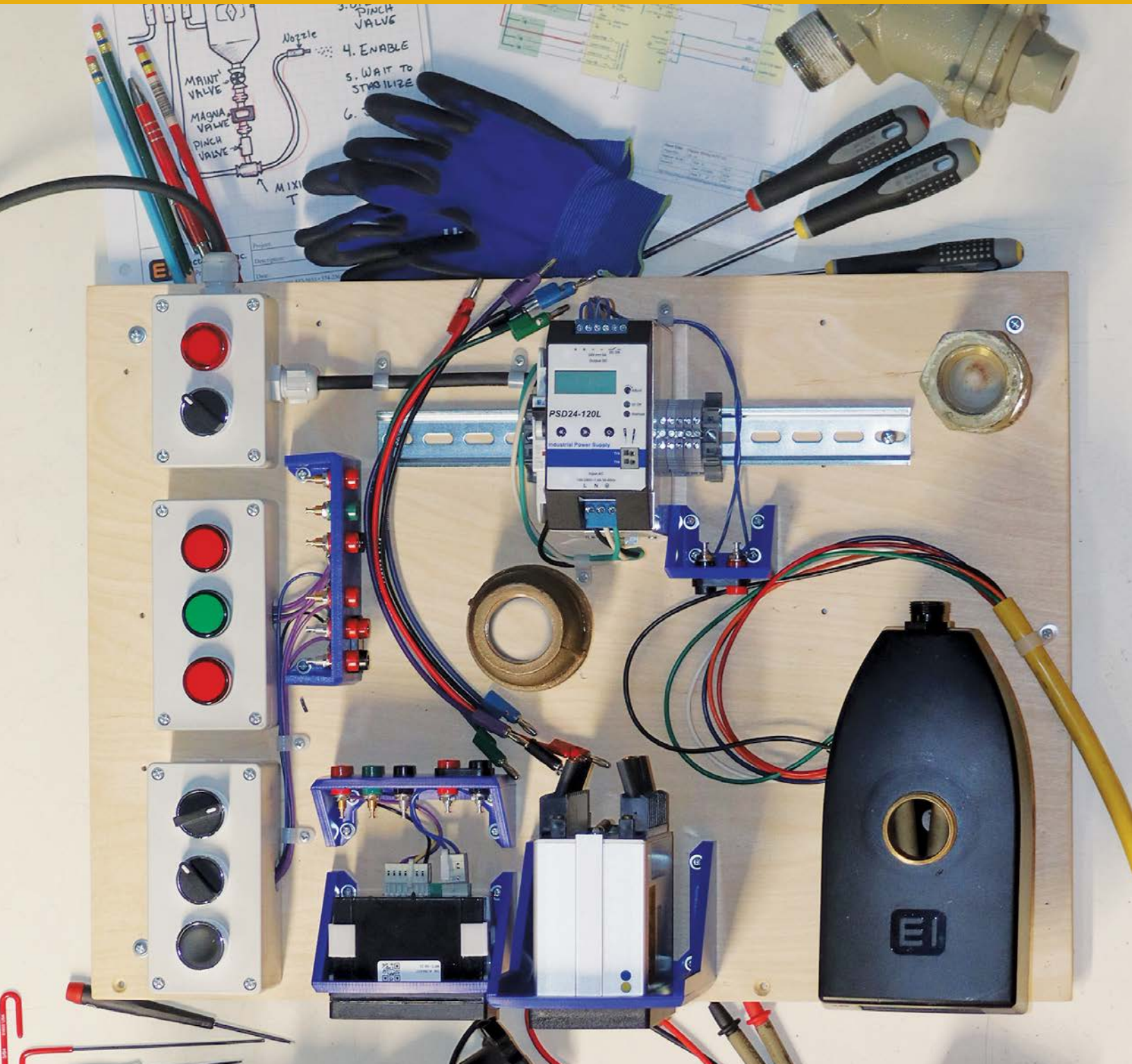


# The Shot Peener

Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries



New from EI's Training Division: Technical Service Training

# Peening Innovation

COVERAGE  
CHECKER



## COVERAGE CHECKER

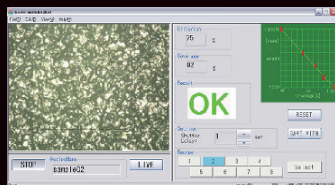
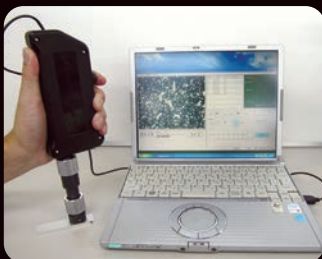
COVERAGE CHECKER the device for easy and precise coverage measurement



### UV Light version New arrival!

- UV light version Coverage Checker measures coverage by the fluorescent paint peeling rate, using UV light. Therefore, measurement result will not be affected by surface condition.
- UV light version Coverage Checker can measure the coverage even on oxidized surfaces and uneven peened surfaces, which was difficult to measure with normal version.

### Coverage Checker (Original) Easy USB connection to your PC



※PC is not included ※Device image

※Specifications of this device may be changed without notification.



Positron  
Surface  
Analyzer



PSA Type L-II

PSA Type L-P

## Non-Destructive Inspection

by Anti-coincidence System  
US Patent : US 8,785,875 B2

#### Application

- Shot peening inspection  
(Inspection Depth : Down to 100 micron)
- Evaluation of Fatigue behavior
- Evaluation of sub-nano size defect
- Free volume on Polymer and Glass

#### Specification

Device size : Type L-II W400 X L400 X H358 [mm]

Type L-P W125 X L210 X H115 [mm]

Positron source : Na-22(under 1MBq)

Option : Autosampler function ( 4 - 8 stage)

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**Electronics Inc. Training Division: Technical Service Training**

EI's Training Division developed the Technical Service Training (TST) program – a curriculum designed to equip OEM engineers and advanced service technicians with the knowledge and hands-on skills necessary to properly install, calibrate, troubleshoot, and repair MagnaValves in their own regions.



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*Almen test bench for multi-pressure setup*

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*Automated wheel-type shot-peening cell*

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*Vapormatt Cougar+*

**THE SHOT PEENER**

Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries



## OPENING SHOT

Taylor Bowman | Editor | *The Shot Peener*

# Stepping Forward

My introduction to shot peening was not exactly traditional. I joined EI as an intern and spent my first two years in research and development before I ever touched a shot peening machine. My early experience in the industry revolved around testing, data, and product refinement rather than standing in front of a blast cabinet. Over time, my role evolved – from R&D to documentation to quality systems – and now, Editor of *The Shot Peener*.

That path has given me a unique perspective. I've had the opportunity to work alongside seasoned peening professionals as well as academic researchers who are pushing the boundaries of what we understand about the process. Seeing both the practical and the theoretical sides of shot peening has shaped how I think about where we are and where we can go.

I'm genuinely optimistic about the future of this industry.

We are at a point where automation is more accessible, data is more available, and analytical tools are more sophisticated than ever before. I hope to see shot peening continue to lean into those advancements – not just adopting new technology because it exists, but using it thoughtfully to improve consistency, expand applications, and better understand the processes we rely on every day.

One of the most encouraging signs of that progress was the collaborative spirit I witnessed at the 15th International Conference on Shot Peening. The open exchange between researchers, OEMs, and end users was a reminder that innovation rarely happens in isolation. When we share knowledge across roles and disciplines, the entire industry benefits.

I know I have big shoes to fill stepping into this role. *The Shot Peener* has long served as a place where experience is shared, ideas are tested, and progress is documented. My goal is to continue that tradition, delivering content that is practical, educational, and engaging for readers at every stage of their careers.

Shot peening has always balanced force with precision. As we look ahead, I hope this publication continues to reflect that balance: grounded in experience, informed by research, and open to what comes next. ●

## THE SHOT PEENER

### Editor

Taylor Bowman

### Publisher

Electronics Inc.

