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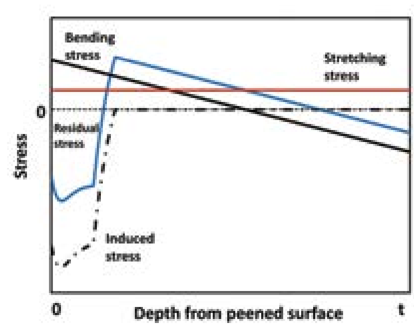
The Shot Peener

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

Purdue University School of Materials Engineering

Host of the 15th International Conference on Shot Peening



A graph from the shot peening research paper on page 14.

A how-to tip when attaching or removing pipe fittings: Use two pipe wrenches—one on the valve pipe and one on the pipe fitting.

Mec Shot's machine with X-Y manipulator.

THE SHOT PEENER
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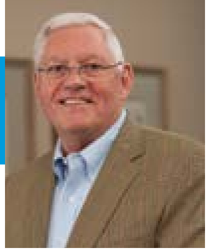

OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

EI Celebrates 50th Year Anniversary

I would like to thank all our employees, customers, distributors, and vendors over the years who have contributed to our continued success. I am truly grateful for the loyalty, contributions and sacrifices made to that end.

We have been blessed to be in a worldwide industry that is like family. We had customers, vendors and competitors from all over the world who weathered 90˚F/32˚C temperatures to join us in Mishawaka for our 50th anniversary in business. We had guests from Japan, Germany, Mexico as well as far corners of the United States to help us celebrate our golden milestone.

As we prepare for the next 50 years, I think we are just getting started. Surface technology and material science has much to contribute to making the world a better place. We should all be proud of our contributions.

Our industry may be only a pebble in the ocean but we are making a ripple. Cheers and thank you.

THE SHOT PEENER

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Electronics Inc.

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David Bahr | Conference Chairman of the 15th International Conference on Shot Peening | Info-icsp15@purdue.edu

ICSP15 Update

WE'RE LOOKING FORWARD to hosting ICSP15 at Purdue University School of Materials Engineering on September 22-25, 2025.

With this in mind, we wanted to give you an update about the progress that's been made to prepare for the conference.

First, the conference website (www.icsp15.org) has been operational for some time and is capable of accepting your abstract(s) for the technical program.

Professor David Johnson (ICSP15 Vice Chairman for the technical program) and myself have already reviewed and accepted a number of your submissions.

That said, we're looking forward to having a robust slate of presentations from both academia and industry. The deadline for abstracts will be in the spring of 2025, similar to the timing of previous ICSP meetings, and the website will update with the deadline date this fall.

Next, the Local Organizing Committee for the conference has been selected and is comprised of the following people:

- Jennifer Brown – American Axle Manufacturing
- Mike Schmidt – General Electric Aerospace
- Steve Ferdon – Cummins
- Jim Whalen – Progressive Surface
- Eric Rossol – Sinto America
- Kumar Balan – Ervin Industries
- Shota Watanabe – Toyo Seiko

Also, we're pleased to announce that the following companies have agreed to sponsor the conference:

- Presenting Sponsor – Electronics, Inc.
- Opening Reception – Progressive Surface
- Conference Dinner – Sinto America
- Lunch Sponsor – Toyo Seiko
- Lunch Sponsor – Ervin Industries
- Lunch Sponsor – Yamada Infra Technos Co., Ltd.

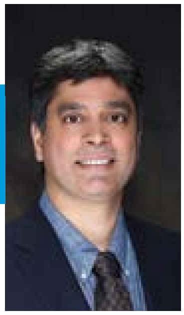
There are a few remaining sponsorships and anyone interested in discussing those and/or the remaining exhibitor spaces should contact ICSP15 Vice Chairman Mark Gruninger at mgruninger@purdue.edu.

For those of you looking at travel this far out, there is now a direct air service from Chicago-O'Hare to West Lafayette (airport code LAF), so getting here may be even easier than we had anticipated.

Unveiled in 2005, The Boilermaker statue pays tribute to the origin of the moniker given to the Purdue football team in 1891 after "the burly boiler makers" thrashed Wabash College 44-0.

The Engineering Fountain is positioned in the heart of campus on the Purdue Mall.

The "Gateway to the Future" arch symbolizes the bright future for Purdue students and graduates.



AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

Future of Wheelblast Peening

Background

The image of a shot peening machine seldom includes centrifugal blast wheels. Instead, it is more common to see blast nozzles articulating in an automated arrangement with sophisticated work handling systems. In an effort to provide a balanced training experience, I start my first class at the shot peening workshops enquiring about the volume of wheelblast machine users in the audience. Along with the small fraction of hands that are raised, I am often greeted with quizzical stares offering validation that I had just introduced them to a new concept!

Though wheelblast machines have been used for shot peening long before nozzles became prominent, their lower population can be attributed to the dominance of Aerospace peening applications. In Aerospace, barring a fraction of wheelblast peening machines for structural components and landing gear, the majority of applications use compressed air type media propulsion. Therefore, it is not surprising that much has been documented and reported on airblast peening techniques and less with blast wheels.

I started my career working with wheelblast machines and later got introduced to airblast. This has provided me the opportunity to understand the subtle nuances of both types of propulsion systems while appreciating the role different process variables play in both, particularly in shot peening. A detailed discussion can be found in a two-series article[1], and I will try to incorporate some new perspectives on such machines through interviews with wheelblast equipment manufacturers and end-users.

Bob Schoen, Director of Technical Services at Blast Cleaning Technologies (BCT) in West Allis, Wisconsin (USA), is a good friend and past work colleague and he was kind enough to contribute to this discussion. An average month has me visiting upwards of twenty customers in multiple industries. Through these visits, in addition to Bob Schoen, I have interviewed several end-users to add to the content of this article. Due to corporate confidentiality reasons, I am unable to list their identities here.

[1] The Role of Wheelblast in Shot Peening – Part I and II, *The Shot Peener*, Spring and Summer 2017.

My goal is to address the following:

(a) key considerations when designing a wheelblast machine suitable for shot peening,

(b) mechanical and controls enhancements between cleaning and peening,

(c) challenges when peening with blast wheels and possibilities to overcome them, and finally

(d) where the R&D dollars are being allocated in wheelblast peening equipment.

Stepping outside of airblast

With the exception of a handful of Aerospace applications identified earlier, wheelblast machines are prevalent in other industries that peen their components. These include Automotive, Mining and Railway to list the major ones. Machine types are tables, tumblasts, spinner hangers and some with pass-through work-handling arrangements. Though AMS conformance may not necessarily be their target, users in these industries understand the need to monitor and control media velocity, size and flow rate. Since blast wheels are less discriminating in impacting specific areas, users regularly employ innovative masking techniques, including shadow masks that are not generally seen in airblast machines. The ultimate goal of countering tensile stresses in their components by imparting compressive stresses remains the same as in airblast applications.

As a design engineer during the early part of my career, the challenge of proper blast wheel placement often made me nervous. The flexibility of an articulating nozzle regularly mocked the rigidity of a blast wheel with its permanent seat on the cabinet walls. I learnt early on that wheel placement could spell trouble if not done properly. Bob Schoen (BCT) explained the importance that his company places on blast patterns. "At BCT, we spend a great deal of our preliminary engineering time focusing on wheel patterns and locations. Our 3-D simulation software not only scans the part geometry but also extrapolates changes in its position during rotation and re-positioning (indexing) during different stages of the peening cycle. Unlike cleaning, in peening applications we do not rely on rebound/ricochet for coverage. Our faith is in the first impact which we know is critical in peening to ensure

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uniform transfer of energy. Our engineers are also mindful that the rebound stream does not conflict with the outbound media from the blast wheel, thereby preventing loss of incident velocity. Instead of creating potential confusion with multiple wheel styles, we have focused our energies on perfecting the design and material of blast wheel parts so that wear is predictable. This helps standardize media velocity and assists with the ability of the media stream to impact the desired part surface."

