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The Shot Peener

Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries

Additive Manufacturing

Composites

Electric Vehicles

The Technology Issue

What is shaping the shot peening industry?

PLUS: FATIGUE TESTING GUIDELINES | COVERAGE SCIENCE | NASA INVESTIGATION UNCOVERS FRAUD | SELF-PEENING TITANIUM ALLOYS

Peening Innovation

COVERAGE CHECKER

COVERAGE CHECKER

COVERAGE CHECKER the device for easy and precise coverage measurement

Easy USB connection to your PC

※PC is not included ※Device image

- UV light version Coverage Checker measures coverage by the fluorescent paint peeling rate, using UV light.Therefore, measurement result will not be affected by surface condition.
- UV light version Coverage Checker can measure the coverage even on oxidized surfaces and uneven peened surfaces, which was difficult to measure with normal version.

※Specifications of this device may be changed without notification.

Positron Surface Analyzer

Non-Destructive Inspection

by Anti-coincidence System

US Patent : US 8,785,875 B2

Application

- Shot peening inspection
  (Inspection Depth : Down to 100 micron)
- Evaluation of Fatigue behavior
- Evaluation of sub-nano size defect
- Free volume on Polymer and Glass

Specification

Device size : Type L-Ⅱ W400 X L400 X H358 [mm]
Type L-P W125 X L210 X H115 [mm]
Positron source : Na-22(under 1MBq)
Option : Autosampler function (4 - 8 stage)

Distributor

Country	Company	TEL	E-MAIL
USA	Electronics Inc.	+1 574-256-5001	sales@electronics-inc.com
CANADA	Shockform Inc.	+1 450-430-8000	sales@shockform.com
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The Technology Issue

These articles address the influencers on shot peening today and in the future.

THE SHOT PEENER
Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries

OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

A Vision Come True

The Surface Engineering and Advanced Materials Processing Conference held at Purdue University this spring had a special significance to me. I have wanted to establish a shot peening center (now called surface enhancement) at a US university since I hosted the International Conference on Shot Peening in San Francisco in 1996.

Technically, that conference was very successful. During analysis after the conference, however, I was disappointed to recognize that the academic audience had only one person from the USA. It was Professor Ralph Stevens from the University of Iowa, a former student of Henry Fuchs at Stanford. (Mr. Fuchs was the founder of Metal Improvement Company.) I knew Stevens from my participation in the SAE committees. The reason he attended was because I needed a keynote lecturer. The recognition that so many foreign universities were active in shot peening instilled in me a desire to make a change.

I can now say that a change, indeed, is happening. The Center for Surface Enhancement and Engineering (CSEE) was highlighted at the conference. Purdue's CSEE is well on its way to joining the other universities with its world-class facilities, staff and equipment. This is very rewarding. Several projects are already underway such as Media Inspection Using Image Analysis, Weld Enhancement for Infrastructure Using Needle Peening, and Improvements to Fuel Systems Components.

During the conference, participants had the opportunity to engage with the Purdue engineering department's world-class faculty, and commercial and governmental partners. They also learned about Purdue's advanced capabilities and current research in the areas of surface engineering and materials processing.

Another example of the leadership from Purdue is the paper by Brice and Bahr where they share their research on Ti-Based Shot (page 22). Electronics Inc. has done a lot of research on medical device peening (US Patent 7,131,303 Shot Peening of Orthopaedic Implants for Tissue Adhesion) and I see this as an interesting approach to the reduction of contamination in a novel way.

The Purdue School of Materials Engineering hosted more than 50 attendees from over 30 companies for the Surface Engineering and Advanced Materials Processing Conference.

THE SHOT PEENER

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Electronics Inc.

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Kathy Levy | Associate Editor | The Shot Peener

Adding Additive Manufacturing to Your Toolbox

SHOULD ADDITIVE MANUFACTURING (AM) be in a shot peening facility's toolbox? I sought answers at a recent Additive Manufacturing Summit hosted by ITAMCO (Indiana Technology and Manufacturing Companies). A presentation by Bob Sutton, Managing Director with Springboard Engineering Solutions, was very useful to me. I'll share his input on the decision-making process when purchasing a 3D printer and the best uses for a printer today. Along the way, I will write about industry leaders in shot peening that are successfully using 3D printers.

DO YOU NEED A 3D PRINTER?

First, a reality check. Mr. Sutton advises manufacturers to not get caught up in the 3D printing hype. (He has decommissioned three 3D printers for clients in the past few years.) "Make a careful business decision based on a planned use case and calculated costs. Don't follow the glitz," said Mr. Sutton. He outlined the ways to avoid buyer's remorse including: 1. Matching your application with the appropriate 3D printer—no easy task—2. Realizing the hidden costs, and 3. Identifying the ways a printer will make or save money.

BUYING THE RIGHT PRINTER

Since AM is relatively new, matching the process and related machinery to an application can be overwhelming. At this time, there are seven main AM processes with subcategories in each:

1. Material Extrusion
2. Vat Photopolymerization
3. Powder Bed Fusion
4. Material Jetting
5. Binder Jetting
6. Directed Energy Deposition
7. Sheet Lamination

Mr. Sutton recommends careful research to find the ideal printer for your needs. Here are a few of the resources he likes:

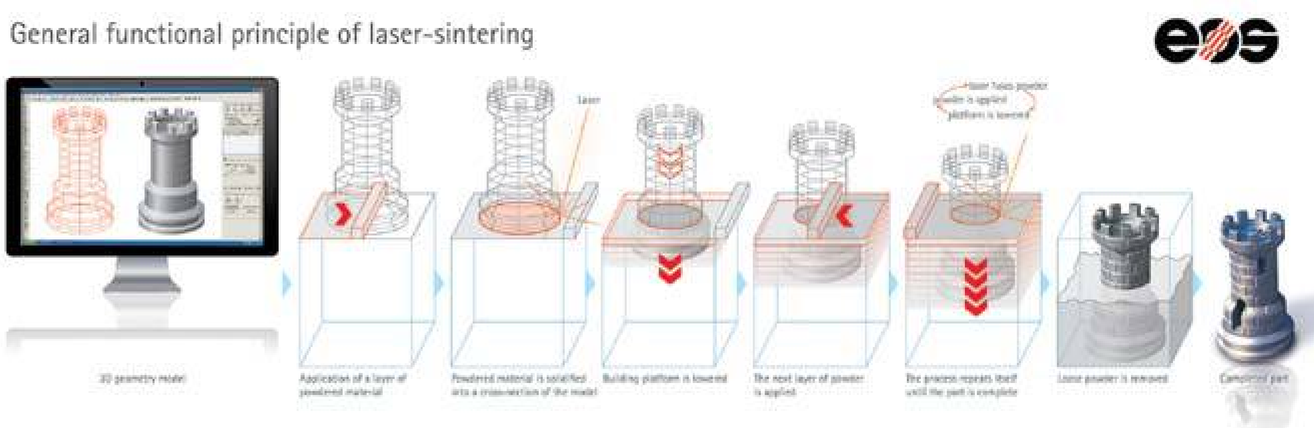
- TCT Magazine (www.tctmagazine.com)
- Rapid eNews (www.multibriefs.com)
- The 2020 Rapid + TCT Tradeshow

In addition, since companies in our industry are already using AM, I advise talking to OEMs, students and instructors at an EI shot peening workshop and tradeshow. Advice from someone that's already using AM is priceless.

