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The Shot Peener

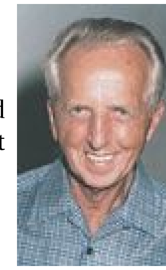
Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries

THE NEW IN-LINE RESIDUAL STRESS MEASUREMENT SYSTEM BY SINTOKOGIO

PLUS: POSITRON ANNIHILATION LIFETIME SPECTROSCOPY | WORK-HARDENING DURING PEENING STUDY | NEW UNIVERSITY & INDUSTRY ALLIANCE

(a) Stand-alone type (b) Portable type

Overview of Positron Surface Analyzer (PSA)



INDUSTRY NEWS

THE SHOT PEENER

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

My Shot Peening Bucket List

PEOPLE THAT KNOW ME WELL won't be surprised to read that I have a shot peening bucket list. Here are a few of the opportunities for improvement on my list:

JACK CHAMPAIGNE

- How do we achieve better methods of process control?
- Can we improve productivity by peening to only 85% coverage? This takes only 20% of the time as compared to 98-100% coverage. The fatigue benefit is the same. The productivity is a five-fold improvement.
- Can we adapt computer image analysis systems to qualify the media instead of the age-old practice using sieve screens?
- Instead of relying on the simple media drawings (cartoons) that have been in the specs for over half a century, can we assign a numerical value to the sphericity of the media?
- Real-time process monitoring can become a reality as we follow the trends of factory automation and data gathering.
- Is there a higher density ceramic media capable of performing peening at the mid- to high-"A" intensity levels, thus avoiding ferrous contamination of the product?
- Is there a way we can evaluate the residual stress level of the part as it comes out of the shot peening machine so we know the process is "In Control"?*
- Can we develop more efficient nozzles that consume less compressed air at lower pressures but achieve the same peening intensity and perhaps at a higher coverage rate?

Professor Martin Lévesque and Hong Yan Miao at Polytechnique Montréal, along with graduate students, are working in collaboration with the Canadian government and Montreal's aerospace community to advance shot peening research and development. Similar collaborations exist in Germany, Japan and China. Now it's time for the Made in America team to step up. This is being done at my Alma Mater, Purdue University. The new Center for Surface Engineering and Enhancement (CSEE), headed by Materials Engineer David Bahr, is poised to address some of the items on my bucket list. Read more about it on page 36. Several machine builders and media manufactures have indicated an interest in CSEE.

There are many new opportunities awaiting exploitation and the best is yet to come.

*Sintokogio (page 6) and Toyo Seiko (page 18) are making great strides in developing products that validate the shot peening process. Don't miss these articles on their exciting new products.

THE SHOT PEENER

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PRODUCT ANNOUNCEMENT

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Introducing the PSMX-II

The new in-line residual stress measurement system by Sintokogio

DEAR READER... as you are aware, shot peening improves the fatigue strength of metal parts such as gears or springs. Shot peening improves fatigue strength through compressed residual stress.

Arc height, measured with Almen strips, is commonly used as a parameter for understanding the strength of the shot peening process. This method was developed in 1945 and it is widely used today.

The arc height and the residual stress have a correlation, but with the arc height it is not possible to know the exact value of the remaining residual stress in each part.

The Almen strip measurement method is good for monitoring the condition of the shot peening process. In order to know the residual stress value (in MPa); however, it is necessary to employ specific measurement equipment.

The existing equipment technology to measure residual stress value is too lengthy a process to be utilized in line and would cause a loss of production.

To solve this problem, Sintokogio developed an In-Line X-Ray Residual Stress Measurement device, the PSMX-II.

The PSMX-II

The PSMX-II uses x-ray technology to measure the compressive residual stress in shot peened pieces. This equipment was designed to work in-line, guaranteeing the process control of shot peening and providing the residual stress in each manufactured piece (Figure 1).

In addition to providing the level of residual stress, the PSMX-II identifies the Full Width Half Maximum (FWHM) and the size of the crystal grain.

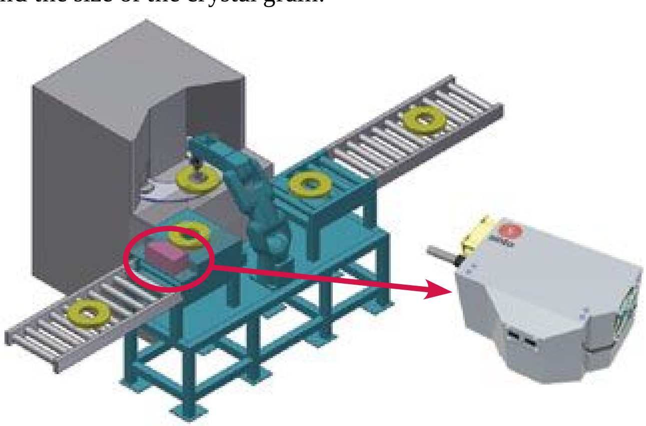

Figure 1. The PSMX-II is an in-line residual stress measurement tool that produces results in five to 10 seconds

The residual stress measurement time is between ***five and ten seconds*** and can be reduced further in certain parameters. This short measurement time is possible because the PSMX-II measures only the residual stress without any kind of analysis. The accuracy will change according to material, shape, measuring time and distance of the surface.

PSMX-II Applications

The PSMX-II can be used for in-line inspection of automotive parts, such as gears and springs, as a preventive inspection before the machining process in order to avoid the eventual high residual stress cause deformation in the piece after machining. The PSMX-II can also measure large parts such as wind turbine generators and construction equipment parts. Very high stress occurs in components made in large equipment such as the machine in Figure 2.

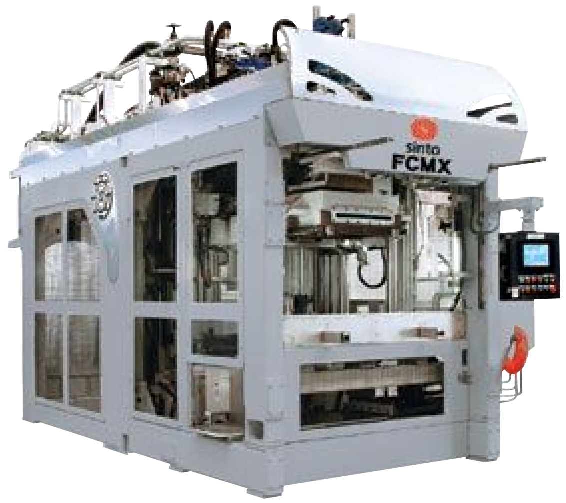

Figure 2.

If the part achieves the predefined residual stress, it proceeds to the next process. If the part does not achieve the predefined residual stress, it is removed from the line. The PSMX-II is easy to operate, fast, and ensures that only good parts will be processed.

The Measurement Process

The functions demanded of parts are their form (machining precision) and the mechanical properties of the materials, mainly material strength. Mechanical properties are parameters such as hardness and durability. Destructive

inspection has been necessary to measure these parameters. These processes were checked to see if they satisfied the predefined mechanical properties in the actual production line as construction took place. In order to do so, by utilizing devices for those processes, experiments are performed by changing each type of processing condition. Through this, we can confirm whether or not the processes satisfy the required mechanical properties. This is referred to as process capability assurance. With process capability assurance, specifications are not directly verified, but rather the process capabilities are secured as surrogate parameters.

For companies that internally handle the entire manufacturing process from the first step to the last (from materials to shot peening), if process capability assurance is performed at every step, residual stress measurement after the shot peening process may not be necessary. But for those companies that request outside handling for at least one step in that full process, there is the added work of verifying the process capabilities for delivered parts when they are received. For the final shot peening process, as long as residual stress is confirmed, that product's capabilities are satisfactory. Thus, confirmation of residual stress can be useful in improving quality control.

In addition, with the recent interest in IoT (Internet of Things), recording various parameters for the manufacturing process can be useful for the optimization of process design and the operation of the overall plant. To achieve this, even if process capabilities have been satisfied, PSMX-II can be used to check the residual stress of all parts, and improvement of product quality control can also be expected.

In Figure 3, the device is measuring the residual stress of the bottom of a gear that has undergone carburization heat treatment. Residual stress is generated by gears that have undergone proper carburization heat treatment, and by using PSMX-II, that residual stress can be measured. Additionally, if there has been an abnormality in the heat treatment, changes appear in the count rate and Full Width Half Maximum. This

Figure 3. A production process for transmission gears

can be used to determine the quality of the parts. Of course, it also measures and records those parameters after shot peening has taken place. In addition, the acquired data can be sent to other devices, including a PLC.

Heat Treatment and the PSMX-II

There is a possibility of decarburization near the surface of the part after heat treatment. If decarburization occurs near the surface, the surface hardness will be reduced 0.2% proof stress depending on the hardness (Figure 4). Therefore, decarburized material will have lower residual stress. We can see the difference in residual stress between parts with and without decarburization (Figure 5). As you know, we can't find decarburization material by visual inspection. Now we can measure residual stress individually in the production line.

For more information on the PSMX-II, please send an email to Sightia@sinto.co.jp.