Bob went on to explain the importance of proper fixture design which goes hand in hand with wheel placement. "Fixture design must allow unimpeded drainage to prevent semi-closed areas from flooding with shot. Majority of our cleaning and all of our peening machines are fitted with variable frequency drives to alter the speed (velocity) of the blast wheels and MagnaValves for flow control. We follow a strict regiment of controlling the wheel current in peening machines within a closed feedback loop. Ensuring an uninterrupted flow of media to all wheel locations is critical, and shallow feed angles must be avoided at all costs, and with that the unreasonable expectation that shot will flow like water through a pipe!"

Mechanical advances in wheelblast

"Our portfolio includes a large percentage of machines destined for less-forgiving production environments such as foundries and primary steel," explained Bob Schoen. "For such applications, we designed an innovative airwash separator with an intuitive lip that opens only when shot volume for full length of media curtain is established. We use a similar system for our peening machines as well." Bob describes the lung of any blast machine—the **Airwash Separator**. Though we generally do not associate generation of dust with peening operations, it remains important to eliminate broken media particles (fines) and any dust from the media stream. A discontinuous shot curtain at the airwash will result in inadequate separation of dust from media.

Media analysis for size and shape is required for new and in-process shot. New media is evaluated before being introduced into the machine and requires no more than a sample splitter to obtain a representative sample. Sample collection for in-process media is a bit more involved, especially in a wheelblast machine. "To facilitate retrieval of a true sample, we have designed a remote abrasive sampling port that can be attached to the feed spout of the blast wheel. This is as close as practical to obtain a media sample that is just about to be introduced to the blast wheel," stated Bob. I regularly remind our customers to refrain from collecting media samples from an area of static accumulation such as from inside the blast cabinet.

Wheelblast patterns comprise of a heading, tailing and hot spot where about 70% of the energy of the media stream is concentrated. Wheel parts such as the control cage, impeller and blades are subject to constant wear, and this results in gradual shifting of the blast pattern. Most manufacturers will recommend blast testing a template and study the pattern to assess wear halfway through the expected life cycle. This will be followed by re-adjustment of the control cage clock dial to return the hot spot to its original position. One of the risks associated with this practice is the possibility that the control cage might not be installed correctly after reset.

Bob Schoen explained to me that BCT has eliminated this and recommend replacement of the control cage altogether after designated usage. "To facilitate this, we manufacture our wear parts from material with greater wear resistance than currently offered within the blast industry," added Bob.

In one of my earlier articles, I introduced our readers to a technology that was introduced by the German Technology Center of Wheelabrator where they had installed sensors at the extremities of the control cage opening to detect wear outside of preset tolerance and automatically adjust the control cage to its original setting. In addition to such techniques, the industry has undertaken several other initiatives to:

(a) improve material technology of blast wheel parts to increase wear life (leading to predictability of wheel patterns and velocity),

(b) quick-change arrangements to remove wheel parts or the entire blast wheel during times of maintenance, and

(c) mobilize blast wheels by fitting them on to oscillating panels that coordinate with part movement in the blast cabinet. All of them aim to ensure accuracy, repeatability and consistency of results that are pivotal to a successful peening operation. Given the volume of shot that a blast wheel propels, such practices are not easily accomplished in wheelblast machines.@

Process-related advancements

Aerospace end-users are familiar with PVTs (Part Verification Tool) and MVTs (Machine Verification Tool). This concept is now being developed in wheelblast machines as well as for non-Aerospace applications. Though the optimum means of peening a part is to spin it about its own axis, the spinner hanger does not always offer good predictability in terms of impact from rebound media on part areas that are on the far side of a pattern. The classic example is an X-mas tree type hanger fixture that is fixtured with individual, small automotive components on its branches. When tested at regular intervals, an MVT comprised of a fixture with Almen blocks on different branches of this fixture can be used to validate that all parts will receive proper coverage at the required intensity and impart the expected residual compressive stress.

One of the earliest machines used for shot peening is the popular Tumblast. A batch of parts is tumbled in an endless mill in this machine type, with active part-part


FROHN

contact. When testing Almen strips in this machine, common practice is to toss in a couple of Almen blocks to read arc heights. Manufacturers, such as BCT, advocate validating arc heights with the blocks in static condition and testing without running the mill. Though it is important to conduct testing in conditions that would prevail when peening actual parts, movement of parts in a tumblast is random and a better measurement of impact energy can be obtained with the Almen strips in static position.

It will be inspiring to see the following process-related advancements:

- Realtime measurement of media velocity. I acknowledge the challenge that this could present given the widespread nature of the blast pattern generated by a wheel. However, I am confident that alternate parameters to wheel speed and diameter could be utilized to characterize this critical variable.
- Coverage predictability based on media flow rate and part positioning. With blast wheels flowing about 10x the amount of peening media as nozzles, a better estimate of coverage could positively impact processing time and operating cost.
- Advanced techniques in in-line size and shape control since current technology limits the monitoring to a fraction of the total flow rate.

Where are we headed with wheelblast?

The answer to this question is subject to the industry to which it is posed. Let me explain the response I received from users in Automotive. A census of machines in this industry revealed the average age of equipment to be around 25 years. Users reported that most of these machines are overdue for replacement and will benefit from technology developments such as direct drive wheels, VFDs, MagnaValves, etc., when replaced. Some of those relay-logic controls will benefit from PLCs and HMIs that are more intuitive to the operator. As the awareness of proper peening techniques increases, these control systems have started to incorporate saturation curve solver software as part of the HMI, leading to reporting and storage of critical data.

Aerospace end-users report a different dynamic. Though their machines are also aged, I noticed that their ability to maintain these machines to higher repeatability levels is quite impressive. We are aware of the challenges the pandemic posed on almost all industries including Aerospace where its highly skilled workforce started receding. To mitigate the impact of such events in the future, there is a push towards automating certain activities that are currently manual. This includes machine tending, fixturing, part loading/unloading and transfers. There are discussions around AGVs to transport components from one operation to the other and robotization initiatives that were until now commonly seen in automotive.

End-user needs are ideally provided by the equipment manufacturers, and to some extent that is true in our industry as well. That said, I would like to report on a fascinating experience with a foundry customer that might evoke some ideas in others too. This customer realized that their specific reporting needs can only be addressed by those close to their process. This led to in-house development of software for real-time monitoring and reporting of its shot addition, waste analysis, and quality of shot input to its machines.

Though my intention is not to diminish the efforts and advances of our equipment manufacturers, it seems to me that the most efficient process design is not obtained by picking from a database of screens but achieved through a healthy collaboration with the end-user. The progress with wheelblast machines may not appear to keep pace with robotic nozzle peening machines, but there still exist many opportunities for optimization in those high-volume applications peening Automotive parts that might set the precedent for advancements in wheelblast.


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Practical Examples and Implications of Almen Strip Physics

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Introduction

For several decades, Almen strips have been valuable tools to provide shot peeners insights and expectations pertaining to the peening conditions they are employing. During the same time period, several excellent models have been proposed and developed which provide physical and mathematical bases for the interactions between the impinging media and the strip. Since one of the guiding principles at Purdue's School of Materials Engineering (MSE) is to "intersect" industrially relevant research with "real world" engineering education, multiple studies have been undertaken to examine the relationships between fundamentally developed models with conventional shot peening practice.

