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The Shot Peener

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

DOMINIC CIMINO

2017 Shot Peener of the Year

PLUS:

- SHOT PEENING PROCESS OPTIMIZATION
- NON-CONVENTIONAL PEENING TECHNIQUES
- DECARBURIZATION: THE SILENT ENEMY

THE SHOT PEENER
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In Recognition...

Dominic Cimino

I met Dominic for the first time at the EI Shot Peening Workshop this fall where he was given the 2017 Shot Peener of the Year award. You might ask, “How could you give Dominic the award if you had never met him?” The answer is simple: Four of his co-workers nominated Dominic. In fact, the list of his contributions to peen forming on page eight are from his work associates. That impressed *The Shot Peener* staff and we all agreed that he deserved the award. Congratulations, Dominic.

Dr. David Kirk

I praised Dr. Kirk’s article on decarburization to my Associate Editor more than once while we worked on the magazine. As I read it, I visualized him lecturing at Coventry University, keeping his students spellbound. David has the gift of being able to explain complex concepts in a simple manner.

I had no idea how our lives would intermix when David invited me to join the International Scientific Committee for Shot Peening in 1993. One of the smartest things I’ve done as Editor of *The Shot Peener* was to invite him to write articles for the magazine. His work has advanced the understanding of shot peening and surface enhancement for our readers and he makes my life so much easier—when someone asks me a technical question, I refer him to David’s articles at www.shotpeener.com. Thank you, David.

The 13th International Conference on Shot Peening

Electronics Inc. and *The Shot Peener* magazine are pleased to have been part of this successful event. Based on the large turnout, the energy, and the collaboration between academics and industry leaders, the future looks bright. As an example, Nihad Ben Salah with Safran Research Center gave a keynote address titled, “Shot Peening Applications and Future Research in the Aerospace Industry.”

Thank you to everyone who made the conference possible including the International Scientific Conference for Shot Peening, Professor Martin Lévesque (the Conference Chairperson), the Local Organizing Committee, the presenters, the exhibitors, and the École Polytechnique de Montréal staff.

Professor Mario Guagliano (Department of Mechanical Engineering at Polytechnic University of Milan) will be hosting ICSP-14 in Milano, Italy in 2020.

As Chairman of the International Scientific Committee for Shot Peening, I gave opening remarks at ICSP-13.

THE SHOT PEENER

Editor
Jack Champaigne

Associate Editor
Kathy Levy

Publisher
Electronics Inc.

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The Shot Peener
56790 Magnetic Drive
Mishawaka, Indiana, 46545 USA
Telephone: 1-574-256-5001
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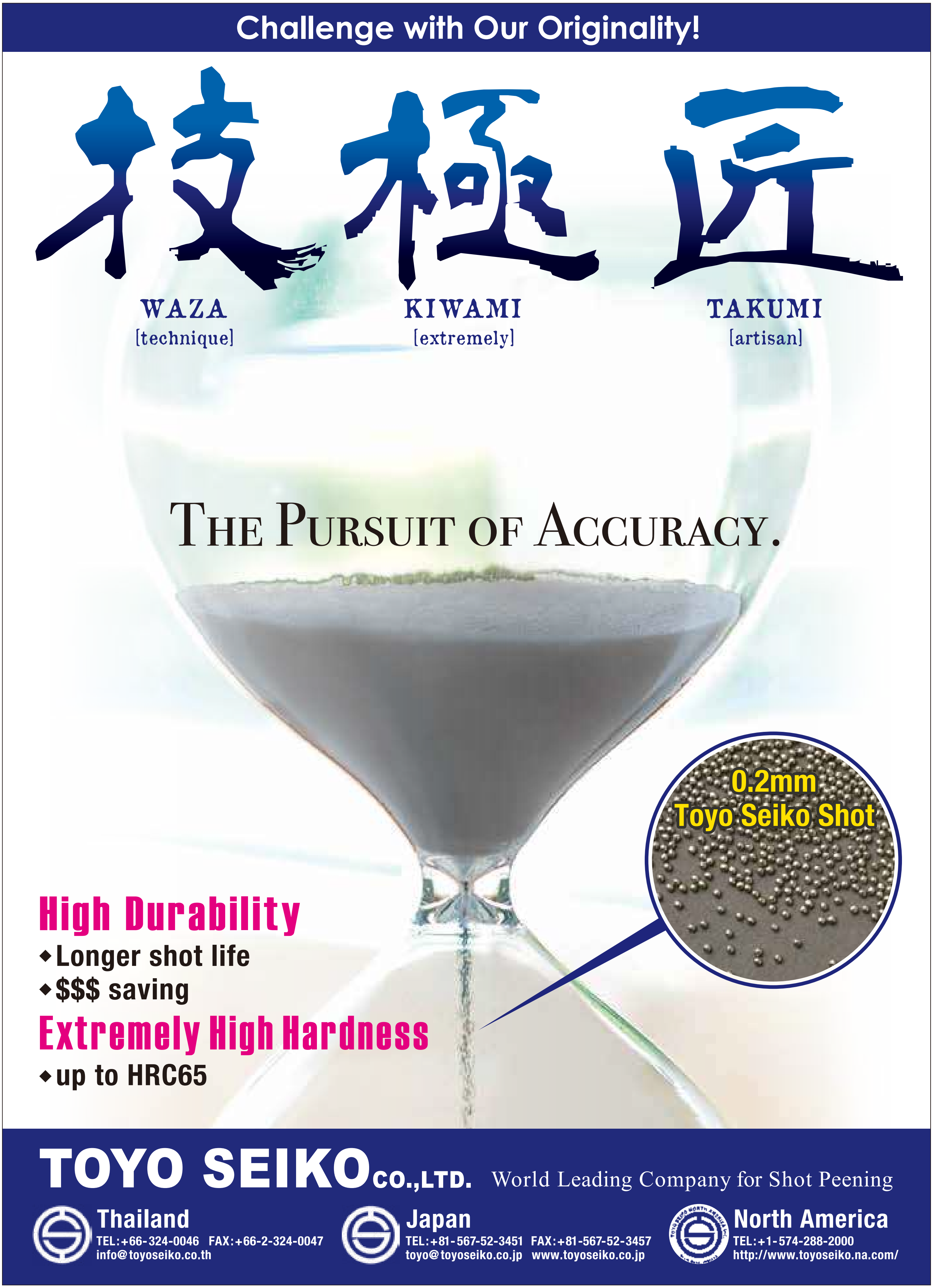
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The 2017 Shot Peener of the Year
Dominic Cimino

DOMINIC CIMINO, Regional Manager of the North America Shot Peening Group for Curtiss-Wright Surface Technologies, received "The Shot Peener of the Year" award for two reasons. The first reason is his substantial contributions to the advancement of peen forming and shot peening. The second reason is because he was nominated by not one, but four of his work associates. An internal nomination carries a lot of weight with us since no one can make a better assessment of one's value to the industry than co-workers. The following are Dom's thoughts on his career.

"I graduated from Stevens Institute of Technology with a Bachelor's degree in Mechanical Engineering. My first job out of college was as an application engineer in a company selling steel wire strand for pre-stressing concrete. This is actually similar in principle to what we are doing with shot peening. The strand is stretched and concrete beams or floor sections are cast around it. The strand is then released, imparting a compressive stress in the concrete. When I interviewed for a job with Curtiss-Wright Surface Technologies, my understanding of residual stresses was an advantage in winning the job as Project Engineer for forming Airbus A310 wing panels in 1980.

I also became involved with developing and improving the forming procedures for the Canadair Challenger and Dehaviland Dash 7. At the time, forming was basically a trial and error method of development. I was lucky enough to work with Charles Barrett, the 1994 Shot Peener of the Year and a Metal Improvement Company (MIC) employee. I learned a great deal from him.

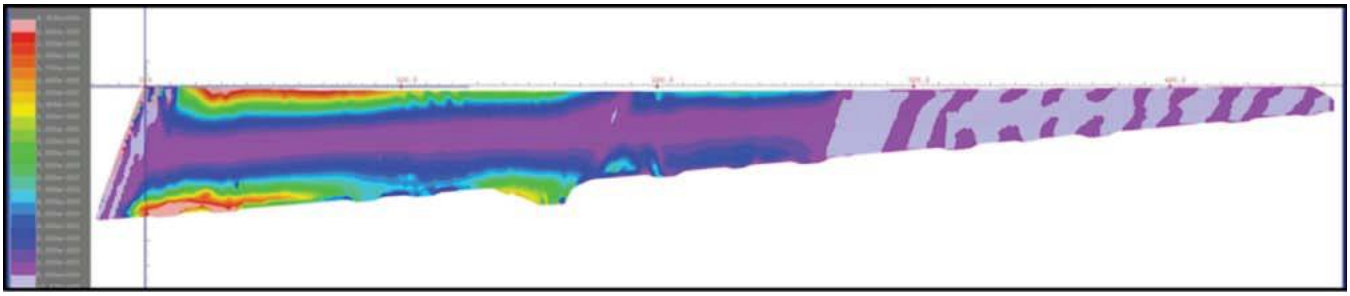
I moved on to become General Manager of our plant in Long Island and worked with forming skins for the Grumman A-6 and E2, as well as the Fairchild A10. We also corrective formed the titanium skins for the F-14, which were creep formed.

I always thought there should be a way to determine the feasibility of peen forming a given shape other than trial and error. As a result of being unable to form the Gulfstream G4 by using purely shot peen forming, I was motivated to develop formulas which would predict whether a given wing skin compound shape was within the capability of peen forming.

These analysis techniques were first used in forming the wing skins of the Cessna Citation X in 1995. Cessna included Metal Improvement Company early in the design process and, as a result, we were able to improve the manufacturing producibility of the panels.

Dave Francis, the 2002 Shot Peener of the Year and another MIC employee, translated the formulas into a computer program, which allowed the analysis to be displayed graphically. Below is an example showing the peening required to achieve the desired shape. The colors depict the intensities required with the red to pink being the greatest intensity and the gray being the least.

MIC utilized the same basic formulas while determining parameters for laser peen forming of a wing panel from the 747-8. This exercise enabled us to confirm the predictability of the equations as the laser peening energies could be very



The colors in this graphical analysis depict the intensities required to achieve the desired wing shape with the red to pink being the greatest intensity and the gray being the least.


Control
EMPIRE

precisely controlled, and the shape forming results were as predicted.

MIC has since used these predictive techniques to help design and form the wing panels for the Embraer KC390 and the E2 versions of the 175 and 195. These techniques were also used to develop forming programs for the Pilatus PC-24, and enabled Pilatus to produce a one-piece skin whereas the original design required multiple wing skin sections.

MIC is now using these techniques to predict distortion of metal parts and ways to avoid or correct post-machining distortion in peened parts.

I have enjoyed working for almost 38 years in the shot peening industry, and am greatly honored to receive this award. I have learned the science and capabilities of shot peening from others, and I'm hopeful that my contributions have helped advance the state-of-the-art in shot peening and create new applications for shot peening in the future."

Dom was chosen to be a Technical Fellow of the Curtiss-Wright Corporation in 2015. This honor is reserved for the top 1-2% of Curtiss-Wright's engineers.

Dom's work associates submitted the following contribution highlights and research projects.

Contribution Highlights

Throughout his tenure at Curtiss-Wright Surface Technologies (CWST), Dom has had the distinction of managing nearly every one of CWST's 24 shot peening business units in North America. Dom's knowledge extends from the operational aspects of meeting peening specifications within CWST's facilities to providing design expertise to CWST's customer base. His flat panel calculation models have contributed significantly to CWST's long-term partnerships with aerospace OEMs, and his input has been sought by numerous wing skin design groups in many countries.