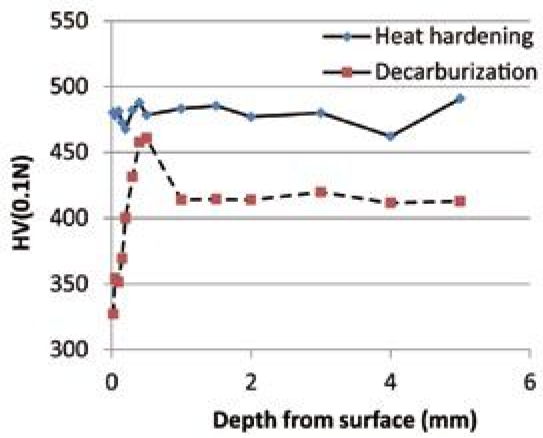

Figure 4

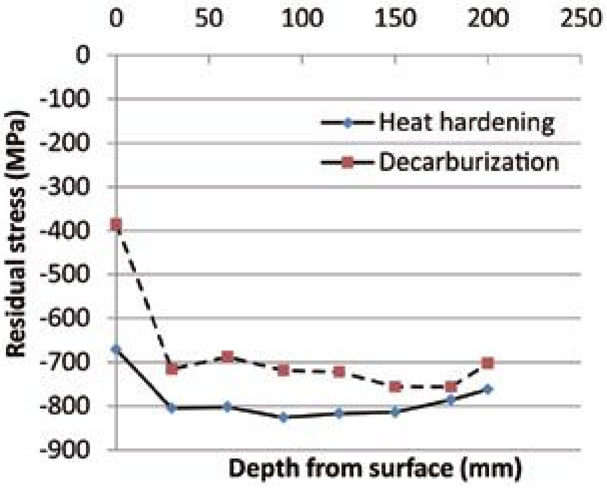

Figure 5


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AN INSIDER’S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

The Role of Wheelblast in Shot Peening – Part II

PART I OF THIS SERIES focused on application-centric reasons to help determine the choice of airblast or wheelblast for your shot peening equipment needs. The relatively higher amount of blast media propelled by wheelblast machines resulting in faster production throughput than airblast machines was recognized as a major contributing factor in this choice. An experienced shot peener knows that whether airblast or wheelblast, shot peening is primarily governed by the basic four concepts: (1) How hard we throw (intensity), (2) How much we throw (coverage), (3) What we throw (shape and size of peening media), and (4) Where we throw (targeting and masking). Shot peening relies heavily on controlling these four aspects to achieve repeatable results. Part II of our discussion will focus on the above in relationship to wheelblast machines.

Comparison of Common Parameters

The following table lists the comparable parameters for both types of media propulsion systems.

Wheelblast	Airblast
Blast Wheel • Wheel power • Wheel speed/diameter	**Blast Nozzle** • Nozzle size/bore • Air pressure
Blast Angle • Wheel positioning/location • Wheel oscillation • Control cage setting/ movement	**Nozzle Manipulation** • Follow part contour • Multiple fixed nozzles

Abrasive Velocity - *how hard we throw*

In a wheelblast machine, the blast wheel propels media like a nozzle does in an airblast machine. Larger diameter blast wheels propel media at high velocities, exhibiting direct proportionality (empirical formula for velocity: wheel diameter in inches x speed in rpm / 180 = approximate velocity in feet per second). Blast wheel motors used in peening machines are almost always fitted with variable frequency drives that allow speed alteration, leading to higher or lower velocities. The power of the motor driving this wheel will determine the media flow rate, also in direct proportionality. The following process parameters are controlled in almost identical ways in both machine types:

- Media flow rate: Flow control valves (e.g., MagnaValve)
- Media classification: Vibratory classifier (for size) and spiral separator (for shape)
- Part exposure: Alteration of conveyor speed, table speed, etc.

Wheel Power and Media Flow – *how much we throw*

Every blast wheel has an associated “No Load Amps” (NLA) which is the power/amperage required to rotate the wheel without the load of blast media. This value is based on the wheel design. The term “Full Load Amps” (FLA) refers to the maximum amperage that the motor can handle given its horsepower (HP) rating. For example, the FLA of a 20 HP motor is 22.5 and the NLA based on a specific wheel design could be 7 Amps (smaller and more efficient wheel designs have lower NLA). This means that the useful Amps available with this motor is:

$$22.5 - 7 = 15.5$$

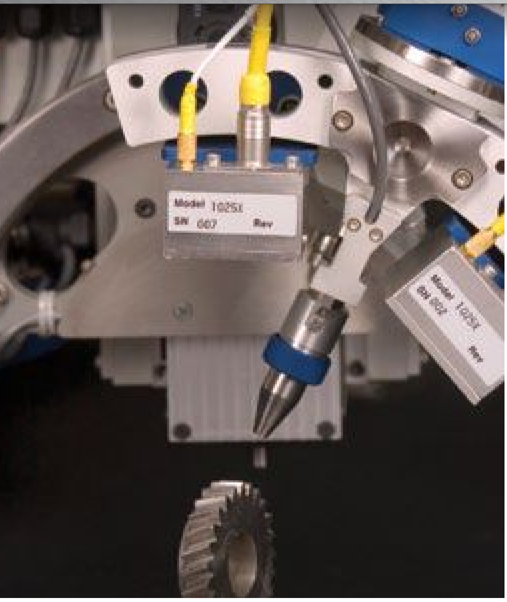
In other words, this wheel can only flow media (lb/minute) to the extent that 15.5 Amps will permit. Greater media flow rate will cause an overload condition in this motor.

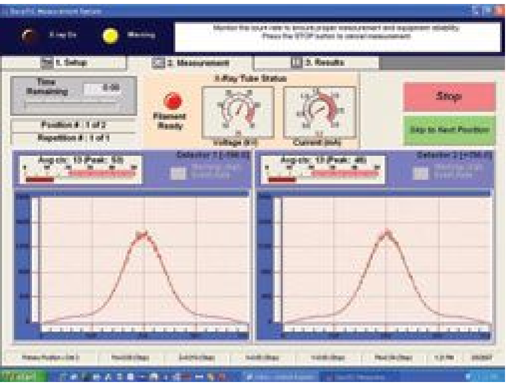
User groups in the Automotive sector will find this data of greater relevance than those in Aerospace. This is because the greater emphasis is on higher volumes and production rates in Automotive than Aerospace. Wheelblast peening machines for landing gear or aircraft structures will commonly use motors no greater than 20 or 25 HP, which will include sufficient margins on actual power requirements.

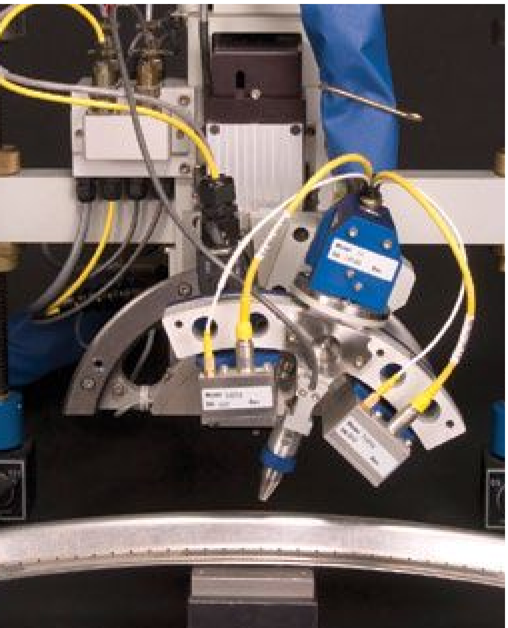
In airblast systems, larger diameter nozzles flow greater amounts of abrasive but in no comparison with the quantity through a blast wheel. Though different manufacturers of airblast machines may claim superiority of their specialty nozzle designs, the basic nozzle design remains similar—commonly used nozzles are either straight bore or venturi. The wheelblast industry, however, is flooded with hundreds of wheel designs, differentiated by the quantity and shape of blades, material of construction, ease of maintenance, design of control cages, impellers and so on.

Media flow rate through blast wheels is monitored and controlled in a closed feedback loop using specialized flow control valves. (MagnaValves by Electronics Inc. perform this function at different operating ranges. The popularly used model VLP-24 operates within 200-1000 lb/min). Similar

Materials Testing Services







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A VLP-24 MagnaValve on a wheelblast machine

flow control valves perform the same function at every nozzle (with the valve located at the blast tank outlet) in airblast machines.

It is essential to conduct regular media drop tests in both types of machines. In airblast machines, the nozzle discharges peening media into a calibrated container for a specified amount of time when conducting a drop test. In a wheelblast machine, the blast hose feeding abrasive to the blast wheel feed spout is disconnected at the spout and the abrasive is collected in a drum for a defined time interval. The flow rate must be verified for each wheel. Values in both cases are compared to the digital display on the controller and then adjusted as required.

Media Size Control – *what we throw*

Media size control in a wheelblast machine is accomplished using a Mechanical Vibratory Classifier. Due to the large volume of media propelled by a blast wheel, conventional classifier capacities can't handle 100% of the total flow. Therefore, it is an approved practice to divert a fraction of the total flow through the classifier and achieve "continuous" classification of the peening media.

Tim Carey, Vice-President of Business Development at Midwestern Industries, a leading manufacturer of vibratory classifiers, provided the following capacities chart.

Screen Diameter (Inches)	Shot Capacity (lb/hr)	Grit Capacity (lb/hr)
18	2,010	250
24	4,000	500
30	8,000	1,000
48	20,000	2,500

He also shared the following useful tips. "These capacities are indicative and field conditions could result in lower values. Classifier maintenance is key in achieving repeatable peening results. A tear in the screen, or a screen plugged with foreign objects, could lead to good abrasive being diverted to trash. Such damage could also result in a mix of media sizes and incorrect peening results," Tim said. He suggests the screens be inspected at least once a week for signs of damage.

Airblast machines use classifiers to classify 100% of the media flow. In a wheelblast machine, a flow control valve located upstream to the classifier restricts the flow to a lower value. Even though 100% of the media isn't classified in a wheelblast system, it is continuous and therefore conforms to commonly used shot peening specifications.

Media shape control is carried out by a spiral separator (spiralator). This device design allows only a finite quantity of media to flow through it. The exact capacity varies with size and type of media; it's typically around 20 lb/min. Therefore, the spiralator design is the same regardless of whether it is for a wheelblast or airblast machine.

Masking – *where we throw*

The blast pattern generated by a 15" diameter blast wheel is usually around 30" long by 2"- 2.5" wide. However, dispersion of this pattern and its impact will be in an area larger than the pattern size. This means that anything in the path of this pattern will get impacted. In other words, masking is not as simple as for an airblast machine that provides targeted impact in designated areas. Plugs and caps are commonly used on parts to protect holes, threaded or machined. In some cases, wear-resistant, but ultimately sacrificial shield plates, are strategically located inside the cabinet. These are also used to protect/mask certain areas of the part when physical masking on the part surface is not practical.

