Spring 2023
Volume 37, Issue 2 | ISSN 1069-2010

The Shot Peener

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

The new mobile Laser Peening without Coating System

PLUS: ANALYZING WHAT WE KNOW ▮ SHOT PEENING MATERIALS SCIENCE
CHOOSING THE PROPER NOZZLE ▮ MEDIA SELECTION: TO MIX OR NOT TO MIX?

Peening Innovation

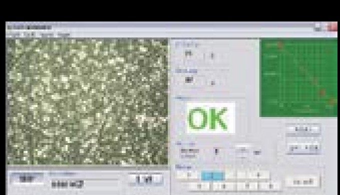
COVERAGE CHECKER

COVERAGE CHECKER the device for easy and precise coverage measurement

UV Light version
New arrival!

- 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.

Coverage Checker (Original)
Easy USB connection to your PC



※PC is not included ※Device image
※Specifications of this device may be changed without notification.

Positron Surface Analyzer

PSA Type L-Ⅱ

PSA Type L-P

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)

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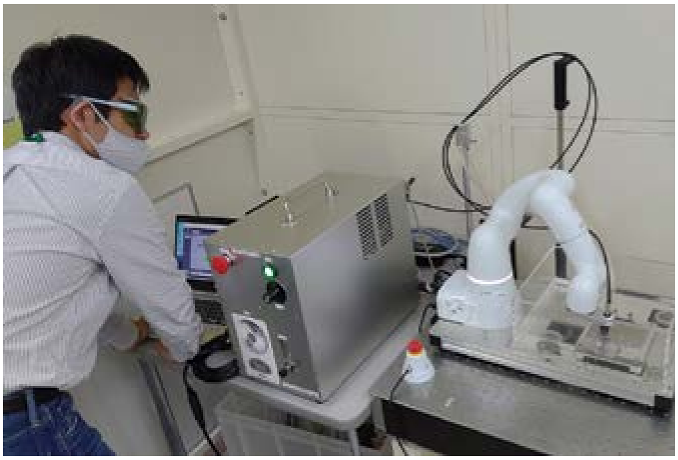

THE SHOT PEENER

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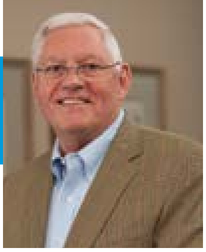


OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

Homage to John O. Almen

LEARNING IS A NEVER-ENDING OPPORTUNITY. John Otto Almen invented the gage we use today for shot peening process consistency. While struggling with early fatigue failures of automotive valve springs, he decided to "shot blast" the springs to remove the scale from the springs. The blasted springs lasted much longer on the fatigue testing machine and now he needed a way to consistently "blast" the springs. He filed his patent for a gage in 1942 and it was granted in 1944 (Patent Number 2,350,440). I found a copy of a General Motors drawing dated November of 1943 showing a new generation of gage that already used four-ball support instead of two-knife edges. A graphic was created to allow conversion of measurements made on either test strip.

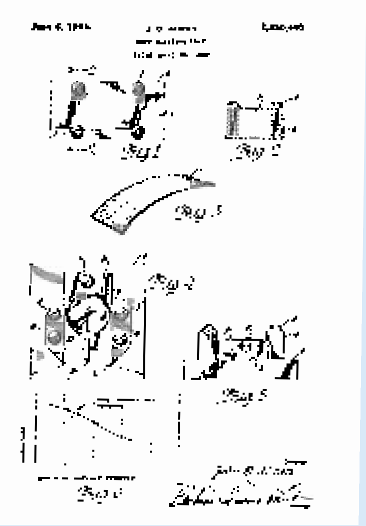
The advantage of the four-ball support was that it accounted for the combined length and width curvature of the strip. The original method of determining intensity required blasting strips for longer time periods and creating a graph of the arc height readings—"Intensity is the arc height of the graph at the knee of the curve." That was a little subjective so a method to assign a mathematical answer to intensity was created using the 10% rule. The first point on the curve that increases only by 10% when the exposure time is doubled is considered the intensity of the process.

Professor David Kirk developed the Almen Saturation Curve Solver Program that automatically determines the Almen intensity and creates smooth fitted curves that could identify the intensity of the saturation time T1. Dale Lombardo of General Electric collected saturation curve programs from multiple sources and helped create the SAE document J2597 titled "Computer Generated Shot Peening Saturation Curves" in 2010. Any algorithm that could achieve the answers to a battery of arc height data within a tolerance band could declare compliance with J2597.

Newer versions of curve solvers continue to be developed; some with capabilities of selecting the proper algorithms depending on the number of data points (more is better). We now see peening operations that require extremely tight consistency performance for periodic testing such as ±0.001 inch repeatability. Plotting this data into SPC charts helps confirm if the process is in control or needs attention. I'm sure John Almen would be pleased to see what we have done with his pioneering work.

This image is from John Almen's patent. The patent and many other articles on John Almen and the original Almen gage are available in the library at www.shotpeener.com. A sampling of these articles include:

- *"Peening Intensity Measurement," 1945, by R. L. Mattson and H. E. Fonda with GE*
- *"The Almen Gage and Almen Strip" by Jack Champaigne (The Shot Peener magazine, Spring 1990)*
- *"The Care and Feeding of Your Almen Gage" by Jack Champaigne*



THE SHOT PEENER

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Professor Dr. Yuji Sano | *LAcubed and SANKEN, Osaka University and* ***Volker Schneidau*** | *sentenso*

Downsizing for New Flexibility in Laser Shock Peening

Laser Peening without Coating for Process Versatility and Surface Excellence on Challenging Part Areas

Introduction

Laser Shock Peening (or Laser Peening) is well-known for its high intensity and impact to achieve high residual stresses in extraordinary depth when compared to shot peening. Now Professor Yuji Sano from LAcubed and his team from SANKEN, Osaka University have succeeded in developing an extremely compact and mobile demonstration unit for Laser Peening without Coating (LPwC). A new bonding technology between optical components realizes a laser head with the typical size of a pen for the peening of specific and critical part areas with an amazing surface quality.

Professor Sano is considered one of the pioneers of the industrial use of laser peening since he developed LPwC for Toshiba Corporation in the 1990s to combat stress corrosion cracking (SCC) of components in nuclear power plants. In close co-operation with the Japanese team, sentenso in Germany built a small automated system with the laser head that peened a 3D surface and was controlled by an industrial robot. In a live demonstration in December, 2022 at the ECOMAT development centre of Airbus in Bremen, sentenso and the laser experts showed a typical application on aluminium samples in front of about 30 development engineers and material scientists. Immediately afterwards, sentenso was able to prove the induced residual compressive stresses with the help of the mobile µ-X360s X-ray stress analyser. LAcubed and sentenso are now proceeding to develop industrial applications for various materials and parts.

Technical explanation of the system

The LPwC system consists of a finger-sized laser mounted on a 6-axis compact robot arm, a power supply box, and a PC as a controller. The power supply box has a laser diode inside which pumps the laser at the tip of the robot arm via an optical fibre cable. Water used for LPwC can be recovered and reused by a water circulation system inside the power supply box. The complete system weighs only 20 kg and can be operated on 100-230 V with a maximum power consumption of 400 W.

The finger-sized laser was realized by a novel architecture using monolithic microchip laser technology developed by Professor Takunori Taira of the Institute for Molecular Science (IMS). He integrated all optical components into a single chip

The mobile LPwC system that can be carried as two pieces of check-in baggage on an airplane. Operation can be re-started within one hour after arrival on site.

by room-temperature bonding to achieve robustness of laser oscillation against vibration and temperature changes. Thus, the laser can be operated stably under ambient conditions without air conditioning, typically as an end effector of a robot.

Laser and process parameters

The effect of LPwC is governed by its main process parameters:

- irradiated pulse energy,
- laser spot size, and
- pulse density (number of pulses irradiated per unit area).

The LPwC system uses a laser with pulse energies as low as 1 to 10 mJ, three-orders of magnitude less than current LSP systems. Thanks to low-energy laser pulses, the ablation volume is much less than with current technology, resulting in superior surfaces with a roughness Ra typically 1 µm after processing. The laser spot size on the sample is as small as 0.2-0.5 mm, making it much more adaptable to complex 3D geometries. However, the smaller spot size reduces the working speed.

Coverage and working speed

In LPwC, the surface is sequentially irradiated with successive laser pulses as if a wall is tiled, so the concept of the “coverage” is different from shot peening. The coverage in


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Characteristics and advantages of LPwC versus traditional LSP

Criteria	Traditional LSP	Downsized LPwC
Setup	Typically needs a container for generator and two robots for laser head and part	Desktop size generator, finger-to palm-sized laser head, setup depending on size of working area, allows for automated machines with small footprint in serial production
Part preparation	Needs ablative coating prior to peening	Works without coating
Controllability of stress induction	Not easy to control process area precisely due to large spot size	Can control process area precisely by using small spot size
Versatility in process direction	Fixed laser direction	Flexible, all directions
Adaptability to parts with various thicknesses	Works well on thick parts, hardly applicable to thin parts due to distortion	Works for both thick and thin parts due to sensitive control of stress level and stress depth
Adaptability to edges	Not to be used on edges or close to functional areas	Can work close to edges (even on edge) and functional areas
Adaptability to different materials	Works for almost all metal materials	Works for almost all metal materials including some ceramics
Difficult-to-reach areas	Not to be used in narrow areas or inside holes	Small laser head allows access to narrow areas, applicable even in holes (under development)
Surface quality after peening	Major increase of surface roughness	Smooth surface, roughness Ra typically 1 µm, thin oxide film forms on surface
Working speed	Typically up to 2 m^2/h	Typically only up to 30 cm^2/h
Mobility	Possible, but heavy and bulky equipment of approximately 2 m^3	Smallest execution can be carried in two suitcases including robot, setup completes in less than one hour after transport

LPwC means how many pulses hit one point on average, and simply calculated by $(\pi D^2/4) \times \rho$, where D is the laser spot size (diameter) and ρ is the pulse density (number of pulses irradiated per unit area).

The area that can be peened with a single laser pulse is small, therefore typically 100-800 pulses are irradiated on 1 mm^2. The corresponding working speed is 36-4.5 cm^2/h based on the current pulse repetition rate of 100 Hz. Since the working speed is roughly proportional to the average laser power, the working speed of LPwC is much smaller than the traditional LSP.

