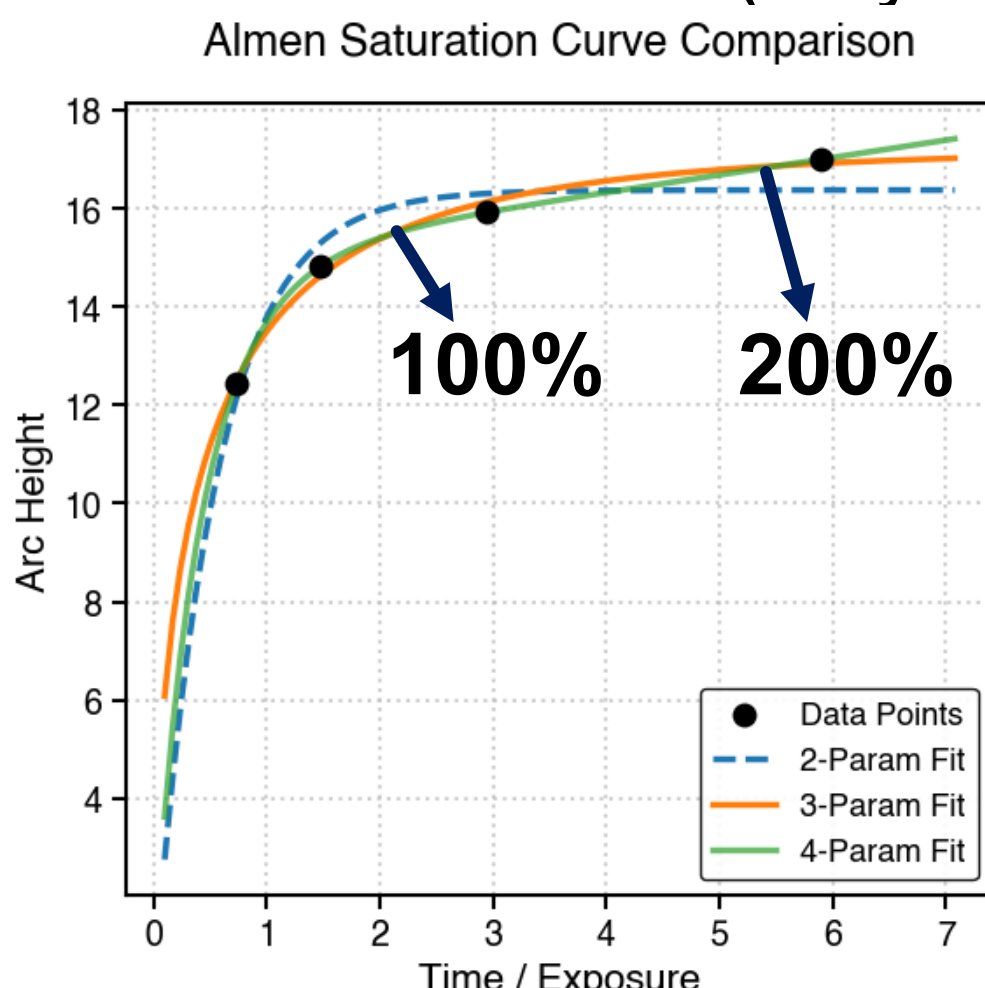
Surface Roughness Analysis: Quantify surface roughness changes from unpeened to the 100% and 200% coverages.

Model Comparison: Compare experimental results to industrial models and simulations.

