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※PC is not included ※Device image

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Analyzer**



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PSA Type L-P

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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]

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Progressive Surface Installs Shot Peening System at Purdue University

Students and research teams will be using a cutting-edge shot peening system this fall in Purdue's Manufacturing and Materials Research Laboratories.



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Shot Peening Research: Practical Application of PALS in Japan

Since 2010, Toyo Seiko has been working with the National Institute of Advanced Industrial Science and Technology to develop a positron lifetime measurement device for industrial use. This article introduces the new device.



Positron standard model : PSA Type-LII

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An Insider's Perspective: Specifications beyond Aerospace

Kumar Balan opens the discussion on reviewing SAE J2441. He introduces key aspects of a relevant document with the expectation that our readers will provide constructive feedback for a future document.

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The Application of Science

Dr. David Kirk describes the general methodology that is involved when science is applied to the solution of problems.

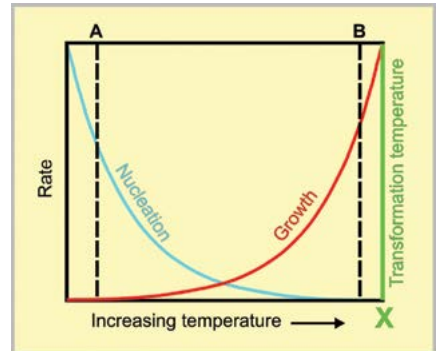


Figure 4 from Dr. Kirk's article

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GelSight Press Release

GelSight® launches Modulus™—a precision inspection tool for previously inaccessible places.

40

National Peening Press Release

Technical Metal Finishing announces rebranding to National Peening.



Gelsight's Modulus devices

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OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

Going Forward

MY, HOW TIME FLIES. I remember the launch of *The Shot Peener* in 1987. Seems like a hundred years ago. It was the result of my effort to advertise. This led to adding names to our database and identifying individuals who sought to enhance the shot peening process.

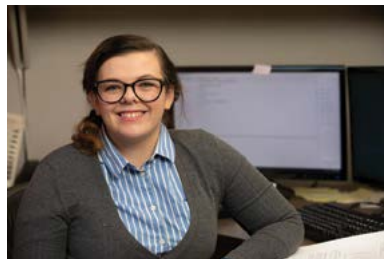
The format changed in 1994 with the addition of Kathy Levy to the team, resulting in significant improvements to the format. We enhanced the masthead and evolved to a four-color design. This led to substantial improvements, including attracting new advertisers.

And then, the world changed forever with the advent of the internet and the launch of the shotpeener.com's web page. Mary Doezma Cooper was our webmaster, and we offered our library of articles along with a Buyer's Guide. She then continued to create the web page for Electronics Inc. so we could offer our products for shot peening control, such as the MagnaValve, the Almen gauge, strips, and much more. That same year she created the website for the International Scientific Committee on Shot Peening at www.shotpeening.org. This helped promote the work started by Abbas Niku-Lari in 1980 for tri-annual conferences and provided a repository for conference papers, allowing free access to them.

However, as time passes, change inevitably includes retirement. Both Mary and Kathy get to close their work chapters and start new adventures. *The Shot Peener* magazine is now read around the world. The EI website is the portal for the finest equipment for shot peening control.

Thank you, Mary and Kathy. You were the driving force behind our success. Enjoy your retirement and don't forget to maintain your subscription to *The Shot Peener* magazine.

Going forward: Taylor Bowman will now coordinate the publishing of *The Shot Peener* magazine and the websites for EI, www.shotpeener.com, shot peening training, and the magazine. With the retirement of Professor David Kirk, we are looking forward to periodic articles from the Purdue University Center for Surface Enhancement and Engineering (CSEE). Time goes on. Join us for "the rest of the story." ●



Taylor Bowman will be the new Associate Editor for the magazine.

THE SHOT PEENER

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Jack Champaigne

Associate Editor

Kathy Levy

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Progressive Surface Installs Shot Peening System at Purdue University

STUDENTS AND RESEARCH TEAMS will be using a cutting-edge shot peening system this fall in Purdue's Manufacturing and Materials Research Laboratories (MMRL). The shot peening system was built and installed by Progressive Surface. "We provided this machine as a cost share with Purdue because we believe in the mission of the Center for Surface Engineering and Enhancement (CSEE) and want to be a part of improving the understanding and implementation of peening across all industries," said Jim Whalen, President of 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. The company is in Grand Rapids, Michigan, USA.

The shot peening system is designed to shot peen parts up to Ø30" x 30" tall and weighing up to 300 pounds. The system's features include:

- Heavy duty 1/2" thick plate construction
- Work door for access to the machine
- Viewing window on front and side of machine
- Ease of programming for a wide variety of components using the FANUC R-30IB controller and teach pendant
- Flexible work envelope from the FANUC LR-10iA robot (22 lb payload capacity)
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- Stairs and platform for Sweco access
- Allen-Bradley Panelview operator interface with data logging
- Allen-Bradley CompactLogix PLC
- FANUC R-30IB controller

"The machine specifications were based on our industrial experience as well as our understanding of the projects conducted at CSEE," said Mr. Whalen. "It meets the most



Compact Layout, Robot Flexibility and HMI with data collection make this a perfect system for MMRL activities

stringent requirements of the aerospace industry." The Progressive Surface team provided training in the operation, maintenance, and programming to the CSEE and MMRL staff.

Langdon Feltner, a Graduate Research Assistant with the School of Materials Engineering at Purdue University, is one of the people that will be working with the Progressive Surface machine. He is a researcher with expertise at the confluence of solid mechanics and stochastic processes, and he is devoted primarily to the modeling and experimental validation of shot-peening induced residual stress fields.

Regarding the installation of the shot peening machine at Purdue, Mr. Feltner said, "I believe that the Progressive Surface unit can simultaneously support cutting-edge research while also enriching hands-on teaching experiences for both undergraduate and graduate students. Professor Mike Sealy, Associate Professor of Mechanical Engineering at Purdue University, teaches a course on additive manufacturing



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A Cut Above

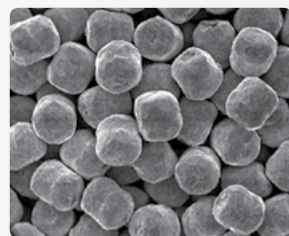


The advantage of Premier Cut Wire Shot

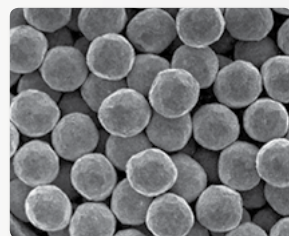
- **Highest Durability** Due to its wrought internal structure with almost no internal defects (cracks, porosity, shrinkage, etc.) the durability of Premier Cut Wire Shot can be many times that of other commonly used peening media
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that takes an in-depth look at the application of peening as a treatment for additively manufactured components. Additionally, the School of Materials Engineering's industry-sponsored senior capstone projects allow small groups of students to gain first-hand experience operating the machine. Overall, this partnership between Progressive Surface and Purdue University represents a unique commitment to providing formal education in shot peening and supporting MMRL's mission to advance American manufacturing." ●



Two 600 series MagnaValves control media to two nozzles

Purdue's Manufacturing and Materials Research Laboratories (MMRL)

MMRL is a 30,000 square feet facility with the latest in manufacturing machinery and processes. In collaboration with industry and government partners, the Purdue teaching and research faculty is sharing advancements in shot peening, laser machining, particle coating, roll-to-roll printing, additive manufacturing, and more.

Along with Purdue's new eXcellence in Manufacturing and Operations (XMO) initiative—an initiative to build a national coalition of academia, government, and industry partners—MMRL and XMO focus on manufacturing research and experimentation to create a renaissance in U.S. manufacturing that will ensure jobs and national security.

