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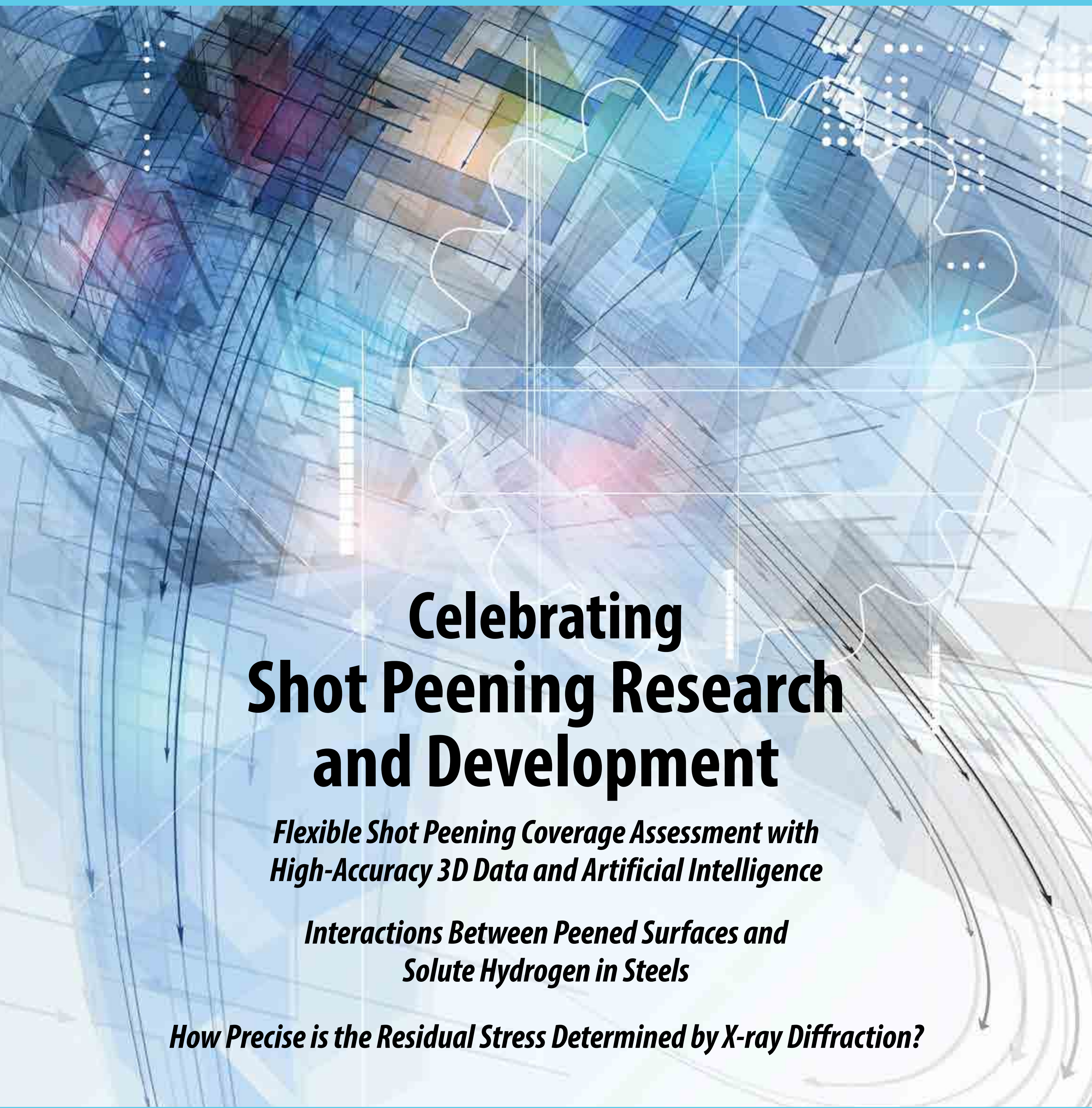
The Shot Peener

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



Celebrating Shot Peening Research and Development

Flexible Shot Peening Coverage Assessment with High-Accuracy 3D Data and Artificial Intelligence

Interactions Between Peened Surfaces and Solute Hydrogen in Steels

How Precise is the Residual Stress Determined by X-ray Diffraction?

PLUS: AN INSIDER'S PERSPECTIVE | QUESTIONS FOR SHOT PEENERS | THE SHOT PEENING AND BLAST CLEANING FORUM

Celebrating Shot Peening Research and Development

We're highlighting a few of the many advancements in shot peening research from leading universities and organizations.

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

OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

EI's Fiftieth Anniversary

Employees, customers, and vendors celebrated the 50th anniversary of Electronics Inc. with a party on June 21. We will have photos in the next issue of *The Shot Peener*.

A brief recap of EI's history: The early projects at EI met the demands of the 1974 Clean Air Act by providing air pollution controls to reduce dirty air in American steel factories. The first product was a simple fan damper control that allowed remote setting of air volume for a baghouse dust collector. Eventually this evolved into feedback controls that regulated the damper position based upon desired motor power limits since the load changed with the air temperature. Another control model then detected the temperature of the air going into the baghouse system which would quickly open cold air dampers to dilute the hot air so that the bags were not damaged.

These controls were developed in cooperation with Wheelabrator-Frye in Mishawaka, Indiana. They already made abrasive blast cleaning machines for foundries that required baghouse dust collectors. They eventually spun that division off to Rust Engineering in Pittsburg, Pennsylvania as the Air Pollution Control Division.

The experience gained from that association led to a Wheelabrator project with Boeing Commercial Airplane for wing skin peen-forming. A sixteen-wheel mono-rail machine provided the saddle-back shape to the wing skin and I got to provide the media flow rate controls. This alerted me to the shot peening market and I was soon making MagnaValves for wheel-type and air-type peening machines.

EI is now shipping products and providing shot peening training around the world. None of this would have been possible without the support of our employees, customers, distributors, and vendors.

Twenty-four WM 3000-24 MagnaValves and AC-24 Controllers are ready to ship to an aerospace company in China.

THE SHOT PEENER

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Jack Champaigne

Associate Editor
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Publisher
Electronics Inc.

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Coverage Assessment Using 3D Data and Artificial Intelligence

EXISTING CHALLENGES

Although the degree of coverage in shot peening has a significant influence on the resilience of a surface, coverage assessment still faces a number of unresolved challenges. First and foremost, the quality of the manual process is highly dependent on external conditions and the condition of the employee carrying out the inspection. In addition, the qualification process is complex and the recruitment of suitable personnel is difficult in the current labor market situation. Another issue is manual documentation which is also time-consuming and prone to errors.

A typical solution would be to automate the coverage assessment. An automated system should be used from the initial data collection to the final report. An automated inspection process would also be the logical last step in the highly automated shot peening process chain.

AUTOMATION OF THE COVERAGE ASSESSMENT

Automating the coverage assessment essentially means an automated evaluation of surface data. The stability of the evaluation depends largely on the quality of the input data. For 2D images, it is particularly important that the contrast or color information in a pixel is kept stable so that stable parameters can be defined for an evaluation. To achieve this, stable environmental conditions must be created and then maintained. This in turn leads to limited system flexibility.

With 3D data, the X, Y and Z components of individual points on the surface are considered. The illumination of 3D sensors is usually part of the sensor used and is therefore less dependent on ambient light. However, peened surfaces are challenging for many 3D sensors due to the materials under consideration and noise often occurs. In many cases, the noise is of the same order of magnitude as the geometric deformation caused by the peening which makes evaluation impossible. Only a few technologies are therefore suitable for use with this problem. One suitable technology is white light interferometry.

COVERAGE ASSESSMENT WITH WHITE LIGHT INTERFEROMETRY

The white light interferometry method provides stable 3D data on a wide variety of surfaces. In addition, the method offers a resolution in the sub-µm range in the decisive dimension. A good compromise between measuring field size and resolution must be set laterally along the surface. A resolution of 6 µm is usually selected for a measuring field of 6 x 6 mm. The method is based on constructive interference of coherent light in a Michelson interferometer setup. (Figure 1). The sensor used performs most of the operations on a microprocessor and thus delivers up to 1024 images per second. A volume of 6 x 6 x 8 mm can thus be recorded in approximately one second. The data quality is so good that even the finest topological information, such as individual indents from peening media impacts, can be displayed.