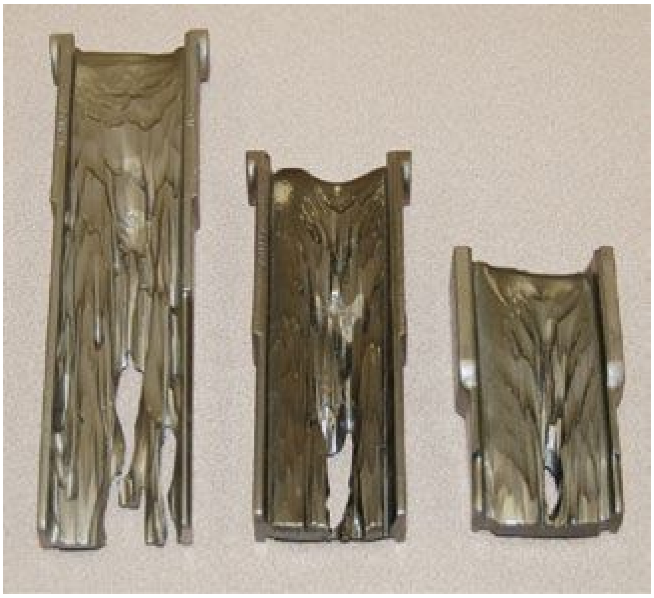
Wheel Part Wear and Its Effect on Peening Results

A dowel pin to identify an 1/8" increase in the bore of a blast nozzle is a common practice. The nozzle with this amount of change in bore is then considered to have enough wear to affect peening results. Nozzle wear also increases compressed air and blast media consumption, making it an undesirable overall outcome, even for cleaning applications. The nozzle and connected hose are then replaced. In a suction blast system, this would involve replacing the airjet in addition to the nozzle. The discussion gets a bit more involved in wheelblast machines.

Design of a blast wheel is relatively complicated and involves a greater number of moving parts. Let's first identify and understand the components of a blast wheel:

- The Feed Spout is located at the center of the wheel and receives abrasive from the storage hopper above the wheel. Though not a critical wear item, it is important to ensure its proper fit to prevent a dangerous shower of leaked abrasive onto the floor below.

- Blast media enters the blast wheel at its center and drops into the rotating Impeller. The impeller accelerates the flow of media stream through the wheel. It is the first in a series of wear items within the wheel.
- Concentric to the impeller is a fixed wheel-type component called the Control Cage. The control cage is designed with an opening along its circumferential width which, when aligned with the rotating impeller, allows the abrasive to exit the impeller and pass on to the blades before leaving the blast wheel. This is a very critical part of the blast wheel since the opening size and orientation determine the exact location of abrasive discharge and subsequent impact on the workpiece. Control cages are available in a variety of angles for the opening to suit the work being processed. The alignment is adjusted and recorded using a clock dial reference marker on the wheel housing. Wear of the control cage could misdirect the blast pattern to an undesirable location on the part or inside the blast cabinet, resulting in cabinet wear. Although control cage wear can be compensated by re-adjusting it using the clock dial, ultimate replacement of the control cage will be required to maintain the location of the blast pattern on the part. In sophisticated peening machines, automatic control cage adjustment is used to compensate for wear, and in some cases the movement is used to generate a sweeping pattern.
- The blast media discharges from the control cage onto the blades that propel it on the work surface. Blades are typically cast alloy steel with a flat surface along the length to allow the abrasive to roll, glide and ultimately discharge from the blast wheel. This causes wear in the blades in the form of grooves, ridges and holes. Any interruption to the smooth flow of abrasive due to damage will result in loss of velocity and directional diversion of media. Extreme wear of wheel components due to lack of maintenance, especially in blades in cleaning applications, will affect the consistency and repeatability of the process. For example, we are aware of the importance of maintaining a specific blast angle—wheel wear will alter this angle, affecting the impact energy and intensity.



Worn blades

Dave Hannusch, Project Manager at Wheelabrator Group, a global manufacturer of wheel and airblast equipment, has spent many years installing and trouble-shooting wheelblast machines for shot peening applications. "When addressing wheel wear, it is important that all critical parts be replaced at the same time, and not just a worn impeller or blade," he advises. "Blades are all dynamically balanced at Wheelabrator given the high rotational speeds at which some of these wheels operate. For our wheels, we supply a Tune-up Kit (TUK) which includes an impeller, control cage, set of blades and the fastener. With wear, the entire TUK is replaced instead of individual components in the list," he added.

Gibson Abrasive Equipment is another manufacturer of quality wheelblast machines for cleaning and peening applications. Geoff Gibson, General Manager, is emphatic about the importance of identifying wheel wear on time lest one experiences its detrimental effects on peening. He cited two machine examples from their range of equipment for peening. "We have several installations of tumblast machines for engine valve spring peening. Most of these tumblasts have a single wheel on the cabinet roof and the control cage opening is selected and aligned to span about 70% of the length of the tumblast barrel. When we test these machines, we mount Almen blocks with strips on an angle section or flat bar spanning the barrel length. We use this as a benchmark for the future. When the same test fixture is used by the customer at a future date, and if unable to achieve the arc height values as first tested at our plant, we know that components of the wheel are worn. In another example, we supply spinner hanger machines to de-burr shafts and gears with two or sometimes three blast wheels. Wheel wear in such machines will not only lead to improper cleaning (or peening), but will also impact cabinet areas (typically the roof or the floor, depending on the direction of wheel rotation), causing wear. Like the tumblast example, we use a benchmark hotspot sheet from thin gage steel and verify the hotspot location during testing and for future verification to identify a shift in pattern," he said.

By industry definition, when blasting a test sheet, the hot spot is the "blue" area burned on the sheet where the majority of abrasive impact has taken place. This hot spot will shift with wear of wheel components, especially the control cage. Therefore, a satisfactory test sheet used during machine set-up is used as a benchmark when testing the machine in

Control

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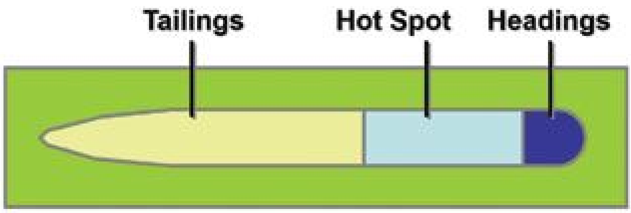

Blast Pattern Test Sheet

the future for wheel wear. Movement of the hot spot signifies important wear aspects that might lead to adjustments of wheel part replacement.

Summary

Here are the key points of wheelblast equipment for a shot peening application.

- Ideally suited for larger surface areas and when masking isn't needed and overspray isn't a concern
- Mainly for ferrous media
- Open or exposed areas only
- High media flow rates with faster cycles
- Commonly seen in Automotive peening applications
- Media flow, size and shape control similar to airblast machines
- Due to high media flow rate, wheelblast machines are not suited for use with multiple media sizes
- Some applications can be serviced by both wheelblast or airblast. Applications such as Automotive Gear Peening and Landing Gear Peening can be serviced by either wheelblast or airblast.
- Wear of blast wheel parts will affect peening results

If your steel shot/conditioned cut wire peening process calls for coverage in clearly exposed areas without concerns of overspray, and the masking requirements are minimal, it is prudent to consider wheel over air.

Naoya UESUGI | TOYO SEIKO Co., Ltd.

Application of Positron Annihilation Lifetime Spectroscopy

INTRODUCTION

The positron annihilation lifetime spectroscopy (PALS) has been widely used for probing open volume defects in various materials [1]. PALS has been applied for detecting the fatigue damages and is considered to be an effective method to evaluate fatigue damages [2), 3]. In previous studies, it was required to cut the specimens into two pieces, although PALS is essentially a non-destructive method. This is because PALS requires two same specimens to sandwich the positron source. In case of sandwiching a positron source with a specimen and another material, half of the positron wouldn't annihilate in the specimen and the positron lifetime spectrum is seriously contaminated by the false signals. Therefore it was difficult to continuously evaluate the accumulation of fatigue damages of the identical specimen by conventional PALS. As a technique to solve this problem, a novel method of PALS that does not require cutting out the specimen was developed by Yamawaki *et.al.*[4]. Briefly, the positron source is sandwiched between the specimen and a plastic scintillator which is a positron detector. The γ-ray signals relevant to the positron annihilation in the plastic scintillator are eliminated by application of anti-coincidence processing with the signal positron detected in the plastic scintillator. This technical paper describes the principle of the PALS system which is Positron Surface Analyzer developed by TOYO SEIKO and the results of several applications.

2. PALS PRINCIPLE AND PSA INTRODUCTION

2.1 Positron annihilation lifetime spectroscopy (PALS) principle

The positron is the anti-particle of an electron. When the electron and positron come together, they annihilate and produce two γ-rays having approximately 511 keV energy. The positron lifetime is the time distribution before positrons annihilate with electrons. The positron lifetime is inversely proportional to electron density of the site where positrons are annihilated. If lattice defects, such as dislocations and vacancies, exist in materials, positrons are attracted and are annihilated there. Since electron density is lower in such defects, positron lifetime becomes longer when compared with the defect-free materials (Fig.1). Further, the penetration depth of positron is about 100 micron, so non-destructive inspection could be possible.

Positrons are emitted from radioactive 22Na with γ-rays of 1.27 MeV. These γ-rays act as "start" signals. As is mentioned above, γ-rays of 511 keV are emitted when positrons are annihilated with electrons. These γ-rays act as "stop" signals. The positron lifetime is defined as time interval between start and stop signals. Approximately 10^6 events are accumulated to obtain positron lifetime spectrum with sufficient accuracy.