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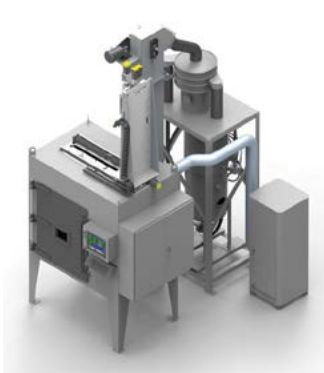
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Practical Application of PALS in Japan (Sub-Nanometer Material Evaluation)

Toyoseiko Co., Ltd. - Yoshihiro Watanabe, Mitsuru Handa, Kanehisa Hattori
National Institute of Advanced Industrial Science and Technology (AIST) - Masato Yamawaki

1. Introduction

Positron annihilation lifetime spectroscopy (PALS) is a technique that can evaluate atomic-level defects and inter-molecular space and pore structures with nondestructive and high sensitivity. PALS is used to evaluate the free volume void size of polymer materials and the degree of fatigue accumulation in the early stages of metal fatigue, and in recent years, material evaluation using PALS has been actively conducted. Since 2010, Toyo Seiko has been working with the National Institute of Advanced Industrial Science and Technology (AIST) to develop a positron lifetime measurement device (PSA) for industrial use. Today, this device has been improved to the point where positron lifetime values can be obtained without requiring specialized knowledge or skills, and it has begun to be used in general industry as well. This article introduces PSA developed by Toyo Seiko and AIST.

2. Issues and solutions in device development

Before Toyo Seiko and AIST developed PSA, positron lifetime measurement method was a technique that was basically only used by a limited number of researchers in legally designated radiation-controlled areas in Japan.

The most significant development was the improvement of ^{22}Na sealed radiation source for positron lifetime spectroscopy by Japan Radioisotope Association (JRIA). Figure 1 shows the current sealed ^{22}Na source. The thickness of the Kapton film was thinned down to $5.0\ \mu\text{m}$, and the annihilation within the film was significantly reduced. Since radioactivity is less than $1.0\ \text{MBq}$, no controlled area or personnel qualifications are required for handling in Japan. Other points that were important for the commercialization of PSA are shown in Table 1.

3. PSA device

There are three types of PSA, and the standard model is shown in Figure 2. The configuration of the PALS system is shown in Figure 3, and the sample setup (actually just placing the sample on sealed radioisotope) is shown in Figure 4.



Fig. 1 Sealed ^{22}Na source supplied by JRIA

Table 1 Issues and Solutions

Thema	Issues	Solutions
Preparation of measurement sample	The most common setup for the measurement sample is to sandwich a sealed source film between two measurement samples. So researchers had to deal with sealed sources.	The anti-coincidence method (patented Technology ^[1]) has been put into practical use, making it possible to perform measurements using a single sample without handling sealed source.
Measurement and analysis program	The equipment is designed for professionals, so it is difficult to use for people who are not familiar with PALS.	We have developed dedicated software with a simple interface that allows measurements and analysis to be completed with just a few clicks.
Positron lifetime standard material	They are available only for polymer and quartz, and are not supplied for semiconductors or metals.	Four types of reference materials are supplied by AIST to suit any user's needs.



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Fig. 2 Standard model : PSA Type-LII

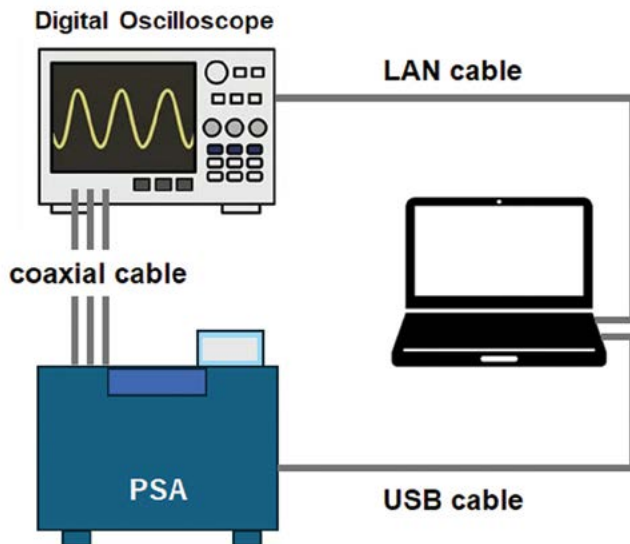


Fig. 3 Configuration of PSA

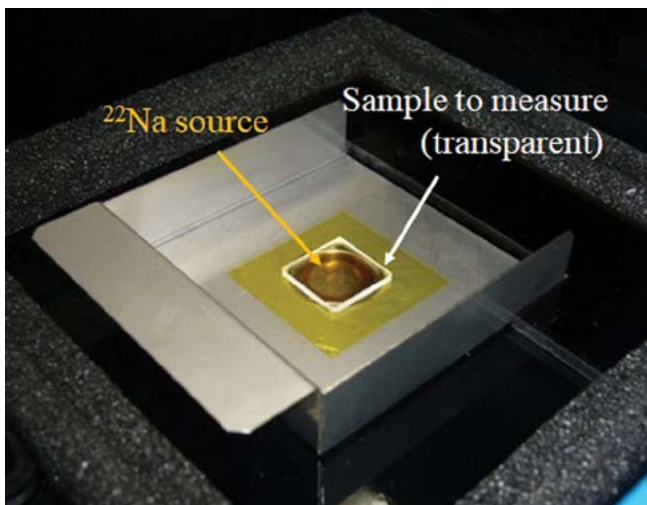


Fig. 4 Sample set-up in PSA

4. Case studies of PSA measurement

① Shot peening on stainless steel [2]

Bright annealed Type 304 stainless steel was shot peened with several levels of coverage and was measured by PSA. The shot peening conditions are shown in Table 2, and the results of the positron lifetime measurements and the FWHM (Full Width at Half Maximum) of X-ray diffraction are shown in Figure 5. As shown, the positron lifetime increases and saturates faster than FWHM. This phenomenon can be explained: PSA evaluates the increase of dislocations, whereas FWHM captures the variation in lattice spacing. In this way, PSA makes it possible to evaluate trends even in cases where X-ray diffraction does not clearly capture the trend of change.

In addition, PSA has the following advantages over X-ray diffraction and other analytical instruments:

- Detects vacancy-type lattice defects (sub-nano size) with high sensitivity. Physical properties can be evaluated using a different approach from residual stress evaluation.
- Evaluates coarse crystals and single-crystal material. Also, liquids can be evaluated.
- Evaluates ten times deeper than X-ray diffraction. Therefore, the quality of shot peening can be evaluated non-destructively.

Table 2 Shot peening conditions

Sample	Type 304 stainless steel (15 x 15 x 3 mm)
Shot media	CCW12 (Φ0.3 mm, 500 HV)
Shot peening machine	Direct air pressure type
Nozzle	Φ10 mm
Pressure	0.20 MPa
Peening time	0, 12, 36, 72, 120 sec

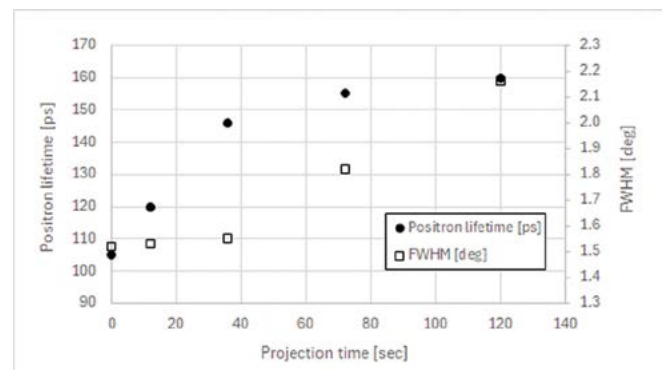


Fig. 5 Changes in positron lifetime and FWHM of shot-peened Type 304

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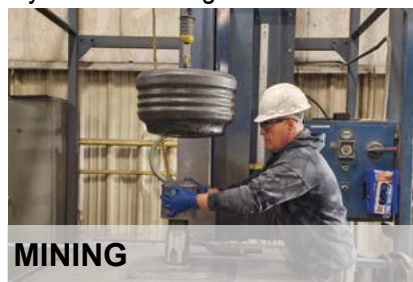
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② Monitoring fatigue process^[3]

The fatigue process of the rotating bending fatigue specimens Type 316 was monitored by PSA. The shape of the specimen is shown in Figure 6. A single notch was introduced on the surface of the specimen to make it easier to observe the fatigue crack growth from the notch. The positron lifetime was measured at the notch and at the 180° opposite side.

