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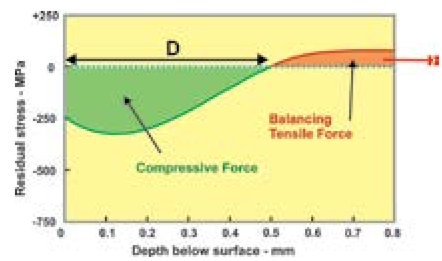
The Shot Peener

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



THE SHOT PEENER
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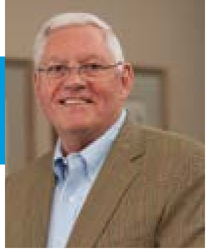

OPENING SHOT
Jack Champaigne | Editor | The Shot Peener

Milestones

Toyo Seiko Celebrates 50th Anniversary
Congratulations to Toyo Seiko as they enter their 50th year. The company was founded in 1975 as a manufacturer of cut wire media for mechanical descaling machines for wire rods manufactured by its parent company, Miyazaki Seiko. Today, Toyo Seiko is an indispensable partner to a global market. Read more about this milestone on page 36.

Over 10,000 Students Trained by EI Shot Peening Training
To assist industry growth, Electronics Inc. introduced the Shot Peening and Blast Cleaning Workshops and Seminars in 1991. Under the leadership of the Director of Training, Dave Barkley, the number of students completing the workshops, seminars, and on-site programs has surpassed 10,000 in 2025. Many of these attendees achieved their Level I, II and III Certifications for shot peening and rotary flap peening. The individuals and companies that participate in these programs advance the quality of shot peening around the world.

The Purdue 2025 Distinguished Engineering Alumni Award
On April 10th, I received the DEA award at a dinner and awards event at Purdue University. According to Arvind Raman, the Dean of the College of Engineering, "This award is the highest honor bestowed by the College to its alumni, and recognizes those who have made outstanding contributions within their fields."

Anyone that knows me well, knows how much Purdue University means to me so this recognition is special. When I learned I was receiving the DEA award, I was convinced I didn't belong in a group of astronauts and industry titans. I graduated from Purdue in 1968 in Electrical Engineering. The School of Materials Science nominated me for the award for my history in surface enhancement technology. As I reflect on my career I realize it has been an amazing journey. Surface enhancement is a critical aspect of product design in preventing fatigue failures. Any metal that is flexed in use is a candidate for failure. I am glad to have been a "cheerleader" and advocate for product safety.

A handshake from Arvind Raman, the Dean of the College of Engineering.

THE SHOT PEENER

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Japan's Infrastructure Situation and Peening

Proposal of Pre-post Fatigue Crack Maintenance that Can Be Carried out during Repainting Process on Existing Steel Bridges

Fukuoka University Koji Kinoshita, Gifu University Yuki Banno
Yamada Infra Technos Co., Ltd. Shohei Yamada, Motohiko Tsuruta
Toyoseiko Co., Ltd. Yoshihiro Watanabe

1. Background

The aging of infrastructure, particularly steel bridges constructed during Japan's period of rapid economic growth (1955-1973), is accelerating and has become a pressing social issue. According to infrastructure maintenance data published by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), of the approximately 730,000 road bridges (with a length of 2 meters or more) whose construction year is known, it is estimated that around 30% will be over 50 years old by March 2020, about 55% by March 2030, and approximately 75% by March 2040[1)]. MLIT's estimates indicate that, for infrastructure under its jurisdiction, total maintenance costs over a 30-year period could be reduced by about 30%[2)]. "Preventive maintenance" is projected to cost approximately \$1.2 to \$1.3 trillion, compared to \$1.7 to \$1.9 trillion for "post-defect maintenance." In response to this situation, MLIT highlighted the importance of shifting toward preventive maintenance in their 2024 New Year's address.

This paper presents a case study involving both post-defect and preventive maintenance of fatigue cracks on an existing steel bridge under MLIT's jurisdiction. Fatigue cracks identified during the repainting process were addressed through post-defect maintenance using needle peening, while shot peening was applied as a preventive measure in areas without cracks. Based on the results of this case study, a series of processes necessary for future infrastructure maintenance is proposed.

2. Current situation and issues of bridge maintenance

The main repair methods for fatigue cracks as post-defect maintenance have been rewelding and reinforcement using bolted steel plate joints. These methods have proven effective for repairs. However, similar welded joint details where no fatigue cracks have yet been observed could potentially have new cracks in the future unless preventive maintenance is carried out. In fact, in the case of the existing steel bridge discussed in this paper, reinforcement using bolted steel plate joints was carried out in 2017, but new fatigue cracks were found during construction in 2023, highlighting the need for fundamental preventive maintenance measures rather than relying solely on post-defect maintenance. Reinforcement using bolted steel plate joints is typically used in urgent cases where cracks have progressed to the base material. Therefore, applying this method to cracks that are in their early stages and have not yet affected the base material may be considered an excessive repair. Streamlining post-defect maintenance will allow for better allocation of budget to preventive measures, ultimately reducing the Life Cycle Cost (LCC) of maintenance (Fig.1).

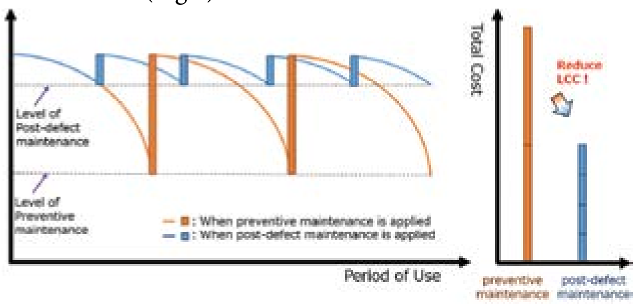

Fig.1 Reducing LCC of maintenance

3. Overview of bridge construction projects

3.1 Target bridge

The bridge targeted in this paper is shown in Fig.2, and its specifications are listed in Table 1. The bridge was constructed in 1974, approximately 50 years ago, and is part of a regional expressway. It is a heavy traffic route with frequent trailer traffic, and fatigue damage has been confirmed.

3.2 Construction history

Fatigue cracks were not detected until the 2014 inspection, during which cracks rated as S1 (requiring further

Fig.2 Bridge appearance

Table 1 Bridge specifications

	SPECIFICATIONS
Year of completion	1974
Name of road	National Route 1
Regulations applicable to superstructures	Specifications for highway bridges (1972)
Length of bridge	46 m
Width of bridge	18.4 m
Superstructure	Steel I-girder

investigation[3)]) were identified. In 2017, fatigue cracks were confirmed by magnetic particle testing (MT) and repaired using bolted steel plate joints. In the 2019 inspection, no new fatigue cracks were found, although corrosion and a decline in corrosion prevention function were observed.

3.3 Construction overview

Following the 2019 statutory inspection, repainting work was conducted in 2023 to restore corrosion protection. During the work, cracks were found on the paint, suggesting possible damage to the base metal. After blasting off the paint, MT revealed fatigue cracks. As shown in Fig.3(a), seven new fatigue cracks were identified. They were located at welded joints similar to those reinforced with bolted steel plate joints in 2017 where no cracks had been found at that time. The cracked joints, shown in Fig.3(b) and 3(c), were at intersections of main girders with cross beams or lateral bracings. These areas are prone to fatigue due to stress from differential deflection between girders and deck plates[4)]. Because the bridge has many similar details where cracks have previously occurred, MLIT requested not only post-defect maintenance for the cracked areas, but also preventive maintenance at similar locations without cracks to prevent further fatigue damage.

3.4 Proposed post-defect and preventive maintenance methods during repainting construction

In this paper, post-defect maintenance without the use of bolted steel plate joints and preventive maintenance were proposed and implemented:

- As a post-defect maintenance measure, crack closure treatment using portable pneumatic needle peening* (PPP) was proposed to suppress fatigue crack propagation. A PPP device developed by Toyo Seiko was used for the treatment, as shown in Fig.4.
- As a preventive maintenance measure, a shot peening method was applied to improve the fatigue strength of welded joints with the same shape as those where cracks had occurred. A circulating shot peening method* (Fig.5), which can be applied in parallel with repainting work, was used.