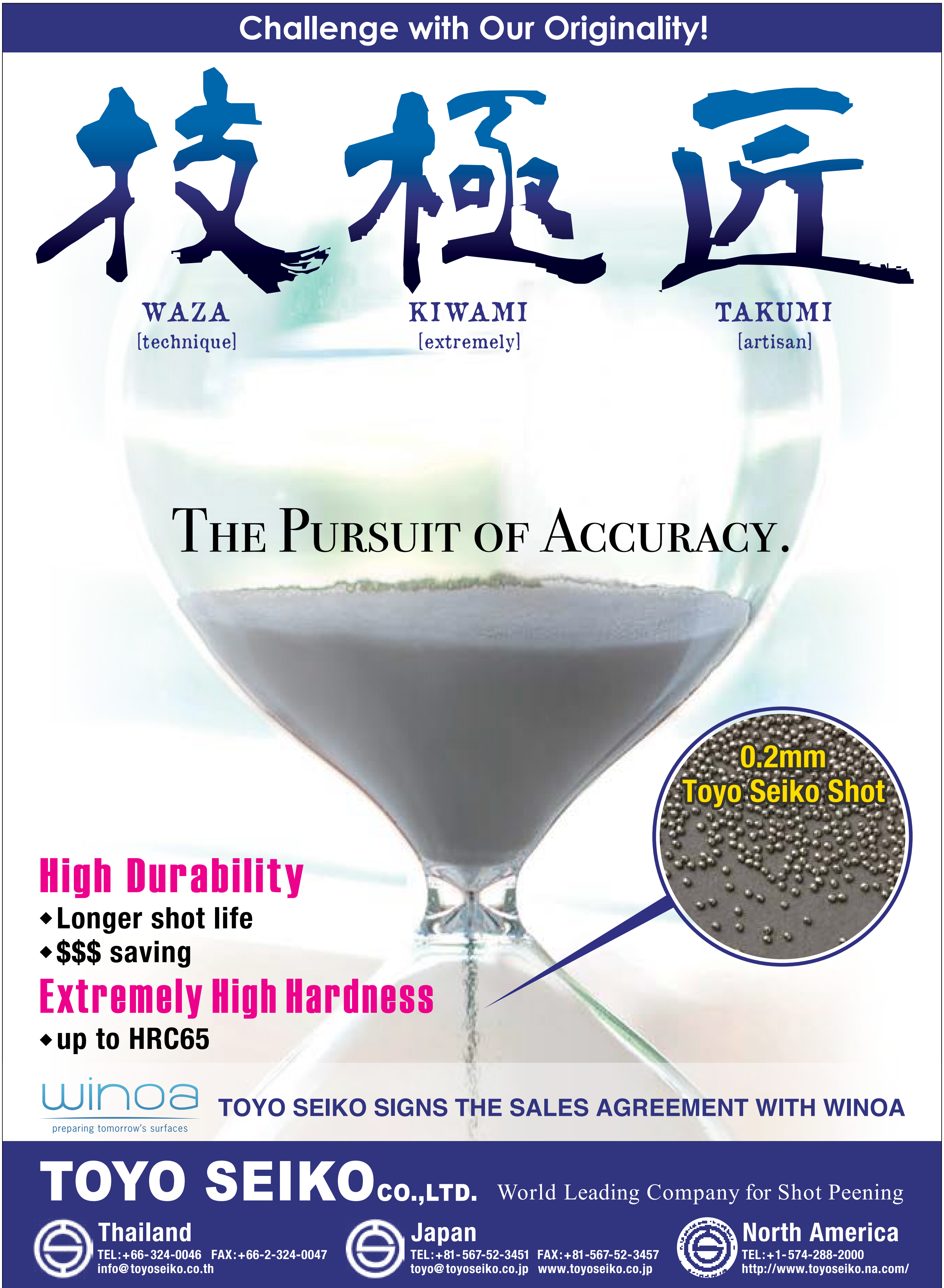
THE COST OF OWNERSHIP

Many of a 3D printer's initial and ongoing expenses are like any capital expenditures. There are, however, a few unique start-up and ongoing costs of this equipment, including:

- Employee training and the learning curve – "Startup can be slow. Do not expect good parts the first day," said Mr. Sutton.
- File preparation software research, purchase price, and ongoing licensing fees
- Raw material shelf life
- Raw material disposal (many of these materials aren't recyclable)
- Utilities – "Did you notice how much power it pulls? That heat goes somewhere," said Mr. Sutton.
- Time and materials for post processing



Laser-sintering is a Powder Bed Fusion process. Laser-sintering is ideal for manufacturing because of its easy design process and it allows users to build complex geometries. Parts typically possess high strength and stiffness. (Image source: EOS)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- Quality control in part geometry and material properties
- Build plates and other consumables

SHOW ME THE MONEY

There are three uses for 3D printers that are common in our industry: Non-functional prototypes, functional prototypes and tooling. Mr. Sutton said, "If a picture is worth 1,000 words, a 3D-printed part held in the hand is worth a million." All the benefits of prototypes—fit-and-form checks, assembly space management, and good communication—can be realized quickly and efficiently. We can print metallic components, saving days, weeks or even months rather than waiting for a machine shop to fabricate a functional prototype. It's a cliché but it's still true: Time is money. In addition, many types of tooling can be made with AM and an exciting application is the ability to produce specialized tools that you can't buy.

Next, I will tell you about three companies that have successfully integrated AM into their workflow.

REAL-LIFE APPLICATIONS

ITAMCO

As early as 2012, ITAMCO was using their MakerBot 3D printer to replace plastic parts on equipment in their open gearing and machining facility. "Rather than ordering an expensive replacement knob from the machine OEM and waiting a long time for it, we make a new knob on the MakerBot," said Joel Neidig, Director of Research and Development at ITAMCO. In 2015, the company launched their "Strategic Technology Initiative for Additive Manufacturing." At the same time, ITAMCO was part of a group that received R&D funding from the National Center of Defense Manufacturing and Machining (NCDMM) to conduct research on the support structures used in additive manufacturing. They purchased an EOS M 290 additive manufacturing printer for the project and have continued to expand their AM capabilities. They developed the Atlas 3D software for 3D print designers and are working on several projects with the US Army, Department of Defense and the Air Force, including a confidential gearing project for the US Army. Closer to their facilities in northern Indiana, ITAMCO supplies additive-manufactured prototypes for local companies. "We are continually stretching our capabilities to cross new boundaries in additive manufacturing," said Mr. Neidig.

Electronics Inc.

The engineering team at Electronics Inc. (EI) wanted a 3D printer to make prototypes. After researching the options, they chose an Objet30 Pro by Stratesys. "A good example of how we use the printer are the prototypes we made for a modification on the 700-24 MagnaValve," said Bryan Chevrie, Product Engineer with Electronics Inc. "We wanted to change the blade angle on the valve so we tested prototypes of a new mount. We were able to find the ideal solution in a short period of time."

The engineers at EI began to see other opportunities for the technology. They now depend on it for tooling and fixtures. "The software and hardware are user friendly so it's easy to develop new uses for the printer. The only real learning curve was in optimizing the expensive print material," said Mr. Chevrie.

Progressive Surface

"We bought a 3D printer so we could rapidly print machine component geometry or part geometry. We wanted to test design concepts for machine features and evaluate clearances and access for process viability," said Jim Whalen, Vice President of Sales and Marketing for Progressive Surface. Mr. Whalen provided two examples of how 3D printers are used in machine design at Progressive.

1. We needed to determine if we had enough clearance to get a deflector lance into a complex part feature. We printed a sub-scale version of the complex part and an equally scaled robot-end effector. We could then determine actual deflector lance geometry to get access to the area that needed peening.
2. We utilize 3D printing to make part-holding tooling for prototype process application work.

Progressive began using 3D printers five years ago and they have upgraded to get improved software and capacity. Mr. Whalen has advice for anyone thinking of getting a 3D printer, "Understand what you intend to do with this tool so that you can establish the printing materials you will need. That will lead you to the right printing technology."

Author's Note: Don't miss the article from Colin McGrory, Technical Director with Sandwell UK, on page 10. Mr. McGrory was using Additive Manufacturing 20 years ago and he has good advice for anyone thinking of starting an AM program.

CONCLUSION

I trust I've made the case for Additive Manufacturing. ITAMCO, EI and Progressive Surface are successfully using the technology and I'm sure many of our readers are, too. Those of you in aerospace and medical might be working for companies that are making production parts with AM. Many job shops are shot peening additive-manufactured components. So as Mr. Sutton said, "A 3D printer is possibly the best and most flexible tool in the manufacturing engineer's toolbox. In fact, it's a whole new drawer in the toolbox."

About Springboard Engineering Solutions

Springboard Engineering Solutions offers expertise in a wide range of engineering services, including Additive Manufacturing, to help designers, inventors and manufacturers bring their products to market. Contact Mr. Sutton at (574) 514-4351 or bsutton@springboardengineers.com.

Colin McGrory | Technical Director | Sandwell UK

Additive Manufacturing at Sandwell UK

IT WAS SOME 20 YEARS AGO that I purchased two SLA machines for my employer. We were primarily developing quarter- and third-scale wing profiles for wind tunnel testing. It was the quickest method to produce a large volume of components for intensive development programmes. At the time it was the only method available so the options we have now are something of a sweet shop of methods and materials.

Colin McGrory, Technical Director with Sandwell UK, was the 2016 Shot Peener of the Year

In 2018, the staff at Sandwell decided it was time to investigate the Additive Manufacturing market for our own needs. Much of our shot peening and finishing work is low-volume and rapid turnaround; hence, 3D manufacturing looked to hold the key for both masking and fixturing.

After trawling the Internet, we decided there were too many options. Whilst all the machines promoted this and that feature we had a pretty fixed idea of what we needed to achieve from a machine. SLA and powder bed machines were out—too messy, too complicated, especially on the powder management side.

We wanted the simple world of FDM (Fused Deposition Modeling). With the wide range of filament materials available now, it would provide us with a toolkit of materials to suit our applications. The operational side and functionality was not immediately evident from the 2D world of the Internet, so we decided to visit one of the large trade shows.

It became apparent that there was much to learn—heated beds, feed rates, filament sizes, multiple print heads, temperature ranges, etc. In a world where the technology is developing so rapidly we decided to jump in, purchase what we considered to be a good professional machine, and use it as a platform to understand the process. Once installed and the software downloaded, these machines are incredibly easy to use.

We embarked on a series of trial-and-error builds in different orientations and using different materials. We referenced the same model to check for dimensional stability and accuracy (and the resistance to shot impacts).

Within a few weeks we had shortlisted three materials that provided support, stability and accuracy. These materials could be used in a shot peening machine and, providing our program didn't dwell too much on these fixtures, they were perfectly adequate for our short batch-run applications.

Now, after 12 months, we could not do without our 3D printer. It is used daily and forms part of our suite of machines used for the production of masks and fixtures alongside our CNC mill and lathe.

OK, so you do need good CAD skills to get the best from one of these machines, but once you appreciate the flexible manufacturing approach and capability there are very few limitations to what can be produced. You really do have to rethink the design process. The design options are limited only by your imagination with a 3D printer.

We are shot peening and finishing more and more of our client's additive-manufactured parts so it's rather satisfying to produce masking and fixturing by the same process.

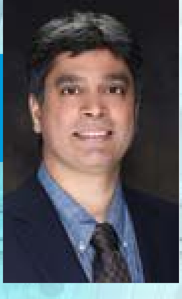
3D Printer Glossary

Mr. McGrory references the following 3D printers in his article. This information is taken from the "Guide to Additive Manufacturing" by ITAMCO (www.itamco.com).

Fused Deposition Modeling (FDM) is a form of Material Extrusion. It's perhaps the best known additive manufacturing process. FDM extrudes a thermoplastic filament through a heated nozzle and onto a build platform. The material then solidifies as it cools, although not until it fuses to adjacent layers. FDM uses a wide variety of thermoplastic filaments, metal and wood.