Dom is an important technical advisor to the entire Curtiss-Wright organization, providing guidance on appropriate shot peening specifications. In recognition of his contributions, Dom was chosen to be a Technical Fellow of the Curtiss-Wright Corporation in 2015. This honor is reserved for the top 1-2% of Curtiss-Wright's engineers. The following are a few of the projects that led to this achievement.

1. Dom's development in 1980 of the initial peen forming processes for the A310 Airbus led to a partnership with Airbus that continues today. CWST's facility in Chester, United Kingdom has peened over 55,000 production panels on various Airbus aircraft from the A310 to the A380.

2. Dom provided critical guidance to the team that designed and deployed the dual-sided shot peening equipment that was installed in Evora, Portugal. The equipment supported Embraer's new business aircraft manufacturing facility. Dom's input included basic design principles—driving equipment cost down and performance up—as well as a number of operationally focused design-for-manufacturing enhancements.

3. Dom's shot peen forming prediction models were adapted to the challenge of laser peen forming a highly curved 747-8 lower wing skin, which led to the installation of a shop-in-shop laser peening cell at Boeing's facility in Frederickson, Washington.

Research Projects

Based on experience and empirical data throughout numerous shot peen forming projects, Dom determined the physical characteristics that drive the response in the base materials. He created models to predict the metal growth required from shot peening to achieve specific compound wing shapes using various engineering CAD and FEA tools. These models were further enhanced to predict the initial machined flat panel designs required to meet a final desired wing panel shape. The models are critical in the design stage of all new wings, and Dom's work has been broadly utilized in the industry.

Visit the magazine's website at www.theshotpeenermagazine.com/shot-peener-of-the-year for a complete list of past Shot Peener of the Year award recipients.

The peen forming predictive software developed by Dominic Cimino was used to design the one-piece upper and lower wing skins used on the Pilatus PC-24 aircraft.

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Dr. John Cammett and Dr. N. Jayaraman | Lambda Technologies Group

Shot Peening Process Optimization: A Cost-Effective Means of Improving Component Life and Performance

INTRODUCTION

The material in this brief article has been used in previous articles in this publication; however, here the emphasis is different. Here the emphasis is that not only can process optimization be considered; it must be.

It certainly is recognized that process optimization may not be possible for everyone. If you are a peening operation doing work for a customer who specifies a fixed level of coverage, then obviously you must perform peening to customer requirements. If you are a prime with specific coverage requirements per internal specification, then you are constrained to those requirements. On the other hand, an organization which either has design authority for a part or is free to change a process is a prime candidate for shot peening process optimization.

Creation of optimized shot peen processing will lead to substantial cost savings and even improve durability and quality of parts as a result. Read further to see how this can be accomplished and the justification for doing so. In previous articles, the case has been made to show not only that peening can successfully involve less than full coverage, but that the level of partial coverage, properly assessed and employed, can produce equivalent or better part quality and durability than application of full or greater than full coverage. Rather than send the reader back to previous articles on the subject, some of this information will be repeated herein for completeness and convenience.

BASIC JUSTIFICATION

There is no free lunch with peening. The benefits in part quality and durability gained by creation of a subsurface layer of compressive stress may well be mitigated by surface damage such as laps, folds, dents and defects caused by surface deformation. An example of surface plasticity-induced defects created by excessive coverage is shown in Figure 1, a metallographically prepared section through the peened surface of a fatigue tested truck leaf spring. Here a fatigue crack is seen emanating from a plasticity induced defect created by peening to an excessive coverage level, >200% in this example.

The information presented in this article flies in the face of conventional wisdom and lore in shot peening, which essentially embodies the belief that islands of unimpacted material on a part surface constitute sites at which fatigue crack initiation will occur preferentially and prematurely relative to a part peened to full coverage. This is simply not so. It is not the relative incidence of shot peening impacts on the surface that is relevant, but the effect of impacts on the subsurface material and the overlap of the plastic zones created by the impacts. Alternately stated, if subsurface plastic zones overlap, then the physical overlap of impact dents on the surface is not needed. This is illustrated schematically by Figure 2, which indicates the relative proportions of a peening dent and the attendant plastic zone. As represented by Figure 2, the plastic zone extends radially from the dent to a much greater extent than the size of the dent itself. Thus, it is not necessary to create overlapping impact dents on a peened

Figure 1 – Metallographically Prepared Section of Steel Leaf Spring Normal to Peened Surface after Fatigue Testing

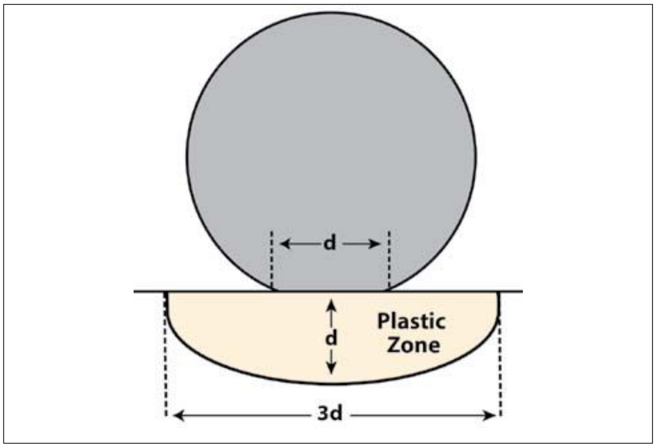

Figure 2 – Schematic Illustration Showing Relative Proportions of Impact Dent and Resulting Plastic Zone


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surface for full peening effect. It requires only the creation of overlapping plastic zones at and below the surface. The authors do not warrant that the relative sizes of dent and plastic zone for different materials will always be the same. Thus, desirable optimization of results from the peening process will require experimental investigation.

OPTIMIZATION STRATEGY

The authors certainly recognize that optimization of the peening process may involve peening parameters and considerations other than coverage. Certainly, choice of media and intensity may also be involved. The authors are not dismissive of the importance of these factors, but the importance of coverage is overshadowing as regards to process cycle time and resulting cost savings.

The elements of coverage optimization strategy are as follows:

1. Control media flow rate to achieve consistently the same coverage for any given cycle time.
2. Consistently measure coverage.
3. Measure surface and subsurface residual stresses at selected coverage levels to determine at what coverage level the residual stress distribution is stabilized.
4. Verify durability and quality by testing, e.g., fatigue or stress corrosion cracking.
5. Determine process tolerance for robustness, i.e., determine the effect of varying coverage about the optimum on results.

AN OPTIMIZATION EXAMPLE

In this section the authors synopsize earlier work on peening optimization conducted at Lambda Technologies. This work formed the basis for the issue of a US Patent (US 7,159,425 B1, Method and Apparatus for Providing a Layer of Compressive Residual Stress in the Surface of a Part) involving peening coverage optimization.

Figure 3 shows the surface appearance of AISI 4340 steel coupons (38 HRC) peened at the various levels of coverage shown. Figure 4 shows the resulting coverage curve from 0 to 100% coverage. This non-linear curve is typical of peening, whereby the increase in coverage is high initially as many new dents are created at previously unimpacted sites. The rate of coverage decelerates as coverage increases, reflecting that as 100% coverage is approached, most impacts occur at previously impacted sites, and do not contribute to coverage increase. Figure 5 (page 14) shows the residual stress distributions associated with the coverages shown in Figure 3. Most interestingly, the depth of the residual stress distribution increases through coverages of 3%, 10% and 20%, but does not change systematically for coverages of 80% and greater. Beyond 80% coverage, the variation in compressive stress depth may be a reflection of scatter in stress and depth measurements; however, the clustering of results at less than full depth is remarkable. Certainly one may agree that no significant change in the residual stress distribution occurs beyond 80% coverage. Figure 6 shows fatigue S-N test results at various coverage levels. The most interesting features of the S-N data are the decrease in endurance limit for coverages greater than 100% and that life results for 80% coverage are essentially the same as for 100%. The overriding significance of these results is that coverage less than 100% (e.g., 80%) gave essentially the same fatigue life and residual stress distributions. Coverages greater than 100% also resulted in lower fatigue strength. The authors do not warrant that the same results will occur for all materials; however, essentially the same results were obtained from experiments with a nickel-base alloy Inconel 718. Other materials may give different quantitative results; however, it is highly likely,

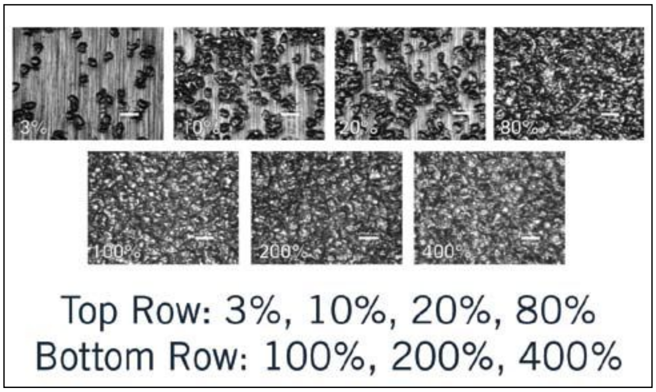

Figure 3 – Surface Appearance of AISI 4340 Steel (38 HRC) after Peening to Various Coverage Percentages

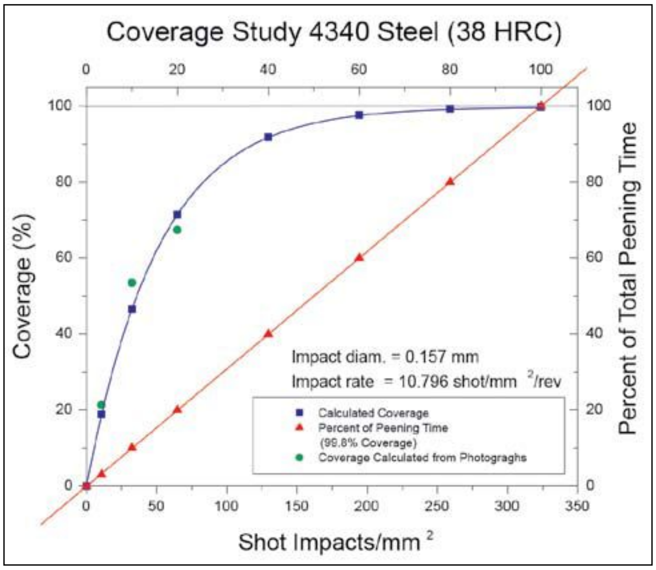

Figure 4 – Peening Coverage Curve Representing Coverage Progression from 0 to 100% for 4340 Samples

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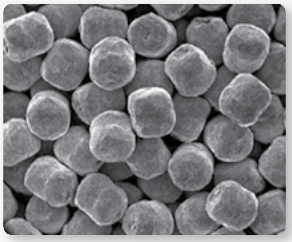
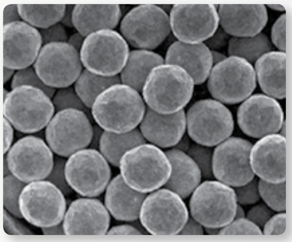


Normal Conditioning



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even certain, that results would show full peening benefit at coverage less than 100%.