The fatigue damage was non-destructive and sequentially evaluated by PSA. The results are shown in Figure 7. The positron annihilation lifetime increased with increasing fatigue loading cycles. Lifetime at the notch root became longer than that at the smooth section after crack initiation. The precision of lifetime analysis was high enough to detect small plastic zones with high dislocation density at the fatigue crack tips.

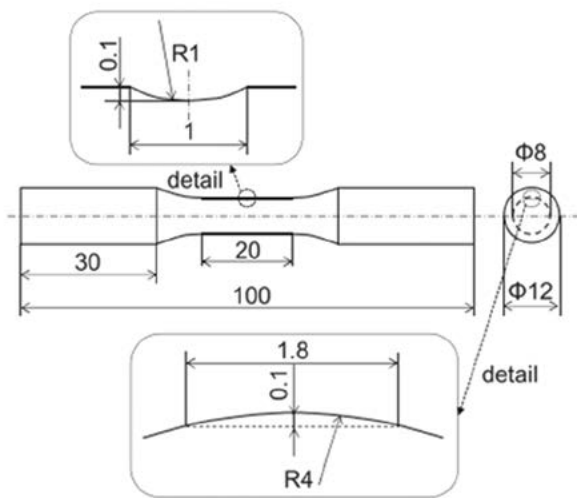


Fig. 6 Fatigue specimen configuration and the detail of notch

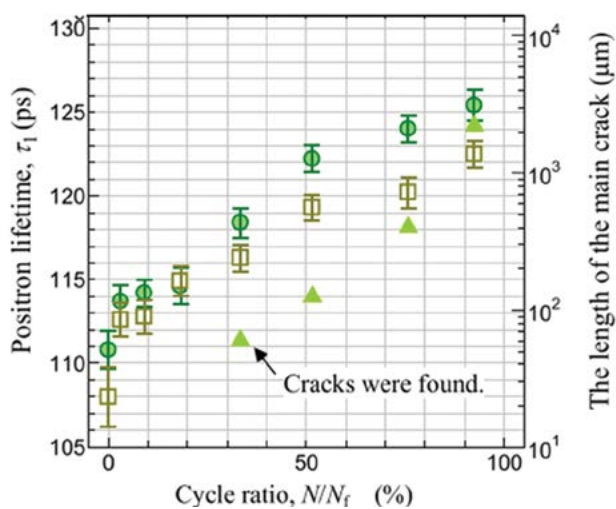


Fig. 7 Positron annihilation lifetime analytical results and crack length

5. Conclusion

In this article, we have described the challenges and solutions for practical application of a positron lifetime measurement device, PSA, which is a measurement method that can evaluate atomic-level defects and intermolecular gaps and pore structures non-destructively and with high sensitivity. In addition, as case studies of measurement of metallic materials, the positron lifetime during shot peened Type 304 and the fatigue process of Type 316 were discussed.

We believe that this device has achieved its goal of practical application in terms of developing the basic components. However, positron lifetime measurement technology is still in the development stage for industrial use, and improvements are being made toward further practical use.

6. Acknowledgements

We would like to thank for the generous cooperation in promoting the industrial use of PSA to JRIA.

Reference

- [1] US 8,785,875 B2
- [2] N. Uesugi, M. Yamawaki, K. Hattori, Y. Watanabe, "Application of on-site positron annihilation lifetime spectroscopy system as non-destructively shot peening evaluation technique", proceedings of 14th international conference of shot peening (ICSP-14), 2022058.
- [3] Y UEMATSU, T KAKIUCHI, K HATTORI, N UESUGI and F NAKAO, "Non-destructive evaluation of fatigue damage and fatigue crack initiation in type 316 stainless steel by positron annihilation line-shape and lifetime analyses", Fatigue Fract Engng Mater Struct, 2017, 40, 1143–1153.

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Specifications beyond Aerospace

AS I START MY 36TH YEAR of gainful employment, 95% of which has been in this industry, like most of you, I too have accumulated many interesting stories. However, this one stands apart and worthy of repetition, with apologies, if you have already heard it from me. As an impressionable engineer in my 20s, I was tasked to sell air pollution control equipment for any dust emitting source from a blast machine to an electric arc furnace.

During one such meeting in a part of the world where electricity was then scarce and moderated, I was pitching a fume extraction system that required a 75HP exhaust fan downstream to it all. When calculating the operating cost of this system with the end-user, I was informed that this fan would only be operated selectively, maybe a few hours every month. This left me baffled (pun intended) since as we all know, no ventilation system can function without its exhaust fan on, first.

My technical knowledge was less than appeased with the end-user's explanation that the purpose of this fume extraction system was not to control air pollution, rather to satisfy pollution control authorities! Therefore, the fan's operation was timed to operate solely during inspection visits by said authorities! This experience helped me decide the type of industry I wanted to spend my career in. I wanted to work with end-users that would sometimes by choice but every time by requirement work in compliance with a specification. Aerospace was the perfect candidate for that and here I am!

As the benefits of peening get recognized by industries outside of aerospace and automotive, I have often questioned the significance and usefulness of AMS process documents among non-aerospace shot peeners. Are 2430, 2431 and 2432 mere numbers to them? What do they consider specifications and how do they go about achieving conformance? I suspect such questions keep you up at night as well. Therefore, this discussion! My research involved speaking to users in automotive (spring, transmission), oil and gas (torsion bars) and railway (wheels).

SAE J2441 Shot Peening is a Surface Vehicle Standard intended to provide direction to shot peeners outside of aerospace. During the last SAE meeting (May 2025), I learnt that the SAE had not sold many (or possibly none) copies of

this document in a while. Given that I had offered to sponsor this document and revise it to current relevance, I figured it needed to be re-written to aim for status between the historic MIL-S-13165C and contemporary AMS 2430. The task of marketing such a product will be herculean, given that the wild west of specifications outside aerospace is a vast unknown! But I need to start somewhere. In our discussion, I'd like to bring some of the key aspects of a "relevant" document with the expectation of receiving constructive feedback from our community on other content you would like to see in a future document.

Background

1. MIL-S-13165 was first published in 1953 and updated four times until June 1989. Since a vast majority of users are familiar with this document, I would like to highlight key aspects of MIL-S-13165C before its cancellation:

- Process control such as shut down limits was part of the last version. Though the specific tolerances were not published until future versions of AMS 2432, this MIL document in sections 6.8 and 6.9 identified all key variables such as shot flow rate, air pressure/wheel speed (velocity), and nozzle and work stand-off that needed to be monitored and shutdown the process when it strayed outside tolerance.
- Peening intensity tolerance was established by this document (3.3.6). For drawings that listed a single (minimum) value for intensity, a variation of -0, +30% and in no case less than three intensity units was specified.
- Better definition of coverage, boundary variation, minimum shot size based on smallest (fillet) radius on the part were part of this document.

MIL-S-13165C was cancelled in February 1998 when the military transferred its ownership and responsibility for future updates to AMS, which then replaced it with AMS-13165. For more details on this, read *The Shot Peener*, Summer 2020 edition.