Powder Bed Fusion (PBF) melts particles and fuses them together. Particles of plastic or metal powder are either "sintered" (partially melted) or fully melted using thermal energy in the form of a laser, beams of electrons, or a heated print head.

Stereolithography (SLA) uses the Vat Photopolymerization process. Its roots are the first 3D printers. SLA uses a build platform in a tank of liquid polymer. A UV laser shines from beneath the object and maps each layer. When finished, the platform rises and liquid resin pools below the object to begin the next layer.



AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

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.

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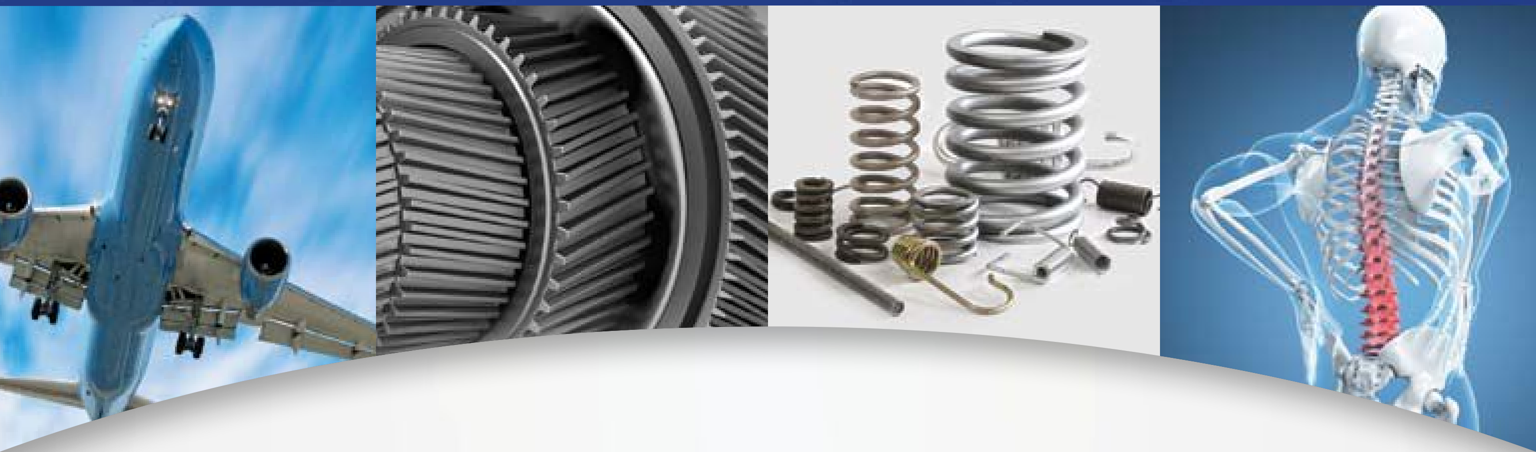

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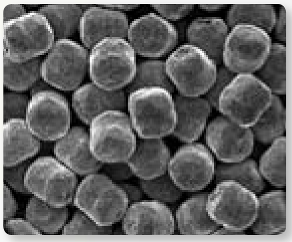

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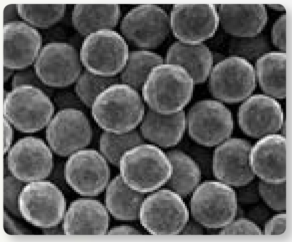

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Fatigue Testing Guidelines

These guidelines are a collaboration between Dave Breuer (Curtiss-Wright Surface Technologies) and Charlie Li (DANTE Solutions). Since most shot-peened components receive heat treatment, Mr. Breuer and Mr. Li work together to provide solutions for customers interested in residual stress from both processes.

WHEN QUALIFYING shot peening (SP), engineers utilize data such as computer simulation and fatigue testing in a controlled setting. This data is faster, relatively inexpensive and useful to making decisions on SP. This lower cost data may qualify the SP so when expensive field testing occurs, it verifies what was already proven on subscale components.

The intention of this article is to discuss guidelines for proper laboratory fatigue testing. The following items will be discussed in greater detail:

- Specimen Geometry
- Accelerated Testing
- Stress Gradients

Specimen Geometry

Most fatigue failures occur from bending or torsional loading. Bending/torsion leads to crack initiation at the surface as the applied stress is highest for both types of stress. Shot peening is a surface treatment ideally suited for surface-initiated failures.

Figure 1 shows a finite element simulation of fatigue loading of the tooth root of a test gear. The adjacent graph shows the applied stress plotted against depth. The bending stress is highest at the surface and drops almost 50% at 0.5 mm depth.

It is not unusual for a part to be loaded in an axial direction and the high-stress area to not be axial stress, but rather bending or torsion stress due to geometry (cross holes) or misalignment. A compression spring experiences an axial load along its centerline and produces a torsional stress on the wire.

The most common type of fatigue test equipment performs axial, tension-tension (T-T) pull testing. If possible, the fatigue test engineer should avoid using axial T-T fatigue testing when the shot-peened component experiences primarily bending/torsion stress. Unlike bending/torsion, axial stress is more uniform across the cross section. Subsurface failure can occur, often initiating just below the shot peening compressive layer which is in residual tension (as it balances the residual compression at the surface). It is difficult to quantify shot peening performance on laboratory test coupons that experience subsurface failure when the actual component experiences surface-initiated failure.

Figure 2 (page 20) shows a finite element simulation of an axially loaded round fatigue coupon. The high-stress area occurs at the surface of the narrowest part of the coupon.

The adjacent enlarged view of the center area shows 270 degrees of the surface along with the centerline of the coupon. Under axial loading, the coupon's gradual taper produces a slight bending stress at the surface with the core also being in tension. This coupon is not optimal for a shot peening study on a component that experiences pure bending (or torsional loading).

A potential solution when using an axial fatigue test machine to represent pure bending is to put a "C" shape in the center area of the pull-pull specimen. This produces a bending tensile stress in the weak area of the coupon that is expected to fail while keeping the grip areas in the same location for mounting on the test machine. Additive-manufactured coupons can be printed relatively easily with almost any geometry.

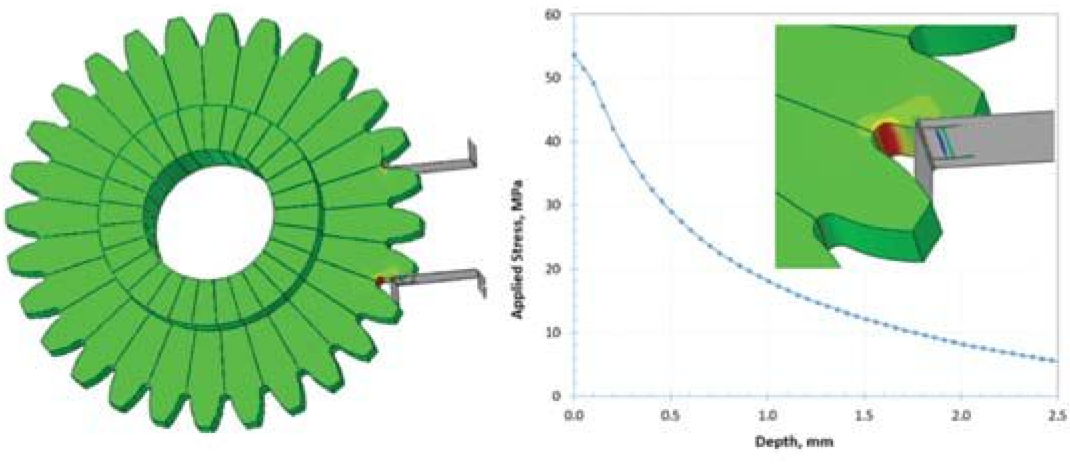

Figure 1.

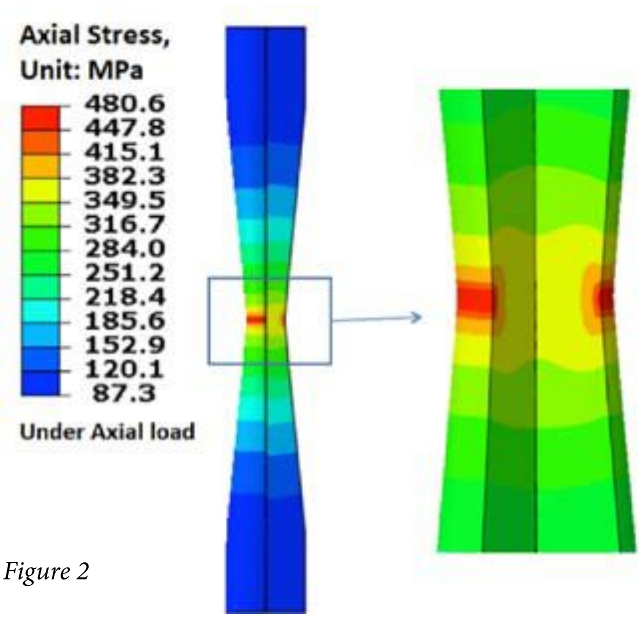

Figure 2

Accelerated Testing

When performing sub-scale component testing, the shot peening provider generally fears the statement, "We don't have a lot of time so we are increasing the test stress." Obviously, higher stress translates to reduced fatigue test life and less time (and cost) in the test lab. The concern with this approach is that shot peening is generally successful in lower-stress, higher-cycle fatigue environments.

If the test stress is increased sufficiently, it becomes a high-stress, low-cycle fatigue environment where shot peening may not prove effective. A decision maker may conclude that shot peening is not a proper solution simply because the test environment deviated significantly from the real world (lower) stress where shot peening would be effective.