Typical use cases

Since the pulse energy of the finger-sized laser is 1-10 mJ and the laser spot size is 0.2-0.5 mm, the depth of compression by LPwC is shallow; typically, 0.1-0.6 mm. Therefore, LPwC is effective for application to thin parts that would be distorted by the traditional LSP. Furthermore, the small spot can follow uneven surfaces, making it suitable for peening applications to precision parts with 3D shapes. sentenso identifies several typical use cases:

- on thin sections,
- along edges or cut-outs,
- close to functional areas, such as thread ends,
- on narrow geometries, such as tooth roots of small gears of module <0.3 mm, pitch <1 mm
- on narrow lines, such as laser welds

Stress profiles and fatigue test results of aluminium and titanium alloys

LPwC was applied to an aluminum alloy A7075-T73 with an irradiated pulse energy of 7.5 mJ and a spot size of 0.42 mm. The pulse density was varied from 100 to 1600 pulses/mm^2. Surface residual stress was measured by X-ray diffraction (XRD) using an X-ray stress analyser µ-X360s, and the depth profile was estimated by alternately repeating XRD and electrolytic polishing of the sample. Compression reached a depth of 0.3-0.6 mm depending on the pulse density. For harder materials at lower pulse energies, e.g., 1.5 mJ for Ti-6Al-4V, the depth of compression was found to be as shallow as 0.05 mm.


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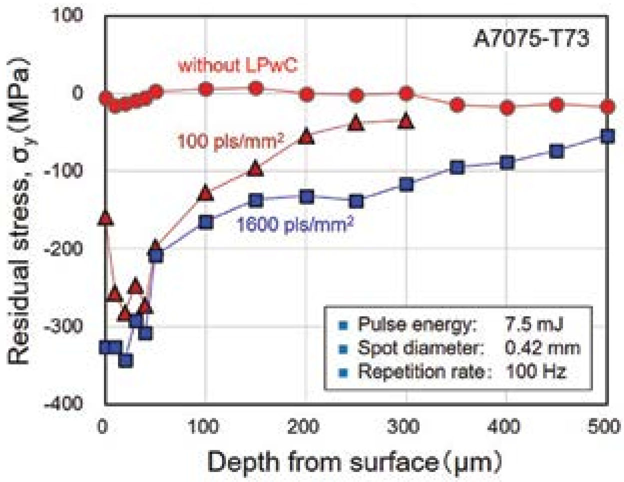
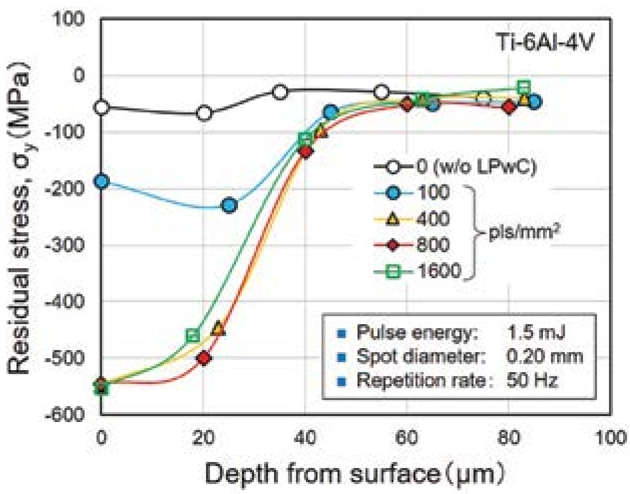
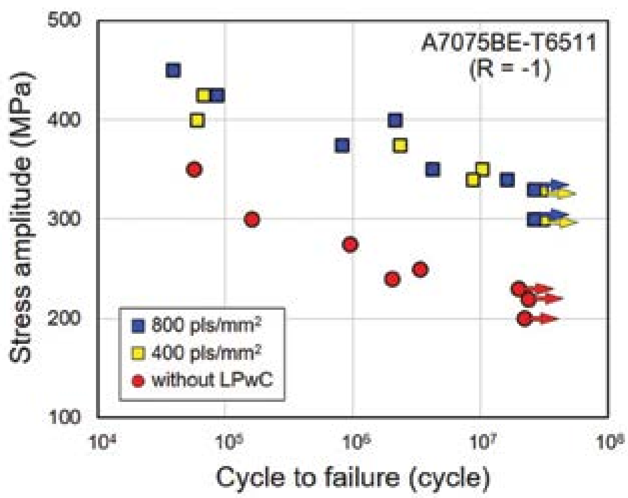


Residual stress depth profile of A7075-T73



Residual stress depth profile of Ti-6Al-4V

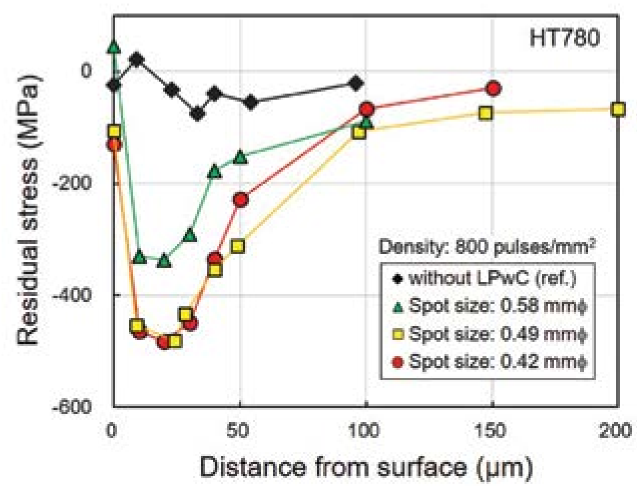


Fatigue test results for A7075BE-T6511

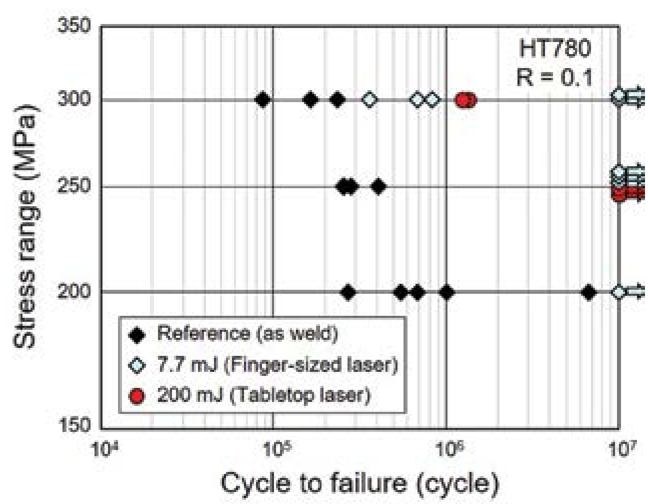
The effect of LPwC on improving fatigue properties was confirmed. Rotating-bending fatigue tests were conducted for aluminum alloy A7075BE-T6511 samples after LPwC with an irradiated pulse energy of 1.7 mJ, a spot size of 0.3 mm and pulse densities of 400 and 800 pulses/mm². The induced depth of compression was shallow, approximately 0.15 mm, but the fatigue strength was improved by 50 MPa and the fatigue life was extended by 100 times compared to the unpeened reference.

Stress profiles and fatigue test results of high-strength steel

Improving the fatigue properties of welded joints is an attractive application. For example, welding largely reduces the benefit of using high-strength steels due to softening and resulting tensile residual stresses. To recover the fatigue properties and the benefits of using high-strength steels, welded joint samples of a 780 MPa grade high-strength steel HT780 were subjected to LPwC with a pulse energy of 7.7 mJ, spot size of 0.49 mm and pulse density of 800 pulses/mm². Uniaxial fatigue tests showed that LPwC was evidently



Residual stress depth profiles of HT780 base metal



Fatigue test results for HT780 welded joint samples

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effective and improved the fatigue strength of the weld joint samples by at least 50 MPa, although there was a large scatter in fatigue data due to manual welding. LPwC with pulse energy of both 7.7 mJ and 200 mJ were equally effective in improving fatigue properties. Process conditions can even be optimized to obtain higher compression on the top surface.

Benefits and outlook

LPwC is as simple as irradiating a water-covered sample with successive laser pulses. No ablative coating or other pretreatment is required for the sample. LPwC has a small laser spot, which makes it easy to precisely follow the shape of a 3D part, but it has the restriction of a low-working speed. Therefore, the development of higher energy lasers within a size that can be manipulated by robots is underway. Currently, the team around Professor Sano have realized a palm-sized 25 mJ × 100 Hz laser and expect to achieve 1 mm depth compression into aluminum alloys. Furthermore, there is potential to increase the pulse repetition rate to the kHz range in the future to compensate for the low-working speed.

LPwC of a 3D-shaped sample by using an industrial robot.

In the coming months, the peening experts from sentenso and Japan will intensify their co-operation to work out potential applications with pilot customers and with an open mind for ideas of interested process engineers. Furthermore, there is a number of universities and institutes looking into multinational research projects.

To watch a video on Downsized LPwC, scan the QR code or visit https://share.sentenso.de/s/LSPwC.

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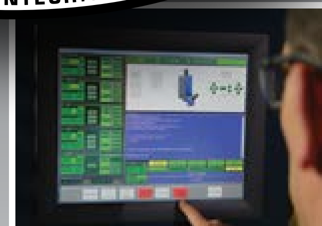
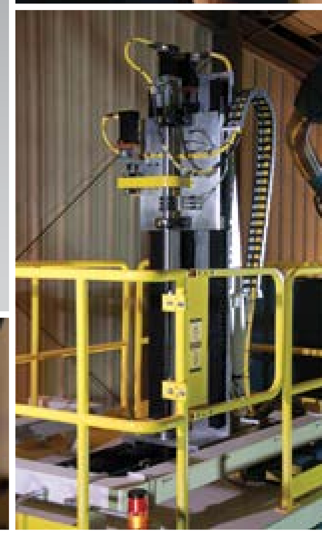





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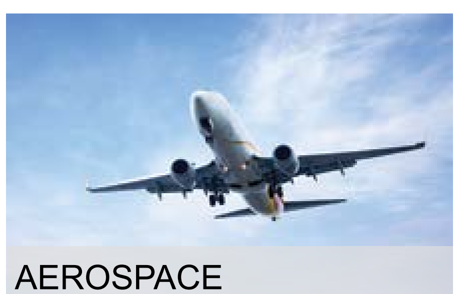

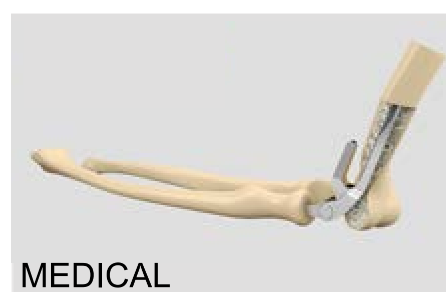

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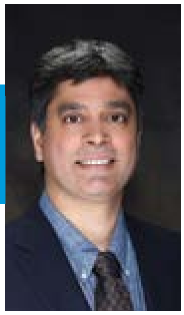

AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

Analyzing What We Know

Part 1

COMPLEXITY OF SHOT PEENING

The heading to this section is intentionally deceptive since shot peening is not a complex process if you acknowledge its importance, understand it, and do it right! Albert Einstein's famous quote states, "If you can't explain it simply, you don't understand it well enough." My goal through our discussions is to simplify, normalize and adapt seemingly complex concepts in peening and blast cleaning and explain them in a manner that is conducive to use. If I have made any of your work lives easier through my attempts, I will be satisfied to have achieved that goal. The need for simplification does not imply that the readers of *The Shot Peener* magazine cannot grasp complexities. On the contrary, like me, I too expect that your adoption of proper peening techniques will be greater if made simple.

