

# *The* Shot Peener

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



The Future of  
Shot Peening  
Has Arrived

*The New  
Intelligent Machine by  
Progressive Surface*

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- OPTIMIZATION OF SHOT PEENING COVERAGE
- BLAST CLEANING CASE STUDY

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Easy USB connection to your PC



COVERAGE  
CHECKER



Coverage Measurement Device

# COVERAGE CHECKER

\*Device image

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※Specifications of this device may be changed without notification.

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**6** **Progressive Surface** has chosen our spring magazine to introduce their Intelligent Machine. This shot peening system with many innovative features will help meet the manufacturing challenges for a rapidly growing segment of the aerospace industry.



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**ITAMCO Connects Forklifts to the Industrial Internet of Things**

Forklifts, the workhorses of the plant floor, are more valuable than ever at ITAMCO. The company has connected their forklifts to the Industrial Internet of Things (IIoT)—the integration of machinery and equipment with networked sensors and software.



**THE SHOT PEENER**

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

# This and That

## In This Magazine

I am so fortunate to be in the shot peening industry. I joined SAE in 1983 and became involved with the Surface Enhancement Division of Fatigue Design and Evaluation Committee. This committee assumed the work of The Iron and Steel Committee which previously maintained the documents relating to Shot Peening. I inherited many papers from this committee and it was always interesting to see what was important many years ago. I found several references to shot peening coverage (dating back to the early 1960s). You would think by now we had this topic pretty well covered (poor pun). Read Dr. Kirk's article on coverage and see what we've been missing. It's dramatic.

Ken l'Anson makes a reference to John Almen in his article. Coincidentally, I recently received a phone call from a woman who said she is John Almen's niece. We plan to follow up with her and will share any interesting information she can provide on her uncle.

## Notable Events

The tenth annual Japan shot peening workshop in February was a big success. It was hosted by EI Shot Peening Training and Dr. Katsuji Toshi of Meiji University and sponsored by Toyo Seiko and Sintokogio. A record number of students from several companies attended the classes and participated in achievement examinations. Special attention was paid to Nadcap and audits due to the large number of aerospace companies in attendance. Hands-on flapper peening training was led by Brigitte LaBelle from Shockform.

The first call for papers for the 13th International Conference on Shot Peening (ICSP-13) has been published. Dr. Martin Lévesque is Chairman and Host. ICSP-13 will be held September 18 - 21, 2017 in Montreal, Canada.

This conference occurs every three years and gathers both scientific and industrial communities working with the shot peening process. The conference will feature technical talks from both academia and industry, as well as an exhibition of the latest peening-related equipment. The deadline for the abstract submission is December 31, 2016. More information can be found at [www.polymtl.ca/icsp13/en/index.php](http://www.polymtl.ca/icsp13/en/index.php).

On a final note, I'm the Chairman of the International Scientific Committee for Shot Peening—the group that sponsors the conferences—and if you're interested in joining the committee, please email me at [jack.champaigne@electronics-inc.com](mailto:jack.champaigne@electronics-inc.com). ●



**JACK CHAMPAIGNE**

## THE SHOT PEENER

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# The Future of Shot Peening Has Arrived!

**THE SPRING EDITION** of *The Shot Peener* is a wonderful place to showcase new beginnings. Following a long, cold and dark winter season, everyone looks forward to the spring when dormancy is replaced with renewed growth and optimism.

After five years of Research and Development at Progressive Surface and collaborative brainstorming with several key clients, we have chosen the spring of 2016 to introduce **The Future of Shot Peening** to the general peening population. This new age of shot peening is the solution to a quickly growing problem in the aerospace industry.

### The Problem

Components for the newest generation of commercial aircraft engines—the LEAP and geared turbofan (GTF)—have very complex geometries, narrow tolerances and demanding surface treatment requirements. These components need a wide variety of shot peening tools and frequent peening nozzle and lance changes to access all of their surfaces.

Compounding the manufacturing challenge is the popularity of these quiet, fuel-efficient, and low-maintenance engines. The demand for the new engines will soon outpace manufacturing unless automation is adopted. The combined production rate of the 737 MAX and A320neo will reach 110 aircraft per month in 2018 and each aircraft will require two engines. The sales figures for these two aircraft models are now at nearly 8,000 confirmed orders. The LEAP and GTF are being placed on other popular aircraft models as well. Industry analysts are saying there is no end in sight for the demand of these two new engines.

### The Solution

The answer to this opportunity is industrially hardened and process specific automation for the shot peening environment.

The shot peening industry will never be known as an “early adopter” of automation. This is not due to a lack of interest or desire, but rather an environmental issue. Shot peening has always been associated with very abrasive media, process dust and impact energy, making this industry a poor candidate for automation...that is, until now.

In response to industry demands, Progressive Surface has manufactured several fully automated shot peening

systems. “Fully Automated” means robotic part loading and closed-loop parameter control and monitoring, but the game changer for shot peening automation is the “tool changer.”

Our new shot peening system can robotically change from a conventional nozzle to a rotary lance head. It also has the ability to change between different sizes (length, diameter) of conventional nozzles and process/part specific lance nozzles. The Progressive Surface Tool Changer uses a



*The Progressive Surface Automated Tool Changer with Nozzle Magazine*

# Control

Empire Abrasive Equipment continues to lead industry with best in class peening and grit-blast solutions. Our highly controlled air-blast and recovery technology enables quicker production times. Our multi-discipline team of experienced engineers, along with state-of-the-art manufacturing and testing facilities, deliver solution driven designs for a diverse range of industries; from aerospace and automotive to energy and medical.

For over 70 years, we've been perfecting air-blast technology. Today, Empire has the most extensive range of advanced solution-driven equipment to exact any of your air-blast needs.

Let Empire engineer your competitive edge.



common blast hose delivery system with a highly specialized nozzle/lance holder. This Tool Changer resembles and operates as seamlessly as the Tool Changers used globally in multi-axis machining centers.

Imagine shot peening a turbine disc or maybe a complex blisk. Conventional peening nozzles have always been adequate for easy line-of-sight surfaces, but the disc has blade slots and a variety of small bores that require a Rotating Lance nozzle. Additionally, the part has hidden areas in the main bore that need a non-rotating L-Shaped lance, requiring a nozzle change. Or maybe it's the complex blades of a blisk that need to be peened without distortion, requiring a two-nozzle blisk tool.

If this describes your shot peening operation, then you're no doubt familiar with stopping the process and entering the peening cabinet to change nozzles. Maybe you need to check the alignment of the new nozzle and, most likely, run an Almen strip test. All of the above steps create non-productive, non-revenue producing machine downtime. These actions also invite operator error to enter the equation.

The Progressive Surface automated tool changer is the game changer our industry has been seeking. The shot

peening process and related industry is nearly 100 years old. I can't help but wonder what Mr. Almen would think of the today's shot peening industry—from its humble beginnings of manually grit blasting automotive valve springs to the peening of today's complex aerospace components.

Speaking of the past and future, is the new Tool Changer our industry's equivalent to Marty McFly's Hoverboard? (Reference: Back to the Future II)

### Two Key Features of the Intelligent Machine Cabinet-Mounted Camera

The Progressive Surface Automated Cell illustrated in this article includes a cabinet-mounted camera interfaced directly to the two robot controllers. This is a valuable, error-proofing tool. The camera compares the part to be peened to the associated image stored in its part program. If the part loaded does not match the stored image's information, the process will not start and the attending operator is given an alarm message. When the correct part is loaded, the camera compares the part orientation and automatically adjusts the robot off-sets to match the exact part position. This feature eliminates nozzle/part collisions and lance nozzle breakage.

### Features of the Progressive Surface Intelligent Machine

- Two articulated industrial robots, each with a dedicated wall-mounted tool rack
- Two RLD (rotary lance drives), each dedicated to a robot
- Two pressure pot media delivery units, dedicated to a robot, with closed-loop media and air pressure control with infinite adjustments and settings
- Six changeable nozzles/lances with no limit to the number of nozzles other than cabinet interior space
- Dual work stations: one for processing and one for loading
- ShotMeter velocity sensor that drops from the ceiling to measure media velocity
- Robotic camera to check part number via unique features and part orientation/position



*The Progressive Surface Intelligent Machine*

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*The Progressive Surface ShotMeter*

### **The ShotMeter**

The second Automation Plus feature is the ShotMeter. The ShotMeter is an optical sensor that accurately senses, measures and records the actual shot peening media velocity. For the system discussed in this article, the ShotMeter sensing head is located in the ceiling of the peening cabinet, extending for easy robot access and retracting when not in use. Once programmed, the robot will present the peening nozzle to the sensing head and the media velocity will be measured and compared to the part program requirements. After the velocity comparison is complete, the peening cycle can commence.

