Winter 2007

The Shot Peener

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Volume 21, Issue 1

Safe Landings

Good processes ensure the safety of your business and everyone that flies

Plus:

- Covering the Basics
- Shot Peening Techniques for Springs
- 2006 Shot Peeners of the Year

What industry magazine do you enjoy enough to read on vacation?

Photographed: Jim Chambers, Surface Improvements, vacationing in Cuba

Winter 2007
Volume 21, Issue 1

The Shot Peener

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The Shot Peener

- 20 years in publication
- Over 5,000 readers
- Read in 85 countries

The Shot Peener (ISSN 1069-2010), in print since 1986, is a quarterly publication from Electronics Incorporated with a circulation of over 5,000 readers 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 newsletter. 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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Of Lawyers and Laxness

by Daryll McKinley

L: Please state your name and address for the record.

D: Jimmy James, 2006 Main Street, Limerick, North Dakota

L: Thank you, Mr. James. Is there any reason that you are unable to give a full, proper testimony here today?

D: No.

L: Are you ill, on any medications, or otherwise hindered to give full and proper testimony today?

D: No.

L: Ok, then, shall we proceed?

D: Sure.

L: Mr. James, what is the name of your business?

D: Shot Peening, Inc.

L: What service does this company provide?

D: We shot peen aerospace and automotive components.

L: Please, for the record, what is shot peen, or shot peening?

D: Shot peening is a metal treatment in which the surface of a metal part is bombarded with small shot.

L: What is the purpose or result of shot peening?

D: It extends the fatigue life of the part.

L: If it is performed properly, correct?

D: Yes.

L: How long has Shot Peening, Inc. been in business?

D: 42 years.

L: That's a long time, congratulations.

D: Thank you.

L: How many employees do you have?

D: 14.

L: How many of these employees perform shot peening?

D: Seven.

L: Do you have a quality department?

D: Yes, I have two inspectors.

L: What type of peening equipment do you have?

D: Three manual booths, two automated booths, and one robotic booth.

L: Ok, I'll ask for an in-depth description of those later today. So, you peen aircraft components?

D: Yes.

L: Do you consider this a critical process?

D: Of course.

L: So you must own and use all of the required tooling and fixtures during this process, correct?

D: Yes.

L: Please tell me the types of tooling and fixtures you use.

D: Almen strips, Almen gages, tracer dye, Almen fixtures, and microscopes.

L: Wow, that sounds complicated. Is there a specification that you use or follow to ensure that you are properly performing the peening?

D: Yes, AMS 2432.

L: Please tell me the title of this specification?

D: I can't recall.

L: Really? I would think you would know it well. Are you sure?

D: Perhaps it will come to me.

L:: Let's hope. Will you please tell me how it is that your company failed to properly shot peen an engine turbine disk that failed in-flight, causing the aircraft to crash, and resulting in the death of 180 passengers and seven crew members?

D: Uhhhhh ....

L: Mr. James, did you understand the question?

D: I believe the turbine disk material was found to be defective.

L: Well, sir, the NTSB thinks otherwise. Their report specifically states that the spindle exhibited inadequate shot peening. And my experts have agreed with that finding.

D: I've read all of those reports.

L: And do you agree with the findings?

D: No, I don't.

L: Of course you don't. Have you brought with you today, as required in your subpoena, all of the inspection reports for the subject type spindle?

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Premier Shot
A cut above

The advantages of Premier Cut Wire Shot

- **Highest Durability -** Due to its wrought internal structure with almost no internal defects (cracks, porosity, shrinkage, etc.) the durability of Premier Cut Wire Shot can be many times that of other commonly used peening media.
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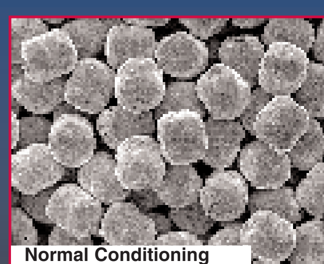
- **Substantial Cost Savings -** The increase in useful life of Premier Cut Wire Shot results in savings in media consumption and reclamation, dust removal and containment, surface contamination and equipment maintenance.