Having accomplished that complex introduction, I would like to take you through a journey of exploring certain known and some not-so-familiar peening concepts. My purpose is to question their validity and applicability in a production environment. I'll also attempt to add some suggestions based on field experience. These topics include:

- Shot hardness and intensity
- Nicks and part fatigue life
- Reclaim system and process control
- The Almen strip

I had the opportunity to attend the International Conference on Shot Peening where our world gathered to present and discuss their recent research and findings. Select topics from this conference hold promise to me, and I intend to apply the same litmus test for our future discussions. The confluence of academia and industry is a wonderful thing and making it lucid creates an environment that will help our industry grow. Given the extent of information that our colleagues world over are working on, I take the liberty to extend this discussion to part two for subsequent publication.

MEDIA HARDNESS AND INTENSITY

An age-sensitive quote in our industry reflects positively on the health of the machine until the addition of media (abrasive). Facetious as that may sound, media characteristics most certainly dictate the outcome of your cleaning and shot peening operation. Therefore, ensure its proper selection, use, and maintenance. Media is characterized by its size (screening), shape, chemistry, microstructure, and hardness. Hardness is primarily determined by the chemistry and thermal treatment that the media particles are subject to. Standard hardness of high-carbon cast steel shot is 40 to 51 HRC, with custom hardness ranges taking it as high as 60 plus HRC in distinct steps.

Common recommendation by all media manufacturers for cleaning applications is to employ standard hardness abrasive and choose increased hardness selection only if warranted. In other words, if the part is contaminated with heavy scale or rust that is not easily dislodged by standard hardness abrasive, increasing the hardness might help cleaning it. Since hardness and durability are inversely proportional, there is a price to pay in terms of accelerated machine component wear, especially with the use of higher ranges of hardness. This brings us to our discussion on peening intensity and hardness.

Most peening instructions seldom specify media hardness. Instructions are typically restricted to media type (cast shot, cut wire shot, glass bead or ceramic), size, intensity, and coverage. With metallic media, my recommendation over the years to my customers has been to use the softest grade to obtain the required intensity. Though durability is important to minimize risk of broken and sharp-edged particles in the mix, the reason for choosing the softest grade extends beyond just durability concerns. Harder grade of shot will result in an intensity value that is at least 0.015" to 0.002" greater than that produced by a lower hardness shot of the same size. This value increases exponentially with larger shot sizes (S330 and greater). I attribute that to the non-linear increase in volume of the shot particle with increase in diameter.

There is another feature worth listing. Choosing a harder grade of the same size maintains the particle count per pound of shot and with it the rate of coverage (and productivity). In summary, when shot hardness is not specified, start with the softest grade. However, if process or machine constraints result in the inability to achieve the desired intensity, altering

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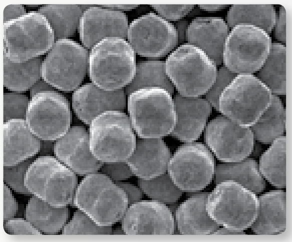
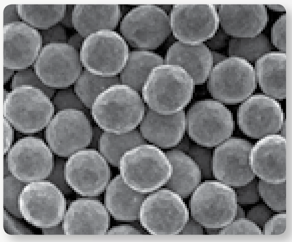
As Cut


Normal Conditioning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media hardness is another means of marginally increasing the value without changing rate of coverage. On a related note, be aware that AMS 2431 allows for only two ranges of shot hardness (45 to 52 HRC, Regular and 55 to 62 HRC, High) whereas SAE recommended practices list four ranges. If your process requires conformance to AMS 2430 or AMS 2432, you are limited to these two hardness grades.

Very often we come across specifications that were drafted several decades ago and based on the data available at that time. Case in example is the now redundant MIL-13165C that listed cast iron as one of the materials that could be used to manufacture shot peening media. Cast iron is brittle and its rapid breakdown (and formation of sharp edges) renders it unsuitable for peening applications. It is not uncommon, especially in non-Aerospace applications, for this specification to be listed as the conformance document.

Therefore, if you happen to be in an industry sector that cites this specification for conformance, it will benefit your peening service provider if you could specify the media type (cast steel or cut wire in metallic media) and possibly indicate the hardness as well. The issues with using media that is not suited for peening can be drastic with potential damage to expensive components in the form of nicks and scratches.

DAMAGE TO PART SURFACE

Foreign object damage (FOD) is a widely discussed and undesirable aspect in the aerospace industry— it is something that is never ignored. In shot peening, a foreign object could be anything that is not part of the usable media or customer's component (which is not expected to disintegrate and generate its own foreign object!). Foreign objects are considered a threat to the integrity of the part being peened. They could cause a nick or other severe damage to the part surface, resulting in the creation of a local stress riser with serious implications during use. These are the nuts, bolts, and other large contaminants that sneak into the peening machine, passing the reclaim system and causing potential surface damage. This phenomenon is also believed to be incited by fractured media particles (cast shot) or those that are not sufficiently conditioned (cut wire shot). The process of conditioning to round-off the sharp edges of cylindrical as-cut material (cut wire shot) can be expected to retain certain particles with sharp edges; more so in smaller sizes.

It is impractical to assign part damage to a broken particle of cast shot since a broken particle will contain only a fraction of its original mass as compared to a particle of unconditioned cut wire that continues to retain its original mass. When analyzing the breakdown mechanism and process parameters that lead to this event with both media types, the extent of damage to the part is at best unpredictable due to constant rounding of sharp edges. Process parameters that influence include media velocity, angle of impingement, stand-off distance from the part, and the failure mechanism (fracture, flaking, etc.). There is no reliable measure or monitor of how this angular edge impacts the component being peened and at what time in the cycle. In my opinion, part damage from foreign object other than media is more likely than that caused by the media. Though I am not trying to advocate permitting the use of sharp edges in peening media, I do question the probability of creation of surface defects by media particles and the ensuing effect on part life.

Professor Paul Mort and his team at the Center for Surface Engineering and Enhancement (CSEE) at Purdue University have been working on models to characterize shot size and shape for shot peening applications. Their study concludes that non-spherical shapes (mainly imperfections that may even qualify as "acceptable" samples by AMS) diminish the "work efficiency" of the peening process. Upon speaking with Professor Mort, he explained that future work on this topic will quantify the extent to which such non-spherical shapes could influence failure and impact part life. This paves the way for more sophisticated means of evaluating peening media shape in the future than the current visual check.

RECLAIM SYSTEM AND PROCESS CONTROL

As a young engineer involved in the design of a 16-wheel blast cleaning machine for railcars, I was fascinated by the 10,000 lb. of media flow rate per minute. The media reclaim system was a mechanical type to be effective with the amount of abrasive in circulation. Later, I was introduced to air-type shot peening machines, and with that to media flow rate that was a small fraction of wheel machines. Such machines work with a vacuum reclaim system to move the media. These are two ends of the spectrum and neither media reclaim system has seen any significant change over the years.

On the blast cleaning side, there have been marginal improvements to the process in which abrasive is "cleaned" to eliminate sand in foundry applications and scale in primary steel processes. This includes development of "smart lip" separators that ensure a full length of abrasive curtain and other related sensory tools. Magnetic separators are also popular to recover shot and eliminate sand from the working abrasive mix. Though these undeniably add to the productivity and lower operating costs, they are not exactly revolutionary.

In shot peening, our reliance on process control for repeatability and accuracy has led to incorporation of shot maintenance devices such as classifiers and spiral separators for size and shape control. Metallic and non-metallic peening media when used in the same machine are separated by the above-mentioned magnetic separators. Again, nothing game altering. I often wonder if we are taking the existence of such systems for granted and ignoring the possibility that they

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could be tuned to deliver more towards process control. I submit the following to ponder:

- Enhanced reclaim systems that are not reliant on gravity and steep feed angles for efficient conveyance (Advantage: shorter overall height and ease of maintenance since they will be closer to floor level)
- Technology, perhaps optical, to separate different sizes of shot (Advantage: flexibility of using multiple, near sizes of shot without risking cross-contamination)
- Predictability of outcome (coverage time) based on quantity and size distribution (within allowable tolerance for peening) of shot exiting the flow control valve to the nozzle/blast wheel

THE ALMEN STRIP

One must respect the sustaining power of the Almen strip, the de facto standard to validate the peening process. Those of you that have access to more sophisticated means have used X-ray diffraction to directly measure the compressive residual stress generated in the peened component. I too have commented on the possibility of substituting the Almen strip in favor of direct X-ray diffraction measurement. However, there could be other possibilities and questions that I would like to explore:

- Are there new technologies that can reliably replace the Almen strip. (I am not referring to alternate strip types or close comparisons.)
- Are we at a stage where we should evaluate alternate testing methods such as eddy current inspections—perhaps before and after peening the part? Eddy current inspection is proven technology, relatively inexpensive, portable, and quick. This technique is equally efficient with simple and complex geometries that Aerospace components are known to exhibit. It is non-contact type, mitigating any fears of marking, etc. This inspection testing accommodates for variability with change in frequency as may be required for certain part metallurgies.
- Almen strip arc heights lead us to saturation curves, and what has those curves taught us? Saturation curves relate the story of the process in so many details that I personally will miss the curve if we stop using them! Saturation curves remind us that the process with Almen strip arc height measurement is agnostic to the metallurgy of the component and time for part coverage. It gives us a benchmark to assess repeatability of the peening process when running verification strips. It warns us of media contamination when a double-knee is witnessed as part of the curve.
- Is it time to increase our reliance (and accessibility) on quality and result assurance tools such as velocity sensors and minimize the dependence on quality control? These devices are seen in sophisticated machines, but their widespread utilization is not evident. I think our community will greatly benefit from a less-expensive alternative with reduced sophistication and trimmed-down features.

WHAT TO EXPECT IN PART TWO

Our discussion will include topics that are being researched by academics with a focus on relating to the industry soon. These include:

(a) portable (handheld or robot-mounted) lasers,

(b) controlling surface roughness through optimal shot distribution (surface roughness caused due to shot peening is a concern in some Aerospace applications which specify a finish profile after peening),

(c) techniques to predict intensity and coverage, and

(d) shot peening electric battery components to increase charging speed, and other such related topics.

The sources of my inspiration will be listed as we discuss each topic to allow you to learn more if you choose to. I look forward to connecting with you in the summer magazine!

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Honeywell Begins Testing with Sustainable Aviation Fuel

The Honeywell location in Phoenix, Arizona USA has begun testing sustainable aviation fuel (SAF) for the development and production testing of auxiliary power units (APUs) and propulsion engines. Honeywell's repair and overhaul facility at the site will also test the fuel on fielded units.