SUMMARY

These results argue that optimum peening results can be achieved by peening to less than 100% coverage. The resulting cost savings are reflected in an exemplary timeline shown in Figure 7. This clearly illustrates that peening to 80% coverage occurred in only 20% of the time required for peening to 100% coverage, as confirmed in Figure 4. The savings in cycle time, along with increase in durability relative to peening to greater coverages, virtually demands process optimization. Lambda Technologies has the capability to assist in this area.

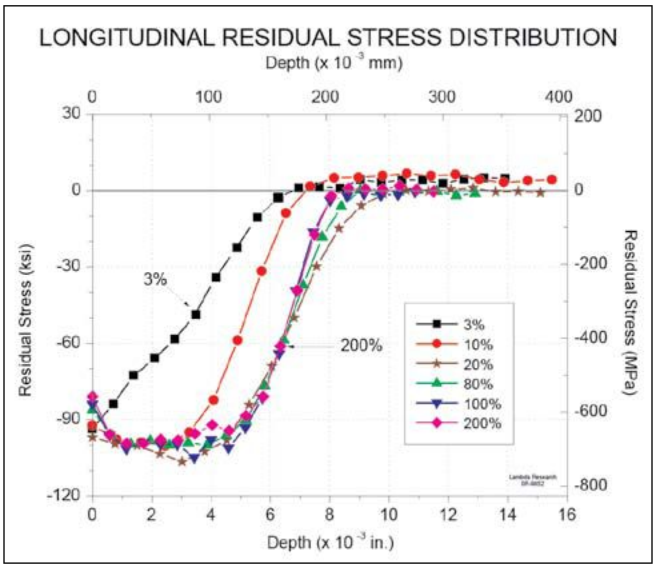

Figure 5 – Residual Stress v. Depth Distributions for Various Coverage Percentages of 4340 Samples

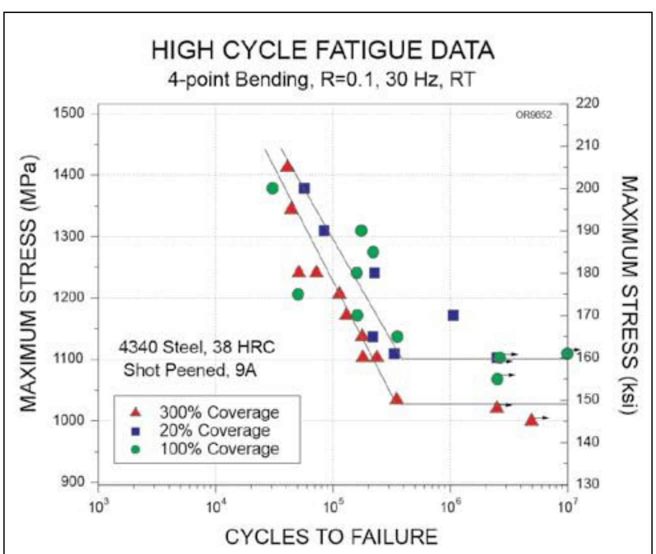

Figure 6 – Fatigue S-N Data for 4340 Samples

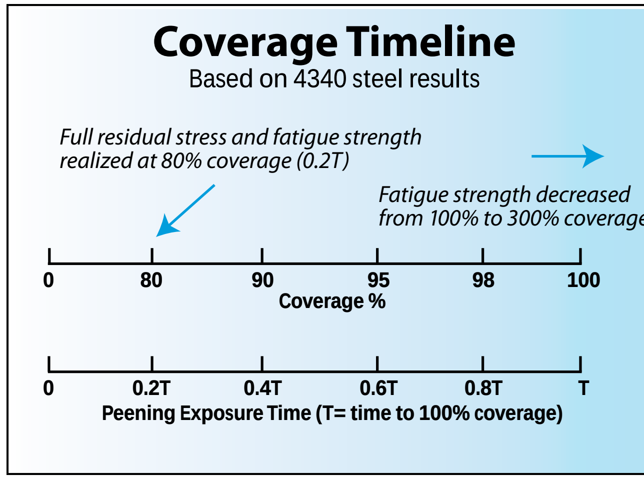

Figure 7 – Coverage Timelines Showing Relative Peening Times to Various Coverage Levels

Contact Information

Dr. N. Jayaraman, Director of Materials Research
Dr. John Cammett, Consultant
Lambda Technologies Group
3929 Virginia Ave
Cincinnati, Ohio 45227
513-561-0883
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AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

Non-Conventional Peening Techniques

INTRODUCTION

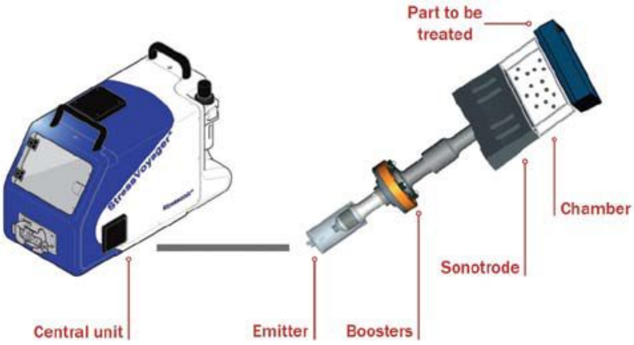
To quote the great Chinese teacher and philosopher Confucius, "Real knowledge is to know the extent of one's ignorance." As I looked around the exhibition hall at the recent Electronics Inc. (EI) shot peening workshop in Orlando, Florida, I noticed the industry landscape was changing with new technology and that meant it was time to replenish our respective databases with the developments.

The EI shot peening workshops have always attracted quality manufacturers of blast cleaning and shot peening equipment along with the vendors of critical components. Over the last few years, this line-up has been further enriched by companies that shot peen using non-conventional techniques such as ultrasonics, needles, vibration and micro-media. The industry has grown familiar with the use of lasers and flapper peening to a greater extent than with these newer techniques. Therefore, it is incumbent upon us to give the other techniques the importance they merit and monitor their growth leading to the overall progress of our industry.

How do these techniques work? How do they compare with established techniques using air and centrifugal force (wheel)? How effective are they in generating the required residual stresses? Are they governed by specifications? We will attempt to answer these questions in the paragraphs that follow with specific reference to Ultrasonic Shot Peening (USP) and Vibratory Peening.

ULTRASONIC PEENING (USP)

Julien Jeanneau of Empowering Technologies, the North American division of Sonats, is a specialist in USP. He explains this technique by drawing parallels with conventional shot peening where energy is transferred from the peening media (shot) to the part being peened. Media propulsion in shot peening uses compressed air or centrifugal force. "At Sonats, we refer to USP as 'Stressonic' technology, which uses the acceleration of a vibrating surface (called a sonotrode) to propel a small sample of shot against the surface to be treated. Since this takes place in a controlled and sealed chamber that envelopes the local area to be treated, there is no escape of media. This allows the process to use a few grams of high quality media for repeatable peening results," said Julien.



The StressVoyager by SONATS is a portable ultrasonic shot peening solution.

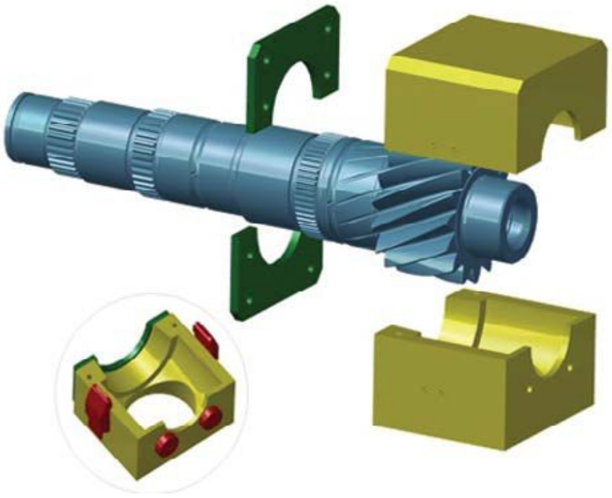
Ultrasound, as some of us may know, is a sound wave with a frequency above the limit of human hearing. Ultrasound equipment operates with a frequency of vibration in the ultrasonic wave range (20 Khz and greater). This is the second point of differentiation from compressed air and centrifugal wheels—this source makes noise that is inaudible to us.

Unlike in shot peening machines where the blast chamber is designed around the part style, size, and work handling systems, the enclosure in the USP process is a hermetic chamber designed to closely wrap around the contour of the part being peened.

Conventional shot peening machines allow for part access and space for maintenance. Cabinets in such machines are built with work doors, access doors, viewing windows, safety interlocks to shut down the operation if any of these doors are accidentally opened, cabinet lining, sound insulation, and lighting. The list continues subject to the manufacturer's practice and the end-user's requests. Moreover, it is essential to mask the parts in areas needing protection from the blast. The manufacture and maintenance of fixtures are additional time-consuming activities associated with conventional shot peening machines. USP eliminates the need for all the above with a small chamber enveloping the part.

Process Control in USP

Some of the key parameters in conventional peening are media



The USP sonotrode and hermetic chamber surrounds the part.

velocity, shape and size, quantity (flow rate), and secondary variables including stand-off distance, nozzle/wheel type, etc. USP using the following parameters to control the process.

Media quantity: In general, media flow rate is directly proportional to the cycle time and productivity of a blast cleaning and shot peening operation. However, increasing the media flow rate has a contrasting impact on the intensity value generated by an airblast and wheelblast process. All other parameters remaining unchanged, the intensity in an airblast process will decrease with increased flow rates since the same amount of energy has to now propel a greater amount of blast media. In a wheelblast machine, increasing the flow rate, limited only by the motor capacity to handle it, will correspondingly increase the rate of coverage, thereby reducing the cycle time. USP behaves like an airblast machine in this aspect with faster cycles but at lower intensity when the media flow is increased.

The optimum quantity of media is determined as part of the USP process development, and either counted or weighed before and after peening. AMS 2585 describes tolerance and good practices similar to the drop/catch test in conventional peening.

Media quality: Just as conventional peening relies on conformance to AMS 2431 for peening media quality, USP follows AMS 2585 for media properties such as hardness, sphericity, size distribution, material and density.

Velocity: Media velocity is governed by air pressure and wheel speed/diameter in air and wheel machines respectively. Similarly, in USP, for a given size of media, higher amplitude of vibration results in higher intensity. For a given amplitude, larger size media produces a higher intensity. The amplitude of vibration is variable, monitored and controlled in USP, similar to velocity control through closed feedback loops for air pressure and wheel speed in air and wheel machines.

As for the secondary variables, design of the enclosure/chamber determines the part distance, angle, and media containment in USP.

With all the above parameters in place, USP relies on Almen tests for arc height values, saturation curves for intensity, and inspection of the actual part for coverage determination (SAE J2227).

Is USP going to be the answer to your next shot peening challenge? Let's look at some of the possible limitations.

Limitation With Promise

Conventional air or wheel peening has been well-established over the years. The end user may not permit an alternate process like USP. This is a major impediment in adoption of USP and other such non-conventional processes for shot peening.

USP is an in-situ process and it doesn't require dismantling of a landing gear, for example, to peen specific areas of the gear. The utility requirements of USP are remarkably lower than air or wheel type peening. An average cycle requires less than 500 Watts to create vibration that energizes the peening media and abut 12 CFM for cooling. This is significantly lower than the compressor horsepower required for one or multiple blast nozzles, or to operate a wheel motor in a wheel blast machine. It is a very effective process when peening small areas with similar and repeating geometries. Anything different requires a new, custom chamber to contain the media. This tooling design and development could be an onerous task, at least for peening operations that see a variety of components as in a job shop. That said, if one runs an audit of the time taken to dismantle a component from a sub-assembly, prepare it for peening (masking, etc.), set-up the conventional peening machine with suitable process parameters and then carry out the operation, USP might work out to be more cost and time effective.

