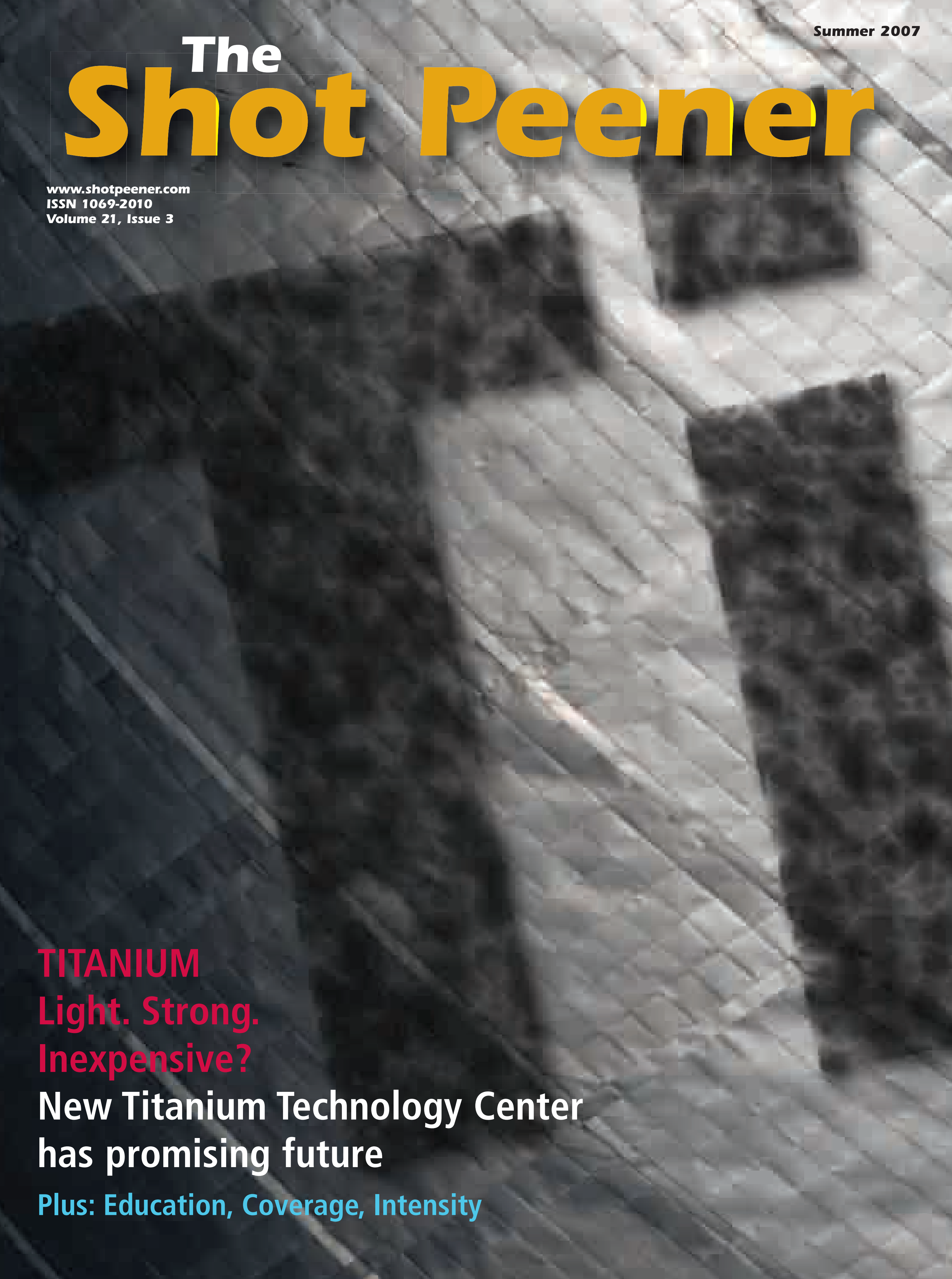
Summer 2007

The Shot Peener

www.shotpeener.com
ISSN 1069-2010
Volume 21, Issue 3



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On the left is a net-shape form produced by LMC, Inc. from titanium powder from International Titanium Powder LLC. Read more about these companies and their new titaniun technology center on page 4.

Cover: Background is a photograph of the titanium cladding of the Glasgow Science Centre

The Shot Peener

Summer 2007
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The Shot Peener

- 20 years in publication
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The Shot Peener (ISSN 1069-2010), in print since 1986, is a quarterly publication from Electronics Incorporated with a circulation of over 5,000 subscribers worldwide. It is dedicated to raising the awareness and appreciation for the shot peening and abrasive blast cleaning industries.

Contributions to The Shot Peener are always welcome including the announcements of seminars, application notes, joint efforts, and press releases on new products and services. However, while it is our goal to include all newsworthy information in The Shot Peener, we are able to use these items only as space allows and we cannot guarantee their placement in the magazine. Inclusion of articles in The Shot Peener does not indicate that The Shot Peener management endorses, recommends, or disapproves of the use of any particular commercial products or process, or that The Shot Peener endorses or concurs with the views expressed in articles contributed by our readers.

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New Titanium Technology Center

A successful titanium metal powder process would provide components with the same strength and weight advantages has products made from large, solid pieces of titanium, at a fraction of their present cost. Currently, few industries can justify titanium's high price tag. The opportunities are tremendous for companies that can bring a viable titanium metal powder process to market.

In the fall 2006 issue of **The Shot Peener**, we reported on an alliance between DuPont and MER Corp. that was formed to develop a new titanium metal powder process. Since that time, we have discovered another very promising project. It's unique due to the expertise and scope of the involved companies and its alliance with a university.

A new titanium technology center has been created by Northern Illinois University's Rapid Optimization of Commercial Knowledge (NIU-ROCK). The ROCK Program is a joint research and development program between commercial component fabricators in the Rockford area and Northern Illinois University (NIU). The ROCK Program draws upon NIU faculty expertise to conduct research with commercial team members awarded by subcontracts.

According to a recent press release issued by NIU-ROCK, "A center being created by NIU-ROCK will use a series of new technologies for processing and shaping titanium that will cut the cost of creating many parts by 80%. The process that will be piloted by NIU-ROCK in Rockford, Illinois would lower the price of titanium to about $2 a pound by simplifying the process for making titanium powder, then compacting it into a suitable shape for final machining."

This project will be a collaboration of companies with considerable expertise and technological proficiency:

International Titanium Powder, L.L.C. (ITP)
ITP has perfected a process that creates high-quality titanium powder at a fraction of the cost of traditional methods. Specifically, the company is commercially deploying the Armstrong Process—"a breakthrough technology for the manufacture of titanium powder". The Armstrong Process produces titanium by the reduction of titanium tetrachloride through reaction with sodium. In this process, $TiCl_4$ is injected into a stream of molten sodium. The sodium flow rate is in excess of the stoichiometric requirements for sodium reduction of $TiCl_4$. The excess sodium cools the reaction products and carries them to separate stages where the excess sodium and salt are removed. The reaction product is a continuous stream of powder. With simple modifications of the process, it is possible to make vanadium/aluminum alloys.

The advantage of the Armstrong Process is that it is a relatively simple, continuous process that makes powder. Powder analysis that has been conducted on ITP's product reveals that it has met the standards for strength and ductility for commercially-pure titanium. "Relatively simple" is an understatement, as liquid sodium is very difficult to handle. Many of ITP's staff members were former employees at the Argonne National Laboratory, one of the U.S. Department of Energy's largest research centers, where they gained considerable experience in advanced science, engineering and technology.

LMC, Inc.
LMC has designed and built a machine capable of economically forming titanium powder (like that created through the ITP process) into complex parts that require little additional machining and can be used in many applications where titanium is appropriate, at a fraction of the cost of parts created through traditional methods. LMC's patented High Velocity Adiabatic Impact of the ITP product is creating titanium with densities of 97% and above.

Materials Modification Inc.
MMI uses a process involving tremendous pressure and plasma heat, which can further consolidate the material to near 100% density, healing minute flaws in the titanium and allowing it to meet the highest quality standards. This process is slower than LMC's but the output will meet aerospace standards.

SuperMaterials Inc.
This newly-formed company will take the lead in commercializing the MMI process. The company's goal is to deliver engineered materials solutions that provide stronger, tougher, lighter or faster competitive edge products. One of MMI's key industries is aerospace.

Of course, at **The Shot Peener**, it's all about the shot peening industry and we want to know if NIU-ROCK's success could benefit us. Alan Swiglo, Associate Director, Manufacturing Processes Research at Northern Illinois University, answered many questions for us. "Once we are in the position to make near-net-shape products or machined versions, shot peening is a likely candidate process to provide improved surface compressive residual stresses. That may be beyond the current scope of our program, but may become important later in the project or in a potential follow-on project", said Mr. Swiglo.

Mr. Swiglo is a metallurgist and has made major contributions to the field throughout his career. He is a trustee for the Gear Research Institute and serves on the metallurgy committee for the American Gear Manufacturers Association.

"Thanks for reminding me to think about the potential benefits of shot peening, as it may apply to titanium products. I am very well aware of, and have successfully used, the benefits of shot peening for critical parts such as gears, springs and chain links. Shot peening has saved a few projects for me in the past," he added.

The current status of the NIU-ROCK titanium project is the completion of demo parts by LMC. In the next year, the program is expected to be machining real parts. The new processes have the potential to impact the economies of the total titanium market—military and commercial. Not to be overlooked are the research benefits for the engineering department at Northern Illinois University and the economic boost to Rockford, Illinois. It is a win-win situation for everyone involved in the program.

And back to us: "My intuitive feeling is that shot peening will fit into the NIU-ROCK titanium project," said Mr. Swiglo.

Making the Grade in Montreal

Editor's Note: Ken I'Anson was the keynote speaker at the Electronics Inc. shot peening workshop this spring in Montreal. His presentation was such a positive message on the importance of shot peening education that we wanted to share it with you.

Montreal Workshop – Keynote Address by Ken I'Anson

Why Are We Here?

Electronics Inc. and a supporting cast of instructors and trade show exhibitors have provided informational workshops around the globe. Only a few cities, such as Singapore, Atlanta, Phoenix and now Montreal, have brought us back for a second workshop. Why Montreal? Montreal is the undisputed hub of aerospace shot peening in Canada.

If you didn't know, the Montreal area hosts shot peening practitioners such as General Electric Aircraft Engines, Pratt & Whitney, Rolls-Royce, Bombardier, Air Canada, Sonaca NMF and Messier-Dowty. There must be close to 100 additional sub-tier suppliers that support these companies. Beyond the manufacturers, the Montreal area has a great amount of R&D activity and academic opportunities provided by McGill University, University of Montreal and NRC (National Research Canada). One of NRC's spin off companies, Tecnar, has developed a particle velocity sensor that measures the velocity of shot particles, on-line. This brings our industry one step closer to reducing our reliance on Almen strips.

Montreal is a "world class city". This beautiful, culturally diverse city hosts the world comedy festival, Just For Laughs (Just pour Rire), and a jazz festival. For car fans, Montreal has a Formula One race and an Indy Race on one of the city's islands.

This brings me to the second reason to ask, "Why are we here?" If you look at the shot peening industry from its beginnings in 1920 or 1930, many of the most significant changes or advancements have been made in the last 15 or 20 years. I believe that these workshops are contributing to many of the advancements. Our industry is networking and communicating like never before and networking is a major attribute of the workshops.

I also believe the shot peening workforce is better trained. Through attendance and participation at these workshops, our operators have an broader understanding of the process and specifications. In my opinion, since the workforce is networking and better trained, aircraft engineers have more confidence in the process. The engineering community can tighten the shot peening specifications and expect reliable and repeatable results.

In my 28 years in the shot peening industry, I've witnessed shot peening coverage requirements dropping to 100% and 200%. I believe this is a direct result of the use of digital Almen gages, specially-graded Almen strips, accredited training and saturation curve software.

The shot peening industry is now considered a repeatable, reliable manufacturing process and due to this fact, NADCAP has included shot peening in the processes that are audited and accredited.

Last point to the question, why are we here? We're here to learn universal best practices. We're here to meet peers that we can network with in the future. We're here to discuss issues and problems with industry specialists and question the trade show exhibitors about their products and services that can benefit us in the future.

We're here to learn, be tested and put our newfound knowledge to practice.

I'd like to encourage each and every student to meet your fellow students. Discuss your issues with your peers. Build your personal network. Test your knowledge by getting tested and certified as a Level I, II or III shot peener. Stay active online with the www.shotpeener.com website.

Thank you for attending this workshop, I wish you the best of luck in this most interesting industry.