2. AMS-S-13165A has since been cancelled (December 2007). This was the prevailing document for almost a decade before being made redundant by AMS 2430 and AMS 2432



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(which, though in existence were not commonly in use as a replacement).

3. AMS 2430 and 2432 are process specifications, supported by a host of material specifications such as AMS 2431/x for peening media, and SAE recommended practices for additional details.

4. SAE J2441 is a surface vehicle standard, which I am proposing should be re-written to better accomplish the goals of a non-aerospace spec document. Highlights of this document in its current version (June 2015):

- J2441 is a process specification with no reference to AMS documents (as expected) for new media requirements. All references are to J documents.
- In-process media requirements for size (screening) are as per AMS 2430. There is no reference to shape maintenance except for a brief mention that tolerates 10% maximum of a representative sample as broken. In contrast, AMS 2430 (and 2432, which refers to 2430) has detailed instructions on in-process media inspection for shape along with the sample window size for visual assessment for different media sizes, magnification for assessment and tolerance. This is true for metallic and non-metallic media.
- While on the topic of media, this specification does not list AMS 2431 as a reference document. Note that users of this document will be in conformance if they choose to use industrial grade media (SAE J827 and J444) for shot peening without needing to use AMS grade (formerly and still colloquially known as MILSPEC) media bearing higher shape and size tolerance (accompanied by a greater investment requirement for media purchase).

Comment: If you are wondering whether this aspect makes it a less-precise shot peening process, let me explain. Neither AMS 2430 nor J2441 will pin you down to use a vibratory classifier or spiralator for size and shape control. These are recommendations/suggestions in both documents, perhaps a bit sterner in 2430 ('Equipment may include a media separator to mechanically control size and shape such as vibrating screens, spiral device or inclined belt') as compared to 'at least one determination of shot size and uniformity shall be made when the size or type of media in the machine is changed, every 8h of continuous machine operation with metallic shot.....and 'Uniformity shall be determined using the sampling and sieving procedures defined in SAE J444'.

Therefore, a conscientious shot peener that recognizes the value such control offers to a stable process and repeatable

results, without creating surface damage to the parts being peened, will install features to ensure that the process always operates with consistent size and shape of shot in the machine.

- Intensity verification is specified to be within the tolerance specification on the drawing (as in AMS 2430). However, the original tolerance from minimum peening intensity is allowed to be -0, +40%, as compared to +30% in 2430.
- Overall, the information contained in J2441 mimics 2430 with a truncated level of detail.

Industry feedback

The adoption of J2441 is minimal at best, with its barely acknowledged existence! To learn more, I spoke to end-users and other stakeholders including OEMs that build shot peening equipment. As expected, there was lack of awareness of anything starting with the letters AMS among non-aerospace shot peeners. The word aerospace triggered intimidation in terms of specification conformance. The fear was two-fold: The process being too cumbersome and difficult to adopt/conform and their equipment not being capable of meeting the requirements to conform. However, their interest to learn more and potentially adopt a usable and practical specification was evident.

Don Paul, Manufacturing Engineer at Matthew Warren Spring in Logansport, Indiana, provides insight into the company's approach to quality and process control in spring manufacturing. The facility specializes in producing cold coil springs, retainer rings and carbon composite springs. "Our peening specifications are an extension of our work technique or instruction," Don explained. "Through process control, primarily managing velocity, media flow rate and media size tolerance—we ensure that we meet the requisite intensity within the specified range and establish part coverage. Along with our customers, we are aware of the criticality of shot peening in the fatigue life of springs we manufacture."

Don anticipates the increasing demands for process repeatability and precision will shape the future of the industry. However, he expresses some skepticism about the widespread adoption of any new overreaching specification. "Though I am not familiar with the AMS documents you have referenced, our internal quality plan closely aligns with customer-mandated specifications," he noted. Due to confidentiality agreements, access to specific internal or customer-driven specifications was not possible at the time of this discussion.

Blast Cleaning Technologies (BCT), West Allis, Wisconsin, is a manufacturer that specializes in centrifugal wheelblast equipment. Benjamin Roche is a fellow Applications Engineer who also has attended the EI Shot Peening training. He works on shot peening applications for

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BCT's customers that shot peen cast and forged components in different industry sectors with BCT manufactured equipment. "Commonly, we are provided with customer written specifications to follow, which will occasionally reference SAE, AMS, or MIL specifications. Often, the SAE specifications that are referenced in customer specification documents are J441, J442, J443, and J444," explained Ben. "Our design philosophy for peening, and most cleaning applications, is to offer full control of the intensity of blast (and peen) by installing inverters on blast wheel motors. All peening applications that I've been involved with are wheel machines where wheel ammeters were expected to provide a loose indication of media flow rate. This combined with MagnaValves closed the loop for media flow control. The least common equipment that customers have on hand is a classifier for size control," said Ben. Not a surprise, given that classifiers are not manufactured with the capacity to handle 100% of the media flow in a multi-wheel machine and can only be expected to continuously sample a percentage of the total flow. This is an acceptable practice that users need to be made aware of.

Ben was optimistic about the value of a new specification. "I think this would be well received, especially by the automotive industry users. In some of the automotive peening applications, OEMs use their own specifications which can be confusing and contradictory in some cases. I think it would help those operations to reference common specifications when developing their shot peening process."

What is important in a specification?

On a macro, yet fundamental level, we are dealing with impact energy ($1/2 \times \text{mass} \times \text{square of velocity}$) and our ability to deliver this value consistently. When using this concept to construct a specification, the document will need to deliver instructions on the following to initiate simple relevance, interest and eventual adoption:

1. A constant mass of peening media particles within a specified tolerance. This is ensured by maintaining at least 80% of media particles within a specified size (sieving standards for new and in-process media). Inspection intervals such as listed in 2430 for machines with and without separator (classifier) are useful to incorporate in the document, especially given earlier feedback that this is the most often missed tool among users.

2. In addition to misshapes and sharp-edged media particles not having the same uniform mass, there exists the added possibility of sharp edges impacting and damaging the part surface. Clear notes on eliminating such particles when their numbers increase beyond tolerance to prevent inconsistent energy transfer and damage to fatigue-critical parts. Possibly optical and electronic means of reviewing media samples as an option for those operations that can afford it.

3. Measurement – the need for accuracy and repeatability must be reflected in this document with reasonable allowance for anticipated and practical process-centric deviation. In other words, I would like to submit that the specification for non-aerospace be relaxed to allow the verification strip Arc height to be outside the main intensity range of the drawing so long as it is within the ± 0.0015 " tolerance.

4. Clarity between arc height and intensity. Though all specifications refer to SAE J443, a more practical explanation that ties to energy transfer will help with the end user's understanding of the difference.

5. Coverage – the reference here is to SAE J2277. Though this is a comprehensive document in its current version, inspection and agreement on coverage percentage continue to be subjective. A new specification document must incorporate suggestions of practical techniques for coverage inspection on the part.

6. Other practical notes in this document could be discussions on:

- (a) presence of rust in media and techniques (storage and de-rusting) to render it useful, (b) effect of angle of impingement on intensity, (c) wear patterns of common parts such as blast wheels and nozzles and methods of identification. Though these might seem like pages out of a manual and not a specification, I feel that their usefulness, even if included in the 'Notes' section, cannot be underestimated. Wear is a subjective topic, but extreme wear that affects the outcome is well within the scope of being incorporated in a specification.

7. Training – like rotary flapper peening training, there needs to be some detail in the specification that identifies the minimum training required to carry out shot peening on any component—mission critical and otherwise.