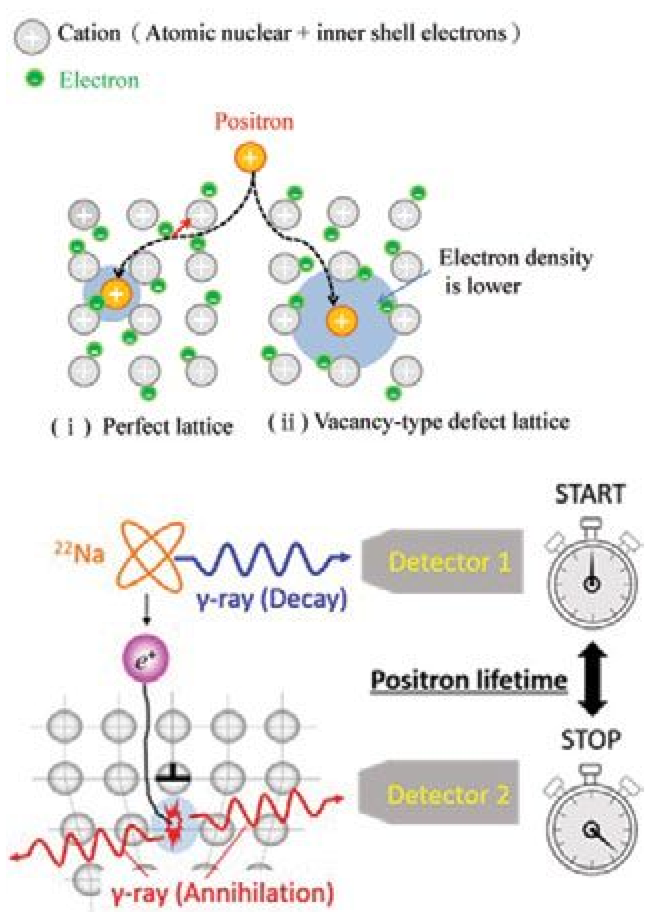

Fig. 1 The principle of Positron annihilation liftime spectroscopy


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(a) Stand-alone type

(b) Portable type

Fig. 2 Overview of Positron Surface Analyzer(PSA)

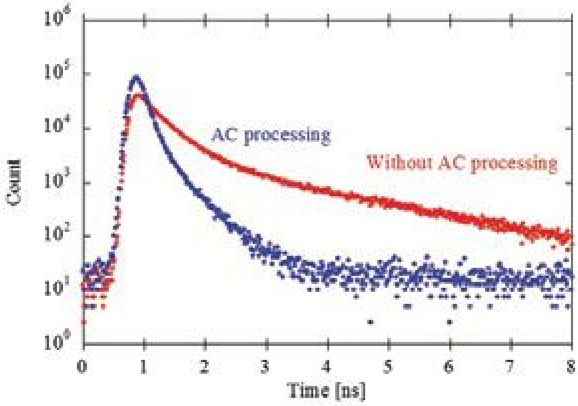

Fig. 3 Positron lifetime spectrum with and without AC processing

2.2 System of PSA

The overview of the PSA system is shown in Fig.2(a) stand-alone type and (b) portable type. The system consists of the positron source, two BaF^2 scintillation detectors, a positron detector, digital oscilloscope (DSO) and PC. The positron source is sealed radioactive sources of 22Na [5]. 22Na is sealed with two thin Kapton films. This positron source can be used without legal regulations or qualified person since radioactivity is under the lower limit. The positron detector is used for anti-coincidence processing (AC). The positron detector is composed of a plastic scintillator which is machined to fit the specimens and photo multi-amplifier tube. The positron source is sandwiched by the specimen and the positron detector. In this case half of positrons are annihilated in the plastic scintillator. When the scintillation light generated upon the passage of a positron through the plastic scintillator is coincident with positron lifetime events, these events are removed from the lifetime spectrum by anti-coincidence processing. Therefore the accuracy of measurement is largely improved even without specimen cutoff. Fig.3 shows the comparison of the positron lifetime spectrum with AC and without AC. It is obvious that the long lifetime component (attributed to noises) on the graph right side is almost removed by AC.

3. APPLICATION OF MEASUREMENT

3.1 The relationship between the positron annihilation lifetime and fatigue cycles[6]

Fig. 4 shows the relationship between the mean positron lifetime and fatigue life ratio. The mean positron lifetime increased monotonically with the fatigue life ratio. This increase indicates increase of lattice defect density (mainly dislocation density) in the specimen. The maximum of the mean positron lifetime is 125.4 ps just before fracture at *N/Nf* = 92%. The results shows generation and accumulation of lattice defects in fatigue process on the identical specimen.

3.2 Evaluation of shot peening effect

Fig. 5 shows the relationship between coverage and the positron annihilation lifetime at the peened Almen test strip.

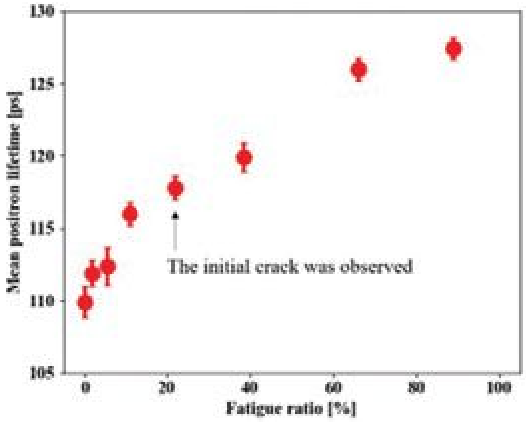

Fig.4 Relation between fatigue life ratio and positron lifetime

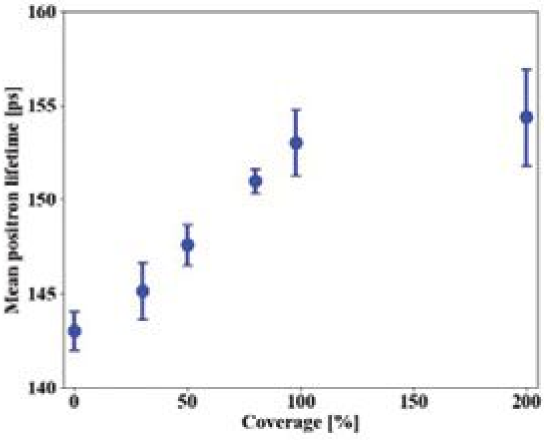

Fig.5 Relation between coverage and positron lifetime

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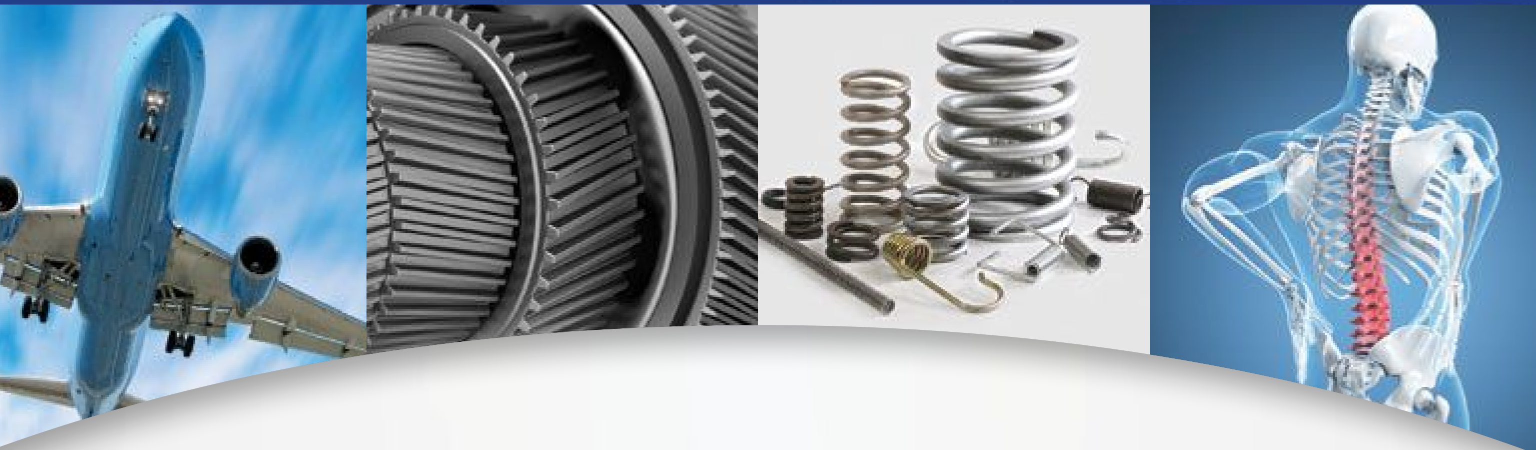
A Cut Above



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- **Highest Resistance to Fracture** Premier Cut Wire Shot media tends to wear down and become smaller in size rather than fracturing into sharp-edged broken particles, which may cause surface damage to the part.
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- **Substantial Cost Savings** The increase in useful life of Premier Cut Wire Shot results in savings in media consumption and reclamation, dust removal and containment, surface contamination and equipment maintenance.

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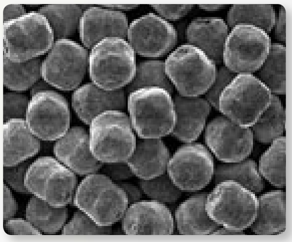

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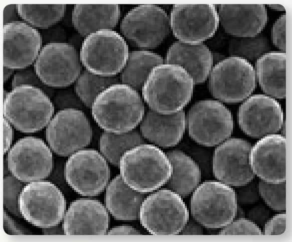

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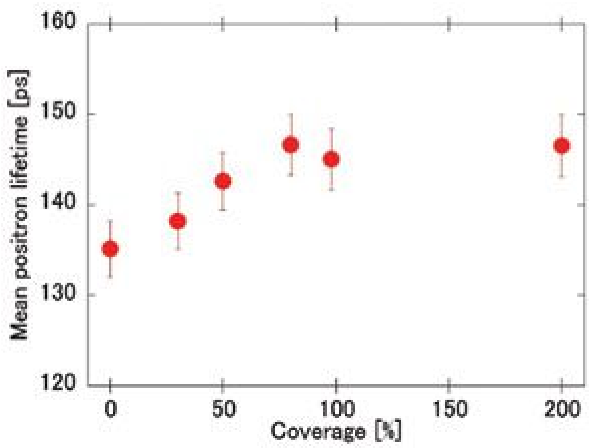

Fig.6 Relation between coverage and positron lifetime using portable PSA unit

The mean positron lifetime increased with the fatigue life ratio and saturated over 100% coverage. This tendency is very close to the saturation of residual stress profile at over 100%.