An appropriate place to start is Kirk's discussion of the physics that lead to the bending of shot peened Almen strips [1,2] which involves the plastic deformation of a peened Almen strip surface and the subsequent formation of a compressive residual stress. The imparted peening intensity is proportional to the depth of this compressive residual stress region. Thus, if the residual stress versus depth curve is known, then the corresponding arc-height (H) can be estimated from a simple elastic bending analysis. For this case, the estimate arc-height (H) for bending along the length of the strip is [1]:

$$H = 3ML^2/2Ewt^3 \quad (1)$$

Where M is the bending moment, L is the Almen gage reference distance, E is Young's modulus, w is the width, and t is the thickness of the strip. The bending moment is then proportional to the area under the compressive stress versus depth curve. Taking an average value for this area as $\sigma \cdot d$ where σ is the average compressive stress induced from the peening, and d is the average depth, the bending moment (M) can then be written as [2]:

$$M = w(\sigma \cdot d)(t-d)/2 \quad (2)$$

As noted by Kirk [1], "the problem is greatly simplified by assuming that all of the required energy is for elastic bending." Thus, for a given induced stress versus depth curve, the arc-height can be estimated using equations 1 & 2. These curves are typically not measured with respect to the Almen strip itself. The standard Almen strip thicknesses are specified in SAE J442 [3] (N vs. A vs. C), and the recommended intensity limits (SAE J443) [4] for A strips are from 0.1 mm A (0.004 in A) to 0.60 mm (0.024 in A). However, intensity ranges for N and C strips are not specifically given in a SAE specification. As part of a senior design project, MSE students investigated the response of Almen strips of different thickness for the same peening intensity. This article will briefly summarize those results as related to the above described "Almen strip physics".

Experimental

A series of tests were made using A-1S, N-1S, and C-1 Almen strips that were provided by Electronics, Inc. Peening was done at Progressive Surface with a CNC robotic arm equipped shot peening machine. The goal was to achieve a set of peening conditions to produce a complete range of intensities for A-strips extending beyond that specified by SAE J443 [4]. The selected peening conditions are listed in Table 1. At each intensity, the arc-height for C and N strips were also measured.

Stress versus depth profiles were measured for the peened Almen strips with measurements made at the center of the peened face. Residual stress at a given depth was measured with a Pulstec μ-x360s residual stress analyzer which employs the cosine(α) method [5]. Material was removed by electro-etching with a 3 wt% NaCl solution at 130 mA over a 5 mm diameter for 2-minute intervals. The depth of the resulting impression was then measured with a 0.01 mm precision dial indicator.

Results and Discussion

The stress versus depth profiles for all the peened strips listed in Table 1 are shown in Figure 1. These results show the expected strong correlation between the peening intensity and the depth of the compressive stress for N, A, and C type strips. Figure 2 shows a schematic stress versus depth profile for a fully constrained strip (or one that has a semi-infinite thickness). The area under this curve (units of work/area) represents the average area ($\sigma \cdot d$) denoted in equation-2. Assuming an Almen strip is fully constrained in the holder, once it is removed after peening, the strip is free to elastically bend and stretch [6]. These stresses are also sche-

matically shown in Fig. 2 which result in the final residual stress state in the strip. Thus, the stress profiles shown in Fig. 1 (or any appropriately derived residual stress-depth profile) correspond to the residual stress profile as marked in Fig. 2 where the "net" work ($W_{residual}$) is the result of the induced work ($W_{induced}$) less the work that is associated with bending and stretching.

In order to determine if the work performed for identical peening conditions is the same for all three strips (once their thickness is taken into mathematical consideration), the first step is to quantify the area under the residual stress curves ($W_{residual}$) for given strip intensities. Next is to estimate the work for the induced stress curve ($W_{induced}$) for all three strip types. A spline fit and the trapezoidal method with MatLab [7] were used to find $W_{residual}$ for all the residual stress curves shown in Fig. 1, and these values are listed in Table 2. For each strip type, the work ($W_{residual}$) increases with increased peening intensity.

To find an average work value (σ·d), appropriate average values of σ and d should be determined. Noting that the shape of residual stress curve resembles a Weibull distribution function as shown in Fig. 3, the properties of the complementary cumulative Weibull distribution can be used. This can be written as:

$$w(x) = (w^*)\exp(-x/x^*)^m \qquad (3)$$

where w* is the total cumulative work, the constant m is the Weibull modulus, and x* is characteristic depth defined as 63% of the total area under the residual stress profile for the case when x=x* and w(x)=37% as shown in Fig. 3. This method provides a consistent numerical approach to find the characteristic depth between curves and peening conditions. Using this procedure, x* was found for all the residual stress depth curves, and these values are also listed in Table 2.

To estimate the area under the induced stress curves ($W_{Induced}$ per area) for the conditions listed in Table 1, equation 2 can be rearranged as:

$$W_{induced} = (\sigma \cdot d) = M/[(w(t-d)/2] \qquad (4)$$

where M is found from equation-1 using the measured arc-heights and d=x* (the characteristic depth) values. For example, an A-strip peened at condition D from Table 2 has a measured arc-height of H=11.6 [in/1000] or 0.295 mm and a characteristic depth of $d = x^* = 112.3 \times 10^{-6}$ m. Then using L=31.75 mm from the Almen gage, a strip width of w=19 mm, thickness t=1.295 mm and an elastic modulus of E=200 GPa, the bending moment is found to be M=1.61 Nm which gives a work value of $W_{induced} = 143$ kJ/m^2. Figure 4 shows the comparison of the A, N, and C strips for the different peening conditions. As noted above, the same value of $W_{induced}$ is expected for the A, N, and C strips for the same peening condition as this represents a strip that is fully constrained in the holder. This is observed when comparing N and A strips as shown in Fig.4(a) since the slope of the ratio between the induced work is one. Conversely, this is not the case when comparing the A and C strips. Here, the slope is approximately 0.70 which implies that arc-heights for C strips would be overestimated using the current analysis. This can also be shown by comparing the ratios of the arc-heights between strips. Using the values from Table 1, $H_N/H_A \approx 2.65$ and $H_A/H_C \approx 4.5$. These ratios are similar to those reported earlier [8]. From equations 1 and 2, these ratios should also approximate the inverse ratios of thicknesses squared when d is small. For example taking the values in mm, $(t_A/t_N)^2 = (1.295/0.785)^2 = 2.72$ which reasonably agrees with ratio above, but conversely the ratio $(t_C/t_A)^2 = (2.385/1.295)^2 = 3.38$ is not as close.

A possible explanation for the somewhat departed calculated peening response of the C-strips may be related to the degree that the strip is constrained during peening. The calculation of the induced stress assumes a fully constrained strip (e.g., a semi-infinite strip thickness). In practice, the strip is constrained only by the 4 set screws of the Almen strip holder. Thus, it may be possible for the strip to elastically distort while in the holder, for example the formation of a cross-bow curvature, to relieve the stress. Since the C-strip is thicker than the A and N strips, it should naturally be more fully constrained. As peening is a continuous operation, the formation of the induced residual stress can be considered a pre-existing compressive elastic stress at later times. If a greater pre-existing compressive elastic stress develops in the C-strip, this could reduce the indent size and result in a smaller arc-height.