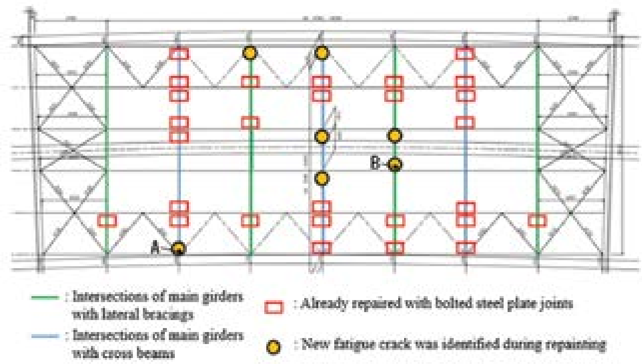

Fig.3(a) Found fatigue cracks during blast

Fig.3(b) Fatigue crack (main girders with cross beams)

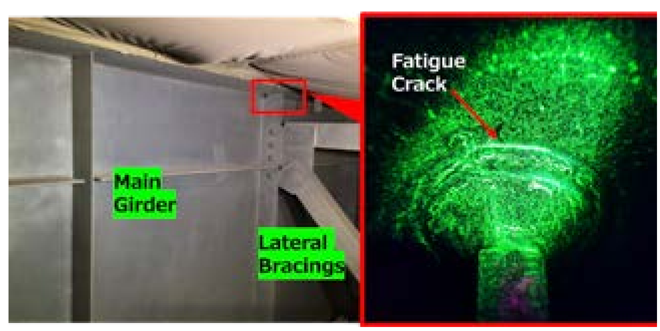

Fig.3(c) Fatigue crack (main girders with lateral bracings)

Fig.4 Portable pneumatic needle peening device

**Note: The portable pneumatic needle peening device is a patented product developed by Toyo Seiko in Japan (No.5719032). The circulating shot peening method is a patented technology of Yamada Infra Technos Co., Ltd., registered in Japan (No.6304901, No.6501718), the United States (US 11,959,148 B2), and South Korea (10-2025-0019722).*

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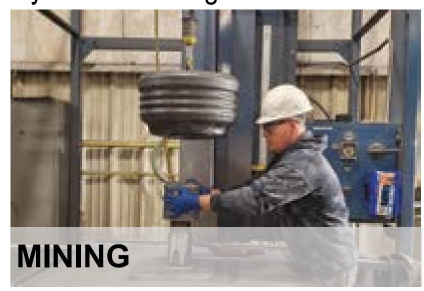

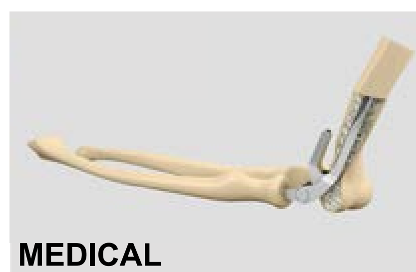

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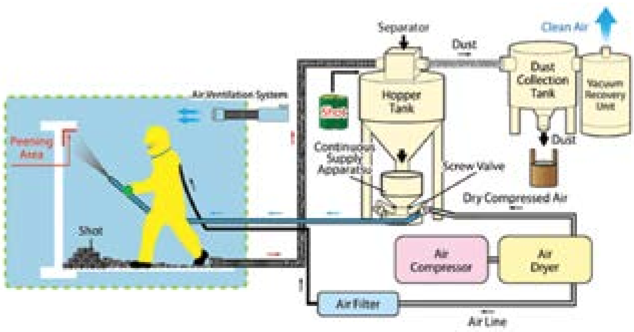

Fig.5 Circulating shot peening method

4. Post-defect maintenance for cracked areas

4.1 Comparison of crack closure treatment with conventional methods

Post-defect maintenance methods for fatigue cracks are summarized in Table 2. Conventional techniques include:

- grinding out small cracks using a grinder.
- installing bolted steel plate joints to bypass stress at the crack location.

Table 2 Post-defect maintenance methods for fatigue cracks

	Conventional technology		New technology
	Rotary Grinder	Bolted Steel Plate	Portable Pneumatic Needle Peening (PPP)
Feature	Cracks that have occurred from weld toes are removed by cutting, and the shape is made smooth to reduce stress concentration.	Bolted Steel Plate is bolted steel plate using high-strength bolts to bypass the stress at the fatigue crack location.	A portable pneumatic needle peening device is used to strike and close microscopic cracks found at the weld toes.
Constructability	The work requires personnel skills, because it must be carried out under vibration caused by the traffic load. It is difficult to access the narrow areas because of device size.	Sufficient space is needed to install the bolted steel plate and tighten the bolts. On-site drilling of holes is required.	The system can apply a constant impact force to the target area with a certain degree of flexibility in the construction angle, allowing access to narrow areas. Moreover, the device enables stable operation regardless of the operator's skill level. It is also equipped with a vibration-absorbing mechanism that reduces the risk of vibration-related disorders for the operator.
Number of constructions possible per day*1,*2	8 Location/day	3.3 Location/day	**23.9** Location/day
Cost*1,*2 (per location)	$161	$706	**$50**

*1) Calculation are based on NETIS(MLIT's New Technology Information System) unit price data
*2) Calculated at 150 yen/1 dollar

Grinding requires a high level of operator skill to avoid over-grinding and cannot be applied in tight spaces where access is restricted. Installing bolted joints takes time from crack detection to installation and tends to increase the cost per repair location. Furthermore, on-site drilling is required with strict tolerances, posing a risk of cross-sectional loss in structural members.

4.2 Methods implemented in this paper

The needle peening method proposed in this paper closes fatigue cracks by inducing plastic flow and generates compressive residual stress. The system uses a 60 mm-long needle pin with a tip curvature radius of 1.5 mm, enabling access to narrow areas such as scallops. Moreover, the device is equipped with a control box that regulates compressed air flow to control the needle impact force, allowing stable operation regardless of the operator's skill level. When applied to fatigue cracks that have not yet reached the base metal, this method can extend the fatigue life of the component by a period equal to or longer than the time it took for the crack to form as shown in Fig.6[5)]. In this construction, since the cracks had not progressed to the base metal, the method provided advantages in both construction speed and cost. By adopting this technique, fatigue cracks can be repaired quickly and cost-effectively, enabling efficient and effective post-defect maintenance.

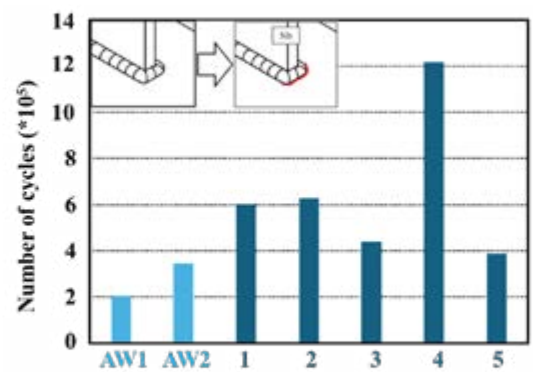

Fig.6 Effect of PPP treatment [5)]

4.3 Implementation procedures

The construction process is shown in Fig.7. The locations and extent of the cracks were identified in advance using MT. Before the treatment, the areas to be peened were marked with a special pen-type highlighter (PEENSCAN PEN 220-6) from Electronics Inc. to visually confirm whether the treatment had been properly applied. Peening was performed on the crack area, within ±2 mm of the crack line, and a black light was used to detect any untreated regions. As shown in Fig.6, this method is expected to be highly effective in extending the service life of structures by repeatedly striking and closing fatigue cracks[5)]. If any untreated areas were found, the cracks were retreated to ensure complete closure. Finally, penetrant testing (PT) was conducted to confirm that all treated areas had been fully closed.