As-cut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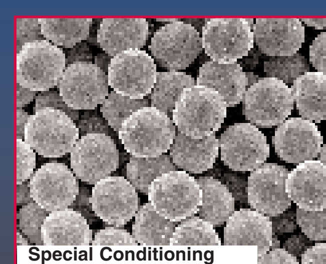
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OF LAWYERS AND LAXNESS
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D: I have them for the last year.

L: Is that all? Aren't you supposed to keep inspection records for a longer period of time?

D: We don't.

L: What does the process specification state?

D: I'm not sure.

L: Have you brought with you today, as required in your subpoena, all of the artisan certification documents for your employees that perform peening?

D: Most of them.

L: Why not all of them?

D: They must have been misfiled.

L: Mr. James, are you involved in the day-to-day operations of your business?

D: I'm in the office everyday.

L: That's wonderful, sir, but it doesn't answer my question. Again, are you involved in the day- to-day operations of your business?

D: Yes, I oversee all of the operations.

L: Are you the person who trains the artisans?

D: Yes.

L: And you trained your inspectors?

D: Yes.

L: When was your last audit?

D: Did you say audit?

L: Yes, Mr. James, an audit performed by a customer or a third party to ensure that your processes are being properly performed.

D: Oh, so far I've not been able to accommodate an audit.

L: I see. Sir, do you think your shot peening process may be out of control?

D: No, not at all.

L: Have you been lax in your responsibilities to your client and the public?

D: Not in my opinion.

L: Perhaps we will seek a subpoena to inspect your premises and to assess your shot peening process. You might consider it your first audit.

The above is a segment of a fictitious deposition, which very well could have lasted for a few days. As much as you may hate lawyers (L), he was just doing his job against the deposed (D). Could your shot peen shop or business withstand the scrutiny of the legal system? Especially a lawyer whose job it is to pick the meat off of your bones during a deposition?

I have worked as a consulting forensic engineer performing aviation and automotive accident investigations. The majority of my experience involved litigation and finding fault in either the manufacturer's product or an overhauler's repair. This means that I worked with, corresponded with, and was deposed by lawyers. In these litigious days in which we live, all aspects of failed components are studied and scrutinized. As much as we may tease and joke about lawyers, it is litigation that helps keep the public safe in many regards.

I have also audited peening shops in which the artisans had no idea of the purpose of shot peening and its effect on parts. Develop a saturation curve? Measure the pre-bow on an Almen strip? Inspect for complete coverage? These were foreign thoughts to the artisans. I might as well have been speaking Urdu. It is my hope that with the progress that has been made in the shot peening industry during the last decade, these types of shops will become nonexistent. Unfortunately, the following are real-life examples of component failures due to improper shot peening.

> On August 14th, 1968, a S-61L helicopter crashed at Compton, California. All eighteen passengers and three crewmembers were killed and the aircraft was destroyed by impact and fire. The crash occurred when one of the main rotor blades separated from the main rotor. The failure was caused by a single fatigue crack in the spindle that originated in an area of substandard hardness and inadequate shot peening (1).

> On December 8th, 2002, during take-off, a Boeing 767 experienced failure of the left engine. An emergency was declared and the aircraft returned to the airport, without further incident. An investigation determined that the Stage 1 high pressure turbine disk had undergone repair work in 1998 to remove nicks and other damage. The repaired area required shot peening to match the original condition of the part. An errant shot peening process produced peened surface extrusion folds (PSEF), a detrimental over-peening effect, which reduced the fatigue life of the part and caused fatigue cracking (2).

> On July 4th, 1999, a Fokker 100 experienced severe vibration subsequent to landing and during taxi. Three months later, on October 9th, 1999, the same aircraft suffered another severe vibration, this one occurred throughout the airframe and caused substantial damage. None of the 84 passengers or crew members were injured.

> In May of 2001, a similar incident involving another Fokker 100 occurred at Dallas-Ft. Worth International Airport, and an investigation was performed. During previous overhaul work of the landing gear, repair work had been performed to remove scoring from the hub. The technical report stated that comparison of the repaired area and the original surface revealed a "markedly different" intensity in the shot peening of each area. The intensity in the repaired area was lower than that of the original, thereby reducing the fatigue resistance and leading to fatigue cracking of the component (3).

In each of these cases, the failed component was in a critical application in which human life and limb were endangered, and in the S-61L helicopter crash, lives were lost. There are likely other unreported cases. I did not research automotive accidents involving faulty shot peening leading to death or injury, but I would not be surprised if they existed.