Ken I'Anson has been a major contributor to the EI shot peening workshops since their inception in 1991. He has contributed articles and papers that are used in the workshop training manual and has attended the workshops, as an exhibitor and speaker, since the first workshop. He also is the only speaker and exhibitor to take and pass the Level I, II and III exams.

Ken I'Anson is a Sales Engineer for Progressive Technologies. He has worked in the shot peening industry from the equipment side for 28 years. Ken has held positions over the years with Wheelabrator Corporation, Blast Cleaning Products (BCP), Blastworks Inc., and U.S. Filter. His experience is unique in that it has covered both centrifugal wheel peening and compressed air nozzle peening. Ken's present focus is on airframe and land-based turbine shot peening applications. He lives in Grimsby, Ontario with his wife and daughter.


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Shot Peening Coverage– the Real Deal

Dr. John Cammett

In an article in **The Shot Peener** Spring 2007 (Shot Peening – Getting It Right), I stated that coverage is the least understood and least appreciated concept in peening. It is often the least observed in terms of meeting coverage requirements in practice. My statements stem from many years of observation of company specifications, conversations with practitioners and contact with attendees at workshops and onsite training classes. With regard to the latter, often one of the principal barriers to overcome is to uncouple the concepts of peening intensity and peening coverage which, though separate and distinct, are often traditionally and curiously commingled in practice. I will come back to this later in the article, but for now, I will say that the confusion usually centers on the use of exposure times in deriving peening intensity from Almen saturation curves to gage component coverage. Coverage and exposure time of an Almen strip, in general, have nothing whatever to do with peening coverage on a component. Let me leave it at that for now with a promise to return to the subject in later discussion. Before doing that, I will present some of the basics in coverage, then make good on my promise while offering some highlights and arguments concerning the importance of coverage as regards to component performance and peening process economics.

Coverage Basics

What do we mean by coverage?

Coverage or coverage percent up to 100% is defined as the percentage of a given surface area obliterated by shot peening impressions, commonly referred to as dents or dimples. Coverage beyond 100% is defined as multiples of the time to achieve 100% or full coverage. Thus, 200% coverage requires twice the time for full coverage, 150% coverage requires one and one-half the time for full coverage, etc. For practical purposes, full coverage and 100% coverage may be considered synonymous. In detail, however, they are slightly different whereby convention is that full coverage is slightly less (98%) than 100% coverage. This subtle difference arises from recognition that coverage percentages are difficult to discern as 100% coverage is approached and that the rate of coverage in this range is quite low. Further explanation of the latter point is offered later in discussion of how coverage develops.

The time to achieve a given coverage percentage is influenced by media size, peening intensity and media flow rate. Media size and velocity as related to peening intensity dictate the size of peening dents (diameter and depth) presuming spherical media. It should also be noted that media hardness will have a minor effect on coverage. This is because the media hardness relative to component material hardness, for a given velocity, will determine how much energy is transferred into making the impression versus how much energy is consumed in deforming the media particle. Media flow rate (how much media we throw per unit of time) will thus determine the rate at which coverage is achieved. ***It cannot be overemphasized that coverage control cannot be achieved or maintained unless media flow rate is also positively controlled and maintained.***

How does one determine coverage?

Before delving into methods of coverage measurement, I must stress that coverage percentage must be determined by observations on the component. Unless the component material is the same as the Almen strip (AISI 1070 spring steel) or a steel of the same hardness and microstructure, component coverage at given exposure times will not be the same as observed on Almen strips. Moreover, impact angle and component geometry, in addition to hardness, will also influence coverage. In some cases, Almen strip coverage may provide an approximate guide to component coverage, but in the final analysis, coverage must be determined by observations on the component. Exposure times on Almen strips and exposure times on components, in general, have no relationship to each other. For given peening conditions, peening dimple size is a function of material hardness. Softer component materials will achieve coverage more quickly than Almen strips (~45 HRC) while harder component materials will take longer. ***Leave Almen strips to do their one job and that alone is to determine intensity—not coverage.***

As detailed in SAE J2277[1], the most common and usual means for determining component coverage is by optically-aided observation at 10-30X magnification. This can be conveniently accomplished by use of commercially available magnifiers. If component size or geometry precludes direct observation of an area in question, then replicas of the surface may be made and then examined optically to determine coverage. Figure 1 shows two photographic examples of areas peened under the same conditions, but for different exposure times. The exact coverage percentage associated with the peening time for the partial coverage example is argumentative, but it was obviously insufficient to yield full coverage. Peening time was cumulatively increased until full coverage was achieved as evidenced by complete dimpling as in the full coverage example. Viewing replicas of peened surfaces is greatly facilitated by use of a top-lighted stereo microscope. Determining coverage by optical observation may also be facilitated by use of coupons with a ground or sanded finish, particularly for

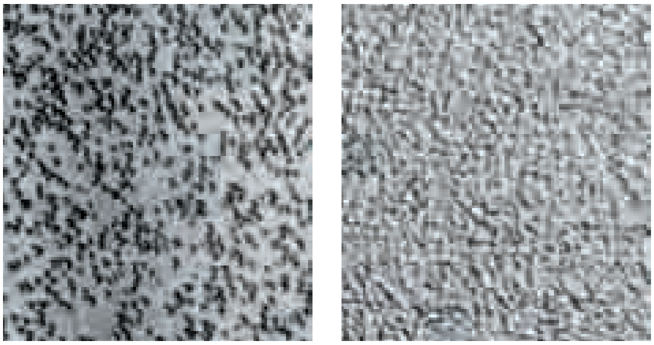

Figure 1. Coverage Examples (Magnification altered from original 10X in reproduction.)

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hard materials as the striated surface appearance will provide good contrast for observing peening dents.

There are methods other than optically-aided observation that may be used to determine coverage. These include video imaging which is a special form of optically-aided observation. This technique requires skill and relatively expensive equipment. Another technique is scanning electron microscopy, either on small components, sections cut from components or on replicas of component surfaces. Because of expense and time, this is not a favored technique, but it can be useful when dimples are difficult to resolve optically as on components of very hard materials. There are also methods involving coating a component and observing relative removal of the coating after peening. This practice most often employs a fluorescent coating observed under black light or the blue dye commonly used in machine shops. These methods require care to either ensure that there is a one-to-one relationship between media impacts and the amount of coating removed or a means to correlate coverage percentage with coating removal.

How does coverage develop?

When considering how coverage develops in peening, one must first realize that coverage is not linearly related to exposure time. Certainly the number of media impacts is linearly related to exposure time; however, peening is a random process and not every media particle impacts a new site. Rather many sites are repeatedly impacted by particles as the process proceeds. As modeled by Lombardo[2], after 90% coverage eighty percent of sites have been struck twice or more with five percent of sites struck five times or more. At 99% coverage, eighty-five percent of sites have been struck twice or more with fifty percent of sites struck five times or more. At 99.9% coverage, more than ninety-five percent of sites have been struck twice or more with eighty percent struck five times or more. In the latter case, more than twelve percent of sites have been struck ten times or more. Figure 2 schematically illustrates the effect of a media impact on a metal surface.

As illustrated in cross-section, a particle impact creates a visible dent in the surface and an associated zone of plastic flow beneath the surface. This plastic zone is often up to three times the diameter of the dent. Thus, it is not necessary for surface dents to overlap in order that subsurface plastic zones overlap as illustrated in Figure 3. Here in cross-section, the plastic zones associated with separated dents overlap.

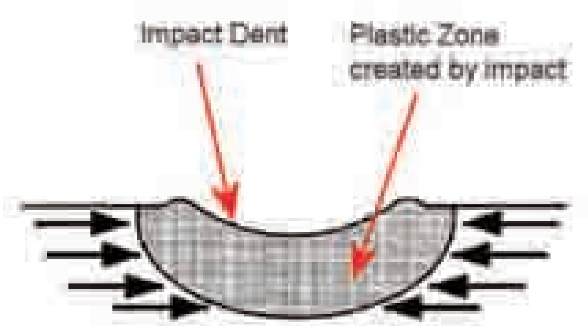

Figure 2. Schematic of Media Particle Impact and Resulting Plastic Zone

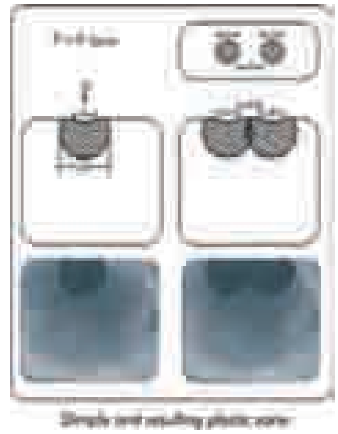

Figure 3. Superposition of Plastic Zones Associated with Adjacent but Separated Dents

In the above figure, the lower images were produced by metallographic etching of cross-sections through a plastic zone created by pressing a hardened ball into the metal surface.

The development of coverage may be expressed graphically as a coverage curve with an actual example from work by Cammett and Prevey[3] shown in Figure 4. The straight line relationship with triangles as data points represents the accumulation of media impacts with time. The decelerating curve with squares as data points represent coverage accumulation with time as given by the model of Kirk and Abanyeh[4]. The open circles, in good agreement with the coverage model, represent actual coverage observations up to the point at which some individual dents could be resolved. The shape of the coverage curve is typical of that for all other cases I have observed.

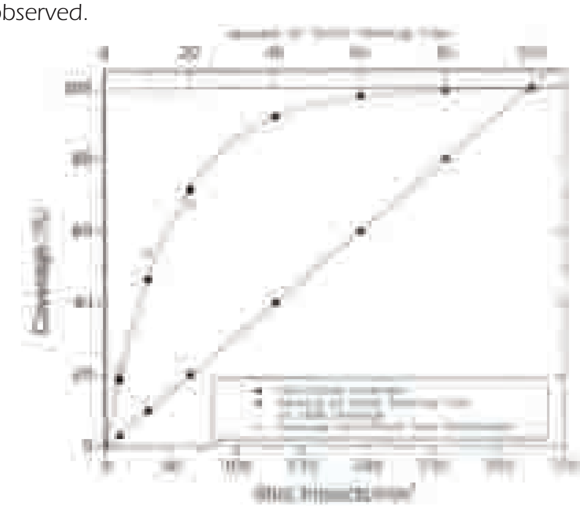

Figure 4. Coverage Curve (4340 Steel, 38 HRC, 9A Intensity, S280 shot)

Some interesting observations may be made from the coverage curve in Figure 4. The initial rate of coverage was high, but decreased markedly as 100% coverage was approached. In fact the time to achieve the final 10% of coverage was 1.5 times that to achieve the first 90%. The final 1% of coverage required 20% of the total time to 100% coverage while the final 2% of coverage required nearly 40% of the total time. The latter fact highlights the significance of considering 98% rather than 100% as full coverage. Hitting 98% on the button isn't easy, but significant cycle time savings could result from excellent and reproducible coverage control.