The sustainable aviation fuel was developed by World Energy LLC in Paramount, California, using Honeywell's UOP Ecofining™ technology and distributed by World Fuel Services. According to the World Energy's website, SAF is a 100% sustainable fuel made entirely of renewable resources and contains no fossil-based feedstock. It is not co-processed with fossil fuel in traditional oil refineries, and its carbon attributes comply with all state and U.S. federal regulations for advanced biofuels. Its lifecycle carbon emissions are currently up to 85 percent lower than conventional jet fuel. It is approved at a 50/50 blend level with conventional jet fuel for commercial use.

In a recent press release, Honeywell stated that its blended SAF requires no changes to engine or aircraft fuel systems or fuel infrastructure. Honeywell also has plans to test other SAF blends and to run engines and APUs on 100% SAF in the future. "At Honeywell, we see SAF as a logical path to decarbonize the aviation industry and we consider our facilities as laboratories for sustainable innovation," said Dave Marinick, president of Engines and Power Systems, Honeywell Aerospace. "Honeywell has a wide variety of ready-now solutions to help create a more sustainable future for the aviation sector, and we are proud to make this progress on our sustainability commitments in our propulsion and power systems portfolio. Running our engines and APUs on SAF is a further demonstration of our commitment to our customers to do our part to reduce our carbon footprint."

Honeywell's first auxiliary power unit took to the skies in 1950, and the company has built more than 100,000 since then. More than 36,000 APUs, including both fixed wing and rotary wing, are in service today across more than 150 regional, executive, commercial and military applications. Honeywell engines have been at the forefront of aircraft propulsion since 1953. Honeywell's propulsion engines, like the HTF7000 with more than 1.7 million flight hours, focus on safety, performance and reliability, offering business jet operators enhanced performance and fuel efficiency at a lower cost of ownership. Honeywell is committed to achieving carbon neutrality in its operations and facilities by 2035. About 60 percent of Honeywell's new product introduction research and development investment is directed toward products that improve environmental and social outcomes for customers. (Source: www.honeywell.com)

Erickson's S-64 Composite Main Rotor Blades are a Success Story

Several years ago, Erickson faced a critical decision for its S-64 Air Crane® helicopter. The six-blade heavy-lift helicopter had aluminum blades that were manufactured with extrusion equipment developed in WWII. These blades wore out due to the harsh demands on the workhorse S-64 helicopters—they are integral to the management and fighting of wildfires and lifting heavy loads.

The old blades were retired and so came an opportunity—Erickson partnered with Toray Advanced Composites to develop a composite rotor blade. Toray's BT250E-6 resin system was chosen for Erickson's design.

To highlight the success of the new blade, Erickson created an infographic titled: "From Legacy to Legendary: Composite Main Rotor Blade." The document lists the benefits of the new blade:

- Significant fuel burn reduction
- Reduced maintenance costs
- Increased performance at hot and high-altitude conditions due to advanced airfoils developed by NASA
- A payload increase by 88%—that's an additional 755 gallons of water

According to Toray Advanced Composites, there are several more benefits of the composite rotor blade:

- Dramatic reduction in engine torque required when lifting objects out of the water
- Dramatic reduction in vibration, especially during transition from forward flight to hover, resulting in less wear and fatigue on the whole airframe and the pilot

Read more about the S-64 helicopter and Toray Advanced Composites at www.ericksoninc.com and www.toraytac.com.

An Erickson S-64 Air Crane helicopter fights a wildfire over Mount Hymettus, Greece. Photo credit: 248837368 © Lefteris Papaulakis | Dreamstime.com

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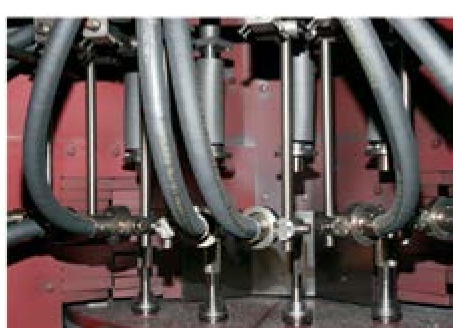

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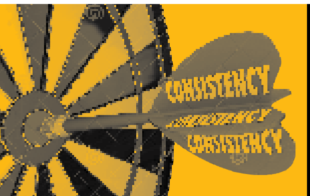

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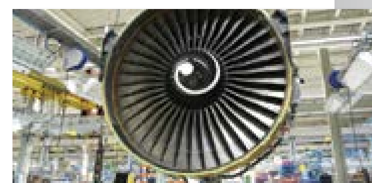

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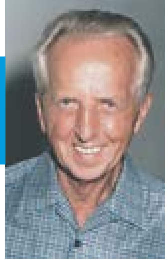

ACADEMIC STUDY

Dr. David Kirk | Coventry University

Shot Peening Materials Science

INTRODUCTION

The most important question in the Universe is probably "Why?" For shot peening it applies to the several materials that are at the heart of the process. For example, "Why is steel shot so commonly used?". Materials science covers all of the materials used in shot peening—metals, ceramics and polymers. This article attempts to provide answers to why particular materials are selected for shot peening applications.

SHOT PARTICLES

The ideal shape for a shot particle is a sphere, but real shot particles are not perfect spheres. The most commonly employed media are cast steel and iron shot, cut steel wire shot, glass beads and ceramic beads. These media are manufactured either by spheroidizing solid particles (cut steel wire and some glass beads) or by direct production of near-spherical shapes. Because of the method of manufacture, variations from sphericity are inevitable.

Cast Shot

Steel, cast iron and glass shot particles are produced by liquefying the material and then dispersing it as fine particles that solidify as they cool. The controlling factor affecting shape in these particles is surface tension. Surface tension is present in both liquid and solid particles, but reveals itself more dramatically for the liquid state. We are made aware of surface tension if we watch a drop of water forming from a faucet (tap) that is not completely closed. A "spherical cap" forms first, which grows, begins to "neck", and finally is suspended as if by a thread. When the water droplet breaks free, it immediately assumes a near-spherical shape. The liquid droplet contains two components of energy—internal and surface. The internal energy is independent of the shape of the particle and is directly proportional to its volume. The surface energy of a particle is given by multiplying its area by the intrinsic surface tension (energy per unit area). A cylinder of unit volume with a diameter equal to its height has a surface area of 5.537. That compares with the surface area of unit volume cubes and spheres of 6.000 and 4.831 respectively. The minimum surface area/volume ratio for any particle is therefore a sphere. It is a fundamental, inescapable law that any system tries to reduce its energy. Hence, cast liquids sprayed into another fluid—such as water or air—will form near-spherical shapes. It must be noted, however, that the difference in surface area between a near-spherical shape and a perfect sphere is negligible. Consequently, there is insufficient driving force to form a perfect sphere. Real cast shot particles can, therefore, only approximate to perfect spheres. "Roundness" and "Angularity" are the two parameters relating this approximation (see fig.1).

The controlling factor affecting cast steel shot size is the velocity of the water jet stream as illustrated by fig.2.

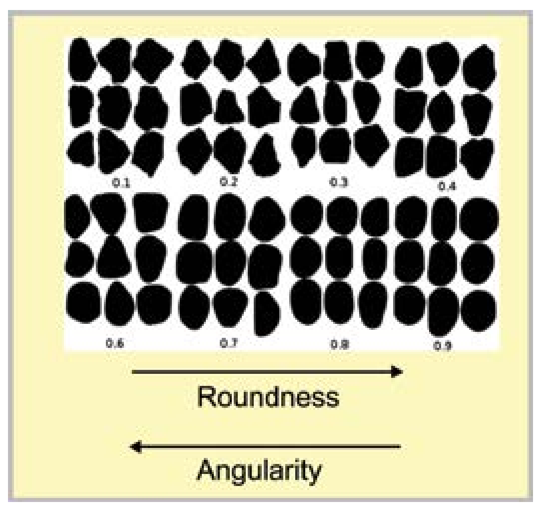

Fig.1. "Roundness" on a scale of 0.1 to 0.9.

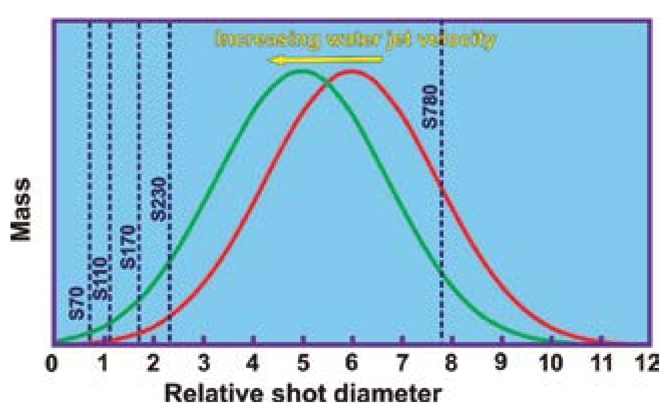

Fig.2. Effect of water jet velocity on cast steel shot size ranges.


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Spheroidized Glass Beads
An alternative production route for glass beads is to spheroidize crushed glass ("cullet"). This can be achieved by blowing hot gas through a fluidized bed of the crushed glass particles. As the glass particles become very hot, the surface tension effect becomes active. Each particle reduces its surface area, and therefore its total energy, by changing its shape towards that of a sphere. A major production problem is that the hot glass particles tend to coalesce if they touch one another. This problem can be overcome by coating every particle with "carbon black". Finely-divided carbon is very cheap to produce and will adhere readily to surfaces (as every chimney sweep of olden times found out!). The fine coating of carbon prevents coalescence and is subsequently removed, conceivably by oxidation in a fluidized bed at a lower temperature than that which causes coalescence. Again, particles can only achieve near-sphericity.

Cut Steel Wire Shot
This is a very useful medium because the steel used is in the wrought form— hard-drawn wire. It is axiomatic that wrought steel of a given composition has superior strength properties to those of the as-cast form. There are obvious differences in morphology of cut wire in its commercially-available forms: as "as-cut", "conditioned", "double-conditioned" and "spherical-conditioned" shot. In the as-cut state, we have pieces that resemble cylinders having lengths that are almost equal to their diameters. The actual shearing operation is critical, as a perfectly-cylindrical shape of as-cut particle is impossible. Fracture propagation during wire cutting can be inferred from microscopic examination of as-cut wire samples. A detailed account of cut steel wire shot production was given in a previous *The Shot Peener* article (Fall, 2003).

A feature of cut steel wire shot is that its size distribution is much smaller than that for cast steel shot. Size distribution is commonly represented using "Normal Distribution Curves". Fig.3 is a simple example of Normal Distributions. Curve A is much sharper than Curve B, indicating a difference in one or more properties.

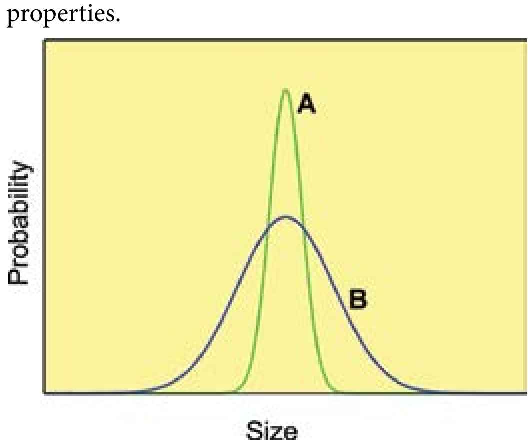

Fig.3. Normal Distribution Curves.