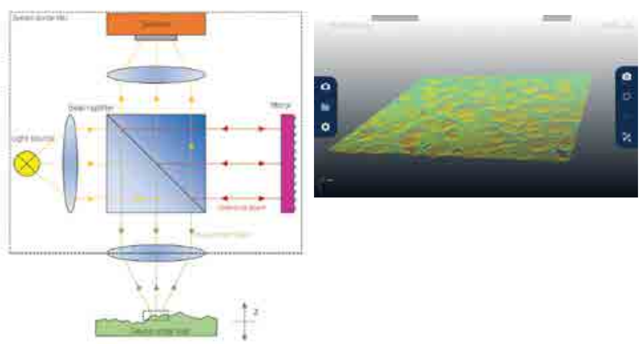


Figure 1: left: Michelson interferometer setup, right: 3D data of peened surface

Another important part of automation is sensor handling. The sensor presented in this article cannot be held by hand which is why a handling device must be used. Depending on the degree of automation, different scenarios are conceivable here. With the HP-AX of 3D.aero, the sensor is guided fully automatically along a previously automatically planned robot path following a component surface. The HP-FX uses a collaborative robot that can be flexibly positioned by an operator on the areas of the surface to be inspected and then holds this position or automatically changes its position very precisely following input from the operator. It is mobile and can therefore be used in the workshop close to the part that should be inspected.

EVALUATION OF 3D DATA

Our first approach to evaluating the degree of coverage in white light interferometer data was to set different geometric parameters to derive a decision as to whether a 3D pixel is covered or not. During development, however, the number of parameters has steadily increased, making it almost impossible

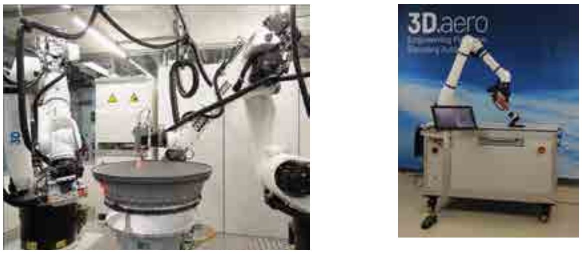


Figure 2: left full automatic HP-AX, right collaborative HP-FX

to manually define a parameter space for the coverage. This is why we switched to an approach based on artificial intelligence at this point. Here, a large number of parameters are defined automatically and decision limits are set. As is well known, the quality of the evaluation with artificial intelligence algorithms stands and falls with the labeling of training data. Here, 3D.aero has developed a software tool that standardizes the input data and enables pixel-precise labelling (Figure 3). The labeled data is then used to train a suitable neural network. The trained network is then connected to the 3D.OS framework of 3D.aero and thus enables an in-line coverage assessment on 3D white light interferometer data.

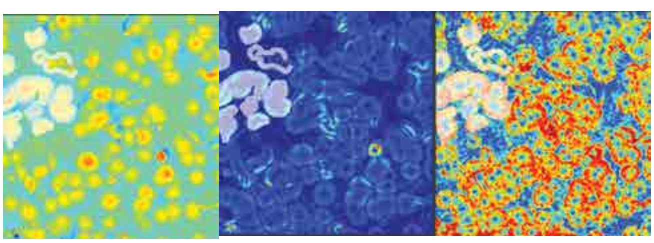


Figure 3: Data from labeling software tool: left depth, mid gradient, right intensity

RESULTS OF THE ALGORITHM

The performance of the different approaches was to be determined using a reliable reference. The coverage comparison samples from sentenso presented in the spring 2024 issue of *The Shot Peener* were very well suited for validation. This set contains samples for various combinations of material, shot type, degree of coverage and intensity. The reference kindly provided was used to generate both a data set for AI training and one for testing. Figure 4 shows an evaluation on one of the test images—covered areas are shown in green, uncovered areas in red. According to the algorithm, the coverage is 75.72%. The coverage of the sample in question is 75% according to conventional visual assessment and ~70% according to pointwise manual labeling. It must be emphasized at this point that this image was not part of the training set. The recording was therefore not known to the AI beforehand. Evaluation not known beforehand.

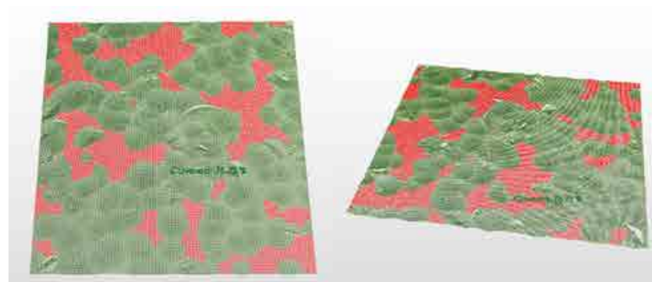


Figure 4: Surface data evaluated with AI approach

The difference between the automatically determined coverage and the coverage according to manual labeling is currently below 10% over a wide range of peening parameter combinations.

SUMMARY

With an automatic system based on high-resolution 3D data from a white light interferometer and artificial intelligence algorithms, the degree of coverage can be determined quickly and stably on different surfaces after shot peening. The system presented delivers reproducible results and is independent of ambient conditions. It is possible to choose between a fully automatic or a semi-automatic system version. An initial study on reference coupons showed results that were in line with manual coverage determination, both by visually assessed coverage percentage and selection of areas compared to manually pointwise labeled test data. Current focus lies on further refining the algorithm and hardening against variations in input data.

ABOUT THE AUTHORS

The authors, Anton Janssen and Tomas Domaschke, both work for 3D.aero. Anton is responsible for the HP-FX projects and Tomas is responsible for the white light interferometry product line and at the same time is part of the founding team of 3D.aero.

The company, which currently has 40 employees, is based in Hamburg, Germany and counts many of the major aviation companies among its customers. One of the three product pillars are turnkey automation solutions for aviation production and maintenance.

In addition to coverage inspection, 3D.aero also offers solutions for anomaly detection and measurement as well as component position detection as finished products on the market.

Interactions Between Peened Surfaces and Solute Hydrogen in Steels

Jia-Huei Tien, Megan Reger, David R. Johnson, David F. Bahr
School of Materials Engineering, Purdue University. West Lafayette, Indiana 47907 USA

ABSTRACT
Once a peened surface is placed in service, the interaction with the environment can alter the state of the material. This paper demonstrates how hydrogen, a common element which can dissolve into many metallic systems, can decrease the compressive residual stress in shot-peened steels.

INTRODUCTION
Solute hydrogen in steels can dramatically reduce the toughness of the material. Hydrogen embrittlement is a perennial problem for steels in corrosive environments where the hydrogen uptake is driven by electrochemical corrosion reactions. In these cases, the contact with hydrogen is often not desired but unavoidable. With the increased interest in de-carbonizing power systems, there is added opportunities for situations where hydrogen gas will be in contact with steels as an energy carrier for power generation, via fuel cells or combustion where contact with hydrogen is part of the design. The decomposition of H_2 to H, which may occur during combustion processes, provides yet another pathway for dissolving atomic H into steel. In either planned or unavoidable scenarios, dissolving H into the steel requires both entry and subsequent diffusion into the alloy. When in the steel, H can be mobile or trapped to features such as precipitates, grain boundaries, or dislocations.

Shot peening and similar surface processing methods, in general, produce biaxial compressive stresses on the surface of material. They add plastic deformation content to those surfaces that would be likely to be exposed to hydrogen, and they alter surface films or micro-scale surface roughness on peened materials. The interplay between stresses in the near-surface region of steels, the increase in dislocation density due to plastic deformation, and how hydrogen enters and subsequently diffuses into the sample is complex. Ball burnishing has been suggested to decrease H uptake [1], and in ferritic-pearlitic steels shot peening can change the number of H-trapping sites [2,3]. Recent studies from Kawamori et al [4] showed that when peened medium carbon steels are electrolytically charged, peening could either improve or have deleterious effects on H embrittlement due to changes in surface films, H uptake, and the extent of compressive stresses in the material.

This study aimed to examine peened medium carbon steel samples (using commercially available Almen strips) to determine if electrolytic hydrogen charging would change the compressive stress profile of peened parts.

PEENING AND CHARGING PROCEDURES
Almen "A" strips (provided by Electronics Incorporated) were peened using S230 media in a commercial system (courtesy of Progressive Surface). A series of samples were peened to an arc height of ≈0.020". Residual stresses in the samples were measured using a PulsTec μ-X360s residual stress analyzer; both surface stresses and depth profiles were measured pre- and post-electrochemical charging. Electrochemical H charging was in 0.5M sulfuric acid with 1g/L Thiourea at a current density of 35 mA/cm^2. The charging time was between 24 and 120 hours.

