



AN INSIDER'S PERSPECTIVE

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Non-Conventional Peening Techniques

INTRODUCTION

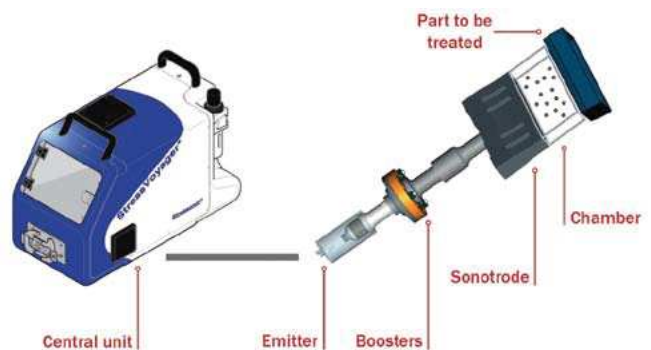
To quote the great Chinese teacher and philosopher Confucius, "Real knowledge is to know the extent of one's ignorance." As I looked around the exhibition hall at the recent Electronics Inc. (EI) shot peening workshop in Orlando, Florida, I noticed the industry landscape was changing with new technology and that meant it was time to replenish our respective databases with the developments.

The EI shot peening workshops have always attracted quality manufacturers of blast cleaning and shot peening equipment along with the vendors of critical components. Over the last few years, this line-up has been further enriched by companies that shot peen using non-conventional techniques such as ultrasonics, needles, vibration and micro-media. The industry has grown familiar with the use of lasers and flapper peening to a greater extent than with these newer techniques. Therefore, it is incumbent upon us to give the other techniques the importance they merit and monitor their growth leading to the overall progress of our industry.

How do these techniques work? How do they compare with established techniques using air and centrifugal force (wheel)? How effective are they in generating the required residual stresses? Are they governed by specifications? We will attempt to answer these questions in the paragraphs that follow with specific reference to Ultrasonic Shot Peening (USP) and Vibratory Peening.

ULTRASONIC PEENING (USP)

Julien Jeanneau of Empowering Technologies, the North American division of Sonats, is a specialist in USP. He explains this technique by drawing parallels with conventional shot peening where energy is transferred from the peening media (shot) to the part being peened. Media propulsion in shot peening uses compressed air or centrifugal force. "At Sonats, we refer to USP as 'Stressonic' technology, which uses the acceleration of a vibrating surface (called a sonotrode) to propel a small sample of shot against the surface to be treated. Since this takes place in a controlled and sealed chamber that envelopes the local area to be treated, there is no escape of media. This allows the process to use a few grams of high quality media for repeatable peening results," said Julien.



The StressVoyager by SONATS is a portable ultrasonic shot peening solution.

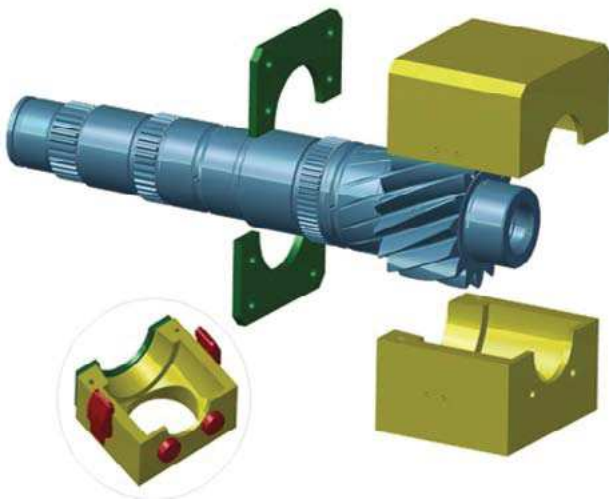
Ultrasound, as some of us may know, is a sound wave with a frequency above the limit of human hearing. Ultrasound equipment operates with a frequency of vibration in the ultrasonic wave range (20 KHz and greater). This is the second point of differentiation from compressed air and centrifugal wheels—this source makes noise that is inaudible to us.

Unlike in shot peening machines where the blast chamber is designed around the part style, size, and work handling systems, the enclosure in the USP process is a hermetic chamber designed to closely wrap around the contour of the part being peened.

Conventional shot peening machines allow for part access and space for maintenance. Cabinets in such machines are built with work doors, access doors, viewing windows, safety interlocks to shut down the operation if any of these doors are accidentally opened, cabinet lining, sound insulation, and lighting. The list continues subject to the manufacturer's practice and the end-user's requests. Moreover, it is essential to mask the parts in areas needing protection from the blast. The manufacture and maintenance of fixtures are additional time-consuming activities associated with conventional shot peening machines. USP eliminates the need for all the above with a small chamber enveloping the part.

Process Control in USP

Some of the key parameters in conventional peening are media



The USP sonotrode and hermetic chamber surrounds the part.

velocity, shape and size, quantity (flow rate), and secondary variables including stand-off distance, nozzle/wheel type, etc. USP using the following parameters to control the process.