A good balance for testing high-cycle fatigue components in the lab is to design the coupon stress and test machine to produce failure at 75,000 ±25,000 cycles in the unpeened condition. This fatigue life is not low-cycle fatigue and significantly less than one million cycles. Different shot peening iterations should produce different outcomes to identify which peening parameters are optimal.

The S-N (Stress versus Number of cycles) curve explains the theory. The vertical axis is a linear scale and the horizontal axis is exponential. As shot peening (residual) compressive stress offsets the (applied) tensile stress of fatigue loading, the component believes it is experiencing lower stress and experiences a large increase in life cycles. The reader may want to investigate the S-N graph for additional background.

Stress Gradients

Shot peening is usually applied to geometry changes at a part's surface (radii, holes, keyways, etc.). This geometry can be referred to as a "notch" and the tendency for fatigue cracks to start in these areas can be attributed to the part's "notch sensitivity".

When qualifying the effect of shot peening on a part, the test apparatus will be designed so the coupon experiences similar stress as the component experiences in the final assembly. In addition to matching the applied stress, the stress gradients from the manufacturing processes should be similar between actual part and test apparatus.

Using DANTE software, Figure 3 shows calculated stress distributions of a four-point bending coupon (with a large radius) and a gear tooth root under bending. Both coupon and gear are loaded in bending to produce similar tensile stress at the surface. The coupon with the large radius has the tensile stress field spread over a larger area.

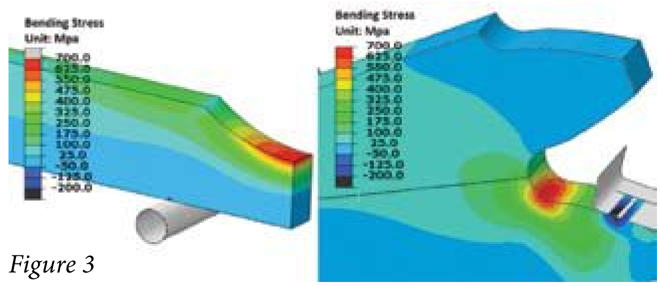

Figure 3

One should not expect the crack behavior (initiation and growth) to be similar if the stress gradients are different. To represent the gear-bending fatigue behavior, it is recommended to design the four-point bend coupon to have the same residual stresses from heat treatment and shot peening processes. With the proper applied load and geometry designs, the combined applied stress and residual stress of the coupon can effectively represent the gear bending stress behavior.

Shot peening compressive stress is concentrated in the 0.003-0.005" closest to the surface. Should one perform the simulation and plot the resultant (residual + applied) stress, different stress gradients may exist. Different stress fields will likely produce different crack behavior in different geometries.

The authors have many years of experience in the collection of fatigue data to validate and apply shot peening. Zhichao (Charlie) Li is president of DANTE Solutions which specializes in computer simulation of residual stress and fatigue life. Dave Breuer works for Curtiss-Wright Surface Technologies, helping customers to understand and apply shot peening on components in many industries.

About DANTE Solutions

DANTE Solutions is an engineering consulting and software company, specializing in metallurgical process engineering and thermal/stress analyses of metal parts and components. The company is the home of the DANTE Heat Treatment Simulation Software.


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D. A. Brice and D. F. Bahr | Center for Surface Engineering and Enhancement School of Materials Engineering, Purdue University

Self-Peening of Titanium Alloys with Ti-Based Shot

INTRODUCTION

Surface contamination from shot peening is a well accepted, but less often reported, consequence of shot-based surface modification processes. Residue from shot material on treated surfaces has been reported to decrease corrosion performance for Al, Fe and Mg alloys [1-3]. It would seem logical that using shot media with a similar chemical composition to the target material, i.e., self-peening, could be a possible solution to minimize surface contamination incurred by shot peening. Since Ti alloys are often used in corrosive environments (from chemical processing to biomedical implants), offering a self-peening solution for these alloys may be particularly helpful to assuage any fears about surface chemical contamination. This study shows a new process to harden Ti powder that can then be used as shot media for self-peening. The performance of the Ti-shot was evaluated in regards to the surface composition after shot peening and the residual stress evolved from shot peening, and then compared to peening with glass bead media.

CREATING TITANIUM SHOT

Production of the Ti-based shot media requires a single step and low temperature heat exposure that allowed for controlled oxidation. The process did not cause the sintering of titanium particles. The same process was applied to a bulk piece of commercially pure grade 2 Ti (Cp-Ti) that had an approximate composition to the powder to measure compositional changes and hardness changes resulting from the processing (see Figure 1-c). Compositional measurement shows that a large concentration of oxygen is present near the surface. This has resulted in nearly the tripling of the surface hardness in relation to the as-received hardness of the titanium, and even surpassed hardness of Ti21s after age hardening. Nanoindentation hardness measurements performed on the processed Ti powder coincide with the bulk measurements. SEM microscopy of the powder shows that the surface is covered in small islands of titanium oxide (see Fig. 1 a-b). Consequently, the tripling of the hardness of the processed Ti powder is caused by solute hardening from oxygen ingress into titanium and oxide islands on the surface.

SELF-PEENING TITANIUM

Specimens of Ti-64 were shot peened with glass beads (SiO_2) and Ti-shot. The SiO_2-shot had an average diameter of 300 µm and the Ti diameter was, on average, 100 µm, and densities of 2.52 and 4.50 g/cm3, respectively. All specimens were peened with a propelling pressure of 80 psi for 40 seconds on test coupons 20 mm x 20 mm x 1.60 mm. The compositional measurements from Glow Discharge Spectrometry (GDS) (see Fig. 2-a) show that shot peening caused penetration of contaminants from shot media as trace amounts of Si (SiO_2-shot) could be detected 14 µm from the surface. Specimens peened with Ti showed a significantly decreased content of oxygen on the surface, and lesser penetration when compared to the specimen peened with SiO_2. Residual stress profiles produced in each specimen are presented in Fig. 2-b. The residual stress from both SiO_2 and Ti-shot is similar

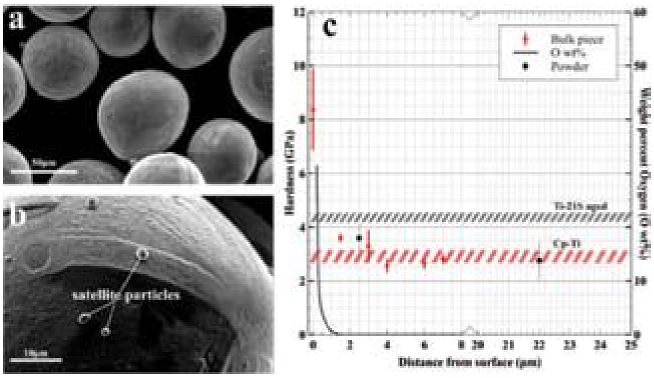

Figure. 1 Scanning electron microscope images (taken with a secondary detector) show (a) surface of treated powder and (b) higher magnification image of surface showing small oxide domains. (c) Oxygen concentration and hardness measurements of treated titanium. Red band shows average range of hardness of Cp-Ti. Grey band shows average hardness range of age hardened Ti-21S, a particularly hard Ti alloy. The surface of the oxidized Ti shot exceeds the hardness of bulk materials.

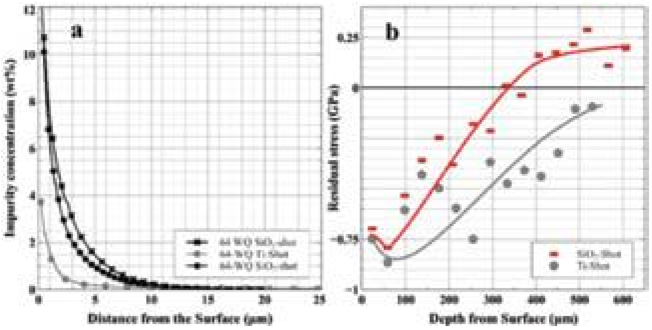

Figure. 2 (a) Glow Discharge Spectrometry quantitative depth profiles comparing surface contamination, and (b) Residual stress measurements of Ti-64 peened with glass and Ti.

in magnitude and penetration, with the smaller Ti-shot producing slightly more compressive residual stress.

CONCLUSIONS

The newly developed Ti-based shot media has been successfully produced and used to peen Ti alloys. Use of Ti-shot clearly minimized the introduction of contaminants to the peened surfaces, providing a proof of concept for justifying the interest in self-peening. Self-peening could eliminate the need of subsequent cleaning processes after peening. The residual stresses produced from Ti-shot were similar to those produced with SiO_2-shot, even though SiO_2-shot was significantly larger. The higher density Ti-shot can achieve similar residual stresses to lower density shot while keeping shot size small and consequently decreasing possible surface roughness. Our next steps will be a comparison to iron-based shot and exploring the effectiveness on larger Ti-shot.

ACKNOWLEDGEMENTS

The financial support of industrial partners with the Center for Surface Engineering and Enhancement at Purdue University is greatly appreciated.

[1] Q. Sun, Q. Han, X. Liu, W. Xu, J. Li. The effect of surface contamination on corrosion performance of ultrasonic shot peened 7150 Al alloy, Surface and Coatings Technology 328 (2017) 469-479.

[2] C. Muller, R. Rodriguez. Influence of Shot Peening on the Fatigue and Corrosion Behavior of the Die Cast Magnesium Alloy AZ91 HP. Conf, Proc. ICSP–8 (2002) 271-277.

[3] P. Zhang, J. Lindemann, C. Leyens. Shot peening on the high-strength wrought magnesium alloy AZ80—Effect of peening media, Journal of Materials Processing Technology 210 (2010) 445-450.