RESULTS
To demonstrate that the H charging conditions indeed led to hydrogen embrittlement, a simple impact test post charging was carried out on a peened and a charged specimen. As shown in Figure 1, the peened sample bent while the charged

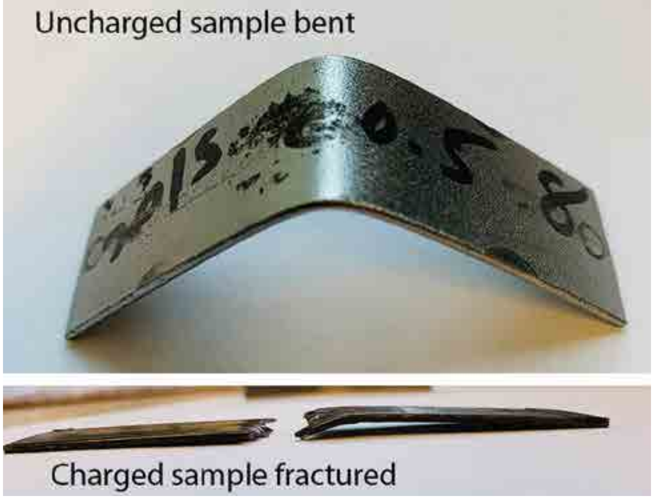
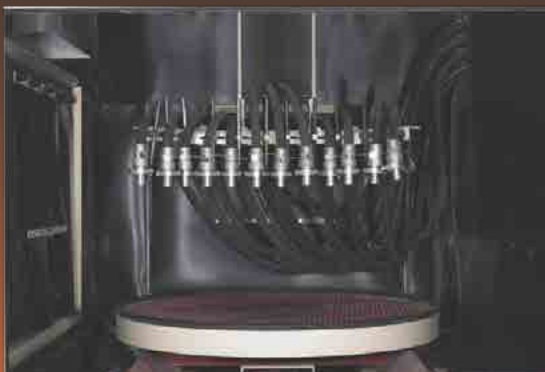


Figure One

AUTOMATED SHOT PEENING SOLUTIONS

HIGH PRODUCTION



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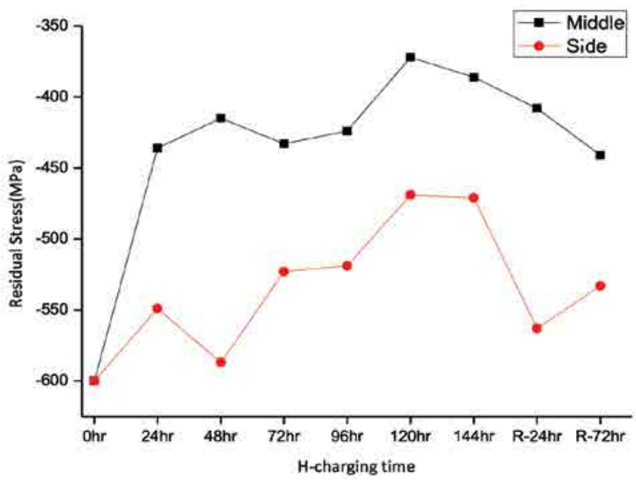

Figure Two

The surface stress is not the only value used in assessing the beneficial aspects of peening as the complete depth profile also impacts processes like resistance to fatigue cracking. Figure 3 shows the depth profile on the peened and the unpeened (back) surfaces (both were hydrogen charged). Hydrogen charging decreased the maximum compressive stress but moved it deeper into the sample.

To explain this phenomena, we examined the full width at half maximum (FWHM) of the x-ray measurements. The FWHM increases with increasing dislocation content in metals. As shown in Figure 4, the FWHM decreased slightly after charging, which strongly suggests that solute H was interacting with the dislocations created from the peening process, and likely causing those dislocations to re-arrange and annihilate. The Hydrogen Enhanced Localized Plasticity (HELP) model of hydrogen embrittlement [5], where solute hydrogen increases the mobility of some dislocations and

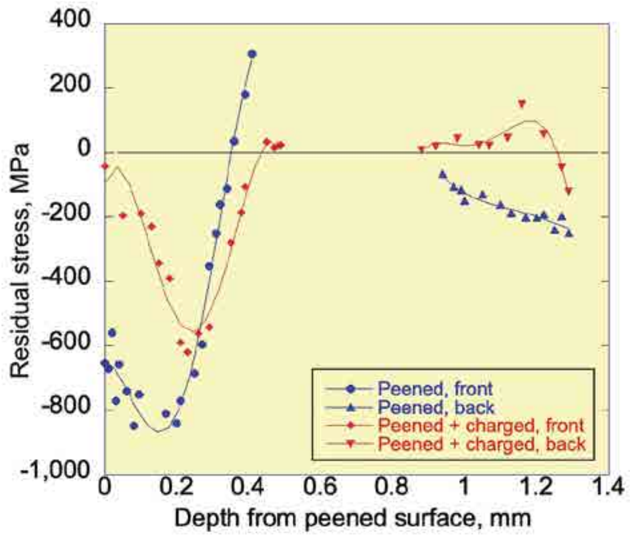

Figure Three

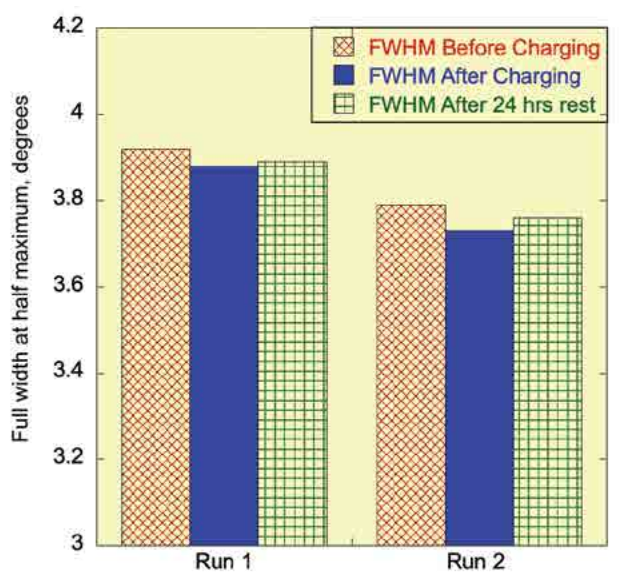

Figure Four

enhances planar slip, could decrease the dislocation content in the surface (where plasticity was the highest after peening). This gradient in plastic deformation and hydrogen content likely could also be responsible for the semi-permanent nature of the change in residual stresses in peened samples after hydrogen charging.

CONCLUSIONS

Hydrogen is, and will continue to be, prevalent in many engineering systems where peened components are used to enhance the surface properties of materials. In medium carbon steels that have been shot peened, we demonstrated that hydrogen which enters the steel can reduce compressive

stresses in the sample, and that these effects are not completely reversible (i.e., when the hydrogen is removed a fraction of the reduction in stress remains). Therefore, peened parts being placed in hydrogen containing environments may suffer a degradation in their compressive stresses imposed from peening. Further work by researchers in Purdue's Center for Surface Engineering and Enhancement will continue to explore the interaction between hydrogen environments and peened materials.

ACKNOWLEDGEMENTS

This work was supported by the Purdue University Center for Surface Engineering and Enhancement, an industry funded consortium. In particular, the support of Jack Champaigne of Electronics Inc. in South Bend, Indiana and Jim Whalen of Progressive Surface in Grand Rapids, Michigan is greatly appreciated. We are grateful for the assistance with initial stress measurements and sample preparation from Nathan Lieu, Aleena Masaeng, and Matthew Wright, undergraduate students at Purdue University.

REFERENCES

1. A. Dreano, M. Alnajjar, F. Salvatore, J. Rech, C. Bosch, K. Wolski, G. Kermouche, and F. Christien, "Effect of ball-burnishing on hydrogen-assisted cracking of a martensitic stainless steel," Int J Hydrogen Energy, vol. 47, pp. 39654–39665, 2022, doi: 10.1016/j.ijhydene.2022.09.110.
2. Y. Wang, X. Wu, and W. Wu, "Effect of α martensite content induced by tensile plastic prestrain on hydrogen transport and hydrogen embrittlement of 304L austenitic stainless steel," Metals, vol. 8, pp. 1–23, 2018, doi: 10.3390/met8090660.
3. X. Li, J. Zhang, Y. Wang, M. Ma, S. Shen, and X. Song, "The dual role of shot peening in hydrogen-assisted cracking of PSB1080 high strength steel," Mater Des, vol. 110, pp. 602–615, 2016, doi: 10.1016/j.matdes.2016.07.121.
4. K. Makoto, U. Wataru, and Y. Satoshi, "Improved hydrogen embrittlement resistance of steel by shot peening and subsequent low-temperature annealing," ISIJ International, vol. 61, pp. 1159–1169, 2021, doi: 10.2355/isijinternational.ISIJINT-2020-463.
5. H. K. Birnbaum and P. Sofronis, "Hydrogen-enhanced localized plasticity-a mechanism for hydrogen-related fracture." Materials Science and Engineering, vol. 176, pp. 191–202, 1994.

