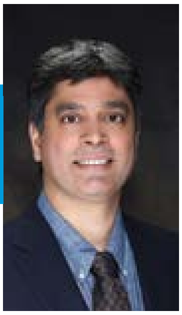

AN INSIDER'S PERSPECTIVE

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Analyzing What We Know

Part 1

COMPLEXITY OF SHOT PEENING

The heading to this section is intentionally deceptive since shot peening is not a complex process if you acknowledge its importance, understand it, and do it right! Albert Einstein's famous quote states, "If you can't explain it simply, you don't understand it well enough." My goal through our discussions is to simplify, normalize and adapt seemingly complex concepts in peening and blast cleaning and explain them in a manner that is conducive to use. If I have made any of your work lives easier through my attempts, I will be satisfied to have achieved that goal. The need for simplification does not imply that the readers of *The Shot Peener* magazine cannot grasp complexities. On the contrary, like me, I too expect that your adoption of proper peening techniques will be greater if made simple.

Having accomplished that complex introduction, I would like to take you through a journey of exploring certain known and some not-so-familiar peening concepts. My purpose is to question their validity and applicability in a production environment. I'll also attempt to add some suggestions based on field experience. These topics include:

- Shot hardness and intensity
- Nicks and part fatigue life
- Reclaim system and process control
- The Almen strip

I had the opportunity to attend the International Conference on Shot Peening where our world gathered to present and discuss their recent research and findings. Select topics from this conference hold promise to me, and I intend to apply the same litmus test for our future discussions. The confluence of academia and industry is a wonderful thing and making it lucid creates an environment that will help our industry grow. Given the extent of information that our colleagues world over are working on, I take the liberty to extend this discussion to part two for subsequent publication.

MEDIA HARDNESS AND INTENSITY

An age-sensitive quote in our industry reflects positively on the health of the machine until the addition of media (abrasive). Facetious as that may sound, media characteristics most certainly dictate the outcome of your cleaning and shot peening operation. Therefore, ensure its proper selection, use, and maintenance. Media is characterized by its size (screening), shape, chemistry, microstructure, and hardness. Hardness is primarily determined by the chemistry and thermal treatment that the media particles are subject to. Standard hardness of high-carbon cast steel shot is 40 to 51 HRC, with custom hardness ranges taking it as high as 60 plus HRC in distinct steps.

Common recommendation by all media manufacturers for cleaning applications is to employ standard hardness abrasive and choose increased hardness selection only if warranted. In other words, if the part is contaminated with heavy scale or rust that is not easily dislodged by standard hardness abrasive, increasing the hardness might help cleaning it. Since hardness and durability are inversely proportional, there is a price to pay in terms of accelerated machine component wear, especially with the use of higher ranges of hardness. This brings us to our discussion on peening intensity and hardness.

Most peening instructions seldom specify media hardness. Instructions are typically restricted to media type (cast shot, cut wire shot, glass bead or ceramic), size, intensity, and coverage. With metallic media, my recommendation over the years to my customers has been to use the softest grade to obtain the required intensity. Though durability is important to minimize risk of broken and sharp-edged particles in the mix, the reason for choosing the softest grade extends beyond just durability concerns. Harder grade of shot will result in an intensity value that is at least 0.015" to 0.002" greater than that produced by a lower hardness shot of the same size. This value increases exponentially with larger shot sizes (S330 and greater). I attribute that to the non-linear increase in volume of the shot particle with increase in diameter.

There is another feature worth listing. Choosing a harder grade of the same size maintains the particle count per pound of shot and with it the rate of coverage (and productivity). In summary, when shot hardness is not specified, start with the softest grade. However, if process or machine constraints result in the inability to achieve the desired intensity, altering media hardness is another means of marginally increasing the value without changing rate of coverage. On a related note, be aware that AMS 2431 allows for only two ranges of shot hardness (45 to 52 HRC, Regular and 55 to 62 HRC, High) whereas SAE recommended practices list four ranges. If your process requires conformance to AMS 2430 or AMS 2432, you are limited to these two hardness grades.

Very often we come across specifications that were drafted several decades ago and based on the data available at that time. Case in example is the now redundant MIL-13165C that listed cast iron as one of the materials that could be used to manufacture shot peening media. Cast iron is brittle and its rapid breakdown (and formation of sharp edges) renders it unsuitable for peening applications. It is not uncommon, especially in non-Aerospace applications, for this specification to be listed as the conformance document.

Therefore, if you happen to be in an industry sector that cites this specification for conformance, it will benefit your peening service provider if you could specify the media type (cast steel or cut wire in metallic media) and possibly indicate the hardness as well. The issues with using media that is not suited for peening can be drastic with potential damage to expensive components in the form of nicks and scratches.

DAMAGE TO PART SURFACE

Foreign object damage (FOD) is a widely discussed and undesirable aspect in the aerospace industry— it is something that is never ignored. In shot peening, a foreign object could be anything that is not part of the usable media or customer's component (which is not expected to disintegrate and generate its own foreign object!). Foreign objects are considered a threat to the integrity of the part being peened. They could cause a nick or other severe damage to the part surface, resulting in the creation of a local stress riser with serious implications during use. These are the nuts, bolts, and other large contaminants that sneak into the peening machine, passing the reclaim system and causing potential surface damage. This phenomenon is also believed to be incited by fractured media particles (cast shot) or those that are not sufficiently conditioned (cut wire shot). The process of conditioning to round-off the sharp edges of cylindrical as-cut material (cut wire shot) can be expected to retain certain particles with sharp edges; more so in smaller sizes.