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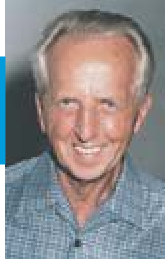

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Coverage Science

INTRODUCTION

Science is almost always able to provide answers to questions about observed phenomena. Consider as examples: “Why are snowflakes sometimes large and sometimes small?”, “Why are honeycombs made up of regular hexagons?” and “Why will a glass of warm milk solidify more quickly than an identical glass of cold milk when placed together in a freezer?” The ability of science to provide answers also applies to subject areas such as metals science, aka metallurgy. We do not need, however, to be subject specialists in order to appreciate and utilize the answers that can be obtained.

This article concerns shot peening coverage science. Most of the actual science involved is already available in several previous articles in *The Shot Peener*. Their content has been condensed so as to produce a simplified presentation.

Coverage is defined as the percentage of a component’s surface that contains peen-induced dents. As peening progresses, the percentage of the surface containing dents increases. This increase, for a given shot stream, is exponential towards 100%, rather than being linear. Fig. 1 illustrates the theoretical shape of a coverage/peening time curve. The peening time scale is arbitrary as it depends on the indentation rate.

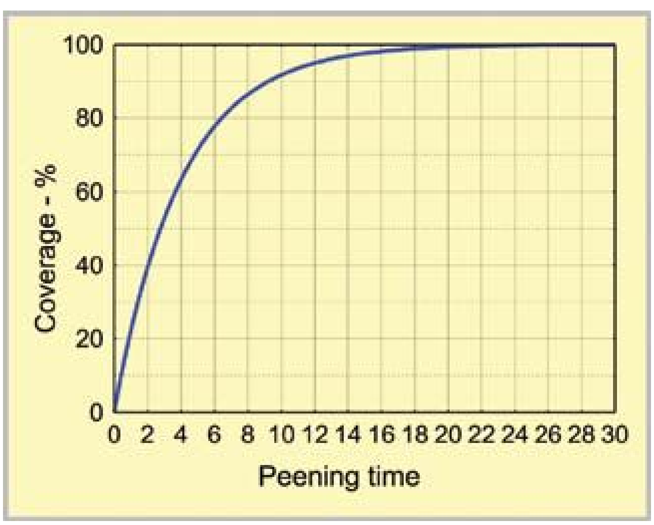

Fig. 1. Theoretical coverage versus peening time curve.

COVERAGE RATE

Coverage rate is important to shot peeners because it determines how long a component must be peened in order to impart a customer’s specified amount of coverage. The equation for coverage versus peening time is:

$$\mathbf{C = 100(1 - \exp(-\pi r^2.R.t))} \qquad (1)$$

Where **C** is the percentage coverage, **r** is the average radius of each dent, **R** is the rate of impacting (number of dents imparted per unit area of surface per unit of peening time) and **t** is the peening time. The coverage rate, **K**, extracted from equation (1) is therefore given by:

$$\mathbf{K = \pi r^2.R} \qquad (2)$$

For which the πr^2 term is the area of each dent.

Equations (1) and (2) allow us to exercise quantitative coverage control!

If we can assign a value to **K**, we can predict the coverage that will be achieved in any given peening time, **t**. Equation (1) then simplifies to:

$$\mathbf{C = 100(1 - \exp(-K.t))} \qquad (3)$$

The coverage rate, **K**, is simply the product of the dents’ average area multiplied by the rate at which these dents are being produced. Dent diameter can be determined either directly on a peened component or theoretically using a dent diameter prediction equation. The equation was published in the Spring, 2004 edition of *The Shot Peener* as:

$$\mathbf{d = 1.278\ D.(1 - e^2)^{0.25}\ .\rho^{0.25}.v^{0.5}/B^{0.25}} \qquad (4)$$

Where **d = dent diameter, D = shot diameter, e = coefficient of restitution, ρ = sphere density, v = sphere velocity and B = Brinell hardness of component.**

It is much simpler, and quicker, to actually measure average dent diameters on a component that has been subjected to a low coverage percentage. Having established the average size of dents we next need a value for the rate, **R**, at which the indents are being produced.

A value for the rate of impacting, **R**, can be predicted by considering the geometry of the shot stream and the flow rate of shot particles. Consider, as an example, an air blast nozzle producing a conical shot stream (see fig. 2 on page 30). We know the feed rate, **F**, and the shot diameter, **D**, of shot flowing through the nozzle and we can measure the diameter of the peened circle, **CD**, when the shot stream is impacting a flat component’s surface. From the feed rate and the average

mass of the shot particles, we can estimate the flow rate of particles. If, for example, 100 shot particles per second are indenting an area of 400 square millimetres, the rate of impacting is 0.25 dents per square millimetre per second. If the area of each dent is 1 square millimetre then the coverage rate, **K**, will be 0.25 per second (1 mm^2 times 0.25 $mm^{-2}s^{-1}$). This $0.25s^{-1}$ coverage rate happens to be that used in plotting fig. 1.

An ability to vary the coverage rate, **K**, allows us to tailor peening in order to give a desired coverage in an economical time. The three control parameters are: size of dents, rate of denting and peening time. Size of dents depends on the factors included in equation (4). In practice, peeners have little control over the size of dents being imparted. Varying the shot velocity, for example, would affect the peening intensity. This leaves us with having to rely on the rate of impacting, **R**, and the peening time, **t**, in order to control coverage. As a reminder, **R** is the rate of impacting (number of dents imparted per unit area of surface per unit of peening time). For a specific nozzle, **R** can be varied by simply varying the feed rate. Two factors must be borne in mind: (1) the feed rate has a maximum at which the nozzle becomes choked and shot flow stops and (2) increasing feed rate for a given nozzle increases the efficiency of power usage. The first factor is very familiar to air-blast shot peeners, the second factor much less so.

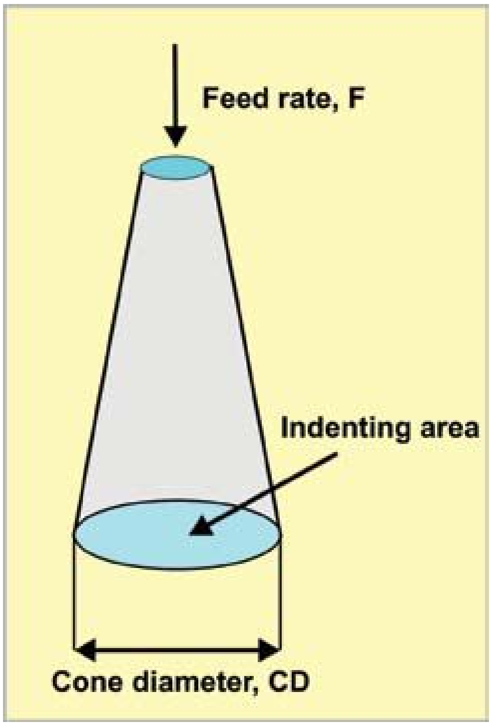

Fig. 2. Conical shot stream.

The reason for the conical shape of a shot stream emerging from a straight bore nozzle is that emerging air pushes the particles sideways. This is a non-uniform effect so that the indenting area becomes inhomogeneous. The center of the indenting area receives higher velocity shot particles than does outer areas. As a consequence, the coverage rate is highest at the center.

EFFICIENCY OF AIR-BLAST POWER USAGE

Power is required to accelerate the air in the nozzle. It is also required to accelerate the shot particles. Power usage efficiency, η can be defined as:

$$\eta = P_{shot}/P_{air} \tag{5}$$

Where P_{shot} is the power needed to accelerate the shot and P_{air} is the power needed to accelerate the air. For a given nozzle, shot and peening intensity, P_{shot} is almost linear function of the feed rate whereas P_{air} is almost constant. If the feed rate is zero then the power usage efficiency is also zero—we are simply blowing air! As the feed rate increases so does the power usage efficiency up to the rate at which the nozzle becomes choked.

In order to increase the coverage rate beyond the choke rate, we have to use a larger diameter nozzle. Estimating the effect of nozzle diameter on power usage efficiency requires consideration of how nozzle diameter affects P_{air}. For a given maintained air pressure the air flow is proportional to the cross-sectional area of the nozzle. This cross-sectional area is $\pi D^2/4$ where **D** is the nozzle's diameter. The power needed to produce the air flow is therefore proportional to D^2. Power needed to accelerate the shot to its emergent velocity is still (almost) a linear function of the feed rate, **F**. Fig. 3 is one example of the effect of nozzle diameter on air-blast power usage efficiency ratio. For this example, feed rates having a range of 0.8 to 8 has been combined with nozzle diameters having a range of 1 to 10 mm.

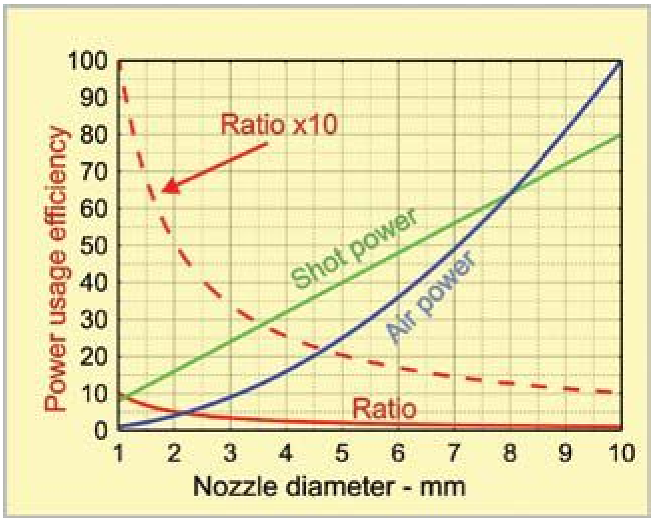

Fig. 3. Effect of nozzle diameter on power usage efficiency ratio.