Jack Champaigne Receives the Purdue College of Engineering 2025 Distinguished Engineering Alumni Award

The Distinguished Engineering Alumni/Alumnae Award for the Purdue College of Engineering is presented to men and women who have distinguished themselves in any field in ways that reflect favorably on Purdue University, the engineering profession, or society in general.

These alumni are engaged in engineering work and their record of accomplishments is indicated by their growth into positions of increasing responsibility.

This award is the highest honor bestowed by the College to its alumni and it recognizes those who have made outstanding contributions within their fields.

To mark this occasion, a celebration is set for Thursday, April 10, 2025, at 6:00 p.m.

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AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

So, Are You Shot Peening?

INTRODUCTION

Confucius, the great Chinese educator and philosopher, said, "To know what you know and what you do not know, that is true knowledge." I start with this thought not to insinuate anything about peening practices but to establish the fact that there is still so much for all of us to learn. Confucius strived to make education broadly available which is our goal as well through this platform! During the early part of my sales career, I had an excellent boss whose line of motivation was, "go out and even lose a project, at least I know you're doing something." I am going to draw on some examples from the past to demonstrate that "something" which continues to be categorized as shot peening by different users. At that time, it appeared that such users were cleaning and not peening. However, upon more recent contemplation, I am beginning to wonder if their activities did have merit and perhaps my dismissive attitude was premature. Condoning a supposed peening process as incorrect or terming it blast cleaning is an obvious outcome when looked at under the lens of specifications that we are required to conform to. Justifiably, to most of us, work life outside of these peening specifications is non-existent and our actions are heavily influenced by the need for conformance to such documents!

In these discussions, I propose to infuse renewed energy into those entities, projects, and applications that perhaps do not (required to) monitor velocity, media shape, size, credit them as appropriate and maybe offer a few suggestions to help them develop their processes.

THE CLEANING/PEENING MACHINE

A satisfying day's work must involve a good story. A combination of all such stories generates an interesting resume. An interesting resume sometimes leads to a good job. A string of good jobs could result in a fulfilling career! This story for me certainly counts as one within that string.

A few years ago, during a routine machine/process inspection at a spring peening facility, I was exposed to what was described to me as a "cleaning/peening" machine. Let us term this Machine A. Machine A was routinely fed "peening" media that was deemed unsuitable for a more critical peening process Machine B that used larger media (S-550). Machine B, through use, broke down the S-550 into smaller sized particles which were deemed suitable/adequate for what Machine A did. In other words, Machine A always received a working mix of media.

When questioned, I was told that Machine A was a cleaning/peening machine depending on the needs of that day. There were parts with heat-treat scale that were processed in the machine for descaling. There are other batches of clean parts that were processed through for shot peening. Therefore, the moniker. Typically, we thrive with and insist on a working mix of multiple size particles for efficient cleaning but never for peening.

Our claim is that only a single, constant media size, within tolerance, is capable of transferring repeatable and identical impact energy on all surfaces and geometry of the component being peened. We do not qualify anything short of that as proper peening. As I finished explaining this to the engineer, he revealed to me that: (a) it has always been done this way, and (b) x-ray diffraction has shown that the components regularly register the required residual compression at three depths (their process requirement).

My attempt at starting a discussion about saturation curves and the possibility of a double-knee due to the presence of small- and large-sized particles was also nullified. The value created by the creation of compressive residual stress more than satisfied the requirements of this manufacturer's end-user. So, a process that would leave you AMS 2432 types in shock continues to provide perfectly acceptable results to this OEM. My conclusions upon further review of this process are:

- Non-mission critical components governed by OEM specifications have not been updated to reflect the need for process control.
- Possibly a higher than required value of intensity compensates for potential misgivings from using non-conforming media particles in a relaxed process.
- The true relationship between intensity, process control and residual stress is still not well-researched. This understanding is of great importance to all of us, particularly when drafting or reviewing peening specifications. Are there aspects of shot peening that are forgiving without significantly altering the result?
- Is the marginal amount of peening and residual stress created when simply blasting a part during cleaning sufficient for most non-critical peening applications?

RAILWAY – A MODEL NON-AEROSPACE SPEC DOCUMENT

My first exposure to shot peening was with railway wheels in a centrifugal wheelblast machine at one of the Indian Railway plants. Being the densest railway network in the world, India has multiple railway wheel plants that clean and shot peen railway wheels, in distinct machines. But first, about the application. Railway wheels are typically forged or cast with the former used in passenger cars and latter in freight cars. These wheels are peened on both sides (front and back) simultaneously in the area extending from one-half of the way into the hub fillet and one half of the way up the rim fillet. In other words, in the areas of maximum tensile stress concentration.

Shot peening is managed by AAR M-107/M-208 (Association of American Railroads). I will start with the current version of this document (implemented 09/29/2020), section 7.0 Shot Peening. My focus for this discussion is to illustrate the clarity and simplicity with which a non-aerospace specification document can be written (take note, non-aerospace industries that are working on developing a specification document).

1. 7.1 – the scope clearly describes the purpose of peening as "improved resistance to plate fatigue and stress corrosion cracking by the introduction of beneficial compressive residual stresses." It lists all variables such as mass, hardness, velocity, angle of impingement and stand-off distance. It talks about coverage, both on the strip (yes, you read that right) and part surface.
2. 2. 7.2.1 and 7.2.2 – Shot and size control. The document offers tolerance to shot size selection and leaves the choice open to S-660 or larger. Shot addition practices indicate the minimum percentage requirement of a designated shot size.
3. 3. 7.2.3 – Intensity determination is explained as being through plotting a saturation curve and lists the minimum intensity at 10C. The description for processing time (cycle time) is a bit fluid in this document for understandable reasons (due to wide tolerances including, S-660 or larger shot size, minimum 10C intensity, etc.). Therefore, it places a constraint that "the processing time must be no less than the time required to reach saturation as determined by the saturation curve." Since wheels are manufactured in different diameters, this document states that the processing time for large wheels can also be used for the smaller diameter wheels. There is no room for ambiguity. If you are thinking that cycle time is a function of coverage/exposure, you are correct. The specification recognizes that as well and elaborates that in future sections.
4. 7.2.4 – Coverage. It explains that coverage has to be assessed on a "complete previously unpeened wheel" and lists the requirement in SAE J2277 for inspection. Interestingly, it also describes coverage measurement on the Almen C strip. Though this is not an indication of processing time, it addresses the need to have uniform denting on the strip to determine arc height. Note: An earlier version of this specification had listed that the minimum peening time had to only ensure that full coverage was attained on the Almen C strip. The document has since been revised to a more elaborate and accurate description of coverage than before.

The purpose of this discussion is to introduce our readers in industries outside of aerospace to the possibility of a specification that is not as onerous as an AMS document and yet addressing important requirements. I would like to point out that the AAR document is not an OEM specification, but one that is developed by an industry association. This might provide inspiration to industries such as Mining and Power (Oil & Gas) to work on a similar document.

SPECIFICATIONS FOR NON-PEENERS

Though there is room for improvement, I believe that credit should be given to those users that have adopted the tenets of the process even without a binding document. This includes, but not limited to: (a) grit blasting applications commonly seen in medical and aerospace, (b) etching applications in automotive, (c) applications that "dent" the surface to create smooth reservoirs to store lubricant, and the list goes on.

I was approached by a foundry user of blast cleaning equipment recently to find ways to use their cleaning machine for the occasional peening project. He explained that the occasion could be frequent over a six-month period and then none for the next few months, eliminating justification for a new, dedicated machine. Being an organization that relied on standards and structure, they were interested in a document that would allow them to peen in their existing set-up. With some minor equipment modifications such as the inclusion of an inverter with the blast wheel motor, an offline media classifier and media flow controls, the equipment was able to perform shot peening functions.

However, this was not all. The transformation of the machine from cleaning to peening could not happen by the mere flip of a switch. A section of their specification document listed all the necessary steps to be followed to initiate a successful transformation. This involved a thorough clean-out to eliminate contaminants such as scale and tramp metal dislodged during cleaning (by operating the reclaim system without parts in the machine for at least four hours), continuous classification of shot through the classifier to maintain uniform shot size, calibration of critical components such as blast wheel motors (speed/velocity), flow control valves (through media drop tests), and proper saturation curves instead of a single verification strip.

The process was rigorous, but in the end a document evolved that allowed them to convert it into a multi-purpose machine. I am not implying that this could be done every-

where. However, in situations where users are "testing out" the process for its efficacy, a different style of specification curated to their application needs can be designed. This could be a stop-gap arrangement and a reference document to use until a dedicated peening machine can be incorporated into their production process.