For a free subscription of *The Shot Peener*, go to [www.theshotpeenermagazine.com](http://www.theshotpeenermagazine.com)

### *The Shot Peener*

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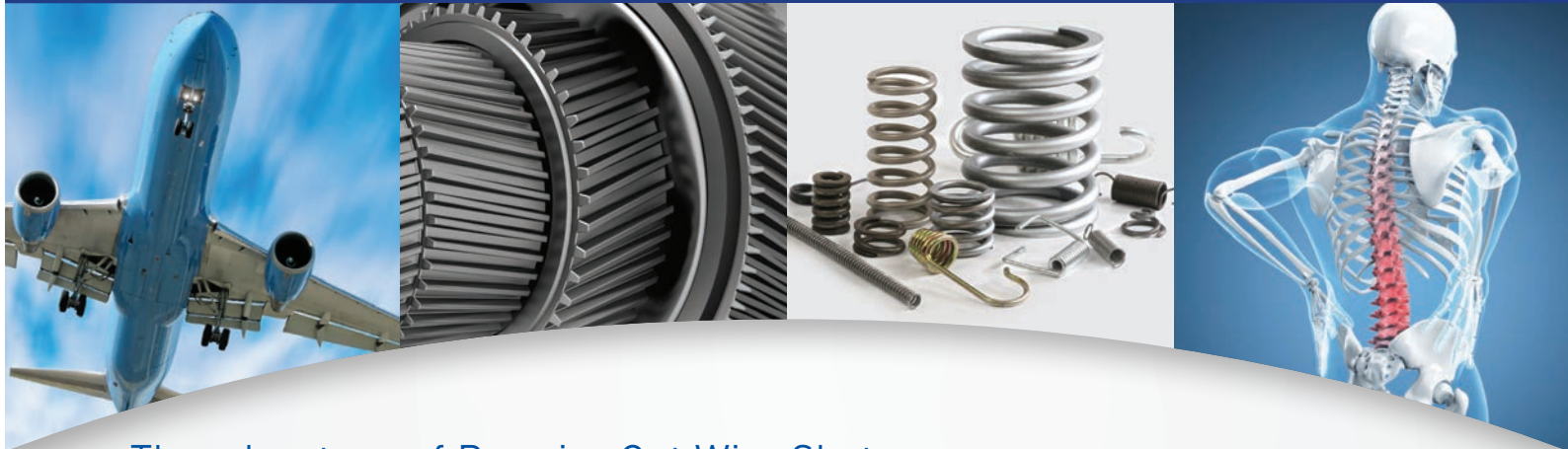
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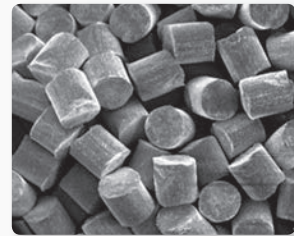
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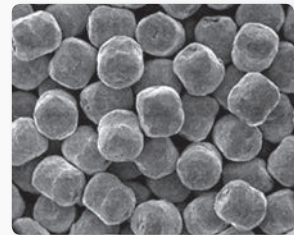


## The advantage of Premier Cut Wire Shot

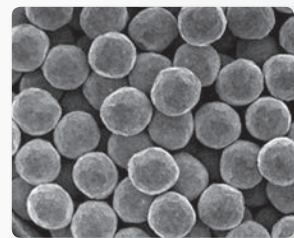
- Highest Durability** Due to its wrought internal structure with almost no internal defects (cracks, porosity, shrinkage, etc.) the durability of Premier Cut Wire Shot can be many times that of other commonly used peening media
- Improved Consistency** Highest consistency from particle to particle in size, shape, hardness and density compared to commonly used metallic media.
- Highest Resistance to Fracture** Premier Cut Wire Shot media tends to wear down and become smaller in size rather than fracturing into sharp-edged broken particles, which may cause surface damage to the part.
- Lower Dust Generation** Highest durability equals lowest dust levels.
- Lower Surface Contamination** Cut Wire Shot doesn't have an Iron Oxide coating or leave Iron Oxide residue — parts are cleaner and brighter.
- Improved Part Life** Parts exhibit higher and more consistent life than those peened with equivalent size and hardness cast steel shot.
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# Technical Service Training: New from E.I. Training Division



## Technical Service Training

Technical support in our industry often follows a familiar pattern. You discover an issue with your peening machine. You call EI, and troubleshooting begins over the phone. You uninstall the MagnaValve and ship it back to EI for evaluation. The MagnaValve is evaluated, but the problem can't be replicated. You finally reinstall your freshly calibrated MagnaValve — only to discover that the issue originated elsewhere in the machine! Downtime stretches. Frustration grows. Production schedules are affected.

Recognizing this cycle, EI's Training Division developed the Technical Service Training (TST) program – a curriculum designed to equip OEM engineers and advanced service technicians with the knowledge and hands-on skills necessary to properly install, calibrate, troubleshoot, and repair MagnaValves in their own regions.



*Samuel successfully identifies an in-line obstruction to flow.*

### CURRICULUM OVERVIEW

Technical Service Training goes beyond product familiarity. Conducted by Bryan Chevrie, Lead Engineer, and Mark Ingram, Senior Engineer, the program provides comprehensive instruction covering:

- Overview of the MagnaValve product lines
- Appropriate media selection
- Plumbing, mounting, and wiring
- Calibration and operational procedures
- Troubleshooting and basic repairs



*(Left) Samuel practices electrical installation of a MagnaValve. (Right) Samuel shows off a successful installation.*

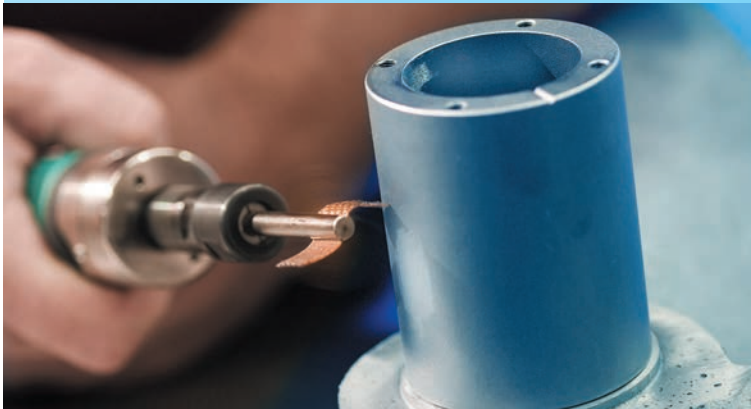


*Students learn to use the terminal program for calibration.*

Through a combination of written instruction and hands-on exercises, technicians learn techniques that promote flow

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*Get rotary flap peening training from the company that knows how to do it right. Dave Barkley is the Director of EI Shot Peening Training and one of EI's rotary flap peening instructors. Mr. Barkley was the author/sponsor of AMS 2590 Revision A—"Rotary Flap Peening of Metal Parts." He is also the recipient of the 2020 Shot Peener of the Year award.*



*The inaugural training class poses with instructors after certification.*



*Mark demonstrates E.I.'s mini test stand, where new technicians are trained on operation.*



*Bryan Chevrie showcasing common devices installed alongside MagnaValves.*

stability from the earliest stages of peening machine design. They review examples of correct installations, common mistakes, and optimized configurations. They then learn how the MagnaValve adapts to different machine parameters, which allows them to accurately diagnose the source of a problem.

“This training ensures OEMs have a local technician who can calibrate and install in their local markets, reducing downtime for operators,” said Bryan Chevrie, Lead Engineer at EI. “End users and maintenance technicians can learn proper installation and troubleshooting techniques to ensure equipment setups are optimized.”

### SMALL CLASS SIZE, PRACTICAL IMPACT

The training is conducted in a small-group format, allowing participants to bring real-world challenges from their facilities and receive expert feedback tailored to their applications. This interactive format connects product engineering with field experience.

The inaugural training welcomed Samuel Khaw, a technician from Surface Preparation Engineering in Singapore, along



*The inaugural training class poses with instructors after certification.”*

with Ben Gan, Senior Asia Sales Agent at LTH Machinery Pte Ltd. Both participants were trained on the current MagnaValve product family.

“Being more proficient with your products opens doors for the design of our own products,” said Samuel. “We see applications outside of aerospace where this will give better control on the finishing of their products.”

From a sales perspective, Ben noted:

“We sell by part number or model, but this provides more detail for what we are selling. We will be able to answer customers’ very basic technical questions. If it is too complicated, I can pass them along to the technical team for the customer.”

Technical Service Training is designed primarily for engineers and advanced service technicians at OEM peening machine builders. The program will take place at EI’s facility, where the required equipment and instrumentation are available. Participants will receive a certificate upon completion, denoting them as Certified MagnaValve technicians. Class sizes will be limited to preserve the interactive format. Organizations interested in scheduling a session are encouraged to contact EI Sales to arrange training dates.

The Technical Service Training Program opens up new possibilities in MagnaValve support — building stronger local expertise, reducing downtime, and enhancing process reliability worldwide. ●





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## AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

# Reflecting on the evolution of the shot peening process

## INTRODUCTION

A 'state of the union' assessment is essential every few years and starts with identifying our starting point, followed by tracing our path to the present. The origin of this journey will be unique to everyone in our industry, since we have acknowledged, adopted and worked with it under different constraints. I started in this industry when shot peening was barely known as a distinct process. The blast machine that was used to clean parts was re-assigned a new task, to shot peen. With that, came several layers of misunderstanding, fueled by specifications that were open to misinterpretation. We have traveled far from there, and this discussion will review some of the milestones along the way.

Like most professionals from my generation, my exposure to shot peening was through blast cleaning. Gradually, customers sharpened their demands and defined their peening processes. Progressively, my subjective assessment of the cleanliness of a shot blasted steel component was being replaced. I now spent time reviewing deflection results within a few thousandths of an inch on what I would soon learn to be the Almen strip! Specifications gained importance and shot peening evolved.

My first attempt at publishing for The Shot Peener was about two decades ago. Back then, I felt a strong urge to convey the importance of using standards, recommended practices, and audit criteria as guidelines for peening equipment design. This allowed me to focus on certain key factors affecting peening results such as velocity, media size, shape and mass flow rate. However, let me start with a note on process recognition of shot peening.