The media velocity is almost like a fingerprint—the blast hose diameter and length create unique media velocity with each different media flow and air pressure. Over time, the velocity slowly changes as the hose wears. The same is true for the blast nozzle. Virtually each and every nozzle type, length and internal diameter has a unique velocity with a given media flow and air pressure parameter when the nozzle is new. The media velocity is altered as the nozzle slowly



*The Progressive Surface Cabinet-Mounted Camera*

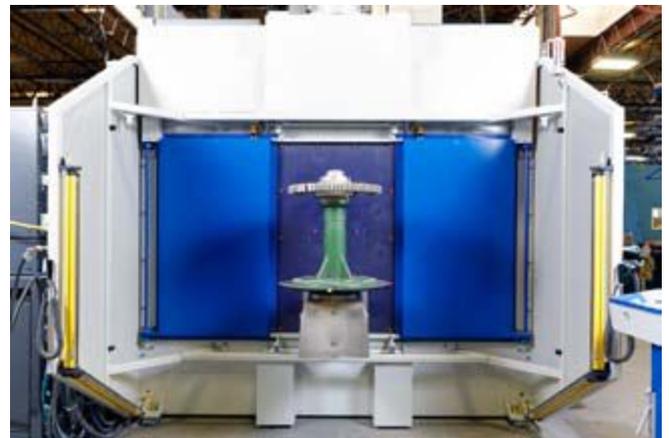
wears. This Automation Plus feature provides very accurate monitoring of the peening process to the point where many users are creating new shot peening specifications that greatly extend the interval between Almen strip test runs.

Note: For now and the foreseeable future, Almen strips will still be used when setting up the initial peening programs and for machine verification.

### **The Future of Shot Peening is Now**

Industry practitioners and experts alike agree there is a need and desire to automate and error-proof the process. Many naysayers have preached that the environment was too harsh and dirty to house cameras and tool-changers. Until now, all of this was true.

A new generation of Automated Shot Peening systems have been designed and proven in the field. Maybe for your application, automation starts with robotic or automated part loading. Maybe your requirements include in-process media changes to complete a part. Or, maybe your part geometry and closing tolerances need more surface-specific peening nozzles. In any of these examples, automation is the answer and with the exciting new generation of shot peening equipment, all is now possible. ●



*The Progressive Surface Intelligent Machine  
at MTU Aero Engines AG*

### **About Progressive Surface**

Progressive Surface™ is a global leader in the design and manufacture of automated machinery and closed-loop process controls for shot peening, abrasive grit blasting, thermal spray coating, and ultra high-pressure waterjet stripping applications in the aerospace, energy, medical, military, and general manufacturing industries.

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# Ultrasonic Shot Peening: From Portable Systems to Robotic Production Lines

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USP differs from conventional shot peening methods by the way kinetic energy is provided to the shot. Instead of using a constant air flow, gravity or high-speed rotation of a turbine, USP uses the acceleration of a vibrating surface called a sonotrode. The frequency of vibration is within the ultrasonic wave range (20 kHz), which explains the name of the technique.

## How It Works

A generator delivers a sinusoidal electric signal that excites a piezo-electric transducer to convert this electric energy into a mechanical displacement. Since the vibration delivered by the emitter is small, the vibration must be amplified by a series of boosters in order to transmit enough kinetic energy to the sonotrode which is directly in contact with the peening media.

Between the sonotrode and the precise area to be peened, a specific enclosure is designed. Thus, the media is hermetically contained in a controlled volume. Longitudinal vibrations of the sonotrode surface randomly disperse media into the treatment volume as molecules into a gas. This gas-like movement leads to a homogeneous treatment on all surfaces of the part being treated.

## Surface Roughness / Peening Intensity Ratio Concerns

In critical applications where deep compressive stresses are required and surface roughness must be kept at a minimum, USP can be a viable alternative to conventional shot peening techniques.

Due to the treatment hermeticity, media quantity is reduced to several grams and USP can thus be performed using high-quality media—such as bearing-balls with high sphericity—that do not abrade component surface. Media with a larger diameter can be used to reach a high intensity, induce deep compressive stresses and lower surface roughness. (For example:  $11.8\mu\text{in}/0.3\mu\text{m Ra}$  obtained on a TA6V part peened

with USP at 7-9A/F19A compared to  $118\mu\text{in}/3.0\mu\text{m Ra}$  in CSP with same Almen intensity.)

## Handheld Hermetic Peening for Downtime Reduction

Reducing downtime—and its related costs—is a major issue for Aeroengine and Gas Turbine manufacturers and MRO industries when handling major repairs on assembled parts.

Portable USP systems by SONATS are the solution for these industries. On-site shot peening with USP eliminates the need to dismantle the component and eliminates the risk of media loss inside the component. Typical applications of this localized shot peening are:

- Fan disk blended areas, without engine extraction, leading to a 80% reduction of repair cycle time
- gas turbine fir tree peening with reduced dismantling and complete media containment throughout the peening operation
- in-situ peening of damaged helicopter blades that saved \$220,000 per blade (See Avion Solution, Inc. article in *The Shot Peener*, Winter issue, page 36)



*StressVoyager® portable USP equipment on a storage trolley*



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*Stressonic®USP dynamic treatment of automotive output shafts*

### Automated Multi-Station Machines for Lean Manufacturing

Automotive gear manufacturers have to maintain high productivity while insuring an efficient and repeatable process to critical transmission parts. In this framework, major OEMs are utilizing USP automated machine integration in specific part production lines, thereby ensuring lean manufacturing preservation. Specifically in USP machines for gear peening, treatment is performed in dynamic mode to reach a pre-determined takt time. For example, a 40s takt time with a 4-station machine will produce 500,000 parts/year.

USP machines have the following automated functions: robotized handling directly from the previous process operation, media counting (in units or in grams), sonotrodes and media wear-out monitoring, operator warning when lifetime is reached, automated media loading/unloading for each independent workstation, global supervision and periodic quality report issuance. In lower production rate applications, semi-automated solutions are solicited with manual handling of the part through easily accessible windows.



*Stressonic®USP automated 4-station machine for automotive output shafts*



*Stressonic®USP tooling plate for automotive output shafts*

On multi-station production machines, the part tooling system includes a specific hermetic enclosure, part support and positioning tailstock (see photograph above).

The tooling systems are modular. They can be set up in any machine station, independently from part reference group.

Process requirements for transmission parts are specifically demanding. USP is preferred in critical applications, such as carburized gears and 20MoCr4 steel shafts, when high surface compressive stresses need to be homogeneously induced on the teeth flanks and teeth roots. USP is able to generate -1100MPa (145Ksi) surface compressive residual stresses while maintaining a low Ra value.

### Robotized Cells

The highest automated solution for USP process is the complete handling of the process by 6-axis robots. For the treatment of aerospace blisks, for example, a recent USP implementation included the global handling of the part and robotized enclosure positioning to perform treatment on blades, disc central bore, and disc holes. The decision to use USP technology for the blisks was mainly motivated by its ability to generate very similar residual stress profiles on both intrado and extrado sides of the blades, insuring the aerodynamics of the part without distortion. ●

### About SONATS

Founded in 1991, SONATS, Europe Technologies Group, is an innovative industrial company specializing in metal surface treatments using a patented ultrasonic process technology called Stressonic®. The company headquarters are located in Nantes, France. SONATS provides equipment, services and competencies throughout the world through an international network.

EMPOWERING TECHNOLOGIES INC., SONATS American subsidiary, is located in Alabama and provides Northern America with local process support and equipment after-sales services.