3.3 EVALUATION OF SHOT PEENING EFFECT USING PORTABLE PSA SYSTEMS

Fig. 6 shows the relationship between coverage and the positron annihilation lifetime at above peened test strip using PSA portable unit (b) at Fig.2. The mean positron lifetime increased with peening time (coverage) and saturated over 100% coverage. This tendency is very close to the results of stand-alone PSA. In conclusion, a portable PSA unit could be used for not only test specimens but also peened industrial products like coil springs and carburized gears.

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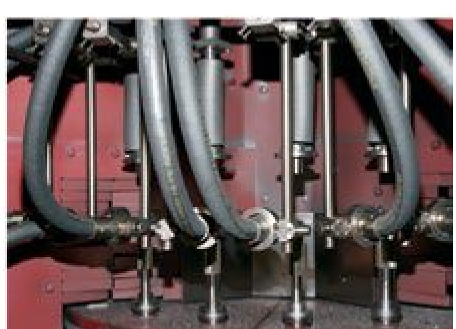

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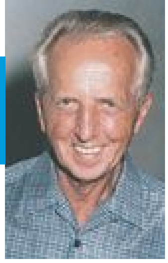

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Work-Hardening During Peening

INTRODUCTION

Shot peening is normally applied in order to improve the fatigue properties of components. This improvement is due to two factors:

(1) Work-hardening of the surface layer and
(2) Compressive residual stress in the surface layer.

This article is about work-hardening and fatigue improvement and is aimed at shot peeners rather than scientists. The key to understanding work-hardening is a crystal defect called a "dislocation." In the early 1900s, scientists were baffled as to why metals started to plastically deform at much smaller stresses than their predicted theoretical strength. About 1934, various scientists proposed that the puzzle could be explained if the metals contained "dislocations". Many metallurgists remained skeptical of this dislocation theory until the development of the transmission electron microscope in the late 1950s. With further research, based on transmission electron microscopy, we can now understand how work-hardening progresses during plastic deformation.

For most components, fatigue life depends upon the applied levels of both static stress and alternating stress. Consider, as an example, a simple railway wagon as illustrated schematically in fig.1. If the wagon was stationary, then a certain level of force, F, would be exerted on the axles inducing a corresponding stress level. The magnitude of F would vary according to the amount of cargo put into the wagon. If now the wagon is being pulled along the track, with a force P, an alternating stress is superimposed on the static stress being applied to the axles. The fatigue life of the axles depends upon the combination of these two stresses. Any increase of either stress will shorten the fatigue life.

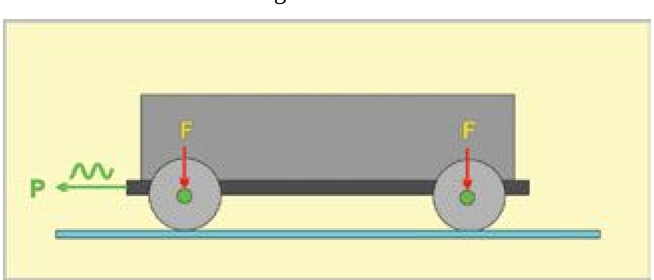

Fig.1. Static and alternating loading of railway axles.

Most shot peeners are familiar with the effect of alternating stress on fatigue life through so-called "S-N" curves (stress versus number of applied stress cycles). Much less familiar is the contribution of the static stress which is often represented by a so-called "Goodman Diagram." A section of the article is devoted to introducing the significance of Goodman Diagrams.

PICTORIAL EXPLANATIONS OF DISLOCATION YIELD STRENGTH REDUCTION

Why does a caterpillar move in the manner illustrated in fig.2? The answer is because it puts much less stress on its system. A small part of the body is progressively moved forward. Only a small fraction of its feet are involved. In the region of the "hump" this fraction is being "dislocated" from the twig.

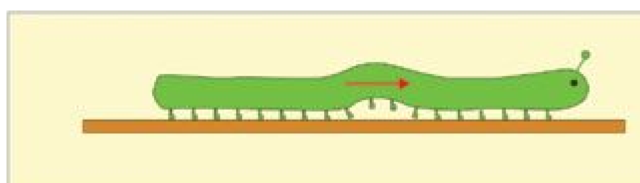

Fig.2. Localized movement of a caterpillar.

Fig.3 (page 28) illustrates the parallel situation for a metal crystal. A background image of the caterpillar has been included to emphasize the analogy. There is an extra half-plane of atoms, X, which, at its intersection with the slip plane, is analogous to one foot of the caterpillar being lifted.

The caterpillar analogy is two-dimensional. A nearer analogy to a crystal dislocation is a ruck in a carpet, as illustrated in fig.4 (page 28). Carpet layers have known for millennia that a relatively small force, F, will make a carpet move in a required direction. The line, AB, is analogous to a dislocation line.

Another analogy is to consider waves hitting a beach. Wind cannot move the whole of the sea's surface all at once. Instead it moves just the amount contained in a wave.

SPEED AND MULTIPLICATION OF DISLOCATIONS

Dislocations have two characteristics that explain work-hardening by shot peening:

(1) During deformation, dislocations move at the speed of sound and

(2) During deformation, dislocations multiply at an astronomical rate.

Once the yield stress is reached, the only thing stopping initial movement of dislocations on slip planes is the speed of sound in the metal. During movement, dislocation lines multiply at an astronomical rate. As an example, annealed steel containing 10^6 dislocation lines per square centimeter may contain 10^{12} after denting. This equates to a million-fold increase in, say, a thousandth of a second!

DISTRIBUTION OF DISLOCATIONS IN WORK-HARDENED METALS

As dislocations ferociously multiply, they meet with various obstacles such as grain boundaries and intersecting slip systems. Enormous pile-ups occur leaving each metal grain with a dislocation substructure. This substructure (a.k.a. nanostructure) has been described as "Regions of high dislocation density surrounding regions of low dislocation density." Figs.5 and 6 are purely pictorial representations. Fig.5 represents the low dislocation content of annealed metals within a structure of grain boundaries. Fig.6 indicates the difference in dislocation content and distribution for just one grain, A, if it had a cold-worked structure. The blue lines indicate the boundaries of the sub-grains.

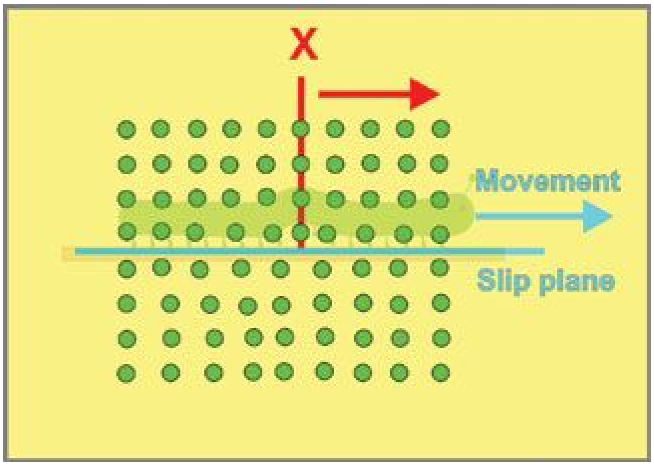

Fig.3. Progressive movement of 'extra half-plane', X, along its 'slip plane'.

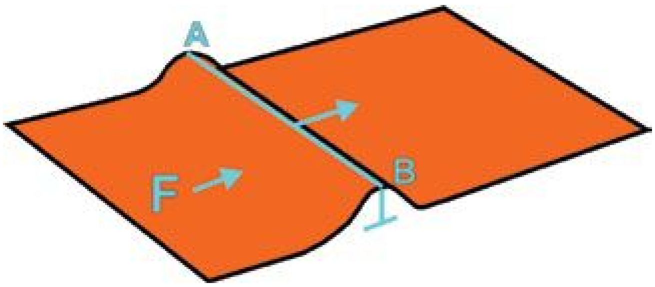

Fig.4. Ruck-in-carpet analogy of a dislocation line, AB.

HARDNESS CHANGE WITH INCREASING AMOUNTS OF PEENING DEFORMATION

Hardness is proportional to the stress that is needed to start dislocations moving. It is also proportional to the yield strength of the material. Fig.7 illustrates how yield strength

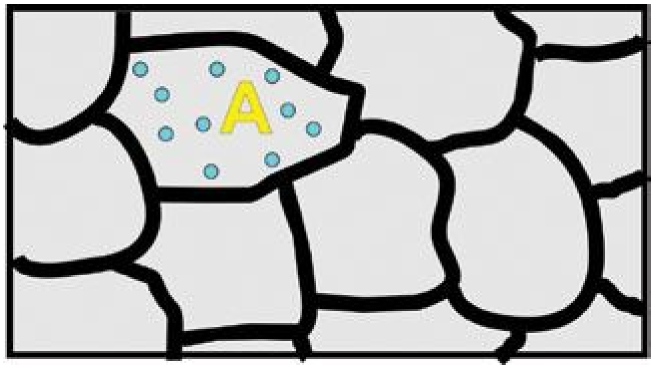

Fig.5. Schematic representation of an annealed structure with individual grains having low dislocation content.