Shot peening originated in the automotive industry to increase/assure the useful life of springs, suspension and progressed to transmission components. The process gained better traction when aerospace adopted the technique while adding levels of monitoring and controls. Though not as quickly as we would prefer, the process has gradually been adopted by other industries such as mining, oil & gas (power),

and medical. I wish I could report rapid proliferation in these sectors, but that has not been the case over the past 2-3 decades. The adoption has not only been slow, but most of these industries continue to operate with specifications that have since been canceled (MIL-S-13165C / AMS 13165). I continue to be optimistic at the opportunity to increase the cognizance and acceptance of the benefits of peening and expect adoption to grow.

Allow me to review specific aspects of the process that have changed over the years, starting with velocity.

## WHEEL AND AIR

I have written on multiple occasions about velocity in both types of media propulsion but let me summarize for the benefit of our first-time reader. Centrifugal wheel speed and diameter are directly proportional to the tangential velocity generated by the blast wheel. Though wheel diameter remains fixed wheel speed can be varied by installing a variable frequency drive. An approximate computation of this velocity in feet per second is the product of wheel speed in RPM and wheel diameter in inches divided by 180. When I first started in the industry, OEMs had one or maybe two models of wheels in their arsenal. The wheel that first introduced me to the industry was 19.5" in diameter and turned at 2250 RPM, generating approximately 240 FPM velocity. This default wheel was universal to all applications, and I did not know enough to question the choice! Wheel designs have evolved over the years to the point where an 18" diameter wheel turning at 3600 RPM generates 360 FPS velocity. Though not many applications demand such a high velocity, it is available for the asking.

Wheel design is not only about velocity. The wheel model I referred to earlier was a belt-driven arrangement. Therefore, varying the wheel speed for a shot peening application required a lot of wrangling with a mechanical pulley arrangement that an after-market supplier had designed. The belt losses, slippage, and additional bearings to complete this installation impacted the wheel efficiency and increased the

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inventory of spare parts. I am sure you share my concern about what this would mean for a controlled operation like shot peening.

All this changed with the introduction of the direct-driven blast wheel, where a “magical” inverter (variable frequency drive) allowed adjustment of the wheel speed and hence the velocity. This was achieved by inserting the value as a field in the part recipe/technique. A closed PID loop ensures that the wheel speed always matches its pre-set value, within a pre-set tolerance. The motor bearings were specially designed to balance the axial load of a C-face motor.



*The M3A TwistLOK™ e-Wheel™ from Blast Cleaning Technologies with blade lengths upto 17.5” spins at 3600 RPM with a direct-drive motor to generate velocities upto 350 feet per second*

Most wheels currently in operation are fitted with wear components, including blades, control cage, and impeller, which are steel castings. As a step towards increasing wear life, some specialty designs are manufactured from tool/hardened steel and carbide to further enhance wear life. Better materials help maintain the integrity of wear parts such as blades and the control cage that direct blast media through and out of the wheel.

Velocity in airblast machines is reliant on the air pressure. Intensity variation in airblast machines is highly sensitive to pressure fluctuations. Therefore, it is critical to maintain constant air pressure during the cycle, within the tolerance allowed by the specification. Well-designed shot peening machines are designed with a PID loop to maintain constant air pressure, with required correction, throughout the cycle.

Blast nozzle design has experienced a couple of variations over the years from straight bore to single and double venturis. Venturi nozzles provide a uniform spread of blast pattern as compared to the straight bore versions. Nozzle material toggles between boron and tungsten carbide subject to the type of media used for shot peening.

Though airblast machines comprise most shot peening machines, particularly in aerospace, the blast nozzle has undergone relatively less design growth when compared to blast wheels. As a case in point, the original venturi design in blast nozzles is almost three decades old, with minor modifications such as a double-venturi over the years.

### **MEDIA MAINTENANCE**

I always get a chuckle from my audience when I comment that every ‘self-respecting’ peening machine must incorporate a vibratory classifier (screener). However, that was not (and likely continues to be) always the case. The concept of diverting a small percentage of media through a classifier in a wheelblast machine to address the unit’s capacity constraint is relatively recent. Wheelblast machines are almost always installed in environments with high production volumes. Such process controls for media maintenance made it to such machines only if this was identified as a requirement by a discerning engineer during the procurement process. That was asking for too much three decades ago. That said, I was pleasantly surprised to see a classifier and a spiral separator as part of a railway wheel peening machine around that age. However, it was unfortunate that both these sub-components were no longer functional parts of the machine and were positioned as props next to the machine! Upon enquiry, I was informed that they were ‘bottlenecks’ in the production process. It appeared that they had ignored the capacity constraints of these units and loaded them to the entire flow capacity of the blast wheels. I gave them points for their good intentions and moved on! Capacity constraint is not an issue with airblast machines with relatively low flow rates. Such machines almost always allow 100% of their media flow through the classifier.

Media maintenance has been recognized as a critical aspect of peening controls, and advancement in this sector continues to be specification driven. Over the past five years, there has been several discussions among SEC and ASEC committee members on digitalization of inspection techniques for both shape and size. Classifiers and spiralators will continue to be part of our shot peening machines. Routine inspection for size uniformity and sphericity within tolerance will likely shift to optical analysis or other means, replacing the subjective, visual assessment techniques currently being used. As a short comment on mass flow rate, flow control valves such as the



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MagnaValve continue to be employed in both wheel and air machines. Though the fundamental operation of the valves remains unchanged, digitization and feedback loops have been refined over the years, along with the introduction and improvisation of valves to work with non-metallic media.

### CONTROLS – PROCESS AND AUTOMATION

This sector has dramatically altered the way we view blast cleaning and shot peening machines. I will likely age myself multiple times if I speak too much about how I ordered my coffee this morning or plan to board my plane this evening using advances in controls and automation. Therefore, let me focus on the machine world, where I started with relay logic controllers to sequence our machine operations a few decades ago. This meant that an electric control panel for a simple 4-wheel machine was lit up like a Christmas tree with all its indicator lamps, gages, pushbuttons, and switches. The extensive wiring that made this possible also increased the possibility of wiring errors, shorts, and other issues, making troubleshooting a daunting task. As a young Applications Engineer, I remember listing PLCs as an option in my proposals. The price was prohibitive and about 10% of our customers opted for this 'luxury'!

The industry was soon introduced to PLCs and gradually HMIs (which were then called GUI – Graphic User Interface). Sequencing of machines became a lot simpler and 'Slick 500' entered the vocabulary of electrical engineers and machine programmers. SLC 500 (Small Logic Controller) from Allen-Bradley became a staple in almost every quality blast machine in addition to other makes preferred by end users. This was paired with PanelView Plus or other such HMIs for a winning combination! You could operate your blast machine by touching a screen just like the kid behind the counter at McDonald's punched in your lunch order. Yes, we were behind the times but rapidly catching up! The industry was progressing with CNC controls, servos, zero-backlash gear reducers etc. Blast nozzles started moving, locating and re-locating themselves within fractions of an inch. Nozzle patterns had not changed from the past, but we were ensuring that no matter how they wore, their paths were repeatable and accurate as they traced the contour of a complicated aerospace component. Controls continue to develop, and I will only be repeating several discussions that have already been presented by The Shot Peener magazine on this topic.

Having spent a large part of my career in automation, I believe this is primarily dictated by customer requirements. The hesitation to use robots in the blast environment of the 80s has been replaced with the assurance of effective seals and shrouds that allow robots to grace our machines with their presence within a blast cabinet. They function with the same

precision as they do when placing the engine in a car while assembling it in an auto plant. Robots are now ubiquitous in blast machines. They are more accessible, with prices that are affordable to even small shops. The precursor to robots is the multi-axis nozzle carriage. Such arrangements though effective, were characterized by OEM design engineers who had determined the standards for mechanical design and programming. Understandably, standardization was impossible. Robots have changed all that. Nozzle carriages are installed outside the blast cabinet and require elaborate roof or wall seals to access the nozzles inside the cabinet. This is now challenged and improved by a standard, off-the-shelf robot from multiple robot manufacturers that claim plug and play operation with an equally user-friendly path program executed by anyone with robot programming skills.

If one were to summarize the two main benefits that the industry has derived from controls and automation growth, they would be repeatability and accuracy.

### HOW CAN WE NOT TALK ABOUT AI?

I derive inspiration from a lecture at the recent American Foundry Society Regional Conference in Brookfield, WI where the speaker spoke about the challenges of infusing AI into what we do. His contention, which I acknowledge and agree, was that the data available to us severely lacked in quality to expect actionable outcomes. I can vouch from personal experience the challenge in learning about the media replenishment practices in a blast cleaning machine from the operator. The same can be said about a non-sophisticated user of a shot peening machine when questioned about saturation curves (Aerospace, I am not talking about you). To illustrate my point (and to validate that this article was not AI-generated), let me end our discussion with a short anecdote.