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# Visions of the Future

*Part two of a two-part series on the past, present and future of shot peening and blast cleaning from industry leaders, including Michael Brauss, Dominic Cimino, Jim Harrison, Scott Nangle, Alain Portebois, Jim Whalen and Ron Wright*

**WELCOME TO PART TWO** of our discussion on “Visions of the Future” in the shot peening world. In Part One, we established the current status of our shot peening industry through interviews with Jim Whalen of Progressive Surface, Ron Wright and Alain Portebois of Wheelabrator, Michael Brauss of Proto Manufacturing, Jim Harrison and Dominic Cimino of Curtiss-Wright/Metal Improvement Company and Scott Nangle of Empire Abrasive Equipment Company. This eclectic group further enlightened me on their thoughts on where we are headed—let’s see what they had to say.

## The Next Generation of Peening Equipment

Our group of experts was unanimous in their opinion that computer-controlled equipment—for better monitoring and control of the peening process—was the most important innovation in the past 20 years. However, each member of this group had a slightly different picture of the future.

“Progressive Surface has successfully experimented with ‘intelligent’ machines that reduce set-up time in the field,” said Jim Whalen of Progressive Surface. To explain the concept of intelligent machines, let’s use the auto industry as an example. In the last decade, the automotive industry has developed the driver interface with safety features such as lane control, back-up cameras and collision avoidance systems. They have concentrated less on the traditional engine, drive train and suspension. Similarly, Jim believes the shot peening machines of the future will incorporate error-proofing, enhanced internal communication and better process design, leading to a clearer handle on the machine’s health. He summarized, “This in turn will result in a machine that will not just raise alarms when the process is off track, but will actually be a few steps ahead in working towards a fix.” Jim also raised a very valid concern: The challenge of finding personnel capable of working with these intelligent systems.

Alain Portebois and Ron Wright of Wheelabrator see the future a bit differently, though still leading to a similar conclusion. “Peening equipment design is heading in the direction of a machine tool, much like a machining center. There is a growing similarity in accuracy, repeatability and controls intuition,” said Ron.

Alain added, “Aerospace customers of Wheelabrator are favoring offline programming techniques to optimize machine utilization.” Alain also said that part programs are prepared well ahead of time with 3D models of components. Wheelabrator R&D is working on techniques to improve the efficiency of existing media propulsion techniques in both wheel- and air-type systems.

Scott Nangle of Empire Abrasive Equipment Company also believes in connectivity. “We are already seeing our sophisticated customers connect their peening machines with the rest of their production machinery and processes. This is not just for validation and transfer of peening results, but also to put their already available electronic footprint to productive use,” said Scott. He feels the end goal is to make the diagnostics more intuitive, leading to earlier predictability of maintenance. This is especially valuable for aerospace and medical components.

Jim Harrison of Curtiss-Wright/Metal Improvement Company explained his vision relating to component design. “The future is about building shot peening process recipes as part of the component design. This will greatly reduce set-up time, costs and add better value to the entire operation. The design of aerospace components will follow tighter norms with the use of finite element analysis,” said Jim.

Michael Brauss of Proto Manufacturing believes X-Ray Diffraction (XRD) will eventually become part of the peening specification. “More companies are following their Almen strip validations with our XRD services,” said Mike.



# PREMIER

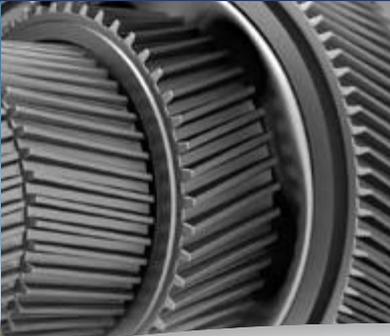


## PREMIER SHOT COMPANY

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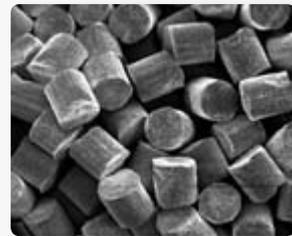
Twinsburg, OH 44087

# A Cut Above

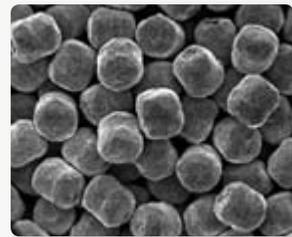


## The advantage of Premier Cut Wire Shot

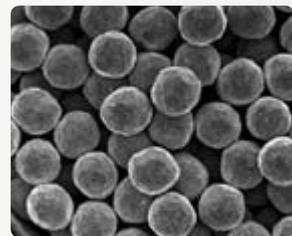
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### Specifications and Conformance

Dominic Cimino of Curtiss-Wright/Metal Improvement Company is well-informed on specifications. He said, "We don't see a relaxation in specifications. We see them getting tighter as companies spread their operations over multiple locations."

Jim Whalen said, "Specifications have been harmonized to a great extent and they're the best they've ever been. As a future step, they might include closed-loop monitoring of impact energy, and not just its constituents such as air pressure and media flow. XRD could gain a place in specifications, too."

Scott Nangle commented that the next stage in the evolution of specifications will include machine diagnostics, additional traceability measures and features to make the process smarter for the user.

Michael Brauss mentioned the liability issues of specification non-conformance. He thinks the use of specifications will spread through industry sectors.

While Ron Wright and Alain Portebois agree with their colleagues, Ron thinks there is a possibility that specifications may be relaxed in the future because improved technology and machine controls will assure repeatability.

### Almen Strips and Process Validation

"Almen strips will remain the prime process monitoring tool. We know the processing history of the part prior to peening will impact the effectiveness of peening. We use XRD to quantitatively validate the effectiveness of the peening process in introducing sufficient residual stress into the part. When the Almen strip results indicate peening process changes, it is important to use residual stress characterization by XRD to understand the actual impact on the part. XRD will continue primarily as a quantitative audit process," said Michael Brauss. When quizzed further on XRD and the likelihood of inline measurements, Mike said, "Inline measurements are used now. However, in order to conduct them in a completely non-destructive manner, there needs to be more developments in critical components such as X-Ray tubes and detectors to allow non-destructive stress with depth measurements."

Jim Whalen was pragmatic in his response and feels that quite a few users are still in the process of learning the traditional validation technique using Almen strips and this technique will continue to be popular. Scott Nangle maintains that traditional validation techniques such as Almen strip tests and media drop tests will continue to be used and he emphasized the need for education in such techniques so users derive the benefits of these practices.

My discussions with the group from Wheelabrator and Curtiss-Wright/Metal Improvement Company yielded the same feedback about traditional validation techniques, with an added comment from Jim Harrison. "Fatigue testing is also very important. Users can't solely rely on XRD or

validation with Almen strips," said Jim. Jim's employer, Metal Improvement Company, is often involved in this process from the initial stages of component design.

### Alternate Materials

Most of us have read about the increased use of composites in airframes. No one in our group views composites as a threat to the shot peening equipment industry.

### The Future

The future is here. We are already exposed to some of the elements our respondents have mentioned. What does this mean for users of peening equipment? There is no doubt that education is key. The technology that runs the process is as important as the peening process itself. As a pleasant surprise, the lower cost of electronic inputs hasn't resulted in increased costs in technological innovation. In addition, healthy economic cycles, industry consolidation and increased competition will ultimately result in quality peening equipment.

The potential skills gap identified by Jim Whalen is of great concern to me and everyone with a vested interest in the growth of this industry. Michael E. Porter of Harvard University uses a five point analysis to rate the competition within an industry. These are: Bargaining Power of Suppliers, Threat of New Entrants, Bargaining Power of Buyers, Threat of Substitutes and Rivalry Among Existing Firms.

In the shot peening industry, however, an ageing workforce adds a sixth dimension to competitiveness. I think it's time to retract our heads from the sand and ask the difficult question, "Do we have a new generation that is willing and able to take on the challenges and act on the opportunities identified here?"

Inherent weaknesses always present opportunities. For example, an industry-academia alliance for the metal surface finishing industry has been established by Purdue University to provide research to its members, establish a knowledge base and provide research experience for students. Since primes and their tiers can hardly be expected to share their R&D activities, university alliances provide research at a reasonable cost for smaller companies.

Stakeholders in this industry need to develop and protect the industry knowledge of its current workforce. However, the growth of technology in the surface finishing industry, particularly in shot peening, is sure to attract bright new talent. The potential for technological innovation in areas of intuitive controls, robotics, new applications, innovative materials and academic research will draw talent to this industry from other advanced manufacturing sectors.