Lastly, the average work from the residual stress curves ($W_{residual}$) can be estimated by subtracting the work needed to bend the strips flat (W_{bend}) from the $W_{induced}$ values. These values can then be compared to the measured ones listed in Table 2. Here, W_{bend} can be found by integrating the bending equation, as plotted in Figure 2, over the distance d. The resulting equation is:

$$W_{residual} = W_{induced} - W_{bend} \qquad (5)$$

where $W_{bend} = \sigma_{bmax}[(d)(1-d/t)]$ and σ_{bmax} is the bending stress at the peened surface. Considering case D from Table 2 for the A-strip again, the surface bending stress is simply [M(t/2)]/I where I is the second moment of area ($wt^3/12$). Substituting the values from above gives $\sigma_{bmax} = 302.8$ MPa and $W_{bend} = 31$ kJ/m^2 so that $W_{Residual} = (143 - 31)$ kJ/m^2 or 112 kJ/m^2 which corresponds well with the measured value listed in Table 2.

Figure 4(b) shows a comparison between the estimated and measured values for the A and N strip showing reasonable agreement between the two. Furthermore, since the range of peening conditions in this study extended beyond that recommended in SAE J443, the linear correlations shown in

Figure 4 suggest that useful information can still be obtained from strips peened beyond these limits for the current peening conditions.

Summary

These results and analyses were from a MSE senior design project which used industrially relevant peening protocols and gave students practical shot peening experience. Two key outcomes were: 1) understanding and documenting the effect of thickness on peening response and 2) comparing the measured correlations between standard Almen strip types as a function of peening intensity using well-founded physical materials science as its basis.

Acknowledgements

Appreciation is extended to Electronics Inc. and Progressive Surface for supporting this project and to students Nathan Lieu, Aleena Masaeng, Matthew Wright, and their graduate advisor, Langdon Feltner, for their work and enthusiasm.

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1) David Kirk, "Quantification of shot peening intensity rating", *The Shot Peener*, Winter 2015, p. 24.

2) David Kirk, "Strip factors influencing Almen arc height", *The Shot Peener*, Fall 2009, p. 26.

3) SAE International Standard J442, "Test Strip, Holder, and Gage for Shot Peening," 2022.

4) SAE International Standard J443, "Procedures for Using Standard Shot Peening Almen Test Strip," 2017.

5) Keisuke Tanaka, "The cosα method for X-ray residual stress measurement using two-dimensional detector," *Mechanical Engineering Reviews*, 6 (2019) p. 18-00378.

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7) The MathWorks Inc. (2022). MATLAB version: 9.13.0 (R2022b), Natick, Massachusetts.

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Peening conditions and Variables						Arc-height Intensity (1/1000")		
Condition	Incidence Angle (°)	Air Pressure (psig)	Media Feed Rate (lbs/min)	Transverse speed T1 (in/min)	Nozzle Type	N-type	A-type	C-type
A	35	9	28	22.73	(3/8)" venturi	8.5	3.2	0.2
B	45	9	28	22.73	(3/8)" venturi	10.6	3.9	0.7
C	90	9	28	20.83	(3/8)" venturi	14.6	5.4	1
D	90	10	5	21.28	(3/8)" venturi	29.4	11.6	2.6
E	90	20	5	31.25	(3/8)" venturi	38.4	17.4	4
F	90	30	5	37.04	(3/8)" venturi	N/A	21.22	4.5
G	90	40	5	33.33	(3/8)" venturi	N/A	24.5	5.5
H	90	55	5	33.33	(3/8)" venturi	N/A	28.3	6.3

Table 1: Arc-height intensity results for N, A, and C strips. Highlighted cells are strips within the recommended range of SAE J443.

	N-Strips			A-Strips			C-Strips		
Peening Condition	N-Intensity [in/1000]	N-Depth [μm]	N-Work [kJ/m²]	A-Intensity [in/1000]	A-Depth [μm]	A-Work [kJ/m²]	C-Intensity [in/1000]	C-Depth [μm]	C-Work [kJ/m²]
A	8.5	55.1	33.6	3.2	45.8	45.5	0.2	55.7	40.8
B	10.6	71.0	39.0	3.9	63.4	51.4	0.7	63.2	45.4
C	14.6	89.0	57.7	5.4	91.1	88.4	1.0	84.1	69.2
D	29.4	164.2	76.8	11.6	112.3	110.0	2.6	189.0	139.0
E	38.4	259.3	130.0	17.4	182.4	152.0	4.0	172.1	107.0
F	--	--	--	22.2	222.2	185.0	4.5	218.5	151.0
G	--	--	--	24.5	223.2	195.0	5.5	157.7	100.0
H	--	--	--	28.3	267.2	192.0	6.3	277.0	191.0

Table 2: Listing of the $W_{residual}$ values found from the measured residual stress vs. depth curves (from Fig. 1) and the associated characteristic depth values (x).*

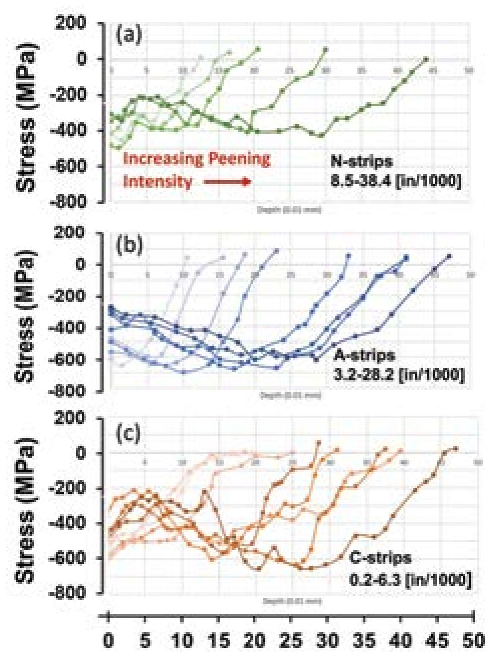

Figure 1: Compressive residual stress versus depth curves for the set of strips listed in Table 1.

Figures 2 - 4 on page 20.

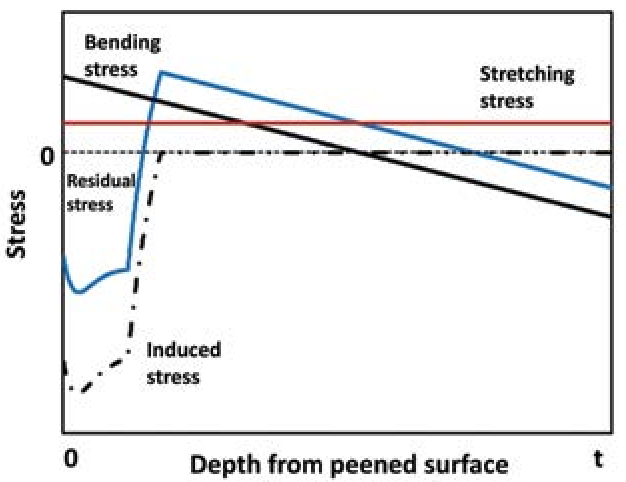

Figure 2: Schematic compressive stress versus depth curves for a fully constrained strip (induced strip) and the resulting residual stress curve for the unconstrained strip, after [6].