I received a phone call on a late Friday evening from an anxious customer who wanted to know if he could get shot on Monday. To clarify, he was interested in purchasing ASR110. Later that evening, I posed his question to Google Gemini and ChatGPT, assuming this to be the default action in current times. The responses were comical. After five iterations that included getting directions and links to the closest place for a Covid shot, a number for a suicide hotline and other such irrelevant details, I was nowhere close to an acceptable response! With this, I am not diminishing the value this new tool can provide, since it is constantly learning. There is still a steep learning curve for many of us to get better versed on the technology to derive the benefits of AI for our processes. Therefore, the verdict remains out there as to whether the pace of future growth will match that of the past 2-3 decades in our industry. I look forward to reporting more on this. ●

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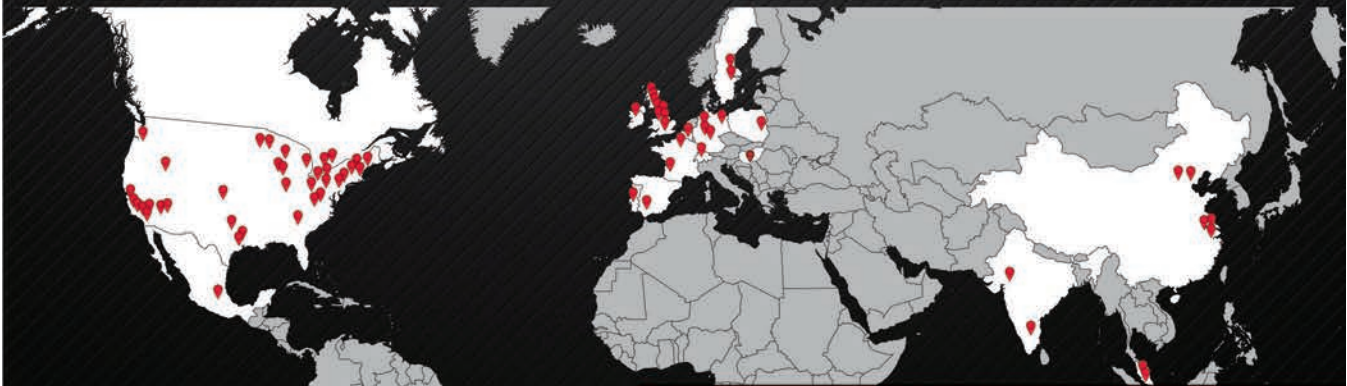
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# Development and Validation of Velocity-Intensity Correlation for Shot Peening Media Using Shotmeter G3

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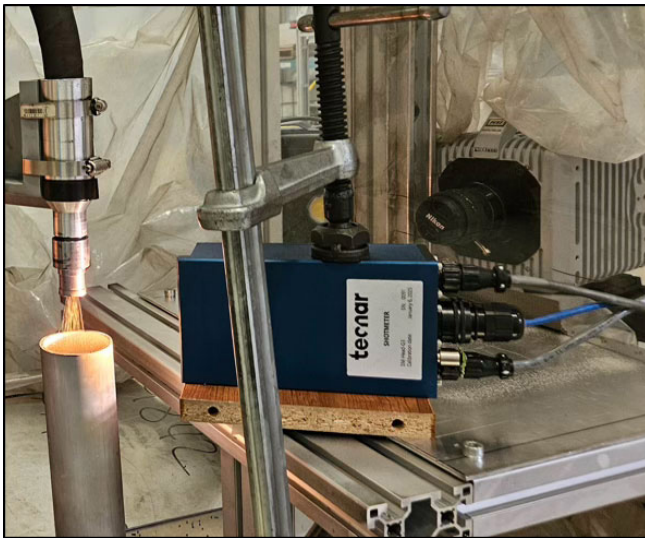


Figure 1: Data Acquisition – Shotmeter G3, Photron Fastcam

## INTRODUCTION

Repeatable and accurate shot peening results rely on closed-loop monitoring and control of critical process parameters. Fundamentally, the transfer of energy during shot peening can be summarized into a simple equation relating mass of the peening media and velocity of impact ( $1/2 \times \text{mass} \times \text{velocity}^2$ ). Assuming that constant mass of peening media particles is maintained using a vibratory classifier and regular inspections, velocity becomes a key factor that will influence the intensity. Therefore, it becomes imperative that we understand the relationship better and possibly arrive at a desired level of predictability. Our research project identified three media sizes/types, S-550, 1/8" steel balls and CCW-28 to study the relationship. This data-driven approach to correlate shot velocity with peening intensity was carried out using a robotic shot peening cell equipped with a Tecnar Shotmeter G3 and Photron FastCam. We derived polynomial and linear regression models to predict intensity from velocity measurements through a custom-developed application. Traditionally, intensity is calculated through a saturation curve that is generated by a minimum of four data points and then verified periodically, pre-process using Almen strips. This introduces delays and increases the possibility of variability. Our project

addresses the need for real-time intensity estimation by leveraging velocity measurements from different types of sensors and correlating them to Almen intensity values.

## METHODOLOGY

Experiments were conducted at the Centre Technologique en Aérospatiale (CTA), a research center specializing in aerospace technology development. The data acquisition was done through a robotic shot peening cell operating within a pressure range of 20-80 psi. The media types evaluated were the S550, 1/8" diameter ball bearing shot and CCW28. Measurement tools included the Shotmeter G3 (Optical based velocity sensor) and a Photron FastCam (high-speed imaging). The validation process was done through Almen strip (A and C) arc height measurements, which were fixed to the test bench (Figure 2).



Figure 2: Almen test bench for multi-pressure setup

Velocity readings were recorded via a dedicated application (Developed by Tecnar) that associates machine parameters and media type with timestamped data. Polynomial and linear regression models were computed to establish predictive relationships between pressure and velocity, as well as velocity and intensity.

## RESULTS AND DISCUSSION

### Pressure-Velocity Relationship

For S550 media (nominal particle diameter 0.0555"), the particle velocity exhibited a significant increase from 16.1

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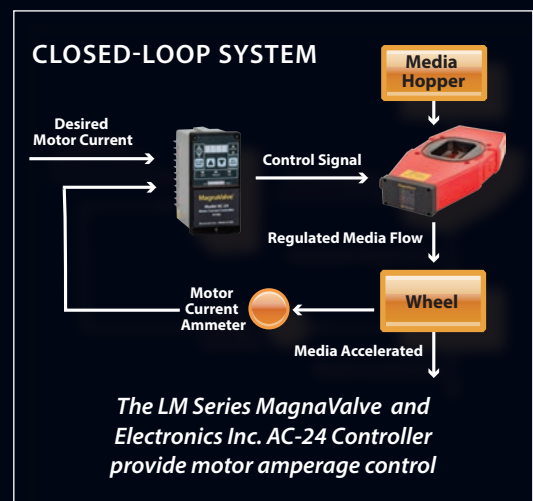
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m·s<sup>-1</sup> at 20 psi to 38.5 m·s<sup>-1</sup> at 80 psi. The relationship between velocity (*v*) and pressure (*P*) can be best described by linear model, where (*R*<sup>2</sup>) is the correlation coefficient:

$$v = 0.3947P + 7.7812, \quad R^2 = 0.9909$$

A similar trend was observed with the use of 1/8" steel shot and CW28 (nominal particle diameter 0.028") media, with CW28 demonstrating the highest velocity response, likely attributable to its lower mass.

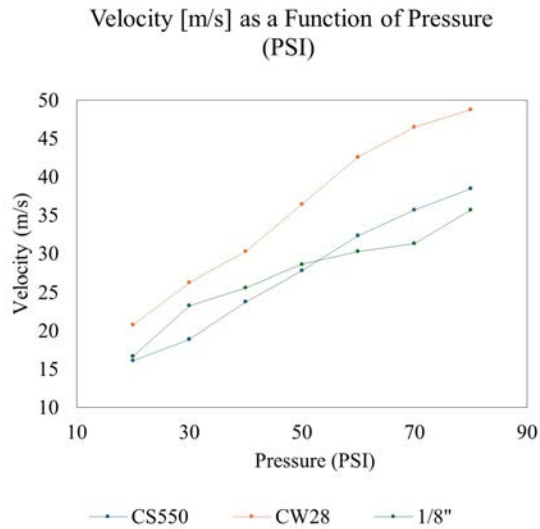


Figure 3: Almen test bench for multi-pressure setup

Media	Curve Type	Trendline	R
CW28	Poly	$V = -0.0019P^2 + 0.6823P + 7.4714$	0.9835
CW28	Linear	$V = 0.4882x + 11.546$	0.9859
CS550	Poly	$V = -0.0008P^2 + 0.4735P + 6.088$	0.9842
CS550	Linear	$V = 0.3947P + 7.7812$	0.9909
1/8"	Poly	$V = -0.0028P^2 + 0.5621P + 7.214$	0.923
1/8"	Linear	$V = 0.2946P + 12.401$	0.9627