Ceramic Beads
Glasses are amorphous (non-crystalline) materials, whereas the ceramics used for beads contain a mixture of crystalline and amorphous phases. Both materials are based on mixtures of stable oxides (silica, alumina, sodium oxide, zirconium oxide, etc.). As a mixture, they have much lower melting points than the constituent oxides. It is possible to produce ceramic beads by cold- or hot-pressing of powder mixtures followed by sintering at high temperatures. The general route, however, is similar to that for cast glass beads. Mixtures are used that have sufficient fluidity to be "atomized" as particles directly from the liquid state. These are then cooled in air or gas streams to produce the solid-state beads. One problem is that the fluidity (inverse of viscosity) is still marginal for spheroidization. Work has to be done by the "skin" to change the shape of the liquid particle. The greater the fluidity, the less work has to be done by the skin to achieve a given amount of shape change. Major improvements have been made by making additions of oxides, such as cerium oxide or hafnium oxide, to a basic zirconium oxide/silica mixture. The surface tension effect is then sufficiently powerful to pull the liquid droplets into near-spherical shapes.

CARBON STEEL SHOT

Most shot peening is carried out using plain carbon steel shot. Finished carbon steel shot particles have a tough core with, of necessity, a brittle skin of iron oxide (see fig.4 where the skin thickness has been deliberately exaggerated).

Fig.4. Section of spherical carbon steel shot particle.

The iron in carbon steel oxidizes when exposed to air. Iron plus oxygen gives iron oxide. Iron oxide is a brittle, ceramic-type material that fractures very easily on impact. It follows that steel shot impacting a component shatters part of its oxide coating contributing vast numbers of minute iron oxide particles to the "atmospheric dust" inside the peening

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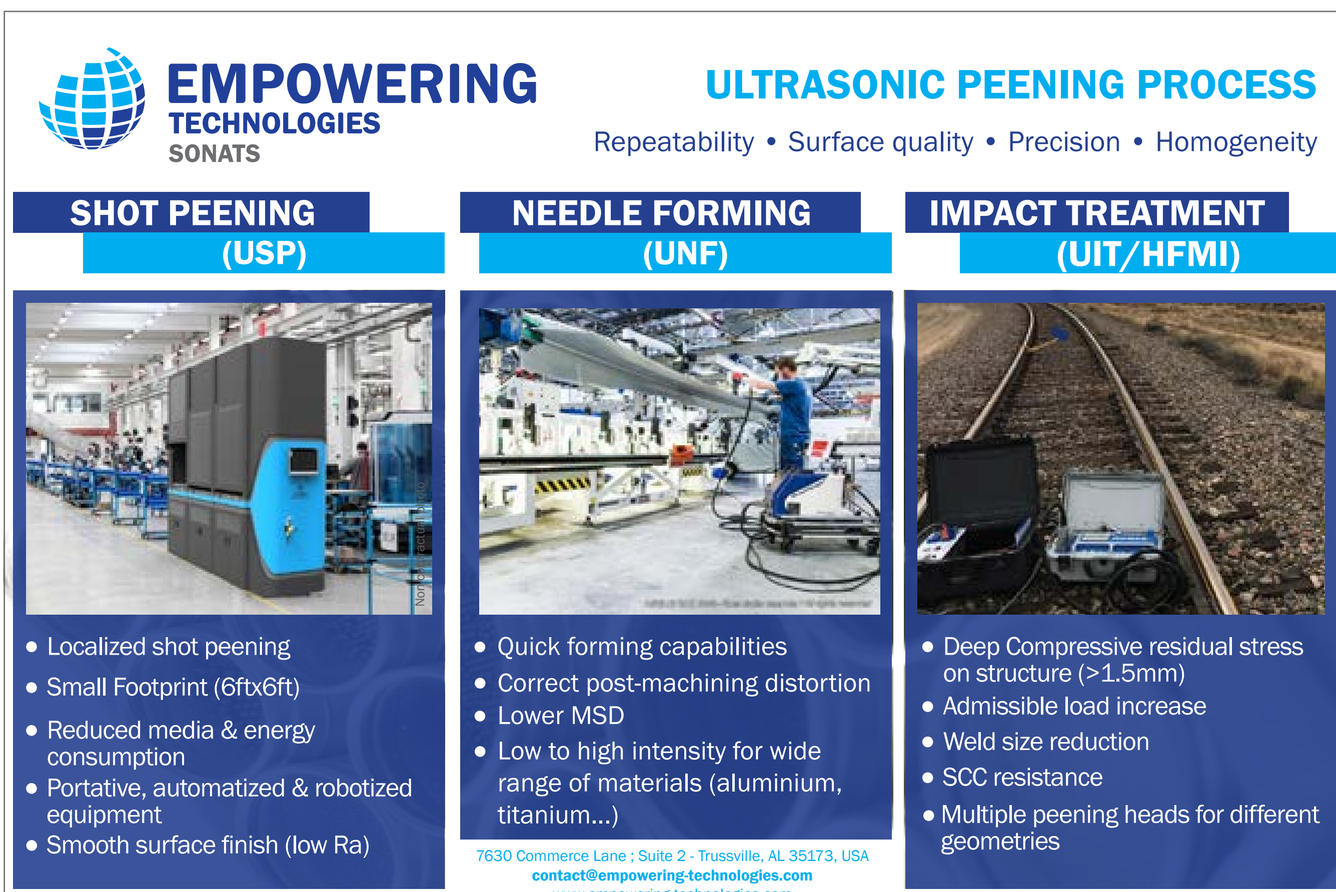

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cabinet. When iron oxide shatters, the skin on the shot particle is rapidly healed by further oxidation. The net effects are that (a) a small loss of shot mass on impact is unavoidable and (b) clouds of iron oxide particles are generated that can explode.

Fig.5 represents a slice of a carbon steel shot particle. The iron oxide coating has a variable chemical composition—**Fe_xO_y**. The ratio of y to x varies continuously from 1 at the shot interface to 1.5 at the air interface. A ratio of 1 gives FeO, 1.33 gives Fe_3O_4 and 1.5 gives Fe_2O_3.

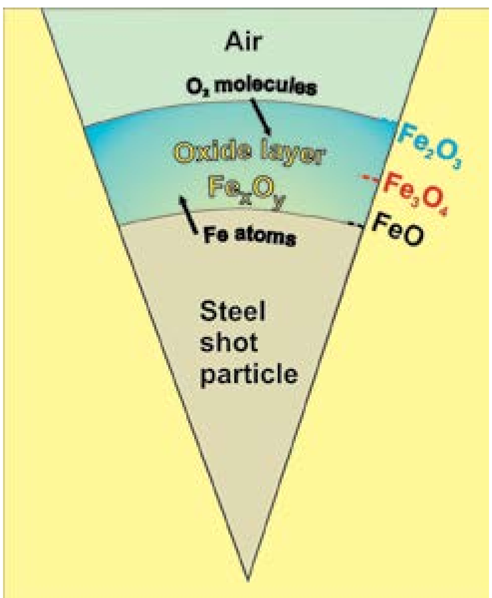


Fig.5. Slice of shot particle showing iron oxide layer of variable chemical composition.

When carbon steel shot is heated in an air furnace, the oxide layer grows thicker and thicker. The mechanism is that iron atoms diffuse into the layer at the shot/oxide interface whereas oxygen atoms diffuse into the opposite side of the layer at the oxide/air interface. Hence the outer layer is saturated with oxygen and the inner layer is saturated with iron. Layer thickening can be reduced, even reversed, by controlling the atmosphere in the furnace.

HIGH-TEMPERATURE STRUCTURE OF CARBON STEEL SHOT

If carbon steel is heated to an appropriate high temperature, then it adopts a very simple crystalline structure called "austenite". Carbon atoms are free to roam within a face-centered-cubic matrix of iron atoms. At a shot particle's surface they can either emigrate (de-carburization) or immigrate (carburization) depending on the surrounding atmosphere. Within the particle they are randomly distributed in the holes (interstices) between the iron atoms, moving freely from hole to hole. A key factor is the relationship between carbon content and the "appropriate high temperature". Fig.6 illustrates the relationship.