Summary

I hope to incorporate most or all the above in my attempt at reviewing SAE J2441. As indicated earlier, I welcome any feedback on making this document efficient and useful to the new and seasoned user. ●

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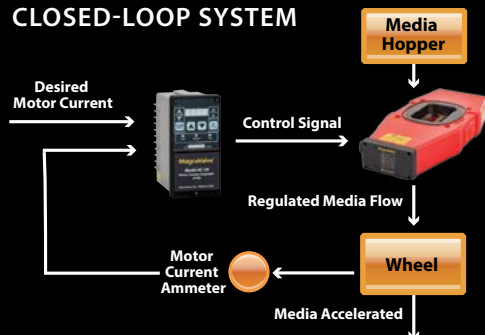


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The Appliance of Science

INTRODUCTION

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

This article describes the general methodology that is involved when science is applied to the solution of problems. The three universal problems quoted above are used as examples. A Google search for solutions to these problems was surprisingly unrewarding. As a consequence, the author’s own attempts are presented. Science can, of course, also be applied to all aspects of shot peening. Graphical representation is included here as being a particularly relevant topic.

Why are Honeycombs Made Up of Regular Hexagons?

Fig. 1 (a photograph by Matthew T. Rader on Unsplash) shows the remarkable structure of bees’ honeycombs. The problem is “Why do bees choose this structure?”



Fig. 1. Regular hexagon structure of a honeycomb.

The solution to this problem is reasonably incontrovertible. Bees make honeycombs using eight parts of honey to one part of wax secreted from their own bodies. The honeycomb provides storage space for honey. It follows that they need maximum storage space for each unit of beeswax. Put another way they want to have maximum “bang for buck.” The storage space needs to be made up of identical interlinked units that are two-dimensionally symmetrical. It turns out that there are only three possible shapes that will satisfy this criterion: squares, equilateral triangles and regular hexagons. Fig. 2 presents these three shapes as interlinked arrays. This introduces the concept of models which are widely used in science because they simplify any calculations that have to be made.

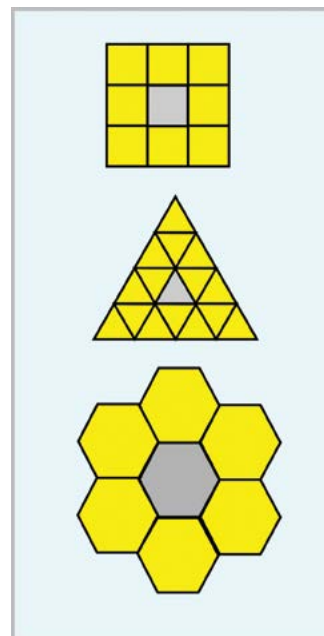


Fig. 2. Interlinked squares, equilateral triangles and regular hexagons.

The “bang for buck” efficiency of the three alternative shapes can be deduced by simple calculations using the three greyed units. Let us assume that each straight side has the same length of 1 unit.

(1) Square

The area of a square of unit side is the square of its side length, therefore:



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$$\text{Area} = 1.00$$

All four sides of the square contribute to a neighbouring square. The square's area of 1.00 has therefore consumed only two sides. Hence we have that:

$$\text{Square storage efficiency} = 0.500$$

(2) Equilateral Triangle

The area of an equilateral triangle of unit side length is given by:

$$\text{Area} = 3^{0.5}/4 = 0.433$$

All three sides of the equilateral triangle contribute to a neighbouring triangle. The area of 0.433 has therefore consumed $1\frac{1}{2}$ straight sides so that equilateral triangular storage efficiency is given by:

$$\text{Equilateral triangle storage efficiency} = 0.433/1.5 = 0.289$$

We see that the triangular storage efficiency is much lower than that of square storage efficiency.

(3) Regular Hexagon

The area of a regular hexagon of unit side length is given by:

$$\text{Area} = 3^{1.5}/2 = 2.598$$

All six sides of the regular hexagon contribute to a neighbouring hexagon.

The area 2.598 has consumed three straight sides so that regular hexagon storage efficiency is given by:

$$\text{Regular hexagon storage efficiency} = 2.598/3 = 0.866$$

We see that regular hexagon storage efficiency is much higher than that of square storage efficiency and very much higher than that of equilateral triangle storage efficiency.

Bees worked this out 100 million years ago!

Metal Packing Efficiency

The three common metal crystal structures are body-centered-cubic (b.c.c.), face-centered-cubic (f.c.c.) and close-packed hexagonal (c.p.h.). F.c.c. and c.p.h. metals both contain close-packed planes of ions. These close-packed planes correspond to maximum packing efficiency. Their packing is illustrated by fig. 3 in which a hexagon has been inscribed. It took until the 20th Century before Sir Lawrence Bragg, using x-ray diffraction, was able to discover close-packed planes.

Why are Snowflakes Sometimes Large and Sometimes Small?

A solution to this problem can be found by employing nucleation and growth theory. This theory has numerous applications such as explaining the properties of heat-treated metals.

Whenever a phase change takes place, such as freezing of water or pearlite formation in steels, nucleation and

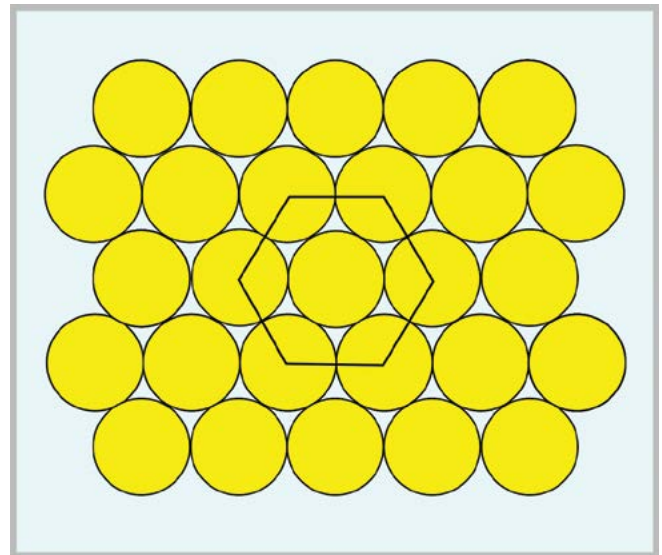


Fig. 3. Arrangement of ions as close-packed planes.

growth are the controlling factors. These can be regarded as competitors. New particles are trying to be nucleated while growth is competing to use the available phase change energy. *Temperature has opposite effects on nucleation and growth rates* which is the key to explaining the phenomenon. Fig. 4 is a schematic representation of the effect of temperature on competing nucleation and growth rates. The axes are deliberately non-dimensional because the effects apply universally.

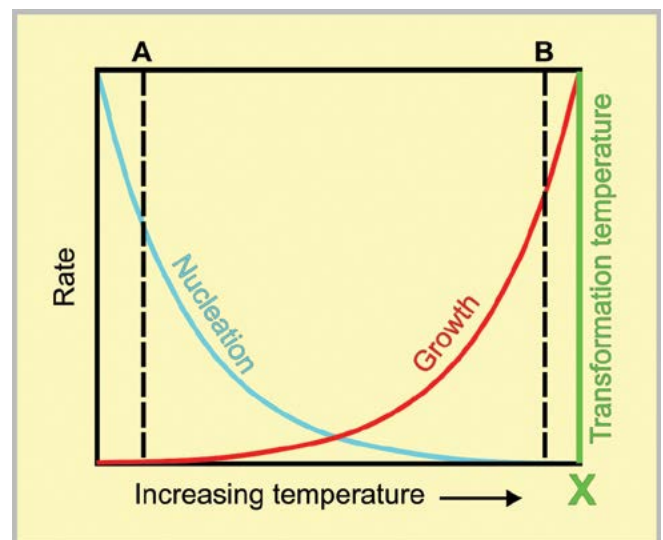


Fig. 4. Effect of temperature on nucleation and growth rates.