It is impractical to assign part damage to a broken particle of cast shot since a broken particle will contain only a fraction of its original mass as compared to a particle of unconditioned cut wire that continues to retain its original mass. When analyzing the breakdown mechanism and process parameters that lead to this event with both media types, the extent of damage to the part is at best unpredictable due to constant rounding of sharp edges. Process parameters that influence include media velocity, angle of impingement, stand-off distance from the part, and the failure mechanism (fracture, flaking, etc.). There is no reliable measure or monitor of how this angular edge impacts the component being peened and at what time in the cycle. In my opinion, part damage from foreign object other than media is more likely than that caused by the media. Though I am not trying to advocate permitting the use of sharp edges in peening media, I do question the probability of creation of surface defects by media particles and the ensuing effect on part life.

Professor Paul Mort and his team at the Center for Surface Engineering and Enhancement (CSEE) at Purdue University have been working on models to characterize shot size and shape for shot peening applications. Their study concludes that non-spherical shapes (mainly imperfections that may even qualify as "acceptable" samples by AMS) diminish the "work efficiency" of the peening process. Upon speaking with Professor Mort, he explained that future work on this topic will quantify the extent to which such non-spherical shapes could influence failure and impact part life. This paves the way for more sophisticated means of evaluating peening media shape in the future than the current visual check.

RECLAIM SYSTEM AND PROCESS CONTROL

As a young engineer involved in the design of a 16-wheel blast cleaning machine for railcars, I was fascinated by the 10,000 lb. of media flow rate per minute. The media reclaim system was a mechanical type to be effective with the amount of abrasive in circulation. Later, I was introduced to air-type shot peening machines, and with that to media flow rate that was a small fraction of wheel machines. Such machines work with a vacuum reclaim system to move the media. These are two ends of the spectrum and neither media reclaim system has seen any significant change over the years.

On the blast cleaning side, there have been marginal improvements to the process in which abrasive is "cleaned" to eliminate sand in foundry applications and scale in primary steel processes. This includes development of "smart lip" separators that ensure a full length of abrasive curtain and other related sensory tools. Magnetic separators are also popular to recover shot and eliminate sand from the working abrasive mix. Though these undeniably add to the productivity and lower operating costs, they are not exactly revolutionary.

In shot peening, our reliance on process control for repeatability and accuracy has led to incorporation of shot maintenance devices such as classifiers and spiral separators for size and shape control. Metallic and non-metallic peening media when used in the same machine are separated by the above-mentioned magnetic separators. Again, nothing game altering. I often wonder if we are taking the existence of such systems for granted and ignoring the possibility that they could be tuned to deliver more towards process control. I submit the following to ponder:

- Enhanced reclaim systems that are not reliant on gravity and steep feed angles for efficient conveyance (Advantage: shorter overall height and ease of maintenance since they will be closer to floor level)
- Technology, perhaps optical, to separate different sizes of shot (Advantage: flexibility of using multiple, near sizes of shot without risking cross-contamination)
- Predictability of outcome (coverage time) based on quantity and size distribution (within allowable tolerance for peening) of shot exiting the flow control valve to the nozzle/blast wheel

THE ALMEN STRIP

One must respect the sustaining power of the Almen strip, the de facto standard to validate the peening process. Those of you that have access to more sophisticated means have used X-ray diffraction to directly measure the compressive residual stress generated in the peened component. I too have commented on the possibility of substituting the Almen strip in favor of direct X-ray diffraction measurement. However, there could be other possibilities and questions that I would like to explore:

- Are there new technologies that can reliably replace the Almen strip. (I am not referring to alternate strip types or close comparisons.)
- Are we at a stage where we should evaluate alternate testing methods such as eddy current inspections—perhaps before and after peening the part? Eddy current inspection is proven technology, relatively inexpensive, portable, and quick. This technique is equally efficient with simple and complex geometries that Aerospace components are known to exhibit. It is non-contact type, mitigating any fears of marking, etc. This inspection testing accommodates for variability with change in frequency as may be required for certain part metallurgies.
- Almen strip arc heights lead us to saturation curves, and what has those curves taught us? Saturation curves relate the story of the process in so many details that I personally will miss the curve if we stop using them! Saturation curves remind us that the process with Almen strip arc height measurement is agnostic to the metallurgy of the component and time for part coverage. It gives us a benchmark to assess repeatability of the peening process when running verification strips. It warns us of media contamination when a double-knee is witnessed as part of the curve.
- Is it time to increase our reliance (and accessibility) on quality and result assurance tools such as velocity sensors and minimize the dependence on quality control? These devices are seen in sophisticated machines, but their widespread utilization is not evident. I think our community will greatly benefit from a less-expensive alternative with reduced sophistication and trimmed-down features.

WHAT TO EXPECT IN PART TWO

Our discussion will include topics that are being researched by academics with a focus on relating to the industry soon. These include:

(a) portable (handheld or robot-mounted) lasers,

(b) controlling surface roughness through optimal shot distribution (surface roughness caused due to shot peening is a concern in some Aerospace applications which specify a finish profile after peening),

(c) techniques to predict intensity and coverage, and

(d) shot peening electric battery components to increase charging speed, and other such related topics.

The sources of my inspiration will be listed as we discuss each topic to allow you to learn more if you choose to. I look forward to connecting with you in the summer magazine!