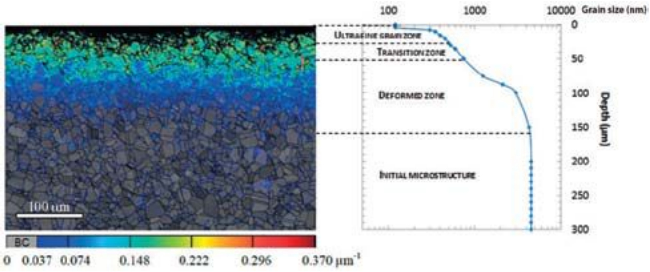
Notable Benefits of USP

1. A portable process that doesn't require dismantling the sub-assembly to peen a component that's part of the assembly.
2. Adaptable to any part by changing the tooling/enclosure design.
3. Uses special-purpose peening media that can be re-used multiple times without fracture or other damage. The quality of peening media determines repeatability, accuracy, and consistency of peening results in any shot peening process. Therefore, peening media that retains its shape and size after multiple impacts will definitely benefit the process.
4. Residual stress values in the range of -1400 MPa, up to a depth of 1 mm (0.039"). In comparison, commonly generated values of compressive stress in conventional shot peening is around -900 MPa with much shallower depths in the range of 0.25 mm (0.010").

5. Surface roughness in conventional peening is related to the shot size and intensity. For the same intensity, smaller-sized shot creates a deeper dent than larger-sized media, resulting in a rougher surface finish. This is not the case with USP, where the high-quality media used always ensures a smoother surface finish.
6. USP offers the same amount of process control as conventional shot peening, including real-time monitoring and control.
7. USP can achieve intensity values in the range of 4N to 10C, thereby meeting most of the peening applications in automotive and aerospace.
8. The formation of nanocrystals. A nanocrystal is a material particle having at least one dimension smaller than 100 nanometres (a nanoparticle) and composed of atoms in either a single- or poly-crystalline arrangement.[1] According to Sonats, USP generates, when specific conditions are applied, a severe plastic deformation of the work piece surface. This plastic deformation generates a nanocrystallized surface layer without any change to the core microstructure. (Conventional shot peening also creates nanocrystals, but to a lesser degree.)

    The benefits of a nanocrystallization layer (generally between ten micron and 50 micron deep) come into play when components require heat treatment. During nitriding, a heat treatment, nitrogen is diffused into the surface of a metal to create a case-hardened surface. Benefits are also seen when diffusing chromium and carbon as part of other thermal treatment techniques. These processes are most commonly used on low-carbon, low-alloy steels.[2] Nitriding is often used on transmission components such as shafts, gears, and other power transmission parts such as screws, crankshafts, and camshafts.

    The diffusion efficiency of nitrogen is increased when this treatment is performed at high temperature (600˚C) for a significant time. However, this increased time has a detrimental effect on the metal microstructure and properties. Nanocrystallization results in decreased heat treat time and temperature thereby preventing any potential damage to the metallurgy of the component.



Microstructure evolution after USP (nanocrystallization occurs to a depth of about 50 micron).

VIBRATORY PEENING

Vibratory peening is another non-conventional shot peening process that's deserving of our attention. Most of us are familiar with vibratory finishing as a process to polish a metal surface and decrease its roughness. Given that conventional shot peening creates a rough surface, it's also common practice to polish peened components in a vibratory finishing machine without any effect on the residual stress value. Most specifications will allow polishing to remove material up to 10% of the Almen "A" intensity value with the belief that this will not affect the residual stress created during the peening process.

Vibratory peening polishes, reduces roughness and induces compressive residual stress on metal components all in one process. Brian McGillivray, President, Vibra Finish Ltd. Canada, explained this process at the 2017 International Conference on Shot Peening while referencing the vibratory peening equipment built for an aerospace customer. "Aircraft engine blades are fixtured horizontally in an oscillating tub containing specialized, spherical media resembling small balls seen in a bearing. Vibrating impact of this media on the multiple blades fixtured in the bowl induces the desired residual compressive stress values, simultaneously creating a smooth surface finish not possible with conventional shot peening," said Mr. McGillivray.

Mr. McGillivray and researchers at École Polytechnique de Montreal (Hongyan Miao, Leo Canals and Martin Levesque) carried out extensive studies on this technique using AA7050-T7451 samples. They reported the following:

- Better surface finish with vibratory peening than conventional shot peening (comparisons tests were conducted with an air-type peening machine)
- Compressive residual stress values (surface and maximum) were higher with conventional peening, but deeper with vibratory peening (340 micron below the surface with shot peening compared to 520 micron depth with vibratory peening, for the same residual stress of -50 MPa)

Almen strips used for process validation in a vibratory peening machine.

[1,2] www. wikipedia.com

AN INSIDER'S PERSPECTIVE

Continued

- Similar fatigue lives with both processes, with vibratory peening showing more uniformly distributed values (lower standard deviation).

Vibratory peening is a relatively new process, and these studies will attempt to validate this technique on a larger scale. Given the nature of the process, and our knowledge of vibratory finishing, we can list some of the advantages of vibratory peening over conventional shot peening:

- A gentler and more repetitive process leading to the uniform generation and distribution of residual stress over the treated surface
- Longer media life than in conventional peening
- No dust generation
- Lower utility costs than conventional peening

Some of the limitations that are currently being addressed by Vibra Finish include:

- Scalability
- The need for custom and unique fixturing for specific part styles
- The need for masking when peening specific areas

SUMMARY

The intention of our discussion is to recognize non-conventional peening processes. Not only do they exist, they're quite prevalent within the industries like automotive and aerospace where conventional shot peening is well established.

Ultrasonic Shot Peening (USP) comes with the obvious benefits of operating in a completely contained atmosphere. The peening media used in this process is closed-loop to the extent that it doesn't leave the enclosure. The limited amount of media required allows the process to utilize highly durable materials resulting in long life cycles, no dust generation, and an overall surface finish that's superior to conventional shot peening. The eco-friendliness of this process is also validated by its significantly lower power and compressed air requirement.

As mentioned before, vibratory peening is an emerging technology being taken upon by a premier research institution, the École Polytechnique, for further study and validation. The combined polishing and compressive residual stress generating attributes of vibratory peening promises to create its niche in advanced manufacturing sectors such as aerospace and medical. The advantages of this process closely mirror those of USP and we will soon see further research findings on the process leading to its wider commercialization.

The exhibitors at the EI shot peening workshop and the International Conference on Shot Peening taught me to not only look for advancements in conventional processes, but also in alternate processes for shot peening. I hope this discussion initiates the same in you.

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ACADEMIC STUDY

Dr. David Kirk | Coventry University

Decarburization: The Silent Enemy

INTRODUCTION

A large proportion of metallic engineering components are made from carbon steels. These components may encounter high temperatures during furnace heat treatment and/or hot working. High strengths combined with adequate ductility are achieved by heat-treating carbon steels. This involves heating to a high temperature followed by quenching and then tempering. Hot working includes processes such as rolling and forging. It is at high temperatures in air that "The Silent Enemy" (decarburization) can strike. Carbon can be sucked out of the component, resulting in a severely weakened surface layer. The surface layer is just where we need the component to be at its strongest. Maximum applied stresses and defects acting as stress-raisers occur at the surface. Shot peening is much less effective if applied to a decarburized component. Decarburization would not be a problem, however, if post heat-treatment machining was applied to all sensitive areas.

High-strength carbon steel typically contains about 0.8% of carbon. That does not sound like very much but carbon atoms are much lighter than iron atoms with atomic weights of 12 and 58.8 respectively. If we express carbon content in terms of proportion of atoms, we find that the carbon content is about 4%. In other words, about one in every twenty-five atoms is a carbon atom.

Decarburization occurs if carbon atoms in the heated steel component have both (a) a mechanism for migrating and (b) a desire to migrate to the surface. If decarburization is occurring, then a continuous surface layer of soft ferrite is being produced together with ferrite formation around austenite grains further away from the surface.

This article considers the migration mechanism and migration desire involved in decarburization together with property effects and methods of detection. The description of the migration mechanism uses an analogue involving shot particles. Overall the article is meant to be complementary to standard specifications such as ASTM 1077-14.

A proposed rapid-test technique for decarburization is based on the ratio of drop height to rebound height for an indenter given a range of energies.

MIGRATION MECHANISM

Imagine four large identical spherical shot particles arranged in a square formation as shown in fig.1. These four enclose a four-pointed hole that scientists call an "interstice." A smaller shot particle could rest neatly in the hole provided that it was of the required diameter. The square arrangement of spheres replicates the cubic nature of steel crystals.

Carbon steel at a high temperature has a closely packed face-centered-cubic (f.c.c.) structure. Carbon atoms in f.c.c. austenite grains are then too large to fit into the hole shown in fig.1. In order to be accommodated, a carbon atom has to push four iron atoms slightly apart as shown in the scale drawing fig.2. The ratio of diameters is 52 for the hole of fig.1 to 80 for the enlarged hole of fig.2 (page 28). Pushing the iron atoms slightly apart generates possible escape routes for the carbon atom. These routes are, however, too narrow for escape to occur.

The iron atoms in steel are actually positively charged ions. They therefore repel one another just as the positive ends of two bar magnets tend to push on each other. What holds the lattice together is the so-called "electron cloud"—vast numbers of negatively charged electrons whizzing

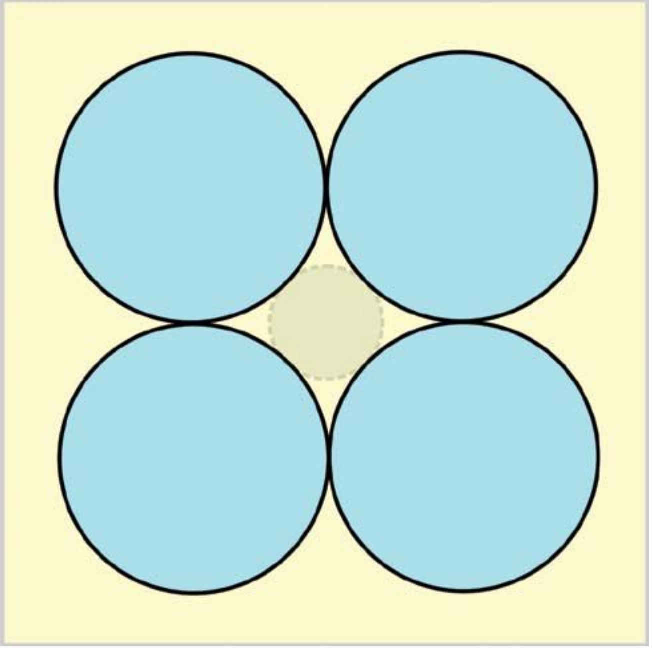

Fig.1. Square arrangement of spheres enclosing an interstice.