Consider the current problem of water freezing to form snowflakes. The temperature marked X in fig. 4 would then be 0°C . If the air temperature was well below 0°C (A in fig. 4), the nucleation rate would be very high but the growth rate would be very low — hence we get small snowflakes,

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Conversely, if the air temperature was only just below 0°C (B in fig. 4), the nucleation rate would be very low but the growth rate would be very high, leading to large snowflakes.

Large snowflakes are only just below their melting point. Squeezing a handful injects sufficient energy for some melting to take place at myriad contact points. Immediate re-freezing at these points gives rise to a usable snowball. Small snowflakes, well below their melting point, do not respond by melting and re-freezing on squeezing, leaving one with a handful of powder.

Why Will a Glass of Warm Water Solidify More Quickly Than an Identical Glass of Cold Water When Placed Together in a Freezer?

This is a popular puzzle question first posed by Mpemba in 1963 whilst in Form 3 of Magamba Secondary School, Tanganyika. The headmaster had invited Dr. Denis Osborne from the University College in Dar es Salaam to give a lecture on physics. After the lecture, Mpemba asked the question, "If you take two similar containers with equal volumes of water, one at 35°C (95°F) and the other at 100°C (212°F), and put them into a freezer, why does the one that started at 100°C (212°F) freeze first?" He was ridiculed by his classmates and teacher. Osborne, however, later experimented on the proposition back at his workplace and confirmed Mpemba's finding.

The fact that warm water can freeze faster than cold water has been known for thousands of years, being first recorded by Aristotle and later studied by many scientists including Bacon and Descartes. No generally accepted explanation for this anomalous behaviour has, however, been put forward so here goes with my own!

The heat that has to be extracted from the water is in two parts. Firstly that for lowering the water's temperature to its freezing point and secondly that required to extract the latent heat of freezing. If the warm water was 50°C above the temperature of the cold water then 50 more calories per cc would be required to be extracted by the freezer than would be required for the cold water before freezing could take place. This amount is, however, dwarfed by the magnitude of the latent heat for freezing the water. Rounding up this magnitude we get 350 calories per cc — freezing therefore requires about seven times the heat extraction needed for simply cooling the water.

Figs. 5 and 6, drawn to the same scale, represent the different stages anticipated for glasses of cold and warm water when placed together in a freezer.

The liquid cooling stage, $0 - A$, for the warm water must be longer than that for the cold water. This time difference is much less than simply the initial temperature difference because of the stronger convection currents in warm water. The freezing stage will, however, be much shorter for the warm water than for the cold water!

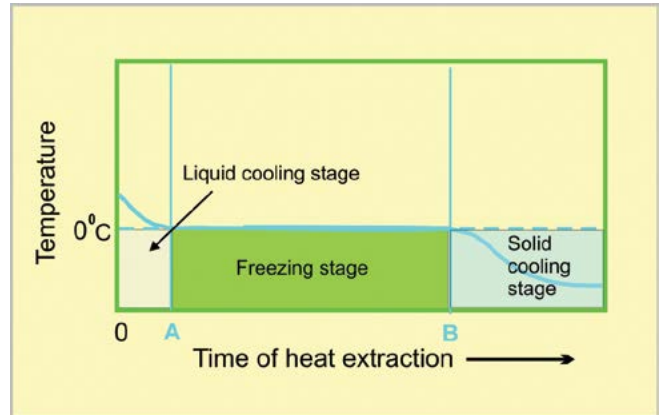


Fig. 5. Cooling curve for glass of cold water placed in a freezer.

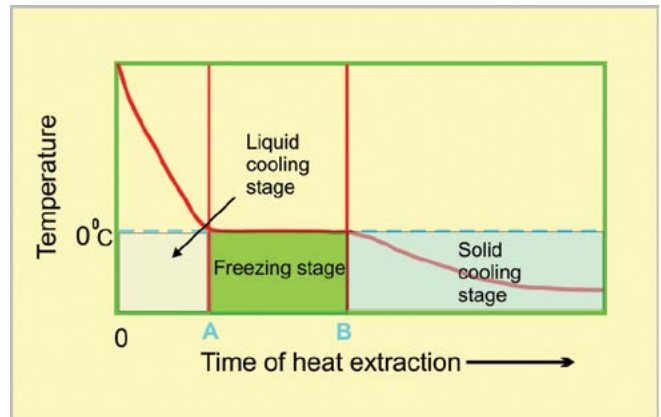


Fig. 6. Cooling curve for glass of warm water placed in a freezer.

During the freezing stage, ice crystals are being nucleated and subsequently grow. Ice crystals can only nucleate slowly on the outside of a warm water glass — the warmth preventing the temperature from falling much below the freezing point. These crystals can, however, grow inwards quickly because the water temperature is being kept just below its freezing point. This results in a short freezing stage. For the cold water, ice crystals form rapidly on the outside of the glass because its temperature is being reduced well below the freezing point. These myriads of tiny crystals can, however, only grow slowly. This results in a much shorter freezing stage. Hence, the overall time for solidification, $O - B$, is shorter for the glass of warm water than it is for the glass of cold water.

NUCLEUS FORMATION AND GROWTH

Nucleation and growth controls the properties of all of the metals used by shot peeners. They go together like the proverbial "horse and carriage."

Nucleus Formation

Metal atoms are very reluctant to collectively change from

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one state to another. There has to be a sufficient driving force available if a different state particle is to nucleate. Hot steel exists as a face-centered-cubic arrangement of ions. The steel has to be cooled sufficiently for the ions to form nuclei that have a body-centred-cubic arrangement. Solid-to-solid changes of state are the essence of metal heat treatment.

The surface of a nucleus corresponds to a negative energy force whereas the inside corresponds to a positive energy force. If the positive energy is greater than the negative energy, the nucleus will be stable. If smaller, then it will be unstable. The ratio of energies depends on the particle radius as depicted in fig. 7. Particle A will be unstable (negative energy being greater than the positive energy) whereas particle B will be stable (positive energy exceeding negative energy).

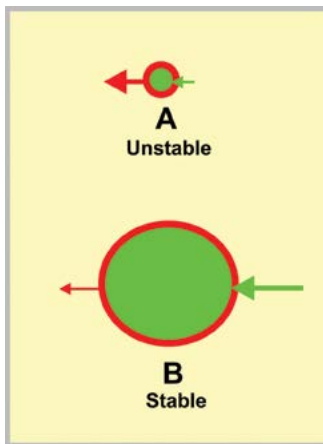


Fig. 7. Effect of radius on interior/surface energy ratio.

It is worth noting that spheres have the smallest surface area-to-core volume ratio of any physical shape. When cast steel shot is manufactured, a powerful water jet blasts into a stream of liquid steel. Myriads of solid particles are formed that minimise the ratio by forming spheres. The Earth and planets approach sphericity.

Nucleus Growth

Once a nucleus has reached a stable size it has a natural tendency to grow. The precise mechanism involved depends upon the state change — gaseous-to-solid, liquid-to-solid or solid-to-solid. Gaseous-to-solid, liquid-to-solid and solid-to-solid particle growth all follow the same basic principle — reducing energy by increasing the interior/surface energy ratio.

The most important example of nucleus growth is that involved in the formation of the planets. Gaseous matter is attracted to their surfaces by gravity. Once deposited on a surface, matter reduces its energy. Heat treatment examples include precipitate particle growth and austenite coarsening. Both are speeded up by raising the temperature.

GRAPHICAL REPRESENTATION

Scientific principles are involved in all of the graphs used

by shot peeners — for example, in peening intensity curves, residual stress profiles and shot size distributions.

Peening Intensity

Curve-fitting is an essential feature of computer-based peening intensity estimation. We first decide on an appropriate equation for the curve and then employ a program to fit the curve normally using a technique called “Least Squares”. Fig. 8 is a typical Solver Suite peening intensity curve that uses a two-parameter exponential equation. A key feature of the Solver Suite of programs is the RMS value. This tells us, quantitatively, by how much data values deviate from the fitted curve. For the example given as fig. 8 the RMS value for the residuals (RMS-R) is 0.14 which is excellent.