Table 1: Almen test bench for multi-pressure setup

**Intensity-Velocity Correlation**

Almen intensity exhibited a strong linear correlation with

particle velocity across all media types. The relationship can be expressed as:

For S550,  
 $Intensity (C) = 0.0002v, \quad R^2 = 0.9951$

For 1/8" media:  
 $Intensity (C) = 0.0009v, \quad R^2 = 0.9905$

For CW28 media:  
 $Intensity (A) = 0.0004v, \quad R^2 = 0.9989$

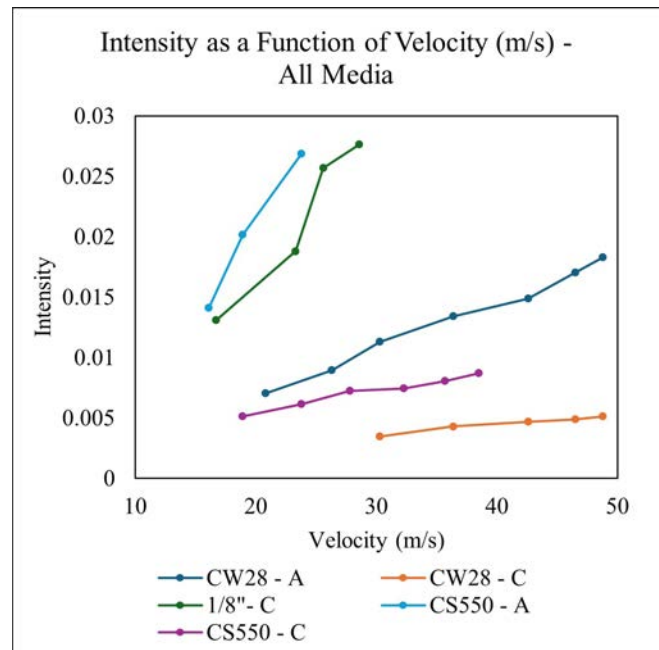


Figure 4: Intensity as a Function of Velocity

These predictive models enable real-time estimation of shot peening intensity based on shot size and velocity. This technique could help reduce the dependence on pre-process validation, or at the very least reduce the processing time when using conventional verification techniques.

**PRACTICAL IMPLICATIONS**

Implementing velocity-based intensity prediction can significantly improve process control in shot peening, particularly in aerospace and other advanced manufacturing industries that have embraced this process. However, our study acknowledges that the entire process is very dynamic with variations associated with wear of machine components and peening media. Efficacy of media size classifiers with size tolerance offered by specifications will play a role in the accuracy of intensity predictions. Media sphericity is maintained with the inclusion of a media shape separator (spiralator). However, not all peening machines are designed with this sub-component.



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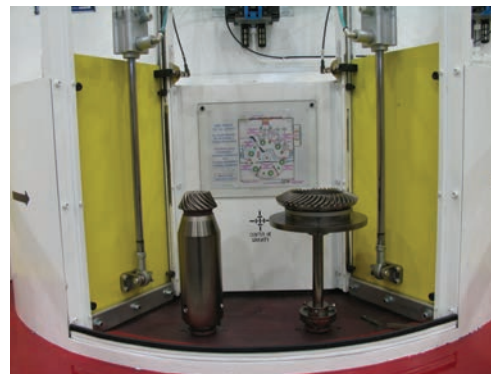


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## CASE STUDY *Continued*

A broken or worn media particle, if not separated due to its size incompatibility, will contribute to affecting the accuracy of prediction. A possible solution could be to integrate an online device (e.g., optical analyzer) to constantly analyze and report on media quality and a means of eliminating unacceptable shapes/sizes.

Additionally, there are challenges for in-plant deployment in the form of sensor portability and environmental constraints. Recommendations include:

- Use of protective white backgrounds for sensor signal stability
- Integration of mobile platforms for sensor transport
- Calibration routines to account for measurement errors that can occur when using optical sensors instead of high-speed cameras

### CONCLUSION

This study validates a robust correlation between shot velocity and peening intensity across multiple media types. The proposed approach supports real-time monitoring and predictive control, aligning with industry goals for process reliability, repeatability and accuracy. . Future steps in our research will include:

- Developing a comprehensive matrix with the inclusion of other media types and sizes
- Adding other dimensions of impact angle and stand-off distance and study their effects on velocity and intensity
- Study the effects of the above on surface profile
- We look forward to connecting with this community on our progress.

### ACKNOWLEDGMENTS

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Photron USA, Inc. Fastcam, <https://photron.com/pfv/> Centre Technologique Aérospatiale (CTA), Quebec, Canada

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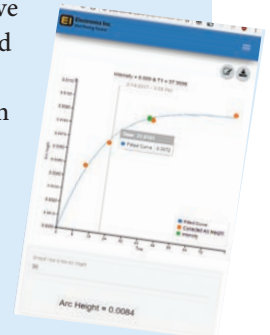
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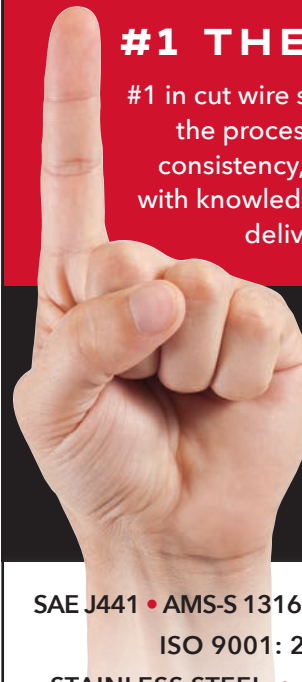
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## CASE STUDY

Utkarsh Ashok Singh | Mechanical Engineer, LS Industries — Wichita, Kansas, USA

# Re-Engineering Shot Peening: From Manual Air Nozzles to Automated Wheel Systems

### INTRODUCTION

Shot peening rarely attracts attention outside specialist circles, yet it quietly protects the parts that matter most. When an aircraft structure survives a long service life, or when a rail component resists years of cyclic loading, it is often because the peening was consistent. That balance is difficult when parts are long, thin, or complex in shape. The engineering task is to achieve the required residual compressive stress without distorting the component, and to do so in a way that production teams can repeat day after day.

This work describes the migration from a legacy manual air routine, which occupied roughly a week per part, to a wheel-type system with an integrated monorail and recipe-driven controls. The result was a single, steady pass through the cell that finished in about twenty-five minutes while maintaining low Almen A intensities and high coverage. Beyond the headline numbers, the value is that operators now work with clearer recipes, steadier handling, and a process that is easier to audit. Customer-specific details are withheld by agreement, but the methods and results are transferable to similar programs.

### CASE STUDY AND MEASURED IMPACT

The change delivered an immediate improvement in output and operating cost. Cycle time fell by more than ninety-five percent. Measured electrical draw for the wheel cell, materials handling, and the cartridge dust collector indicated a reduction in energy per part by roughly two orders of magnitude compared with the former compressor-based routine. Using a conservative grid factor of 0.40 kg CO<sub>2</sub> per kilowatt-hour, the calculated carbon per part dropped by approximately ninety-seven to ninety-eight percent. Coverage reached at least ninety-eight percent, and the intended low Almen A window was held from end to end of the component.

Parameter	Manual Air Peening	Wheel-Type Cell	Improvement
Cycle time per part	≈ 40 hours	≈ 25 minutes	> 95% faster
Energy per part	≈ 1,200–1,800 kWh	≈ 29–39 kWh	≈ 97–98% lower
CO <sub>2</sub> e per part*	≈ 0.48–0.72 t	≈ 0.012–0.015 t	≈ 97–98% lower
Coverage	≈ 95% (typical)	≥ 98%	+ 3% absolute
Almen intensity (A)	0.006–0.010 (target)	0.006–0.010 (held)	Within specification

Table 1. Summary of measured outcomes

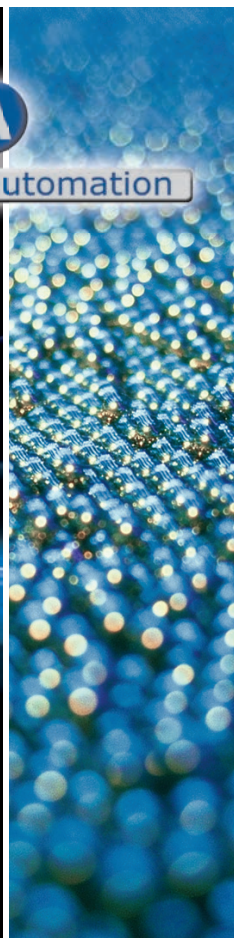
\*Assumes 0.40 kg CO<sub>2</sub>/kWh. Energy values compare compressor duty in the legacy process with measured draw for the wheel cell, materials handling, and a cartridge dust collector. Figures are order-of-magnitude guides to illustrate the scale of change.