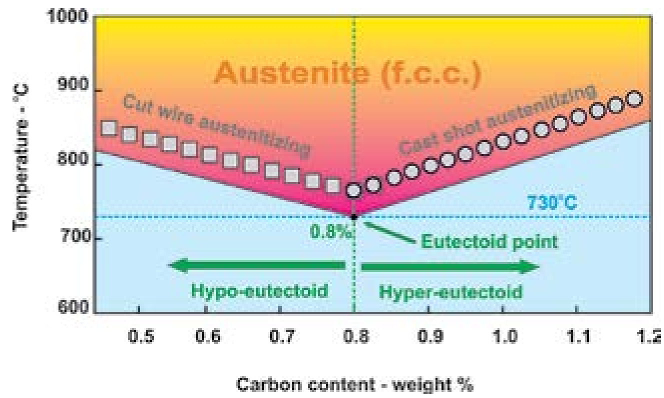


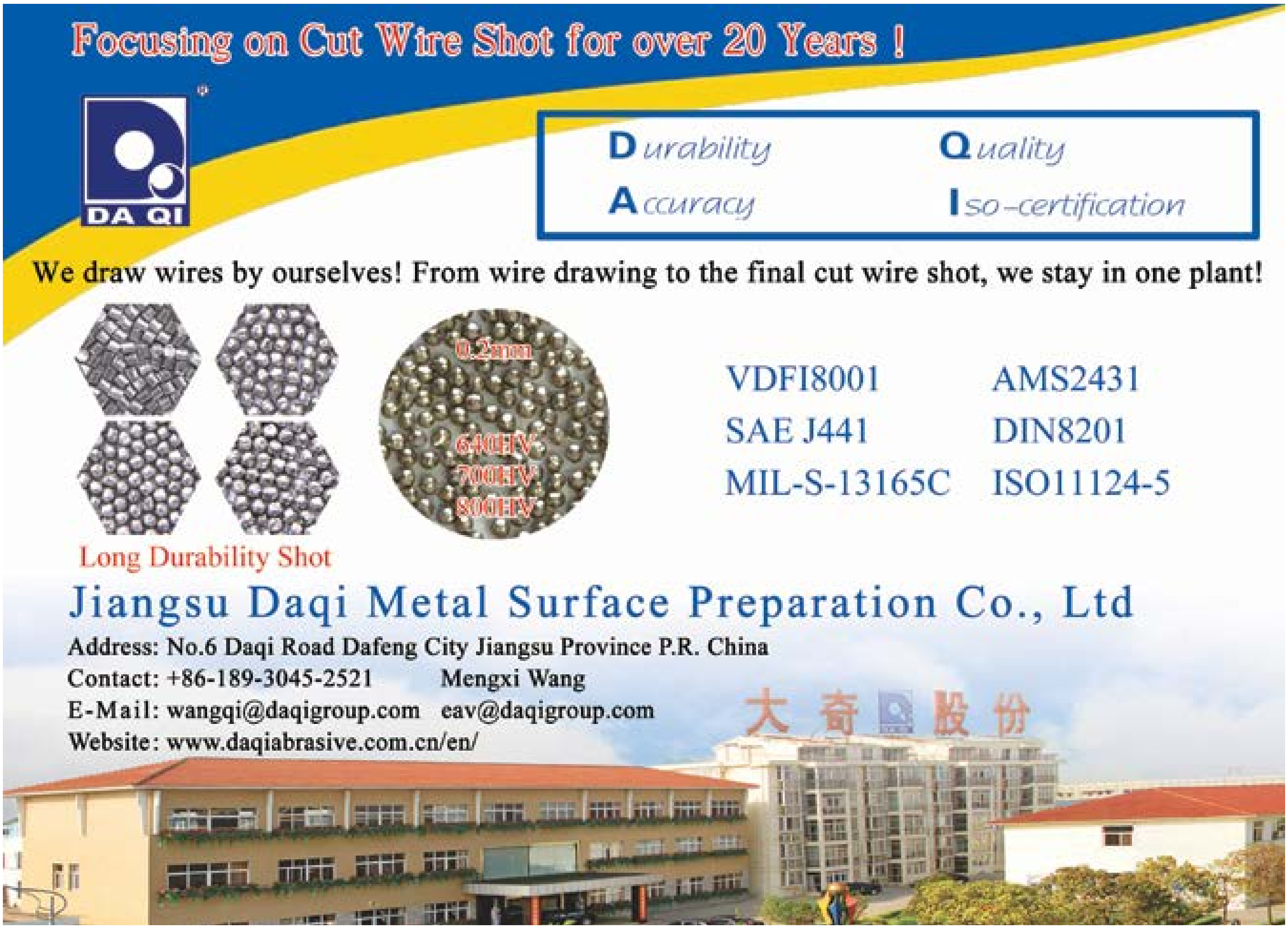
Fig.6. Schematic representation of carbon steel shot austenitizing.

The minimum temperature above which carbon steel austenitizes is about 730˚C for a 0.8% carbon steel. This is the so-called "eutectoid point". Lower and higher carbon contents than 0.8% require higher temperatures than 730˚C. Lower carbon content steels are called "hypo-eutectoid" and higher carbon content steels are called "hyper-eutectoid". These words derive from the Greek word "eutectos". The values of 730˚C and 0.8% carbon vary slightly with the presence of minor alloying elements. The appropriate austenitizing temperature for cut wire shot varies from about 780˚C to about 870˚C depending on its carbon content—as shown in fig.6. Cast steel shot can be austenitized at temperatures between 780˚C and 900˚C—again depending on the carbon content. Austenitization temperatures should not greatly exceed the minimum in order to avoid coarsening of the austenite grains (which results in a lowering of eventual properties).

Austenitizing is a vital part of carbon steel shot manufacture. Only one austenitization is necessary for cast steel shot. The as-quenched shot particles are normally austenitized before hardening by quenching and subsequent tempering. Production of the wire for cut wire shot requires several austenitizations.

A consequence of the foregoing factors is that a carbon steel of close to the eutectoid temperature is very popular for converting into shot. Such steels require the lowest temperature of re-heating in order to be austenitized. Heating to these lower temperatures is quicker and cheaper than heating to higher temperatures. A very important additional benefit is the reduced amount of oxidization that occurs at lower austenitization temperatures. The thickness of oxide skin layer can therefore be minimized.

Occasional use is made of steel shot that has a carburized skin imposed on a lower-carbon core. The skin is much harder and wear-resistant than the core which itself is relatively tough.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LOW-TEMPERATURE STRUCTURE OF CARBON STEEL SHOT

At high temperatures, iron and carbon atoms co-exist happily as austenite. At low temperatures, the opposite is true. Carbon atoms are forced to migrate, forming structures that depend on the rate of cooling from the austenitic state.

Slow Cooling

If austenite is cooled relatively slowly then there is time for the carbon atoms to be migrated as an extreme act of segregation. Most of the iron atoms then form themselves into "ferrite" which is virtually pure body-centered-cubic iron. The remaining iron atoms bind themselves to the carbon atoms in a highly-regimented format—three atoms of iron for every carbon atom. This three-to-one ratio leads to its chemical formula of Fe_3C—a brittle ceramic substance called "cementite". Layers of cementite alternate with layers of ferrite to form crystals of "pearlite", shown in fig.7. Pearlite consists of seven parts of soft, ductile ferrite to one part of hard, brittle cementite. As a combination, this structure has sufficient ductility to allow the huge amounts of cold working needed for wire production.

The microstructure of slowly cooled carbon steel depends on its carbon content. Fig.5 illustrates the relationship. For hypo-eutectoid steel compositions (less than 0.8%) cut wire, the slow-cooled structure consists of pearlite with some ductile ferrite—the amount of ferrite increasing as the carbon content reduces. For hyper-eutectoid steel compositions (more than 0.8%) cast shot, the slow-cooled structure is pearlite with some brittle primary cementite—the amount of brittle primary cementite increases as the carbon content increases. Fortunately, cast steel shot does not need to be slow-cooled at any stage of its manufacture.

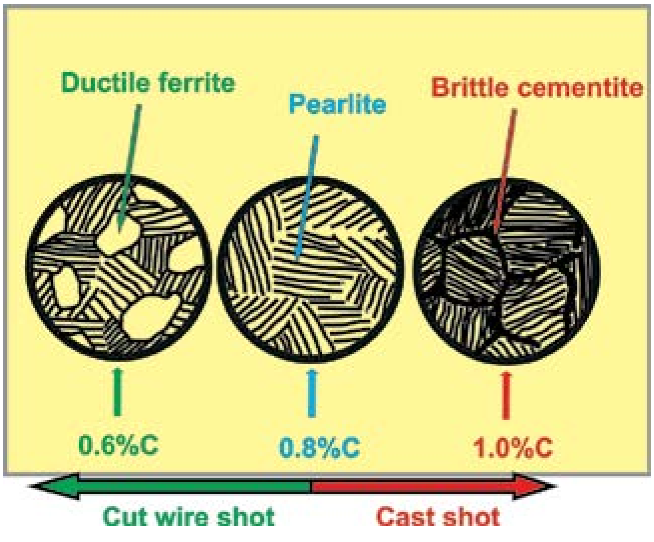

Fig.7. Schematic representation of slow-cooled carbon steel structures.

Rapid Cooling

If austenite is cooled rapidly, there is insufficient time for the carbon atoms to migrate through the lattice to form either pearlite or cementite.

Quenching to far below the critical temperature of 730˚C (see fig.6) induces a truly cataclysmic change in structure. At room temperature, austenitic carbon steel has so much pent up energy that it "explodes" into a structure called "martensite". Needles of martensite nucleate and then propagate, at almost the speed of sound, in any one of twenty-four directions within each austenite grain. Enormous micro-stresses are generated as the growing needles crash into each other and become locked together. The enmeshed martensitic structure is very difficult to deform—hence its high hardness. The corresponding brittleness can be alleviated by post-quench heating—"tempering". Heating to a few hundred degrees Celsius allows a very limited amount of carbon atom migration to more comfortable locations and reduces the micro-stress levels. The resulting structure is called "tempered martensite". Tempering increases toughness and deformability.

The crystal structure of martensite is almost identical to that of ferrite (which is body-centered-cubic). A cube has three edges of identical length. Carbon atoms in quenched austenite do a "shimmy" towards just one of three edges, see fig.8, at the same time as the face-centered-cubic austenite transforms itself into a body-centered cubic arrangement of iron atoms. The carbon atoms are smaller than the iron atoms but still have to push them apart to fit into the available space. This type of crystal structure is called "body-centered-tetragonal". Because the carbon atoms are pushing the iron atoms apart in just one of three possible directions then that direction, "c", becomes larger than that of the other two directions, "a".

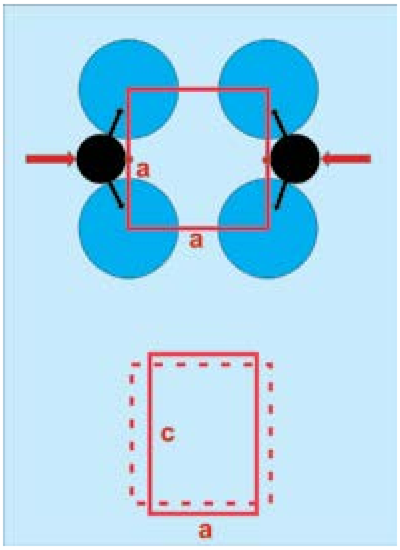

Fig.8. Carbon atoms distorting cubic arrangement of iron atoms.

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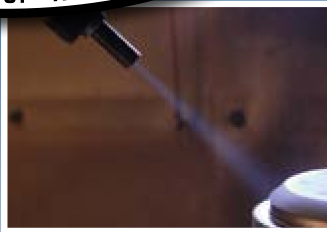

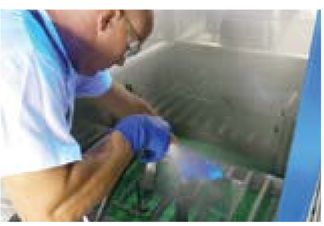
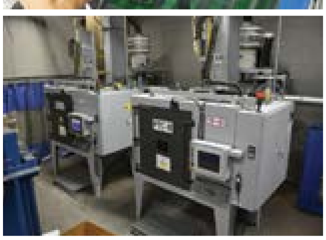
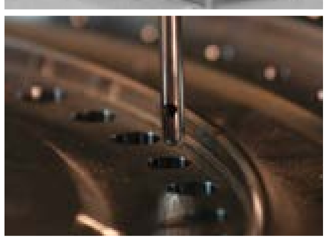


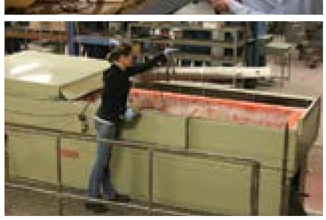

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The ratio of **c** to **a**, "tetragonality", increases with carbon content as does hardness.

Cold-Working of Carbon Steel

Cold-working of carbon steel increases its hardness but decreases its ductility. A maximum hardness is reached beyond which the hardness starts to fall—a phenomenon called "work softening". Cast steel shot is not cold-worked prior to use. Cut wire shot, on the other hand, suffers very considerable cold-working as a necessary part of both wire drawing and conditioning. Drawn wire must have its ductility restored at intervals of drawing. Cutting of the drawn wire into cylindrical pieces involves massive plastic deformation at the sheared interface. This induces localized work-hardening and can even induce phase transformation.