I would like to again refer to section 7.3.1 in the AAR document discussed earlier, Wheel Surface Condition. This clause goes to the extent of specifying that "the peened appearance of rim and hub shall not be cause for rejection." Some of us polish peened parts to remove the "dented" appearance. This clause explains that this may not be necessary when peening wheels, especially given the high intensity that these wheels are peened to. Practically any aspect of your process that is specific to your application or part can be inserted into a specification to make it relevant to you. The AAR document, along with several other clauses specific to their industry, teaches us that.

WHY BOTHER NOW?

Knowing what you don't know is true knowledge. I'd like to extend that to read, "adapting what you know to what is useful to you is true wisdom." Though I am not suggesting that you bind yourself with a rigid specification, you might want to consider documenting what you do and establish a set of rules for your peening process. This document will help with the following:

1. Standardization of your process through multiple manufacturing locations
2. Traceability when non-conformities creep in
3. Assurance and consistency of quality—following a well-documented process will lead to predictable results
4. Accurate estimation of costs and selling price of the final product
5. First-mover advantage if you initiate a document before being forced into one by others

"Are you still using MIL-S-13165" (*The Shot Peener,* Summer 2022) provides some references as you consider working on a document. That is because, before we started adopting AMS 2430 and 2432, we focused on MIL-S-13165 alone. This document is comprehensive, particularly for non-aerospace users of this process. Though cancelled, this document continues to be used outside of aerospace. Perhaps this could be your reference document and if you feel that your process can withstand more rigor, you can move up to the AMS adaptations referred above.

CONCLUSION

As I get this draft ready for review, a small group consisting of industry participants from different parts of the supply chain are getting ready to meet at SAE in Troy, Michigan. At this meeting, we will discuss modifications to several SAE and AMS documents. Ideas will be exchanged on how best to re-write a certain clause on testing techniques, clarify a screening tolerance, add a paragraph that reflects advancement in equipment, characterize shot shape in a more scientific method than pictorial representations, and so on. Such interactions help us keep pace with the technology growth being experienced by our customers, who are also part of this group.

Different committees work together towards a common goal—advancement of our industry. Your goal might have a different benefits analysis. Maybe the components you manufacture are not mission-critical and not left without recourse at 40,000 feet above sea level, yet you recognize the benefit of adopting this process. This discussion is for you. Starting to peen is important, peening correctly is growth. It is not that complicated. Transfer a constant magnitude of impact energy on to a component and manage all those variables that will assure this constant!

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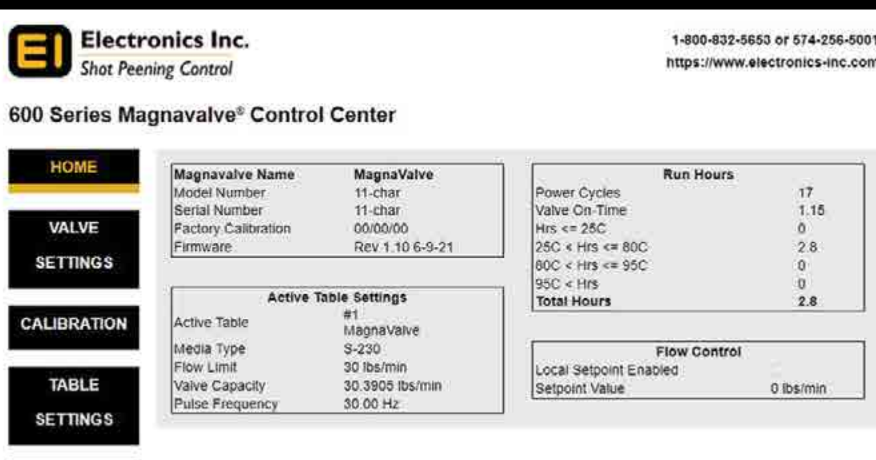

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ACADEMIC STUDY

Dr. David Kirk | Coventry University

Questions for Shot Peeners

INTRODUCTION

Shot peeners are often asked a variety of questions relating to shot peening. These give us opportunities to expand the knowledge of the questioners. Our answers must, however, be based on each questioner's current knowledge. It would be pointless to "blind them with science."

This article is based on the author's own experience of fielding questions. It starts with very basic questions appropriate for the "general public." Later questions are perhaps more appropriate for attendees at shot peening workshops.

Of necessity, the article reflects a very personal approach. As such, I cannot claim any particular merit for any of the answers. They should be regarded simply as guidelines.

QUESTIONS AND POSSIBLE ANSWERS

Q1: "What is shot peening ?"
A1: "Millions of hard, near-spherical particles, are fired at the surface of engineering parts—mainly of moving vehicles such as airplanes, tanks, submarines and cars. It is similar to what happens with a shot gun. The main difference is that we use a continuous stream of high-velocity shot particles rather than firing a one-off bullet."

Q2: "Why is shot peening useful?"
A2: "Shot-peened engineering components last very much longer than if they had not been shot peened. Most components are nowadays designed with minimum weight. This means that they will only last for a specified time before fractures occur. If some idiot had forgotten to have vital components shot peened the vehicle will crash prematurely!"

Q3: "Why does shot peening increase component life?"
A3: "Shot peening does two useful things to the component. The first is that it work-hardens a thin layer of the component's surface. Secondly, it induces beneficial compressive residual stresses in the surface layer. Both of these help to stop cracks forming at the surface."

Q4: "Why is compressive residual stress useful?"
A4: "It helps to stop cracks forming at the surface. Let's use an analogy. Imagine the rubber sleeve on, say, a hockey stick. The rubber is stretched tightly over the handle. This means that we have a tensile residual stress situation in the rubber sleeve. If we were to cut through the rubber using a safety razor blade, as in A of fig.1, the tension in the rubber would cause it to pull apart, as in B. If, magically, the rubber was being in a state of compression the rubber would not pull apart. The compressed surface layer produced by shot peening offsets applied tensile stresses."

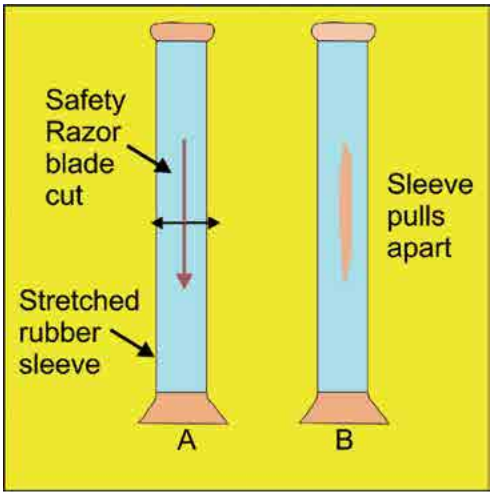

Fig.1. Analogy using rubber sleeve failure.

Q5: "What sort of improvement does shot peening impart?"
A5: "Moving vehicles have lots of components. They are subject to alternating stresses. If the alternating stresses are high enough, component failure will occur by what's called "Fatigue". Metallic components are made up of atoms arranged in a regular pattern as crystals. When the metal is pushed and pulled millions of times the crystals get tired of having to resist. Getting tired of the work involved is synonymous with the word "Fatigue". It simply gives up by forming cracks that cause the component to break apart so that no applied alternating stresses have to be endured. Shot peening introduces a surface layer that resists failure by fatigue."

Q6: "How much improvement does shot peening impart?"
A6: "We can quantify the amount of improvement using graphs. Before that, consider individual components subjected to fatigue stressing. Imagine that the designers have worked out that an unpeened component will last for only 100 hours of fatigue stressing before failure. With shot peening, tests show that the component will now survive for at least 20,000 hours of fatigue stressing—Eureka! If the component only has to last 5,000 hours before being replaced, fatigue failure is averted by shot peening.

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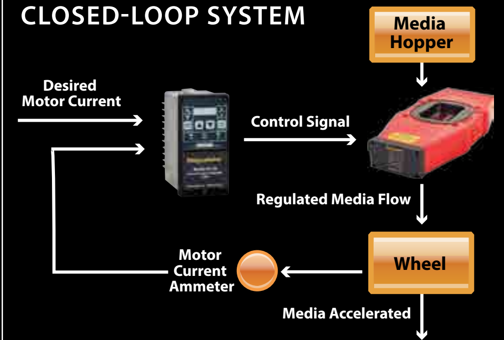

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Improvement is illustrated quantitatively by fig.2. Look at point **A** for an alternating applied stress of four (arbitrary) units. Fatigue failure is predicted to occur after 10,000 applied alternating stress cycles for unpeened component. Peened components are, however, predicted to last ten times as long—100,000 cycles. Now consider point **B** with a lower applied alternating stress level of three units. Peened components are now predicted to last indefinitely at this stress level whereas unpeened components are predicted to fail after about 100,000 cycles.

