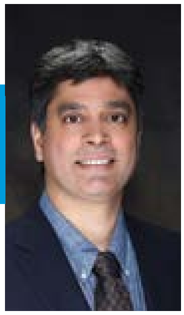

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Analyzing What We Know

Part 2

Opportunities arising from new developments

In Part 1 of our discussions in the spring edition of *The Shot Peener*, we discussed four topics of varying familiarity in blast cleaning and shot peening. We explored the effect of shot hardness on the resulting intensity and the possibility of increasing intensity without affecting coverage rate which is the case with the use of larger peening media. We debated the potential damage that broken media and unconditioned particles of cut wire could cause on the part surface. We suggested alternate means of validating peening intensity rather than Almen strips. Finally, we touched upon the subject of reclaim system efficiency—a discussion that is not often prevalent among users of shot peening equipment. These topics were chosen for their ability to generate a transfer of ideas that will be useful during an operational crisis such as when investigating foreign object damage on a peened component, or a new component requiring a higher intensity without sacrificing coverage rate, and so on. My hope and expectation are that this discussion will help the reader apply such possibilities before a crisis attains critical mass.

Continuing along the same theme, but looking ahead into developments in our industry, Part 2 of our discussion will focus on four other topics that I found interesting. These subjects could lead to increased efficiencies in existing processes and perhaps pave the way for some new ones: (a) Use of portable (handheld or robot-mounted) lasers, (b) controlling surface roughness through optimal shot distribution, (c) techniques to predict intensity and coverage, and (d) shot peening electric battery components to increase their charging speed.

Academic advancements run the risk of being deemed esoteric and therefore not commercialized. Here, I will use the following evaluation criteria to assess the concept's viability and adoption probability:

- Does the concept have practical adaptability?
- Has the concept been fully developed and tested?
- Is the concept financially feasible?
- Is the concept scalable?
- Are the resources required for its implementation readily available?
- Is the concept widely applicable (or is it specific to an industry sector?)

Portable lasers

Back in Fall 2021, we learnt the intricacies of Laser Shock Peening[1] and noted the multiple advantages of this alternate peening process over conventional shot peening. Higher depth of compressive residual stress, the absence of media (breakdown), and dust in the process make this process particularly attractive to critical sectors. These sectors include specialty aerospace, power plant component repair, and similar areas that have zero tolerance for foreign object damage.

Two papers on Laser Shock Peening were submitted at the 14th International Conference on Shot Peening (ISCSP) in 2022. The first article[2] in reference presents the following findings. A handheld pulse laser oscillator was used instead of the pulse laser device that is commonly employed for laser peening. The ensuing increase in fatigue strength confirmed its use as a viable laser peening source. Laser peening with this source, though responsible for creating a rough surface, the roughness average was still lower than caused by conventional peening and current laser peening techniques. The practical adaptability of this process can be matched with Rotary Flapper Peening which enjoys a special place in applications that require in-situ processing. We have known laser peening to incorporate elaborate equipment with techniques that have been custom developed for specific parts and peening targets. Whether this portable technique opens avenues to make this alternate process more approachable and universal and most importantly financially viable, remains to be seen.

A second paper[3] at this conference extends this theme with a compact laser peening tool including a handheld laser the size of a human thumb and mounted on a collaborative robot (COBOT)[4]. This project utilized a microchip laser as the powering device for the laser which is also responsible for the compact size of this unit. The following features of this system

[1] *"Laser Shock Peening", Kumar Balan, The Shot Peener, Fall 2021*
[2] *"Improvement of fatigue property of A7075 aluminum alloy by laser peening with handheld laser device", K. Masaki, Y. Sano, Y. Mizuta and S. Tamaki*
[3] *"Development of a peening device with a handheld laser on a collaborative robot", Y. Sano, Y. Mizuta, S. Tamaki, K. Yokofujita, K. Masaki, T. Hosokai and T. Taira*
[4] *Collaborative robots, also referred to as COBOTs, are designed to work in conjunction with humans and do not pose the same interference danger as conventional robots. They are deployed where flexibility is key as compared to a traditional robot that excels in repeated tasks.*

make it an attractive package: A water circulation system, that is part of the power supply, recovers and reuses the water used in laser peening. The portability claim of the system is that it can be transported as "two checked pieces of airline baggage"! Since the handling is by a COBOT, the authors claim that this system eliminates the need for perimeter fencing and other such safety requirements. Though this claim will likely be location-dependent, and subject to verification by regulations, the high-power microchips along with the COBOT present opportunities for its use in onsite peening.

