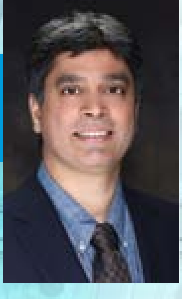

AN INSIDER'S PERSPECTIVE

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Breaking New Ground with Shot Peening

IN THE SPRING 2014 EDITION of *The Shot Peener*, we debated the sophistication of control systems in shot peening equipment, particularly with respect to CNCs, PC-based interfaces and the capabilities of HMIs. Our discussion concluded on a practical note which will always remain popular with me: "Machines are secondary, your peening process design comes first!" During a recent discussion with an auto parts manufacturer in Asia, they emphasized that the operating tolerance for their machine needed to be as stringent as a CNC machining center and also limit the operating sound level within 70 dBA!

The futility of both requirements got me thinking about the growing expectations we, as an industry, have created over the past 20 years. Impractical requirements are the norm in some cases—no matter whether we are peening a flight-critical aerospace component or a simple transmission gear. This conversation also got me thinking about other demands that could be imposed on equipment manufacturers in the future. However, I drew a blank. It seems we have done it all! Does this mean we are saturated in terms of technological breakthroughs, and at best left with marginal enhancements to equipment design and functionality?

If the above is the true state of our industry, where do we go from here? Will there be new applications? Electric vehicles, additive manufacturing, composites and related technologies and materials are exciting prospects, but it seems like they pose a threat to the volume of components that are currently shot peened and blast cleaned. The purpose of this article is to invoke thought, be proactive and discuss future possibilities. We will first summarize our equipment design accomplishments to date and explore possible advancements, no matter how incremental they might be. We will then address two critical questions that have the ability to re-shape our industry: (1) additive manufacturing and its effect on shot peening, and (2) electric vehicles and their impact on production volumes of shot-peened components. Well-known industry experts have weighed in on these topics to provide their valuable thoughts and enrich our discussions.

Background

A well-designed shot peening machine today can:

- Monitor all critical process parameters such as velocity, consistency of media size, shape and flow rate
- Provide repeatable and accurate motion control through CNC and other motion control systems, using robotic arms and carriages with multiple interpolating axes
- Allow the creation, storage and retrieval of part programs/techniques that eliminate repetition of operational tasks
- Proactively warn the user of impending wear of critical parts such as nozzles and blast wheel components, either through sensors or maintenance alerts
- Can be tied to a central control system to allow for remote monitoring, program storage and data reporting

In a fully-automated environment, the above features continue to minimize operator-influenced errors.

Physics and our knowledge of this science haven't changed to the extent that we can practically derive more tangible benefits from monitoring and controlling the peening process. The fundamentals of energy transfer from the peening media on to the part and the subsequent compressive stress and longevity that result from this impact are what this process encompasses. The controls we've designed help us achieve this target with accuracy and repeatability. Consider where controls fail, or don't exist in the first place. For example, an older style machine that functions without a vibratory classifier could potentially result in non-uniform rates of energy transfer due to a mix of shot sizes. Similarly, each process variable that deviates from its pre-set values will influence the end result in a detrimental way. Such controls have been time tested and require no debate to the seasoned shot peener. As new users and manufacturers start participating in our industry, they bring with them their experiences from other industry sectors in terms of incremental but welcome improvements and changes in machine and process design. However, these are often marginal because the mechanism of peening remains unchanged, even with non-conventional peening techniques.

Additive Manufacturing (AM) and Shot Peening

Progressive thinkers that we humans are, our next challenge lies in identifying growth areas for propagating peening technology. Or, at least we should be aware and plan for upcoming hurdles to growth. To quote Scott Nangle, Vice President of Sales at Empire Abrasive Equipment Company

of Langhorne, Pennsylvania, "Although changes may not take place overnight, with the pace of advancement in materials technology, shot peening industry runs the risk of looking a lot like today's newspaper industry 25 years from now." Interesting analogy which doesn't predict complete elimination of the need, but a definite shift in demand. A *Wall Street Journal* article reports that over 333 sidewalk newsstands in New York city now function primarily as snack stands and sell 5-10 copies of *New York Times* newspapers as compared to the 200 copies they used to sell everyday for over 20 years! I am not sure if shot peening machines can be re-purposed for anything other than blast cleaning. Scott's comment was in response to my question as to whether non-metallic parts made with Additive Manufacturing (AM) would slowly eliminate the need for shot peening.

In terms of metallic components made with AM, the industry's opinion is unanimous. Dave Breuer, Director of Sales, North America, Surface Technologies Division of Curtiss-Wright (CWST), said that CWST has identified AM components as a growth area for shot peening, especially when used in a fatigue environment. He added, "Shot peening improves AM surfaces that are very rough. Complementary processes to shot peening, such as super finishing, will likely benefit if surface finish enhancement is required. CWST anticipates AM components to grow by 20% and shot peening to parallel this growth." CWST is the largest global service provider for shot peening services, including laser peening.