Media quantity: In general, media flow rate is directly proportional to the cycle time and productivity of a blast cleaning and shot peening operation. However, increasing the media flow rate has a contrasting impact on the intensity value generated by an airblast and wheelblast process. All other parameters remaining unchanged, the intensity in an airblast process will decrease with increased flow rates since the same amount of energy has to now propel a greater amount of blast media. In a wheelblast machine, increasing the flow rate, limited only by the motor capacity to handle it, will correspondingly increase the rate of coverage, thereby reducing the cycle time. USP behaves like an airblast machine in this aspect with faster cycles but at lower intensity when the media flow is increased.

The optimum quantity of media is determined as part of the USP process development, and either counted or weighed before and after peening. AMS 2585 describes tolerance and good practices similar to the drop/catch test in conventional peening.

Media quality: Just as conventional peening relies on conformance to AMS 2431 for peening media quality, USP follows AMS 2585 for media properties such as hardness, sphericity, size distribution, material and density.

Velocity: Media velocity is governed by air pressure and wheel speed/diameter in air and wheel machines respectively. Similarly, in USP, for a given size of media, higher amplitude of vibration results in higher intensity. For a given amplitude, larger size media produces a higher intensity. The amplitude of vibration is variable, monitored and controlled in USP, similar to velocity control through closed feedback loops for air pressure and wheel speed in air and wheel machines.

As for the secondary variables, design of the enclosure/chamber determines the part distance, angle, and media containment in USP.

With all the above parameters in place, USP relies on Almen tests for arc height values, saturation curves for intensity, and inspection of the actual part for coverage determination (SAE J2227).

Is USP going to be the answer to your next shot peening challenge? Let's look at some of the possible limitations.

Limitation With Promise

Conventional air or wheel peening has been well-established over the years. The end user may not permit an alternate process like USP. This is a major impediment in adoption of USP and other such non-conventional processes for shot peening.

USP is an in-situ process and it doesn't require dismantling of a landing gear, for example, topeen specific areas of the gear. The utility requirements of USP are remarkably lower than air or wheel type peening. An average cycle requires less than 500 Watts to create vibration that energizes the peening media and about 12 CFM for cooling. This is significantly lower than the compressor horsepower required for one or multiple blast nozzles, or to operate a wheel motor in a wheel blast machine. It is a very effective process when peening small areas with similar and repeating geometries. Anything different requires a new, custom chamber to contain the media. This tooling design and development could be an onerous task, at least for peening operations that see a variety of components as in a job shop. That said, if one runs an audit of the time taken to dismantle a component from a sub-assembly, prepare it for peening (masking, etc.), set-up the conventional peening machine with suitable process parameters and then carry out the operation, USP might work out to be more cost and time effective.

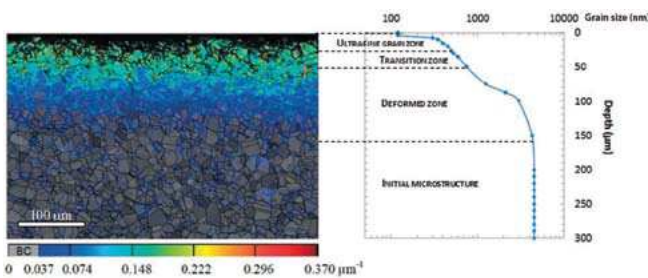
Notable Benefits of USP

1. A portable process that doesn't require dismantling the sub-assembly topeen a component that's part of the assembly.
2. Adaptable to any part by changing the tooling/enclosure design.
3. Uses special-purpose peening media that can be re-used multiple times without fracture or other damage. The quality of peening media determines repeatability, accuracy, and consistency of peening results in any shot peening process. Therefore, peening media that retains its shape and size after multiple impacts will definitely benefit the process.
4. Residual stress values in the range of -1400 MPa, up to a depth of 1 mm (0.039"). In comparison, commonly generated values of compressive stress in conventional shot peening is around -900 MPa with much shallower depths in the range of 0.25 mm (0.010").

5. Surface roughness in conventional peening is related to the shot size and intensity. For the same intensity, smaller-sized shot creates a deeper dent than larger-sized media, resulting in a rougher surface finish. This is not the case with USP, where the high-quality media used always ensures a smoother surface finish.
6. USP offers the same amount of process control as conventional shot peening, including real-time monitoring and control.
7. USP can achieve intensity values in the range of 4N to 10C, thereby meeting most of the peening applications in automotive and aerospace.
8. The formation of nanocrystals. A nanocrystal is a material particle having at least one dimension smaller than 100 nanometres (a nanoparticle) and composed of atoms in either a single- or poly-crystalline arrangement.¹ According to Sonats, USP generates, when specific conditions are applied, a severe plastic deformation of the work piece surface. This plastic deformation generates a nanocrystallized surface layer without any change to the core microstructure. (Conventional shot peening also creates nanocrystals, but to a lesser degree.)