Evaluation: Laser peening is not commonly seen in high-production environments, but in specific applications that require compression beyond the extent provided by conventional peening. The above techniques certainly enhance the reach of this technology to new avenues (bridge repair, infrastructure maintenance, etc.). Laser peening is spreading its applicability, and the resources for its adoption are also available. Several companies (vendors and labs) are testing such systems for niche applications that are slowly bridging the applications gap between conventional and laser peening. At the present time, this technology continues to be in developmental stages for mainstream, high-production applications due to its known limitations of cycle time and investment requirement.

Media size distribution in shot peening

Blast cleaning relies on a healthy work mix of sizes of abrasive particles. Larger size particles dent the rust and scale, pulverizing them whereas smaller size abrasive in the mix get into tight areas to accomplish cleaning. However, we have always professed that this should not happen in shot peening where our reliance on constant shot size is high on the agenda to maintain uniformity of the residual stress generated and distributed in all part areas. But intensity and coverage are not always the only goals in peening—the resulting surface roughness after peening is also important. A paper[5] submitted by the Center for Surface Engineering and Enhancement (CSEE) at Purdue University explains a new possibility. The subject of this study was to predict roughness and residual stresses on a peened part as a function of shot size distribution and impact velocity. Surface roughness after peening needs to be limited since increased roughness runs the risk the developing stress rises leading to fatigue failure.

This test is explained in the context of dual peening. Dual peening is where a component is subject to two rounds of peening—the first with larger size shot that generates the required residual stress at the desired depth, and the second a smaller size shot to minimize surface roughness. Another documented advantage of dual peening is that it spreads the compression over a greater depth on the part. Calibration of this test was done by using experimental Almen strips. The shot sizes chosen were 0.6, 0.43 and 0.35 mm (S230, S170 and a size smaller between S110 and S170). The study arrived at two interesting conclusions. When the test piece was peened with a controlled distribution of shot sizes (for example: 33% of each size or 20-40-40 of the three sizes), the resulting surface roughness matched (was as smooth as) that created by sequential peening except that this was achieved in a single pass (around 25 Rz microns at 80 m/s shot velocity).

The second conclusion of this experiment was that the compressive residual stress generated with a mix of shot sizes was greater than that developed with sequential impacts (peening with large shot size and repeating with smaller shot). Evaluation: This study has far-reaching impact considering dual peened parts must be processed in a second cycle requiring additional processing time and resources (additional machine, space and associated operating costs). Though a pilot project, CSEE has the resources to scale the learnings to commercial applications for those readers that are interested in exploring this avenue for their production peening process.

[5] *"Controlling surface roughness through shot media size distribution", David Bahr and Siavash Ghanbari, Purdue University*

Predicting coverage

I find it a bit unsettling that an important process variable such as coverage still relies on human assessment which is subjective at best. This unfortunate fact also validates drawings reflecting the end-user's skepticism requiring the peening provider to achieve greater than 100% coverage. Though tools such as fluorescent tracers, dye markers, replicas and computerized coverage checkers are employed for coverage assessment, all these require human validation at some point in the process. In a separate discussion last Fall[6], we learnt about the extent of AI in our world and how it could impact our immediate world of cleaning and peening equipment[6]. A group of scientists at the ARTC (Advanced Remanufacturing and Technology Center) in Singapore applied Deep Learning to predict coverage on a peened part[7].