Fig.7 Crack closure treatment status

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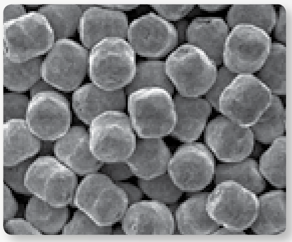
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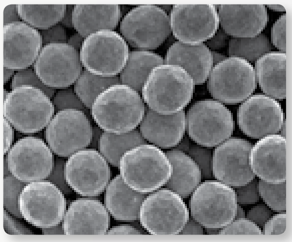
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5. Preventive maintenance for areas where fatigue cracks are expected to occur

5.1 Circulating shot peening process

Preventive maintenance methods for welded joints to avoid fatigue cracks generally fall into two categories:

- inducing compressive residual stress to counteract tensile residual stress
- relieving structural stress concentration

In this paper, the circulating shot peening method was adopted to introduce compressive residual stress into welded joints and thereby improve fatigue strength. The circulating shot peening method utilizes the same circulating blast method® used during repainting for paint removal. By replacing the abrasive media with conditioned cut wire conforming to JIS G 0951, and using existing scaffolding and protective equipment, this method can be implemented efficiently. It is an environmentally friendly maintenance technology for existing steel bridge welded joints, enabling the recovery and reuse of shot. This method is less dependent on operator skill than grinder finishing, and consistent construction quality can be achieved by managing the shot and peening conditions. Fatigue test results[6)7)8)] on out-of-plane gusset welded joints show that this method improves fatigue strength from FAT50 to FAT90, according to the classification defined by the International Institute of Welding (IIW) as shown in Fig.8. These results satisfy the fatigue design curves proposed for HFMI treatment in the IIW recommendations[9)].

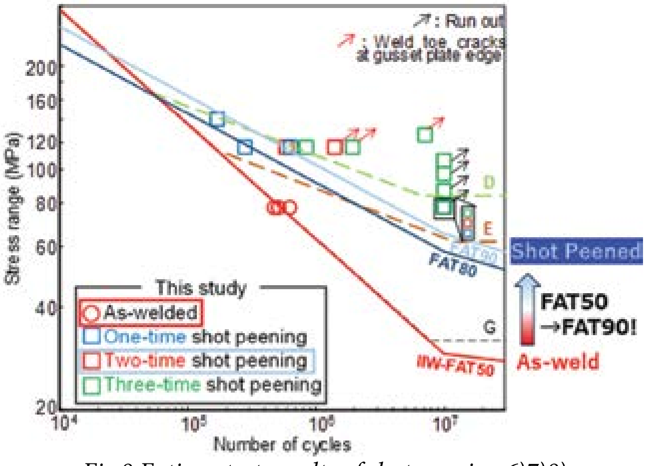

Fig.8 Fatigue test results of shot peening 6)7)8)

5.2 Implementation procedures

The construction process is shown in Fig.9. Before shot peening, a fluorescent tracer was applied to the target areas. After peening, coverage was inspected using UV-CC (Coverage Checker, UV light version) manufactured by Toyo Seiko. The advantage of UV-CC is that it enables accurate coverage measurement even in low-light environments. The inspection process is shown in Fig.10. Shot peening was

Fig.9 Circulating shot peening method status

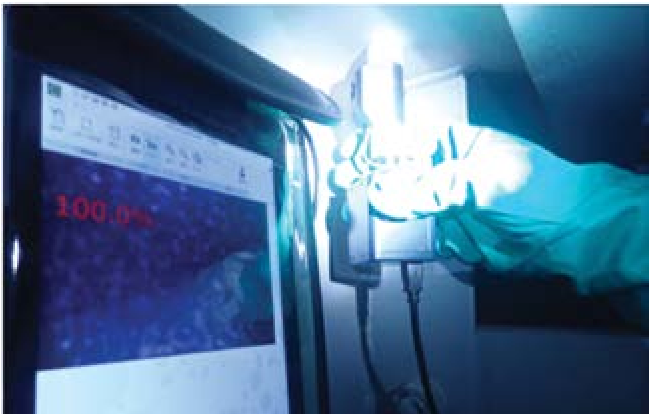

Fig.10 Inspection with UV-CC

carried out under treatment conditions (a coverage rate of 90% or more and a nozzle speed of 72 seconds per meter (Table 3)) that satisfy the fatigue test results shown in Fig.8.

Table 3 Condition of shot-peening

Inner diameter of nozzle	8mm	
Degree of rust	ISO Sa2.5	
Shot	RCW10PH	
	Hardness	600HV
	Diameter	0.8–1.0 mm
Compressed air	Over 0.6 MPa	
Shot coverage	Over 90%	
Shot distance	5–10 cm	
Nozzle angle	60-80 degree	
Shot flow	7 kg/min	
Roughness	Under 80 μm	

As of the end of April 2025, the implementation record for the Portable Pneumatic Needle Peening and Circulating Shot Peening methods by Yamada Infra Technos Co., Ltd. is as follows:

- Portable Pneumatic Needle Peening
  Total: 5 projects
  MLIT projects: 4
  Expressway company projects: 1
- Circulating Shot Peening Methods
  Total: 29 projects
  MLIT projects: 15
  Expressway company projects: 7
  Local government projects: 6
  private contractor projects: 1

7. Summary

Reinforcement with bolted steel plate joints has been a widely adopted post-defect maintenance method for repairing fatigue cracks in steel bridges. Alternatively, the simpler repair method presented in this paper can be applied to cracks found during repainting work, helping to bridge maintenance costs. The effectiveness of the crack closure treatment can be verified through statutory inspections conducted every five years. This approach allows post-defect maintenance costs to be reallocated toward preventive maintenance thereby further promoting a shift to preventive maintenance practices. The post-defect and preventive maintenance methods described in this paper are expected to be applied to other bridges in the future.

1) "Current and Future of Aging Social Capital", Infrastructure Maintenance Information, MLIT, https://www.mlit.go.jp/sogoseisaku/maintenance/02research/02_01.html, 10 Apr 2025. (In Japanese)
2) MLI : MLIT Infrastructure Life Extension Plan (Action Plan), 2021. (In Japanese)
3) MLIT: MLIT Road Inspection Manual, 2024. (In Japanese)
4) Chitoshi Miki et.al.: Repair of Fatigue Damage in Cross Bracing Connections in Steel Girder Bridge, Structural Eng, vol.6, No.1, 31s-39s, pp.53-61, 1989.3.
5) Koji Kinoshita et.al.: Fatigue Strength Improvement and Fatigue Crack Closure by Portable Pneumatic Needle-Peening Treatment on Welded Joints, International Journal of Steel Structures, Vol.19, No.3, pp.693-703, 2019.
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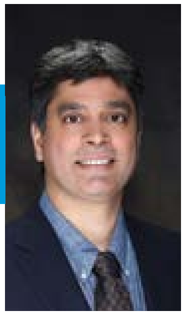

AN INSIDER'S PERSPECTIVE
Kumar Balan | Blast Cleaning and Shot Peening Specialist

Misconceptions in Shot Peening

To err is human, to forgive, especially in shot peening, might need a new saturation curve! Much as we discuss peening fluently within our circles, fundamental concepts of the process continue to be misunderstood even among regular users. Though users that operate the process with strict conformance to specifications such as AMS 2430 and 2432 are expected to have a better understanding of the process, I have noticed gaps there as well.

In this article, we shall discuss some of the common misunderstandings I have seen in our industry. Misconceptions range from deflecting the Almen strip and referring to the arc height as intensity, to several other areas of equal, fundamental significance. The purpose of our discussion is to help current users and those that will be specifying new peening equipment in the future to make informed decisions.

Saturation Time "T" and Cycle Time

Unlike in aerospace, automotive applications are highly motivated and driven by throughput or production volumes. Though I do not intend diminishing automotive users' earnestness in peening a component correctly, I have often seen automotive components either under- or over- peened. Acknowledging the perennial time constraint within this industry, their actions are not surprising. "More" and "faster" are key words. On top of that, the universal statement, "we have always done it this way" is often offered to defend their actions. Our discussion is geared to all such users.

Assuming you have a developed a saturation curve for your process which is re-tested regularly, time "T" from the curve is defined as the time your process has taken to achieve saturation on the "test strip" and under those specific set of process parameters such as air pressure or wheel speed and media flow rate. This is **not** the cycle time to peen your component to. In fact, your process has not yet introduced the component into your machine. You have only dealt with the Almen strip to develop this saturation curve. So, how long do you peen your actual component? The actual peening time is the duration it takes to visually identify 100% (98% is acceptable) indentation on your component. This can be established by visually examining the part at repeated intervals by interrupting the cycle. After assuring yourself of 100% coverage, repeat the process to reconfirm and only then appoint that as your cycle time. It is important that you continue to inspect the peened components at regular intervals even in an established process. Blast machines are dynamic and shifts due to wear of machine components are common.