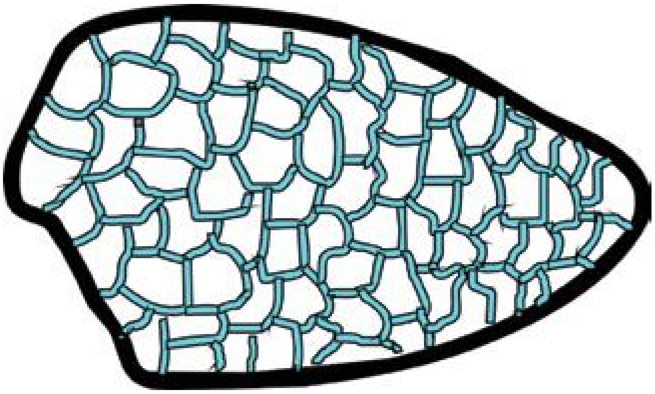

Fig.6. Schematic representation of an individual grain's dislocation sub-structure.

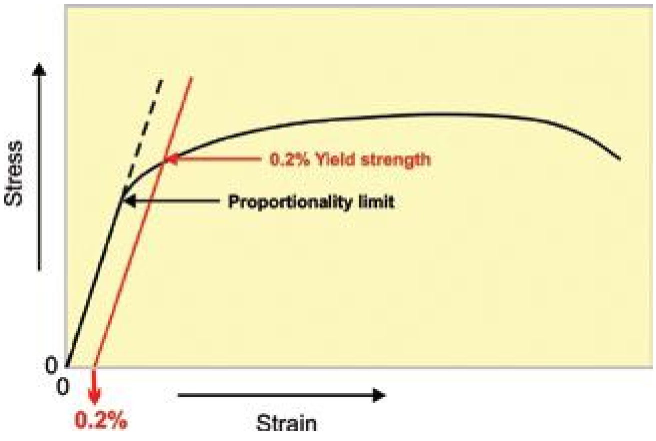

Fig.7. Yield strength estimation from a tensile test stress/strain curve.

is commonly deduced from a tensile test stress/strain curve. Because it is difficult to accurately determine the point at which strain is linearly proportional to stress, yield strength is usually quoted for the point of intersection of the curve with a parallel straight line.

The difficulty of denting metals increases with the yield strength of the metal. It should be noted, however, that:

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

(2) The increase in yield strength with increasing strain is much higher when denting than would be predicted from a simple tensile test. That is because a compressive stress system is set up as described in a previous article (TSP Spring, 2013, "Peening Impressions (Dents)")

Fig. 8 compares the progressive resistance to denting that occurs during shot peening.

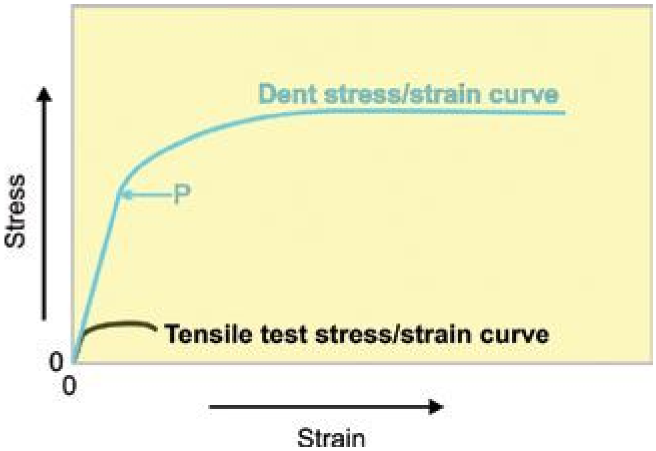

Fig.8. Schematic comparison of tensile and dent stress/strain curves.

The limit of proportionality, P, is much higher for denting than for tensile testing. Maximum hardening and ductility are also much greater.

Fig.9 shows the zone of work-hardening (cross-hatched) that accompanies dent formation. An important feature is that the work-hardening is not uniform. As the moving shot particle reaches its maximum depth, the deformation zone has two strain boundaries. Maximum plastic strain occurs at the contact area between particle and dent—marked as a red line. Zero plastic strain occurs where the applied stress is only equal to the proportionality limit stress, P, and is marked as a blue line. Below that line the component is only elastically stressed.

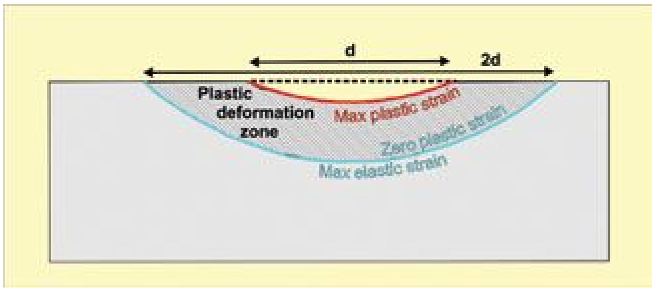

Fig.9. Plastic deformation zone beneath a peening dent.

EFFECT OF MULTIPLE DENTING

As coverage increases, the peened surface is subjected to multiple impacts. Progressively a continuous work-hardened surface layer is produced. The amount of plastic deformation is far higher than that encountered in a tensile test. A pertinent question is "Why doesn't cracking occur during peening?" The answer lies in the different type of stress system that is being applied. Fig.10 (taken from TSP Spring, 2013, "Peening Impressions (Dents)") shows that a three-dimensional compressive stress system is operating. In effect, the metal is being squeezed together during deformation. This is the same as when we make snowballs. Squeezing using cupped hands applies a three-dimensional stress system. Compare that with what would happen if we press using flat hands.

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

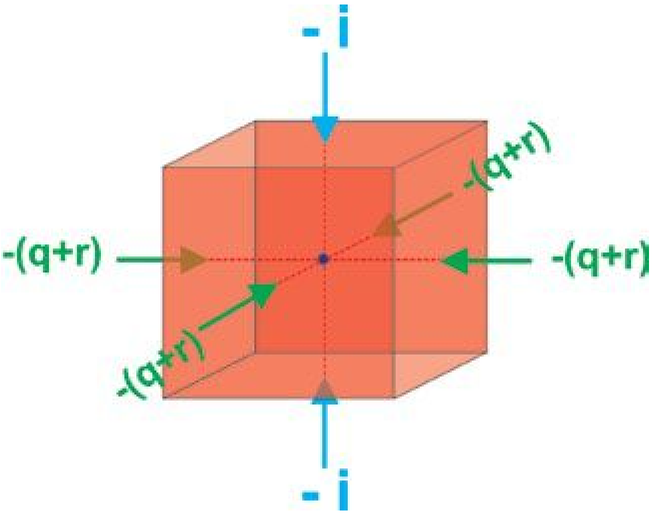

Fig.10. Three-dimensional stress system during denting.

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Aims and Scope

The purpose of this conference is to foster exchanges between the academic and industrial community on processes inducing beneficial residual stresses, as well as their effects, with an emphasis on traditional shot peening. While this is not an exhaustive list, deep rolling, laser peening, ultrasonic peening, cavitation peening, flapper peening and needle peening fit within the conference's scope. In addition, talks dealing with fundamental or applied aspects, modeling, experimental methods, fatigue life, forming and industrial applications are sought so as to generate fruitful discussions between world experts in order to address current and forthcoming issues.

Presentation of Papers

The organizing committee aims at offering at least 75 paper presentations with a question and answer period.

Proceedings

The conference papers will be compiled into a Conference Proceedings booklet.

Best Student Presentation Award

Students (undergraduate, graduate and post-doctoral fellows) are encouraged to present their works at the conference. A jury will evaluate oral presentations made by students and will distribute three "best presentation awards" during the banquet.

Exhibition

An exhibition of commercial products will be held during the conference.

Site Visits to Local Aerospace Companies

Montréal is an aerospace hub and local aerospace companies have agreed to offer site visits as part of the conference. At this time, Bell Helicopter Textron, Bombardier Aerospace, Pratt and Whitney Canada and L3-Communications MAS have agreed to open their doors to conference attendees. Site visits will be included in the registration fee.

Banquet

The conference banquet will feature a three-hour cruise in a Bateau-Mouche on the St. Lawrence river. The river cruise in an open excursion boat includes a gourmet dinner and jazz concert.

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EFFECT OF WORK-HARDENING ON FATIGUE STRENGTH

It is well-established that shot peening improves fatigue strength. This improvement is generally represented in the form of so-called "S-N curves." Fig.11 is a schematic pair of S-N curves for ferritic steels. **S** is the maximum stress applied during cyclic loading and **N** is the number of applied loading cycles—necessarily plotted on a logarithmic scale.

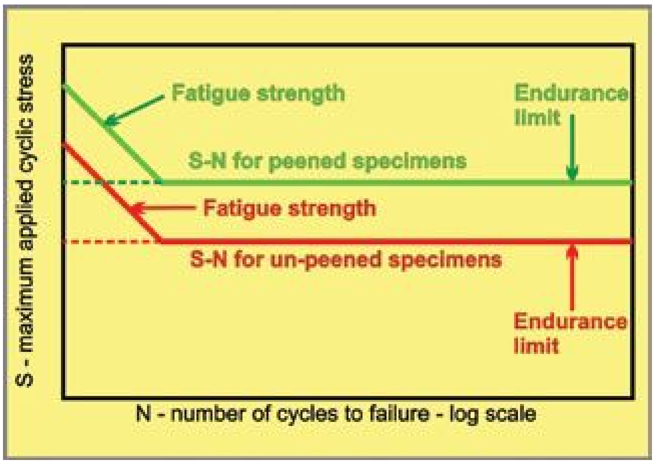

Fig.11. S-N curves for comparing peened and un-peened fatigue.

Fatigue strength is the applied cyclic stress that will cause failure in a specified number of cycles. Endurance limit is the applied cyclic stress below which fatigue failure will never occur. Shot peening normally raises both the fatigue strength and the endurance limit simultaneously. The respective contributions of work-hardening and surface residual stress cannot be simply deduced from S-N curves. Separating the magnitude of the two contributions is an important consideration. The following is one method that has been employed successfully. It is based on what is known as a "Goodman Diagram".