Aren't all shot peened components critical? Isn't every shot peen process critical? If you are involved in the shot

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peening of components, you can bet it's critical and someone is banking on it being done properly. Hopefully, you will be asked questions regarding your shot peen process during an audit, or a pre-audit, instead of at a deposition.

There are many peening shops that have gone to great lengths to get their processes up to the standards imposed by Nadcap, and our hats are off to them. They have achieved certification through Nadcap and have reaped the rewards of increased business and the satisfaction of a job done well and correctly. Through their efforts, and the efforts of manufacturers and vendors of peening equipment, the visibility of the shot peening process and its benefits has increased over the last few decades.

So, if your shop is not up to standards, how do you get there? How do you reach the peak of the Nadcap standard? As they say in football, the best offense is a good defense. I would recommend you begin with an internal audit; collect all of the information, specifications, equipment literature, written procedures, artisan training process, etc., that you have in your shop. All of this data can be used to baseline the current state of your peening procedures. The baseline will indicate areas that are satisfactory and those that are deficient.

The next step would be to contact an unbiased third party to visit your shop for a few days and perform a pre-audit service. The inspector will perform an in-depth examination of your shop, equipment, artisans, and processes (all while wearing a smile!). When finished, you will receive a written report of all findings and a list of recommended actions. The length of this list will depend on the state of your peening process. After a period of time, the inspector will make a follow-up visit to insure compliance and to provide further guidance. At this point, your shop should be prepared for a Nadcap audit, and certification.

Happy peening!

(1) NTSB Aircraft Accident Report, File 1-0016, Dated August 27th, 1969

(2) Aviation Safety Network, Boeing 767-219ER ZK-NBC, Dated December 8th, 2002

(3) Aviation Mechanics Bulletin, September – October 2001, Vol. 49 No. 5

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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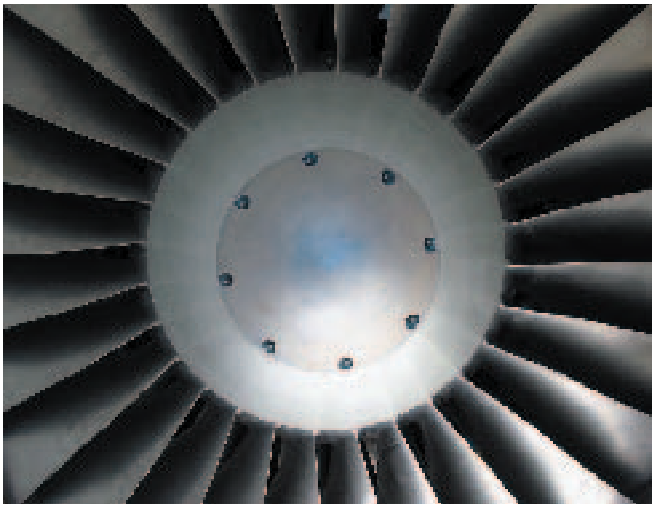
DuPont, MER to Develop New Titanium Metal Powder Process



How would a new titanium metal powder process affect the shot peening and aerospace industry?

The shot peening and aerospace industries should be watching with interest the attempt to create a new titanium metal powder process. According to a news release from Manufacturing.net, Dupont and MER Corp. have been awarded $5.7 million by the the U.S. Defense Advanced Research Projects Agency (DARPA) to develop a new inexpensive, energy-efficient process for making titanium metal powder.

The powder, under heat and pressure, will be used to create strong, lightweight items ranging from armor plating to components for the aerospace, transportation and chemical processing industries.

DuPont will supply the titanium dioxide as raw material and be involved in the design and development of a significantly sized-system. MER Corp., a materials and process development company, is to provide the core technology for converting titanium dioxide to titanium metal, and will conduct experimental work and build and operate the scaled-up system.

DuPont and its customers will fabricate aerospace and other parts to demonstrate the inherent quality of the material produced. Depending on the success of the two-year project, DuPont will develop systems to integrate the overall process and the possible development of large-scale commercialization.

It is expected that the new process will consume less than half of the energy of the conventional 50-year-old process traditionally used to convert titanium ore to titanium metal.

The new process will produce a titanium metal powder that can be directly formed into desired shapes, allowing manufacturers to make parts faster, with less machining and significantly less scrap.