As an Applications Engineer, I used to cringe when an automotive end user stipulated cycle time and threatened unreasonable penalties if that was not met. My best guess usually was a conservative one, but the valid answer was (and continues to be), "we will know only when we peen the actual part in a production machine and check visually for coverage." Nobody likes uncertainty, especially automotive. However, the solution to coverage time is not simple.

An associated discussion with cycle time and coverage is related to over-peening a component. I have met customers that believe that it is acceptable to peen for a longer duration than required. To add to their belief are process sheets that call for greater than 100% coverage. Unless your process sheet calls for greater than 100%, please do not peen in excess. You run the risk of damaging your part by altering the surface topography of the component. Stress risers are not always visible to the naked eye but are a common occurrence on a component that has seen more than its deserved share of peening media!

Cleaning and Peening Machine

An end user during a recent visit proudly introduced me to their "peening and cleaning" machine that did double duty during lean times for either process. If your former cleaning machine has been retrofitted with process control for peening components, you would be ill-advised to go back and forth between the two processes in the same machine. Even though assessment of cleaning result might be subjective, cleaning machines have a clear purpose! The purpose is to eliminate rust, scale, or similar contaminants at a designated cycle time from the component and prepare it for a downstream coating.

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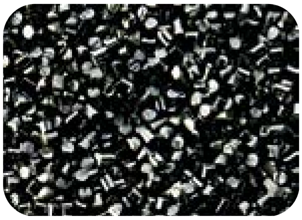

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devices in the machine to ensure that your peening results are repeatable, consistent, and accurate. Among other aspects, this involves keeping the media size consistent and free from contaminants. On the other hand, blast cleaning is a process that thrives on a work mix which is defined as a mix of small and large sized particles. In some situations, the work mix might involve angular grit particles as well. Such angular particles, if mixed with your peening media stream, could impact the component being peened with nicks that could potentially pose as stress risers leading to eventual failure.

The requirements for shot peeing are starkly different. When your peening project volumes are running low and to keep your machine utilized all the time, if you choose to run components in the machine with the purpose of cleaning, you are setting yourself up for difficulty in a future shot peening project in the same machine. Contaminants from the cleaning process such as, scale, rust, etc., could result in FOD (foreign object damage) and be disastrous to your peening operation.

On a related subject, if a component covered with contaminants such as scale and rust is presented for shot peening, instead of impacting the substrate where the residual stress needs to be imparted, you will have scale that is installed with the residual stress meant for the component's substrate. This will be of no benefit given that the scale will flake off at some point.

Plotting Saturation Curves

Though saturation curves do not have to be (re)plotted regularly, with a verification strip being adequate, it is advisable to run saturation curves at least every year. A large prime requires plotting saturation curves every six months unless the process is clearly documented. This is a dynamic process with machine components wearing regularly. Therefore, do not adopt a "once and done philosophy" with your saturation curve. Saturation curve must be re-plotted when a machine issue is narrowed down to bad media, faulty gage, or anything else that could influence the result of intensity. must be peened and measured every shift or with change in the batch of parts.

Machine Flexibility

When specifying a new machine, particularly centrifugal wheel blast for shot peening, please consider the following. It is essential that you have the flexibility to alter the shot velocity and shot flow rate. These are critical parameters that have a major influence on peening results. A machine where these cannot be varied renders your operation extremely rigid and incapable of critical adjustments to tune your process as your machine components wear. Moreover, if you need to shot peen a different component than the one that your machine was originally purchased for, such flexibility helps you repurpose it with relative ease. As compared to wheelblast, process flexibility is easier to achieve in an airblast machine where altering the air pressure and media flow rate leads you to this goal.

Finishing after Shot Peening

Shot peening is the last stage of a manufacturing process. If your work instruction calls for dual or double peening, that is considered continuation of your peening process even though the purpose may partially be to achieve a smoothen surface.

Most specifications, including AMS 2430, will allow fine finishing if it is limited to removing material to a maximum of 10% of the A scale intensity value. Anything more than that is to the detriment of the previously installed residual compressive stress. AMS 2430 also lists the maximum temperature limitations from any post peening thermal process. Therefore, if you are painting your component that has already been peened, refer to these temperature limitations since your process might involve curing the painted components using heat.

Wheel or Air?

I came across a specification from a prominent landing gear manufacturer that restricts processors to use centrifugal wheel type media propulsion for peening landing gear components. Though end users do not need to cite reasons for their choices of media propulsion systems, it is important for you to be aware if you are at the receiving end of such limitations.

Before you embark on a project, survey your potential customer base about the use of a particular type of media propulsion, even if both or more types will satisfy the requirements of the application. With reference to wheel blast machine, please be aware that common sizes of classifiers up to 48-inch diameter will not be capable of handling 100% of your media flow, unless you are peening with a single wheel driven by a 15 or 20 hp motor (media flow rate limitations). However, specifications will permit continuous classification of media and 100% is not a necessity, in which case sampling of the total media flow (about 25%) is common practice. Be mindful that you do not overload your classifier and diminish its sieving efficiency. For most air blast machines, the media flow rate is low enough to allow for 100% classification even on smaller diameter classifier screens.

Multiple Media Sizes – One Machine

Media size is determined by the intensity of your process and provided to you in the drawing. Certain applications require different areas of the part (ID and OD) to be peened to different intensity values. Or you might be multi-purposing the machine for a family of parts, some of which might need to be peened with different shot sizes. The above situations are only applicable for airblast machines (and a specific type of wheelblast machine for etching mill rolls—

(Roll-etch machines are not commonly used and will not be part of our discussion). When more than one media size is used in a shot peening machine, you should plan to mitigate cross-contamination. This is minimized by selecting media sizes that have at least a one size buffer between them (e.g., S-110 and S-230). Keep the sizes distinctly different in terms of storage hoppers and blast tanks. Do not rely on "flushing/draining" the tank of one size of media and loading with a second size during switchover. Though this may have been sold to you as an economical means of getting around using multiple sizes, dedicated blast tanks and hoppers are the most effective means to minimize cross-contamination.

In addition to media sizes, certain applications require peening with steel shot followed by glass bead or ceramic. This requires magnetic separation in your machine since cross-contamination both ways are not acceptable. You must confirm with your end user about them permitting this process to continue in the same machine. Some OEMs require distinct machines for metallic and non-metallic media.

Almen Strips
Shot peening causes plastic deformation on the component surface. A peened strip displays physical deflection as soon as the four constraining screws are loosened. Once deflected, it remains in that state and cannot be re-fastened on the test block given the arc that it has deformed into. A strip once peened cannot be re-used and every data point will require a new Almen strip.

Rotary flapper peening is a technique where the strip is fastened on a magnetic holder. Since subsequent fastening for additional data points is not dictated by screw style fasteners, the Almen strip can be re-used in flapper peening.

Where Do We Go From Here?
It is not my intention to leave you with the impression that peening operations are fraught with mistakes and misunderstandings. "Top five things my customers are doing right" is a discussion published in *The Shot Peener*, Spring 2015, exactly a decade ago. The list identified advanced customers that validated their peening process using X-ray diffraction. Other positive user attributes included their comprehension of the true purpose of peening, consideration to maintaining constant impact energy, and their emphasis on techniques to monitor and control parameters to get their process deliver consistent and repeatable peening results. My goal is to proliferate this message within the shot peening community in all industry sectors. The benefits of this process are many and when done right, with realistic expectations, it opens up the possibility for further development. ●

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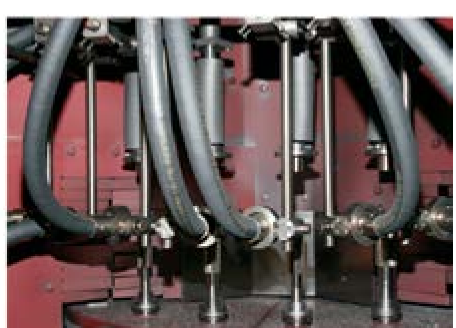

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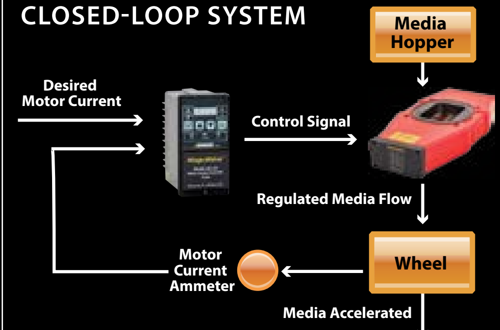

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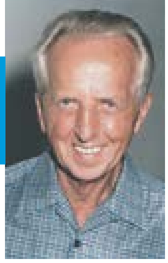

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Estimate Compressed Layer Depth by Using Almen Peening Intensity

INTRODUCTION
Shot peening induces a surface layer that contains compressive residual stress. It is this compressed surface layer that is largely responsible for improved fatigue performance of components. The depth of the layer is therefore of pivotal importance to users. X-ray stress analysis, involving multiple layer removals, is the most accurate method of determining the depth of the compressed layer. Indirect methods, such as micro hardness profiles, also involve multiple layer removals. Both methods are tedious and expensive and are carried out after peening.