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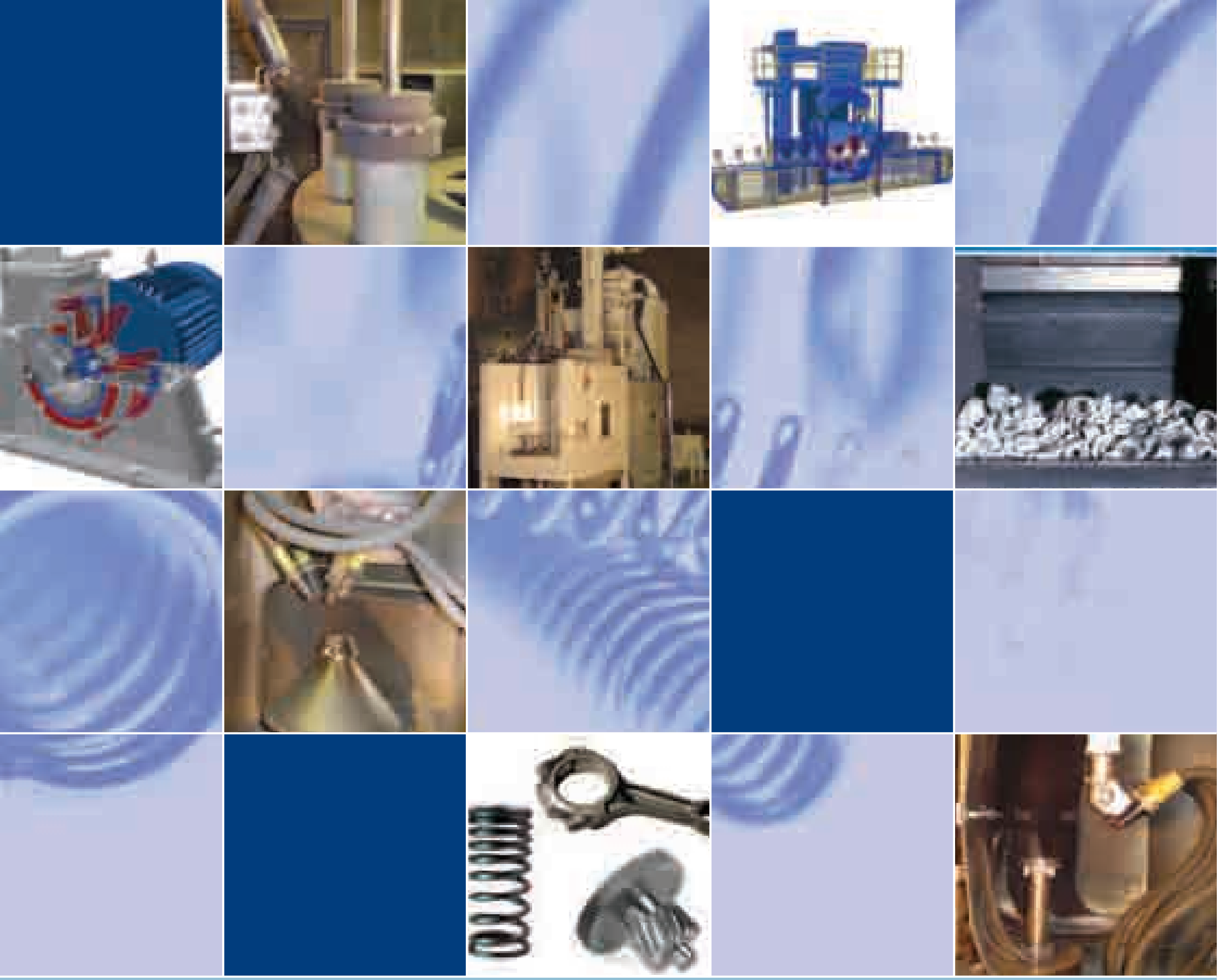

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THE REAL DEAL
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Certainly the Kirk-Abanyeh model, (details not shown here), is an excellent portrayer of coverage development. Application of the model, however, among other things requires measurement of peening dent diameters. This is beyond the practical capability of most peening practitioners. There is yet a much simpler method that may be used for estimating coverage development. Expressed mathematically, the relation is:

$$C_n = 1 - (1 - C_1)^n$$

Here C_n is the coverage percentage (expressed as a decimal) after n peening cycles, C_1 is the coverage observed after one peening cycle and n represents the number of peening cycles (or n units of peening time). It must be recognized that this relationship becomes non-physical as one approaches 100% coverage because n approaches infinity as C_1 closely approaches a value of 1. As a practical matter, nonetheless, one will find it useful to estimate the number of cycles (or time) to achieve 98% (0.98) coverage deemed as full coverage. A log-log plot based upon the above relationship of coverage achieved in one pass vs. passes required for 98% coverage will readily permit full coverage estimation. An example of this is shown below in Figure 5. In this example, after observation of 39% coverage in one peening pass (cycle), an estimate of 8 cycles was made to achieve 98% coverage. Of course, the result is just an estimate and must be checked by actual observation.

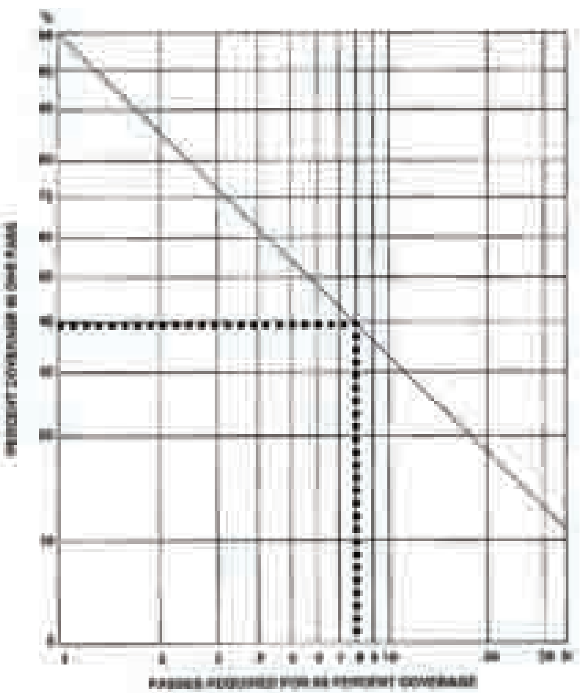

Figure 5. Graph for Estimating Coverage

The Importance of Coverage

Coverage is important first because of its impact on product quality and performance. Insufficient coverage may permit premature component failure by not overcoming tensile residual stresses from prior component processing or by not sufficiently counteracting applied tensile stresses in service. This is widely recognized, but the recognition often results in overdoing coverage. This is not a good thing since excessive coverage, in some cases, may permit premature component failure because excessive coverage creates surface damage. Peening involves a competition between the beneficial effects on component performance of subsurface compressive residual stresses and surface damage created by peening that tends to reduce component performance. Examples of surface damage that may be created by excessive coverage in peening include burrs, microcracks and microlaps which have sometimes been called peened surface extrusion folds (PSEF). Such defects are created by surface plastic deformation associated with multiple overlapping media particle impacts at and near the same site. Examples of such surface damage features are seen in the metallographically-prepared section through the peened surface of a steel component (42 HRC) in Figure 6 from work by Cammett[5]. Cracks in these photomicrographs are fatigue cracks whose initiation was favored by the presence of the defects created by peening.

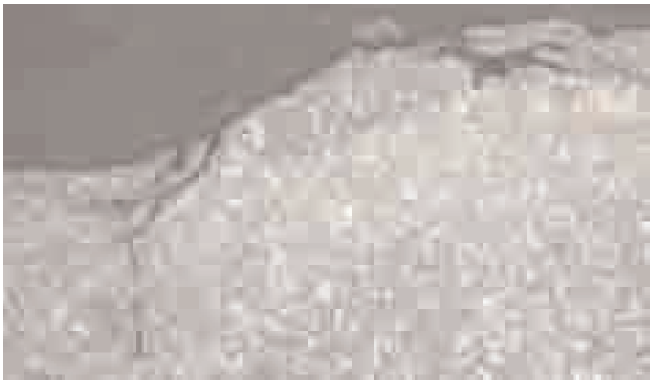

Figure 6. Fatigue Cracks Emanating from Peening-Induced Surface Defects

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Further evidence for the adverse effect of excessive coverage on component performance is highlighted by the fatigue S-N curves for 4340 steel shown in Figure 7 from the work of Cammett and Prevey[3]. Some readers may note that this is the same figure used in my previous article. It clearly shows that fatigue strength and life were degraded by coverage in excess of 100%. Moreover, the apparent fatigue strength for 80% coverage was the same as for 100% coverage. Along with this was the observation that full development of surface and subsurface compressive residual stresses was achieved at 70-80% coverage. This is not to be construed as general advocacy for partial rather than full coverage in peening although there is potential for doing so after careful study and invocation of excellent peening control in terms of both intensity and media flow. It is advocacy for not exceeding full coverage or nearly full coverage in peening. Undershooting full coverage by a small margin is probably not harmful given the logic that overlapping dents on a peened surface are not required for overlapping of subsurface plastic zones as illustrated previously.

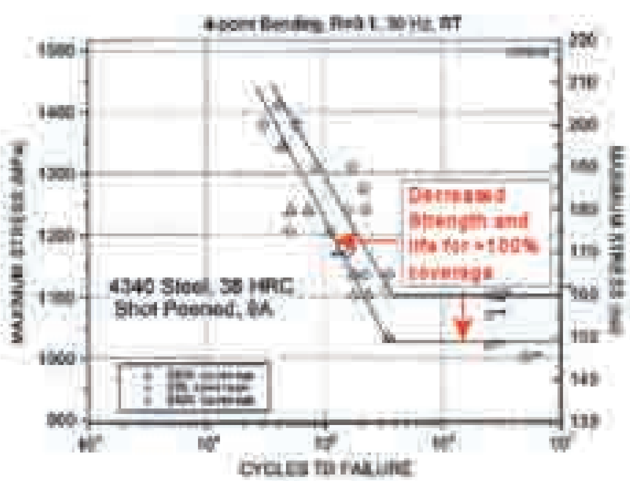

Figure 7. Effect of Coverage on Fatigue of 4340 Steel

As alluded to in the previous discussion, coverage is also important because of its influence on process economics. In the example offered, it was shown that the same fatigue strength in 4340 steel resulted after only about 80% coverage as was attained after 100% coverage. The peening time required for 80% coverage was only twenty percent of that required for 100% coverage. These facts are illustrated by the timelines in Figure 8. Thus, in this example, the full benefit of peening was realized in only one-fifth of the processing time needed to attain 100% coverage. Compared with greater requirements such as 150% or 200%, as are commonly called out, the opportunities for time and cost savings are concomitantly larger. The loss of fatigue strength resulting from peening coverage greater than 100% is further reason to control coverage. The concept of controlled coverage in peening is embodied in a recent patent authored by Prevey and Cammett[6]. I hasten to add again that proper coverage control demands excellent control of media flow.

Peen Lean! Do no more than is necessary to guarantee full process benefit.

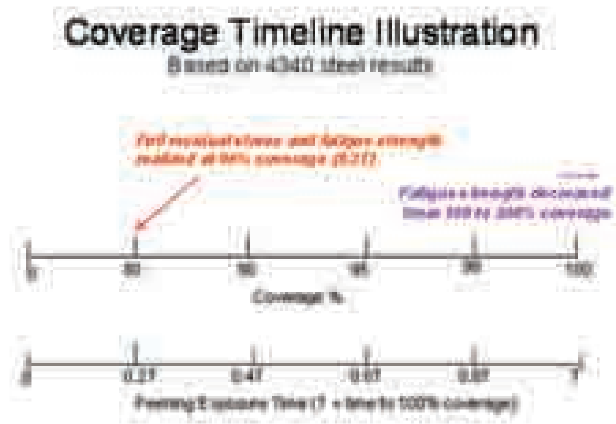

Figure 8. Timeline for Coverage in 4340 Steel

Summary Comments

In this article I have covered basic aspects of peening coverage while addressing and dispelling the erroneous linkage of component coverage with exposure time for Almen strips in saturation curve development and intensity determination. I also addressed the subject of how coverage develops and the matter of coverage curves and their fundamental nonlinearity. Coverage is far too important a consideration to ignore in peening practice as it has significant ramifications in both component quality and in process economics. This is why I have called it the real deal. I leave you with one parting shot… ***Peen Lean!***

References
[1] SAE J2277, Shot Peening Coverage Determination
[2] Lombardo, ICSP6
[3] Cammett and Prevey, ICSP8
[4] Kirk and Abanyeh, ICSP5
[5] Cammett, unpublished work
[6] Prevey and Cammett, U.S. Patent 7,159,452

John Cammett Dr. John Cammett, Materials Engineer/ Metals Branch Chief, recently retired after more than 15 years service with the U.S. Navy (Navair) in the In Service Support Center to the Fleet Readiness Center East, Cherry Point, North Carolina. His more than forty-year professional career has also included materials engineering and management positions at the General Electric Company, Evendale, Ohio; Metcut Research Associates Inc. and Lambda Research Inc, Cincinnati, Ohio. His areas of expertise at Cherry Point included analysis of aircraft component failures, aircraft mishap investigations, development of repair/rework process methods and technical support of depot manufacturing/rework/repair operations, surface integrity investigations and metallurgical applications. A Registered Professional Engineer, Dr. Cammett is a fellow of ASTM, past Chairman of Committee E-9 on Fatigue, Life Member of ASM International and past chairman of the Cincinnati Chapter, also a member of the International Scientific Committee for Shot Peening and a conferee of the 2006 Shot Peener of the Year Award. In "retirement", Dr. Cammett is currently involved in training and consulting activities with Electronics Inc., Nadcap auditing plus other research and consulting activities in the private sector.
Dr. Cammett may be contacted via cell phone at 1-910-382-5771 or email at pcammett@ec.rr.com.

Flapping My Lips

on the importance of a controlled shot peening process

Daryll McKinley

I was recently asked to review/develop a rotary flap peening certification program by a company in the aerospaoce industry. For the purpose of this article, I'll call them Company X. This company performs repair work on critical components, very few of which are shot peened by the original equipment manufacturer. The repair areas consist of slight damage that has been blended out and the areas are less than one square inch. Their need for shot peening is not vast, and the relatively small repair areas on the parts are well-suited to rotary flap peening.