Paul Abram is Head of Technical Services Europe for Ervin Industries in Berlin, Germany. Paul said, "Shot peening of AM components is fairly new and still under research in several applications. Though early results associate a benefit when peening AM components, due to this technique's relative infancy, volumes will be low and restricted to advanced and specialized components." Further, he cautions us that if the increase in skills (shot peening AM components) is slower than the increase in use of AM components, then it could reduce part production volumes. Paul makes an interesting observation that requires elaboration. He raises an important question about the skill-set (or potential process re-design) when peening AM components.

Dale Kroskey, Vice President of Sales at Pangborn Corporation made a similar observation when he said, "It is reasonable to expect that the "layering" of materials in a 3D printed object would benefit from peening to enhance mechanical properties and usage of the final product." Both of them imply that peening such components might actually be different from peening a casting or forging as it is conducted now. Will the layered microstructure behave differently when peened through conventional means? Will shot peening intensity and coverage have to be re-defined for AM components? Would alternative peening techniques such as laser peening or others provide better results than regular shot peening?

Incidentally, Paul Abram directed me to a 2018 article on AM titled "Laser Peening - A tool for additive manufacturing post-processing." (Lloyd Hackel, Jon R. Rankin, Alexander Rubenchik, Wayne E. King and Manyalibo Matthews. Published by Elsevier B.V.) I would like to highlight interesting information from this article:

- The large amount of energy deposited during the process of AM can produce detrimental effects including voids, residual stresses and resulting distortions. Relieving residual stresses at the surface will not be sufficient. Relieving local stresses during layering (when building up a metal component in AM) may actually lead to inducing detrimental deeper internal stresses and compensating tensile stresses elsewhere in the component.

- Shot peening is beneficial to the SN (cyclical stress plotted against cycles to failure) behavior of an AM component; much more when laser peened than if shot peened conventionally.

- Laser peening developed a minimum plastic deformation depth of 3-4 mm, at the lower limit than the 0.2 mm depth created with shot peening. Deeper compressive stresses generally provide better fatigue strength and lifetime enhancement, especially if the component has notches or other stress risers which is not uncommon in a manufactured component.

- Shot peening cold works the component while producing compressive stresses and increased hardness due to the cold working. Whereas, in laser peening there is no cold working or changing of the component's material properties. This makes laser peening a better choice in components with increased local stress risers due to the manufacturing process (like AM).

In other words, perhaps AM components have to be treated differently due to their inherently different microstructure than a casting or forging, and this could be the trigger to the development of a new peening technique suited for AM.

Rosler has consolidated all AM developments under the brand "AM Solutions" and is working in Europe on several projects with AM component manufacturers to jointly develop a viable process for peening. "AM, though gaining momentum, is still limited to high-value components such as in the medical implant industry and luxury automobiles. The general industry will follow soon, within 4-5 years," said Tobias Maaser. Mr. Maaser specializes in high-end peening applications in the aerospace sector for Rosler in Europe.

Electric Vehicles and Shot Peening / Blast Cleaning

The International Organization of Motor Vehicle Manufacturers publishes production data for global vehicle production (cars and commercial vehicles). The 2018 data for the top 10 producing countries in the world in Table 1 is taken from their website at www.oica.net. Assuming it takes 30 minutes to read this article, in that timeframe the world would have been populated by about 7,000 new vehicles—60% would be cars and the remainder commercial vehicles!

This accentuates the importance of this industry to all other manufacturing sectors. Some assumptions are made to determine the quantity of transmission gears, connecting rods, other gears and shafts and springs. Please bear in mind that this data only considers new vehicle production and does not include the vehicles already in use that will contribute to after-market volumes.

Charles Riley, a CNN Business correspondent wrote in the "The Great Electric Car Race is Just Beginning" that critical alliances were being formed in the auto industry to accelerate development of Electric Vehicle (EV) technology. He estimates that about 1.3 million vehicles sold in 2018 were EVs. However, given the billions in investments that each auto maker is pledging to this technology, another auto industry expert expects that electric cars could outsell gasoline and diesel by 2040.

Table 1.