The possibilities at this stage are practically limitless as we look at the future with renewed optimism. ●



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## New Technology for Blast Equipment Keeps Abrasive Cleaner

**WHEELABRATOR** has developed a new technology for abrasive separators that addresses the issue of uneven abrasive distribution and residual sand in abrasive cycles of foundry blast equipment. The Abrasive Curtain Regulator (ACR), showcased at CastExpo 2016 in Minneapolis, ensures a full abrasive curtain is maintained at all times, which results in better cleaning of the abrasive as well as more consistent blast wheel performance.

The ACR can be adapted to fit various Wheelabrator and non-Wheelabrator abrasive separators.

Without the ACR, gaps can occur in the abrasive curtain, allowing air to be freely drawn through the curtain—without the air fully carrying out its cleaning task. An intact abrasive curtain ensures blast media is distributed evenly across all blast wheels, which is important for a consistent treatment of each part. The ACR also stabilizes the condition of the abrasive operating mix, prevents unnecessary abrasive waste and thereby provides better control of operating costs.

Brian Cappallo, Director of Sales and Service at Wheelabrator Plus, explains: “It’s easy to dismiss devices like the ACR as an add-on to an add-on to auxiliary equipment. But especially in heavy-duty environments, this little device can make a huge difference to operations. Abrasive going through foundry blast equipment is a significant cost factor, and a well-controlled blast process is important in achieving consistent product quality. Adding the ACR means foundries can make the most of the abrasive they use, reduce waste and improve the efficiency of the blast process. The device can easily be included in regular equipment upgrades and maintenance and will pay for itself quickly.” ●



*The Abrasive Curtain Regulator from Wheelabrator*

## TITAN Wheel Upgrade Cuts Blast Cycle Time at AVK Polska

**AVK POLSKA**, a manufacturer of valves for water, sewage systems, gas and industrial extinguishing systems in Poland, has reduced the time it takes them to blast clean vital components by around 30%. This significant reduction in cycle time at the company’s Pniewy operation has been achieved by upgrading existing hanger blast machines with Wheelabrator TITAN blast wheels.

The blast machines are an integral part of the production process, and are used to clean cast iron workpieces ahead of powder-coating.

Before the upgrades, AVK was managing long, complicated and time-consuming processes in order to obtain spare parts for the existing blast wheels, causing delays to essential maintenance and unnecessary downtime.

These issues, along with concerns about one machine in particular, prompted the company to contact the team at Wheelabrator Poland.

After assessing AVK’s needs, Wheelabrator replaced the two original wheels on the machine in question with 11kW TITAN blast wheels. Advantages the TITAN wheel offered over the existing wheels included:

- improved blast performance,
- reduced abrasive consumption,
- improved machine uptime, and
- noise reduction.

In addition to these technical advantages, Wheelabrator was able to guarantee local availability of spare parts and short lead times for obtaining them.

As the company has a dedicated office in Poland, the Wheelabrator team could also offer service support locally.

While AVK’s problems around servicing and sourcing of parts was the initial reason for replacing the wheels, operations in Pniewy also benefitted from the 30% reduction in cycle time, which has created headroom for production increases. The company was so impressed with the reliability and performance of the TITAN wheels, they commissioned a wheel upgrade for another machine shortly after.

Leszek Rogacz, Chief Process Engineer at AVK said: “Getting spare parts for our blast wheels was proving almost impossible in the time scales we wanted. We knew there had to be a more efficient way of staying on top of blast wheel

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## BLAST CLEANING NEWS

maintenance. We contacted Wheelabrator initially to ask them to upgrade the wheels on our oldest machine.

“The new TITAN wheels surpassed our expectations. Not only has our parts sourcing become more steady and straightforward, which allows us to plan maintenance better and reduce downtime, but the significant reduction in cycle time has given us more production capacity as well. With results like that, it was just common sense to ask Wheelabrator to replace the wheels on one of our other machines too.”

The upgrades were carried out between August 2014 and July 2015 and were part of the Equipment Modernisation program by Wheelabrator. Benefits of this program include:

- Increase machine uptime and reliability
- Lower maintenance costs
- Reduce blast cycle time
- Reduce machine wear
- Achieve a higher cleaning standard
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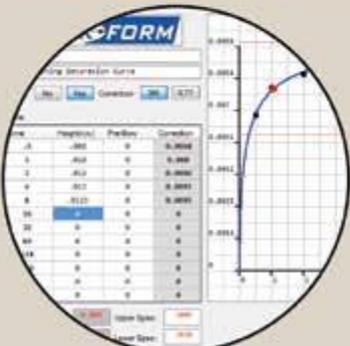
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# Optimization of Shot Peening Coverage

## INTRODUCTION

Shot peening coverage of components is, of course, very important. The importance of coverage optimization is emphasized in SAE J2277 with its: “Effectiveness of shot peening is directly dependent on coverage. Inadequate or excessive coverage may be detrimental to fatigue.”

Unfortunately, many users still believe that “More is Better” and require huge amounts of coverage, e.g., “300%”. This approach ignores the importance of the other factors that govern optimum coverage.

Property optimization normally relates to fatigue life. Variation of fatigue life with coverage depends on component design, material and stressing. For every combination there is a corresponding coverage/property-improvement curve. Fig.1. is a simple type of coverage/property-improvement curve illustrating two important features. Firstly, that the maximum property improvement normally occurs below 100% coverage. Secondly, that the property improvement varies only slightly on either side of the optimum coverage—as indicated by the double-headed arrow. If we can control peening variables to somewhere near the optimum then there will be only a small variation of maximum improvement value.

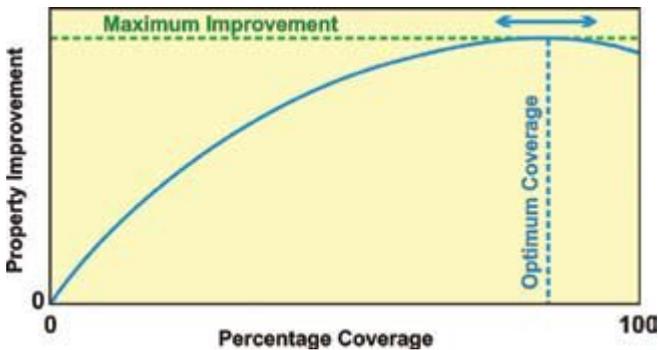


Fig.1. Example of a Property Optimization Curve.

Process control of coverage can only be achieved if the level of coverage can be measured with some degree of accuracy. 98% peening coverage is the maximum level that is recognized as being measurable with any degree of accuracy. It follows that less than 98% should normally be specified if coverage level is to be consistently applied.

Shot peening produces surface dents, work-hardens the surface and also induces compressive residual stress in the surface layer. Three types of coverage can, therefore, be identified:

- Dent Coverage,**
- Hardening Coverage and**
- Stress Coverage.**

Dents in the surface do not normally improve service performance. Hardening and compressive residual stress, on the other hand, do improve service performance. The three types of coverage are illustrated in fig.2.

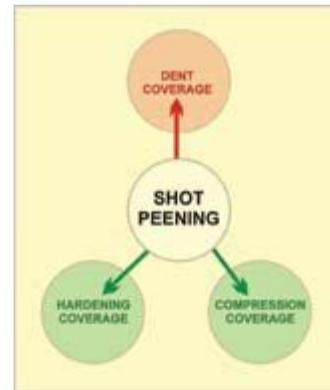


Fig.2. Generation of different types of coverage by shot peening.

The three types of coverage develop at different rates during shot peening. This article considers each type separately and indicates their effects on coverage optimization. Coverage is a quantity and therefore has to have ways of quantifying it. Several equations are included in the article. There is no need to be a mathematician to use these equations. Programs such as Excel will do all the work!

## DENT COVERAGE

Dent coverage is the one type universally recognized by shot peeners. Its great advantage is that it is a visible indication of the amount of shot peening. The SAE J2277 definition of dent coverage is: “The percentage of a surface that has been impacted at least once by the peening media.” This definition embraces two important features of dent coverage:

- 1 Dent coverage increases with amount of peening and**

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**2 The probability of multiple impactions.**

The quoted definition is, unfortunately, followed by: “The minimum peening time required to obtain 100% coverage is determined by gradually increasing total peening time until the entire surface being peened exhibits overlapping peening impressions (dents).” This statement is misleading as it implies that with a sufficient amount of peening, 100% dent coverage can be assured. It also implies that 100% coverage may be advantageous. Both of these are incorrect.