Flapper peening is a manual shot peening process so artisan training is crucial.
(Photograph courtesy of Electronics Inc.)

What's that? You are not aware of rotary flap peening? Well, don't feel like the Lone Ranger! It doesn't make the list of the top ten metal treatment processes. However, it does exist, and has very useful applications. Now, you may be thinking, "Hey, I may have a need for this flap peening to do minor touch-up work on my parts." Or you may be thinking, "Hey, this is an article about a process that I don't need; no thanks." If the latter thought belongs to you, please stick with me. This is not an article about the process of rotary flap peening. If the first thought is the one that came to you, and you would like more information, please contact the staff at Electronics Incorporated and they can give you an information dump on the process and equipment. Also, Electronics Incorporated always lectures on and demonstrates rotary flap peening at their workshops. If you haven't attended an EI shot peening workshop, I highly recommend it. Not only will you get a lot of useful information about shot peening in all of its forms, but you'll get to meet a lot of nice people who have collectively been in the industry since dirt was invented. A nice network of smart people is a good safety net in the small circles of the shot peening industry. Well, that's enough commercial time…

For now, let me say that rotary flap peening was developed by 3M™ for repair of small areas on aircraft and the tools are basic and portable. The equipment consists of a rotary tool with a slotted mandrel, peening flaps, a magnetic Almen strip holder, and a RPM meter. The peening flaps are fabric strips that have one millimeter tungsten carbide balls adhered to their ends. The flaps slip into the slot of the mandrel and the rotary tool is used at a constant RPM to "flap" the balls against the surface of the workpiece. This causes the formation of peening dimples and imparts a compressive stress layer, just like in "normal" shot peening. Of course, as with "normal" shot peening, the intensity is measured by the use of Almen strips and an Almen gage. The key process controls are RPM of the rotary tool and tool stand-off distance. U.S. military specification MIL-R-81841 is the primary document used for process control of rotary flap peening.

So, what are the key elements of establishing a rotary flap peening certification program? Well, it's not that far off from establishing a certification program for any type of shot peening. It is similar to manual shot peening in that the peening tool is in the hand of the artisan, which means that the artisan is the most important link in the process. Feel free to review my previous article, "Of Audits and Artisans" (Summer 2006 issue of **The Shot Peener**), in which I affirm that the most important piece of your shot peening puzzle is your artisan, regardless of the peening method(s) that you use.

With rotary flap peening, since the peening tool is actually in the hand of your artisan, his training must be top-notch. Additionally, training your inspectors in how to detect proper coverage is paramount. The training program should include the artisans, inspectors, shop foremen, and anyone else who has a stake or a role in your peening process.

Classroom and hands-on training for everyone involved in the process is crucial to a successful shot peening program

One of the critical aspects of training is classroom lecture, in which the fundamentals of shot peening are taught, namely why it is done and how to do it correctly. I believe that at least four hours of classroom training is required. When I asked to see Company X's classroom training materials, I was wonderfully surprised to find out that they actually had these materials, and had used them! The lesson material was mostly correct, but was on the skimpy side. I suggested a revision and an expansion of the material.

Subsequent to the classroom training, the artisan should receive practical, hands-on training. This training may be obtained through a third-party or given by an experienced artisan within the company whose method has been reviewed and approved by engineering. Each artisan in training should perform the peening, demonstrate proper peening technique, demonstrate the use of Almen strips and an Almen gage, develop a saturation curve, and inspect for complete coverage. Each phase of this training must be witnessed and recorded by the training authority. Again, Company X was on the ball (pardon the pun) and was able to show me their documents used to record the events during practical training of the artisan. Their training document had check boxes to mark

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satisfaction of each required activity. Needless to say, I was impressed.

Artisans and inspectors must be able to pass written tests on all aspects of the shot peening process

When the classroom and practical training have been accomplished, each artisan and inspector must take and successfully pass a written examination. This examination should cover all aspects of shot peening, ranging from its purpose to its application. Tests that I have used are typically about two pages and twenty questions, including a graph and peening data to be used by the artisan/inspector to generate a saturation curve and to determine the pertinent information on it, such as intensity and exposure time. A passing grade should be established, and I like to use 80%. If the artisans complain, you could ask, "Don't you want to be above average?" Their answer usually consists of a grumble. Again, Company X came through and was able to produce written test materials as well as test results. They had indeed maintained proper training documentation.

By the way, SAE AS7117 is the NADCAP standard that establishes the requirements for shot peening, peen forming, and glass bead peening. Section 7 covers the training and evaluation of personnel, and delineates the activities that an artisan must demonstrate during his or her evaluation. Not all of these activities are applicable to all peening methods, but those that are applicable to your process should be addressed.

Successful shot peening programs are supported by good documentation

Another yardstick of a successful shot peening program is the documentation that defines and controls it. Any company that performs shot peening must have an overarching specification that defines all aspects of the program. This document is the backbone of the program and addresses, at a minimum, equipment, part preparation, training, certification, recertification, decertification, documentation, record-keeping, and fishing (just seeing if you are paying attention). In addition to this program specification, it is advisable to develop and maintain job-specific specifications that describe the tooling and process for each part that gets shot peened. These job specifications will often refer to the program specification, but are much more detailed in their scope with respect to performing peening on the parts. Finally, a logbook should be kept that records the details of each job that was performed. This logbook can be physical (i.e., on paper) or electronic. It should contain the following information for each job: part name, part number, serial number, date of peening, intensity determination, the artisan's identification, and the inspector's identification. (Again, SAE AS7117 contains this information). Company X had both a program specification and a job specific specification, although they were somewhat flawed. For instance, the coverage requirement in the job spec was defined as 2.0. I have no idea what this meant and I'm sure the person that wrote it didn't know either. I recommended a full review and revision of their specifications.

The third leg in the shot peening program tripod is tooling and equipment. We all know that tools and equipment must be maintained and kept in calibration. But, are you using the proper tools? Could your peening process be improved by the use of different, or better, tools? In a paper published by Mr. Pete Bailey of Electronics Incorporated titled "Manual Peening with the Rotary Flap Process"[1], he shares the results of his tests regarding rotary tools and their consistency, which certainly affects the quality of a rotary flap peening job. Mr. Bailey determined that, out of three types of rotary tools tested, a medium-speed air drill provided the most consistent RPM. This is valuable information for Company X, and they could use the information to substantiate their process to a real auditor. The only requirement stated for flapper peening equipment in SAE AS7117 is that the tool is capable of maintaining the required RPM and that it consistently reproduces intensity values. By the way, I also inspected their Almen gage and found it to be of current design, in good repair, and calibrated.

Are you using the proper tools? Are they in good working order?

Stay informed on the newest technology and processes

How does one happen to find the latest shot peening technology information and advice? Well, being involved in the shot peening community will certainly keep you abreast of the latest and greatest. This can be done by participating in workshops and seminars or by becoming involved with the SAE committee on surface enhancements. At a minimum, I advise you to subscribe to newsletters and get on mailing lists of companies that provide information or services regarding shot peening. I make of habit of bookmarking every peening site that I find on the Internet. And, as with Company X, it wouldn't hurt to have someone come in, look over your shoulder, and provide a positive critique of your program.

Have my ramblings provoked any noteworthy thoughts? I hope so. I'll wrap up by saying that regardless of your method of peening, it is imperative that you establish, maintain, and document every thinkable aspect of your process. Training of personnel should be a major portion of your process, as well as documentation. Your documentation should be easily accessible and clear. These are things that an auditor will certainly look for, likely immediately upon his arrival, with the exception of the coffee pot. Thanks for your attention, and, as always, happy peening!

[1] Manual Peening with the Rotary Flap Process, P.G. Bailey, 7th International Conference on Shot Peening, Warsaw, Poland

Daryll McKinley has a Bachelor's Degree in Mechanical Engineering, a Master's Degree in Materials Engineering, and he is a Registered Professional Engineer. During his career, he has developed and conducted shot peen artisan training and certification programs for the U.S. Navy, which were later adopted by private industry. During his employment with the Department of Defense, he conducted shop audits, authored peening process specifications, and wrote equipment specifications. Mr. McKinley's background includes mechanical design and testing, hardware failure analysis, aircraft accident investigation, materials processing, and corrosion control.

He has experience in the aerospace, automotive, military, and litigation fields. His past employers include the Department of Defense, General Dynamics, and a forensic consulting firm. Mr. McKinley now works as a consulting engineer performing failure analysis, mechanical design and shot peening training.

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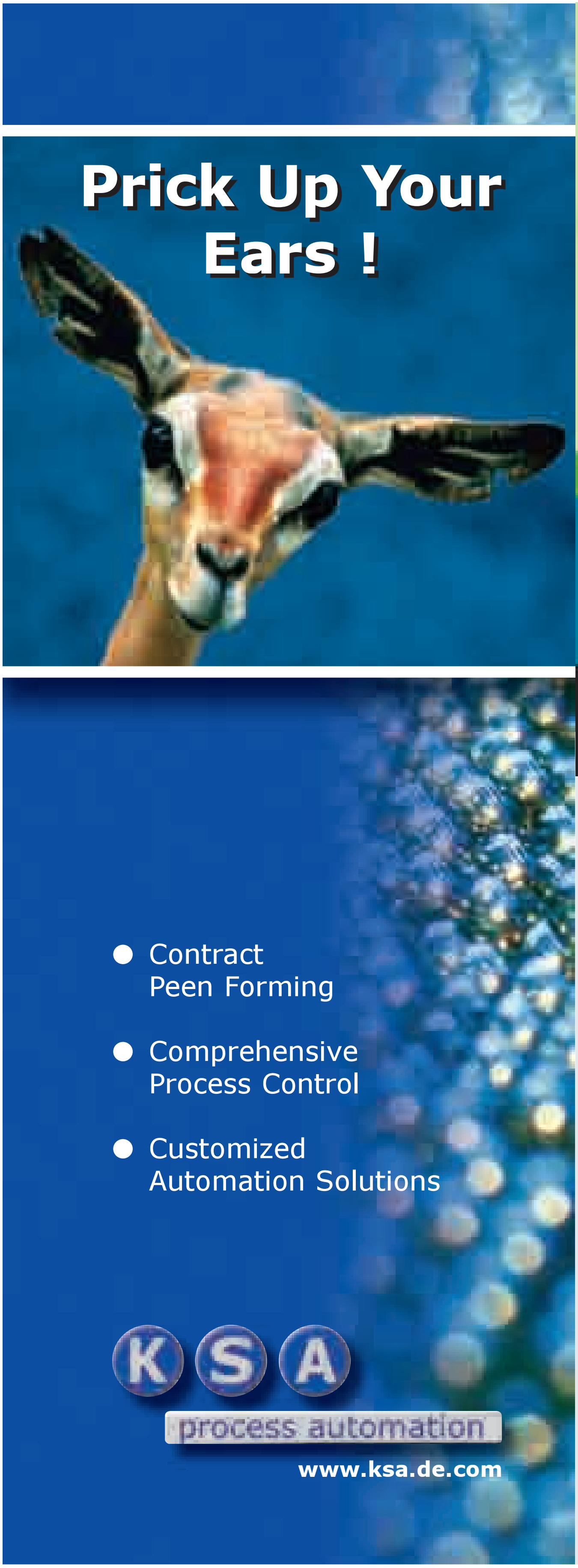

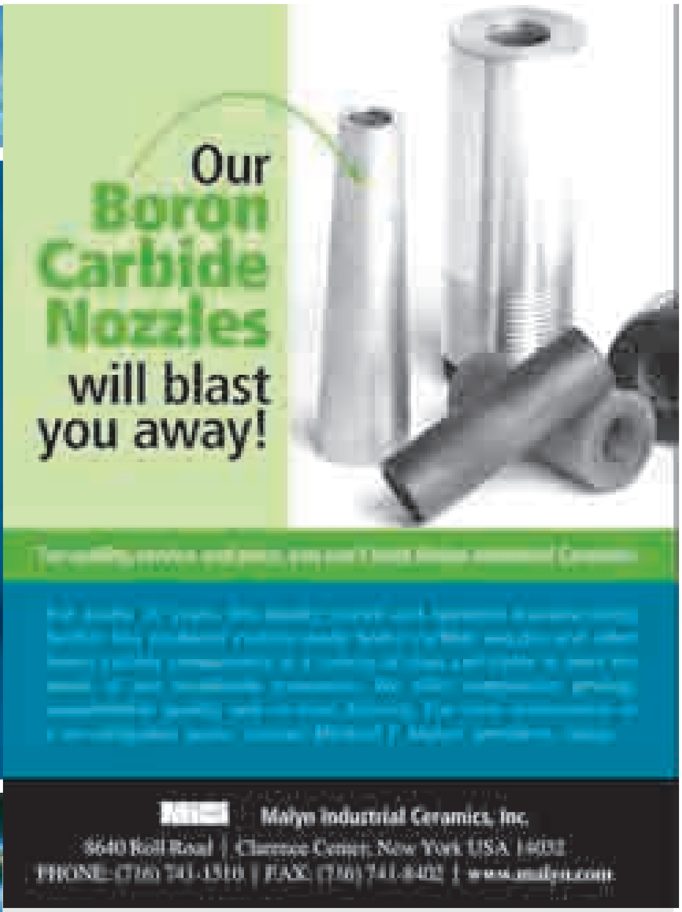

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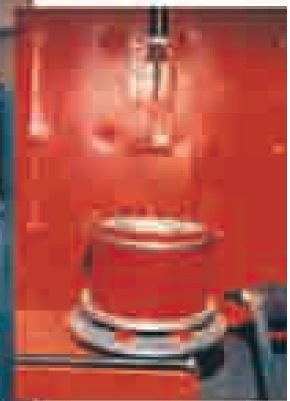

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Peening Intensity Curves

David Kirk

INTRODUCTION

Two parameters dominate shot peening effectiveness: COVERAGE and PEENING INTENSITY. Coverage is two-dimensional, easy to define (percentage of surface covered by indentations), visible and can be measured directly. Peening intensity, on the other hand, is three-dimensional, difficult to define, invisible and can only be measured indirectly.