Almen peening intensity is necessarily available for every peening operation. This article describes how Almen peening intensity can be used as an acceptable guide to the depth of the compressed surface layer.

Most shot-peened components go directly into service. Occasionally, components are fine-finished after peening. This is done either to change the smoothness of the surface or to induce minor dimensional changes. Fine-finishing processes include polishing, lapping, honing and sanding. AMS 2432B provides some guidance as to the amount of material that can be removed without severely affecting the property enhancement provided by shot peening.

This article describes the principles that lie behind the limitation of surface removal by fine-finishing. Essentially only a small fraction of the compressed surface layer should be removed. The thickness of the compressed surface layer is rarely measured, whereas the peening intensity is, of necessity, always available. AMS 2432B attempts to use peening intensity values as a guide to the amount of material that can be removed. To some extent the article is complementary to some sections of AMS 2342B.

DEPTH OF COMPRESSED LAYER
The depth of the compressed surface layer, **D**, is of primary importance with respect to fine finishing – it controls the amount of material that can safely be removed. A typical residual stress profile is shown as fig.1. **D** varies with both peening intensity and hardness of the component material. 10% of the depth, **D**, would seem to be a reasonable maximum amount that could be removed without any significant adverse effects on service performance.

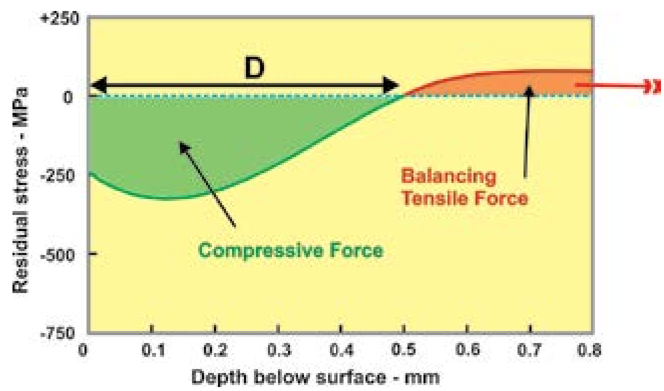

Fig.1. Typical shot peening residual stress profile having a compressed layer depth, ***D****.*

RELATIONSHIP BETWEEN DEPTH OF COMPRESSIVE STRESS AND ALMEN 'A' PEENING INTENSITY
It is reasonably obvious that the depth of the compressed surface layer will increase with increase of peening intensity. Also obvious is that the depth will be greater for soft materials than it will be for hard materials – for a constant peening intensity. Table 1, which uses some of the values in Table 2 of AMS 2342B, quantifies the effect of material strength.

In Table 1, a fixed Almen 'A' intensity, 0.20 mm, has been applied to a range of materials. For the values given, the average measured depth of 0.182 mm for **D** is certainly close

Table 1. Depths of Compressive Stress, D, for peening intensity of 0.20mm using 'A' strips

STRIP TYPE	A
Intensity - mm	**0.20**
Material	**D - mm**
Aluminum	0.25
Titanium	0.18
Steel < 1379 MPa	0.20
Steel 1379 MPa	0.13
Nickel Alloys	0.15
Average	**0.183**

to the applied peening intensity of 0.20mm Almen 'A'. This gives us the very useful relationship that:

The depth of compressive stress is, on average, approximately equal to the Almen 'A' peening intensity.

The values given in Table 1 refer to a specific peening intensity – 0.20 mm A. It is, however, reasonable to suppose that the depth, **D**, will be linearly proportional to peening intensity over the range of allowed range of peening intensities. This effect is illustrated by fig.2 – for which the 0.20 mm 'A' values have been extrapolated.

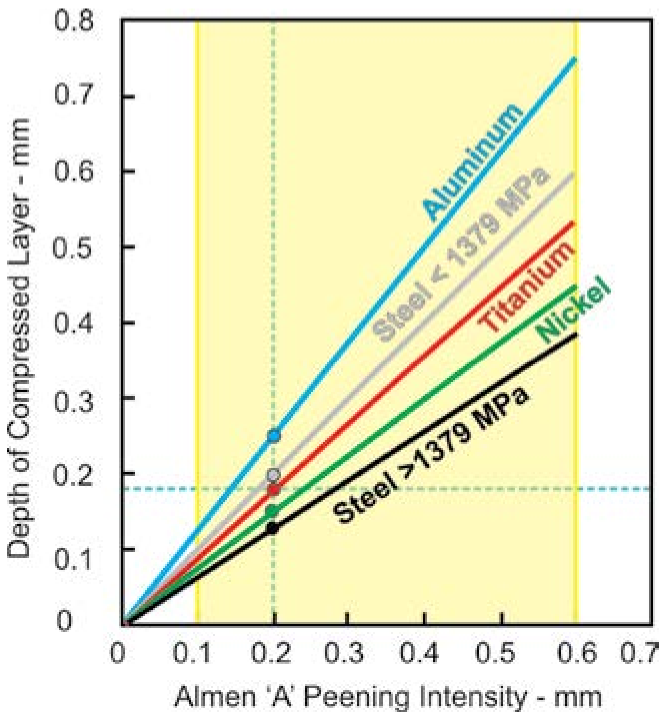

Fig.2. Projected variation of compressed layer depth with Almen 'A' peening intensity.

A second important observation is that:

The range of compressed layer depths (in Table 1) is in a ratio of less than 2 to 1.

To many shot peeners it might appear surprising that the range of depths is so small—given the large range of corresponding material strengths. It has, however, been shown (TSP 2004) that the diameter of a peening indent is inversely proportional to the fourth power of the material's Brinell hardness. A range of 2 to 1 of indent diameters would therefore need the hardness to vary by a factor of 16 (2^4 = 16). Compressed layer depths are directly proportional to indent diameters and Brinell hardness ratios are very similar to tensile strength ratios. For the materials given in the table the range of tensile strengths is about 17 to 1 – which is very close to 16 to 1. Extending that argument, a range of 3 to 1 of compressed layer depths would require the tensile strengths to vary by a factor of 81 to 1 (81 being 3^4) which covers the full range of tensile strengths for available shot-peened materials.

Fig.3 illustrates the relationship between indent diameter and compressed layer depth. For a soft material, **A**, the indent diameter, $\mathbf{d_A}$, and the compressed layer depth, $\mathbf{D_A}$, are both less than those for a hard material, **B**, - $\mathbf{d_B}$ and $\mathbf{D_B}$.

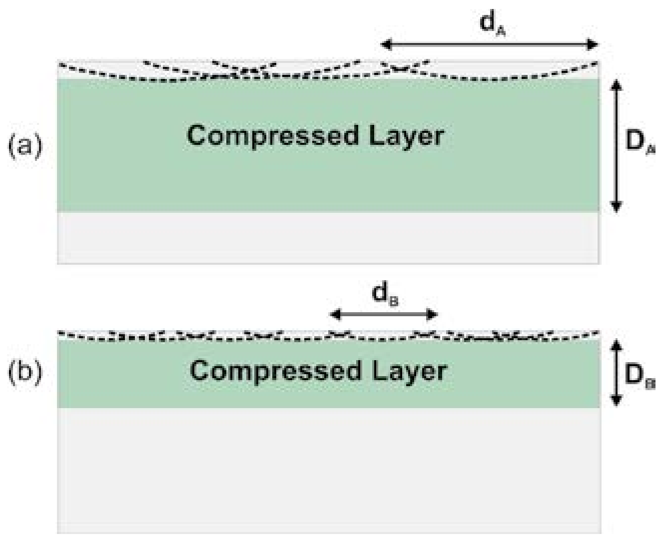

*Fig.3. Doubling indent diameter doubles compressed layer depth, **D**.*

Fig.2 indicates that for the compressed layer depth, D, that:

(1) D is approximately equal to the Almen 'A' peening intensity for materials of average tensile strength,
(2) For very soft materials, such as aluminum, D can be as much as 50% more than the Almen 'A' peening intensity and
(3) For very hard materials, such as high-strength steels, D can be as little as half of the Almen 'A' peening intensity.