The region marked as **HS** in fig.2 represents very high applied alternating stress levels. Failure is then imminent!"

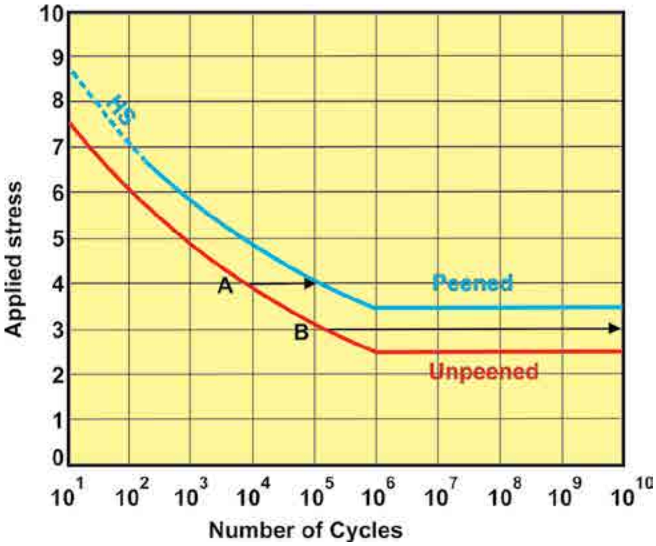

Fig.2. Fatigue curves for carbon steels.

Q7: "How thick is the protective surface layer produced by shot peening ?"

A7: "It depends on the size of the dent that each particle produces. Imagine dropping a ball onto a block of modelling clay. The size of the dent depends on three factors: (1) the size of the ball, (2) the height that we drop it from and (3) the density of the ball. Larger balls, greater heights and larger densities would all increase the size of the dent.

Size, drop height and density all affect the kinetic energy of the ball. Quantitatively, kinetic energy, K.E., is calculated from the equation:

$$\mathbf{K.E. = m.v^2/2}$$

Where **m** is the mass of the ball and **v** is its velocity. **m** is proportional to the cube of the shot particle's diameter but is only simply proportional to its diameter. It follows that a range of shot sizes is very useful from producing different sizes of dent. Fig.3 illustrates available standard steel shot sizes. The largest is almost twenty times greater in diameter than is the smallest. For the same velocity, the largest shot will have 8,000 times the kinetic energy of the smallest shot. Combining shot size and shot velocity gives excellent control of dent sizes."

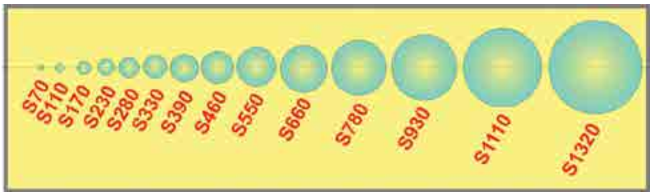

Fig.3. Size range of cast steel shot.

Q8: "Why does denting of a component produce a surface layer that is in compressive residual stress?"

A8: "The impacting shot particles each produce a dent. As a dent is being produced material is pushed outwards. The surface layer resists this movement, pushing inwards. (Newton's Third Law states that when two bodies interact, they apply forces on one another that are equal in magnitude and opposite in direction.) The situation is illustrated by fig.4.

Formation of a dent tends to stretch and bend the component. Resisting this bending puts the surface into compression. Millions of tiny contributions of compression add up to a surface layer that contains compressive residual stress."

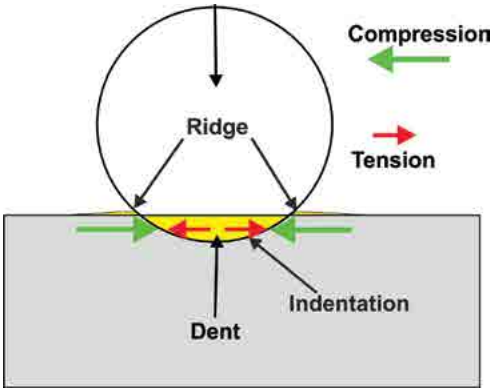

Fig.4. Dent setting up resisting forces.

Q9: "How many dents are needed to produce an effective protective surface layer?"

A9: "That is probably the biggest, most complicated, question that can be asked about shot peening. Essentially, the number of dents required depends on both the size of the component and on the average size of the dents. We use a term called "coverage" that accommodates both of these variables. Fig.5 models what we are looking for. Six dents centered in the unit square would correspond to a low coverage. Twenty-four identical dents would give medium coverage.

The proportion of area covered by dents is termed "Percentage coverage".

Next, we have to consider what percentage coverage is the most effective. We also have to ensure that we can measure coverage with reasonable accuracy. Coverage does not increase linearly with peening time. That is because the dents start to overlap more and more with increased peening. Overlapping is shown for the twenty-four dents in fig.5. The

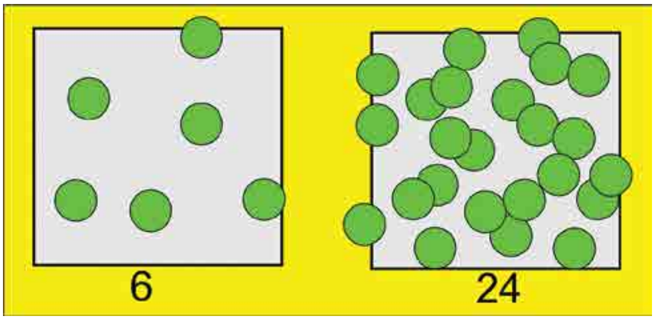

Fig.5. Model of low and medium dent coverage.

overlapping areas do not contribute to coverage. Probability of overlapping increases with coverage.

We use coverage as an indication of the optimum amount of peening that should be applied to a given component.

Theory tells us that coverage increase with peening time should follow an exponential curve as illustrated in fig.6. 98% coverage is shown in fig.6 as occurring at a relative peening time of eight units. This is significant because it has been agreed that 98% coverage is the greatest that can be measured with acceptable accuracy. 98% coverage is now termed "Full coverage."

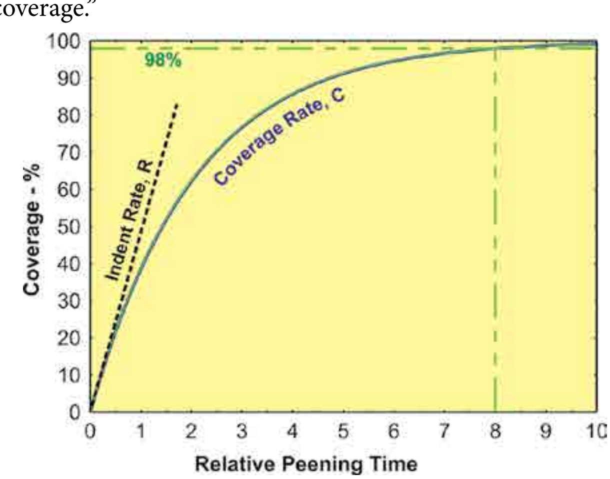

Fig.6. Coverage increase with increase in peening time.

We use coverage as an indication of the optimum amount of peening that should be applied to a given component. The most effective amount of coverage depends on the component. Too little coverage would leave regions unprotected. Too much coverage would run the risk of surface damage with fig.7 showing why. **n** is the number of overlaps. The peening time units are nominal. After one, about 28% of the 37% coverage consists of dents having just one overlap. At 98% coverage only 6% has received just one overlapping area. 40% has received either three or four overlaps. About 2% of the component has dents that have been impacted nine times!"

The equation for coverage versus peening time is:

$$\mathbf{C = 100(1 - exp(-\pi D^2/4.R.t))} \qquad (1)$$

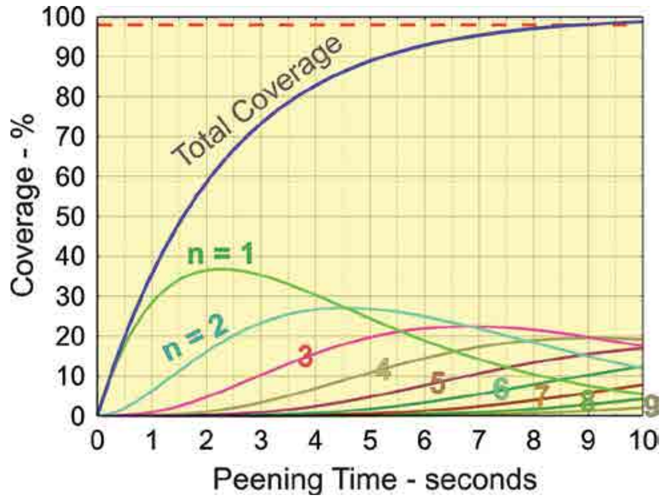

Fig.7. Multiple overlapping of dents.