### ENGINEERING THE PEENING WINDOW

Low, uniform intensity on thin sections depends on sound kinematics and restraint. Single-particle velocity from the control cage to the blade and on to impact was used to set wheel placement, throw angle, and standoff along the full travel of the part. Wheel speed was limited by variable-frequency drives to a band near 1800 RPM. That limit protected delicate regions from over-peening while maintaining enough energy for consistent coverage while also reducing blade wear. Zone-based recipes governed standoff, throw, and media flow so that the component could receive what it needed at each stage of travel. The integrated monorail provided steady, predictable movement through the chamber, which improved consistency and reduced handling risk. Verification

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was embedded from the start: saturation-curve procedures established intensity, and per-zone checks maintained thin sections near 0.006–0.008 A with thicker ends near 0.008–0.010 A. Day-to-day logs captured wheel speed, media flow, and line speed so the production record was clear and auditable. Commissioning and production practice followed the intent of AMS 2430/2432 for process control, SAE J443 for intensity via saturation curves, and SAE J2277 for coverage.

### **MEDIA INTEGRITY AND ENVIRONMENTAL CONTROL**

Media quality was treated as a primary risk because the part was both delicate and high-value. Cut-wire media in a tight size band was supplied from a single-medium reservoir with staged screening and air-wash classification. Interlocks to the HMI and PLC prevented operation if flow or purity moved out of the allowed range. This kept the media spectrum within the intended band, reduced re-processing, and helped maintain intensity.

A cartridge dust collector tuned for peening fines preserved clear sightlines and a stable differential-pressure range, which supported quality checks and housekeeping. Soft start and stop, blade balancing, and a planned maintenance cadence reduced vibration and wear. Over two years of service, the installation has not required replacement parts. The enclosed handling also reduced operator exposure to dust and noise while making inspection work more straightforward.

### **WHERE EACH METHOD FITS**

Wheel-type peening is the natural choice when components are long and when the specification demands a low, uniform intensity over a large area. Air peening remains the better tool for highly localized features, deep pockets, or very small batches where rapid configuration changes are expected. In many programs, the practical solution is a hybrid: the wheel cell delivers the great majority of the work with consistent geometry and movement, and a compact air nozzle is used only for the few places where the shape requires extra attention.

### **A PRACTICAL ROADMAP FOR INCREMENTAL INTELLIGENCE**

The established process can be strengthened without changing how people work. A chamber-mounted vision module can score coverage in real time and highlight missed regions so corrective passes are targeted rather than global. Trends in wheel vibration, current, and temperature can be used to plan maintenance before balance or wear affects intensity. Finally, an adaptive controller can make small adjustments to wheel speed, media flow, and conveyor speed by zone. Internal

trials suggest this combination can reduce additional passes by around twenty to thirty percent and narrow coverage variation by roughly ten to fifteen percent, while leaving operator roles intact.

### **CONCLUSION**

By placing the wheels where the physics said they belonged, limiting speed to protect thin sections, and treating media quality as a design parameter rather than an afterthought, we turned a difficult, week-long manual routine into a single, steady pass that finishes in about twenty-five minutes. The cell now holds a low Almen A window from end to end with coverage at or above ninety-eight per cent, and the production record is clear enough for anyone to audit. Energy use and carbon per part fell by nearly two orders of magnitude, but the day-to-day difference is simpler: operators have a calmer machine to run, fewer surprises, and results that look the same on Monday morning as they do on Friday night. The next steps—on-device coverage scoring, predictive maintenance, and modest adaptive control—are intended to keep that consistency while trimming re-passes and wear. ●



*Figure 1. Automated wheel-type shot-peening cell for large aerospace components.*

## **Author Biography**

Utkarsh Ashok Singh is a mechanical engineer specializing in high-temperature systems, shot-blasting and peening machinery, and industrial dust-collection. At LS Industries in Wichita, Kansas, he has led the design and delivery of more than thirty-five custom machines across defense, aerospace, automotive, rail, mining, oil and gas, and construction. His work spans burn-off and curing ovens, conveyorized washers, and airflow-optimized dust-collection systems from 5,000 to 100,000 CFM. He applies FEA and CFD to improve reliability, safety, and energy performance. Utkarsh holds an M.S. in Mechanical Engineering and is pursuing an MBA.



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## CASE STUDY

Kurumi Narasaki

# Ultimate Guide to Measuring Hardness: Best Practices for Reliable Almen-Strip Testing

### INTRODUCTION

Accurate hardness testing is critical for quality control in shot peening and related processes. SAE-J422 dictates using Rockwell to measure hardness (HRc for A strips and HRa for N strips) but provides no detail on how to measure hardness. Recent studies and production data reinforce three core principles for obtaining consistent and specification-compliant results on Almen strips:

1. Effect of measurement surface orientation
2. Influence of anvil size on hardness readings
3. Validity of hardness conversion methods

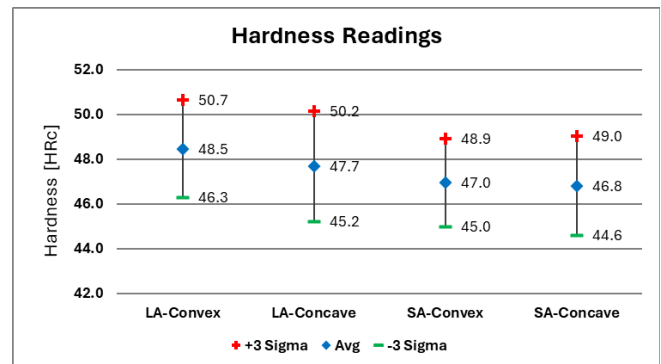
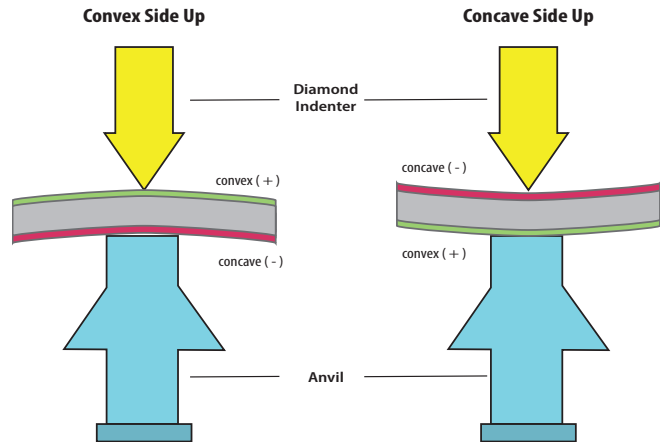
### SURFACE ORIENTATION: CONCAVE OR CONVEX UP?

Dr. David Kirk (2024) evaluated the pre-bow of Almen strips to understand how strip orientation affects hardness readings. His study examined multiple production lots, testing 10 strips per lot with three hardness measurements taken on each strip. Measurements were compared between the convex and concave sides of the strips.

Based on this work, Kirk concluded that Almen strips should be placed curve-up, with the indenter contacting the concave side. This orientation reduces elastic flattening during the test and leads to more accurate and repeatable hardness readings. To further confirm these findings, additional testing was conducted on over 100 samples. For each strip, 3 hardness measurements were taken under four conditions:

- convex side on a large anvil
- concave side on a large anvil
- convex side on a small anvil
- concave side on a small anvil

The expanded dataset reinforced the original conclusion that strip orientation and anvil selection both influence hardness measurement consistency.



Key observations:

- On the large anvil, the convex side measured at an average of 48.5 HRC, while the concave side measured at an average of 47.7 HRC.
- On the small anvil, the convex side measured at an average of 47 HRC, while the concave side measured at an average of 46.8 HRC.
- Convex readings consistently yielded higher values than concave, with larger variability, consistent with Dr. Kirk's conclusion.

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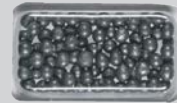
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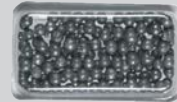
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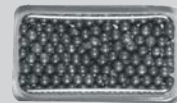
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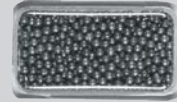
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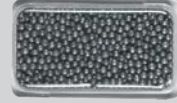
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96% min on No. 18 Screen



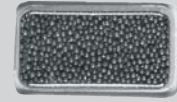
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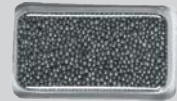
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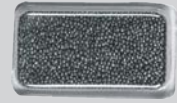
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To determine whether measuring on the concave or convex side truly affects hardness results, a paired t-test was used. This test checks whether two measurements taken from the same strip are significantly different, rather than different due to random chance. In simple terms, if the test result (called a p-value) is below 0.05, the difference is considered real and worth paying attention to.

The analysis showed a clear and meaningful difference between concave and convex measurements for both anvil sizes:

- Large anvil:  $p = 3.09 \times 10^{-55}$
- Small anvil:  $p = 2.35 \times 10^{-35}$

Both values are far below 0.05, confirming that strip orientation has a significant impact on hardness readings and should not be treated as interchangeable.

The difference between large- and small-anvil hardness measurements was evaluated for concave and convex strip orientations. The average anvil-to-anvil difference was 1.225 HRc for convex-side measurements and 0.775 HRc for concave-side measurements. The larger difference observed on the convex side indicates greater sensitivity to measurement setup, while the smaller difference on the concave side reflects a more stable and reliable measurement condition.