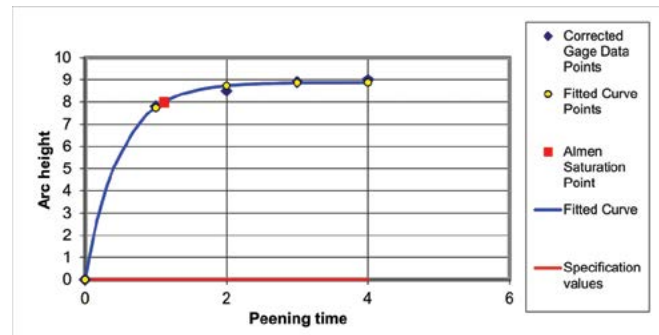


Fig. 8. EXP2P Peening intensity curve.

If a repeat set of data produced using the same conditions gave a much higher RMS value, we should investigate the reason such as faulty equipment, operator error, peening intensity fluctuation, etc. A typical repeat set is shown in fig. 9.

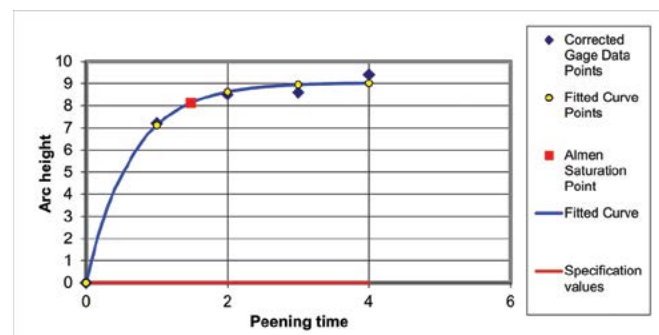


Fig. 9. Repeat EXP2P Peening intensity curve.

Residual Stress Profiles

Residual stress profiles are another form of graphical representation that is familiar to shot peeners. Their shape is quite different from that of a peening intensity curve. Fig. 10 is taken from an early article in this series (“Curve Fitting for Shot Peening Data Analysis”, Spring, 2002). The scientific application here takes the form of modelling. Instead of using actual data, a simple cubic equation is employed. This

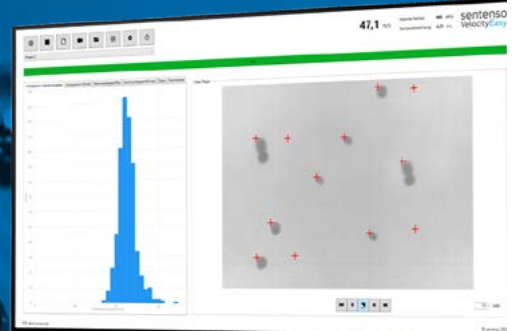
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particular model represents the known shape of residual stress profiles but is based on four assumptions:

1. The level of surface compressive stress is half the yield strength, Y , of the as-peened material.
2. The maximum level of compressive stress is two-thirds of Y and occurs at 20% of the depth of compressed material, D .
3. A balancing tensile stress of 10% of Y is reached at $1.2D$.
4. A cubic polynomial interpolation will be appropriate.

Models are a useful scientific application because they simplify comparisons between actual and expected data distributions. A useful guide when perusing graphical representations is to employ EVA (Expected Versus Actual). Compare one's expectation for a fitted curve versus the actual curve.

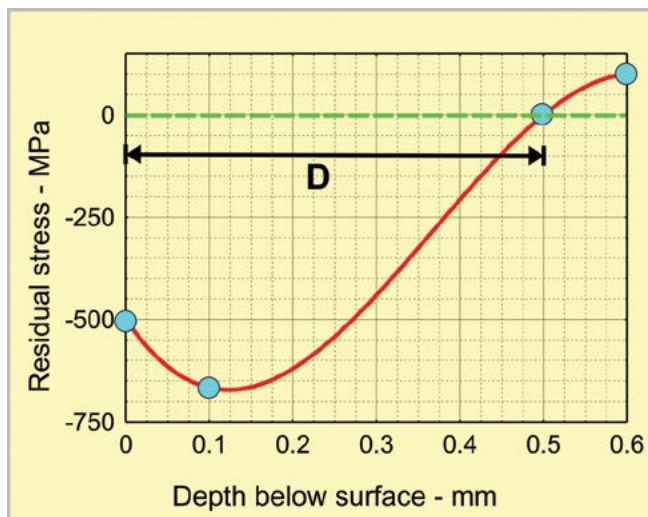


Fig. 10. Model of residual stress profile.

Shot Size Distributions

Specifications, such as SAE J444 and AMS 2431, nominate cast steel shot sizes in terms of sieving results. If we are simply trying to comply with specifications, histograms would not normally be constructed. Histograms can, however, be used to demonstrate shot size distribution. Because of the nature of sieve data, ordinary graphs are inappropriate.

The universal availability of Excel simplifies the task of producing histograms. As an example, consider the Excel histogram shown as fig. 11. A sample of S170 cast steel shot was tested for conformity with J444. Percentage weights on 0.850, 0.710, 0.425 and 0.355 mm sieves were 0, 5, 87, and 6% respectively which satisfies J444 requirements. Each column in the histogram represents the contents of a “bin”. Each bin contains a range of shot sizes — for example, everything between 0.85 and 0.71 mm for the first bin. The individual sieve results are therefore entered as separate bin values.

The example shown as fig. 11 does not, however, tell us very much about the size distribution within the sample. For scientific study we would need to produce a set of bin values involving a larger number of sieve sizes such as 0.85, 0.75,

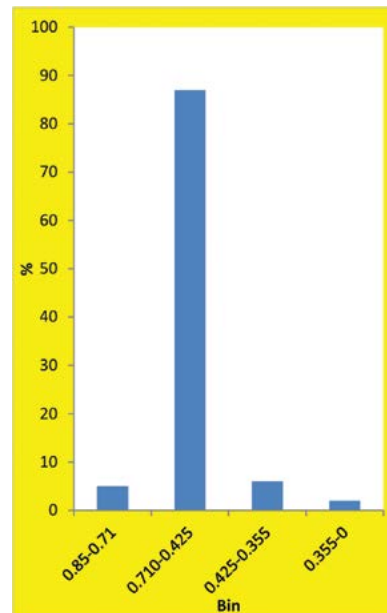


Fig. 11. Specimen sieve results for S170 cast steel shot.

0.65, 0.55, 0.45 and 0.35 mm. An alternative approach would be to use image analysis.

DISCUSSION

This article has attempted to show how science can be applied to explain a variety of problems. Classically, explanations of major problems evolve in stages, starting with a hypothesis, using data to then provide a theory and finally generating a law that is universally acceptable — as with the Law of Gravity. The appliance of science to explain observed experimental features does not, however, always meet with universal accord as Galileo found out to his cost. ●

This article was originally published in the Winter 2020 Shot Peener magazine.

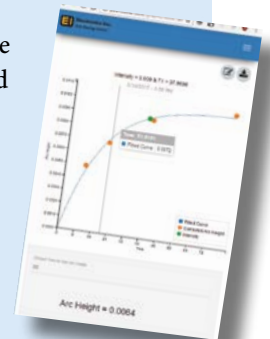
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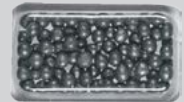
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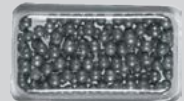
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SAE Size No. SAE J444 SHOT Tolerances

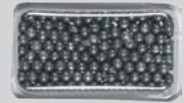
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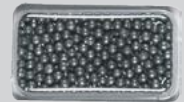
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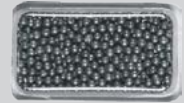
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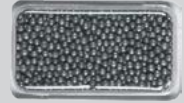
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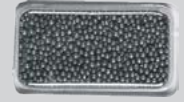
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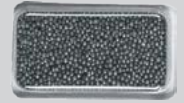
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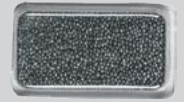
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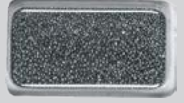
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Unmatched portability – Modulus can reach previously inaccessible areas with ease, including inside bores and tubes, generating new possibilities for inspection and analysis and saving parts from scrap or unnecessary disassembly and rework.