Where **C** is the percentage coverage, **D** is the average diameter of each dent, **R** is the rate of impacting (number of dents imparted per unit area of surface per unit of peening time) and **t** is the peening time.

Q10: "How is coverage measured?"

A10: "The simplest method is to compare an image of the surface with standard reference images. One standard chart is shown as fig.8. There is, however, a subjective element in this procedure. On the other hand, the human brain can act as a marvellous computer—sometimes.

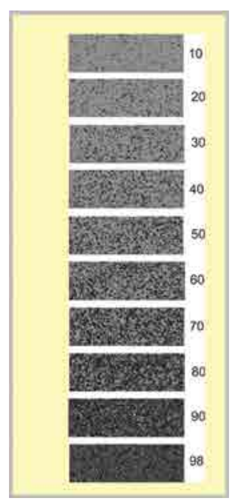

Fig.8. Standard comparison chart.

Coverage estimates based on actual measurements are usually based on linear intercepts. This principle is illustrated by fig.9. Just four short lines are shown though in practice many more longer lines would be analyzed. This to minimize statistical variability. Line four, for example, intersects dents much less than does line three. The length of each line would be taken to be 100% coverage if it only passed through dents. Line one represents measuring three dented areas.

Lineal analysis is very tedious if carried out manually. Computer-based image analysis is now available that is dedicated to coverage measurement. This involves far more lines and dent intercepts than can be employed manually."

Q11: "Which gives more fatigue life improvement—work hardening or compressive surface residual stress?"

A11: "First let us consider another factor that affects the fatigue life of components. For most components the


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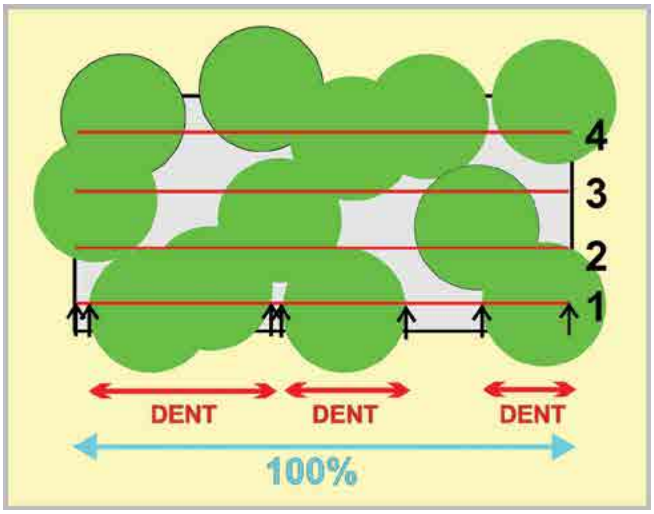

Fig.9. Principle of lineal analysis.

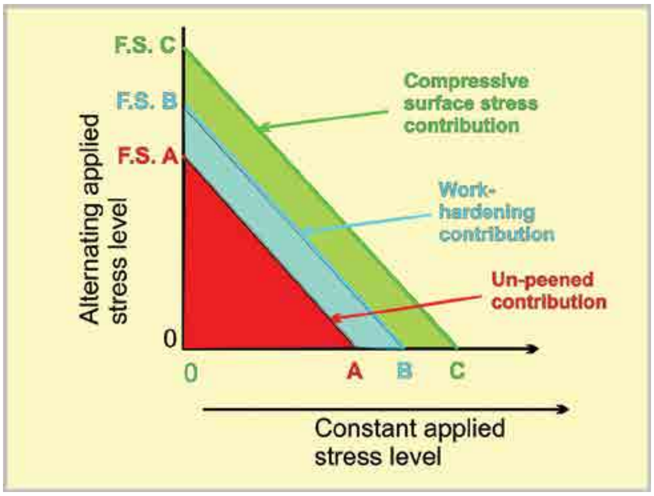

Fig.10. Contributions of shot peening to fatigue strength.

applied alternating stress does not vary by equal amounts above and below zero. A simple example is that of the leaf springs supporting a railway wagon. When stationary, the weight of the wagon applies a constant applied stress to the springs. The heavier the wagon the greater is this constant applied stress. If the constant applied stress were to reach the fracture strength of the springs they would simply break, so that no alternating stress could be applied. This, for unpeened springs, corresponds to point A in fig.10. Peened springs would not break until a constant applied level was greater—point C in fig.10. Work-hardening and compressive surface residual stress both contribute similar amounts to the increased fracture strength.

At lower constant applied stress levels alternating applied stresses can be applied. The lower the constant applied stress level the higher will be the alternating stress that can be applied before fatigue failure occurs. For zero constant applied stress the fatigue strength for unpeened springs is indicated as point **F.S. A** in fig.10. The work-hardening and surface compressive surface residual stress combine to raise the fatigue strength to level to point **F.S. C.** Their contributions to fatigue strength are similar for all constant applied stress levels."

Q12: "What controls are used to optimize shot peening?"
A12: "Customers normally specify the type and size of shot, percentage coverage and what is termed the "Peening Intensity" that should be applied to their components. These are specified based on previous experience. The percentage coverage is controlled by the time that a given shot stream is sprayed onto the component. "Peening Intensity—sometimes called "Almen Intensity"—is a control technique that has become essential for shot peeners.

Thin rectangular steel strips are shot peened on one major surface for different amounts of time. Shot peening plastically stretches the peened surface and generates a surface layer that contains compressive residual stress. These two factors combine to cause bending of the strip. This is illustrated by fig.11. Peened strips develop a curvature, **R**. If a given stream's average shot velocity is constant, the amount of bending will increase with increased peening time.

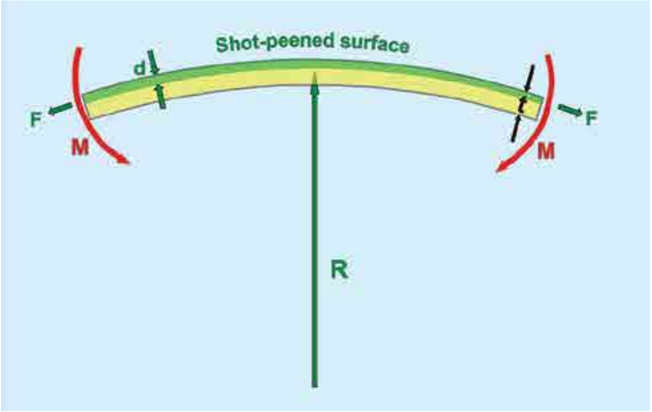

Fig.11. Bending of Almen strip caused by shot peening.

The amount of bending is determined by the "Arc Height" which is the deviation from flatness measured using a calibrated Almen Gauge. Arc heights increase with peening time. Nowadays we use a computer program to discover the curve that is the best fit to the set of measured points. One such curve is shown as fig.12. Note that the curve does not quite flatten out.

Fig.12 also indicates the universally accepted criterion for "Peening Intensity". Peening intensity is an arc height, **H**, that increases by precisely 10% when the peening time is doubled from **T** to **2T**.

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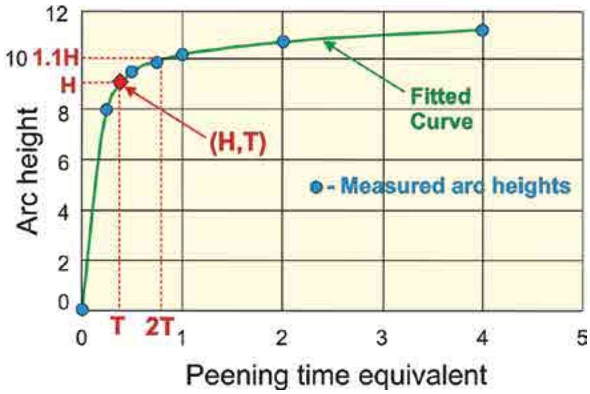

Fig.12. Arc height variation with shot peening time.

There are three different standard thicknesses of Almen strips. This permits sensitive arc heights to be developed over a wide range of peening intensities. The three thicknesses are labelled **N**, **A** and **C** with **N** being the thinnest and **C** being the thickest.

Everything about measuring peening intensity is rigorously controlled in order ensure that different organizations derive very similar values for a given shot stream. Fig.13 shows the basic principle of arc height measurement. An accurate dial gauge presses lightly on the Almen strip having been previously zeroed using a standard metal block. The strip itself is held lightly by magnetic forces generated in the four support balls.