**Prediction of increasing dent coverage with increasing amount of peening.**

The prediction of increasing dent coverage with increasing amount of peening is well-documented. Prediction techniques are, however, normally based on two simplifying assumptions. These are (1) that every dent is circular and (2) that every dent has exactly the same radius. Given those assumptions, we have a coverage/time curve that has a simple shape. This shape has been analyzed and discussed in previous TSP and ICSP articles and is included in SAE J2277.

The mathematical equation that describes the shape of the conventional dent coverage curve is:

$$C\% = 100(1 - \exp(-.r^2.R.t)) \quad (1)$$

**C** is dent coverage, **r** is the fixed radius of the circular dents, **R** is the rate of dent creation per unit area and **t** is the time of peening.

As an example, consider 14 dents per second (on average) being produced within a square 10 mm by 10 mm, with each circular dent having a radius of 1 mm. Therefore  $r^2$  is 1 mm<sup>2</sup>, **R** is 0.14 per mm<sup>2</sup> per second and **t** is in seconds. The units in equation (1) cancel each other out. The product,  $.r^2.R$ , is the “coverage rate factor.” For this example,  $.r^2.R$  is 0.44. Fig.3 uses 0.44 as this factor. Therefore, after 1 second, an area of 100 mm<sup>2</sup> will have received, on average, 14 dents. Equation (1) then predicts an average coverage of 36%.

The theoretical curve, shown as fig.3, has exactly the same shape as the example given in SAE J2277. It is important to note that these curves are only accurate for average dent coverage. This point is illustrated in fig.4 which comprises 14 identical dents of precisely 1 mm radius – equivalent to peening for 1 second. These dents have been placed randomly within a square 10 mm by 10 mm – their centers having been chosen using computer-generated random numbers. For the example shown in fig.4 the measured dent coverage (within the yellowed square) is 42%, shown as “T” on the graph, (measured using several techniques which all gave the same value). Equation (1), however, predicted that the average dent coverage would be 36%. The difference between the measured 42% and the predicted 36% is due to statistical variation. The value of 42% has been included in fig.3 to emphasize statistical deviation. We should, therefore, note that there is a difference

between statistically-variant coverage for a restricted area and average coverage (coverage over a very large area).

Coverage curves of the type shown in fig.3 (and in SAE J2277) are very useful for predicting and controlling average dent coverage. Optimization of dent coverage requires, however, that we consider both the coverage achieved and the amount of peening needed to achieve that coverage.

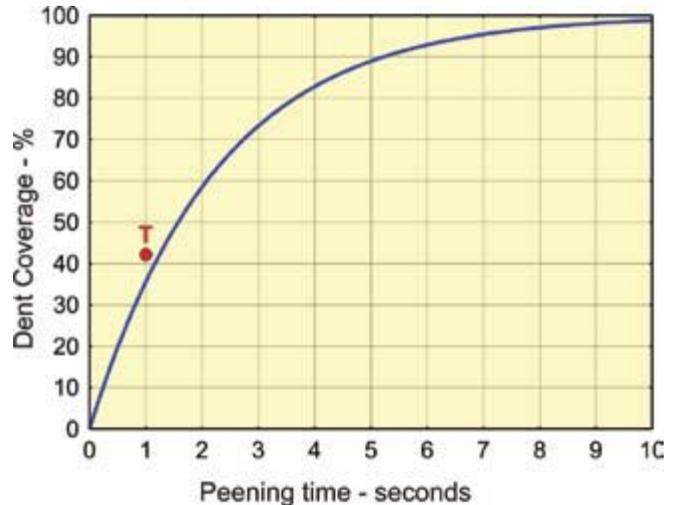


Fig.3. Theoretical average dent coverage curve for dents of 1 mm radius generated at a rate of 14 per 100 mm<sup>2</sup> per second.

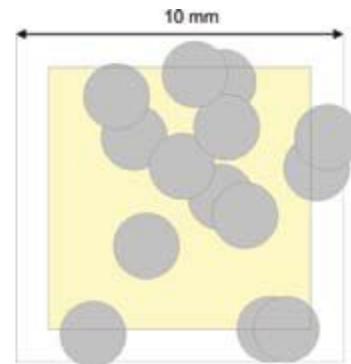
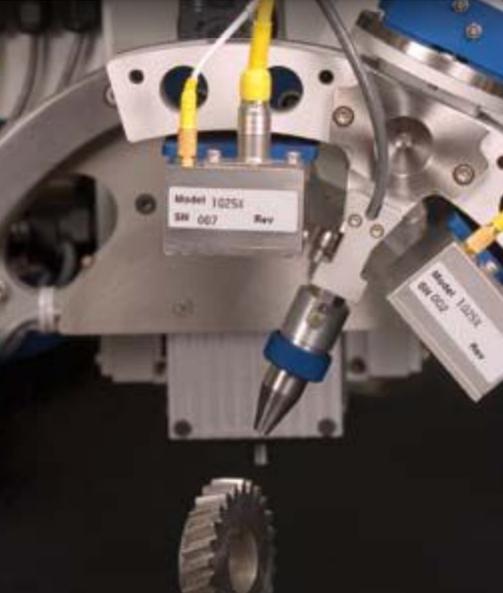


Fig.4. Precision drawing of 14 circular dents randomly distributed with centers within a square having an area of 100 mm<sup>2</sup>.

Fig.5 uses three different values of the peening rate,  $.r^2.R$ , and reverses the coverage axes usually employed. This axis reversal is designed to emphasize taking a different view of achieving desired coverage levels. At the lowest peening rate (shown in black) 86% coverage is predicted to be achieved in half of the time required to achieve 98% coverage. For a desired 98% coverage small changes in the amount of peening will only produce small changes in the induced dent coverage. On the other hand, if the desired level is 86%, small changes in the amount of peening will produce much larger changes in the induced dent coverage.

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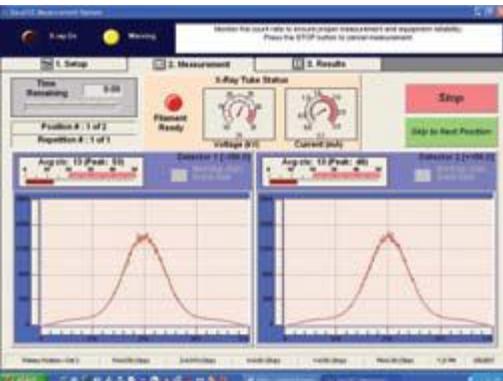
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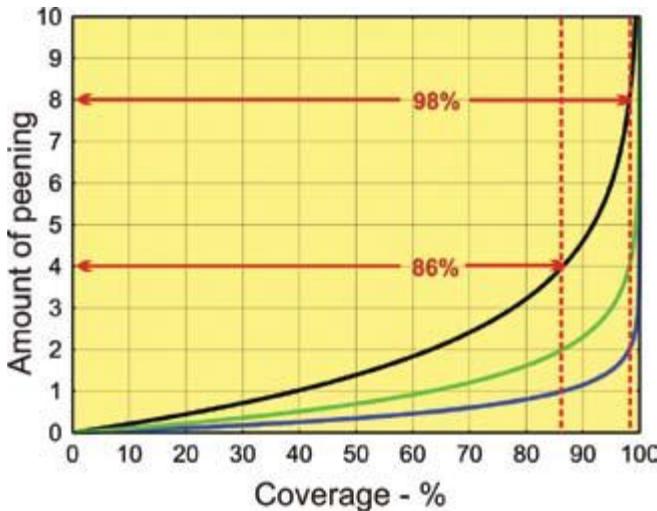


Fig. 5. Coverage curves using reversed axes.

**Prediction of multiple impactions with increase in amount of peening.**

A multiple impaction is defined as the part of a surface where dents have overlapped – either once or more than once. Fig. 6 identifies double impaction at A and triple impaction at B.