The benefits of a nanocrystallization layer (generally between ten micron and 50 micron deep) come into play when components require heat treatment. During nitriding, a heat treatment, nitrogen is diffused into the surface of a metal to create a case-hardened surface. Benefits are also seen when diffusing chromium and carbon as part of other thermal treatment techniques. These processes are most commonly used on low-carbon, low-alloy steels.² Nitriding is often used on transmission components such as shafts, gears, and other power transmission parts such as screws, crankshafts, and camshafts.

The diffusion efficiency of nitrogen is increased when this treatment is performed at high temperature (600°C) for a significant time. However, this increased time has a detrimental effect on the metal microstructure and properties. Nanocrystallization results in decreased heat treat time and temperature thereby preventing any potential damage to the metallurgy of the component.



Microstructure evolution after USP (nanocrystallization occurs to a depth of about 50 micron).

VIBRATORY PEENING

Vibratory peening is another non-conventional shot peening process that's deserving of our attention. Most of us are familiar with vibratory finishing as a process to polish a metal surface and decrease its roughness. Given that conventional shot peening creates a rough surface, it's also common practice to polish peened components in a vibratory finishing machine without any effect on the residual stress value. Most specifications will allow polishing to remove material up to 10% of the Almen "A" intensity value with the belief that this will not affect the residual stress created during the peening process.

Vibratory peening polishes, reduces roughness and induces compressive residual stress on metal components all in one process. Brian McGillivray, President, Vibra Finish Ltd. Canada, explained this process at the 2017 International Conference on Shot Peening while referencing the vibratory peening equipment built for an aerospace customer. "Aircraft engine blades are fixtured horizontally in an oscillating tub containing specialized, spherical media resembling small balls seen in a bearing. Vibrating impact of this media on the multiple blades fixtured in the bowl induces the desired residual compressive stress values, simultaneously creating a smooth surface finish not possible with conventional shot peening," said Mr. McGillivray.

Mr. McGillivray and researchers at École Polytechnique de Montreal (Hongyan Miao, Leo Canals and Martin Levesque) carried out extensive studies on this technique using AA7050-T7451 samples. They reported the following:

- Better surface finish with vibratory peening than conventional shot peening (comparisons tests were conducted with an air-type peening machine)
- Compressive residual stress values (surface and maximum) were higher with conventional peening, but deeper with vibratory peening (340 micron below the surface with shot peening compared to 520 micron depth with vibratory peening, for the same residual stress of -50 MPa)



Almen strips used for process validation in a vibratory peening machine.

^{1,2} www.wikipedia.com



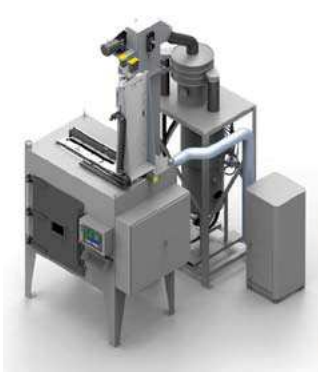
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- Similar fatigue lives with both processes, with vibratory peening showing more uniformly distributed values (lower standard deviation).

Vibratory peening is a relatively new process, and these studies will attempt to validate this technique on a larger scale. Given the nature of the process, and our knowledge of vibratory finishing, we can list some of the advantages of vibratory peening over conventional shot peening:

- A gentler and more repetitive process leading to the uniform generation and distribution of residual stress over the treated surface
- Longer media life than in conventional peening
- No dust generation
- Lower utility costs than conventional peening

Some of the limitations that are currently being addressed by Vibra Finish include:

- Scalability
- The need for custom and unique fixturing for specific part styles
- The need for masking when peening specific areas

SUMMARY

The intention of our discussion is to recognize non-conventional peening processes. Not only do they exist, they're quite prevalent within the industries like automotive and aerospace where conventional shot peening is well established.

Ultrasonic Shot Peening (USP) comes with the obvious benefits of operating in a completely contained atmosphere. The peening media used in this process is closed-loop to the extent that it doesn't leave the enclosure. The limited amount of media required allows the process to utilize highly durable materials resulting in long life cycles, no dust generation, and an overall surface finish that's superior to conventional shot peening. The eco-friendliness of this process is also validated by its significantly lower power and compressed air requirement.

As mentioned before, vibratory peening is an emerging technology being taken upon by a premier research institution, the École Polytechnique, for further study and validation. The combined polishing and compressive residual stress generating attributes of vibratory peening promises to create its niche in advanced manufacturing sectors such as aerospace and medical. The advantages of this process closely mirror those of USP and we will soon see further research findings on the process leading to its wider commercialization.

The exhibitors at the EI shot peening workshop and the International Conference on Shot Peening taught me to not only look for advancements in conventional processes, but also in alternate processes for shot peening. I hope this discussion initiates the same in you. ●