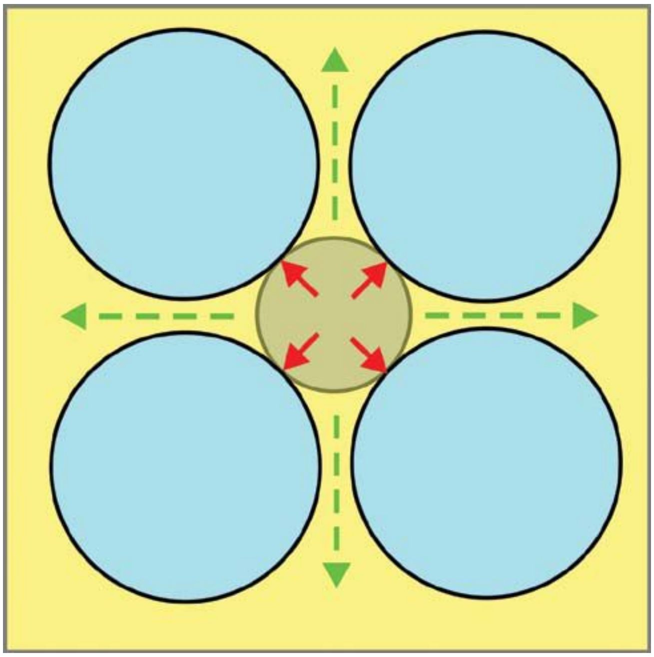

Fig.2. Scale drawing of a carbon atom pushing apart four iron atoms thus generating possible escape routes.

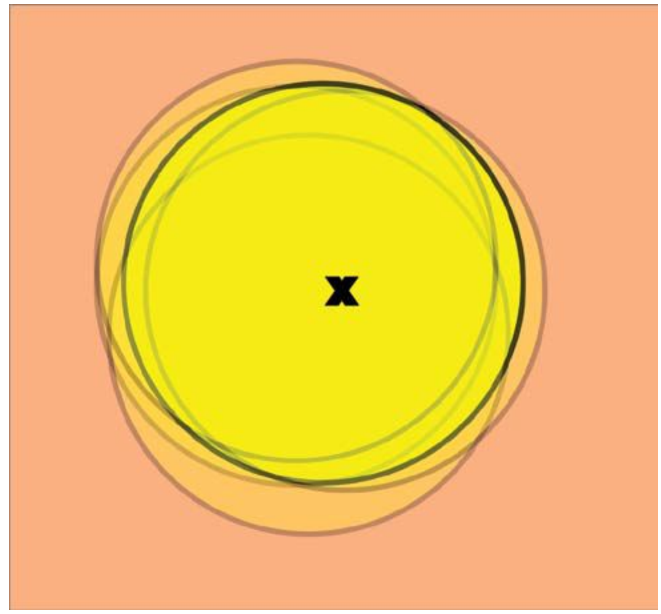

Fig.3. Schematic representation of atomic vibration at high temperatures.

around. Apart from holding the lattice together, the electron cloud is responsible for steel's ability to conduct electricity.

At room temperature, the iron atoms are effectively static in terms of position. However, if the temperature is increased, the amplitude of vibration is also increased. At temperatures in the region of 1000˚C, the amplitude of vibration becomes sufficient to create escape routes that carbon atoms can get through. This effect is the mechanism that allows carbon atoms to move through the lattice and to a component's surface if decarburization is occurring. Fig.3 is an attempt to represent the vibration of an atom at high temperatures. The frequency of vibration is about 10 trillion per second!

The vibration of atoms at high temperatures is sufficient to generate usable escape routes for the otherwise captive carbon atoms. This is represented schematically in fig.4. At some instant in time, atoms have moved apart sufficiently to allow a carbon atom to jump into a neighboring interstice. This confluence is aided by the enormous rate of atomic vibration.

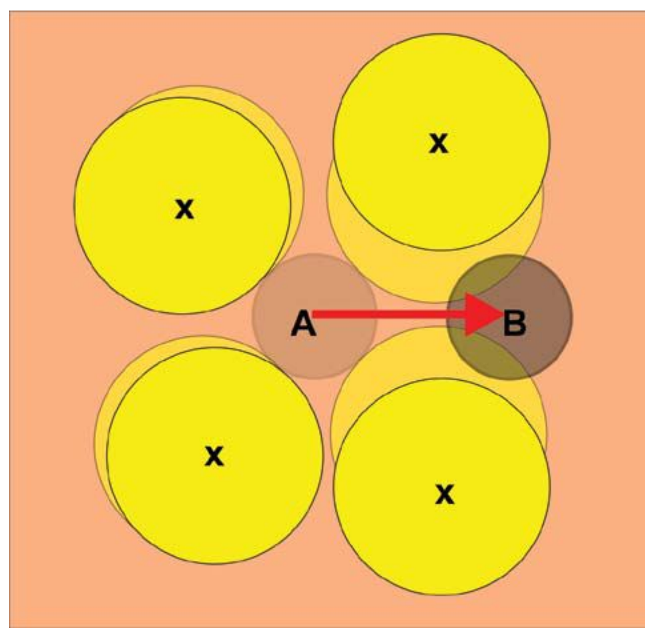

Fig.4. Schematic representation of atomic vibration of iron atoms generating an escape route AB for a carbon atom.

MIGRATION DESIRE

Having established an escape mechanism, carbon atoms will only migrate if there is a desire to migrate—a situation analogous to that of prisoners in jail! The surface of a component represents the only means of permanent escape. If carbon atoms in sufficient numbers do escape from the surface, we then have decarburization.

Surface Escape of Carbon Atoms
(a) Hot-Working

During a hot-working operation, such as hot-rolling, exposure to oxygen in the air is unavoidable. Mill scale forms on the steel surface which is basically solid iron oxide. At high temperatures, the oxygen atoms in mill scale are itching to grab carbon atoms from the component's surface. A typical chemical reaction would be:

$$Fe_2O_3 + 3C = 3CO + 2Fe$$

(b) Furnace Heat-Treatment

The atmosphere in a heat-treatment furnace inevitably contains oxygen molecules (O_2). These are pairs of oxygen atoms bonded together. The oxygen molecules fly about at high speed and often collide with the component's surface. At the temperatures involved, about 1000˚C, the colliding molecules react with surface carbon atoms. The commonest chemical reactions are:

$$C + O_2 = CO_2 \text{ and } 2C + O_2 = 2CO.$$

Vast numbers of carbon atoms can be removed from the component's surface using these reactions to produce a decarburized surface layer.

The rate of carbon removal depends on the furnace temperature and atmosphere. The higher the temperature, the faster is the rate of carbon removal. Plain air furnace atmospheres give the fastest rate of carbon removal at a given temperature. Vacuum and neutral gas furnaces give the lowest rate.

Carbon Gradient

When decarburization is occurring, carbon atoms are being leached out of the component's surface. This gives rise to a carbon gradient with, say, 0.8% away from the surface falling to almost 0% at the surface (for a plain air furnace). The crystal structure near the surface changes from f.c.c. austenite to the less closely packed body-centered-cubic (b.c.c.) structure of ferrite. In effect the surface region is converted into mild steel. Fig.5 is a schematic representation of carbon being leached out from a single austenite grain. Real carbon-steel components when heated to high temperatures contain, however, vast numbers of austenite grains.

The carbon content variation for a multi-grain situation is much more complicated than that shown in fig.5. Atoms in grain boundaries are much more disorganized than those inside a grain. As a consequence, carbon atoms can move much more quickly along grain boundaries than they can within a grain. The carbon content falls sufficiently to allow ferrite formation at grain boundaries. Ferrite has much larger interstices than does austenite. Carbon migration along these

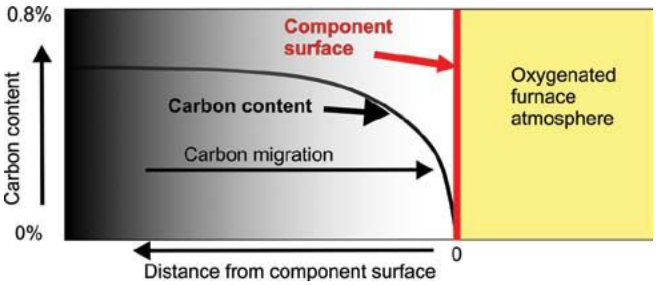

Fig.5. Schematic representation of decarburization from a single austenite grain.

newly created ferritic grain boundaries is relatively very rapid. In a sense we can regard hot ferritic grain boundaries as "super highways" for carbon migration.

It is not possible to obtain a micrograph of decarburizing austenite grains because decarburizing only occurs at high temperatures in furnaces. We have to deduce what has happened from micrographs taken when the steel has subsequently cooled down. A set of such micrographs appears in the excellent article "Decarburization of Steel" by R. Cornell and H.K.D.H. Bhadeshia. It is available at www.phase-trans.msm.cam.ac.uk/abstracts/M0.html.

Fig.6 uses one of their micrographs to illustrate carbon migration. At high temperatures the austenite grains gradually become smaller as the grain boundaries lose enough carbon to transform into ferrite. These grain boundaries become thicker the closer they are to the component's surface.

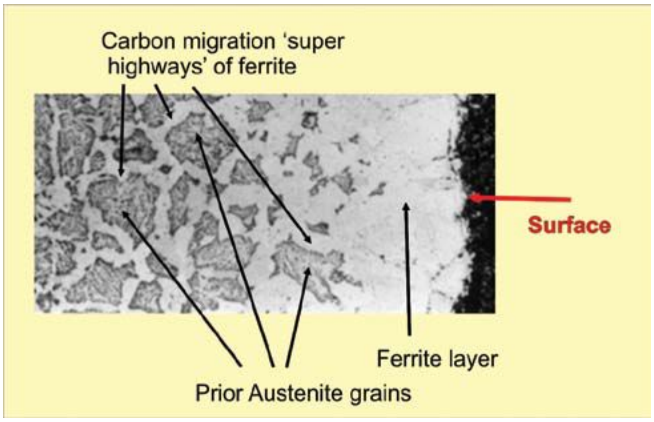

Fig.6. Room temperature micrograph of decarburized steel.

DEFINITION AND DEPTH OF DECARBURIZED SURFACE LAYER

Looking again at fig.6 we can pose the question "How thick is a decarburized surface layer?" We first have to define the end-point of decarburization. One definition could be "the depth at which the ferrite layer ceases to be continuous." Another definition could be "the depth below which no grain boundary ferrite occurs." Using the first definition, the depth corresponds to about a quarter of the width of the micrograph. Using the second definition, on the other hand, puts the depth as being much greater than the total width of the fig.6 micrograph.

Fig.7 (page 32) is a schematic interpretation of the variation in average carbon content associated with the structure shown in fig.6. The indicated depth, D1, would correspond to the first definition of the previous paragraph and is readily detectable. Applying the second definition is relatively difficult.

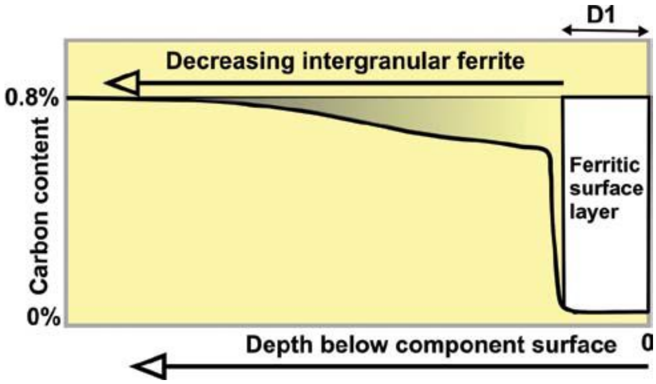

Fig.7. Variation of carbon content with depth below the surface after decarburization.

CONVENTIONAL DETECTION OF DECARBURIZED SURFACE LAYER DEPTH

The ferrite in the surface of a decarburized steel etches differently from carburized steel as evidenced by fig.6. It is also much softer. Chemical analysis of carbon content variation is rarely used. There are, however, two well-established methods for the detection of decarburized surface depth:

(1) Metallography and
(2) Micro-hardness testing.