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UNIFORMITY OF COVERAGE

It must be stressed that:

Coverage achieved is the product of coverage rate multiplied by the actual time of peening.

As a simple illustration, if one dent was being produced per unit area per second then 10 dents would be produced per unit area in 10 seconds. If, however, the coverage rate was doubled to two dents per second then 20 dents would be produced in 10 seconds or 10 dents in five seconds. These actual times of peening are only true if the shot stream is stationary over the component which hardly ever is the case.

In practice, perfect coverage uniformity is impossible to achieve—it can only be approached. Peeners have to contend with two major variables: (a) coverage rate variability within the indenting area and (b) the actual time of peening.

Coverage Rate Variability within the Indenting Area

Fig. 4 is a pictorial representation of coverage rate variability within the indenting area. The darker shade at the center represents higher coverage rate.

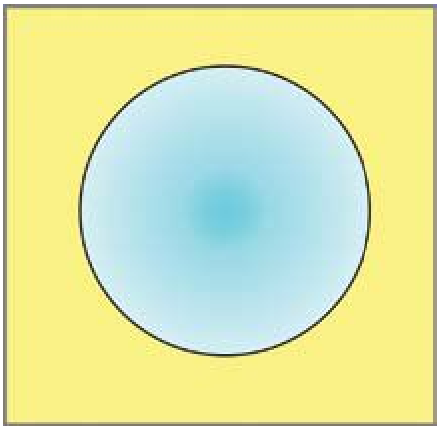

Fig. 4. Coverage rate variability within indenting area.

Actual Time of Peening

If we move a circular-section shot stream in a straight line across a flat component's surface, the coverage of the peened area varies from zero to a maximum. This is because the actual time of peening varies from zero at the top and bottom of the shot stream/component interface to a maximum at the center. Fig. 5 illustrates the variability of coverage produced. This is a very important phenomenon and full details of the science involved appeared in *The Shot Peener* article "Coverage Variability", Winter, 2017.

Consider next the effect of using several offset parallel passes in order to cover a larger area of a component. If the offset is equal to the diameter of the shot stream's indenting area then coverage will take the form of separate individual stripes, as indicated in fig. 6. Reducing the offset will result in a more uniform, but still stripy, coverage, as indicated in fig. 7.

Science can be employed in order to predict the achievement of maximum coverage uniformity. For a single

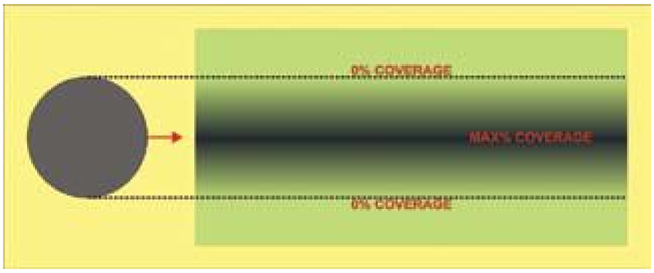

Fig. 5. Variability of coverage produced by a single linear pass.

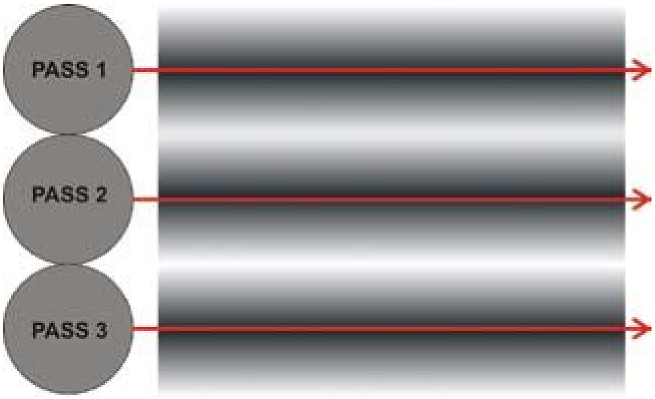

Fig. 6. Stripe coverage imparted by passes offset by the indenting area's diameter.

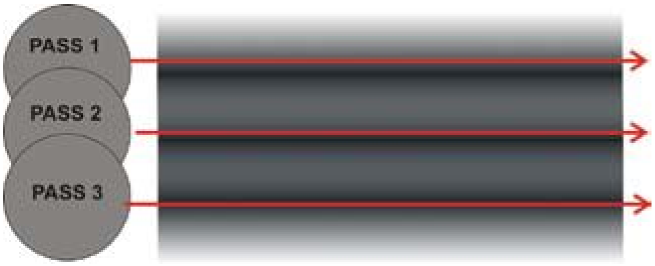

Fig. 7. Reducing pass offset improves uniformity of coverage.

pass, it can be assumed that coverage is zero at the edge of the shot stream's indentation area and rises sinusoidally to a maximum at the centre of the indentation area. If we offset two parallel passes by precisely half of the shot stream indentation area we get, theoretically, the situation presented in fig. 8.

This predicts perfect coverage uniformity! Such perfection would, however, require perfect shot stream positioning and a constant coverage rate over the whole of the shot stream's indentation area. As indicated previously, coverage rate varies substantially over this area (see fig. 4). Notwithstanding these limitations:

Optimum coverage uniformity is predicted to be achieved with a pass offset of half of the shot stream's indentation area diameter.

An alternative approach, when seeking uniform coverage, is to

use a thin-slit nozzle. Fig. 9 illustrates the difference between round- and slit-orifice shot streams' indentation areas. Fig. 10 is a schematic representation of their comparative coverage uniformities with (a) for a round cross-section and (b) for a rectangular cross-section of impacting areas. Consider, as an analogous situation, painting a flat wall. A rectangular brush is always preferable to a round brush for achieving uniform coverage.

Available methods of coverage prediction are fundamentally flawed. This is because they are all based on the assumption of uniform coverage being applied at each pass to a fixed point on the surface.

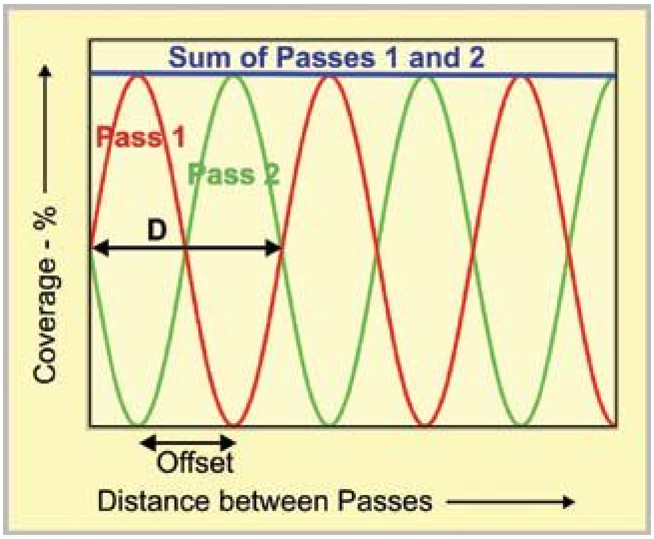

Fig. 8. Predicted optimum coverage using an offset half of the shot stream's indenting area diameter, D.

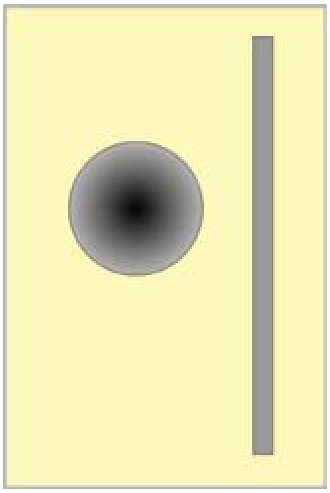

Fig. 9. Indentation areas for circular and slit peening nozzles.

COVERAGE MEASUREMENT

Coverage measurements can be made either manually, using the naked eye, or by employing computer-based image-analysis software.

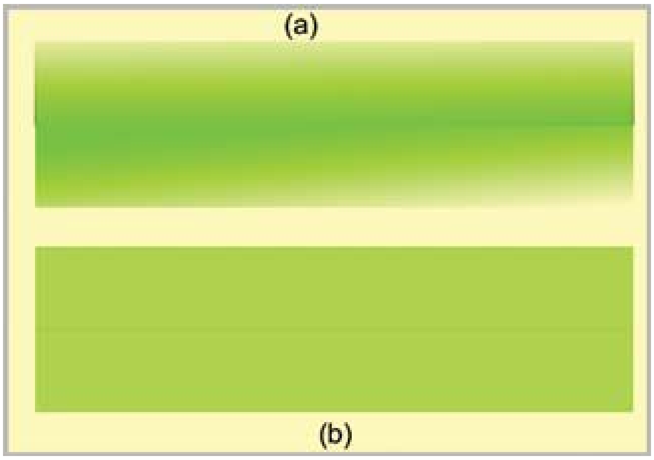

Fig. 10. Non-uniform (a) and uniform (b) coverages produced by round and narrow slit nozzles respectively.

(a) Manual Coverage Measurement

The most commonly used manual method is to compare a magnified image of the shot-peened surface with "standard" images, such as those in fig. 11. There is, however, a subjective element in this procedure. On the other hand, the human brain can act as a marvellous computer. Indeed, in many areas of image analysis, manual measurement is still considered superior to computer-based measurement.

Often overlooked is the lineal analysis method for quantifying coverage. It is similar to computer-based methods insofar as lines on an image are divided into dent and non-dent lengths. The principle involved is illustrated schematically by fig. 12.