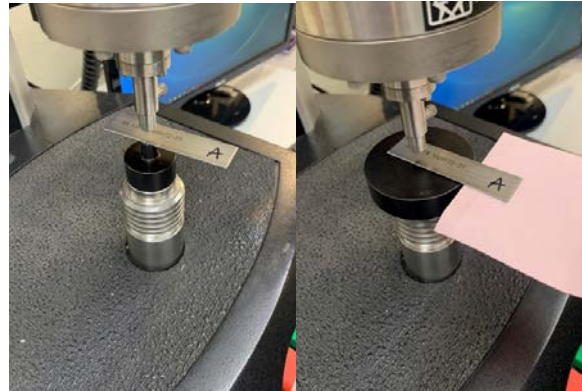
Capability analysis further supports this observation. Concave-side measurements yielded a  $C_p$  of 1.11, indicating tighter clustering, whereas convex-side measurements produced a  $C_p$  of 0.425, reflecting substantially greater variability. Together, these results demonstrate that concave-side measurements provide a more repeatable hardness assessment.

**Takeaway:** Always orient Almen strips concave-up to minimize variability and maximize measurement reliability.

### OPTIMAL ANVIL SIZE

Anvil size also influences hardness readings. Paired t-tests confirmed that measuring on a small anvil versus a larger anvil made a statistically significant difference (convex:  $2.66 \times 10^{-72} < 0.05$ , concave:  $1.24 \times 10^{-48} < 0.05$ ).

- The difference between convex–concave was smaller on the small anvil (0.579) compared to the large anvil (1.025), indicating that the small anvil yields more consistent results.



This effect is supported by Zhang’s thesis in “The Anvil Effect in the Spherical Indentation Testing on Sheet Metals (2015)”: the hardness reading decreases as anvil compliance increases, such as with small anvils. Small anvils have less surface area, which increases localized stress and causes greater elastic deflection under the Rockwell load. Any additional support deflection is interpreted as an additional indentation depth, resulting in a deeper apparent indentation and therefore a lower Rockwell hardness reading. Using a small, appropriately stiff anvil that supports the strip without rocking or tilting reports the true hardness of thin specimens like Almen strips.

**Takeaway:** A smaller anvil reduces within-strip variation and enhances repeatability, making it the preferred choice for production measurements.

### CONVERTING HARDNESS SCALES

Hardness conversions introduce significant risk and potential measurement error. SAE J422 specifies Rockwell hardness for Almen strips. Other measurement scales cannot reliably replace Rockwell testing because conversions rely on polynomial regression approximations, which inherently introduce uncertainty.

Production data shows that Rockwell testing yields tighter clustering and higher process capability than Vickers testing.  $C_p$  describes how tightly hardness measurements cluster relative to the specification width, while  $C_{pk}$  describes both the clustering and how well the measurements are centered within the specification limits. Higher  $C_p$  and  $C_{pk}$  values indicate a more consistent and stable measurement process, reducing the risk of producing out-of-spec results.

	HRc	HV-5	HV-10
CP	2.81	1.12	2.13
CPK	2.46	0.20	0.85
% Range	1.40%	3.74%	2.28%

Table 1. Summary of measured outcomes

Even within Rockwell scales, conversions can be misleading;

## CASE STUDY *Continued*

for example, a direct HRA measurement may fall within specification while a converted HR30N value appears out of range. A measured value of 66.4 HR30N, when converted to HRC using ASTM E140-12b Annex A1.1.8 and A1.1.5, yields 74.511 HRC, which exceeds the Grade 1S specification limit of 73–74.5 HRC, despite direct Rockwell measurements falling within specification at 73.5–73.9 HRA.

Conversions are suitable only for approximate comparison or historical reference—not for specification compliance, quality claims, or production decisions.

Takeaway: Always measure directly in the Rockwell scale specified by SAE J422. Conversions, whether between Vickers and Rockwell or between Rockwell scales, are unreliable for acceptance decisions.

### CONCLUSION

For reliable, repeatable, and specification-compliant Almen-strip hardness testing:

1. Measure concave side-up to minimize elastic flattening effects.
2. Use a small anvil to reduce variability and enhance repeatability.
3. Measure directly in the specified Rockwell scale; do not rely on conversions.

Following these principles ensures accurate hardness readings, reduces operator dependence, and supports production quality control. Rockwell hardness testing remains the standard for a reason: it combines precision, repeatability, and compliance with industry specifications. ●

## References

- [1] D. D. Kirk, “Hardness testing,” The Shot Peener, 2024.
- [2] ASTM International, ASTM E18-17: Standard Test Methods for Rockwell Hardness of Metallic Materials, West Conshohocken, PA, USA, 2017.
- [3] Y. Zhang, M. Dhaigude, and J. Wang, “The anvil effect in the spherical indentation testing on sheet metals,” Procedia Manufacturing, vol. 1, pp. 828-839, Dec. 2015, doi: 10.1016/j.promfg.2015.09.072.



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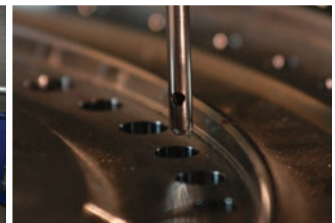
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# Wet shot peening as a process choice for aerospace components

Ryan Ashworth, Head of Sales and Marketing, Vapormatt Ltd

## INTRODUCTION

Shot peening is one of the most established surface enhancement processes in aerospace engineering because its underlying mechanism is well understood and industrially robust. Repeated impact by spherical media produces local plastic deformation in the near-surface region, leaving a beneficial compressive residual stress field after unloading. For components subjected to cyclic loading, that residual stress state can delay crack initiation and reduce the rate of early crack propagation, particularly where failure is governed by surface or near-surface defects.

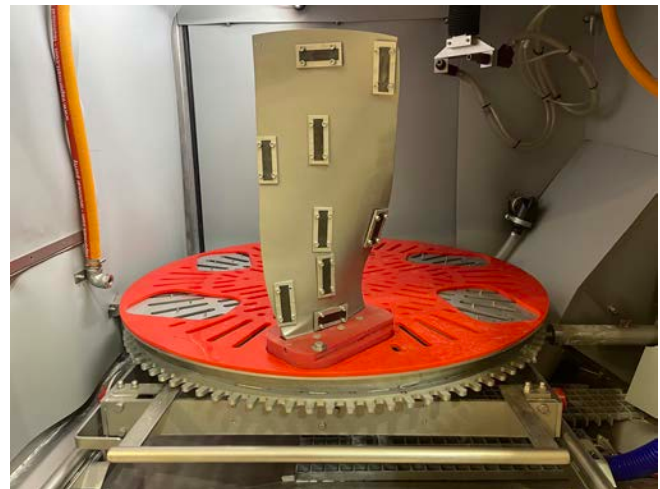
The practical question for aerospace engineers is therefore not whether peening works, but which peening route is most appropriate for a given component, material system, and production environment. In that context, wet shot peening warrants more serious consideration than it often receives in conventional process selection. It is not a universal replacement for dry shot peening, nor does it alter the fundamental metallurgy of peening itself. Its importance lies elsewhere: in many aerospace applications, it improves the way peening is delivered, controlled and integrated into a manufacturing or maintenance workflow.

This is particularly relevant for blade-class components, including fan and turbine blades, where the margin between a beneficial surface treatment and a problematic one can be narrow. These components combine complex curvature, local geometry transitions, thin sections, high cyclic stresses and stringent cleanliness requirements. In such cases, process capability cannot be judged on peening intensity alone. A technically credible assessment must consider the combined outcome: residual stress, surface condition, contamination risk, repeatability and total process control.

Wet shot peening shares the same strengthening mechanism as dry shot peening but differs in the transport medium. The shot is conveyed in a water-based slurry rather than a dry air stream. That difference may appear operational rather than scientific, yet it has direct consequences for process behaviour. The liquid phase influences particle transport, rebound behaviour, dust formation, thermal effects at the surface and the handling of removed contaminants. It can also enable cleaning and peening to occur in a single process step for some incoming part conditions. None of these effects substitutes for correct intensity, coverage or qualification, but

they do change the process window in ways that are highly relevant to aerospace applications.

One of the strongest technical arguments for wet shot peening concerns surface condition. In fatigue-critical components, residual stress is only part of the performance equation. Surface roughness, local defects and embedded contamination can act as crack initiation sites and may erode the fatigue benefit of peening if not tightly controlled. For geometry-sensitive parts, especially those with thin edges or complex aerodynamic surfaces, a process that achieves the target compressive stress state while also supporting consistent surface finish is often preferable to one that is optimised only for impact intensity. Wet delivery can, in many cases, produce a more uniform surface response across complex features, partly because the slurry environment reduces dry dust accumulation and modifies the interaction at the point of impact. This does not guarantee superior fatigue performance in every application, but it can improve the likelihood of achieving a favourable stress-roughness balance.