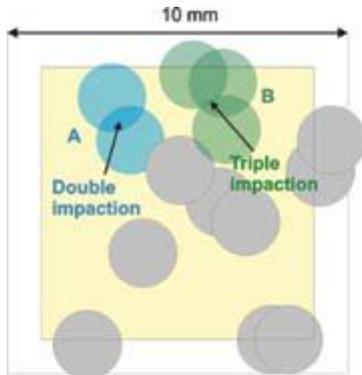


Fig. 6. Multiple impaction examples with only 42% coverage.

As the average coverage increases so does the probability of greater and greater multiple impaction.

The mathematical equation that describes the contribution to coverage by *n* overlapping impactions is:

$$C_n\% = 100[(.r^2.R.t)^n/n!]*exp(-.r^2.R.t) \quad (2)$$

*C<sub>n</sub>* is the contribution to total coverage by *n*-impacted areas, *r* is the radius of the dents, *R* is the rate of dent creation per unit area, *n* is the number of impacts that a particular area has received, *t* is the time of peening and *n!* is the factorial of *n*. Factorial *n* is 1\*2\*3...\**n*, so that, for example, when *n* = 4 then factorial *n* = 24 (1\*2\*3\*4).

Fig. 7 uses equations (1) and (2) to give a graphical representation of multiple impaction contributions to total coverage. The plots are those for which *n* has values ranging

from 1 to 9, *r* equals 1 mm and *R* is equal to 0.14 dent per mm<sup>2</sup> per second (as for fig. 3).

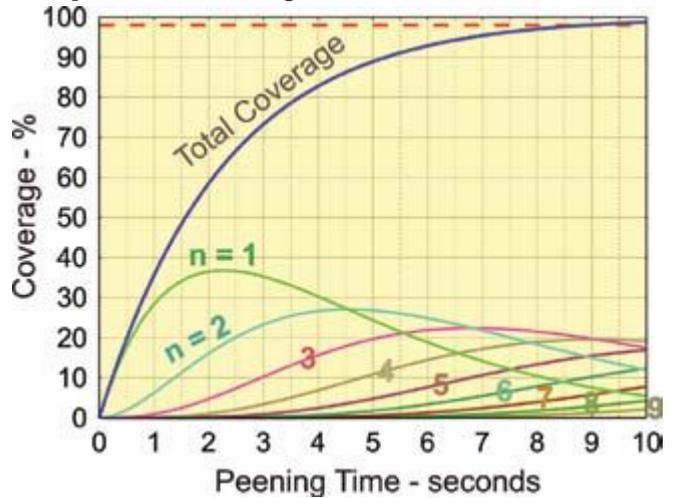


Fig. 7. Contributions of multiple overlaps to total coverage.

Table 1 presents calculations (made using equations (1) and (2)) of percentage coverage contributions for different amounts of peening and of overlapping.

**Table 1. Effect of Peening Time on Multiple Dent Overlap Contributions to Coverage.**

Time - s	1	2	3	4	5	6	7	8	9	10
n = 1	28.34	36.50	35.26	30.28	24.38	18.84	14.16	10.42	7.55	5.40
n = 2	6.23	16.06	23.27	26.65	26.81	24.87	21.80	18.34	14.95	11.88
n = 3	0.91	4.71	10.24	15.63	19.66	21.88	22.38	21.52	19.73	17.43
n = 4	0.10	1.04	3.38	6.88	10.82	14.44	17.23	18.93	19.53	19.17
n = 5	0.01	0.18	0.89	2.42	4.76	7.63	10.62	13.33	15.47	16.87
n = 6	6.49E-04	0.03	0.20	0.71	1.74	3.36	5.45	7.82	10.21	12.37
n = 7	4.08E-05	3.36E-03	0.04	0.16	0.55	1.27	2.40	3.93	5.78	7.78
n = 8	2.24E-06	3.70E-04	0.01	0.04	0.15	0.42	0.92	1.73	2.86	4.28
n = 9	1.10E-07	3.62E-05	8.98E-04	0.01	0.04	0.12	0.32	0.68	1.26	2.09
>9	5.03E-09	3.46E-06	1.34E-04	1.61E-03	0.01	0.04	0.13	0.34	0.76	1.49
TOTAL	35.60	58.52	73.29	82.80	88.92	92.86	95.40	97.04	98.09	98.77

As examples: At 35.6% coverage, single impact (i.e., no overlapping), predominates although more than 1% of the surface has received at least triple impacting. At 88.9% coverage, the largest contribution is now of double impacted areas followed by single impacting, but also with more than 2% having been impacted at least six times.

**HARDENING COVERAGE**

Work-hardening is one of the two beneficial effects of shot peening—the other being surface compressive residual stress development. A zone of work-hardened material surrounds each dent as shown schematically in fig. 8 in cross-section.

In plan view the diameter at the surface of the work-hardened zone, 2*d*, is approximately double that of the dent, *d*.

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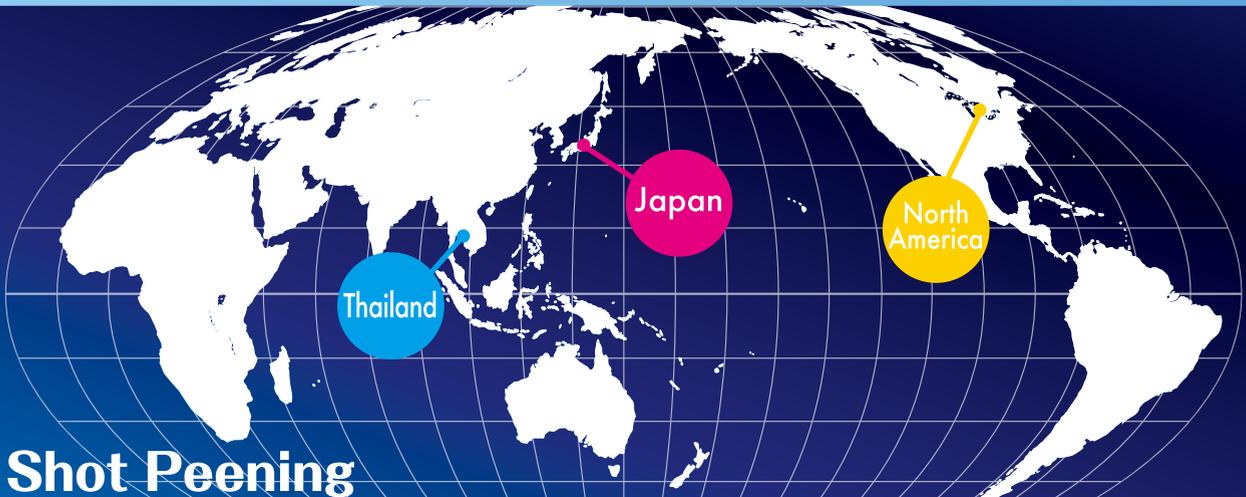


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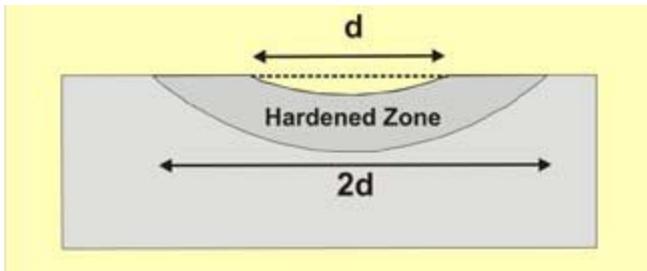


Fig. 8. Cross-section indicating zone of work-hardening surrounding dent.

Work-hardening necessitates that the applied stress exceeds the yield point, meaning that the zone has a definable limit.

The equation that describes the shape of the hardening coverage curve is:

$$WH\% = 100(1 - \exp(-.r^2.R.t)) \quad (3)$$

WH is work hardening coverage, *r* is the fixed radius of the circular hardening zones, **R** is the rate of zone creation per unit area and **t** is the time of peening.

Doubling the radius, *r*, of any zone multiplies the coverage rate factor,  $.r^2.R$ , by a factor of four (e.g., to 1.76 when dent coverage has a factor of 0.44). Note that **R** is the same for both dents and work-hardening zones for a given rate of impaction. Hardening coverage increases at a much faster rate than does dent coverage. Comparative rates are included in the Discussion at the end of this article.

Equations (1) and (3) can be used to quantify the difference between dent coverage and hardening coverage. Equation (1) predicts that 98% coverage will be achieved in 8.9 seconds using 0.44 as the coverage factor. Substituting 8.9 and 1.76 into equation (3) predicts that the hardening coverage would then be 99.99999%. This means that we have virtually complete hardening coverage—a desirable parameter—when the dent coverage has reached 98%.