As an exercise, printing fig. 12 allows the "dent lengths" to be measured using an office ruler. The sum of the dent lengths on each line is then divided by the "100%" length. By way of illustration, on a print of fig. 12 and using 170 mm lines the author found the total dent lengths to be 137, 140, 120 and 140 mm for lines 1, 2, 3 and 4 respectively. Dividing these by 1.7 (in order to arrive at coverage percentage) gave values of 80.6, 82.4, 70.6 and 82.4 respectively. The average is 79.0%. The variation of the values reflects the variability of coverage that occurs, on a micro scale, for actual peened components. In practice, a high-resolution photograph of a peened area can be enlarged and printed for lineal examination. On real peened components, the author aims for making about 20 measurements of dent lengths per line on up to 10 lines (it comes quicker with practice!).

Fig. 12 is schematic, being designed solely to illustrate the principle of the lineal analysis method when applied to coverage measurement. Real peened surfaces are, of course, much less clearly defined. That is where the human eye can score over one aspect of computer-based image analysis. An experienced observer can distinguish dent edge borders individually with reasonable accuracy. The human visual cortex is an excellent image analysis apparatus.

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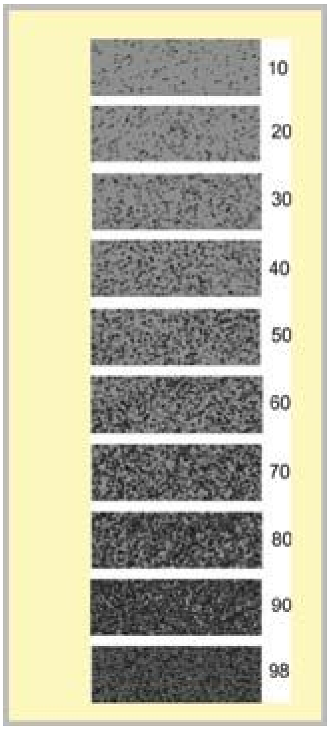


Fig. 11. Standard Comparison images for Coverage Assessment.

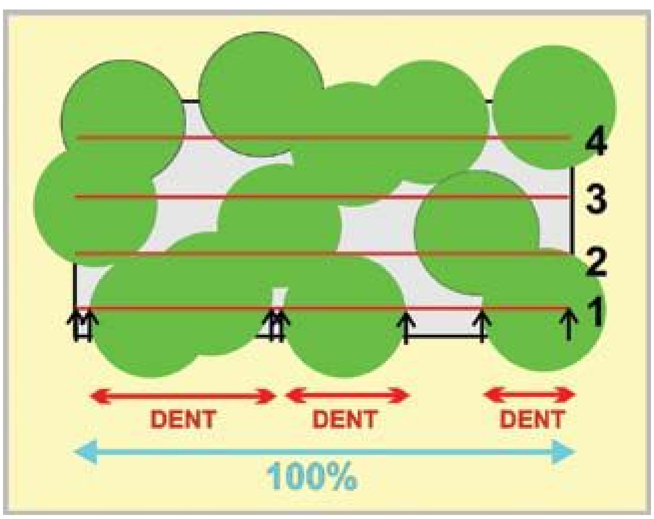


Fig. 12. Identifying dent lengths for a fixed length of measurement.

(b) Computer-Based Image Analysis of Coverage

This method is based on exactly the same principle as the manual lineal analysis technique. The main differences are that each computer scan line normally embraces far more dents and far more scan lines are involved. One major problem, however, is the difficulty of identifying dent edges. This does not arise when computer-based image analysis is being employed to study shot size and shape variation. "Image Analysis and Computer Microscopy of Shot Particles" was the very first article that I submitted to *The Shot Peener* (Vol. 15, Issue 3, Fall 2001).

DISCUSSION

The main aim of this article was to show how scientific principles can be applied to coverage. Traditionally, shot peeners have relied on manual estimates of percentage coverage. This, necessarily, involves a degree of subjective judgement. The human brain is, however, an excellent image analyser. Computer-based image analysis shares with manual analysis the problem of distinguishing between dented and undented regions of a peened surface. The lineal measurements at the heart of computer-based image analysis can also be carried out manually.

A secondary aim of this article was to present a condensed version of the author's coverage-related articles that have appeared in previous editions of *The Shot Peener*.*

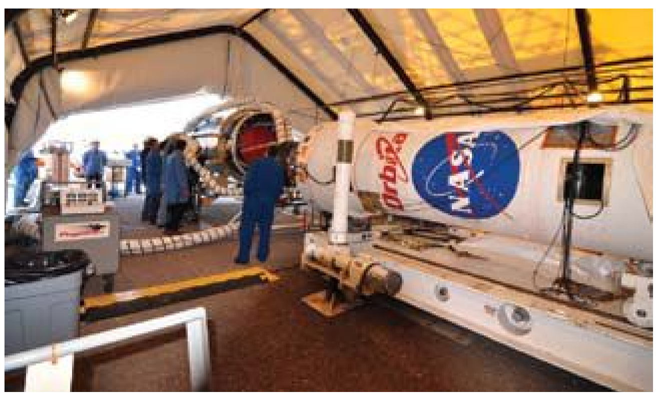
The obvious variability of coverage over the surface of peened components is not generally recognized. Attempts to predict coverage based on repeated passes are only relevant if applied to the same point on the component's surface.

**Previous articles by Dr. Kirk can be found at www.shotpeener.com/library/kirk_articles.php.*

NASA Investigation Uncovers Cause of Two Science Mission Launch Failures

The revelation that NASA purchased sub-standard aluminum for almost two decades serves as a clear message to our industry. Compliance to industry standards and the certification of shot-peened components are critical.

APRIL 30, 2019 - NASA Launch Services Program (LSP) investigators have determined the technical root cause for the Taurus XL launch failures of NASA's Orbiting Carbon Observatory (OCO) and Glory missions in 2009 and 2011, respectively: faulty materials provided by aluminum manufacturer, Sapa Profiles, Inc. (SPI).



Technicians are joining NASA's Glory spacecraft with the Taurus XL rocket's third stage. The launch failed due to faulty materials from Sapa Profiles, Inc. Photo: NASA

LSP's technical investigation led to the involvement of NASA's Office of the Inspector General and the U.S. Department of Justice (DOJ). DOJ's efforts, recently made public, resulted in the resolution of criminal charges and alleged civil claims against SPI, and its agreement to pay $46 million to the U.S. government and other commercial customers. This relates to a 19-year scheme that included falsifying thousands of certifications for aluminum extrusions to hundreds of customers.

NASA's updated public summary of the launch failures, which was published Tuesday, comes after a multiyear technical investigation by LSP and updates the previous public summaries on the Taurus XL launch failures for the OCO and Glory missions. Those public summaries concluded that the launch vehicle fairing—a clamshell structure that encapsulates the satellite as it travels through the atmosphere—failed to separate on command, but no technical root cause had been identified. From NASA's investigation, it is now known that SPI altered test results and provided false certifications to Orbital Sciences Corporation, the manufacturer of the Taurus XL, regarding the aluminum extrusions used in the payload fairing rail frangible joint. A frangible joint is a structural separation system that is initiated using ordnance.

"NASA relies on the integrity of our industry throughout the supply chain. While we do perform our own testing, NASA is not able to retest every single component. That is why we require and pay for certain components to be tested and certified by the supplier," said Jim Norman, NASA's director for Launch Services at NASA Headquarters in Washington. "When testing results are altered and certifications are provided falsely, missions fail. In our case, the Taurus XLs that failed for the OCO and Glory missions resulted in the loss of more than $700 million, and years of people's scientific work. It is critical that we are able to trust our industry to produce, test and certify materials in accordance with the standards we require. In this case, our trust was severely violated."

To protect the government supply chain, NASA suspended SPI from government contracting and proposed SPI for government-wide debarment. The exclusion from government contracting has been in effect since September 30, 2015. NASA also has proposed debarment for Hydro Extrusion Portland, Inc., formerly known as SPI, and the company currently is excluded from contracting throughout the federal government.

"Due in large part to the hard work and dedication of many highly motivated people in the NASA Launch Services program, we are able to close out the cause of two extremely disappointing launch vehicle failures and protect the government aerospace supply chain," said Amanda Mitskevich, LSP program manager at NASA's Kennedy Space Center in, Florida. "It has taken a long time to get here, involving years of investigation and testing, but as of today, it has been worth every minute, and I am extremely pleased with the entire team's efforts."

According to a press release issued by the Department of Justice, SPI disputes NASA's positions, and except for those facts admitted to in the DPA (Deferred Prosecution Agreement) and the plea agreement, the claims resolved by the civil settlement are allegations only. There has been no determination of liability.

Innovative Clemco Employees Improve Efficiency

IT'S FRIDAY 2 P.M., and the weekend begins in 30 minutes for the 50 or so Clemco welders, assemblers, part handlers, and other plant employees who are sitting in the front office's main conference room. But today, like every Friday for the past half-year, the manufacturing team meets to screen their latest 2 Second Lean videos.

In a nutshell, 2 Second Lean is a business philosophy that promotes efficiency. 2 Second Lean encourages all employees to share ideas that can shave wasted time from production, even if only by two seconds, and then video their ideas. On a typical Friday, the Clemco manufacturing team watches 6 to 12 of their coworkers' videos to see the time-saving ideas they've implemented.

Employees have filmed more than 200 videos, most under a minute long, covering topics ranging from:

- Reorganizing work areas and shipping bays
- Redesigning work platforms used for reclaimer construction
- Modifying carts so parts don't fall out
- Altering shelving so pallets easily slide in and out
- Installing designated hooks for hammers, brooms, screwdrivers, hoses, and other tools so workspaces and the shop floor stay uncluttered
- A central location for consumables and welding wire
- Dozens of other ideas

"We encourage our associates to find ways to make their jobs easier and more productive," says Brad Gildehaus, welding supervisor. "We give them a half hour on Tuesdays and Thursdays to put their ideas into practice. They don't need approval from me to get to work on an idea, unless it involves a team. Then we meet on Friday to share what we've accomplished."