Since commercialization of a titanium metal powder has not been successful in the past, the success of this project has big implications—if the new process can make enough titanium to affect the market. Since cast titanium parts will need to be blast cleaned like any foundry product and shot peened for life enhancement, titanium products made from this process should have a positive impact on our industry.

Covering the Basics: Intensity & Coverage

by Jack Champaigne

During an on-site training program, the Electronics Inc. training staff is available to answer questions and address problems. While some problems are unique to each facility, we find that both new and experienced personnel in shot peening are often challenged by the concept of appropriate peening coverage, and the confusion is often related to the saturation curve.

> *Shot peening personnal often confuse Almen strip saturation time with the time needed to fully dent (i.e., cover) the actual part.*

In the beginning, the relationship of peening time to Almen strip saturation time actually had merit. This is because the Almen strip material was based upon the item being peened, namely automotive valve springs of AISI 1070 cold drawn steel. J.O. Almen, the General Motors engineer that pioneered the research and development of modern shot peening in the U.S., designed a process control for this new technology of "shot blasting for fatigue life improvement". Using a small strip of flat steel of the same properties of the valve spring seemed like a good approach. Peening the test coupon caused it to bend in proportion to the shot stream energy and that was exactly what Almen was seeking.

With exposure, the test strip would undergo increased bending deflection until it was fully dented and then it was said to be "saturated", meaning additional exposure resulted in only a marginal increase in curvature. The measurement of the amount of curvature at saturation was then declared to be the peening intensity. The valve springs, being made from the same material with similar hardness, would exhibit a similar coverage rate with exposure as the test strip. It was therefore easy to describe the exposure time: it was the time needed for the saturation curve (i.e., strip arc height versus exposure time) to "flatten out".

The SAE technique in 1952 (Figure 1) was somewhat vague when it states in #5:

> "The gage reading corresponding with the point A where the curve flattens out is generally taken as the measurement of the intensity of that particular peening. In some cases, this point is difficult to pick out and requires some judgment."

SAE offered additional guidance in the 1961 revision of J443 when they added #6:

> "When the machine settings are found that yield the desired arc height, the time of exposure of the part is also indicated." Unfortunately this would lead to problems when it was later realized that parts of different hardness needed exposure times, both different from and unrelated to the Almen strip saturation. So, now there were two significant challenges: "some judgment" to determine intensity and further judgment as to part exposure time as linked to Almen strip saturation time.

Finally, in 1984, SAE adopted a mathematical approach to determining intensity from the saturation curve where they stated "Saturation has been attained when the "knee" of the curve is passed and increasingly longer periods of peening time are required for a measurable increase in test strip arc height. The location of the knee, point A shown in Figure 2 (next page), can be defined as that point on the curve beyond

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Figure 1

Procedures for Using Standard Shot-Peening Test Strip

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved January 1952.

The test strip A is used for arc height up to 0.024 A. (See arc-height designation given in SAE Standard Test Strip, Holder, and Gage for Shot Peening.) For greater degrees of peening, the C test strip is used.

Procedure Based on Arc-Height Exposure Time Relationship

General—1. Fasten the strip A or C tightly and centrally to the test-strip holder.

2. Expose the surface X (Fig. 2 of SAE Standard Test Strip, Holder, and Gage for Shot Peening) of the strip to the blast to be measured. Record the time of exposure or its equivalent.

3. Remove the strip from the holder and measure the arc height on the gage. The zero position of the gage must be frequently checked and, if necessary, adjusted.

4. Using different exposure times, repeat Steps 1, 2, and 3 sufficiently to determine a curve similar to Fig. 1.

5. The gage reading corresponding with the point A where the curve flattens out is generally taken as the measurement of the intensity of that particular peening. In some cases, this point is difficult to pick out and requires some judgment.