(1) Metallography

Fine polishing and etching (usually employing Nital) is the standard metallographic technique used on carbon steels. Cutting a test specimen out of a component and mounting it in, say, Bakelite is very inconvenient. Examining Almen strip surfaces for decarburization does not necessitate cutting. The specified heat-treatment for Almen strips includes heating to austenitizing temperatures prior to quenching. They therefore run the risk of decarburization.

The author's preferred metallographic technique for detecting decarburization is to use "taper polishing" as illustrated by Fig.8. A taper-polished surface presents a range of depths with a maximum of AB, tapering to zero at C. The range of depths can easily be measured using an accurate dial gauge. Etching of a taper-polished decarburized surface will reveal the range of microstructures shown in fig.6.

Taper polishing is not restricted to a flat surface. Components normally have regions that will subsequently be machined. Such regions can be tested for decarburization in situ using localized polishing and etching, together with photography.

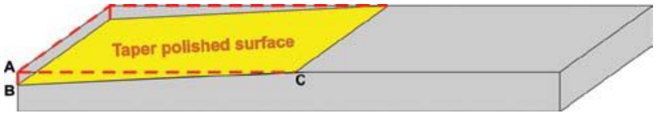

Fig.8. Taper polishing of a rectangular test specimen.

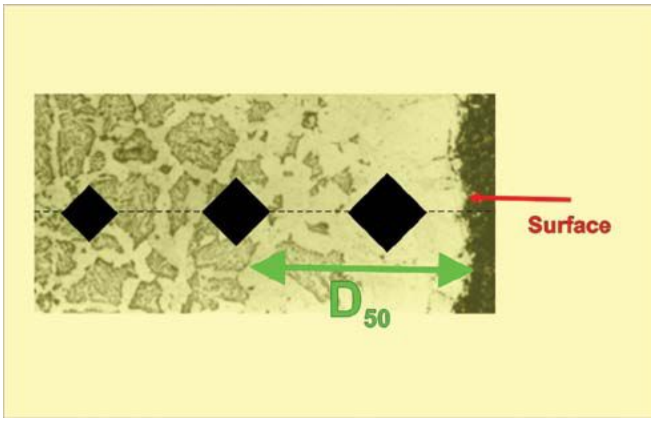

Fig.9. Micro-hardness variation below decarburized surface.

(2) Micro-Hardness Testing

The thickness of the continuous ferrite layer depends on the severity of the decarburization. Discontinuous ferrite normally extends to about ten times the thickness of the continuous ferrite layer. Fig.9 illustrates the application of micro-hardness testing to examine hardness variation in a decarburized steel surface. The black diamonds have been superimposed to represent hypothetical micro-hardness indentations. Indentations become progressively smaller as the hardness increases. The smaller indentations shown in fig.9 average the hardness of ferritic and pearlitic regions.

Micro-hardness testing of mounted cross-section specimens requires that the indentations are spaced both from each other and from the component's surface. Testing of a taper-polished specimen is much less restrictive.

RAPID TESTING FOR DECARBURIZED SURFACE LAYER DEPTH

There is an obvious need for a technique that can rapidly detect the presence and depth of a decarburized surface layer. This section proposes techniques that are based on the energy loss that occurs when impacting objects rebound from the component's surface. The softer the surface, the greater the energy loss. Established rebound hardness test methods include the Shore Scleroscope and the Leeb rebound tester. These methods are, however, designed solely to measure surface hardness rather than decarburized surface layer depth.

Fig.10 (page 34) illustrates the principle of rebound hardness testers. Imagine a small ball bearing is dropped from a height H1 onto the surface of a component. The ball bearing loses some of its kinetic energy as it indents the surface and rebounds to a height H2. (H1 – H2) is the measure used for Scleroscope hardness testing and is a direct measure of the loss of kinetic energy. **The softer the surface material the greater is (H1 – H2).** The Leeb method uses the ratio V2/

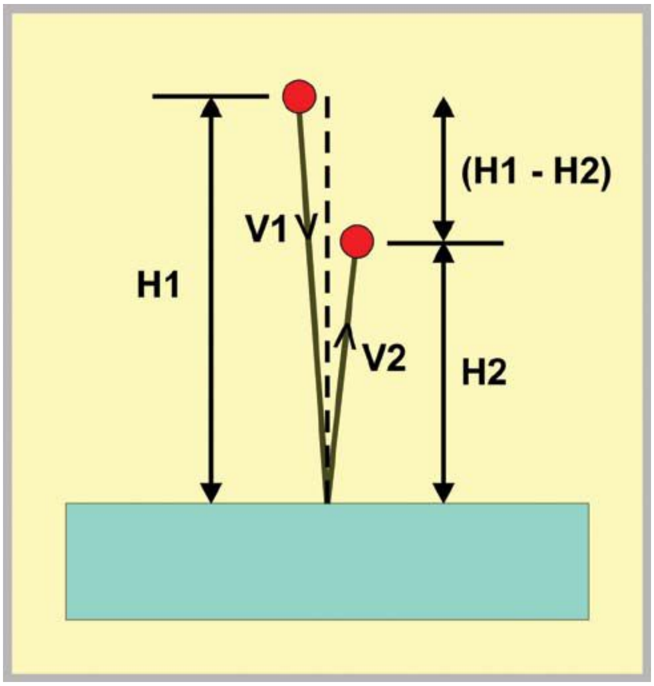

Fig.10. Principles of rebound hardness testing.

V1 as a measure of hardness and again is a measure of kinetic energy loss.

Fig.11 illustrates the nature of our problem when examining decarburized steel components. At the extreme surface there is a thin (hopefully) continuous layer of soft ferrite—shown in red. Below that layer the structure progressively contains less and less soft ferrite. Eventually the structure becomes free of decarburization.

1. Rapid Detection Test

A simple method for detecting the presence of decarburization is to drop a small ball bearing from a known height H1 down a clear, ruled, tube and measure the rebound height H2. Height measurements are best made by using video. If (H1 – H2) is much less than it should be for a normally hard component then we have a problem! Either the surface is decarburized or the entire component has not been heat-treated properly.

1.2 Reference Specimens

Reference specimens allow us to differentiate between decarburization and faulty heat-treatment. They also allow us to quickly estimate the depth of a decarburized layer. Appropriate reference specimens are rectangular blocks that have been heat-treated correctly except for employing an air-rich austenitizing furnace that induces surface decarburization. The heat-treated block is then taper-polished as shown in fig.8 together with grinding-off decarburization from the opposite face. This yields a reference specimen ABCDE as indicated in fig.11 by dashed lines. Heating to

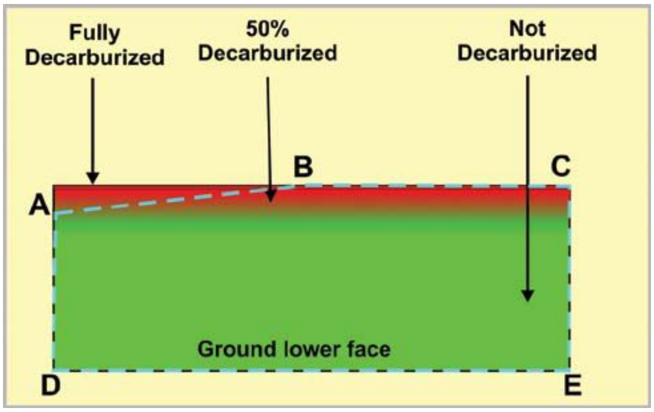

Fig.11. Decarburized layer thickness variation.

different austenitizing temperatures would produce different thicknesses of decarburized surface layer.

2. Decarburization Depth detection

A small-diameter, low kinetic energy, indenter impacting on face BC will confine deformation to the soft decarburized surface layer. This will result in high values for both (H1 – H2) and V2/V1. Turning the sample over and impacting on face DE will give low values for both (H1 – H2) and V2/V1, assuming that the specimen's core has been correctly heat-treated to high hardness. This will confirm that there is a soft surface layer rather than a completely soft component.

The novel part of the proposed technique is to impose a range of impact intensities.

If we increase the indenter's impact intensity, the induced dent will become larger. The plastic deformation zone under the dent will become correspondingly deeper. As the deformation zone becomes deeper, more and more of it represents the hardness below any decarburized surface layer.

Variation of indenter impact intensity can readily be achieved by dropping a weighted carbide ball from different heights, H1. If we do this for the ground lower face of a reference specimen, the ratio H2/H1 will remain reasonably constant. If, however, we do it for a decarburized face (BC in fig.11) the ratio will not be constant. For small values of H1, the rebound height H2 will be lower than for larger values of H1 because deformation is being confined to the soft, fully decarburized surface layer. This means that a plot of H2/H1 against H1 will reflect the hardness variation below the surface. The polished and etched face (AB in fig.11) will reveal how decarburization varies quantitatively with depth below the extreme surface. This can then be used to allow a plot of H2/H1 against H1 to indicate depth of decarburization.

Fig.12 (page 36) is a schematic representation of how H2/H1 would be expected to vary with H1 for different thicknesses of decarburized surface layer. Published work


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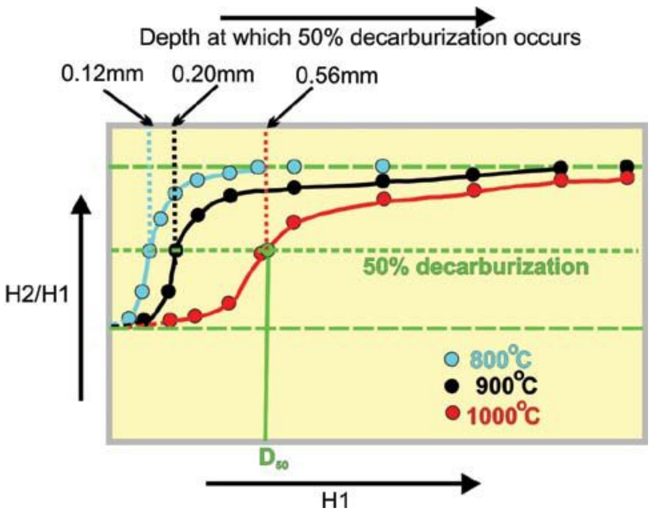

Fig.12. Effect of decarburization depth on H2/H1.

indicates that austenitizing at 800, 900 and 1000˚C would produce a useful range of decarburization layer thicknesses in reference specimens.

Imagine, as an example, metallography on the taper-ground face of a reference specimen treated at 1000˚C revealed that 50% decarburization has occurred at 0.56mm. 50% decarburization must also coincide with being halfway between the maximum and minimum H2/H1 ratios as shown in fig.12. This gives us one point for a secondary axis converting H1 values to depth at which 50% decarburization occurs. See the upper axis in fig.12. Repeating the procedure on specimens treated at 800 and 900˚C would give us two further points for the upper axis. This secondary axis allows rebound tests on components to indicate the depth of 50% decarburization.

DISCUSSION

This article is largely intended to be educational. The migration mechanism and migration desire involved in decarburization have been outlined together with property effects and methods of detection.

A novel rapid test technique has been proposed. The technique is based on rebound testing using a range of impact intensities. At this stage it is purely a theoretical concept, utilizing the author's previous experience of rebound testing to predict dent diameters.

It is hoped, however, that the concept will be taken on board as a project by one or more interested organizations.