"Anything that causes our employees pain, we empower them to make their waste-reduction ideas a reality—and they are coming up with great ideas!" explains Robert O'Daniel, metal-fabrication supervisor. "We've been so successful that the Engineering and Customer Service Departments are now also running their own 2 Second Lean programs. We estimate that our employees' ideas are saving the plant 250 hours a week."

"That's like having six more employees on the floor each week," Brad adds.

Welder Jarrett Vandaveer shows how his invention keeps air hoses off the shop floor.

Part handler Danielle Stanley uses her clamp invention to easily measure the length of flex hose.

Welder Charlie Williams operates the platform he designed.

Winoa Holds First Health & Safety Week

WINOA has enlisted DuPont Sustainable Solutions (DSS) to increase safety awareness among its employees worldwide.

In May 2019, Winoa employees were challenged to keep safety top-of-mind by taking part in the company's first Health & Safety Week. Winoa focused on "incident investigation", kicking the week off all of the company's sites with an official message from the Executive Committee and an e-learning course on incident investigation. The course was paired with a practical "surprise" exercise where employees had to find the root causes behind an incident scene set up on all sites. This exercise aimed to put the theory into practice so that all employees could understand the risks they could face and the importance of putting safety at the heart of their daily activities.

Every employee received a different microlearning course each day on safety-oriented topics, including observation tips, how to deal with stress, slips & trips, emergency evacuation and back injuries. The objective of these microlearnings was to raise awareness on key topics that affect all workers, from office to plant site. Employees shared their experience when it comes to incidents, both in their private and professional lives, to bring more awareness to the fact that safety is a behavior that does not stop in the workplace but is transferred to every aspect of one's life.

"With about 1000 employees and a presence in more than 20 countries," says Pierre Escolier, CEO of Winoa, "we want Health & Safety to be one of the building blocks for a stronger culture within Winoa and it starts by talking about safety. The goal of our collaboration with DSS is not only to raise awareness, but to make safety something personal for each and every one of our employees and make safety an active choice."

About Winoa
Winoa is the leading global manufacturer of steel abrasives serving the transportation, equipment, energy and construction industries. Headquartered in Le Cheylas, France, Winoa employs about 1000 people and operates 11 manufacturing facilities located in France, Spain, Canada, South Korea, United States, Japan, Slovenia, Brazil, Thailand, South Africa and Russia.

About DuPont Sustainable Solutions
DuPont Sustainable Solutions (DSS), a DowDuPont Specialty Products Division business, is a leading provider of world-class operations consulting services to help organizations transform and optimize their processes, technologies, and capabilities. DSS is committed to improving the safety, productivity, and sustainability of organizations around the world. Visit www.sustainablesolutions.dupont.com for more information.

Norican Group Welcomes Joe Everett

THE NORICAN GROUP is pleased to welcome Joe Everett to the Wheelabrator Group team as Director OEM Product Development.

Joe Everett is the Director OEM Product Development for the Norican Group

Joe will lead product and market development in structural and fabrication applications to support customer solutions. As a 35-year veteran of the blast industry, Joe will combine his technical expertise and process knowledge with the broad Wheelabrator portfolio to develop innovative solutions to meet customer surface preparation requirements. Joe will work closely with our sales, applications and product engineering teams to create innovative solutions to exceed customer expectations.

When asked about joining Wheelabrator, Joe replied, "I've always considered Wheelabrator as a formidable and aggressive competitor. I researched their position in the industry versus other suppliers and found a vision for the future, an action plan to renew Wheelabrator's dominance in the surface preparation market and most importantly a commitment to serve customer needs. I want to be a part of that."

Marty Magill, Sr, VP Norican Group commented, "We are excited to add Joe's extensive blast experience and industry expertise to our Wheelabrator team to further enhance the value we can provide our customers. His consultative problem-solving skills will help our customers tackle their toughest challenges."

About Wheelabrator Group
Wheelabrator Group is the global leader in surface preparation technology offering a complete range of equipment, parts and services for air blast, wheel blast and mass finishing solutions. Leading companies in the foundry, automotive, aerospace, energy, marine, rail, construction and many other industries select Wheelabrator Group's products and services to improve their productivity and profitability. Norican Group is home to four leading, globally operating brands: Wheelabrator Group, DISA, Italpresse Gauss and StrikoWestofen. Together, they offer customers around the world a broad spectrum of solutions, spanning end-to-end grey iron foundry equipment, integrated light alloy castings solutions, high-end furnace technology, and surface preparation technology and services.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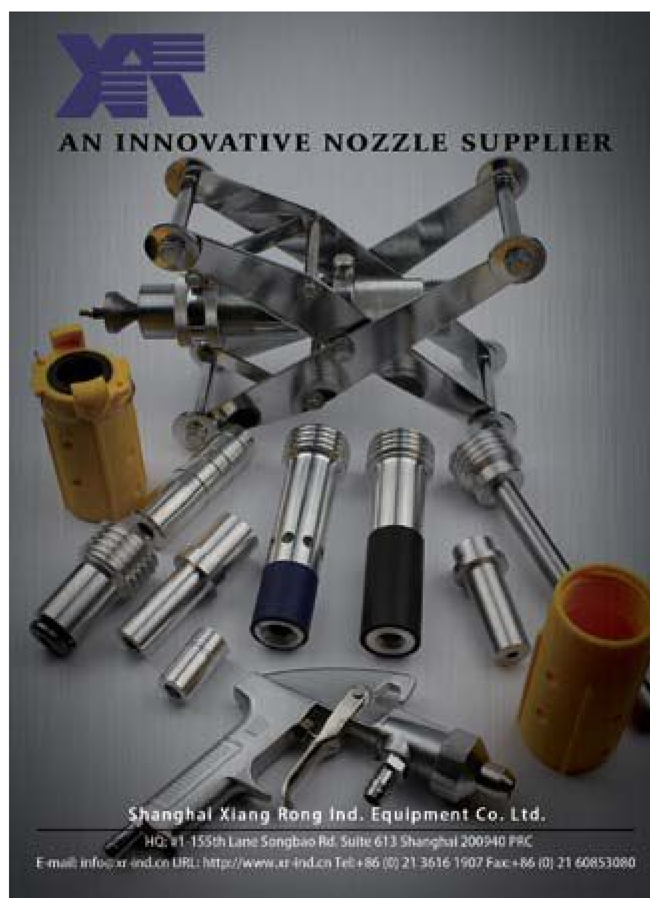
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Blast Cleaning Fracking Valves

Market: Oil and Gas
Application: Abrasive blast cleaning of fracking valves prior to coating

The Challenge:
A major supplier of fracking valves to the oil and gas industry wanted to blast clean the valves prior to coating. They were using two indexing turntable abrasive blast cleaning machines made by an Empire competitor. These machines were suction blast units with six to eight guns per unit.

The valves were cylindrical in shape and approximately six inches in diameter and six inches tall. The surface had several valve seats and a protruding surface, making the blast cleaning process challenging.

Employees manually re-adjusted the nozzles to accommodate the different parts. In addition, some parts were more complex, resulting in a longer set-up time for the guns. The finishing step was very important—a coating was applied after the valves were blast cleaned. However, the manual set-up was time consuming and it was affecting quality and repeatability.

The Solution:
Empire technical sales personnel and application engineers met with the manufacturer to evaluate the current process and determine their requirements. After careful analysis, Empire recommended the replacement of the two suction blast machines with a single automated indexing turntable machine that would employ a pressure blast system rather than suction blasting. Fully programmable, the new machine would dramatically reduce set-up time and make production more efficient.

The Empire machine consisted of a pressure blast system with six pressure nozzles, including one vertical oscillation station with three nozzles and one horizontal oscillator with three nozzles. This system featured a menu controller for the input of the blast parameters for each job. The new machine also employed two-direction part rotation control (clock-wise and counter clock-wise) so when the oscillator stroke was going up, the part would turn in one direction and when the oscillator stroke went down, the part would turn in the opposite direction. The end result of the changing part rotation was a more consistent finish. To further improve the surface finish, the Empire machine employed a higher rotation speed than the machines it replaced.

Benefits:
Empire was able to supply an indexing turntable abrasive blast cleaning system with advanced computer control and segmented blast coverage that not only increased productivity, but also assured a consistent finish quality. This was a major concern in this quality-intensive application that involved critical components. The fracking valve supplier was able to reduce production time from two minutes per part to less than one minute per part while maintaining or, in some cases, exceeding the current quality.

A natural gas fracking drill worksite in the middle of rural farmland in Pennsylvania.

Preventing Fretting Fatigue in CFM56 Aero Engines

DID YOU READ April's cover story in *Aerospace Manufacturing and Design* Magazine? (Read it at www.magazineaerospacemanufacturinganddesign.com/issue/april-2019.)

Dr. Jayaraman, Director of Materials Research at Lambda, wrote how Low Plasticity Burnishing (LPB®) enhanced the fatigue strength of the dovetail edge of the first-stage high-pressure (HPC) blade in the CFM56 aero engine.

The CFM56 aircraft engines power more than 13,400 military and commercial aircraft worldwide. The historical maintenance data on the CFM56 shows a tendency for fretting-induced micro-cracking in the dovetail edge of the first-stage high-pressure compressor (HPC) blade, posing a significant safety concern.

LPB is an FAA-accepted process for repair and alteration of the engine and structural aircraft components. If LPB is trusted to prevent fretting fatigue in thousands of commercial and military aircraft worldwide, imagine how it can improve the life and performance of your critical components.