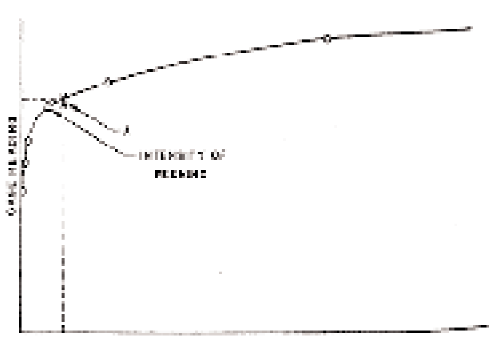

Fig. 1—Intensity Determination Curve

Production Setup Procedure—Blast Measurement—The procedure to be used in making a production setup in which a setting

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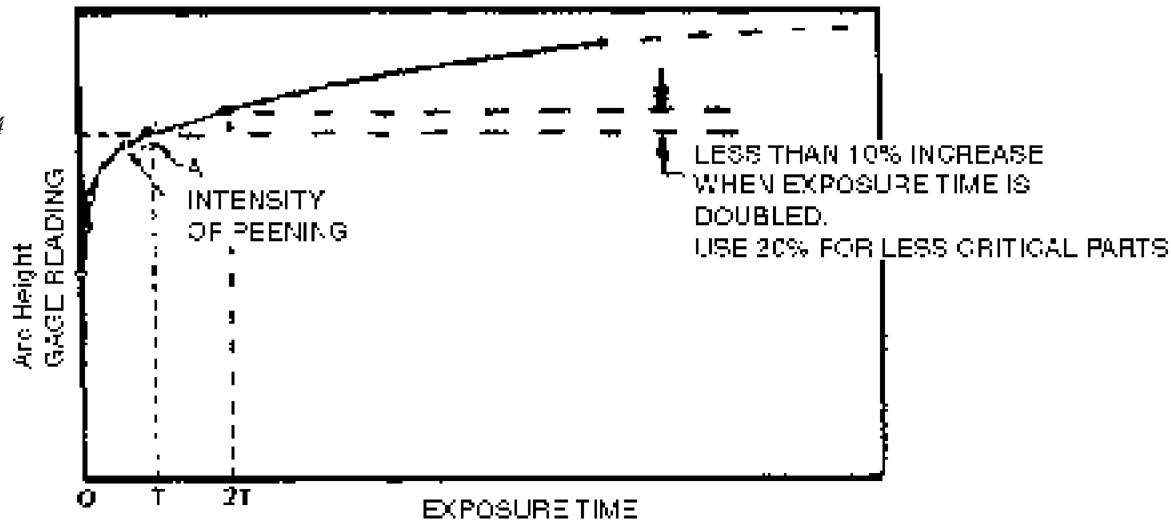
Figure 2
Source:
SAE J443, 1984



which the arc height does not increase more than "X" percent when the peening time is doubled. An arc height increase of 20% for doubled peening time may be adequate for some applications. An increase of 10% for doubled peening time defines the knee for critical applications."

Then, for the first time, SAE suggested that "If part hardness is appreciably different from the 44 to 50 Rockwell C hardness of the test strips, the time required to "saturate" the part also varies from that required to saturate the Almen strip. For instance, a hard carburized part will require more time to reach full visible coverage, while a softer part will require less time than the test strip. So, we have now addressed the two significant challenges posed earlier.

To further elaborate on the differences between intensity and coverage, SAE purged reference to coverage from J443 and then published J2277 "Shot Peening Coverage" as a separate document. (See "From SAE J2277" inset below.)

In the next issue of The Shot Peener, we willl explore the method of intensity determination and introduce the "Curve Solver" routine developed by Dr. David Kirk, past chairman of The International Scientific Committee on Shot Peening. Later, we will explore methods of determining coverage using graphical analysis, PeenTrace pens from Metal Improvement Company and coverage test strips.

From SAE J2277:

3. Coverage-Coverage is defined as the percentage of a surface that has been impacted by peening media. The minimum peening time required to obtain 100% coverage is determined by gradually increasing total peening time until the entire surface being peened exhibits overlapping dimpling. Coverages above 100% are multiples of the exposure time required to achieve 100% coverage.

3.1 Variation in Coverage of Part Versus Test Strip (SAE J443) – Peening time to reach full coverage on parts should not be associated with the times referenced in SAE J443 for determining shot peening intensity/saturation because of the parts' varied shapes and hardness. When all other factors are unchanged, soft surfaces typically require less peening time to achieve 100% coverage than hard surfaces since the size of each impression in soft surfaces is larger.

Jack Champaigne is Editor of *The Shot Peener* and President of Electronics Inc. (EI) Mr. Champaigne is an instructor for the EI shot peening workshops and on-site training programs. He also developed and oversees the online forums for the www.shotpeener.com web site.