Constant versus alternating applied stresses

Goodman diagrams are normally used to represent the combined effects of constant and alternating applied stresses. Fig.12 shows the difference between constant and alternating applied stress.

Imagine pushing steadily down on the end of the strip. The maximum stress induced in the strip's surface, σ_{max}, is where it is clamped at one end. If we push hard enough, the maximum applied stress will reach the ultimate tensile strength, U.T.S., of the strip and it will break. Hence the maximum value of an applied constant stress (shown black in fig.12) is the U.T.S. If, on the other hand, we only push up and down by the same amount on the end of the strip the maximum applied stress alternates about zero (shown red in fig.12).

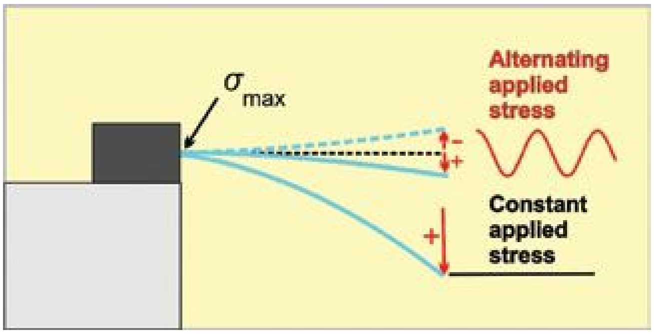

Fig.12. Constant and alternating applied stresses.

Goodman diagram for unpeened material

A basic Goodman diagram for unpeened material is shown as fig.13. This assumes that the surface contains neither residual stress nor work-hardening.

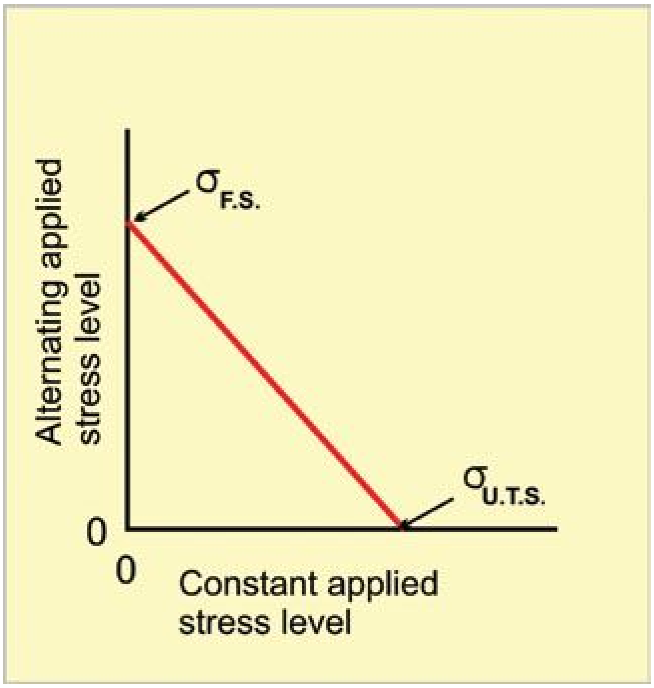

Fig.13. Goodman diagram.

Goodman diagram for peened material

Fig.14 (Page 34) shows how a Goodman diagram can be employed to estimate separate contributions to fatigue strength.

Point A in fig.14 corresponds to the maximum constant bending stress (with no alternating applied stress) that can be applied to un-peened material without exceeding its

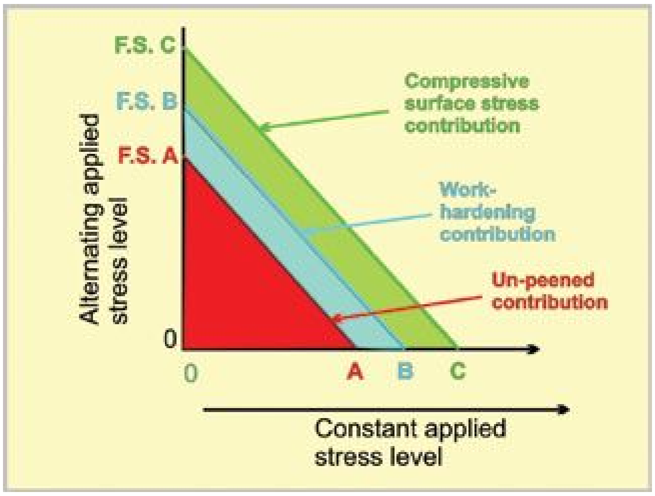

Fig.14. Goodman diagram modified to show separate contributions.

U.T.S. Point C corresponds to the maximum bending stress (again with no alternating applied stress) that can be applied to peened material without exceeding its U.T.S. This raising is due to a combination of work-hardening (which raises the U.T.S.) and compressive surface residual stress (which subtracts from any constant applied stress). The compressive surface residual stress is equal to B – C and is often measured. Hence, AB corresponds to the work-hardening contribution and BC to the compressive surface residual stress contribution. Corresponding fatigue strength values are shown as F.S. A, F.S. B and F.S. C.

SUMMARY

The whole point of shot peening is to improve service properties of components, especially their fatigue strength. Improvement is achieved by a combination of work-hardening and induced surface compressive residual stress. These two factors are of similar importance.

Work-hardening centers on the role of crystal dislocations. These are line defects that multiply at astronomical rates and travel at the speed of sound during work-hardening. They form massive pile-ups—particularly at grain boundaries. The vast dislocation content of cold-worked material is arrayed as a sub-structure.

Goodman diagrams are a convenient method of indicating the relative contributions of work-hardening and induced surface compressive residual stress to fatigue strength. They are, arguably, as important as the more familiar S-N fatigue curves.

Kathy Levy | InfoProse

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The research capabilities of CSEE are available to companies and government agencies. Pre-competitive research is available to member groups as well as specific and proprietary research for individual organizations. The program offers access to the test equipment, research staff, and disciplines most companies do not have.

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Purdue is very successful at establishing these kinds of collaborations. For example, the Cooling Technologies Research Center at Purdue addresses the research and development needs of members from diverse industries and product lines in the area of high-performance heat removal from compact spaces. The research and development is member-directed with a product-oriented focus.

Over 30 individuals representing 18 companies recently attended a one-day workshop to learn how their participation in CSEE will benefit their companies and help the shape the research focus for the next year. Participants included shot peening equipment OEMs and end-users in aerospace, off-highway vehicles, and automotive.

The event featured technical research presentations, a poster session, and roundtable discussions. The research topics presented at the workshop included "Fatigue of Shot Peened Thin Wall Aluminum," "Laser Shock Peening," "Simulation and Validation of Stress Development During Peening of Aerospace Aluminum," and "Particle Making Technology." Workshop attendees then broke into working groups to tackle key topics—identifying key industry challenges and the requirements of the CSEE facility. The groups' findings will advance the development of the CSEE program.

CSEE is supported by annual membership fees from organizations with tiers based on size and participation levels. Robyn Jakes, Director of Development/ School of Materials Engineering can answer your questions regarding membership levels and the next steps for joining CSEE. Call Robyn at (765) 494-4094 or send email to rnjakes@prf.org.

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Our focus is on understanding processing/structure/property relationships in metals during shot peening and other mechanical surface treatments. Our material focus is broad, from steel to aluminum to high-temperature alloys. We aim to create predictive models that allow members to control the performance of their surface-enhanced components."

Dr. David F. Bahr
Professor and Head of Materials Engineering

"As a Purdue alumnus, I am pleased and honored to be a part of the CSEE program. As a manufacturer, I'm eager to have access to research on topics that have interested me for years. Finally, theory will become practice and we will be able to commercialize these ideas. I encourage OEMs and shot peening facilities to take advantage of the immense research capabilities of the CSEE."

Jack Champaigne
President, Electronics Inc.

Bryan Chevrie | Product Engineer | Electronics Inc.

Déjà Vu All Over Again

SHOW OF HANDS: Who has learned a lesson the hard way, only to forget and relearn it again at a later date? I have joined that club many times and I recently renewed my membership. A customer contacted the EI engineering staff a short time ago with a very unique problem with one of our AC-24 Controllers.

The customer complained, "The servo function on any one of the AC-24 Controllers would mysteriously turn OFF randomly." Now we have seen strange things, but this was new.

This customer is a US-based auto part manufacture that has two different wheel blast machines. One of these wheel machines was outfitted with four MagnaValves controlling the flow of media to four blast wheels. The customer complained, "The servo function on any one of the AC-24 Controllers would mysteriously turn OFF randomly." Now we have seen strange things, but this was new.

A colleague and I started by asking the customer the usual stuff: What is on the power supply with the MagnaValves and AC-24s, are the wires going to the MagnaValves in their own conduit or bundled with high voltage AC lines, are the control wires shielded? We were hoping it was something simple. In this case, the customer had the MagnaValves and AC-24 Controllers on their own power supply, all the low voltage controls and PLC were in their own cabinet, and only in a couple of locations were the high voltage AC and the low voltage DC in close proximity. It appeared the customer did a nice job of installing the MagnaValves and AC-24 Controllers on their machine. Deeper investigation was required.

Before arriving at the customer's location, we asked if the event could be caught on video. The customer set up a camera and captured the event on two different controllers at different times. This was a huge help because in both instances, we noticed that a conveyor turned ON at the same time the servo function turned OFF. This small bit of information indicated that noise from a motor could be the culprit to their mysterious function change. Once in front of the troubled machine, my colleague also noticed that all the LEDs on the AC-24 Controller that should be OFF were very dimly lit. This confirmed noise as the culprit.

