AN INSIDER'S PERSPECTIVE

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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 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

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.