Shot Peening Techniques for Springs

by Kumar Balan

A flat piece of leaf spring has, since the days of the black smith, received continued impacts of the hammer long after cooling down in temperature. Though the blacksmith didn't always realize the effects of his actions, it is now known that the life of this leaf spring is enhanced by upwards of 600% by such an action!

The same applies for Coil/Helical Springs and Torsion Bars, with different life enhancements. Various other automotive and aerospace parts such as Connecting Rods, Crank Shafts, Rocker Arms, Ring and Pinion Gears, Jet Engine Blades, Landing Gears, Transmission Shafts are regularly shot peened as part of their production processes.

So, what happens when a part is shot peened?

Mechanism and Effects of Shot Peening

When a part is pelted/bombarded with a stream of round metallic media (referred to as shot), each shot dents the surface of the part that it impacts.

Impingement of metallic media (shot or cut wire) causes plastic deformation on the part surface. This extends the superficial layer creating compressive stresses underneath and providing a balance to the applied working (tensile) stresses. This residual compressive stress delays the formation of fatigue cracks thereby increasing the useful life of a component.

Shot peening is a "cold working" process and is different from metal flow at high temperatures, even though there is a momentary increase in temperature of the surface being peened.

The layer of compressive stress commonly extends to depths varying from 0.005" to 0.030". Greater depths, if desired, are achieved by altering process parameters such as shot size, velocity of impingement, angle of impingement, exposure time etc.

The two commonly used parameters to gauge the effect of peening are intensity and coverage. Where coverage (100%, 200% or higher) is purely a visual check, intensity is measured by deflection of a representative strip of spring steel (commonly called the Almen Strip).

Intensity Measurements

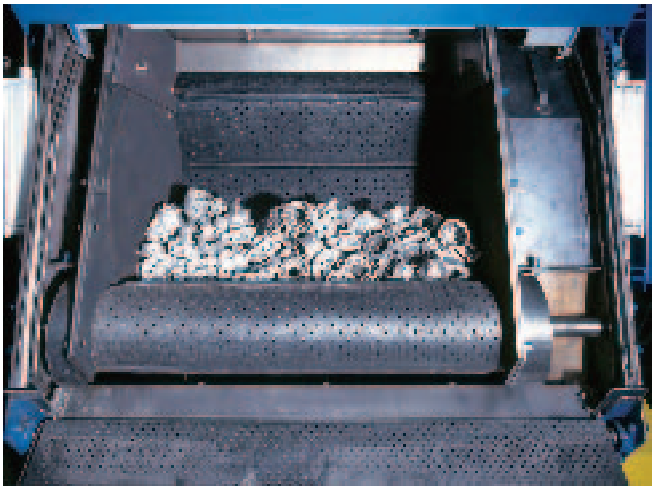
Part Verification Tools (PVT), are designed to hold test Almen strips in strategic locations on the actual or simulated part. Test strips in these locations simulate areas of the part where intensity requirements and therefore measurements are critical.

Intensity ranges could be anywhere from 0.010" to 0.015" on the 'A' scale, depending on the application. Coverage requirements could range from 100% to 200%. The above results are commonly achieved by processing the parts through a centrifugal wheel style blast machine.

Though pressure blast nozzle style systems have been used in the past, they do not render themselves effective when faced with high production rates as are seen in leaf spring and coil spring production lines. A centrifugal blast wheel on an average propels about 10 times the amount of blast media when compared to a blast nozzle, thereby covering larger areas and saturating them at a much faster rate.

Peening Machine Types

The type of peening machine is dictated by the part being peened and production rates.



Batch Style Peening

- Leaf Springs are processed inline on a continuous chain conveyor with multiple blast wheels targeting the part from the top and both sides
- Coil Springs are processed inline on a continuous chain conveyor with fingers that 'push' the spring through. Spinner rollers provided inside the blast chamber spin the coil spring when being blasted. Multiple blast wheels are used for peening
- Relatively smaller size springs, used for engine valves etc. are treated in bulk and peened in a Tumblast style machine
- Torsion bars are also peened in the inline configuration

Process Variables

Regardless of the peening technique or machine type used, achieving the intensity targets in a repeatable and consistent fashion is the primary goal of any operation. It is therefore important to understand the critical variables that alter the final results in a peening process. They are:

- Blast wheel type
- Wheel Horse Power
- Wheel speed
- Blast angle
    - Wheel positioning
    - Control Cage movement

Each of the above process variables influences the final result as follows:

The diameter of the blast wheel determines the tangential velocity of the blast media. In direct proportion, a 17.5" diameter wheel generates a greater shot velocity and therefore higher peening intensity than a 14" diameter wheel at the same speed.