Going from peening intensity plus 50% down to half of peening intensity is a range of 3 to 1. That, as mentioned earlier, corresponds to a range of 81 to 1 in tensile strengths of component materials.

RELATIONSHIP BETWEEN DEPTH OF COMPRESSIVE STRESS AND TYPE OF ALMEN PEENING INTENSITY

Almen 'N' and Almen 'C' strips are also used to measure peening intensity–though not as often as are Almen 'A' strips. Table 2 (page 34) uses all of the values published in Table 2 of the AMS 2432B Specification. Almen 'N', 'A' and 'C', intensities of 0.20 mm have been applied to a range of materials and corresponding depths of compressive stress are presented.

The ratios of 3.14 (for A/N) and 2.95 (for C/A) are close to the "conversion factors" specified in J442. Those are that

Table 2. Depths of Compressive Stress (AMS 2432B values)

STRIP TYPE	N	A	C
Intensity-mm	0.20	0.20	0.20
Material	Depth of Compressive Stress - mm		
Aluminum	0.08	0.25	0.69
Titanium	0.05	0.18	0.46
Steel < 1379 MPa	0.06	0.20	0.64
Steel > 1379 MPa	0.05	0.13	0.38
Nickel alloys	0.05	0.15	0.51
Averages	**0.058**	**0.182**	**0.536**

"C strip reading x 3.5 = A strip reading and A strip reading x 3.0 = N strip reading". Hence, as guiding principles, it can be postulated that:

(1) D is approximately equal to one-third of the Almen 'N' peening intensity for materials of average tensile strength and

(2) D is approximately equal to three times the Almen 'C' peening intensity for materials of average tensile strength.

It has already been shown that: (a) for very soft materials, such as aluminum, **D** can be as much as 50% more than the Almen 'A' peening intensity and (b) for very hard materials, such as high-strength steels, **D** can be as little as half of the Almen 'A' peening intensity. Extending this to 'N' and 'C' strips allows the construction of the graphs shown as figs.4 to 6.

An approximate compressed layer depth can be read off from the appropriate figure using a measured value of Almen peening intensity. For example: in fig.4 a measured Almen peening intensity of 0.5 mm 'N' indicates that the compressed layer depth will be between 0.08 mm and 0.25 mm – depending on component hardness. If the component is known to be of average hardness the depth would be indicated as being 0.15 mm.

PERMITTED LAYER REMOVAL BY FINE FINISHING

A 10% removal of the compressed layer depth would appear to be a reasonable maximum. There are, however, some specifications that provide definite limits – notably AMS 2432B. This allows for the fact that the actual depth of the compressed layer is not usually measured. Instead it relies on the readily available Almen peening intensity values – as stated earlier. A further restriction requires that "… evidence of peening impressions shall remain after material removal."

Specified Amount of Layer Removal

AMS 2432B states: "For parts with a specified minimum tensile strength of 220 ksi (1517 MPa) and over, no more than the equivalent of 5% of the specified minimum "A" intensity …shall be removed from the surface". Hence it would follow

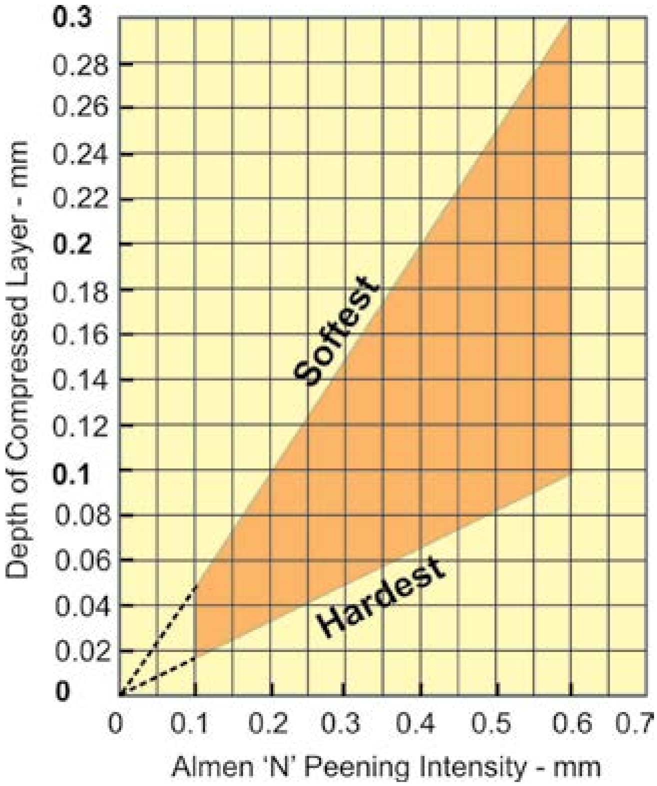

Fig.4. Guideline Diagram for Conversion of Almen 'N' intensity to Depth of Compressed Layer.

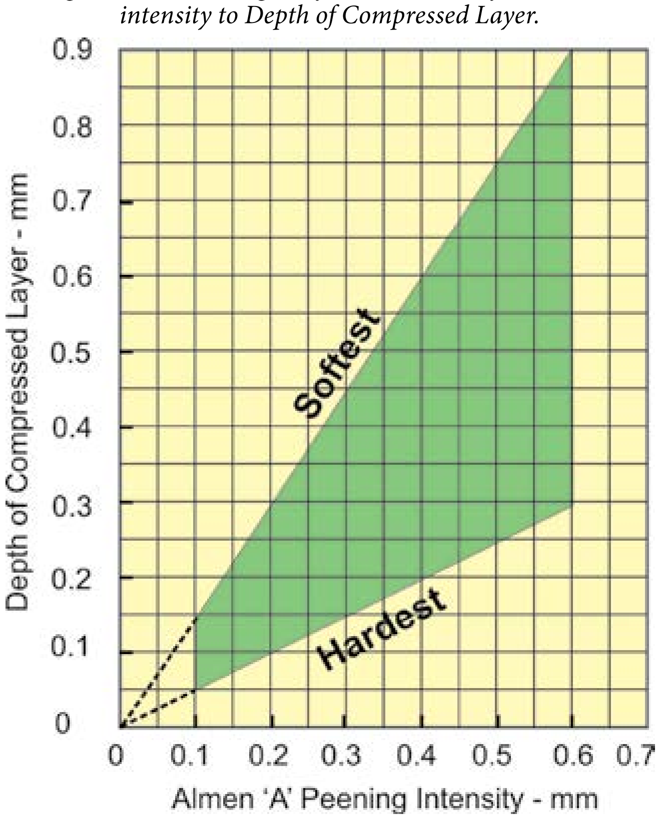

Fig.5. Guideline Diagram for Conversion of Almen 'A' intensity to Depth of Compressed Layer.