Joanna Kennedy | Performance Review Institute (PRI) | www.p-r-i.org

Aerospace Auditing: A World of Opportunity

Nadcap is an industry-managed approach to conformity assessment that brings together technical experts from both industry and government to establish requirements for accreditation, accredit aerospace suppliers and define operational program requirements. This results in a standardized approach to quality assurance and a reduction in redundant auditing throughout the aerospace industry.

One of the technical areas audited by Nadcap is surface enhancement which includes shot peening, peen forming, glass bead peening, computer controlled peening, automated peening, flapper peening and manual peening. There are currently 288 aerospace companies accredited by Nadcap for surface enhancement from 31 countries around the world. Thirty percent of the accredited companies are based in the USA, followed by China at 11%, Japan at 10%, Italy at 6% and the UK and Canada at 5%. Across all the technical areas audited by Nadcap, approximately 6,000 audits are conducted each year around the world.

As a result, Nadcap auditors travel the world to witness the processing of aerospace parts, contributing their expertise and enhancing their own knowledge through the experience. This means there is no need to relocate and the costs associated with traveling to conduct the audits are covered. Nadcap Auditor Chee Soon Lum conducts Nadcap audits for surface enhancement as well as chemical processing, heat treating and non-conventional machining. He has been a Nadcap auditor since 2004. He explains why he got involved and the benefits he enjoys as a Nadcap auditor.

"Following my employment with Sundstrand, I was attracted to Nadcap because the nature of the work was similar, but more in-depth. I like the flexibility of developing my own schedule. I would recommend becoming a Nadcap auditor to anyone who is dedicated to the aerospace industry.

It is a rewarding experience working with a world-class aerospace organization that strives for competitive excellence. I enjoy the work and feel that PRI's services are of enormous value to the aerospace industry.

Working as a Nadcap auditor, I am continually learning about new technology in my field and it also allows me the opportunity to experience different cultures."

George Hayes, another multidisciplinary Nadcap auditor adds: *"My career was spent at the Naval Air Weapons Center at China Lake, California starting in 1957 until I retired as Director of the Materials Test Laboratory in 1992. After retirement I was looking for a way to keep mentally sharp and up to date on emerging technologies, and to continue my involvement in the aerospace industry.*

I was also looking for the possibility to do some travelling. These interests are what attracted me to being a Nadcap auditor. I have the flexibility to choose when to audit and to determine if I want to avail myself of the opportunity to travel and see other cultures.

The time as an auditor allows me to stay involved in my career field and to keep in contact with people in the same profession."

Learn more about becoming a Nadcap auditor at www.eAuditStaff.com

TRAVEL TRIVIA

TOP TEN MOST BEAUTIFUL CITIES IN EUROPE

To all of our European readers and world travelers: See if you agree with this list compiled by Doug Lee at worldindustrialreporter.com.

10. MUNICH
9. LISBON
8. ISTANBUL
7. FLORENCE
6. PARIS
5. VIENNA
4. ZURICH
3. BUDAPEST
2. PRAGUE
1. ST. PETERSBURG

Name That Aircraft Manufacturer

Think you know your aircraft? Take this quiz to test your knowledge. The average score for this quiz is 13 out of 20.

1. Which company manufactured the F-16 Fighting Falcon?
   Northrop — McDonnell Douglas
   General Dynamics — Boeing

2. Which company manufactured the F-104 Starfighter?
   Boeing — Douglas
   North American — Lockheed

3. Which aircraft company manufactured the F-15 Eagle?
   North American — General Dynamics
   McDonnell Douglas — Northrop

4. Which aircraft manufacturing company was responsible for the F-20 Tigershark?
   Boeing — McDonnell Douglas
   Canadair — Northrop

5. Which company manufactured the P-51 Mustang?
   Boeing — North American
   Northrop — Douglas

6. Which of the following aircraft companies manufactured the F-4 Phantom?
   General Dynamics — McDonnell Douglas
   Boeing — Northrop

7. Which aircraft manufacturing company was responsible for the F-14 Tomcat?
   Grumman — General Dynamics
   Northrop — Boeing

8. Which company manufactured the F-117 Nighthawk Stealth Fighter?
   Lockheed — Boeing
   Grumman — Northrop

9. Which aircraft manufacturing company was responsible for the F-111 Aardvark?
   Boeing — Grumman
   North American — General Dynamics

10. Which aircraft company initially manufactured the A-4 Skyhawk?
    Grumman — British Aerospace
    Northrop — Douglas

11. Which of the following aircraft companies manufactured the Harrier?
    Fokker — Panavia
    British Aerospace — Grumman

12. Which company manufactured the A-10 Thunderbolt aircraft?
    Dassault-Bregeut — Fairchild Republic
    Panavia — Lockheed

13. Which company manufactured the A-7 Corsair II?
    McDonnell Douglas — Grumman
    Ling-Temco-Vought — North American

14. Which aircraft company manufactured the A-6 Intruder?
    North American — General Dynamics
    Grumman — Vought

15. Which aircraft company manufactured the Jaguar Gr.Mk1?
    Panavia — Sepecat
    British Aerospace — Grumman

16. Which company manufactured the Ja-37 Viggen aircraft?
    Dassault-Bregault — Sepecat
    British Aerospace — Saab

17. Which company manufactured the CT-114 Tutor aircraft?
    McDonnell Douglas — Lockheed
    Canadair — Avro

18. Which aircraft company manufactured the F4U Corsair?
    Vought — Lockheed
    North American — Grumman

19. Which aircraft company manufactured the Mirage 2000?
    Saab — Panavia
    Dassault-Breguet — British Aerospace

20. Which company manufactured the F-5E Tiger II aircraft?
    General Dynamics — Grumman
    McDonnell Douglas — Northrop

Answers are on page 46. Good luck!
Source: www.funtrivia.com/playquiz/quiz341443eba08.html


Process reliability for peace of mind

Darko Hočevar and Aljaž Molek | FerroECOBlast | www.ferroecoblast.com

An Advanced Robotic Shot Peening Cell

INTRODUCING THE ASP 1200 ECO

The FerroECOBlast "ASP1200 ECO" automatic robotized peening cell was designed and built for a customer in Asia who uses it during the service procedure for shot peening aircraft landing gears. The cell satisfies and even exceeds the demanding requirements of various SAE / AMS standards and requirements in aviation industries, which is facilitated by advanced, computer-based systems.

In shot peening, it is important that the cell provides a repeatable process, i.e., peening the same places from the same distance, with the same speed of nozzle movement, the same pressure, and the same flow of the abrasive. A very important additional factor in the whole system is purification, the elimination of inadequate peening material. It is important that there is no waste in the medium, and that the peening beads are not damaged or broken, which is enabled by the use of various components in the recycling tower, such as different vibration screens, magnetic separators, and spiral separators.

Using a spiral separator, we have ensured the separation of damaged or broken beads from the steel beads with correct shapes. With the use of magnetic separators, we can ensure the expulsion of metal inclusions in non-magnetic media (glass beads).

By integrating the automatic dosing system, we ensure the addition of fresh medium to the system in the event of a detected lack of medium. This enables the customer to eliminate downtime due to the need to refill the system. In order to facilitate easier and faster emptying in the event of a change of medium, we have integrated an automatic emptying of the entire system.

This is just a part of the system that makes up the automated robotized shot peening cell that enables the quality machining of this Asian airline's components and, consequently, safe landings of aircraft.

In the development phase of the automated robotized shot peening cell, the correct development and implementation of the sequence of technological processes with which we perform the peening process on the workpiece are extremely important.

It is necessary to know the material of the workpiece, its behaviour in the process of shot peening, and how this process affects the mechanical properties of the workpiece. Therefore, it is important to know beforehand the technology of aeronautical production and the mechanical and chemical properties of materials on which we will perform the shot peening process.

The FerroECOBlast ASP1200 ECO automatic robotized peening cell

Without knowledge of prior behaviour, the process of shot peening can be performed improperly, and it may also represent a certain risk for the product due to a wrong execution of the shot peening procedure, thus achieving a completely opposite effect. Therefore, the sequence of operations on the workpiece is extremely important.

In addition, the entire system is designed to protect operators during the work process as well as repairers during maintenance. In this case, we use a security key / card technology from Sick, which ensures that the work process can not be started during maintenance. In addition to this system, the equipment includes all other safety warning systems, the so-called security chain, which provides operator safety during the operation, and the safe operation of the entire cell.

UNIQUE FEATURES OF THE ASP 1200 ECO

The ASP 1200 ECO" automatic robotic shot peening cell is special because it is universal and suitable for high-quality

machining of various aircraft components since it has many built-in applications. For example, the peening of long pieces which comprise the chassis, the vertical internal peening unit, the peening of holes with the rotary lance, the automatic tool change with a laser gauge to check the suitability of the selected tool are unique features of the cell.

The mobile cart with a rotating table and eight satellites are important, too. The cart is brought to the outer platform where parts of the chassis are fastened to the rotating table. Large sections of the chassis are usually fastened to the table, and up to eight smaller ones to the satellites. The rotation of the table and the satellites is synchronized with the movement of the robot, which means that we can peen multiple workpieces at a time, enabling substantial savings of time and, consequently, money.

In addition, the cell has a built-in camera that allows us to record and control the process. The entire cell is operated by the user-friendly SCADA system and it has simplified machine management, thus achieving greater operator and supervisor satisfaction.

The cell is built for peening with two basic abrasives: Glass bead and steel shot, that is, the metallic and non-metallic materials inside one cell, which are rapidly and automatically changed, without operator intervention Also, the robot itself changes the necessary tools (nozzles), which again results in a shorter peening (processing) time.

Size classification of peening media

The use of advanced control systems (flux on) ensures the fast and efficient regulation of special MagnaValves, with which we can achieve an accuracy of ±2% of the flow of the medium. Integration of the in-line system for the calibration of the MagnaValves ensures the proper flow of medium, both for steel and glass beads.

Software for the direct recording of Almen test results helps help us control the intensity of shot peening. An on-line camera in the workspace records the machining process of each workpiece in order to ensures the traceability of the workpieces and of each workpiece separately. Finally we have a full information recorded for each single workpiece.

OTHER INDUSTRIES SERVED AND OUR GOAL

Our shot peening cells are used in the automotive industry, gearboxes and suspension, and in the field of internal combustion engine components. We can boast of our own shot peening cell, with which we offer services of shot peening on various products for customers from both the automobile and aviation industries.

Our goal and long-term vision is to conquer other similar areas where such technology is necessary and important. In the first phase, we want to proceed in the direction of surface peening—laser peening, and shot peening in combination with water, so-called wet peening. Here we also cooperate very closely with our partners, the best world-renowned companies and leaders on this field. In the field of nuclear technology, we can already boast our implemented applications for UHP (Ultra High Pressure) surface decontamination.