Country	Total Vehicles Produced	Transmission Gears	Connecting Rods	Other Gears & Shafts	Main Springs
China	27,809,196	278,091,963	111,236,785	278,091,963	111,236,785
Japan	9,728,528	97,285,281	38,914,112	97,285,281	38,914,112
Germany	5,120,409	51,204,091	20,481,636	51,204,091	20,481,636
India	5,174,645	51,746,451	20,698,580	51,746,451	20,698,580
South Korea	4,028,834	40,288,341	16,115,336	40,288,341	16,115,336
USA	2,795,971	27,959,710	11,183,884	27,959,710	11,183,884
Brazil	2,879,809	28,798,090	11,519,236	28,798,090	11,519,236
Spain	2,819,565	28,195,650	11,278,260	28,195,650	11,278,260
France	2,270,000	22,700,000	9,080,000	22,700,000	9,080,000
Mexico	4,100,525	41,005,250	16,402,100	41,005,250	16,402,100
ROW	20,389,084	203,890,842	81,556,337	203,890,842	81,556,337

As we know, electric vehicles are designed and built without the burden of the multiple moving parts in a car with an internal combustion engine. This includes the drastic reduction, or in some cases, the elimination of transmission gears, connecting rods, valve springs and miscellaneous shafts and gears. The electric vehicle, until further advancements take place, will continue to utilize conventional suspension springs to provide a smooth ride. Our panel of industry experts were helpful with their feedback on what this means to their individual businesses.

"Design approach decisions by the auto OEMs will evolve with some choosing to continue using gearboxes or differentials in their powertrains, while others may choose a direct-driven electric motor(s). The economics in driveline design will determine whether a fully electric or hybrid vehicle will hit our roads to make a difference," explained Dale Kroskey of Pangborn. Dale added that although cleaning volumes may drop due to the design of an electric vehicle, peening requirements will likely still exist for suspension components.

With an increase in EV volumes, Paul Abram of Ervin/Europe believes that a reduction in the volume of parts requiring shot peening is on the cards. He said, "Stop/start technology and multi-gear transmissions that rely heavily on peened components will decline, but EVs will still have flywheels, and differentials that require shot peening due to high levels of torque available throughout the range of road and engine speeds." He draws our attention to the fact that electric car battery technology is still weight intensive, requiring suspensions that will require peening. Ervin is a global manufacturer of steel abrasive and who, like others, sees blast cleaning as a larger industry than shot peening. Paul added, "Over the next 5-10 years, we will see a reduced number of parts to be cleaned due to the shift from vehicles with internal combustion engines to electric vehicles. However, some of that should be offset by increased peening of both metal and AM parts. Technology will take longer to meet the heavy demands of the commercial vehicle sector."

Dave Breuer of CWST said, "EV is a negative growth area for the shot peening industry, especially for engine components. Transmission hardware, albeit with fewer components, will likely require shot peening due to the high power and torque transmitted at low speeds."

Tobias Maaser at Rosler shares a similar thought in terms of reduced volume of parts to be peened but doubts there will ever be a 100% replacement of gas engines with EVs. When questioned about whether this will result in a greater number of AM parts that will be blast cleaned, he said, "We need to blast AM parts regularly to make the surface smoother, but this could also be carried out with mass finishing techniques.

In general, the applications for blasting AM parts will rise, but subsequent quantities of traditional castings and forgings will decrease. Therefore, it is difficult to forecast the net result at this stage."

Additive Manufacturing and Shot Peening in Aerospace and Medical Implants

"We will never see a plane made 100% of composites, since certain operating environments (heat and abrasion resistance) offer challenges for component manufacturing using composites," said Tobias Maaser. He believes composites will gain prominence in aerospace, reducing the need for peening. However, large aircraft production volumes with other metallic components will continue to offset the loss, giving us a gently curving incline instead of a drastic decline.

Regarding medical implants, Tobias reminds us of the elaborate approval process involved in switching to a completely different material for implants and believes that the basic material used today will continue to stay as is.

Paul Abram and Dave Breuer share the opinion that complex shapes, duty conditions and safety factors will continue to pose challenges in the use of composites for components such as landing gear and aircraft engines. Dave added, "Shot peening will likely remain the lower-cost alternative with the ability to improve fatigue of any geometry."

Jim Harrison of CWST is a very knowledgeable authority in aerospace peening and a specialist in laser peening. Jim provides some insights into how the end-user industry views this technology. "During a recent AM conference sponsored by an aerospace research group and a large aerospace prime, a determination was made to not permit AM in fatigue critical aircraft structures due to the processing issues involved in melting the powders. Although companies and academia are working on these issues, AM is being used in the aviation industry for tooling and non-flight critical components." Jim added that engineers are still learning to use AM, and they shouldn't limit their thought process to AM alone, but explore new ways of reducing part inventory or produce lighter weight components by using shot or laser peening effectively to overcome fatigue.

Conclusions

We started off our discussions with the implicit belief that everything possible had been accomplished in terms of technological development. From the discussion above, it appears that new manufacturing techniques could demand more process clarity, and possible alterations, too. Alternative peening technologies, such as laser peening and possibly mass finishing, will also gain prominence. Process experts may even consider a combination of vibratory finishing and peening to develop a deeper layer of compressive stress. Exciting times are back for our industry as we progress towards improving and adapting certain basic processes with the back-up of sophisticated and repeatable controls engineering.