Experimental Techniques

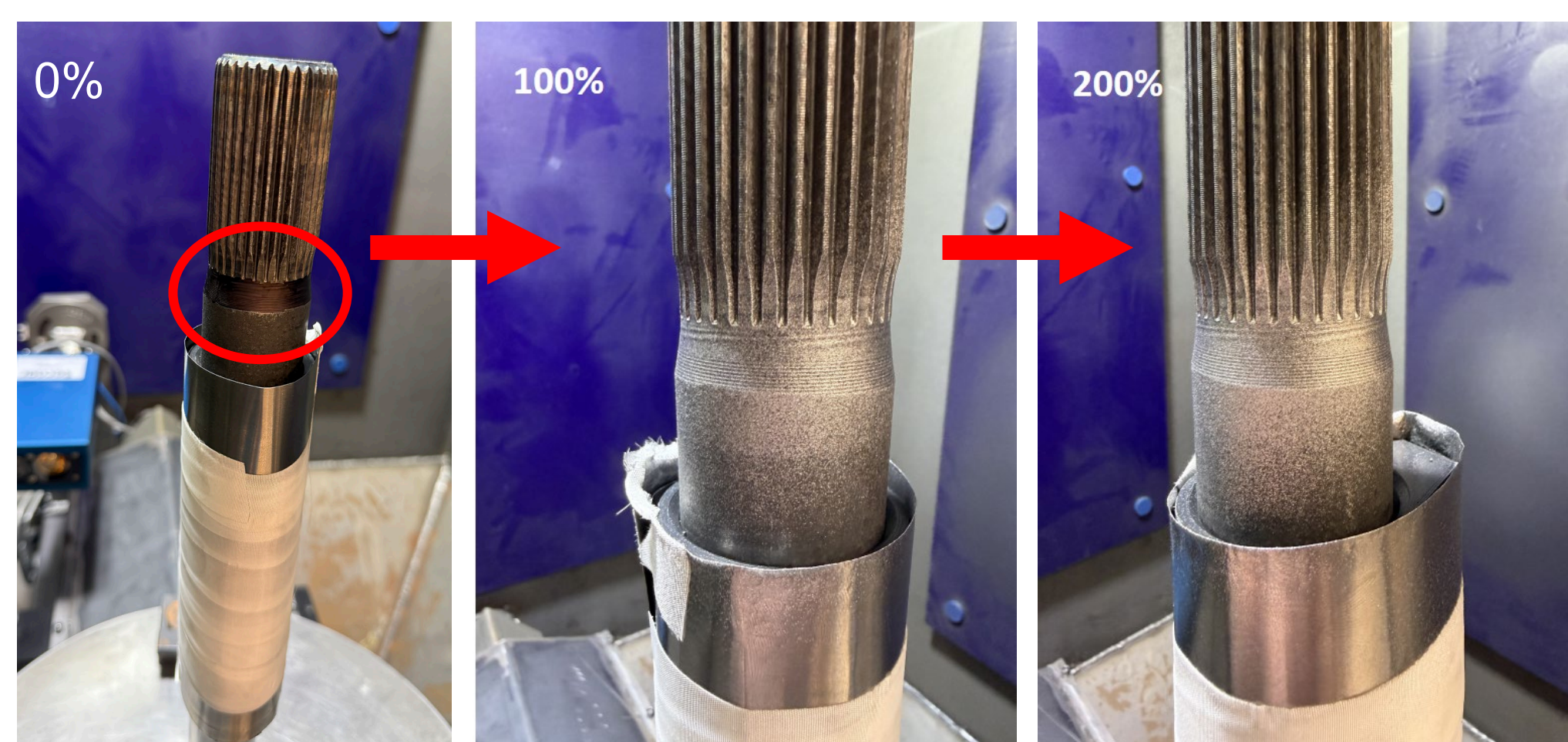
Parameters Used to Develop Target Intensity

- Air pressure = 50 psi
- Media flow rate = 10 lbs/min
- Standoff from nozzle to Almen A strip = 6 inches
- Nozzle angle to strip = 90 degrees
- Translation speed = 33 in/min
- Wheel rotation (only for shaft peening) = 20 RPM



Time (s)	Intensity A (10 ⁻³ in.)
0.7375	12.44
1.4750	14.82
2.9500	15.92
5.9000	17.00