Contact Information

- **Mr. Darko Hočevar, Technical Manager, FAA Certificated Shot Peening expert (darko.hocevar@ ferrocrtalic.com)**
- **Mr. Aljaž Molek, Technical Sales Representative, FAA Certificated Shot Peening expert (aljaz.molek@ ferrocrtalic.com)**

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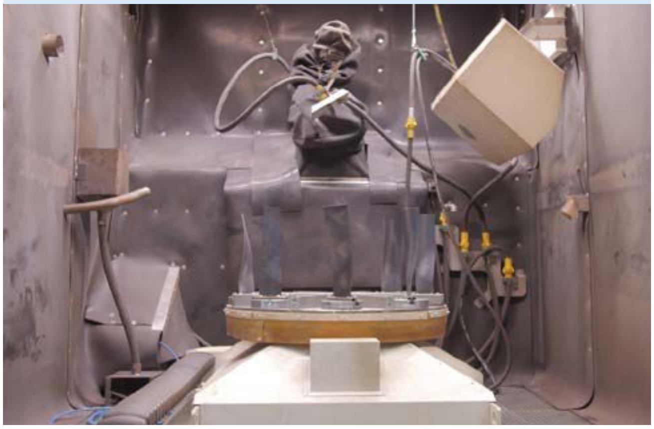

Turntable with rotary satellite, synchronized with robot


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2017 Almen Strip Consistency Testing Results

QUALITY CONTROL TESTING SINCE 2007

Electronics Inc. (EI) developed a performance consistency testing program on their A and N Almen strips in 2007 to ensure they are consistent in thickness, flatness and hardness. The purpose of EI's testing program is to verify that the strips will perform consistently, from lot to lot, from year to year.

TESTING METHOD

EI built an air blast cabinet with a variable speed rotary table with 26 Almen strip holders, a fixture for adjusting nozzle distance from the strips, a MagnaValve® for media flow rate control, and controls to adjust air pressure and table rotation. During testing, the table is rotated at a fixed speed, and the cabinet is set for a specific pressure and constant media flow rate so each strip passes under the blast nozzle at the same angular velocity for the same predetermined number of revolutions.

For each test, a sample size of 40 strips is used. EI measures and records the flatness of the strips before testing. After each test cycle, the arc heights are measured on a calibrated Almen gage and the flatness compensation is applied. The values are put into histograms for analysis. A histogram is a graphical display of tabulated frequencies, shown as bars. It shows what proportion of cases fall into each of several categories. A histogram differs from a bar chart in that it is the area of the bars that denotes the value, not the height of each bar.

TEST RESULTS

Histograms exhibit nearly identical lot-to-lot arc height results, thereby verifying the uniformity of the product. The 2016 and 2017 test results in a histogram format are on page 46 and test results from 2007 to 2017 are available at www.electronics-inc.com.

Each histogram represents a test to verify the performance of an individual lot. The results illustrate the performance consistency of the strips as defined by the nearly identical mean values and the narrow standard deviations. The mean is the sum of the observations divided by the number of observations. The mean describes the central location of the data, and the standard deviation describes the spread. The standard deviation is a statistic that tells how tightly all the examples are clustered around the mean in a set of data. When the examples are tightly grouped together and the bell-shaped curve is steep, the standard deviation is small. When the examples are spread apart and the bell curve is relatively flat, it signifies a relatively large standard deviation. In the case of the Almen strip testing, the tight standard deviation signifies the consistency of the arc height reading.

In addition to documented consistency results, this testing program has provided a substantial technical support base for EI's Almen strip customers. EI has available:

- Current lot-to-lot comparison data on EI strips
- Comparisons of EI strips to other strips
- Performance data on other strips
- Analysis on the effect of variations in manufacturing parameters (hardness, thickness, etc.)

EI's research is thoroughly documented. For each test, EI records the scope, setup parameters, procedures, test results and analysis, histograms, saturation curves (where applicable), and a summary conclusion.

EI uses the performance data to answer customers' questions related to process variables and to help customers identify performance problems such as arc height variations and out-of-spec results with non-EI strips.

When EI does not have data available on a unique problem, EI will perform tests to analyze a customer's problem or even duplicate, as closely as possible, their process setup.

The EI custom test cabinet.

TRIVIA

Continued from page 36

ANSWERS

1. **General Dynamics.** The F-16 was one of only two fighters capable of pulling 9+ g's.

2. **Lockheed**. Known in Canada as the Widow Maker and the Flying Coffin.

3. **McDonnell Douglas**. A mach 2.5 fighter, fastest in the U.S arsenal.

4. **Northrop**. The F-20 was modelled after the F-5.

5. **North American**. The Mustang was a World War II fighter aircraft and it also saw service in the Korean War.

6. **McDonnell Douglas**. The Phantom first entered service in 1960, having been developed and built by McDonnell Aircraft. When the company merged with Douglas, the joint company continued to manufacture the Phantom. Its last operational flight was in 1996.

7. **Grumman**. The Tomcat was the first swept-wing variable geometry wing type aircraft for the U.S Navy.

8. **Lockheed**. The Nighthawk stealth fighter first flew in 1981 although the USAF denied its existence until 1988. It was officially retired from service in 2008.

9. **General Dynamics**. The Aardvark entered service with the US Air Force in 1967 and was operational until 1998 when the EF-111 variant was retired. It was also used by the Royal Australian Air Force, whose planes were in use until 2010.

10. **Douglas**. The Douglas Aircraft Company designed and produced the Skyhawk before it merged with McDonnell in 1967 to form McDonnell Douglas.

11. **British Aerospace**. The Harrier was the most successful of the "vstol" (vertical short takeoff landing) aircraft. It was originally manufactured by Hawker-Siddeley and later developed by British Aerospace.

12. **Fairchild Republic**. This aircraft is equipped with a cannon used to take out tanks and is known as the tank killer. The bullets are made from depleted uranium.

13. **Ling-Temco-Vought**. The Corsair II entered service in 1967 with the last operational flight by a USAF plane taking place in 1991. It continued in service with the Portuguese Air Force until 1999.

14. **Grumman**. The Intruder was in service with the US Navy from 1963-1997.

15. **Sepecat**. The Sepecat Jaguar was a joint Anglo-French aircraft that served with the Royal Air Force from 1973 to 2007.

16. **Saab**. The Saab 37 Viggen served with the Swedish Air Force from 1971-2005. It is not to be confused with the Saab 93 Viggen which was a car.

17. **Canadair**. The Tutor was flown by the Canadian Armed Forces acrobatic team—the Snowbirds.

18. **Vought**. The F4U Corsair was a World War II aircraft that first flew in 1942 and it also saw active service in the Korean War.

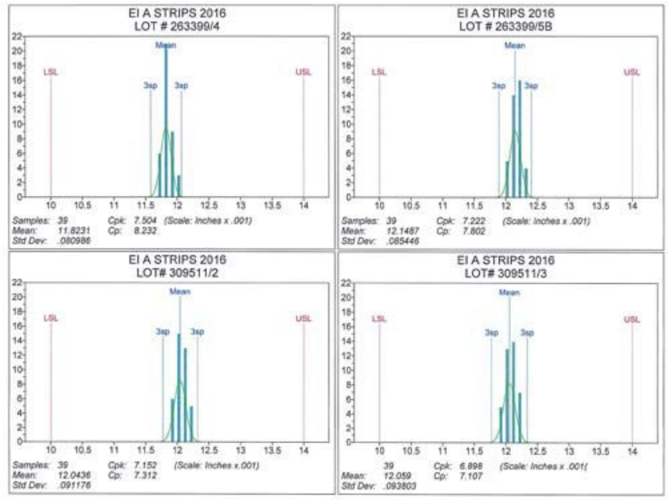
19. **Dassault-Breguet**. The Mirage 2000 was a mach-2 delta winged aircraft.

20. **Northrop**. The Tiger II was used by the U.S Air Force in their top gun training to simulate the Mig-21.

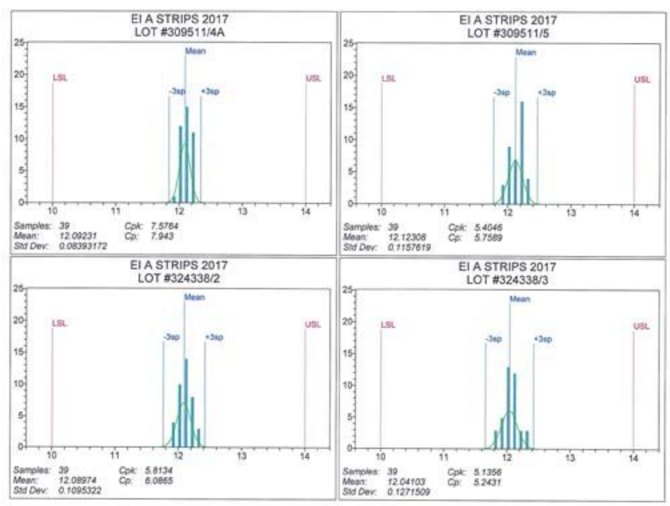
PERFORMANCE TESTING

Continued

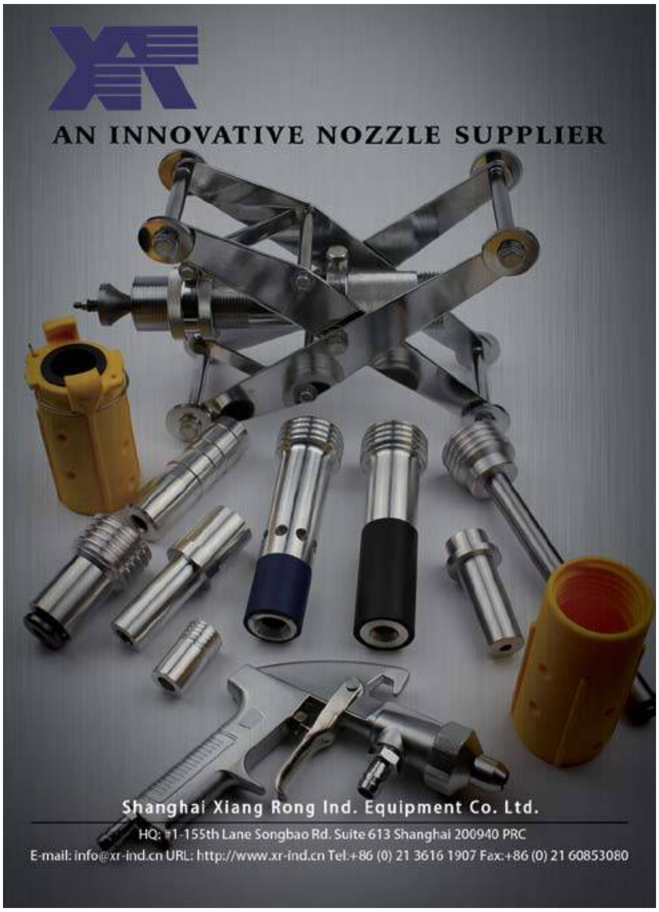
2016



2017



Each histogram represents a 40-piece sample size with the x-axis as the arc height of the strip after peening and the y-axis indicating the number of samples measured at that value (arc height values x .001 inches).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With this product enhancement mentality, we make continual improvements. Some of these improvements are in our line of I-Track Spinner Hangers. The I-Track allows for easy loading and unloading of larger parts as seen in the photograph below. This particular machine, an SH8484 I-Track, was designed to blast very large suspension components for the heavy equipment industry. The part spins around a central axis that allows all sides, including the interior, to be blasted by the three VK PowerMax 1500 blast wheels.

A customer took full advantage of the many options that increased production, promoted safety and reduced maintenance. These options include an OSHA-approved man walk and ladders, fire suppression in the dust collector, rotary scalping drum, auxiliary hopper and sensor, HMI controls, and an industrial vacuum to remove any residual shot from the part that didn't fall into the platform retrieval hopper.

Viking Blast & Wash Systems offers industrial cleaning solutions for all shapes and sizes of metal parts. To receive our brochure or for additional information on any of our shot blast, wash, or vibratory equipment, please call 1-800-835-1096 or send email to sales@viking corporation.com. You may also visit us at www.viking corporation.com.

The SH8484 I-Track Spinner Hanger by Viking Blast & Wash Systems