Enhanced gel technology – GelSight's new gels are more durable and offer a smoother user experience for improved performance and longevity.

Return on investment – Modulus saves time and parts from scrap, allowing previously inaccessible parts to be measured with ease.

"The GelSight team is constantly revolutionizing our product platform capabilities to further enhance surface intelligence in the metrology world. Many of our customers had been pushing for a smaller form factor with even more flexibility to reach new areas and surfaces to alleviate supply chain difficulties and costs," said Youssef Benmokhtar, CEO of GelSight. "With Modulus' flexible and scalable design, customers can now access intricate geometries with the same precision and performance they've always received from our technology. This new platform will not only meet their metrology needs now but help future-proof their operations."

Modulus launches with the new GelSight Mobile 4.2 software which enhances the analysis functions as GelSight's other trusted devices such as the GelSight Series 2 and GelSight Max. GelSight delivers fast, high-resolution surface measurements in places traditional tools can't reach, providing objective, repeatable data to detect defects such as scratches, corrosion, and edge wear with micron-level accuracy. It's a portable, easy-to-use system that transforms subjective inspection into quantifiable decision-making with one-click reporting for instant documentation and traceability.

To learn more about Modulus, visit the company's website at <https://gelsight.com>. ●



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Serial Number	11-char
Factory Calibration	00/00/00
Firmware	Rev 1.10 6-9-21

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Active Table	Power Cycles
#1	Valve On-Time
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S-230	80C < Hrs <= 95C
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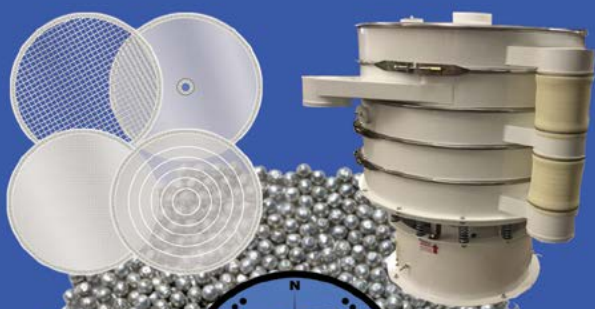
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Technical Metal Finishing Announces Rebranding to National Peening

Technical Metal Finishing, a leading provider of metal finishing services, announced its rebranding to National Peening. Previously, Technical Metal Finishing operated in line with National Peening, both being Sinto America Inc. Group Companies. This name change aligns the company more closely with its long-term vision and the broader capabilities it offers within the precision metal treatment industry.

Larry Papazoglou was recently appointed as Senior Vice President for Sinto America's Surface Technologies businesses. Larry's experience spans over 30 years in various leadership roles with aerospace, industrial, automotive, and medical devices organizations. "It is an exciting period of growth and technological advancement in the industries served by National Peening and Technical Metal Finishing. Both companies have long histories of providing outstanding services. Full alignment of the organization's vision, strategic planning, and execution under the National Peening name will drive our mission to be the preferred services provider and partner for our current and future customers."

While the name is changing, the organization remains the same. Customers can expect the same trusted team, exceptional service, and commitment to quality that have defined Technical Metal Finishing for years.

"The rebranding to National Peening represents a strategic move to unify our brand identity across operations while reflecting our expanded expertise and focus on the shot peening industry," said Michael Halsband, CEO Sinto America. "Our customers and partners can rest assured that our ownership, leadership, and dedication to excellence remain unchanged."

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About National Peening

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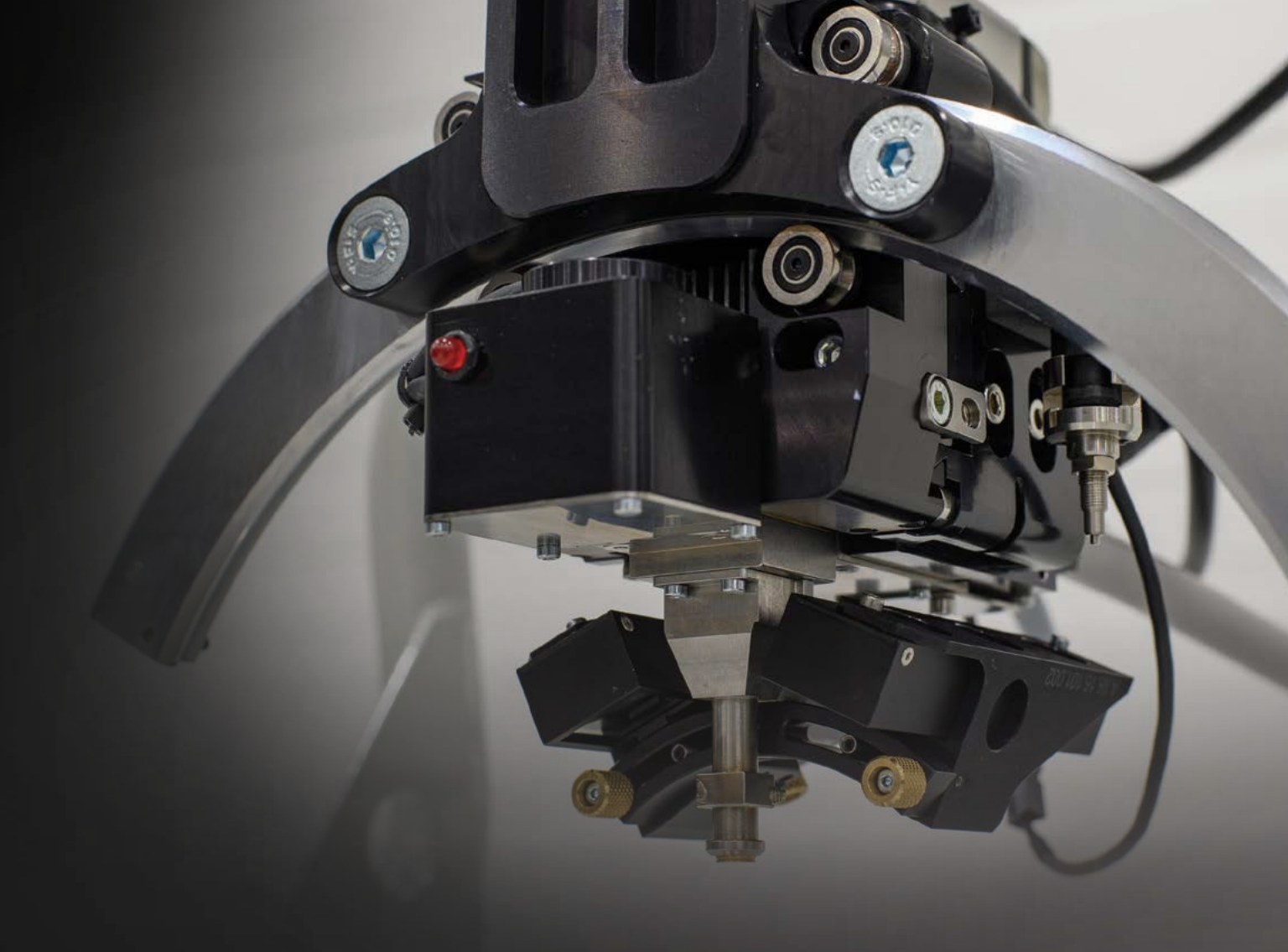
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