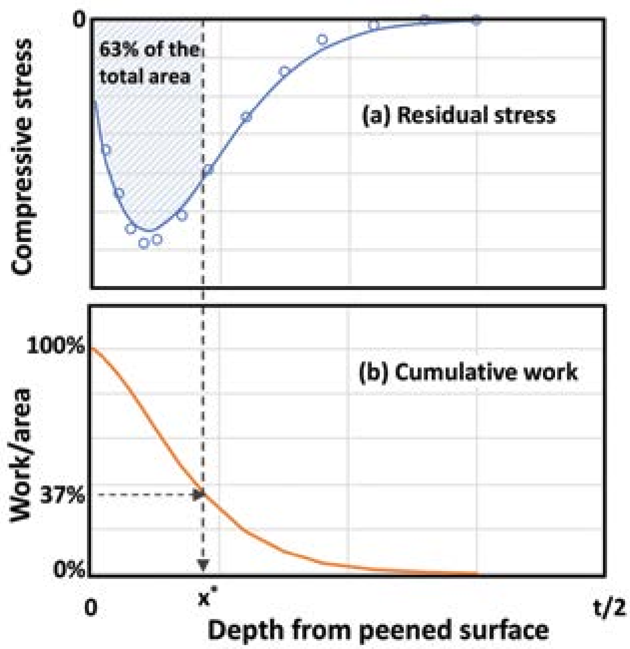

Figure 3: Schematic representation of using a Weibull distribution function to represent the stress vs depth curve and the location of x.*

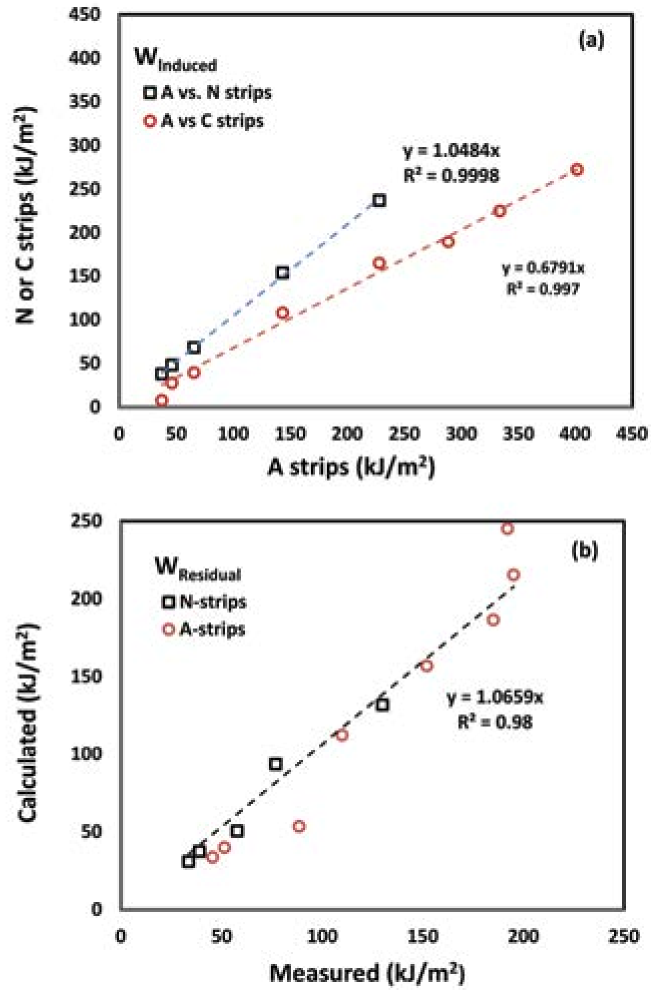

Figure 4: (a) Comparison of the work ($W_{induced}$) values calculated for a given peening condition for A, N, & C strips, and (b) a comparison of the associated work from the residual strip vs. depth curves with the measured values from Table 2.

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Q & A

THE Q & A FORUM at *www.shotpeener.com* is the ideal place to get advice on a wide range of topics from industry leaders and colleagues from around the world that have tackled and solved your challenges.

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

Shot Peening Non-Magnetic Parts with Steel Shots

Questioner: We are having issues with some of our tubulars cracking in shot-peened areas. We shot peen non-magnetic tubulars on the threaded sections (API Connections) with the objective to relieve machining stresses and mitigate galling. The material of the tubulars is 15-15 HS.

Could I have your opinion about the importance of shot peening these non-magnetic tubulars with non-magnetic media, benefits of doing so and risks of not using stainless steel shot. I am trying to understand the pro and cons of shot peening with carbon steel media versus stainless steel media. Would both media improve the corrosion and oxidation resistance of our tubular the same amount?

What would be the risks of shot peening non-magnetic tubulars with carbon steel media? If we were to shot peen our nonmagnetic tubulars with regular carbon steel shot, would we have a greater risk for stress corrosion cracking? Would it make them more prone to develop oxidation and corrosion? Thank you.

Answerer #1: Cast steel shot will leave a ferrous residue on the surface that will eventually rust. I assume these parts are for the oil drilling industry and there very well may be an issue with magnetization if cast steel shot is used. Sensors used to guide the drill head can be negatively effected. In my experience, peening API threads was done with SS Conditioned cut wire shot then followed up by peening with glass bead at a significantly lower intensity. This would clean the part and improve the surface finish. This additional step also could lead to increased fatigue life.

Questioner: Thanks a lot! This helps a lot!

Answerer #2: What is the issue about peening with non-magnetic media? Is there a fear of imparting magnetism to the part?

Stainless steel cut wire media can retain high magnetism. New high-density ceramic bead from St. Gobain could be used for full range of "A" peening intensities.

Questioner: We are not worried about magnetism here at this point. We are just trying to understand why it is cracking axially and radially on our shot-peened areas. Shot peening might be the cause but we are not sure.

I will make sure we use SS shot in the future.

These parts are for the oil drilling industry. What do you think about the following requirements:

- S-110 SS shots at 8-10 "A" intensity, 200% coverage
- S-100 Glass beads at 8-10 "N" intensity, 200% coverage

Thanks in advance.

Answerer #1: I would limit the S-110 intensity to .009A Max. especially if you a using regular hardness media ASR 45-52rc and not ASH 55-52rc.

Peening intensities too high with too small of media becomes abusive to the part surface.

I'm not familiar with S-100 Glass bead. Unfortunately glass bead has numerous designations for size. I'm familiar with the AMS designations such as AGB or the US Military size designation. If you can convert S-100 to one of those perhaps I can be of more assistance.

It seems like you are on the correct track to finding a proper call out for your project.

Questioner: Sorry, not sure what happened here, I did not edit the size properly. I meant 60-80 (#7) Glass Bead. I know we have used that size for other parts but I have no idea what intensity I should run it at.

Thank you for clarifying about the intensity of the S-110. I wasn't aware of that. Thanks a lot for all your help!

Questioner: I am having a real hard time finding charts or standards on what requirements I need for this process. How do you determine the size, hardness and intensity of the media? Is there some charts or document somewhere that gives recommendations for each type of material and each media combination? Any help would be appreciated. Thank you.