Indirect measurement of peening intensity is achieved by exposing Almen strips to the shot stream for different periods (of time or its equivalent in terms of either number of passes or feed rate). When one major face is shot peened, each strip develops a convex curvature whose arc height, h, can readily be determined using an Almen gage. The variation of arc height with peening 'time', **t**, is a peening intensity curve (commonly called a "saturation curve"). "Saturation intensity" is a particular arc height on the curve, **H**, for which doubling the corresponding peening time, **T**, gives a 10% increase in arc height, see fig.1. This parameter is used to quantify differences between peening intensity curves and has become the industry-standard quantitative measure of a shot stream's indentation ability.

A peening intensity curve is a 'continuous function' and has a corresponding equation relating arc height to peening time. Standardized gages and procedures are used to monitor the change of arc height with peening time. Gage measurements can then be used to estimate the peening intensity curve parameters and hence "saturation intensity".

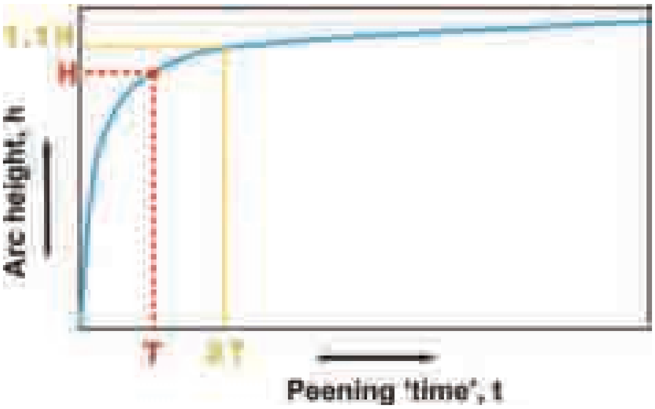

Fig.1 Peening Intensity Curve ("Saturation Curve")

Each impacting shot particle produces a minute amount of plastic stretching parallel to the strip surface. This stretching induces a corresponding minute strip deflection, **δh**. The plastic deformation is **tensile** so that convex curvature occurs. In this respect the situation is very similar to peen-forming.

GAGE MEASUREMENTS

Every measured arc height, h, is the sum of a very large number of individual **δh** contributions. We therefore have features in common with a rain gage. Fig.2 shows the principle involved in rain measurement. Each raindrop will make a tiny contribution, **δh**, to a measurable height, **h**, of rainwater collected over a time period, **t**. The measured height will also depend on the rate, **r**, of drops entering the gage. Hence:

$$h = r.\ \delta h.t \qquad (1)$$

If both **r** and **δh** are known to be constant then equation (1) can be written as:

$$h = a.t \qquad (2)$$

where **a** is a constant (**r. δh**)

Equation (2) is a straight line. Estimation of that straight line could be achieved by taking measurements of **h** at different times, **t**, as shown in fig.2. Measurements have statistical variability and can therefore only be indicators of a known, behavior pattern. In 1805, Legendre introduced the procedure of "least squares" as a method for arriving at a 'best' estimate for a known pattern. Since then, up until the computer era, generations of engineers endured the tedium of having to determine, manually, the 'normal equations' that defined the best-fit equation for each data set.

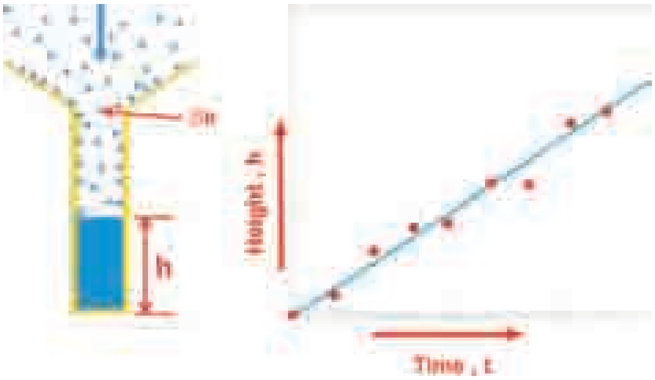

Fig.2. Standard rain gage with hypothetical data set and fitted linear curve.

Fig.3 shows the parallel situation for Almen strip arc height evolution. Each rebounding shot particle has caused a tiny amount of plastic stretching of the peened surface with a corresponding contribution, **δh**, to the arc height, **h**. A data set is shown - fitted to a 'known curve'.

One obvious difference between the curves shown in figs.2 and 3 is their shape. Peening of Almen strips must therefore involve a reduction of **δh** with increase of peening time.

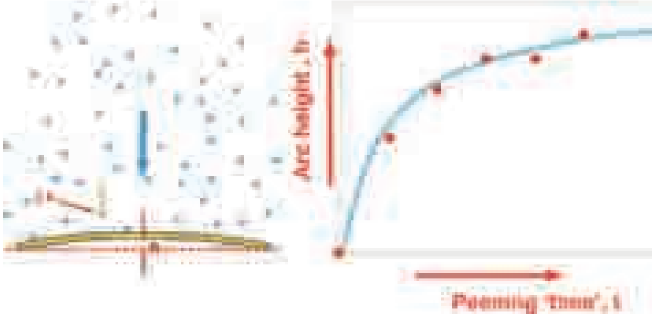

*Fig.3. Almen arc height, **h**, as the sum of individual contributions, **δh**, with hypothetical measurement points and fitted 'saturation' curve.*

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REDUCTION OF ARC HEIGHT CONTRIBUTION, δh, WITH PEENING TIME

The reduction of arc height contribution with increased peening time determines the shape of peening intensity curves. This reduction is primarily associated with the plastic deformation behavior of the surface. The deformed surface layer of a peened Almen strip is made up of innumerable overlapping deformation zones. These deformation zones contain a variable degree of work-hardening. As peening time increases, individual deformation zones progressively overlap and work-hardening accumulates. Fig.4 is a simplified representation of the effect of peening time, together with a corresponding peening intensity curve. The shape of the intensity curve mirrors the development of the deformed surface layer. The final outcome is a fully work-hardened surface layer of thickness, t. That thickness is directly related to the peening intensity, **H**, of the shot stream being used.

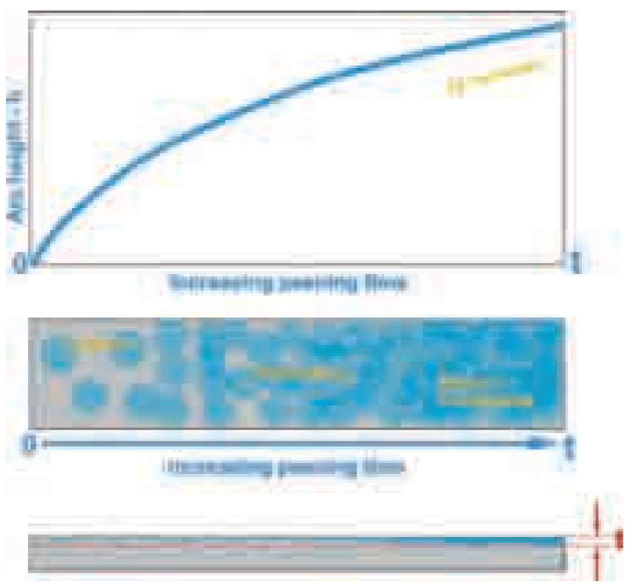

Fig.4. Progressive overlapping of deformation zones to produce a deformed layer of thickness, t.

As peening progresses we work harden the surface, reducing its ductility, so that it becomes progressively more difficult to produce surface stretching.

QUANTIFICATION OF REDUCTION IN δh WITH INCREASE IN PEENING TIME

The reduction in arc height contribution with peening time can be quantified by modifying equation (1) to give:

$$h = r.\sum_{0}^{t} \delta h.dt \qquad (3)$$

The Greek letter Σ simply implies 'sum'– of contributions **δh** that vary in size in minute intervals of time, **dt**, spread over a range of time from **0** to **t**. Peening an Almen strip over a time period, **t**, is therefore a practical application of integral calculus! The strip integrates (sums) the effects of a large number of indentations imposed over a known period of time.

The shape of any curve is defined by its corresponding equation. For peening intensity curves we can invoke a series of equations, of increasing complexity. A 'first approximation' to observed curve shapes is a two-parameter exponential equation of the form:

$$h = a\,(1\text{-}\exp(\text{-}b^*t)) \qquad (4)$$

where **a** and **b** are the two parameters.

If we differentiate equation (4) with respect to **t** we get the equation for indentation contributions:

$$\delta h/dt = a^*b^*\exp(\text{-}b^*t) \qquad (5)$$

Equation (5) is an 'indentation contribution curve'. That is to say it shows how the contribution, **δh**, of individual indentations changes with peening time. Fig.5 shows a peening intensity curve based on equation (4), together with the corresponding indentation contribution curve given by equation (5). It is clear that the contribution to arc height by successive impacts falls rapidly to a very small value.

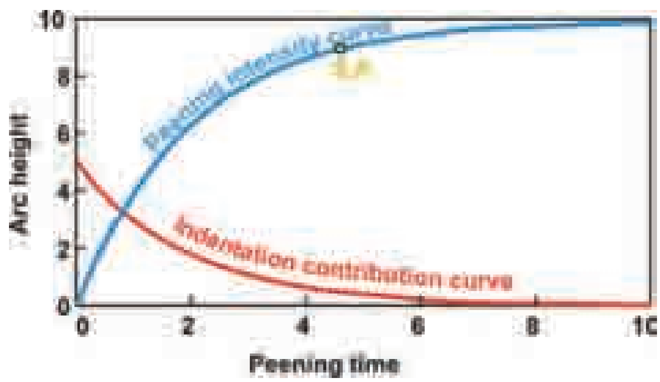

Fig.5. Two-parameter exponential peening intensity curve with corresponding indentation contribution curve and saturation point, S.P.

Table 1 lists four generally-recognized equations that simulate peening intensity curves, together with the corresponding first-differential indentation contribution equations.

Table 1. Peening Intensity and Indentation Contribution Curve Equations

Peening intensity Curve	Indentation Contribution Curve
h = a(1 - exp(-b*t))	dh/dt = a*b*exp(-b*t)
$h = a(1 - \exp(-b^*t^C))$	$dh/dt = a^*b^*c^*\exp(-b^*t^C)$
$h = a(1 - \exp(-b^*t^C) + d^*t)$	$dh/dt = a^*b^*c^*\exp(-b^*t^C) + a^*d$
h = a*t/(b + t)	$dh/dt = a^*b/(b + t)^2$

If we use a two-parameter equation for peening intensity curves then one parameter, **b**, reflects the rate of generation of deformation zones and the other, **a**, reflects the contribution made by those indentations. Since we have only one parameter relating to indentation contributions that implies that only one primary height-generation mechanism is involved – plastically-deformed surface layer formation. The *form* of the equation indicates how the contribution of the indentations decreases with time. It is known, however, that three- and four-parameter equations are rather more accurate expressions of the 'known shape' of saturation curves. The extra parameters accommodate the secondary mechanisms involved in arc height generation.