Several specifications require that shot is produced to two levels of hardness. High-hardness cut wire shot can be produced by controlling the carbon content, work-hardening and heat-treatment hardening contributions. The hardness of cast shot can be controlled by the carbon content and the level of tempering.

WORK-HARDENING OF COMPONENTS

Shot peening induces two very important changes in the surface layers of components. These are work-hardening and compressive residual stress, both of which improve fatigue strength. Fig.9 illustrates their contributions to fatigue strength. Work-hardened material has a greater fatigue strength than does un-peened material. The induced compressive surface residual stress is the "icing on the cake", making an additional contribution.

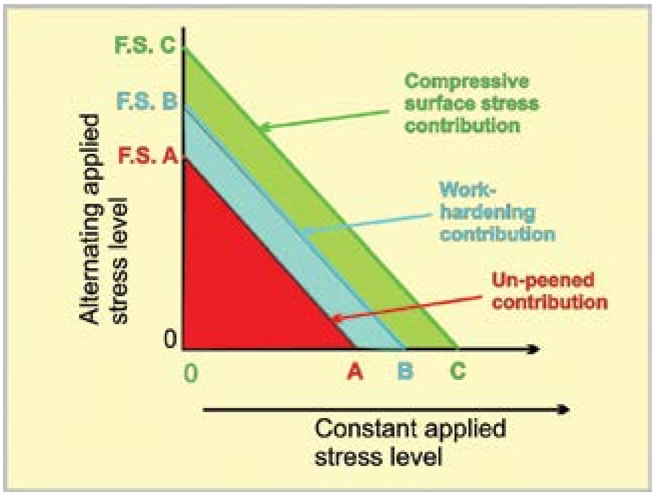

Fig.9. Contributions of Work-Hardening and Compressive Surface Residual Stress.

Surface work-hardening of peened components is quite different from that which occurs during a tensile test. Fig.10 illustrates the difference in behavior.

(1) The quoted yield strength values derived using tensile testing are not the same as the values required to indent when using flying shot particles. That is because yield strength increases with strain rate. The very high strain rates occurring during denting mean that the yield strength is several times greater than that predicted by a slow tensile test.

(2) Relatively-massive amounts of strain occur during shot peening. That is because a compressive stress system is set up, as described in a previous article (*The Shot Peener*, Spring, 2013, "Peening Impressions (Dents)").

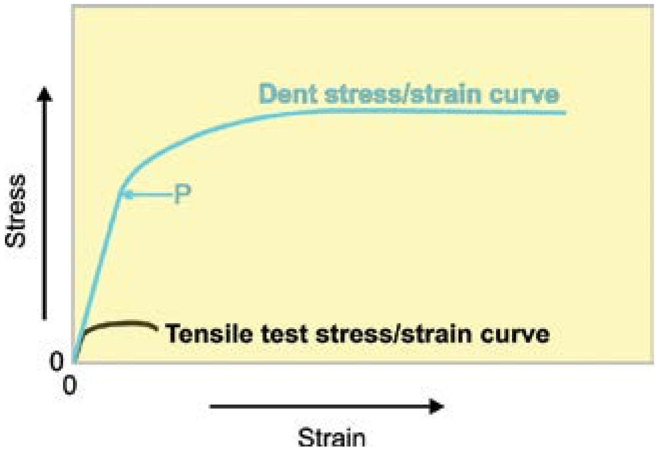

Fig.10. Schematic comparison of tensile test and dent stress/strain curves.

Fig.11 shows the zone of work-hardening (cross-hatched) that accompanies dent formation. An important feature is that the work-hardening is not uniform. As the moving shot particle reaches its maximum depth the deformation zone has two strain boundaries. Maximum plastic strain occurs at the contact area between particle and dent—marked as a red line. Zero plastic strain occurs where the applied stress only equals the proportionality limit stress, P, and is marked as a blue line. Below that line the component is only elastically stressed.

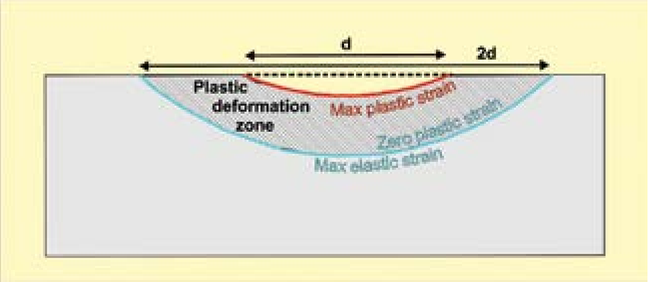

Fig.11. Plastic deformation zone beneath a peening dent.

EFFECT OF MULTIPLE DENTING

As coverage increases, the peened surface is subjected to multiple impacts. Progressively, a continuous work-hardened surface layer is produced. The amount of plastic deformation


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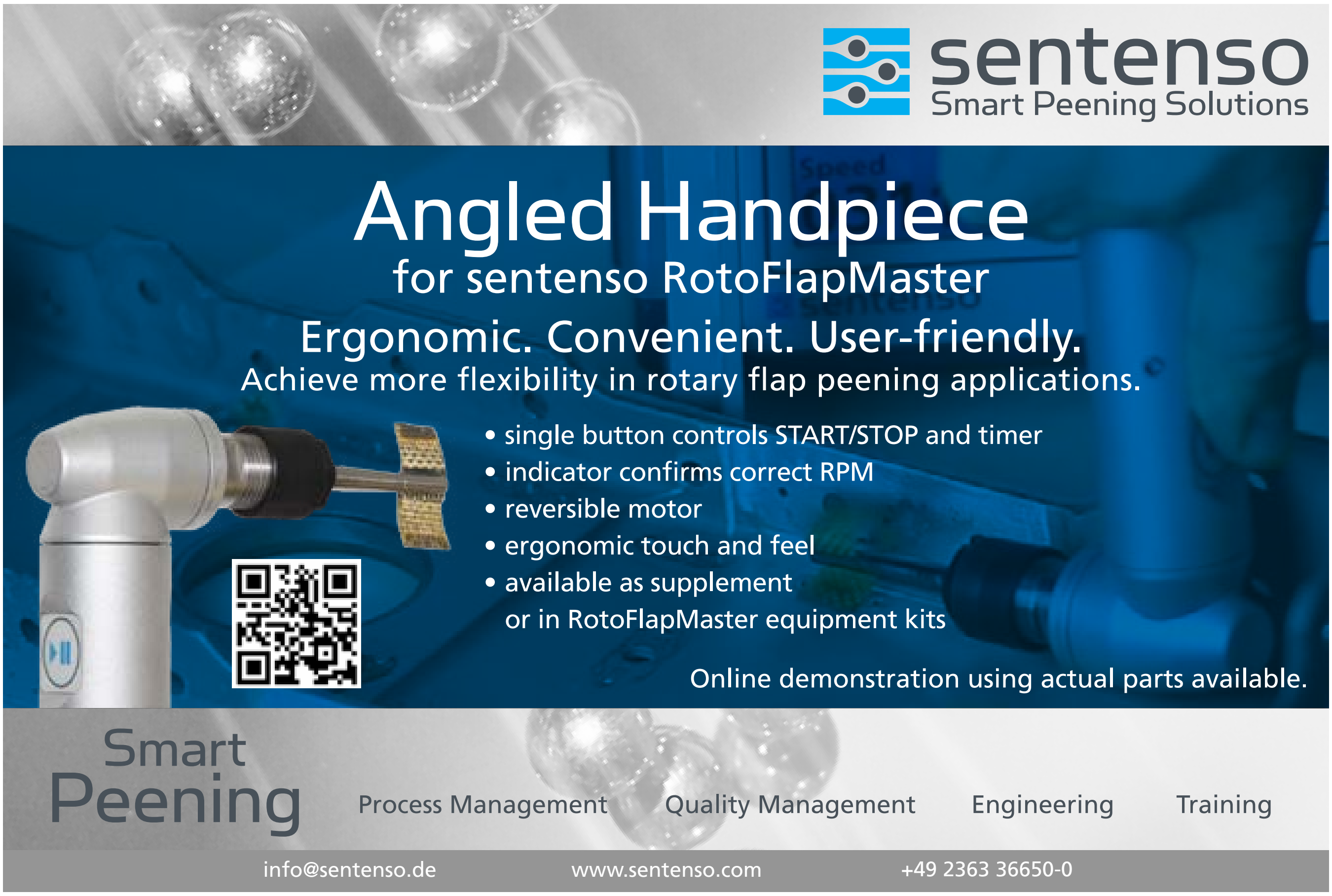
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is far higher than that encountered in a tensile test. A pertinent question is "Why doesn't cracking occur during peening?" The answer lies in the different type of stress system that is being applied. It is because a three-dimensional compressive stress system is operating. In effect, the metal is being squeezed together three-dimensionally during deformation.

This is similar to what happens when we make snowballs. Squeezing using cupped hands applies a three-dimensional stress system. Compare that with what would happen if we press using flat hands.

During tensile testing we are simply trying to pull the metal apart. Cold-rolling involves an element of three-dimensional squeezing. Steel that cracks apart at, say, 10% elongation, can easily be cold-rolled to hundreds of percentage elongation without cracking. Extrusion has the largest three-dimensional compressive component of any metalworking operation. The same steel can be extruded, without cracking, to thousands of percentage elongation.

DISCUSSION

This article has attempted to cover the most significant materials science features that influence shot peening. This coverage has been simplified for the sake of brevity. Expanded accounts are, however, available in other *Shot Peener* articles.

Steel shot remains the most popular medium for shot peening. It has been available for hundreds of years and is reasonably inexpensive and easy to manufacture. Materials science does allow us to understand shot behavior and its limitations.

Great strides have been made in progressing many aspects of actual peening. Shot composition remains, however, relatively static. One avenue could be to test the viability of high-manganese steels. Several high-manganese steels are available in a tough austenitic form which cold-working transforms to hard wear-resistant martensite. This would allow shot to be manufactured that developed a self-healing wear-resistant surface layer.