Answerer #1: This maybe of some help. You have to purchase it from *SAE.org*.
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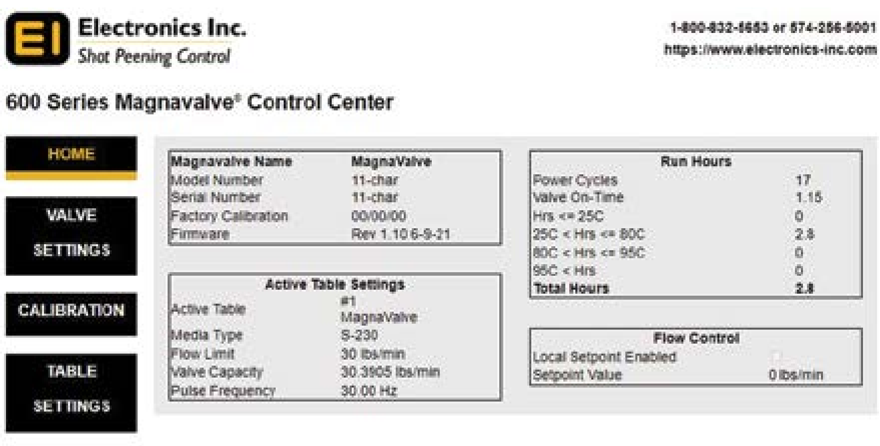

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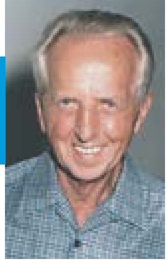

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Estimating Peening Intensity

INTRODUCTION

The estimation of peening intensity is an essential tool for shot peeners. Its magnitude is normally estimated using an Almen strip data set. This data set comprises the arc heights of several Almen strips that have been shot peened for different periods of time using the same shot stream. Plotted as arc height versus peening time then yields a curve. The curve, commonly known as a "Saturation Curve", is used to estimate the peening intensity. Specifications generally require the determination of a point on the curve such that "A doubling of the peening time corresponds to a 10% increase in the arc height." Computer-based techniques enable this determination to be obtained objectively. Fig.1 illustrates one such technique in action, deriving 14.24 as being the peening intensity.

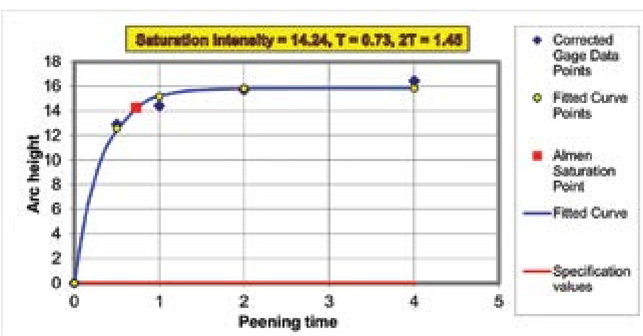

Fig.1. Computer-based derivation of Peening Intensity value.

Computer-based curve fitting requires prior knowledge of an appropriate equation. Initial studies indicated that exponential equations were appropriate, with either 2, 3 or 4 parameters, giving increasingly close fits to data. This led to the "Solver Suite" of programs. A later equation has been introduced via a French specification.

It is very important to note that the peening intensity of a shot stream varies within the stream. This feature is illustrated by fig.2 showing variation within a cross-section.

VARIATION OF A SHOT STREAM'S PEENING INTENSITY

Shot peening intensity is proportional to shot velocity. Emerging shot particles are being blasted out of the nozzle by the conical air stream (colored blue) in fig.3. The edges of the cone experience a retarding effect due to the almost static surrounding air (colored yellow). This slows down the

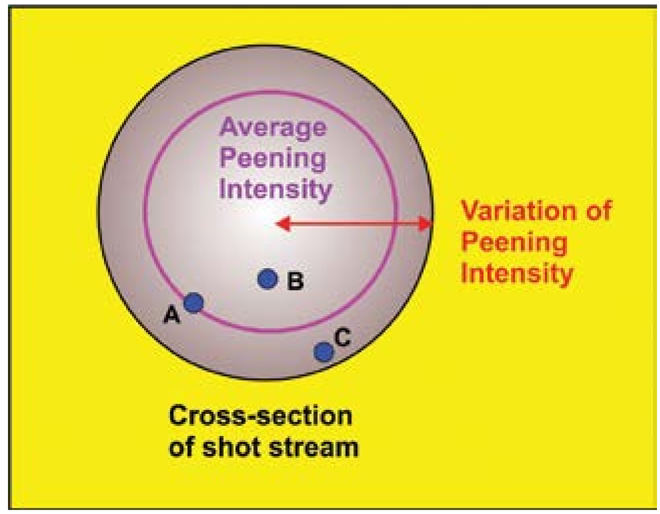

Fig.2. Variation of peening intensity across a shot stream.

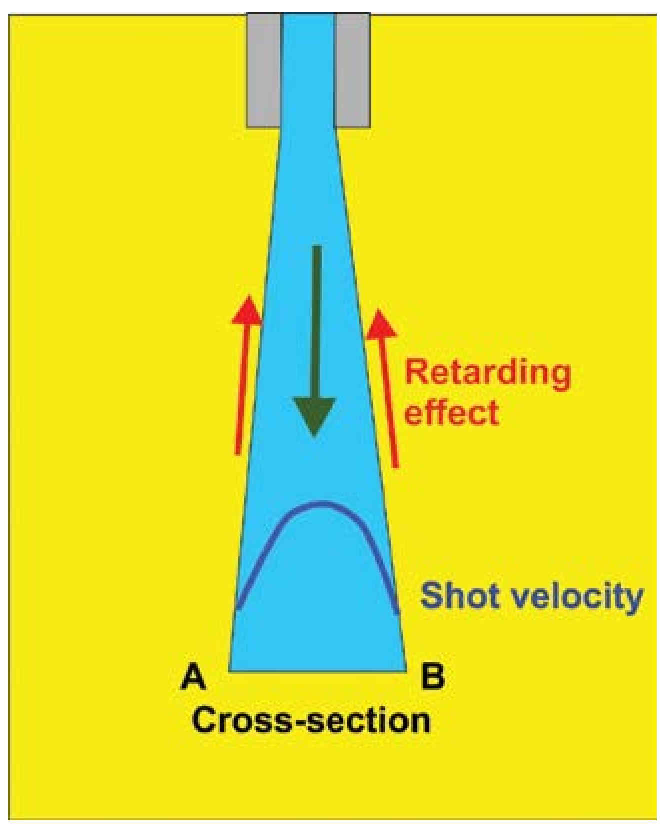

Fig.3. Shot velocity variation within shot stream.

velocity of the air stream at its edges. Consequently the shot velocity (colored blue) becomes higher at the center of the cone than it is at its edges. This means that the shot peening intensity is greater at the center of the cross-section, AB, than it is at its edges. Overall there will be an average peening intensity as at A in fig.2. Intensity will be higher inside the circle of average peening intensity, as at B. Intensity outside the average circle will be lower as at C.

Estimation of peening intensity should take account of the known shot stream variation. This is effected when using Almen strips because they are exposed to most of the shot stream cross-section.

VARIABILITY OF ALMEN PEENING DATA

Peening intensity estimation when using Almen strips requires a data set. Each point in the data set has coordinates of arc height and peening time. Because only two factors are involved we can plot peening intensity data points graphically, as arc height against peening time, giving us the so-called "Saturation Curve". Normally, between 4 and 6 data points are involved. However, every data point has its own variability—meaning that if we repeated the time of peening for a given point we would not get exactly the same arc height deflection. This begs the question "How can we cope with data point variability?" The standard answer is to employ the "Least Squares" method. This technique minimizes the squares of the differences between the data point values and the selected model equation. The following is an explanation of this technique.

Least-squares Curve-fitting

"Least-squares" means minimizing the sum of the squares of differences between data point values and the value lying on an assumed curve equation. This concept is illustrated in fig.4.

For simplicity of mental arithmetic, arbitrary units are used in fig.4. For point 1 the difference between the data point and the curve point is 1. 1 squared is also 1. For point 2 the square of the difference is also 1. For points 3 and 4 the difference between the data point and the curve point is 0.5 whose square is 0.25. The sum of the squares for the four points is therefore 2.5 (1 + 1 + 0.25 + 0.25). Consider next the dashed curve. For point 1 the difference between the data point and the curve point is 3 which squared is 9 — much larger on its own than the all-point sum of 2.5 for the much better-fitting continuous curve. The dashed curve is obviously not a good fit!