COMPARISON OF PEENING INTENSITY AND COVERAGE CURVES

In plan view the indentations that contribute to coverage are smaller in surface area than those of the deformation zones that surround them. We might, therefore, expect that a coverage curve would take longer to reach a nominal 100% than would a peening intensity curve.

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Be It As Simple As To Blast Clean The Plates Or As Complex As
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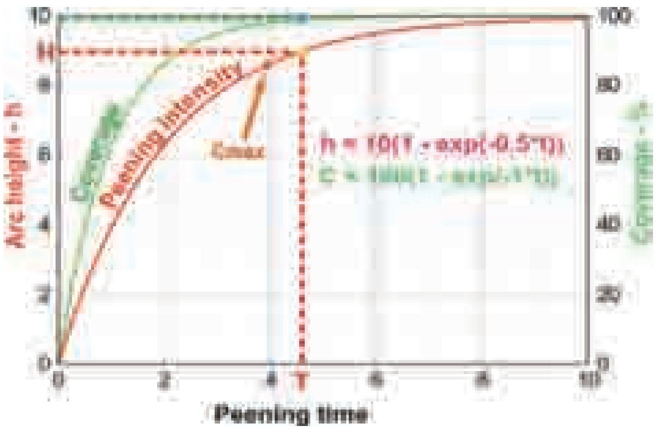
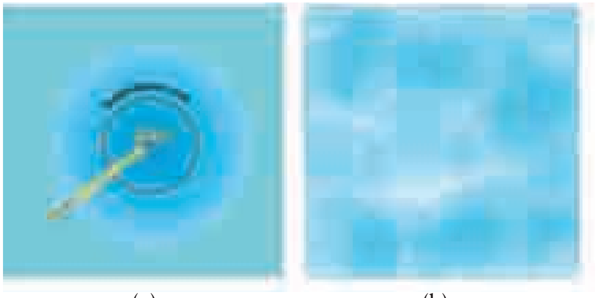


Fig.6. Comparison of Coverage and Peening Intensity curves for the same shot stream.

In fact the reverse is the case – which is paradoxical. The real situation is *modeled* in fig.6. At the ''saturation point' the peening intensity is shown as **H** at a time **T**. At **T** the coverage is shown as being approximately 99%. Peening intensity at **T** is only 90% of its value at **2T** when the deformed surface layer is approaching its maximum thickness. The coverage at **2T** will be 99.9%.

The key to unlocking the paradox lies in a consideration of the variation of deformation within a deformation zone. This variation is modeled for two dimensions in fig.7. Most of the deformation zone, shown in (a), has only had a very small amount of plastic deformation! That means that multiple impacting, shown in (b), will be required to exhaust the material's hardenability. For the model illustrated in fig.7(b) the degree of multiple impacting would correspond to 99.9% coverage but work-hardening is, however, far from complete.



(a) (b)

Fig.7. (a) Deformation zone surrounding an indentation and (b) multiple overlapping of zones.

PEENING INTENSITY

Peening intensity is a parameter that is deduced for each peening intensity curve. It is the arc height, **H**, that occurs at a 'characteristic point' of the curve. This characteristic point has long been associated with the so-called "knee" of the peening intensity curve. The definition (and specification) of the characteristic point has evolved somewhat erratically over a period of more than fifty years. Originally curves were hand drawn and subjective judgment was needed to pick a point where the "knee" occurred. In 1984, SAE adopted a mathematical approach – ostensibly in order to eliminate subjectivity. The 2003 version of J443 clarified the mathematical aspect ("10% rule") but is also ambiguous. The "knee" of a peening intensity curve evokes a mental picture of the region that has maximum curvature. Curvature, **C**, is the reciprocal of curve radius, **r**. Hence:

$$C = 1/r \qquad (6)$$

The smaller the radius the greater is the curvature. A straight line has no curvature - because r = ∞ and 1/∞ = 0. A circle has a constant curvature because the circle radius is constant. *All* other curves have a variable curvature. The "knee" of a curve can be defined, quantitatively, as *the point at which the curve has a maximum curvature*. For curves such as peening intensity curves the curvature is given by:

$$C = d^2h/d^2t/[1 + (dh/dt)^2]^{1.5} \qquad (7)$$

where **dh/dt** and d^2h/d^2t are the first and second differentials of the curve equation.

As an example, if h = a(1-exp(-b*t)) then dh/dt = ab*exp(-b*t) and $d^2h/dt^2 = -ab^2exp(-b*t)$ so that:

$$C = -ab^2exp(-b*t)/[1 + a^2b^2exp(-2b*t)]^{1.5} \qquad (8)$$

The point of maximum curvature occurs when **C** has its maximum (absolute) value. "Absolute" comes in because convex curves have positive curvature and concave curves have negative curvature. A straightforward way of obtaining the maximum value for **C** is to insert the r.h.s. of the equation into an Excel spreadsheet together with values for **a**, **b** and a 'guess' value for **t**. 'Solver' can then be invoked to 'minimise' the r.h.s. value by changing **t**. The derived 'minimized value' for **C** is a negative quantity - because the curve is regarded as being concave.

For illustration purposes if **a = 10 and b = 0.5** then equation (8) yields **h = 8.59** at **t = 3.91** as the point of maximum curvature. This point is shown in fig.6 as **Cmax**. It can be seen that the 'conventional' and 'mathematical' definitions for the knee location are close to one another.

The great advantage of curve-fitting is that it allows us to determine objectively a unique, fixed, quantity that characterizes the peening intensity of a shot stream.

DATA POINTS AND PEENING INTENSITY CURVES

Peening intensity curves are *derived* from sets of data points. Each data point is subject to variability – either random or systematic. If we only have random errors then they can be 'smoothed' by using a curve-fitting procedure. A typical situation, using real data (SAE Data Set 10), is illustrated in fig.8. The fitted curve has smoothed out the variability displayed by the data points. Looking at the box insert the measured arc height at **t=1** is slightly lower than that at **0.75**. This sort of situation would be expected with the random errors that are inescapable in strip testing. None of the data points lies *exactly* on the best-fitting curve. Similarly the derived peening intensity of **5.47** occurring at **t=0.55** does not coincide exactly with any of the data points.

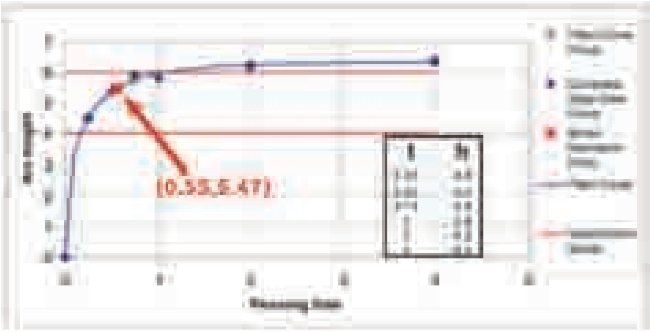


Fig.8. Peening intensity curve derived using six-point data set (shown in box insert).

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For the primary objective of locating the 'knee' of a peening intensity curve it is important to have a data set point distribution that straddles the knee.

DISCUSSION AND CONCLUSIONS

A peening intensity curve is, in effect, an Almen strip peen-forming curve. Tensile plastic deformation within the peened surface induces convex curvature. This induced curvature increases with both the indentation ability of a given shot stream and with the total peening time. Shot stream particles will, of necessity, vary in size, shape and velocity. Almen strip measurements are a remarkably effective, quantitative, means of integrating the indentation effects of the numerous shot particles that contribute to curvature. "Saturation intensity" is a parameter derived from a given peening intensity curve. This has become the industry-standard quantitative measure of a shot stream's indentation ability.

Peening intensity curves are not linear – because of the nature of the mechanisms that are operating. Work-hardening reduces the arc height contribution from individual impacts. The work- hardened surface layer develops more slowly than does coverage – because deformed regions can endure multiple, albeit reducing, plastic deformations. That contrasts with coverage - where each indentation makes a fixed contribution. The depth of the work-hardened surface layer will be proportional to the peening intensity of the shot stream being used.

Individual indentation effects decrease with peening time in a way that can be predicted by differentiating the equation of the corresponding peening intensity curve. This feature allows us to gain an insight into the several mechanisms that co-exist during peening of all materials – not just Almen strips. These mechanisms operate in the three-dimensional surface layer that work-hardens during peening.

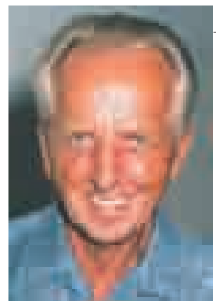
Curve-fitting allows the unavoidable variability of individual strip measurements to be smoothed. Consider, for example, the values given in fig.8. *If* the measured arc height at the time 0.50 had been 5.2 (rather than 5.4) then computerized curve-fitting would derive the slightly-changed values of saturation intensity 5.46 at a time of 0.59. A data-point method of determining saturation intensity, on the other hand, would have changed the estimation from 5.4 at 0.50 to 5.8 at 1. In general, *data point definition of peening intensity is a variable quantity* (for any given peening intensity curve) because its value depends on the particular time used for the data point.

With the universal availability of computers and curve-fitting programs the labor previously involved in curve-fitting has been eliminated. Stored curve parameters can provide very useful reference information.

The equation of a peening curve can be used to obtain a unique and objective measure of peening intensity. Peening intensity has always been associated with the "knee" of the peening intensity curve. At least two methods of knee location are available – the "10% rule" and the point of maximum curvature. Both methods are objective and yield similar values. It is not proposed, however, that there is any need to change from the well-established "10% rule". There is, however, a need for greater clarity in the specification of peening intensity.

It is suggested that a primary parameter H_C, is used to specify "the lowest arc height of a fitted peening intensity curve for which doubling the peening time gives a predicted 10% increase of arc height". The use of a capital H incorporates the fact that this is a unique value and the subscript C that it is a position on a curve – not a data point. For the example shown in fig.8, H_C would be 5.47.

There is some justification for allowing the use of secondary peening intensity parameters. This is primarily because of the importance of verification testing involving single test strips being peened for a fixed number of passes/strokes. A secondary parameter such as h_D could be specified as being "the lowest measured arc height that satisfies a '10% or less' rule". The use of a lower-case h would incorporate the fact that it is not a unique value and the subscript D that it is a data point – not a curve point.



Dr. David Kirk, our "Shot Peening Academic", is a regular contributor to The Shot Peener. Since his retirement, Dr. Kirk has been an Honorary Research Fellow at Coventry University, U.K. and is now a member of their Faculty of Engineering and Computing. We greatly appreciate his contribution to our publication.

Outshining the Competition Isn't Always a Good Thing–Ask a Medical Instruments Manufacturer

Herb Tobben

Problem:

A manufacturer of stainless steel laparoscopic surgical tools wanted to improve efficiencies in their finishing operation. Their instruments were machined and came from the fabrication shop with burrs, small defects, surface oxide, and slight discoloration. With a production volume in the neighborhood of 4,000 pieces per week, they needed to process at a rate of one finished part every 10 seconds. Their finishing objectives included deburring and cleaning to remove oxidation and other contamination from the parts. Their manual process included sanding and wire brushing. A routine step also involved visually inspecting each finished part with a magnifying glass, a painstaking process. Attention to detail and a fine finish were required to meet the demands of their medical community customer base—not to mention outshining their competition.

Rigid endoscope components are loaded on a fixture on a ZERO A-200 indexing turntable cabinet

Solution:

The local ZERO distributor offered to run parts for them to demonstrate how blasting could contribute to improving their operation and the customer took the distributor up on his offer. The surgical instruments were processed with No. 10 glass bead in suction-style (venturi-style) blast cabinet. To the uninitiated, blasting is like magic. The customer purchased a manual cabinet. And not only were they able to achieve their production rate, but also they saw an improvement in the quality of their parts. Glass bead blasting quickly and easily removed the burrs and oxidation and produced a matte finish, which was an unexpected but pleasant surprise. As you know, surprises in a manufacturing environment usually are not desirable! To the manufacturer's delight, their customers raved about the matte-finish—it served to eliminate the reflective glare on the instrument from the operating room's high-intensity lighting, an obstacle they had lived with for years. Removing the shine from the instruments' surface instruments increased surgical productivity.

With this value-added feature, tool production demand increased, and the manufacturer turned to the distributor once again for advice. This time, the distributor came to ZERO with challenging new customer requirements. They wanted to double their production to two parts every ten seconds.

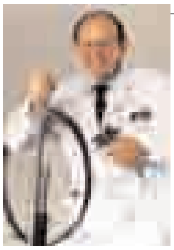
Automating the blasting process involves careful assessment of the parts to be finished, the finishing objectives, any material properties or characteristics of the part that would dictate special handling, as well as consideration for the space and environment where the equipment will be used in the customer's facility.