Fig.13. Almen gauge.

DISCUSSION

A range of typical questions has been presented but it is by no means comprehensive. Some questions that have been fielded were posed by students, some by casual acquaintances. One important consideration is that enlightening questioners must be in the form of short replies. There is a strict limit on the information that can be absorbed in a matter of minutes. Technical articles concentrating on one specific topic can take hours, even weeks, to fully absorb. Illustrative figures for aiding answers to questions can be kept on either a smartphone or a laptop, or both.

ITAMCO Revolutionizes Gear Manufacturing at THRIVE Energy Conference

The recent THRIVE Energy Conference in February, 2024 served as a prime platform for ITAMCO (Indiana Technology and Manufacturing Companies) to unveil its ground-breaking advancements in gear manufacturing technology. Amidst discussions on energy innovation and sustainability, ITAMCO seized the opportunity to showcase its key innovations that are reshaping the landscape of gear production.

At the heart of ITAMCO's presentation was its cutting-edge use of machine learning (ML) and advanced analytics in gear manufacturing processes. By harnessing ML algorithms, ITAMCO has pioneered energy efficient solutions specifically tailored for gear systems. These solutions enable lower energy consumption of the gear manufacturing process.

Moreover, ITAMCO spotlighted its IoT-enabled gear monitoring systems which provide real-time insights into gear performance and health. Through continuous monitoring and data analytics, organizations can optimize gear operation, prevent unexpected failures, and maximize energy efficiency across various applications.

In addition to its technological advancements, ITAMCO emphasized its commitment to sustainability in gear manufacturing. ITAMCO ensures transparency and traceability in the supply chain, promoting responsible sourcing of materials and ethical manufacturing practices made in the USA. This not only aligns with the growing demand for sustainable solutions but also reinforces ITAMCO's dedication to environmental stewardship.

By participating in the THRIVE Energy Conference, ITAMCO demonstrated its leadership in revolutionizing gear manufacturing through innovation and sustainability. Through collaboration with industry peers and stakeholders, ITAMCO continues to drive positive change and shape the future of energy by delivering reliable, efficient, and environmentally conscious gear solutions.

In conclusion, ITAMCO's participation in the THRIVE Energy Conference underscored its commitment to advancing gear manufacturing technology while promoting sustainability in the energy sector. Through its pioneering innovations, ITAMCO is poised to lead the industry towards a more resilient and sustainable energy future.

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How Precise Can Be the Residual Stress Determined by X-ray Diffraction?

A summary of the Possibilities and Limits

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Abstract

Many springs are shot peened and the quality of shot peening is essential for the fatigue life. Today the determination is often done via x-ray diffraction. The lattice distance is measured and out of this information the residual stress is determined (and not directly measured). For this kind of measurement an absolute measurement is not available. The only way is to calibrate it in some way. It is shown how precise measurements today are in relation to different x-ray diffractometers and a specimen must be designed to get something like a usable calibration sample. The difference between statistical and systematic errors is shown and the consequences of these errors are discussed.

Introduction

Today the determination of residual stresses for many products is a common procedure, e.g., to prove the efficiency of the shot peening process or other hardening processes. Mostly it is done with the help of the x-ray diffraction method, because it is fast and not so expensive. The demands of the automotive industry concerning the accuracy and the number of measurements are still increasing. The question is whether precise measurements can be even performed. Here, round robin tests are reported designed to calibrate such a x-ray-diffractometer.

Basics of stress determination by x-rays

One popular method to determine the residual stresses in springs is the x-ray method. The idea is the measurement of the lattice distance within a solid or spring steel. The basic method is called Bragg reflection. A detailed description of the method will be found in the literature: [1;2]. A very brief summary is given here. X-rays with the wavelength λ are sent under certain angles Ψ to the surface normal and the diffraction angle 2θ with the maximum intensity is determined. The following equation can then be used:

$$\varepsilon = (1 + \nu) / E * \sigma \sin^2 \psi - \nu / E * (\sigma_{11} + \sigma_{22}) \qquad (1)$$

From the measured reflection angle a lattice spacing $D = \lambda / (2 * \sin \theta)$ is determined and is compared with the lattice spacing D_0 without any stress ($\varepsilon = (D - D_0)/D$). (E is the Young's modulus, ν is the Poisson's ration, $\sigma_{11} + \sigma_{22}$ are stresses in the main direction on the surface)

The main aspect is that the stress is not measured directly. The lattice parameter is measured at different angles Ψ and a slope m is calculated that depends on material constants and the stress thus:

$$\sigma \; (m = (1 + \nu) / E * \sigma) \qquad (2)$$

Out of this equation the stress σ can be calculated or determined. These considerations show that it is better to speak about determination of residual stress instead of measurement.

Conclusions

When comparing residual stresses from different labs, one must keep in mind that there may be great differences measuring the same objects (e.g., springs). To minimize the variation a calibration sample that has been used in round robin tests is useful. Laboratories have to make their own samples to monitor the long- term stability. Today an absolute calibration of an x-ray diffractometer is not possible and the measurements have a systematic uncertainty of at least 5%.

In many (delivery) specifications very small errors are claimed, which are in no relation to the systematic uncertainty of 50 MPa respectively 5% . One way to solve the problem is to organize round robin tests with a huge number of participants.

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Q & A

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You don't need to register to browse the forum. If you would like to post or respond to a post, however, you do need to register and it's very simple to do. The following are a sampling of the forum's posts. Maybe you will find an answer here to an issue you're facing.

Fluoro-Finder/Peenscan Assistance

Questioner: There are two types of Peenscan pens available, which stipulates Peenscan 220-2 pen for lower peening intensities and 220-6 pen for higher peening intensities.

In addition there is Fluoro-Finder III Tracer which only seems to come in one type.

We would prefer to use the latter as it enables us to get into all areas. But is there any guidance on usage based on is it is high or low intensity peening? The ranges we do are as follows:

6-9A	10-14A
14-20A	6-8C
10-16C	16-18C

Answerer #1: Nice question, the same my problem now. Could anybody give us some advice on this.

Answerer #2: Hi, I suppose you already tried the fluoro finder III by now.

My experience is that 6A is the lower limit for this and almost useless on the N scale.

I've only tried with s-110/cw14. It's possible that bigger shots remove tracer at slower rate.

Answerer #3: In my experience tracer dyes work best on materials and intensities that are easiest to visually inspect at 10x.

Even if our customers require us to use one, we still look at the part under magnification. High-intensity peening on a hard part will result in more of the tracer coming off the part than just the impact area. Some materials will literally soak up the tracer making it very difficult to remove by peening. If peening alone is done to remove the dye, then the part in all likelihood will have several times 100% coverage. Doing so could potentially debit the fatigue life of the part. In my opinion tracer dyes are great tools for original set up to see if your process is pening the correct areas. But there is no substitute for visually inspecting the part at magnification of 7x-10x.

Dark Residue on Shot-Peened Surface

Questioner: Dear all, I am facing a problem of presence of dark residue on shot-peened surface. I don't have deep knowledge of this process so I apologize if the question is very basic.

Practically we are shot peening some parts made of Fe ARMCO or Nickle, but post shot peening if we rub a cotton bud on the surface it becomes dark. We are using glass beads type AGB10. My assumption is that this is because the glass beads are getting broken and leaving their residue. I tried to change the air pressure but nothing changed. Is it normal?

The parts that we are shot peening have to be in an X-ray tube so surface cleaning is very critical to us.

Answerer: Both nickel and Armco iron must have oxide coatings. Nickel oxide as Ni2O3 is black as is Fe3O4 on Armco iron. Peening produces nascent surfaces that readily convert to these oxides when exposed to air. Post-peening removal will reduce the thickness of the black coatings.

Questioner: Thank you for your response. I have proposed to add cleaning with Acetone or pure Alcohol in the process post-peening.

Is there any way to reduce or prevent this oxidation? Because addition of this cleaning will increase lead time of product.

Currently we are using 5 bar pressure AGB10 beads, but the distance between nozzle exit and part is not controlled and operator can move and rotate the part freely.

Answerer: I do not know of any way of preventing oxidation of non-noble metals—oxides must form when exposed to air. How about reverse thinking? Is the dark coating unacceptable to your customer? If it is being formed consistently then it is useful proof of coverage!

That is the reverse of using lacquer coatings that have to be blasted off to prove coverage.

Questioner: I understand. Well that means I must add a post-peening cleaning procedure. Just to add knowledge non-related to this topic: In X-ray tubes, the presence of any kind of pollutant can cause premature failure.

So high care is taken to clean each and every part which has to be inside of the tube. Here the part being shot peened is a focalizer which is inside of the tube.