Least-squares curve fitting involves altering the parameters of the equation being used time and time again until a minimum value is reached.

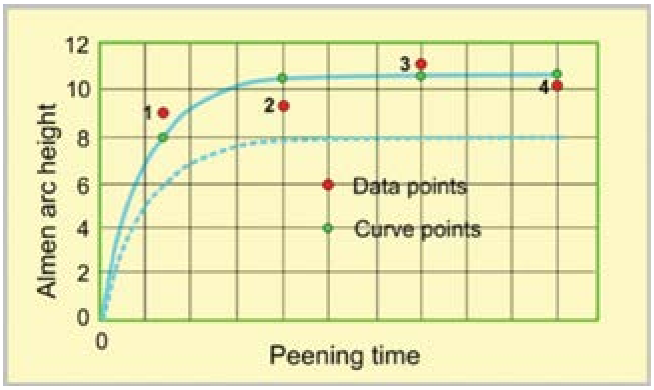

Fig.4. "Least-squares" curve-fitting applied to shot peening data points.

Several factors influence the variability of individual Almen data points. These include:

(1) Almen strip quality. As a general rule the higher the quality of the Almen strips the less will be data point variability.

(2) Almen gauge quality and maintenance. Again the higher the quality of the gauge the less will be data point variability. Routine maintenance is required in order to preserve gauge quality.

(3) User technique. Using an Almen gauge requires high levels of both skill and care. A fair analogy would be that the technique is that required from a surgeon rather than simply that required from a butcher.

(4) Shot stream stability. No-one's shot stream can be exactly constant. Air pressure, average shot size and shot velocity fluctuate. Control measures can minimize these fluctuations but cannot eliminate them completely.

Measuring data point variability is rarely carried out because it is tedious, time-consuming and expensive. Variability can sometimes, however, be obvious. For example, in fig.4 point 3 is higher than point 4. This could only occur due to the presence of one or more variability factors.

CHOICE OF CURVE-FITTING EQUATION

A variety of curve-fitting programs are available either free or propriety. An acid test for suitability is described in SAE J2597. Its ten data sets are as shown in Table 1 (page 30). Each data set contains values for exposure times and test strip arc heights and a corresponding intensity answer. To be satisfactory, a computer program must generate a saturation curve and numerical declaration of intensity which is within the tolerance band for each data set.

Note: Target answers are shown in bold print. Candidate programs must reach all ten target answers to within ± 0.001.

Table 1
Saturation Curve Data Sets

1		2		3		4		5	
time	arc height	time	arc height	time	arc height	time	arc height	time	arc height
4	0.0060	2.5	0.0030	3	0.0065	1	0.0038	4	0.0062
6	0.0069	5	0.0036	6	0.0081	2	0.0051	6	0.0070
8	0.0070	10	0.0044	12	0.0088	3	0.0052	8	0.0072
12	0.0070	20	0.0044	24	0.0090	4	0.0053	12	0.0072
	0.0064		**0.0040**		**0.0080**		**0.0048**		**0.0066**

6		7		8		9		10	
time	arc height	time	arc height	K/Feed	arc height	K/Feed	arc height	K/Feed	arc height
1.1	0.0046	2	0.0055	0.25	0.0081	0.25	0.0108	0.25	0.0045
2.3	0.0087	3	0.0066	0.50	0.0096	0.50	0.0129	0.50	0.0054
4.5	0.0101	4	0.0067	0.75	0.0100	0.75	0.0137	0.75	0.0059
9	0.0107	6	0.0068	1	0.0103	1	0.0144	1	0.0058
	0.0098		**0.0063**	2	0.0108	2	0.0157	2	0.0062
				4	0.0113	4	0.0164	4	0.0064
					0.0093		**0.0137**		**0.0054**

For example, an acceptable derived intensity for data set 1 would be within the range 0.0054 to 0.0074. The arc height values in Table 1 are in inches for illustration purposes only. Some curve solver programs will not function properly with such small values. It is therefore acceptable for the data in Table 1 to be converted into thousandths of an inch for computational purposes. For example: use 12 instead of 0.012".

The pragmatic solution to deciding choice of program is that "Any program will do provided that it satisfies SAE J2597." That said, the author's Solver Suite provides convenient modifications that allow for a variety of factors such as:

- Pre-bow correction
- Flapper peening correction
- Data set comparison and
- Number of parameters in the fitting equation (the greater the number of parameters the more precise is the fit).

Tests can be carried out to compare the suitability of different equations. One such test is illustrated by fig.5. Each of the ten SAE J2597 data sets given in Table 1 has been fed into two different curve-fitting equations—Solver EXP2P and Solver 2PF. For this particular test Solver EXP2P gives peening intensity values that are well within the maximum allowed deviation. Solver 2PF also satisfies the requirement but the Data Set 6 value is close to the allowed maximum deviation.

Two-Point Peening Intensity Verification

Shot peeners are required to verify at regular intervals that the shot stream's peening intensity continues to be within the

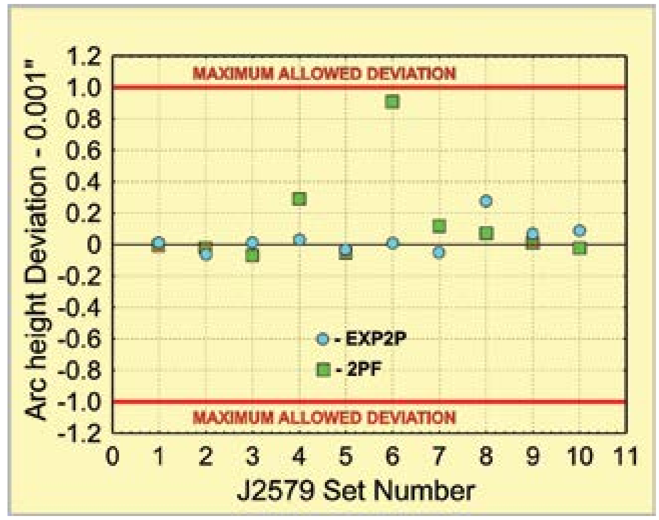

Fig.5. Deviations from the J2579 data set for EXP2P and 2PF programs.

specified range. A balance has to be struck between excessive and inadequate testing. The simplest verification test requires only one strip to be peened. Earlier specifications required that this strip be peened at the peening intensity time, **T**. This is clearly impossible if **T** is not an integral number of passes/strokes/table rotations. SAE J443 now addresses this problem and allows the single strip to be peened at the nearest practicable time to **T**. The arc height reading from the single strip "must repeat the value from the saturation curve plus or minus 0.038 mm (± 0.0015 in)."

A central problem with single-strip procedures is that they cannot verify that the shot stream's intensity is being maintained! That is because an infinite number of saturation curves can pass through any one point (and the origin 0,0). Fig.6 illustrates the phenomenon.

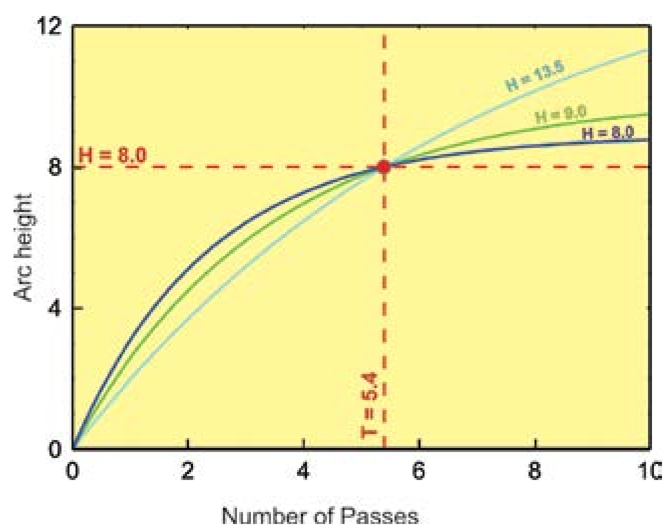

Fig.6. Different saturation curves passing through a notional peening intensity 8.0.