In this instance, the customer needed a machine that would speed the process so that production could be ramped up to meet greater demand. They wanted finished parts with a single process and an easy operational learning curve for the workers. They needed a reliable, easy-to-maintain machine that would run 24/7, if need be.

The parts had to be handled individually and lent themselves to an indexing turntable machine, in which parts are loaded one-at-a-time onto a fixture, and blasted one or two satellite stations at a time. In this application, the customer loaded three parts on one fixture, indexed to send the parts inside the cabinet for blasting, while they removed and reloaded more parts.

The finishing specification called for uniform coverage over 360 degrees around the part. In some medical applications, such as implants, specific roughness average (Ra) finishes are required. In this application, however, the goal was a visually acceptable part. The machine was fitted with eight blast guns and the same No.10 glass bead that was used in their manual blast operation was also used here. To achieve the customer's finishing goals, we created special fixtures designed to hold three parts per fixture. By loading three parts on each fixture, three parts could be completed every ten seconds and the finishing production rate tripled the original manual-process rate, giving the customer room to grow into the machine with increasing demand. For the time being, the additional finishing capacity allowed them to process several different size tools with a simple change-out in fixtures. The automated process assures repeatability, which contributed to greater time and cost savings by reducing the visual inspection rate and virtually all part rework.

The challenge had been to design a machine and process that would offer a simple, elegant solution at a price that was within the customer's budget. Solving customer problems are never a slam-dunk. In this project, with a combination of luck, and of course skill and expertise (!), the customer was thrilled with their investment in a simple automated process, with achieving triple their production rate, and with the assurance that they would not very soon outgrow the machine. Their business continues to grow and in their eyes, we shined.



Got a question about shot peening, abrasive blasting, or sample processing? Clemco can help. Call **Herb Tobben** at 1-636-239-8172 or submit your request at online at www.clemcoindustries.com in the Contact Us section. Herb Tobben is Sample Processing Manager for the ZERO Automation product line at Clemco Industries Corp. He is a regular speaker at the Electronics Inc. Shot Peening Workshop.

Industry News

New Products ▪ New Companies ▪ Awards ▪ Upcoming Events ▪ People in the News

Forum for Applied Mechanics is Formed in UK

United Kingdom. Throughout the U.K. there are a large number of organizations involved in applied mechanics and related activities. The organizations are usually based within a single country and organize events that attract members from within their own country. These events would be of interest to the wider applied mechanics community. It would be difficult for active researchers to join all organizations with that cover their interests mainly due to escalating membership costs. Therefore the Forum for Applied Mechanics (FAM) has been organized that will ensure that members of all participating organizations are aware of events and are offered a discount on attendance these events. To date, the constituent members are:

- British Gear Association
- British Society for Strain Measurement
- Engineering Integrity Society
- Institution of Mechanical Engineers
- Institute of Physics
- NAFEMS

A secondary purpose of the Forum is to provide two UK representatives to EURASEM, the body which, among other things, organized the European Conference on Experimental mechanics every four years. The next meeting in this series takes place this August in Greece. To learn more about FAM, please visit www.applied mechanics.org.

Institute of Spring Technology Opens Branch in India

IST is pleased to announce the opening of its first branch office in Kolkata, India. Mr. Amit Banerjee, who knows the spring industry well from his association with Alloy Wire International, will manage IST's affairs in India, and this will become the association for Indian spring manufacturers. Up to now India has not had a trade association for spring manufacturers. The setting up of this office has already attracted a significant number of new members for IST and could become an effective trade association for Indian Spring Manufacturers.

IST's load and fatigue testing, failure analysis, and spring information services will be marketed by Amit, who will also assist with the sale of IST's CAD programs. The first training course for the Indian market is planned for December 4-6, 2007 in Delhi, and if that is successful, similar courses will be offered in West and/or South India in February, 2008. The training course, given by Mark Hayes, (Senior Metallurgist, IST, UK) will comprise of Day 1 - Material Selection and Spring Manufacturing Technology, Day 2 - Compression, Extension and Torsion Spring Design and Day 3 - Spring Failure & Prevention.

Further details on IST India can be obtained by contacting either Amit Banerjee (amitban@cal2.vsnl.net.in) or Mark Hayes (m.hayes@ist.org.uk), or visiting our website at www.ist.org.uk.

New Goff, Inc.

Seminole, Oklahoma. *After more than 15 years of foreign ownership, DISA Goff has returned to local ownership under the new company name of Goff, Inc. The company's managing director Keith Yerby has purchased the company.*

Goff moved from Oklahoma City to Seminole in May of 1979 and has been in business since 1977 and employs over 100 people. Yerby began his career with Goff in February, 1991 and has served in several management positions over the past 16 years while gaining experience in every aspect of the shot blast industry.

"We concentrate on NAFTA," Yerby stated but Goff's market will continue to be worldwide. The company had a major expansion, doubling the office and shop space recently anticipating continuing growth with increased market share. The company manufactures airless abrasive cleaning equipment in a wide variety of formats: tables, wire mesh, spinner hangers, pass-throughs, batch tumblers, and a full line of aquatic washing systems as well as portable shot blast equipment to blast clean and prep surfaces such as highways, bridges, airport runways, parking garages, and ship decks.

Goff's equipment is used in every facet of metal preparation ranging from descaling, anchor patterns for coating adhesion, simple cosmetic finishing and shot peening. Goff's customers include foundries, die casters, military facilities, heavy equipment manufacturers, prosthetic joint manufacturers, aircraft component manufactures, propane cylinder refurbishes, concrete block manufacturers, oil field service industries, RV manufacturers, automotive manufactures and their sub suppliers, various types of remanufacturers and many more too numerous to list. From the corporate producer to the small independent entrepreneurs, Goff provides unparalleled quality coupled with superior service and support for the life of our equipment.

The majority of Goff products are standard greatly due to a vast product portfolio designs. However, Goff offers customized systems for specific customer applications, utilizing decades of application experience to provide real solution in the form of quality equipment. For more information, visit www. goff-inc.com.

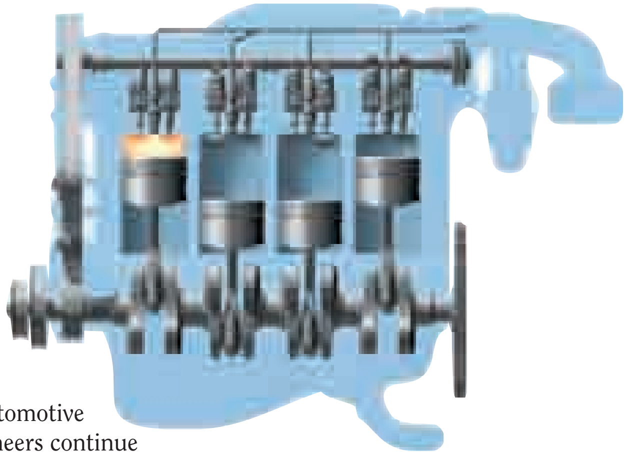
Deadline for Submission of Manuscripts for ICSP10

Tokyo, Japan. *The 10th Annual Conference on Shot Peening will be held in Tokyo, Japan in September 2008. The deadline for the submission of Manuscripts is January 31, 2008. For more information, please contact the conference office:*
Telephone: +81-(0)44-934-7364
Email: icsp10@isc.meiji.ac.jp

It's not too early to make plans to attend this world-class conference. For more information on all aspects of the event, go to Web: www.shotpeening.org.

Specialty Automotive Peening Applications

by Kumar Balan



Automotive engineers continue to rely upon the benefits of shot peening to enhance the useful life of parts they design for cars, trucks and other vehicles of common use. An extension of this utility can also been seen in design of stationary engine components. Commonly, the following components in an automobile are shot peened.

- Crankshafts (descaling and peening)
- Connecting Rods (peening)
- Transmission gears and other shafts
- Ring gears, pinions, sun and planetary gears
- Leaf and coil springs

A large volume of automotive parts, manufactured as castings, forgings, machined components and weldments are also processed in different styles of blast machines to remove scales, burrs and other non-desirable visual surface characteristics.

With shot peening, users have experienced life increases from 600% in case of leaf springs to 1500% for transmission gears.[1] With specific reference to crankshafts, life increases of about 900% have been achieved with shot peening. Needless to say, fatigue life enhancements brought about by the process offer a multitude of advantages. Parts can be designed smaller, lighter and expensive materials can be substituted with lower cost alternatives.

Crankshaft Manufacturing – Blast Cleaning

Heat treated crankshafts are blast cleaned to remove surface scales as part of the manufacturing process. Crankshafts are loaded between spinning rollers that expose the part to multiple blast wheels while traveling under the blast stream. A combination of complex angles created by this relative motion cleans the entire outside diameter of the crankshaft.

The size of the crankshaft determines the type of machine it is processed in. For larger engines, with crankshaft sizes up to 30" (762 mm) diameter x 20'. (6096 mm) long, the part is loaded between a set of rollers mounted on a work car (as seen in inset). Various arrangements are possible to present the part to the wheel. Depending on space constraints in the user's production facility, the work car could be moved under the blast wheel, or the wheel(s) could be moved over the stationary work car. In either case, the crankshaft is steadily rotated while being cleaned.

Smaller crankshafts, typically in the size range of 6" to 8" (152 mm to 203 mm) diameter x 36" (914 mm) are processed in spinner hanger style machines. One or two such crankshafts are suspended from a hanger hook and processed through a blast cabinet with multiple blast wheels. The hanger spins inside the blast cabinet and provides exposure to the parts being processed inline. This arrangement presents higher productivity than batch style machines used for heavier crankshafts.

In either arrangement, the process is very effective in cleaning heavy annealing scales to a production rate of about 250 parts per hour in a spinner hanger style machine.

Though not as critical as would be in shot peening applications, modern blast cleaning machines for crankshafts are monitored for different process variables in order to maintain cleaning quality.

Shot Peening of Crankshafts

The general equipment design prevails whether a crankshaft is blast cleaned or shot peened.

However, when shot peening crankshafts the purpose and goal is more defined than simply inspecting the outside area for cleanliness (descaling). Shot peening induces favorable compressive stresses on the part thereby enhancing its useful life. The measurement of this stress is calibrated in the form of "Almen Intensity" on multiple Almen strips located at various areas along the crankshaft. Coverage, which is the amount of exposure seen on the surface of a crankshaft during peening, is also usually defined by the crankshaft designer and could be in the range of 100% to 200% and sometimes higher depending on the application where this crankshaft is employed.

Though the entire crankshaft is processed in a peening machine without the need for masking any specific areas, highly stressed areas that are critical in failure analyses are those where the intensity is measured. Almen blocks fitted with test strips are mounted in areas of maximum fatigue concentration such as fillets adjoining the ends of bearings on the main and crank journals (root portion of shaft and connecting rod attachment).

Given the hardness of crankshafts and desired induction of compressive stress, hard shot (50 to 55 HRC) in the size range of S 280 to S 330 (0.7 mm to 0.84 mm) is used for peening. This produces Almen intensity in the range of 0.008 to 0.010 C (0.025 on the A scale).

When compared to blast cleaning, shot peening assumes greater process criticality. The following process parameters are monitored in crankshaft peening applications:

- Media flow rate (using flow control valves such as MagnaValves from Electronics Inc.)

- Wheel speed (and thereby shot velocity and intensity) using variable frequency drives on blast wheel motors
- Variable travel speed for work car (or blast wheel traverse)
- Variable rotational speed for part spinner rollers
- Shot size control (using vibratory classifier)
- Blast wheel size used for such applications is in the range of 19.5" diameter (495 mm) and higher

Other Automotive Peening Applications

This discussion will remain incomplete if no mention is made about peening techniques for other parts of the automobile that experience cyclic working stresses. Some of these areas and peening solutions include:

- Ring gears and pinions are peened to induce compressive stress in the tooth root areas with exposure on the drive and coast faces. Peening is carried out in air type or wheel type machines
- Leaf springs are peened in centrifugal wheel type machines in an inline orientation. In some cases, leaf springs are pre-stressed and then peened to further enhance their useful life
- Coil springs are peened in a wheel type machine with vertical fingers to convey the springs through the machine and spinner rollers to rotate them under the blast stream
- Torsion bars are peened in the vertical orientation in a spinner hanger style machine

Conclusion

Awareness of the benefits of shot peening has certainly grown from the blacksmith hammering a piece of leafspring to impart better wear characteristics. Contemporary shot peening machines have sophisticated computer controls that monitor the process to ensure repeatable and consistent results. Such systems ensure tighter control over the process, resulting in alarms for non-critical faults and shut-down commands during occurrence of critical faults in the machine. Peening equipment designers are highly cognizant of the importance of such checks and non-compromising product quality that their customers are faced with in their manufacturing process. Peening equipment design is therefore geared to partner with other sophisticated manufacturing equipment in an auto parts manufacturing plant.