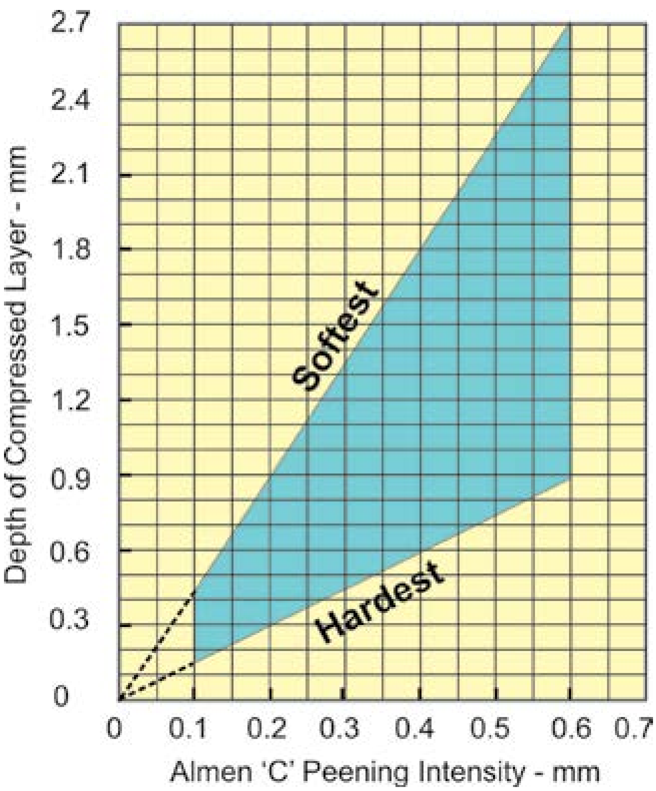

Fig.6. Guideline Diagram for Conversion of Almen 'C' intensity to Depth of Compressed Layer.

that if the specified range was 0.20-0.30mm Almen 'A' then 5% of 0.20 mm would be the maximum that could be removed from components for which the tensile strength was at least 220 ksi (1517 MPa). 5% of 0.20 mm is 0.01 mm. Using fig.5 indicates that the compressed layer depth for very hard materials is about 0.10mm. Removal of 0.01 mm from a layer depth of 0.10 mm corresponds to removing 10% of the layer's thickness.

AMS 2432B also states: "For other parts, no more than the equivalent of 10% of the specified minimum "A" intensity … shall be removed from the surfaces". If the specified range was 0.20 - 0.30mm Almen 'A', then 10% of 0.20 mm would be the maximum that could be removed from components for which the tensile strength was less than 220 ksi (1517 MPa). 10% of 0.20 mm is 0.02 mm. Using fig.5, a compressed layer depth of 0.20 mm appears for materials of average tensile strength. Hence for components of average tensile strength 0.02 mm could be removed, which corresponds, again, to 10% of the compressed layer thickness.

AMS 2432B accommodates the fact that intensity may have been specified using either 'N' or 'C' scales. It does this by using the phrase "… or equivalent "N" or "C" intensity (See 8.6)…" This applies for parts with a minimum tensile strength of 220 ksi (1517 MPa). Section 8.6, Intensity Comparisons, contains the familiar (a) "…Type "A" test specimen deflection may be multiplied by three to obtain the approximate deflection of any Almen test strip Type "N" specimen when shot peened with at the same intensity" and (b) Type C Almen test specimen deflection may be multiplied by 3.5 to obtain the approximate deflection of a Type A Almen test strip when shot peened with at the same intensity". Two examples are:

(1) A specified range of 0.35-0.50 mm Almen 'N' intensity for parts with a minimum tensile strength of 220 ksi (1517 MPa) means that first we must divide the minimum 0.35 mm by 3.5 (giving 0.10 mm) and then divide that by 20 (to give the 5% allowance). This yields 0.005 mm as the maximum that can be removed by fine finishing. Using fig.4 indicates that for an Almen intensity of 0.35 mm 'N' the compressed layer depth would be about 0.058 mm. Removing 0.005 mm from a depth of 0.058 mm is about 9%.

(2) A specified range of 0.30-0.45 mm Almen 'C' intensity means that we multiply the minimum 0.30 mm by three (to give 0.90 mm) and then divide by 20 (to get 5%) giving 0.045mm. Using fig.6 indicates that the compressed layer depth (for hardest material) would be about 0.45mm. Removing 0.045 mm from 0.45 mm is 10%.

Somewhat ambiguously, for "other parts" i.e. of lower tensile strength, AMS2432B refers to its section 8.3.4.2 for guidance on equivalence. That section is, in fact, simply the Table 2 mentioned earlier in this article. For practical reasons it is better to follow the 'equivalence' defined in the previous paragraph. The following two examples refer to "other materials" i.e. less than 220 ksi (1517 MPa).

(3) A specified range of 0.35-0.50 mm Almen 'N' intensity means that again we divide the minimum 0.35 mm by 3.5 to give 0.10 mm. This can now be divided by 10 (to give the 10% removal allowance. Hence we are allowed to remove 0.01 mm. Using fig.4 at 0.35 MM Almen 'N' the compressed depth is about 0.10 mm – for components of average tensile strength. That again corresponds to 10%.

(4) A specified range of 0.30-0.45 mm Almen 'C' intensity means that we multiply the minimum 0.30 mm by three (to give 0.90 mm) and then divide by 10 (to get 10%) giving 0.090mm. Using fig.6 indicates that the compressed layer depth (for material of average hardness) would be about 0.90 mm at 0.30 mm Almen 'C' intensity. Removing 0.090 mm from 0.45 mm is, yet again, 10%.

Evidence of Peening Impressions

AMS 2342B also requires that if fine finishing has been applied then "…evidence of peening impressions shall remain after material removal." It has been shown, in the previous section, that up to about 10% of the compressed layer thickness can be removed by fine finishing. Such an amount can only be removed if evidence of peening remains. This can only be achieved if the peened surface roughness exceeds 10% of the compressed layer depth, **D**.

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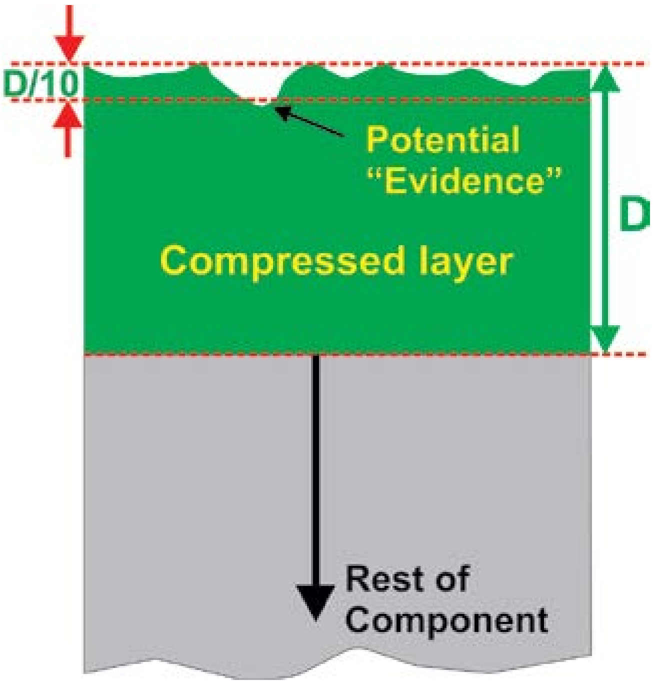

Fig.7. Surface roughness just exceeding 10% of the compressed layer depth, ***D****.*

With 10% of the compressed layer depth, **D**, removed we have the situation represented in fig.8. The required "evidence" of shot peening is indicated in fig.8.

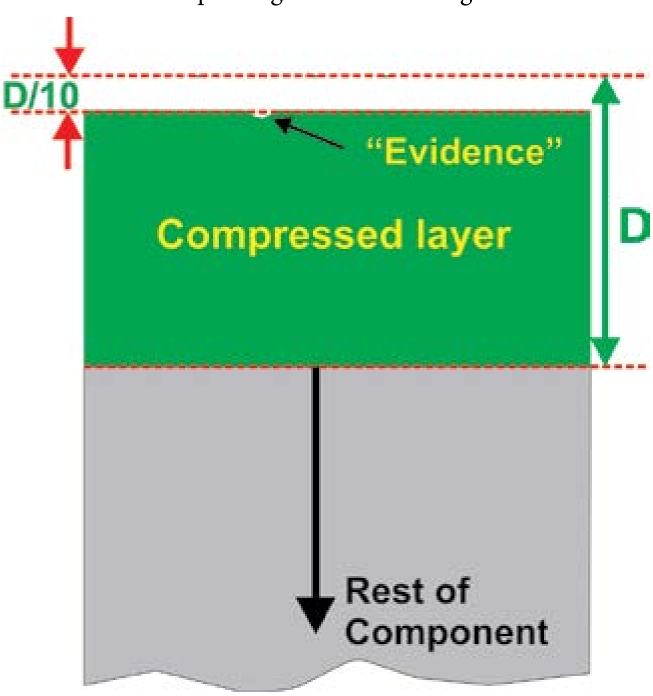

Fig.8. Fine-finished surface with 10% removal of compressed layer depth, ***D****.*

Normally, significantly less than 10% of the compressed layer depth would be removed by fine finishing. It is noteworthy that permitted material removal only involves 'slicing off the tops' of the roughness profile.