Two-point intensity verification avoids the multiplicity problem of one-point verification. Fig.7 illustrates the methodology involved. Two strips are peened for "times" t and 2t. The resulting arc heights are used to determine the values a and b of the equation. The arc height value at the previously determined critical peening time, T, is then determined. This is the value that should be close enough to that previously determined using the multi-point data set. If it is then the shot stream's peening intensity is verified.

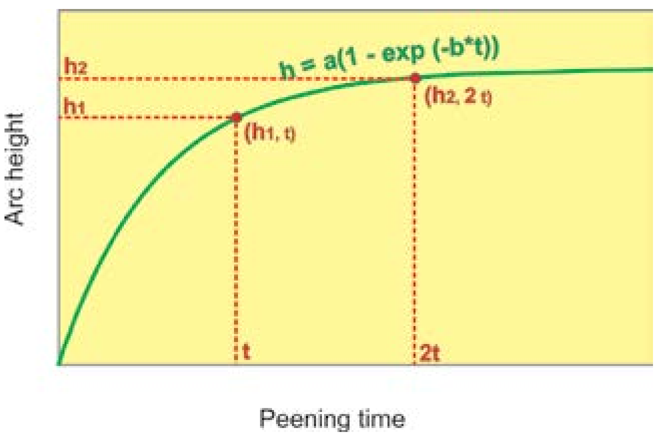

Fig.7. Two data points uniquely defining a saturation intensity curve.

A full description of two-point verification is given in a previous TSP article – Fall 2010.

DISCUSSION

Estimating peening intensity on a regular basis requires that a fixed control procedure is used. This must include:

Regularly calibrated Almen gage,

Same quality Almen strips,

Properly trained operator, and

Standardized measuring procedure.

The number and type of measurement is normally specified by customers.

Are you looking for an earlier article by Dr. David Kirk?

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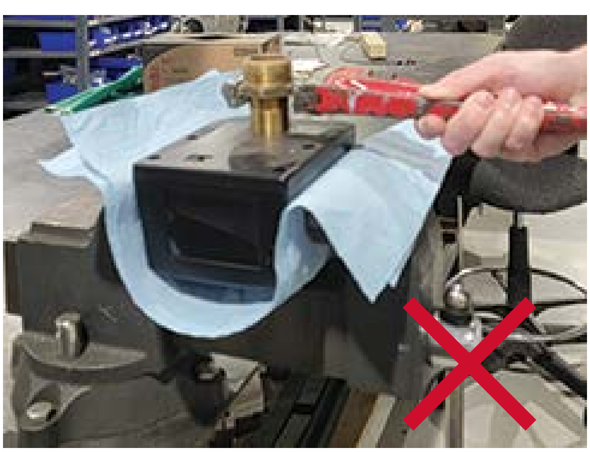
Kathy Levy | Associate Editor | The Shot Peener

How to Attach and Remove Pipe Fittings

When installing a MagnaValve, it is essential to attach and remove pipe fittings to and from the MagnaValve correctly so as not to break the valve body or the pipe from the valve. Below are some of the proper procedures when installing a MagnaValve. These apply, however, to many other instances when using a vise or a clamp.

Don't

Do not use the valve body as a wrenching surface. This can break the valve.



Do not mount the valve in a vise. Do not use a single pipe wrench on the pipe fitting.

Do

Do use two pipe wrenches—one on the valve pipe and one on the pipe fitting.

Do mount the pipe fitting in a vise and use one pipe wrench on the valve pipe to attach or remove the pipe fitting.

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The shot blasting machine works on the direct feed principle incorporated with the X-Y manipulator of nozzles for internal and external cleaning and revolving job on the PU rollers. The nozzle reciprocation through hydraulic arrangement ensures precise movement. The multi-blast nozzles fixed on hydraulic reciprocation stand de-scale and de-burr the submersible pump casing at one satellite position while the residual dust particles are air washed at another position respectively. Air-dust mixture further passes into Dust Collector where the dust particles are trapped in Pleated Filter Bags and the clean air escapes to the atmosphere. The dust trapped in Pleated Filter Bags falls in the Dust Bin due to reveres jet operation.

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PRESS RELEASE
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GelSight Partners with PRAGMA on Integrated Solution for Nondestructive Testing

GELSIGHT, a pioneer in tactile intelligence technology, today announced a new partnership with PRAGMA, a leader in nondestructive evaluation (NDE) 4.0 technologies, to provide integrated solutions to the nondestructive testing (NDT) market. The joint solution incorporates GelSight's tactile sensing technology directly into the PragmaFlex instrument platform, which is embedded with Pragma3D software, to provide more in-depth data and analysis of surface characteristics for NDE.

GelSight's unique technology uses 3D imaging to map surface finish and defects of any material, anywhere at the micron level. By integrating GelSight's tactile sensing technology directly with the 3D position encoding capabilities of the PragmaFlex platform, it provides users with a comprehensive view of the valuable information they need when inspecting parts and surfaces. From there, the Pragma3D software allows for data fusion with ultrasound, eddy current scans, optical 3D scans, CAD, and more.

"We are excited about how this new integrated solution will improve fully automated NDT workflows," said GelSight CEO Youssef Benmokhtar. "By combining GelSight tactile sensors with the PragmaFlex platform, users now have access to micrometer-level measurement data that can be fused with data from different modalities for deeper surface inspection and analysis."

PragmaFlex is the world's first portable NDE 4.0 instrument platform, running Pragma3D software. The platform can support one or two of several NDT modalities, including ultrasonic testing, phased array ultrasonic testing, eddy current testing, eddy current arrays, and bond testing. Pragma3D also unlocks a new revolution in NDT, as it opens the door to free-form 3D scanning with data fusion of multiple modalities. It powers various levels of inspection processes, from manual testing to fully automated inspections with robots and cobots.

"Since PRAGMA is committed to 3D, multi-modality, and data fusion, incorporating GelSight's tactile sensing technology into our ecosystem feels like a natural extension of the PragmaFlex platform," said François Mainguy, President and CEO of PRAGMA. "NDT requires advanced insights on surface characteristics and by partnering with GelSight, we are offering users incredibly detailed data to help them make more informed decisions."

To learn more about GelSight's suite of tactile intelligence solutions, please visit *https://www.gelsight.com/products/*. For more information on the PragmaFlex platform, please visit *https://pragmandt.com/product-pragmaflex*.

About GelSight
GelSight is a pioneer in digital, imaging-based tactile intelligence. The proprietary technology that was invented at the Massachusetts Institute of Technology provides extremely detailed and rapid surface characterization, enabling several surface measurement applications and robotic sensing capabilities. Its elastomeric 3D imaging systems are currently in use in aerospace, automotive, forensics and in many robotic research labs throughout the world. GelSight is Digital Touch and Feel. For more information, please visit *https://gelsight.com*.

About PRAGMA
PRAGMA designs, manufactures, and distributes portable instruments and integrated systems for nondestructive testing of materials. Its manual and automated solutions are used to inspect a wide range of metal and composite parts, to check for material properties and flaws in industries like aerospace, automotive, and oil & gas. PRAGMA is a leader in NDE 4.0 technologies. You can read more by visiting *www.pragmandt.com*.


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