Acknowledgement: Information contained in this article has been assimilated through discussions and valuable suggestions from knowledgeable sources within the North American offices of Wheelabrator Group including Dan Diverty, Ron Barrier and Jay Benito.

[1] Shot Peening – An Ancient Art and a Modern Process (published by Wheelabrator Corporation)

Kumar Balan is a Product Engineer with Wheelabrator Group Equipment/Process Design & Specification Conformance. We commend Mr. Balan for advancing proper shot peening practices to the industry.

Company News

DAFENG DAQI METAL GRINDING MATERIAL CO. LTD.

Since the company's establishment in 1998, DAFENG DAQI METAL GRINDING MATERIAL CO. LTD has been involved in the production and research of metal abrasives. At present, our production scale has exceeded 10,000 ton and we've created more than one hundred million RMB production value each year.

Our carbon steel cut wire for shot peening has reached a level of advanced technology. The product has been very well-recieved internationally. With the development of the shot peening technology, carbon steel cut wire are applied to more fields. Especially in the industry of auto manufacturing and aerospace, more and more attention is paid to using intensified steel shots to take the place of traditional cast steel shots. Compared with the latter, there are several advantages of DAQI steel cut wire as following:

1. Uniformity
   The carbon steel cut wire shot have the highest consistency from particle to particle in size, shape, hardness and density of the commonly used metallic media. Improved shape consistency leads to more consistent processing in shot peening or blasting operations.
2. Longer life
   Because of its wrought internal structure with almost no internal defects, the durability of conditioned cut wire media can be many times that of other commonly used media. This increase in useful life can result in substantial cost savings in terms of media consumption and reclamation expenses.
3. Less contamination
   Since conditioned cut wire media exhibits high durability and resistance to fracture, it also exhibits the lowest dust generation rate of commonly used media. There are no iron oxide coatings over the particle surface and therefore it leaves much less (as much as 10 to 20 times less) iron oxide residue on the part surface after peening or blasting.

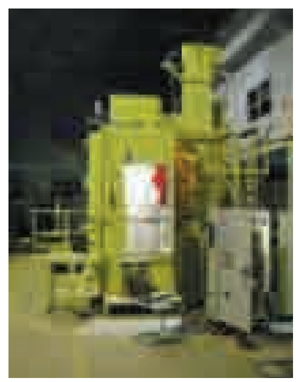
Always keeping the future in view, we will continue to develop the best possible solutions for our customers. For more information, contact Keynes Khu by email at keyneskhu@vip.163.com or by telephone at + 86 515 3859977.

DAFENG DAQI METAL GRINDING MATERIAL President Mr. Wang Qi.

ROBOTIC SHOT PEENING MACHINES FOR TURBINE BLADES from MEC SHOT

Mec Shot manufactured, supplied, erected and commissioned a Robotic Shot Peening machine to a customer for the shot peening of fir tree flanks of steam turbine blades. The peening cabinet was designed and manufactured in tubular construction, internally rubber lined for protecting against erosion for indoor use allowing peening of one blade of equivalent dimension, maintaining an appropriate envelop around the parts for peening device movement.

The door mounted turntable on main door, for easy loading and unloading of the blades and drive by a servomotor of 1.1.KW rating with a variable speed. The turntable interpolate with the 6 axis of Industrial Robot. The speed of the turntable could be chosen on the operator screen in the central control panel.



The rotary table was interfaced with Fanuc Servo Motor and drive controller for rotary table & 6 Axis robot with controller unit.

Steam Turbine Blades are forged out of high temperature, fatigue and creep resistant alloy steel of different grades having tensile strength up to 1050 N/mm2 and hardness about 350 HB30. The automated Shot Peening process enables the repeatability and cost effectiveness. The Robotic Single Nozzle Automatic Shot Peening System was used for controlled shot peening in fir tree flanks of steam turbine blades to induce residual compressive stresses. Portion of the airfoil or transition radius of the airfoil to the base plate was masked and not shot peened.

The nozzle manipulation performed with 6(six) axis industrial robot. Robot area was protected with special jacket to prevent damage during peening operation. The positioning repeatability of robot +/- 0.08 mm. The system equipped with a two-deck vibratory screen separator to efficiently size and separate spent media after passing through the reclaim system.

The shot peening system was equipped with a dedicated recovery, recycling, classification, storage and shot peening system. Close loop air pressure regulator for regulating air pressure through PLC and MagnaValve was supplied for controlling variable flow rate through PLC. To protect the MagnaValve against excessive wear, there was a Pinch Valve above the MagnaValve. The shot flow controller was with digital display.

For more information on Mec Shot's products, call +91 291 2740609 or send email to mecshot@sancharnet.in.

Advertiser Directory

Company Name — **Page Number**

The Parting Shot
Jack Champaigne

Shot peening keeps pace with technology

The Boeing Company is unveiling its long-awaited 787 Dreamliner this summer. It will be the first jet in 13 years from the commercial jet world leader that introduced the 707 in 1954. The company is betting heavily on the need for a technically-advanced aircraft that will provide 20% increased fuel economy.

The gamble seems to be paying off—Boeing has sold out production through 2013 and yet the Dreamliner has never been off the ground. The early success of this aircraft is largely due to international alliances with manufacturers in 135 countries on four continents. Our industry will be part of this new aircraft because Boeing, and many of its suppliers, are evaluating conventional shot peening as well as laser peening, micro-media peening, ultra-sonic peening and composite peening as viable resources.

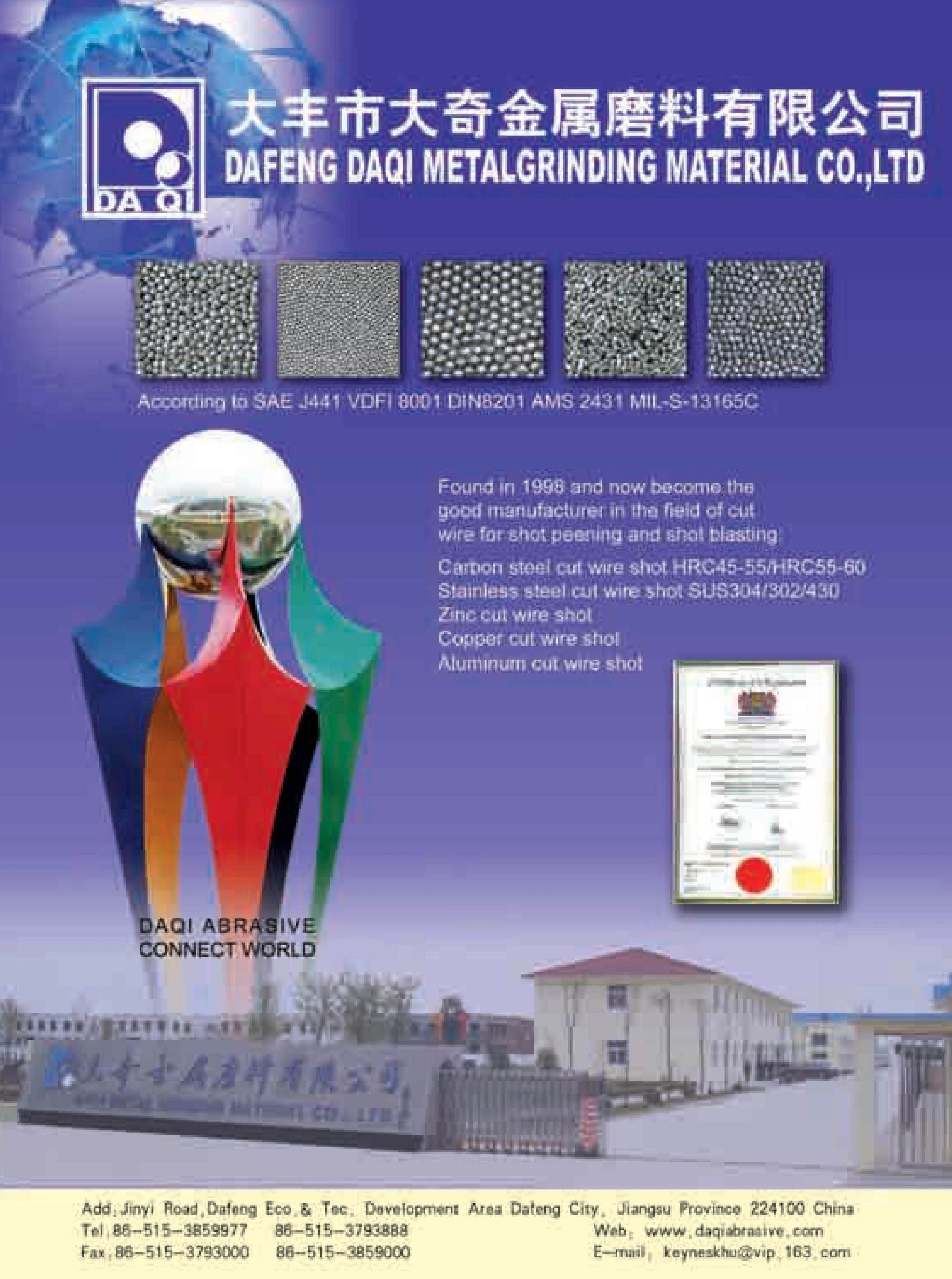
The demand for lighter, stronger, and environmentally-friendly materials and processes are requirements to ensure the success of most manufacturing today. The social, political and Individual responsibilities demand it! On page four, we highlight a developing technology that could reduce the costs to produce titanium. How will this effect shot peening? Would the stronger material replace conventional steel and eliminate the need for shot peening or would cheaper titanium create more opportunity for shot peening and surface enhancement? I believe the latter and have seen over the years how changing technology has improved and benefited our industry. Every new development opens doors to explore how we can optimize the results through shot peening.

Another example: The EI staff was recently invited to attend a medical company's think tank on shot peening. The company's manufacturing section was given the directive to shot peen the company's titanium implants for strength and longer part life. Their manufacturing engineers had attended the Electronics Inc. Shot Peening Workshop and Trade Show in Indianapolis this past fall to learn more about shot peening. They were so impressed with one of the OEMs exhibiting at the trade show that they ordered a multi-axis shot peening machine with plans to order three more. The engineers are going to great lengths to ensure that they use the shot peening process correctly and can validate results every cycle from every operator, every shift and at every physical location a part is processed.

In March, Electronics Inc. was part of an education workshop in Nagya, Japan. The material was presented in Japanese and attended by a cross-section of industry. The workshop was a collective effort by the Japan Society for Shot Peening (JSSP), Sintokogio, Toyo Seiko and Electronics Inc. Dr. John Cammett, Tom Brickley and myself were greeted by our host, Hitoski Takeda, at the Sintokogio world headquarters. The opening by Dr. Kisuke Iida, Past Chairman JSSP, was well-received by the large group. Dr. Yoshihiro Watanabe, Managing Director Toyo Seiko Co., Ltd., was not only responsible for all translations, but was also a presenter. Other speakers included Juji Kobayashi, Hitoski Takeda, and Dr. Katsuji Tosha, the current JSSP Chairman. Due to the success of this event, it has been agreed to hold a second meeting next year. After witnessing the high level of shot peening technology for aerospace and automotive applications, it is clear to us that Japan continues to develop shot peening research, equipment and processes that are a leading example for the world.

This picture, taken June 13, shows the horizontal stabilizers attached to the tailcone with the vertical fin in the background. Final assembly of the first 787 began on May 21 at the Boeing facility in Everett, Wash. The Dreamliner was scheduled to roll out on July 8, 2007. ***Image provided by The Boeing Company.***

Attendees to the EI Japanese workshop. Top row, left to right: Hali Diep, Boeing; Jack Champaigne, Electronics Inc. Bottom row: Dr. John Cammett, Electronics Inc.; and Dr. Kisuke Iida, Past Chairman JSSP.


大丰市大奇金属磨料有限公司
DAFENG DAQI METALGRINDING MATERIAL CO.,LTD
DA QI
According to SAE J441 VDFI 8001 DIN8201 AMS 2431 MIL-S-13165C
Found in 1998 and now become the good manufacturer in the field of cut wire for shot peening and shot blasting
Carbon steel cut wire shot HRC45-55/HRC55-60
Stainless steel cut wire shot SUS304/302/430
Zinc cut wire shot
Copper cut wire shot
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