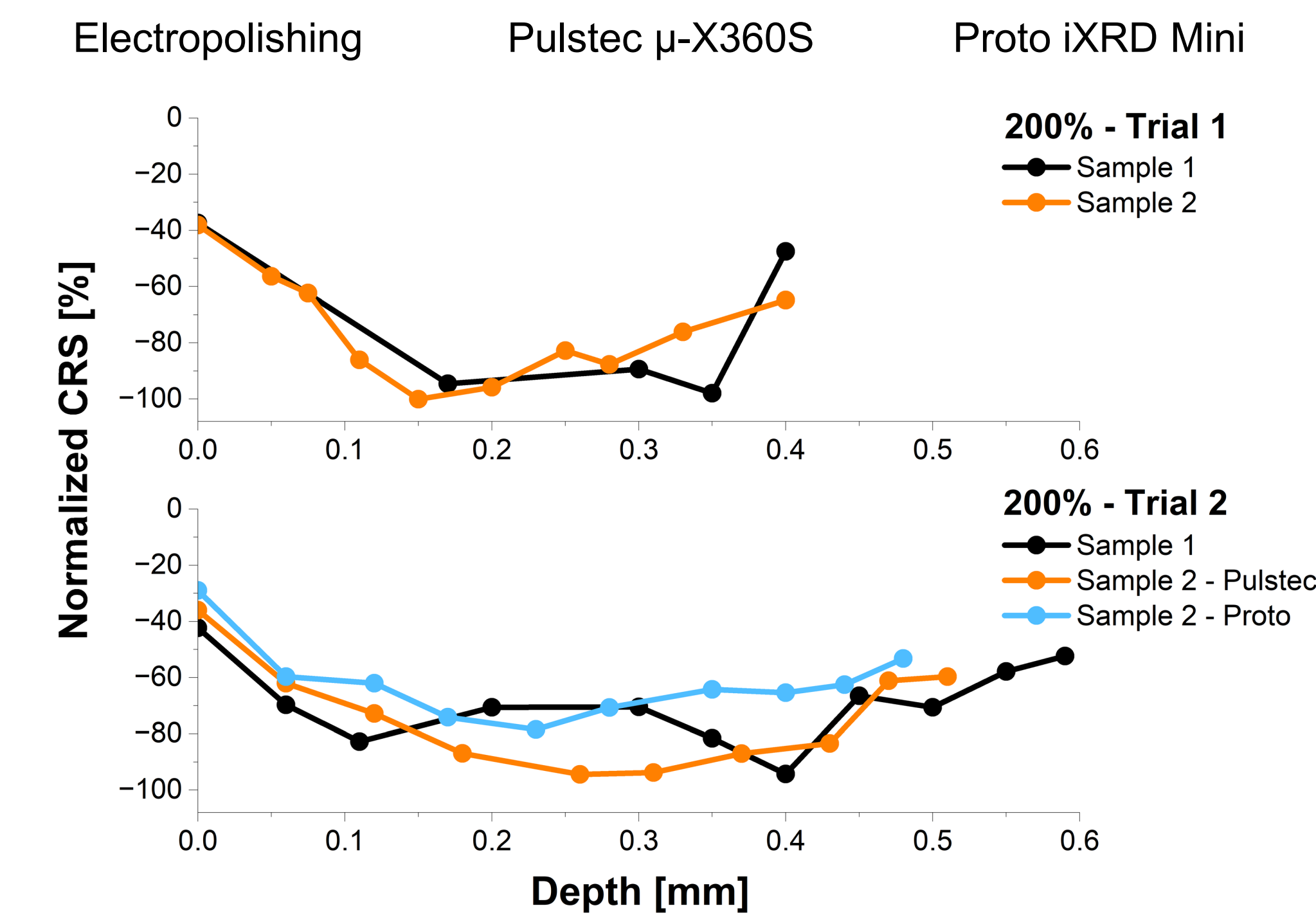
Based on where the intensity curve above saturates, and according to the curve fitting parameters, the achieved intensity is **14.71-14.73A**. The intensity curve **saturation** corresponds to **100% coverage**. The transition region is marked in black ink, and 100% coverage is determined by the full removal of the ink after peening. **200% coverage** is achieved by **doubling the peening time**.



Time frame	Samples Peened	100% Coverage	200% Coverage
Trial 1	8	4	4
Trial 2	8	4	4

Compressive Residual Stress

Shot-peened shafts are **electropolished** using a cotton swab soaked in 4% NaCl solution^[1]. **Depth** is measured with a spring-loaded depth gauge. The Pulstec μ -X360S ($\cos \alpha$) and the Proto iXRD Mini ($\sin^2 \psi$) measure the **compressive residual stress (CRS)** to create CRS depth profiles^[2,3].