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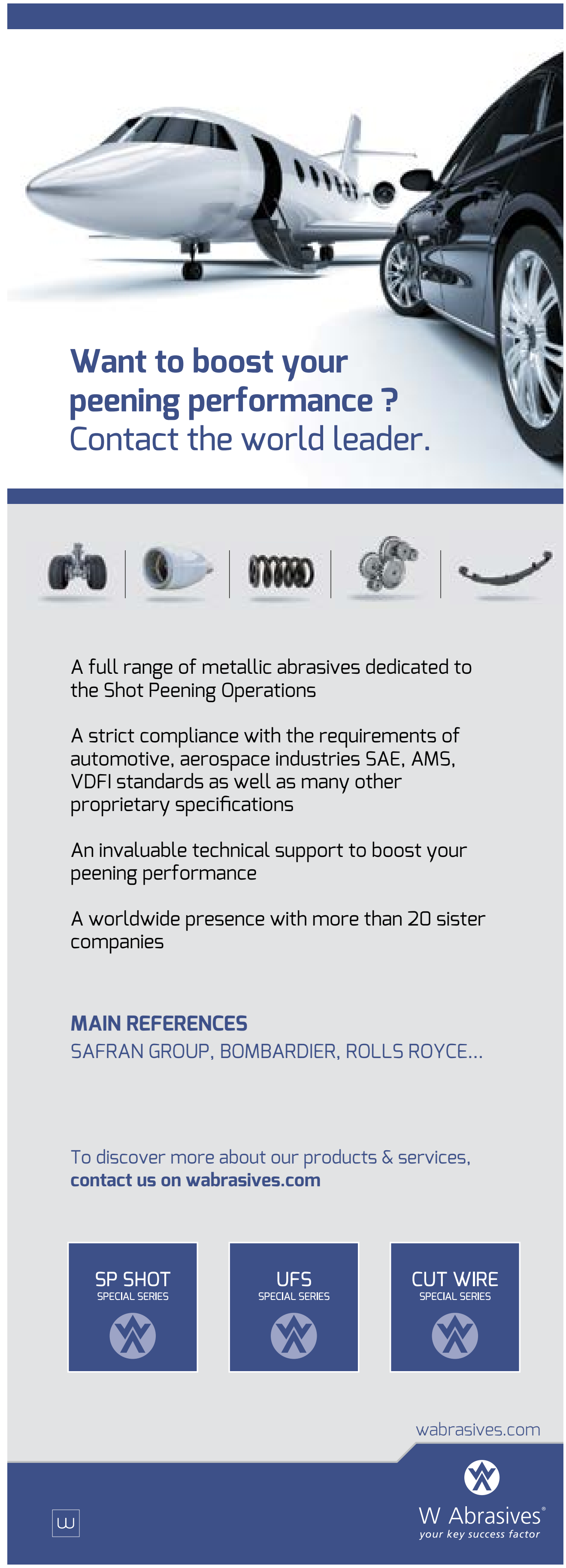

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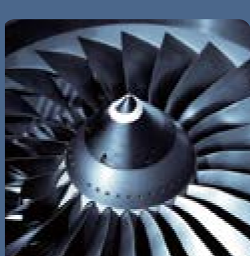

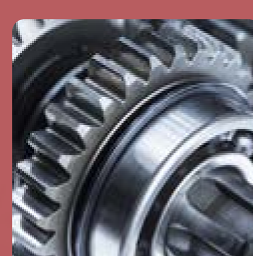
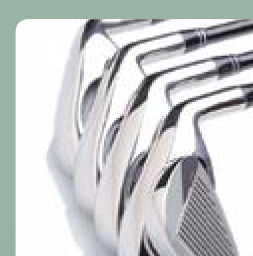

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Repeatability in high-volume parts peening, finishing, or blasting operations is achieved by delivering a uniform quantity of media at a consistent velocity and striking the target surface area in the same way each and every time. The internal shape of the nozzle guides and distributes the media as needed for the application. Different nozzles with different shapes offer different advantages depending on the application.

Pressure blasting is chosen for some high-production air-powered processes because it propels media at a higher velocity through the blast nozzle than suction blasting. In air-powered pressure blasting, media feeds from a pressure vessel into a moving stream of compressed air through a metering valve, blast hose, and nozzle.

Two types of pressure blast nozzles are generally used. Both are designed with unique internal shapes to achieve different objectives. Both types have a broad entry area, which sharply tapers to an orifice—the smallest inside diameter (ID) of the nozzle and, in fact, the smallest area in the entire blast system. The rapid reduction in ID and the controlled expansion of the compressed air, moving through the nozzle, work together to accelerate the media toward their target.

As its name implies, a straight-barrel nozzle has a straight, constant-diameter barrel between the orifice and the exit-end of the nozzle. When the air and media reach the nozzle exit, the less-dense air quickly expands once the influence of the nozzle barrel is absent, and momentum carries the media along the center of the blast pattern.

The straight-barrel shape creates a relatively small blast pattern with a very high intensity and then tapers out to lower impact at the perimeter. While it takes longer to cover a large surface area with such a small hot spot of higher intensity compared with other nozzle shapes, the straight-barrel shape works well in recessed or restricted areas.

Unlike the straight-barrel nozzle, the venturi nozzle gradually tapers outward from the orifice to the exit-end of the nozzle. This gradual exit expansion allows a mixing

Clemco's straight-barrel nozzle

of air and media within the nozzle causing them to expand uniformly before leaving the nozzle.

A venturi nozzle provides excellent peening intensity and cleaning capability with a broad pattern. The performance of the venturi nozzle depends on a precise ratio of length to orifice size, and to entry and exit tapers. This design creates a large blast pattern that produces uniform peening intensity and maximum acceleration for cleaning.

Once the proper nozzle is selected, it is important to monitor the nozzle's condition for effectiveness during ongoing use. Nozzles wear from continuous exposure to high-velocity media when more air and media are allowed to pass through the orifice. The resulting larger area within the nozzle consumes more air volume, which in turn places greater demand on the compressed air source. Unless air volume can keep up with the

Venturi nozzle

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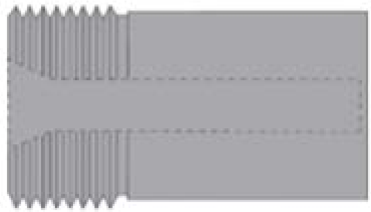
increased flow, pressure at the nozzle will drop. Reduced pressure causes peening intensity and productivity to fall, and efficiency suffers.

A rule of thumb to follow for ensuring continuous high production is to replace the nozzle when the orifice wears to the next larger size, generally to 1/16" or 1.5 mm. In the USA, nozzle sizes are measured in 1/16" increments. A No. 6 nozzle has an orifice of 6/16" (3/8"); the next larger size is No. 7 with an orifice of 7/16" (11 mm). In Europe and elsewhere, nozzle sizes are indicated in millimeters.



Straight-barrel nozzle

The relative life expectancy of a nozzle depends upon the combination of its liner material and the abrasive media being used. The harder the media, the more durable the liner material must be to withstand exposure over an acceptable life.

A commonly employed industry reference for measuring relative hardness is the Mohs' scale, which offers a method of measuring relative hardness on a scale from 1 to 10 for non-metallic media and nozzle liner materials. Metallic media (steel) is measured on the Rockwell scale. Common steel media range from soft Rc-35 to hard Rc-65.

Besides the choices of nozzle shape and liner material, the other critical factor to achieving repeatability when pressure blast cleaning, finishing, and peening is the distance between the nozzle and the target object. The target area must be covered with precision for efficient cleaning and finishing and to adhere to strict peening intensity specifications. Overlapping coverage wastes valuable resources in cleaning and finishing and may not produce the specified results in peening applications.

With the relatively larger pattern produced by the venturi nozzle, it is also important to be able to calculate the area the blast will cover. Calculating the blast pattern size is easy: Simply multiply 0.125 times the distance between the exit end and the target surface and add the ID size of the nozzle orifice. For example: The pattern size produced by a 3/8" (9.5 mm) nozzle positioned 8" (203.2 mm) from the surface is 1.375" (34.9 mm).

Once the blast pattern size is calculated, the area covered by the chosen nozzle(s) can be determined. This helps determine precisely what system configuration (i.e., number of nozzles needed) will do the job in the desired timeframe and within the defined budget. The result will be repeatable results delivered efficiently and effectively.

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Dave Barkley is the Director of EI Shot Peening Training and one of EI's rotary flap peening instructors. Mr. Barkley was the author/sponsor of AMS 2590 "Rotary Flap Peening of Metal Parts." He is also the recipient of the 2020 Shot Peener of the Year award.

EI Shot Peening Training

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MEDIA ANALYSIS

Kathy Levy | Associate Editor | The Shot Peener

Mixing it Up

The following article is derived from a recent email exchange between a media manufacturer and Jack Champaigne, President of Electronics Inc. It will be valuable to our readers that have questions on media usage in peening and blast cleaning machines.

MEDIA MANUFACTURER: When someone is charging a new machine for peening purposes, we always suggest a mix of shot that would represent the eventual working mix. We have a customer with a new machine, and they insist that they want to charge their new machine with all one size. What determines the shot discharge size in a peening operation? Is there a specification or is it just the required profile result of the finish that determines when to discharge shot?

JACK: Wow, get me started. The term "working mix" is common for abrasive blast cleaning operations, especially in foundries for the cleaning of castings. A mix of large shot and then addition of grit is often needed for efficient cleaning. I was perplexed by the term "peening purposes", so I pursued the conversation further.

If the application is for blast cleaning, it is common to have a working mix—for instance, when cleaning castings in a foundry. However, in other applications the customer may wish to use just one size of media if it accomplishes the cleaning efficiently. This eliminates the burden of mixing media in portions trying to maintain a mixture.

If the application is for shot peening, then charging the machine with only one size of media is absolutely required. The type and size of media most likely is contained in a shop order. Going further, the media maintenance rules need to be adhered to. Depending upon the machine's construction, it may have screen separators to classify the shot automatically and therefore inspections are only required after 40 hours of operation. Without the classifiers, inspections must be done every eight (8) hours of operation. See the chart in Table 5 from SAE spec AMS 2430.

MEDIA MANUFACTURER: I know that the US Military specification 13165 indicates that for cut wire .020, for example, the 40 screen (.0165) indicates that 20% can go through that screen. I don't really understand that either. What does that mean?

JACK: Inspections for media size are conducted using a stack of sieves with a 100 gram sample of media. Shaking the sieves will cause media to pass through the stack determined by the size of the media and the opening of the sieves. A machine called the Ro-Tap (rotation and tapping) is used to shake the stack. If you are using cut wire media size 20, then you must meet the requirements of collecting less than 0.5% of media on the sieve #25 and less than 20% passing on the #40 sieve. (Visit https://wstyler.com/particle-analysis/ro-tap-sieve-shaker or scan the QR code to learn more about the Ro-Tap.)

For additional information on media inspections, consider enrolling in a workshop or arranging for on-site training by our education division at Electronics Inc. The courses are sanctioned by the FAA for inspectors' annual recertifications and include training in media, intensity, coverage and use of the Almen strips and gages.

Table Five | SAE specification AMS 2430
In-process media inspection frequency requirements

Media	Machine with Separator (Hours)	Machine without Separator (Hours)
AMS2431/1 Cast Steel Shot Regular	40	8
AMS2431/2 Cast Steel Shot Hard	40	8
AMS2431/3 Cut Wire Shot Carbon, Regular	80	16
AMS2431/4 Cut Wire Shot Stainless	120	24
AMS2431/5 Peening Balls	20	4
AMS2431/6 Glass Shot	8	Note 1
AMS2431/7 Ceramic Shot	8	4
AMS2431/8 Cut Wire Shot Carbon, Hard	80	16

Notes:
1. Media shall be replaced after two hours of peening. No inspection of outgoing media required. When wet glass shot is used, the entire slurry charge shall be changed at frequent intervals for compliance with this requirement. Fresh shot may be added only once between changes of the entire slurry to maintain the media quality.

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