When we determined it was a noise issue, we thought finding the source would be simple. Boy, were we wrong. We started by connecting an oscilloscope to the supply lines and looking at the noise level with the conveyor motor running and the conveyor motor stopped. The noise level did increase when the conveyor motor turned ON. We then probed all other control lines coming into and out of the AC-24 Controller. Every input and output line had noise and that noise increased when the conveyor motor turned ON. The head scratching starts. Which wire contains the source of the noise? Out of desperation, we started to remove one wire at a time and continued to measure the noise on the supply and monitor the dimly lit LEDs on the front of the controller. One-by-one we removed the wires from the controller and none of them proved to be the source of the noise. What the heck? Is there a leak in the matrix? How is this possible?

Then someone said, "That's all the wires, except the ground." My reply, "Remove the ground." Just then, the sea parted and the clouds of electrostatic noise cleared. The noise levels on the supply line dropped significantly and the dimly lit LEDs turned OFF completely. That's when it dawned on me—I spent two days troubleshooting a similar problem in Japan a couple years earlier. As soon as I was back in the office, I dug out my notes from my Japan trip and confirmed that it was in fact the exact same problem.

You might be asking yourself, "How could the chassis ground be the source of noise?" The system used variable frequency motor drives (VFD) to drive all motors on the machine, including the conveyor motor. The VFD generates an EMI (Electro-Magnetic Interference) in the form of leakage currents on the AC power supply lines (not an issue for the DC supply lines) and ground lines. The manual of the VFD stated, "Noise from earthing cable due to leakage current may cause peripheral device to malfunction. Disconnecting the earthing cable from the peripheral device may stop the malfunction of the device."

The wiring diagrams from the customer indicated that the earth/safety ground and 24 V supply common were tied together. Tying the ground and 24 V supply common together is NOT recommended. Tying the ground and common together creates a path for the noise generated by the VFD to enter the low voltage system. This noise will wreak havoc on your system and cause you to question your career choice.

There are three lessons here. One: RTFM. Two: Earth/safety ground has a different purpose than DC supply common and they should not be tied together. Three: Just because you write something down, it doesn't mean you will remember it and you may have to discover the information all over again.

Free Nadcap Regional Technical Symposiums

AT THE END OF 2016, nine Nadcap Technical symposia took place in the USA, Europe and Asia, covering both the East Coast and West Coast of the USA, three European countries and two Asian countries. These symposia were free of charge to companies not normally able to send a representative to Nadcap meetings. The opportunity to gain technical information will help them better prepare for a Nadcap audit. Seventy percent of the attendees had not previously attended a Nadcap meeting, although 85% confirmed that their facility had held, or currently held, Nadcap accreditation.

In total, more than 400 delegates attended the nine symposia, which were held in Dallas, Torrance and Orlando in the USA, China, Japan, Naples in Italy, Bangalore in India, Munich, Germany and Derby, UK. The symposium in Naples was conducted in Italian and the one in Munich in German. The specific technical focus varied per symposium but information about chemical processing, heat treating, non-destructive testing and welding was included as well as technical content such as audit preparation, checklist review and an overview of common non-conformances and how to respond to them. Nadcap subscribers presented their policies on Nadcap, including Rolls-Royce, BAE Systems, MTU Aero Engines, Leonardo Aircraft, Leonardo Helicopters Triumph Group, MHI, The Boeing Company, Lockheed Martin and Pratt & Whitney.

Feedback from the delegates was very positive, with 88% satisfied with the symposium they attended and comments such as "I felt that the sessions were really informative. We had struggled to understand some of the changes and also some historical requirements in the new check sheets for Chemical processing. We were able to ask questions and get clarifications to help with our upcoming Nadcap chemical processing audit" and "An excellent mixture of content from Subscribers, Suppliers and PRI (Technical)."

In response to a number of positive comments from delegates, additional events have been scheduled. Upcoming events are as follows:

August - Seattle, Washington, USA - Nondestructive Testing and Chemical Processing

September - Wichita, Kansas, USA - Composites and Chemical Processing

November - Manchester, UK - Nondestructive Testing and Heat Treating

For more information, please contact:
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Valence Surface Technologies Achieves Nadcap Accreditation for New Shot Peening Facility

VALENCE SURFACE TECHNOLOGIES, the world's largest independent provider of metal processing and finishing services in the aerospace and defense industry, has received Nadcap accreditation for its new state-of-the-art shot peening facility in Everett, Washington, located less than a mile from its existing Valence Blue Streak Operations plant. The new 10,000-square-foot facility is located at the PowderMill Business Center adjacent to the Boeing Everett Factory and has been built to shot peen large aerostructure components up to 30 feet in length.

"Valence has worked closely with its customer base in the Pacific Northwest to understand the process requirements for new and existing programs. We've invested in adding much needed capacity for large part shot peening," explained Matthew Alty, vice president of operations. The plant combines an automated shot peen capability and an integrated digital masking cell specifically designed to streamline the processing of geometrically complex components. By matching large part shot peen capability to its existing 30-foot NDT, chemical processing and paint lines, Valence now delivers a fully integrated solution to its customers. Alty added, "Instead of sending a part to multiple suppliers, customers can now issue a single purchase order to Valence, reducing lead times, transportation and logistics costs."

About Valence

Valence Surface Technologies, with 10 locations, over 530,000-square-feet of manufacturing space, over 2,500 unique industry approvals, and over 15 million parts processed per year, is the world's largest independent provider of special processing services to the aerospace and defense industry. The company provides specialized metal processing and finishing services to a diversified set of fast-growing commercial aerospace, defense, and space/satellite markets.

All Valance sites are Nadcap accredited and offer services including NDT, all types of anodize, chemfilm, passivate, plating, dry film lube, and painting. Valence brings superior value to its customers through its industry leading capabilities, approvals and systems and its continuous drive to provide best in class quality, turn times and supply chain partnership.

New Continuous Shot Blast Machines by Trowal

WALTHER TROWAL GMBH & CO. has recently commissioned a THM troughed belt continuous shot blast machine for a customer in Mexico that is equipped with a brand new generation of blast turbines. These turbines were specifically designed for shot blasting of aluminum components. With a considerably higher blast media throwing speed, the new turbines produce significantly shorter cycle times than previous models.

The Mexican customer already successfully operates four continuous Trowal shot blast machines. Because of their excellent performance, he chose to purchase another THM machine when he had to expand his production capacity.

Up-and-Coming: Aluminum: The Gentle Blast Media

The increasing sales trend at Walther Trowal indicates that ever more customers are switching to aluminum media when shot blasting aluminum components. Because of its lower bulk density, aluminum media is a lot gentler than, for example, stainless steel shot. Typical automotive forgings made from aluminum are steering knuckles or swivel bearings. Aluminum die-castings processed in THM shot blast machines can be all kinds of housings, covers or levers.

Because of its lower density, the impact energy of aluminum media on the work pieces is considerably lower compared to other blast media. To offset this limitation, Walther Trowal developed turbines with curved throwing blades which generate a significantly higher blast media throwing speed than straight blades. This, combined with the fact that in THM machines the turbines are located very close to the work pieces, and the media throughput is considerably higher, results in optimized energy utilization and surprisingly short cycle times. However, the shot blast treatment remains very gentle. In short, despite the relatively low density of aluminum blast media, the shot blast process is highly effective and at the same time surprisingly gentle, preventing any warping or distortions of delicate work pieces.

Another benefit of aluminum blast media is that it reduces the wear rate in the turbines and the machine to a fraction of the wear caused by steel shot, resulting in higher uptimes and lower operating costs.

Walther Trowal offers a range of different machine sizes equipped with up to four turbines. For example, for forged aluminum components the new THM 700/4/E with four turbines and a power of 15 kW for each turbine, produces an exceptionally high degree of productivity.

Specifically Designed for Handling Aluminum Media

To meet all the challenges posed by aluminum shot, the Trowal engineers redesigned many machine assemblies, among them the media dosing system and the turbines. One detail of many: A rough surface of the throwing blades would quickly destroy the aluminum particles. Therefore, Walther Trowal is smoothing the blade surface with in-house vibratory finishing equipment. The result: A greatly reduced blast media consumption, lower dust emissions and significantly improved turbine uptimes.

Visit www.walther-trowal.de for more information on these new shot blast machines.

W Abrasives and ICSP-13

AS A WORLD MARKET LEADER in steel shot and grit, W Abrasives is pleased to participate to the 13th International Conference on Shot Peening.

During the three exhibit days, the W Abrasives team will be presenting the complete line of surface enhancement solutions including high carbon steel shots, cut wire, stainless steel products and ultra-fine shots.

The W Abrasives large spectrum of media offering includes solutions for the Automotive, Aerospace, Spring and many other markets.

In addition to meet the most common SAE standards (J827 and J441), the W Abrasives products can meet the VDFI 8001, AMS 2431/1, 2, 3, 4 and 8, DMR 71-110 (Safran Group) standards, to name a few.

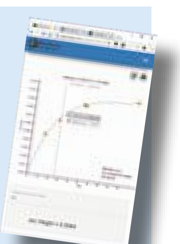
The W Abrasives team will also take the opportunity to present an “ultra fine shot” in the order of 70-100 µm which is used for the peening of small parts such as gears or valve springs.

With its expertise, worldwide availability, innovations and product performances, W Abrasives will be able to optimize its customers’ shot peening applications.

The W Abrasives staff looks forward to seeing you in booth #5 at ICSP-13.

The 13th International Conference of Shot Peening
Hotel Delta Montreal
475, President-Kennedy Avenue
Montreal, H3a 1j7 Canada
September 18-21, 2017

Visit W Abrasives in Booth #5



ICSP-13 Exhibit Space Registration

Registration is open for exhibit space at the 13th International Conference on Shot Peening.

Hotel Delta Montreal
Montreal, Canada
September 18-21, 2017

Exhibitor booths (4′ x 6′ tables) are offered at a rate of $1,500 for the conference. This amount includes one full registration to the conference including meals, but excluding the banquet. In addition, the exhibitor's logo will also be on the conference's website.

The booths will be located around the conference rooms and the coffee break stations for maximum exposure.

Visit www.polymtl.ca/icsp13 for more information, including a current exhibitor's layout and registration form.

ICSP13