Work-hardening zones overlap in the same way as do dents. The effect of multiple overlapping is that there are corresponding multiple work-hardening. More and more hardening is generally beneficial. The exception is when the ductility of the component material becomes exhausted. The mathematical equation that describes the contribution to hardening coverage by *n* overlapping impactions is:

$$WH_n\% = 100[(.r^2.R.t)^n/n!]*\exp(-.r^2.R.t) \quad (4)$$

WH<sub>*n*</sub> is the contribution to total hardening coverage by *n*-impacted areas, *r* is the radius of the hardened zones, **R** is the rate of zone creation per unit area, **n** is the number of impacts that a particular area has received, **t** is the time of peening and **n!** is the factorial of **n**.

Equation (4) can be used to construct an equivalent table to that for dent coverage. For comparison purposes only the hardening coverage values at 98% dent coverage are reproduced in Table 2.

Table 2. Comparison of Coverage Contributions when Dent Coverage is 98%.

	Multiple Hardenings Contribution	Multiple Dents Contribution	Multiple Stress Contribution
Time - s	9	9	9
n = 1	0.00	7.55	1.0011E-39
n = 2	0.00	14.95	4.9555E-38
n = 3	0.01	19.73	1.6353E-36
n = 4	0.03	19.53	4.0474E-35
n = 5	0.11	15.47	8.0138E-34
n = 6	0.29	10.21	1.3223E-32
n = 7	0.66	5.78	1.8701E-31
n = 8	1.30	2.86	2.3142E-30
n = 9	2.28	1.26	2.5457E-29
>9	95.32	0.76	100
TOTAL	100.00	98.09	100

The values given in Table 2 substantiate the previous comment: “This means that we have virtually complete hardening coverage—a desirable parameter—when the dent coverage has reached 98%.” When dent coverage has just reached 98%, less than 1% of the surface has had more than 9 overlaps. That compares with 95% having more than 9 overlapping hardening zones. Values are also included for multiple stress zone contributions and are discussed in the next section.

### STRESS COVERAGE

At the risk of repetition, “Dents in the surface do not normally improve service performance. Hardening and compressive residual stress, on the other hand, do improve service performance.” The work-hardening of the surface by peening induces beneficial compressive residual stress at the surface. Each isolated dent is surrounded by a zone of compressively-stressed material. This zone is illustrated in fig.9. Unlike dents and work-hardening zones, the induced surface compressive residual stress does not have a clearly-defined limit—it just goes ‘on and on.’

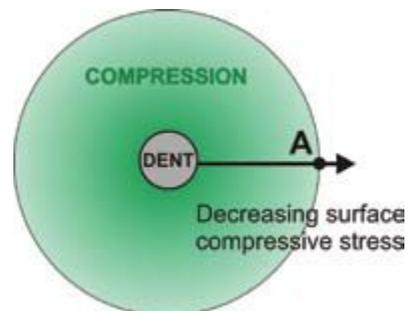


Fig. 9. Schematic representation of effective compressively stressed zone surrounding a dent.

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The level of surface residual stress decreases with distance from the edge of a dent. Fig.9 shows a compressed zone extending to five times the diameter of a corresponding dent. Relevant evidence was presented at ICSP9 (Kirk and Hollyoak, *Relationship between Coverage and Surface Residual Stress*, pp 373-378). This quantified surface residual stress variation with distance from the edge of dents. Fig.10 relates to measured surface stress variation for 0.67 mm diameter dents in mild steel. Induced surface compressive residual stress adds to any pre-existing surface stress. For this example the pre-peening surface stress was found to be tensile - + 20 MPa. Point A on the curve, 1 mm from the edge of the dents, indicates that compressive surface residual stress is within 20 MPa of its maximum level - 120 MPa. Point A corresponds to five times the diameter of the dent and is included in fig.9. Point A could be regarded as representing the maximum radius for effective compressive stress coverage.

Equation (5) is the equation, presented at ICSP9, which predicts surface compressive stress variation (for the mild steel specimens that had been studied).

$$= -140 (\exp(-d^2/10)) + S \quad (5)$$

where  $\sigma$  is residual surface stress in MPa,  $d$  is distance from dent edge and  $S$  is the stress level of the unpeened surface.

The residual stress coverage equation for multiple overlapping zones is:

$$S_n\% = 100[(.r^2.R.t)^n/n!]*\exp(-.r^2.R.t) \quad (6)$$

$S_n$  is contribution to total compressive stress coverage by  $n$ -impacted areas,  $r$  is the radius of the 'Point A' zones,  $R$  is the rate of zone creation per unit area,  $n$  is the number of impacts that a particular area has received,  $t$  is the time of peening and  $n!$  is the factorial of  $n$ .

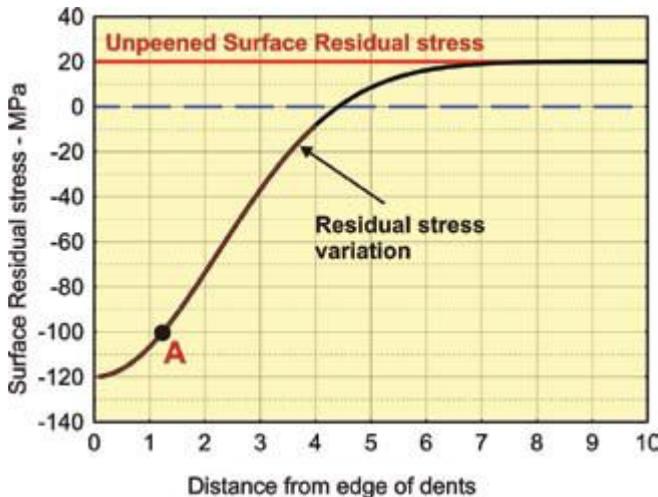


Fig.10. Surface residual stress variation with distance from dents.

Estimates based on equation (6) quantify residual stress coverage in the same way as those derived for dent coverage and hardening coverage. Such estimates confirm that stress coverage approaches 100% very, very rapidly - as illustrated in fig.12. The values given in Table 2 are astronomically small for any region receiving less than 9 overlapping compressively-stressed zones. A pictorial representation is given as fig.11 where just four dents (of the fourteen that generated 42% coverage in fig.4) have been surrounded by induced effective compressive residual stress zones five times the diameter of each dent. Here we have 100% coverage together with general overlapping of these beneficial compressive stress zones (shown green).

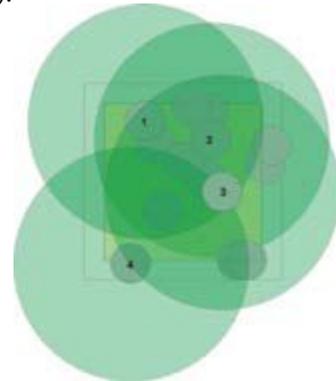


Fig.11. Complete stress coverage with just four dents.

**DISCUSSION**

Optimum dent coverage occurs when desirable service properties reach their maximum. It is not, however, the dents themselves that contribute to property improvement. Work-hardening and the development of compressive surface stress are the principal factors that generate property improvement. Dent, hardening and stress coverage proceed together but at vastly different rates as illustrated in fig.12.

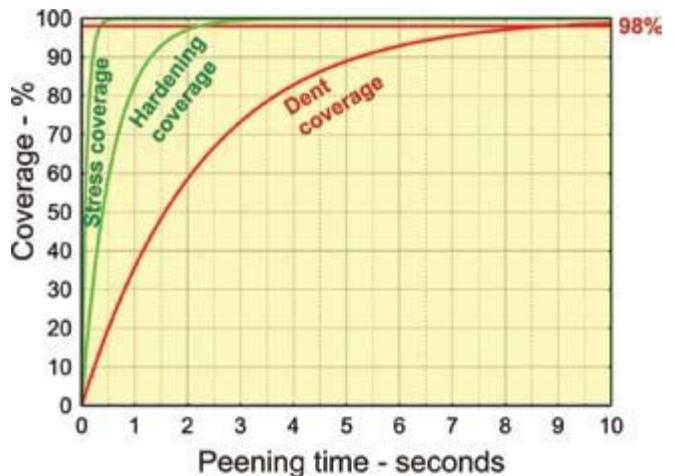


Fig.12. Relative coverage rates for dents, hardening and surface residual stress.