Compliance with the requirement to provide "evidence of prior peening" requires some expertise in identifying such "evidence". A simple way to obtain this expertise involves fine-finishing shot-peened Almen strips. Fig.9 shows an Almen 'A' strip that has been hand-polished in just a part of its convex surface - Blu Tack™ being used on the concave surface to provide grip. After just twenty strokes on medium-grade wet-and-dry emery paper the central region was completely devoid of any "evidence" of shot peening. Away from this region "evidence" progressively appears.

Fig.9. Hand-polished Almen 'A' strip showing area of complete indentation removal.

DISCUSSION

It has been shown that reasonable estimates of compressed layer depth can be obtained using the corresponding Almen peening intensity values. Such estimates would be of particular value in the planning stages of specifying a shot peening treatment for new components. It is important to realize, however, that final implementation should involve confirmation. This is classically available using x-ray diffraction techniques. They do require multiple layer removal and are, therefore, necessarily, expensive.

The analysis presented in this article relies entirely on the published values of layer depth versus Almen intensity presented in AMS 2432B. Further evidence can be acquired by comparing individual published values with the diagrams that have been presented.

Fine-finishing of shot-peened components is occasionally necessary. One question that has been asked is "How much of a shot peened surface can be removed without adversely affecting fatigue performance?" This article shows that, by following the AMS 2432B guidelines, less than 10% of the compressed layer depth will have been removed. Removal "slices off the tops" of the roughness 'hills'. These contain a relatively-low level of compressive residual stress. Fine finishing, of itself, introduces a high level of compressive residual stress. It follows that controlled fine finishing should not reduce fatigue strength and might even improve it.

Editor's Note: This is article is reprinted from the Spring 2014 Shot Peener magazine.


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• Determination of velocity over flight angle
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Toyo Seiko Celebrates 50th Anniversary

TOYO SEIKO is celebrating its 50th anniversary in 2025. The company was founded in 1975 as a manufacturer of cut wire media for mechanical descaling machines for wire rods manufactured by its parent company, Miyazaki Seiko.

After 10 years, Toyo Seiko entered the shot peening field, and in 1989 we completed manufacturing Japan's first high-hardness conditioned cut wire shot by collaborating with Toyota Motor Corporation. Since then, we have expanded our business by focusing on the shot peening field.

Under the philosophy of "Make anti-shot-peening fans to fans," we have developed original inspection equipment such as Coverage Checkers, various peening devices such as air-type needle peening devices, and high-durability cut wire shot to satisfy our customers' needs and contribute to the peening industry's development.

In 2006, we began the contract peening processing for aircraft parts as a shot manufacturer, and in 2015 we were able to expand this business into the Mitsubishi Regional Jet project which Mitsubishi Heavy Industry started.

Since 2010, we have been proactively working to expand our business overseas in response to the globalization of our customers. We have established our first overseas affiliate in Thailand in 2011 and another one in the United States in 2014. These expansions enable us to produce our cut wire meet to customers' demand worldwide.

As a result, our annual sales volume has exceeded 15,000 tons, and global market share has grown to 35%. In addition, Toyo Seiko has been proudly selling the Electronics Inc. (EI) Almen strips and MagnaValve® in Japan as an official sales distributor since 2005 and we have sponsored EI's shot-peening workshops in Japan for decades.

Our company seeks new growth with the vision of "Continuous contribution to the peening society as an ambassador for surface enhancement technology." We aim to be a company that can be trusted as an indispensable partner by our customers by providing innovative imagination while flexibly responding to changes in the market.

Furthermore, we commit to be a company that is responsible for both people and society by developing environmentally friendly equipment, such as the Dust Solidify Device that helps reduce CO2 emissions, and creating a work environment where people can feel happy.

Ceremony

Flower art gift from one of our banks to celebrate our 50th anniversary. The gift nicely shows the TOYO SEIKO 50th anniversary logo.

Gift from TOYO

The 600 Series MagnaValve

The Smart Valve with SteadyFlow Technology

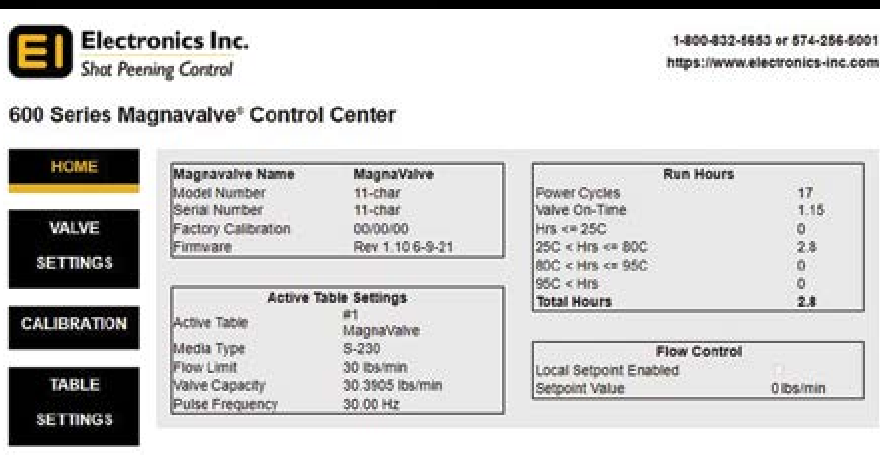
The 678-24
for air-blast machines
Patent Pending

The 678-24 MagnaValve has an embedded web page, a built-in sensor that measures flow rate, a built-in servo, and a flow rate jump-to feature that provides accurate and repeatable flow rates. The flow jump-to feature starts media flow at the desired flow rate instead of ramping up to the desired rate.

MagnaValve®

1-800-832-5653 or 1-574-256-5001
www.electronics-inc.com

MagnaValve is a registered trademark of Electronics Inc.



The Home Screen of the 678-24's web page—its web page is user-friendly and intuitive.

The 678-24 has the same features that make MagnaValves the most dependable and hard-working media valves on the market today, including:

- **Flows most ferrous media**
- **Compliance to specifications is readily attainable**
- **Normally closed**
- **No moving parts for low-maintenance operation**
- **Trusted by OEMs and end-users worldwide**

Electronics Inc.
Shot Peening Control

Mec Shot Manufactures Blast Cleaning Machine for Pantograph Contact Strips

A Pantograph Contact Strip is an apparatus mounted on the roof of an electric train, tram or electric bus to collect power through contact with an overhead line.

The carbon strip's friction and wear properties are affected by the electric current and the wear rate increases with higher electric intensity. Surface roughness plays a crucial role in the pantograph-catenary system used in electric trains. Higher roughness can lead to higher friction, which might increase wear on the pantograph strips, but also provides better grip, improving current collection stability.

Recently, MEC SHOT has designed, manufactured, and supplied a Special Semi-Automatic Pressure Blasting Machine to blast clean pantograph contract strips.

MACHINE FEATURES

- Acoustic Cabinet
- Dual Pressure Tank for Continuous Blasting
- Pneumatic Operated Grit Valves
- Pneumatic Regulator for Air Pressure
- Photo Sensor for Operator Safety
- Zero Speed & Media Level Sensors
- Screw Conveyor Recovery
- Bucket Elevator System
- Horizontal Gun Reciprocation
- Automatic Door Open & Close through Pneumatic Cylinder
- Safety Interlock during Power Failure
- PLC & SCADA System
- Unlimited Recipe as per Job Profile
- CT Dust Collector
- Manometer for Dust Collector

The Industry-Standard Tool for Measuring Intensity

The World's Finest Almen Gage

The #2 Almen gage from Electronics Inc. offers:

- **Patented magnetic grip and end stops (U.S. Patent No. 5,297,418)**
- **An easy-to-read display**
- **0.001 mm (0.0001") resolution**
- **SPC data port**
- **Convenient battery replacement**
- **Ergonomic design**
- **One-year warranty**
- **Calibration services or block kit available (U.S. Patent No. 5,780,714)**

Use the EI Almen gage with EI Almen Strips and J442 Almen strip holder to ensure process repeatability

Also available: The patented Mini-Strip Gage and Mini-Strips

Electronics Inc.

Shot Peening Control

1-800-832-5653 or
1-574-256-5001

www.electronics-inc.com

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Mishawaka, Indiana 46545