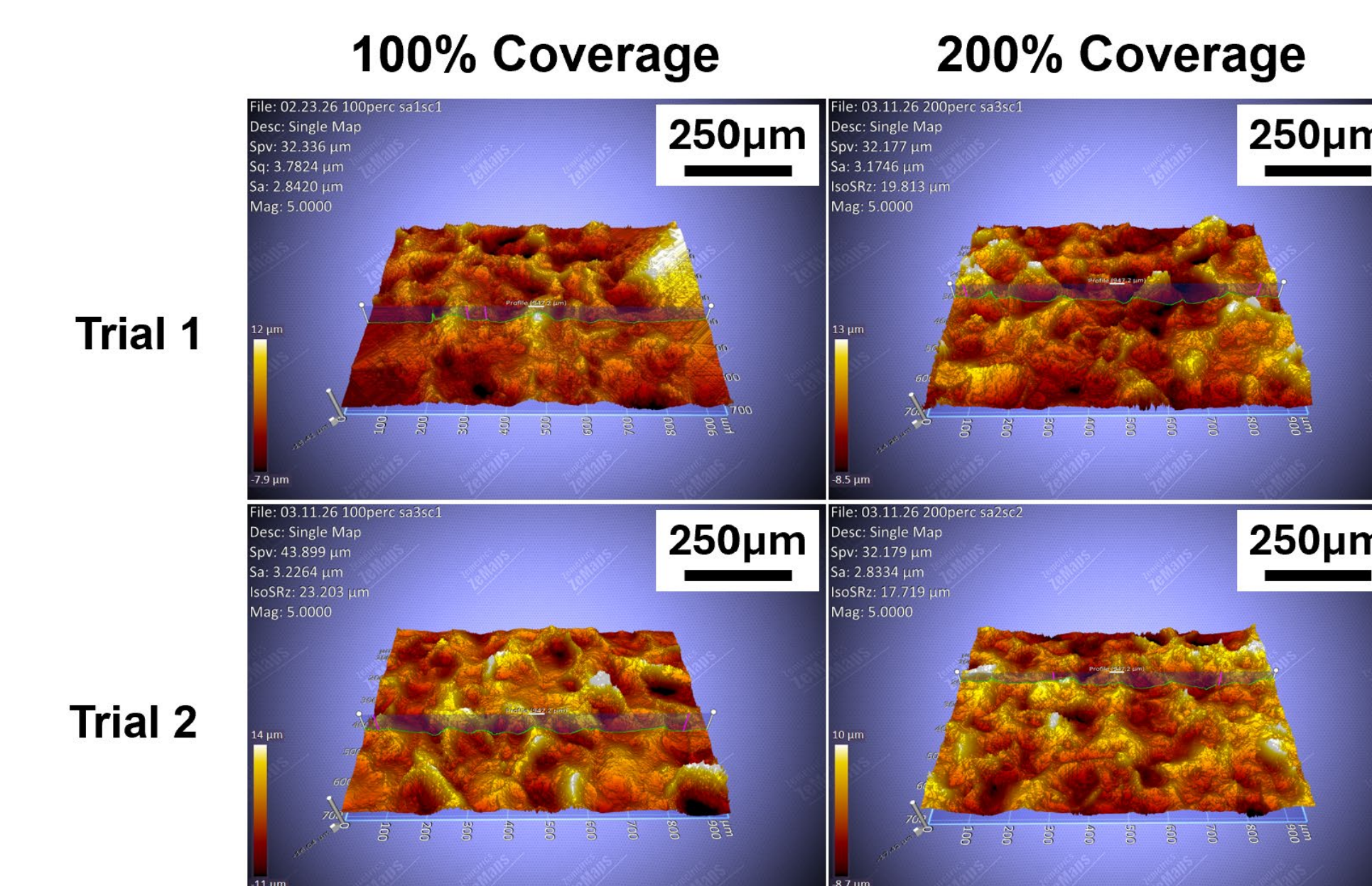


Surface Characterization

Surface topography is characterized with a Zygo ZeScope Optical Profilometer^[4]. **Surface roughness** is quantified with the following parameters:

- Spv:** Maximum peak-valley difference of the entire scan
- Sa:** Arithmetic mean deviation of the entire scan
- ISO SRz:** Mean of 5 sections' max peak-valley differences of the entire scan
- Rz:** Mean of 5 sections' max peak-valley differences of a chosen profile

