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PURDUE PEENER

Shot Peening Research @ Purdue

Purdue MSE’s focus is on the future of the shot peening industry. In surface engineering, "quality" goes beyond exact dimensions—it is driven by constantly changing variables like media wear, material uniformity, and surface texture.

To address this, we are building practical tools to optimize shot peening processes. Our primary goals are to:

- ***Measure***: Develop fast, on-the-line optical measurement systems.
- ***Predict & Control:*** Build digital twins that track media wear and self-correct the machine in real-time.
- ***Act***: Turn guesswork and inconsistent finishes into hard, actionable data.

Figure 1. Progressive Surface Robotic Shot Peening Unit, Tecnar Shotmeter.

PURDUE PEENER: 2nd EDITION

Purdue University — Manufacturing and Materials Research Laboratories (MMRL)

The MMRL is an integrated research facility that advances Purdue University’s eXcellence in Manufacturing and Operations Initiative. While the center supports a wide array of manufacturing processes, advancing surface engineering is a cornerstone of its mission.

Current Additions & Activities:

World Class Shot Peening Center: Progressive Surface Robotic Peening System (pictured) and Tecnar Shotmeter (pictured) enable pilot-to-production scale peening of ***components***, development of process sensing technologies.

Student-Driven Innovation: Active, collaborative hub for both high-level graduate research and industry-sponsored Senior Design groups.

Whether you are interested in exploring our equipment, discussing research, or partnering with our students, we would love to host you. **Come and see us!**

INSIDE THIS ISSUE

- **The New Paradigm for Precision:** A look at how quality in surface engineering is shifting from conventional certification to in process monitoring.
- **The Future of Component Certification**: Why the industry should move beyond indirect proxies (like Almen intensity) and destructive testing (like residual stress depth profiling) toward fast, in-situ methods like optical profilometry.
- **AI-Enabled Control & Digital Twins:** How ***Purdue MSE*** is using Reduced-Order Modeling to build a self-correcting factory floor.

The Future of Component Certification

R. Varma, L. Feltner, D. Johnson, P. Mort

Historically, the peening industry has relied heavily on indirect measurements to certify processes. We typically look to Almen intensity and coverage percentage to tell us what is happening. The reality, however, is that these are just proxies. When it comes to coverage percentage—especially as we push beyond 100%—we cannot even quantify it directly; we are stuck extrapolating model fits.

If we want the actual ground truth of what the process did to the part, we have to turn to residual stress vs. depth measurements like X-Ray Diffraction (XRD) or hole drilling. But let's be candid: these methods are destructive, time-consuming, and cannot be used for real time inspection.

Our Solution

The objective is to shift our reliance away from these post-mortem, destructive checks. We are developing fast, in-situ optical profilometry to infer actual process conditions directly from the surface finish. Here is how the process works:

1. **Scan the Surface:** We use optical profilometry to capture topography of the peened surface.
2. **Isolate the Signal:** Mathematical filtering** to identify process information (normal peening impacts) and surface defects.
3. **Infer the Mechanics:** Map optical signatures directly to the underlying residual stress profile.

Figure 2. Peened dogbone specimen for fatigue testing.

Why This Matters to the Peening Industry

By connecting the optical signature directly to the underlying residual stress, we deliver practical value to the factory floor:

- **Non-Destructive Certification:** Certify the mechanical integrity of a part without cutting it up or destroying it for XRD.
- **Real-Time Inspection:** Move quality assurance directly to the line, catching process deviations immediately.
- **Data-Driven Confidence:** Replace coverage models with objective optical data.
- **Cost Reduction:** Reduce laboratory testing time; improving throughput.

The Bottom Line By moving from indirect extrapolation to predictive, non-contact optical measurements, we bridge the gap between high-confidence component certification and real-time control. This is the foundation for the self-correcting factory floor.

AI-Enabled Control and the Flowsheet Digital Twin

L. Feltner, D. Stumpf, D. Johnson, P. Mort, M. Titus

Modern shot peening operations generate a massive amount of raw data from velocity sensors, load cells, acoustics, and media flow rates. The problem? This data is too complex to be actionable on the factory floor, and traditional high-fidelity physics models are simply too slow for real-time control. We need a way to make immediate, data-driven decisions.

Our Solution

We are bridging high-resolution measurement with real-time control using Reduced-Order-Modeling.

Here is how it works:

- **Compress the Data:** Take massive streams of raw sensor data and boil them down into simple, actionable variables.
- **Track the Wear:** As demonstrated in our *Shot Peening Flowsheet**, the model dynamically tracks the degradation, fracture, and wear of your manufacturing media.
- **Prevent the Failure:** Instead of waiting for a part to fail a post-mortem inspection, the system predicts exactly how media breakdown will shift your surface integrity and stress field outcomes.

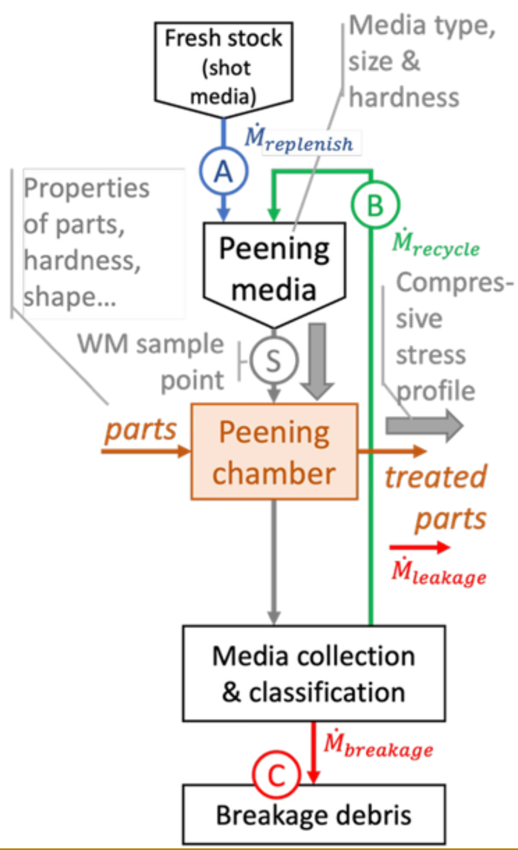

Figure 3. Flowsheet model for industrial shot peening.*

The Bottom Line

The ultimate goal is **active process correction**. By predicting media life in real-time, we can close the feedback loop and create a self-correcting manufacturing system. This allows operators to:

- **Optimize Resources:** Reduce energy waste and maximize media lifespan.
- **Guarantee Quality:** Ensure consistent part quality long before defects have the chance to form.
- **Automate Assurance:** Transition from slow, after-the-fact math to autonomous quality assurance directly at the point of need.

*Langdon Feltner and Paul Mort. "Neural Network-Enabled Process Flowsheet for Industrial Shot Peening." Materials 19.1 (2025): 9.

** Langdon Feltner and Paul Mort. "Spectral Fabric of Stochastic Residual Stress Fields." npj Advanced Manufacturing (2026). In Press.