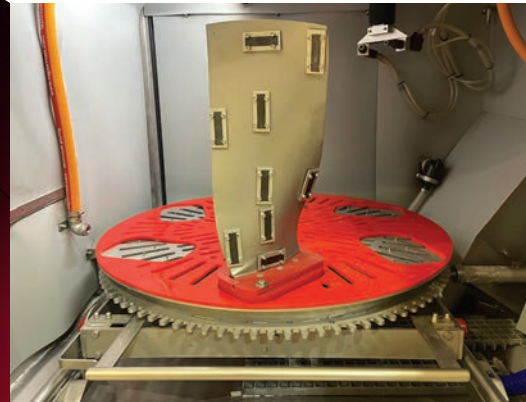


A second advantage is contamination management. Aerospace peening is not only a strengthening operation; it is also a cleanliness-sensitive special process. Wet systems commonly use ceramic or stainless media and confine removed contaminants within the slurry circuit rather than dispersing them as airborne particulate. From a materials perspective, this reduces opportunities for uncontrolled particulate recirculation at the part surface. From a production engineering perspective, it can reduce inspection burden, simplify downstream cleaning

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and lower the probability of contamination-driven rework. In MRO environments, where incoming components may carry variable residues of oil, grease or service contamination, this can be particularly valuable. A process route that tolerates and removes such contaminants during treatment may improve process flow and reduce handling without compromising the strengthening objective, provided the system is properly controlled and qualified.



That qualification requirement is crucial, and it points to a third, often underestimated, strength of wet shot peening: compatibility with modern process control architectures. Wet peening is sometimes described too simply as “shot peening with water,” which obscures the engineering reality. In a production aerospace cell, performance depends on control of slurry concentration, water-to-media ratio, filtration efficiency, broken-media removal, nozzle condition, robot path execution and monitoring of key process variables. The liquid phase introduces additional variables relative to dry peening, and therefore additional opportunities for drift if the system is poorly managed. The converse is also true. When these variables are instrumented and controlled, wet peening can be highly repeatable and well aligned with the traceability expectations applied to aerospace special processes. In that respect, wet peening should not be treated as a gentler but less precise option; properly implemented, it can be a significantly more tightly managed and reproducible process, whilst peening to the same intensity.

This does not diminish the continuing relevance of dry shot peening. Dry peening remains the reference process for many aerospace applications because it is mature, widely specified, and supported by a large installed base of equipment and qualified suppliers. For many component classes, especially where the geometry is less sensitive and the process is already

well validated, dry peening remains entirely appropriate. A scientific comparison between wet and dry peening should therefore avoid categorical claims and focus instead on how each process responds to the constraints of a specific application.

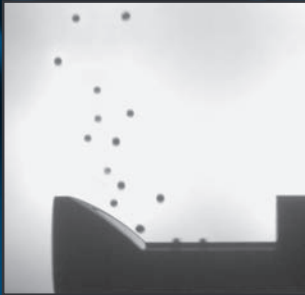
In practice, wet shot peening tends to show its strongest advantages where the risk profile is dominated by surface integrity and process cleanliness rather than by intensity alone. The reduction in airborne particulate is an obvious example. Dust suppression affects operator environment and housekeeping, but it also influences inspection quality, facility contamination control and the stability of the process environment around the part. Similarly, the ability in some cases to combine cleaning and peening reduces transfers and handling steps, which can improve repeatability in high-mix MRO work. Media utilisation may also improve where slurry filtration and media management are well designed, though this is system-dependent and should be assessed quantitatively rather than assumed.

At the same time, dry shot peening may remain preferable in applications where process continuity, installed infrastructure or throughput considerations dominate the decision. Wet systems require slurry handling, water management and filtration infrastructure, all of which are manageable engineering requirements but nonetheless real. The scientific point is not that wet peening is superior in general, but that it shifts the optimisation problem. Where the cost of inconsistency, contamination or excessive handling is high, wet peening may offer a better overall process solution even when the fundamental peening mechanism is shared with dry methods.

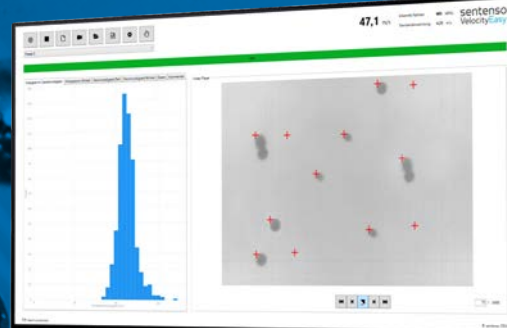
The same balanced view applies when comparing wet shot peening with other peening processes. Laser peening, for example, can generate a significantly deeper compressive residual stress field than conventional shot peening and is therefore selected for applications where stress depth is the dominant design requirement. It occupies a different performance and cost envelope, and its value in depth-critical applications is well established. But many aerospace production and MRO cases are not governed by maximum residual stress depth. They are governed by the need for repeatable broad-area treatment, controlled surface condition, practical throughput and robust process integration. In that operating space, wet shot peening may be the more suitable engineering choice. The processes are best regarded as complementary rather than competitive: laser peening for depth-critical, high-severity cases; wet shot peening for a wide range of conventional fatigue enhancement requirements where cleanliness and surface integrity also matter.

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Needle and flapper peening present a similar contrast. These methods are highly useful in repair scenarios requiring local access, portability or in-situ treatment, and they can be technically effective when applied within their intended scope. However, for uniform treatment of complex components in a controlled process cell, wet shot peening generally offers stronger repeatability, automation compatibility and traceability. That distinction is not about local effectiveness; it is about process standardisation across batches and over time, which is often decisive in aerospace production and tightly controlled MRO operations.

Health and safety considerations are sometimes treated as secondary to process performance, but in aerospace they should be regarded as part of process performance. Dust control is not only an environmental or compliance issue. It affects facility risk, operator exposure, equipment cleanliness, inspection conditions and ultimately process consistency. Wet shot peening's reduction in airborne particulate can therefore be a meaningful technical advantage in metal processing environments, including applications involving alloys that produce challenging fine particulate. This does not eliminate the need for formal risk assessment, engineered controls or validated operating procedures, but it can materially change the baseline operating environment compared with dry particulate processing.



For organisations seeking to evaluate wet shot peening rigorously, the comparison should extend beyond Almen intensity and nominal coverage. Those metrics remain essential, but they are insufficient on their own for modern aerospace process selection. A defensible qualification programme should include measurement of residual stress magnitude and depth (for example by X-ray diffraction where appropriate), assessment of surface roughness and topography, coverage uniformity on representative geometries, metallographic examination for undesirable surface features, contamination and embedment analysis, fatigue testing under representative loading conditions, and capability data for repeatability across production-relevant runs. Total process performance should also be included: cycle time, cleaning and handling steps, media usage, maintenance burden, and the facility implications of dust and housekeeping. Process selection by convention is common; process selection by comparative evidence is better.

The most useful conclusion is therefore a limited but technically strong one. Wet shot peening should not be described as a universal replacement for dry shot peening or for other surface enhancement methods. It should, however, be recognised as a process that can deliver the established metallurgical benefits of shot peening while improving process cleanliness, surface condition control, and repeatability in applications where those factors are critical. For many aerospace components - particularly fan blades, turbine blades, and other complex, cleanliness-sensitive geometries - that combination makes wet shot peening not merely an alternative, but in many cases the more appropriate engineering choice.

Its principal advantage is not that it changes the science of shot peening. It is that, in the right applications, it enables that science to be applied with better control over the variables that often determine real-world aerospace outcomes.

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Factory Calibration	00/00/00
Firmware	Rev 1.10 6-9-21

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Active Table	#1
Media Type	MagnaValve
Flow Limit	S-230
Valve Capacity	30 lbs/min
Pulse Frequency	30.3905 lbs/min
	30.00 Hz

Run Hours	
Power Cycles	17
Valve On-Time	1.15
Hrs <= 25C	0
25C < Hrs <= 80C	2.8
80C < Hrs <= 95C	0
95C < Hrs	0
<b>Total Hours</b>	<b>2.8</b>

Flow Control	
Local Setpoint Enabled	<input type="checkbox"/>
Setpoint Value	0 lbs/min

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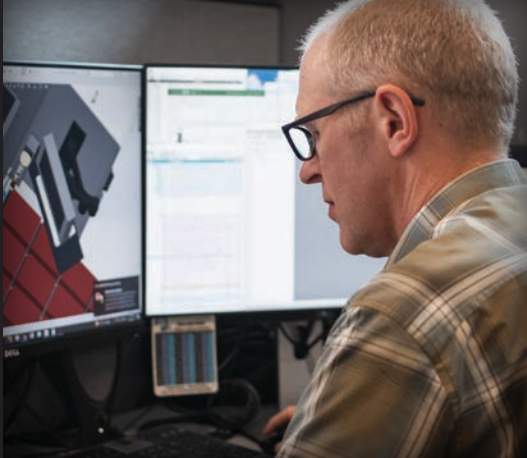
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