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The analysis presented in this article indicates that there is no justification for attempting to induce 100% dent coverage. At the suggested measurable maximum of 98% dent coverage virtually none of the peened surface has received fewer than three overlapping hardened zones. At 98% dent coverage, the area that has received fewer than nine overlapping stress-generated zones is astronomically small—far less than a pinprick for an area equivalent to the Earth's total surface area (510 million square kilometers).

It is delusional to believe that at 98% dent coverage a component contains 2% of unprotected surface as that 2% between the dents is well-protected by a combination of work-hardening and compressive residual stress zones. Practical studies have shown that optimum property improvement for some components often occurs well below 98% dent coverage. As always, "the proof of the pudding is in the eating." Property tests should aim to establish the optimum level of coverage for specific situations, avoiding the fallacy that "more is always better." ●

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# Cornell Forge Company Chooses Blast Cleaning Technologies for Heavy-Duty Drum Blast Equipment

## CORNELL FORGE CASE STUDY

### PROJECT SCOPE

Cornell Forge purchased a 28 cu. ft. drum blast to replace traditional-style tumblast equipment. The new equipment has improved productivity, reduced maintenance downtime and significantly decreased scrap and damaged parts.

### LOCATION

Chicago, Illinois

### METALS FORGED

Carbon Alloy Steel – Up to 100 lb

Stainless Steel – Up to 30 lb

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Cornell Forge, a 80-year-old forging company, began this process by gathering competitive quotes from shot blasting companies that could improve efficiency, and throughput, and reduce cycle time and maintenance downtime.

The Cornell Forge team visited and toured three shot blasting manufacturers that designed and manufactured drum blast style shot blasting equipment. “While some things were similar with all manufacturers, several things stood out about Blast Cleaning Technologies,” said Ray Raddatz, Shipping and Finishing Supervisor at Cornell Forge.

“Being a Midwest company that manufactures heavy-duty equipment in the U.S was a big plus, as well as the tremendous knowledge of the entire team in shotblasting, maintenance, safety and understanding the issues that Cornell Forge was trying to address in the finishing department. However, the thing that really astounded the team during our tour of the facility was the level of spare parts inventory and the care taken to handle and balance the quality of the tune up kits and blade sets,” added Raddatz.

### The Durability of M-28 and Blast Wheel

“The strength, durability and overall aesthetics of the M-28 have been well received by our maintenance team. The “cartridge style” drives on the elevators were very well engineered and



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thought out with maintenance in mind. This is a big plus for us as we see this saving a tremendous amount of time in the future for elevator repairs. Cornell Forge has experience with running and maintaining all types and models of blast wheels and the easy access to the shot blast wheel is great. The e-Wheel™ has saved in maintenance downtime and cycle times of 40 minutes have been improved by 50%," said Raddatz.

### **Improved Performance and Tremendous Savings**

This project began with a mission to get away from the traditional steel flighted tumblast machines. Cornell Forge has many small parts that were constantly pinching in the tumblast and Cornell Forge was determined to find a better blast solution. The single 28-D drum blast replaced two 22 cu. ft. old style tumblast machines. "The increase in productivity has been two fold with the 28-D drum blast and in one year, we have saved \$75k in maintenance downtime," said Raddatz. "We've also saved on shot consumption and our scrap rate is less with significantly fewer forgings being pinched and damaged," said Raddatz.

This was a turnkey project including installation and startup of the equipment. "Service after the sale is extremely important and 14 months later, we are constantly surprised by the level of consistent service we've experienced and the way the BCT team has stood behind the sale," said Raddatz. The footprint and the location of the machine were modified from the original plan. Cornell Forge and BCT worked together and the outcome could not have been better. "The machine fits like a glove," Raddatz added. ●

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## INDUSTRY NEWS

### **Tim McMillin Hired as Sales Director at Blast Cleaning Technologies (BCT)**

Blast Cleaning Technologies is very pleased to announce that Tim McMillin has joined the BCT team as Sales Director. Tim McMillin has more than 25 years of industrial business experience in metal casting, engineering software, and oil and gas exploration and production. He has been very active with industrial organizations including SME, North American Die Casting Association and as a past National President of the American Foundry Society (2011-2012). Tim will be responsible for leading the company in developing the Mexico market, managing the OEM replacement product line and working closely with certain key accounts to further their relationship with BCT.



"Tim brings years of industrial experience and his energy and dedication will be a tremendous asset in expanding our sales organization and managing customer relationships. His leadership and knowledge will support our efforts as we continue to expand our customer base," stated Carl Panzenhagen, President and CEO. ●



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# ITAMCO Connects Forklifts to the Industrial Internet of Things

**FORKLIFTS, THE WORKHORSES OF THE PLANT FLOOR,** are more valuable than ever at ITAMCO. The company has connected their forklifts to the Industrial Internet of Things (IIoT)—the integration of machinery and equipment with networked sensors and software.

ITAMCO is a manufacturer of precision-machined components, specializing in gears—from mining gearing to production runs of CBN-ground transmission gears. In 2012, ITAMCO implemented an MTCConnect®-enabled machine-monitoring program. After key pieces of machinery were connected to MTCConnect and to their Enterprise Resource Planning (ERP) system, ITAMCO developed a communication system for their forklifts.

Now, as soon as a machine operator scans the barcode on a pallet, signifying the completion of the product cycle at his machine, a forklift operator and forklift are on their way to the machine. Each forklift is linked to ITAMCO's ERP system through its GPS and an application on a smart tablet mounted in the forklift. Forklift operators are notified via their smart devices—employees use iPods, iPads and smartphones—when they're needed. The communication system is so efficient it will summon the closest forklift to the machine. The forklift operator will also know how many pallets need to be moved and where they should be taken. If the product is being moved to another workstation, the workers in that area will be notified that the product is on its way.

"We developed the application because both of our facilities are rather large and forklift operators were always looking for forklifts to move their material but could never find one. Also, material would sit for hours at a machine, delaying the next operation. This application

solved the problem by notifying a material handler as soon as the materials were ready to go to the next work area," said Joel Neidig, an Engineer and Lead Technology Developer at ITAMCO. The system has been well received by the ITAMCO employees. "It has definitely helped me schedule the movement of materials from one work center to another," said Arthur Doody, Material Handler at ITAMCO.

Connecting forklifts to the IIoT is just one more way ITAMCO is able to reduce production time and maintain competitive pricing for their customers. "We've seen a 10% reduction in the time it takes to get material ready for the next operation," said Mr. Neidig. To learn more



*A smart tablet, mounted in the front of the forklift, connects the truck to ITAMCO's ERP system. The forklift also has a GPS.*



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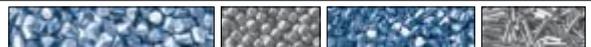
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*The technology team at ITAMCO created an application that links communication among machine operators, forklift drivers, and the company's ERP system.*

about additional innovations at ITAMCO, view Joel Neidig's presentation at a recent Autodesk User Conference at [www.au.autodesk.com/au-online/classes-on-demand/class-catalog/2015/class-detail/11913#chapter=0](http://www.au.autodesk.com/au-online/classes-on-demand/class-catalog/2015/class-detail/11913#chapter=0). Mr. Neidig's presentation is the third presentation at 13:00 minutes.

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### About ITAMCO

Since 1955, ITAMCO has provided open gearing and precision machining services to many heavy-duty industries including mining, off-highway vehicles, marine, and aviation. In addition, the technology team at ITAMCO has launched their "Strategic Technology Initiative for Additive Manufacturing"; implemented MTConnect®, a plant-monitoring system; released over 65 apps for mobile devices; designed and markets iBlue, the first industrial Bluetooth transmitter; and developed an award-winning Google Glass application. Learn more about ITAMCO at [www.itamco.com](http://www.itamco.com) or call (574) 936-2112.





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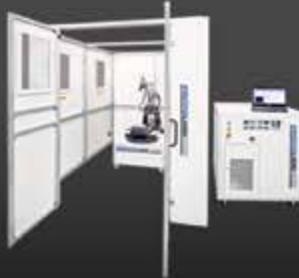
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