Parameter (μm)	Unpeened (Control)	100% Coverage		200% Coverage	
		Trial 1	Trial 2	Trial 1	Trial 2
Spv	64.80	34.35	35.45	33.32	33.04
Sa	9.68	3.52	3.08	3.68	3.00
ISO SRz	23.51	16.92	18.99	19.46	17.15
Rz	14.69	8.50	8.20	10.68	8.59



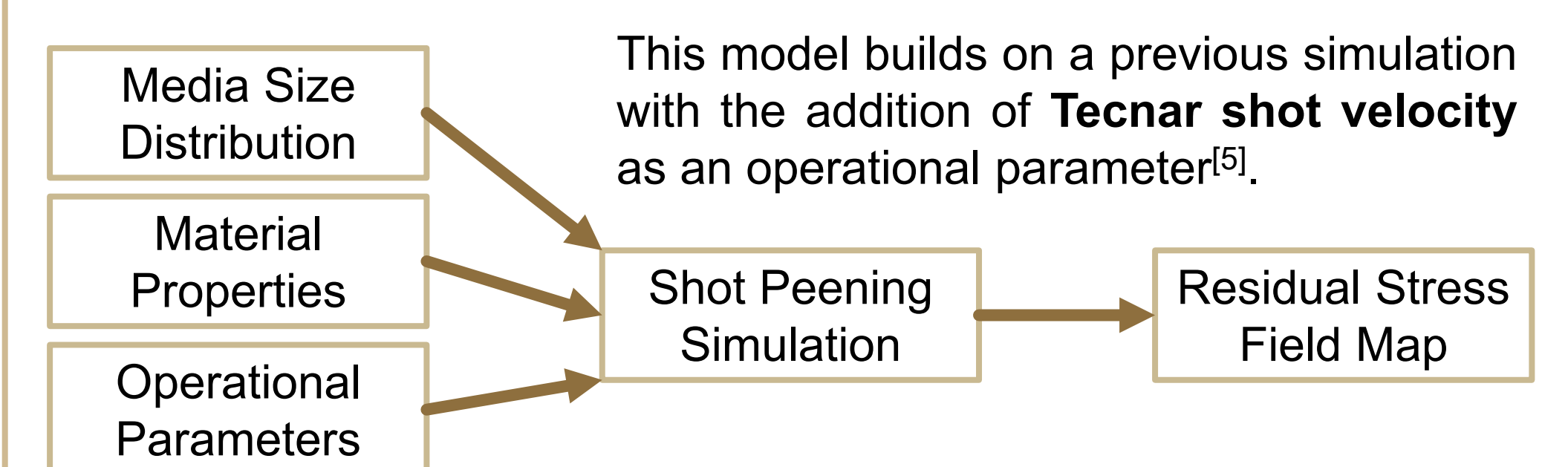
Surface Topography Comments

Qualitative: Impact sites are non-directionally and not uniformly distributed, as expected from shot peening

Quantitative:

- Roughness decreases after peening
- 100% and 200% coverage are similar

Model Development

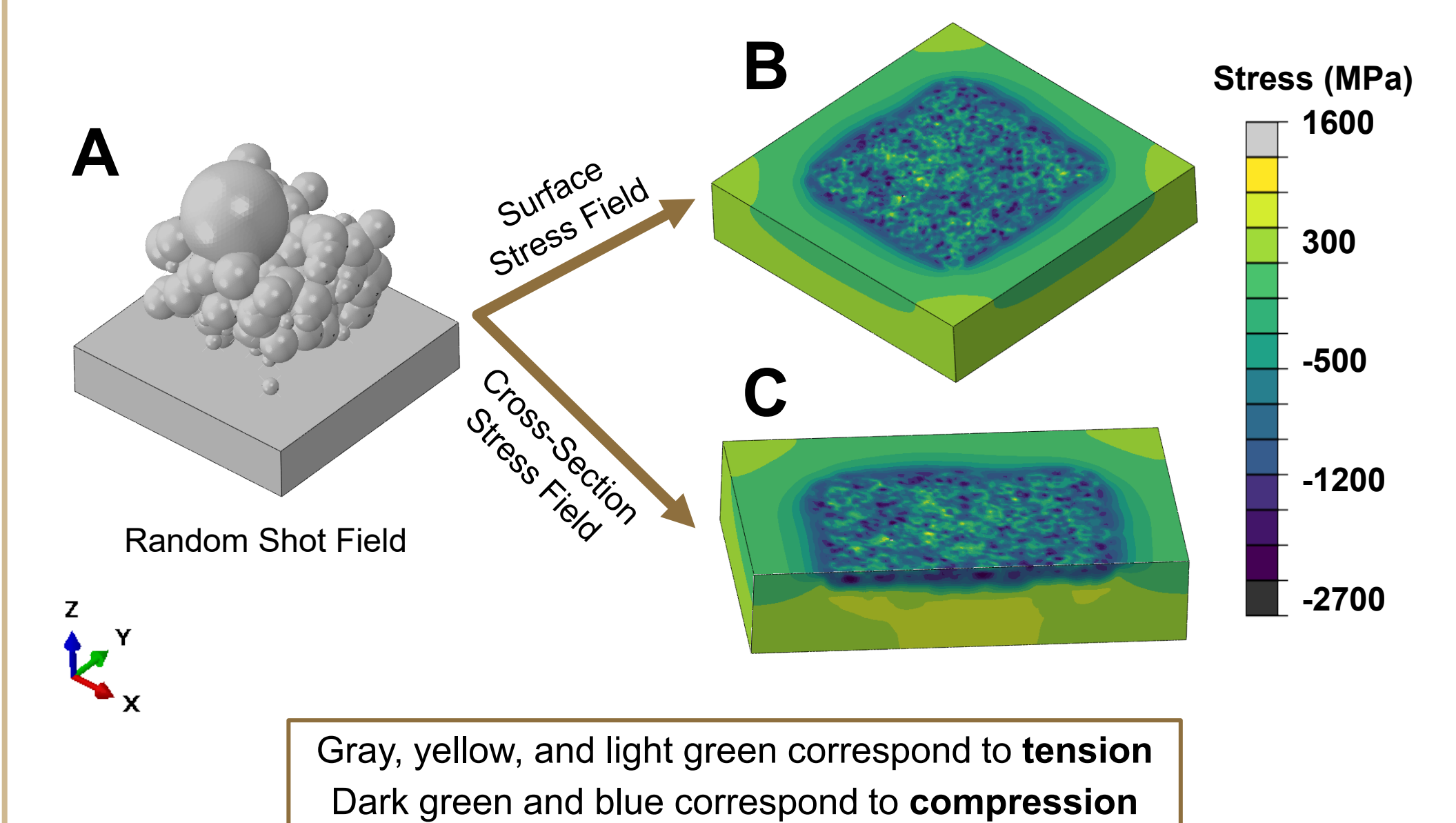


Inputs Description

Media Size Distribution: DCCW20 size measurements

Material Properties: DCCW20 media, and 1050 induction-hardened steel material properties correlated from Rockwell Hardness C measurements

Operational Parameters: Progressive Peener operating parameters plus shot velocity from in-situ Tecnar Shotmeter



The output models above are the results of a **finite element analysis simulation** and visualize the **residual stress field** of a 3mm x 3mm surface area^[5,6].

A. Random shot field shows variation in **media sizes and geometries**

B. Full substrate shows **surface stress field**

C. Section shows **select cross-sectional stress-depth**

Conclusions & Future Work

Conclusions:

The **developed shot peening parameters** demonstrate:

- A measured CRS that **meets the AAM target** for a specified depth
- Trial 1 & Trial 2 CRS + roughness results are consistent, showing **reproducibility**
- Surface roughness is **quantitatively reduced** after peening and as coverage increases
- Surface topography is non-directional and representative of **industrially practiced peening**
- Comparable results between a peening simulation and CRS + roughness measurements indicate a **viable modeling approach**

Future Work:

Data collection of **more types of substrates and shot media** would strengthen the accuracy of the CRS + roughness results and future iterations of the model.

References

- "Electropolishing Standard for Stainless Steel Alloys," ASTM B912.
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- Feltnor, L., and Mort, P., 2025, "Neural Network-Enabled Process Flowsheet for Industrial Shot Peening," Materials, 19(1), p. 9. <https://doi.org/10.3390/ma19010009>.