At the core of Artificial Intelligence (AI) is Deep Learning (DL). As a subset of Machine Learning (ML), DL involves intensive analysis of data to make recommendations. Examples include analysis of medical data, creation of complex musical compositions, etc. This study has followed along this path and combined information from multiple datasets to predict coverage with a high rate of accuracy. The group trained the DL model with actual images from parts made of two different metals at varying percentages of coverage. Like

[6] *"Artificial Intelligence in our industry", Kumar Balan, The Shot Peener, Fall 2022*

[7] *"Application of Deep Learning to predict shot peening coverage", YHA Chua, AB Wang, HC Ang and A Shukri, ARTC Singapore*

with all modeling exercises, the validity is only as good as the input data. To increase the accuracy of their model, this group peened the test samples to five different coverage percentages, had two experienced operators examine them and used the average value as acceptable data. The data was further enriched by taking 30 images of each coverage percentage using a telecentric lens at five different coverage percentages and 10 coverage ranges. Efficacy of this model was based on its ability to predict the correct percentage of coverage over the total number of predictions made. The model accuracy was in values greater than 90%. Inaccuracies were not vague, but in the neighboring coverage range from the actual values.

A commercial software called SuaKIT was employed to develop and train this DL model. This performance of this model is limited to the extent of images that have been provided for its learning. This limitation can be overcome if a conscious effort is made to record coverage rate data over multiple material test specimens.

This technique is best suited for peening operations that process similar or same parts on a regular basis. The percentage prediction accuracy will get fine-tuned with capturing and learning from more images of parts with similar geometry and metallurgy.

Shot peening and electric batteries

No discussion today can be complete without an animated and opinionated conversation concerning the proliferation of electric vehicles! We studied the opportunities this new market can provide to us shot peeners in a recent article[8]. We concluded that a great opportunity exists if shot peening can be "built-in" as an advantageous process for new, high-torque components in an Electric Vehicle (EV). I was highly encouraged when I came across an article on shot peening of electrical battery components at the ISCSP 2022[9]. Rapid charging of electric batteries is a topic of intense research and source of competitive advantage among manufacturers in this sector. However, rapid charging presents a challenge that is brought about in this study, along with a possible solution.

Fast charging results in the generation of lithium dendrite that penetrates the Solid Electrolyte (SE) layer and damages the battery due to an internal short circuit. This limits the speed at which this battery can be charged.

An ASSLiMB (All solid-state lithium-metal battery) is preferred over a lithium-ion battery due to the energy density limitation of the latter. The ASSLiMB battery also uses fire-resistant material as the electrolyte, minimizing its ignition risk. However, as explained earlier, high-speed charging results in dendrite growth and potential damage if it exceeds a critical current density (CCD). The anode and cathode in such a battery is separated by the SE layer. The lithium dendrite grows into this SE layer by developing a crack and connects the anode and cathode, causing the short. Shot peening this SE layer increases its toughness and prevents crack generation. Further, surface roughness, a side-effect created by peening, enhances the electrochemical reaction between the electrolyte and the anode.

I am certain that there are other applications of shot peening and grit blasting in different EV components waiting to be discovered as this technology evolves.

Is peening evolving?

I am often confronted by the existential question—"what now?" In response, I have convinced myself that we are going to see evolution happen in regular, incremental doses. It is not reasonable to expect the same revolutionary impact that the steam engine and electricity had in our ancestors' lives! However, we are faced with some amazing technologies in our lifetime as well. Whether it be through AI, Machine Learning, or ChatGPT, the prudent step would be to utilize such tools to optimize our process responsibilities. I look forward to reporting more on such developments in future articles.

Note: ChatGPT could not have generated this article!

[8] *"Understanding changes to our industry", Kumar Balan, The Shot Peener, Spring 2022*

[9] *"Shot peening of all-solid-state lithium metal battery for high-speed charging", M. Kodama, K. Takashima and S. Hirai, School of Engineering, Tokyo Institute of Technology, Japan.*