Horse Power of the wheel simply determines the amount of media propelled, thereby affecting processing time.

Wheel size works in conjunction with the wheel speed (π x D x N) to achieve the desired velocity and thereby the intensity. Wheelblast peening machines can be equipped with variable frequency drives to vary the wheel speed and therefore the velocity.

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Blast wheels are always mounted in a permanent and rigid location in the blast cabinet. However, blast pattern alterations, if required, are achievable by altering the control cage settings. The control cage location determines the exact point of blast media discharge from the blast wheel.

Other process variables affecting peening results include:

- Media flow rate
- Size of media
- Consistency of size

Media flow rate is controlled using a commercially available flow control valve (MagnaValve – manufactured by Electronics Inc. – is a widely used valve in the industry). MagnaValves are provided at the feed side of the blast wheel, usually at the outlet of the media storage hopper.

Vibratory Classifier classifies the peening media into oversize, right and undersize/fines. A combination of two sieves ensures that consistent size of peening media is available for every cycle.

Size of peening media plays an important role in determining coverage and peening cycle time. As a rule, (a) smaller size of shot allows higher stress on immediate surfaces, and (b) larger sized shot provides stress in material depths.

Leaf Spring Peening

Leaf Springs are individually processed in an inline style peening machine with the concave geometry of the spring exposed to the blast wheel. A typical Leaf Spring Peening Machine consists of a single blast wheel from the top and one blast wheel on either side to process the sides of the spring simultaneously.

Line speeds in excess of 10 feet per minute are achieved in an inline Leaf Spring Peening Machine. Where higher line speeds are desired, the blast machine is equipped with greater number of blast wheels with higher HPs.

Under working conditions, leaf springs are repeatedly subjected to unidirectional bending stresses and are therefore sometimes stress peened. During 'Stress Peening', the spring is loaded or 'statically stressed' in the same direction as the working stress anticipated during service of this spring. On completion of peening, the static stress is released. It has been proven that 'stress peening' further enhances the working life of a leaf spring over the conventional peening process.

Leaf Springs are peened with metallic peening media in a centrifugal wheel blast machine.

Coil Spring Peening

Coil Springs, due to their helical geometry, present a slightly challenging situation than simply blasting flat surfaces as in case of leaf springs. Further, it is important to assess the effect peening has had in the cross-section of a coil in order to fully understand its resistance to fatigue cracking.

Individual springs are transported by means of an inline conveyor into the blast zone. The blast zone is equipped with a set of parallel rollers that rotate the spring when peening. Rotation of the spring in the blast zone facilitates the blast stream to pass between the coils in order to hit the inside surface of the wire where the highest stress is located under service loading.

For Coil Spring production lines with high production volumes, peening machines that peen two springs simultaneously have also been developed.

Developments are underway to determine whether supplementary blast nozzles can be used to target specific areas of the wire geometry in order to address locations of high work stress concentrations.

Peening Torsion Bars

Torsion bars are peened in the inline orientation by conveying individual bars on a skew roll conveyor.

A single wheel with a variable frequency drive (to alter wheel speed and thereby the velocity) is used to peen the bar as it spins and moves along its length.

Valve Springs

Smaller springs (typically used in engine valves etc) are processed in batches in a Tumblast style machine. Verification of peening intensity is carried out by tumbling an Almen block with an Almen strip along with the batch of parts being processed.

Advancements in Spring Peening Equipment

The requirement of consistency and repeatability of peening results cannot be stressed enough. Process checks are built into the equipment with features/components such as the vibratory classifiers for maintenance of consistent media size, variable speed drive for blast wheels to maintain shot velocity, and speed control for work conveyors to alter exposure time.

In situations where such process parameters have to be monitored and displayed, 'real-time' peening equipment controls have evolved to sophistication.

TouchScreen or PC based operator interface units have now replaced multitude of push buttons and indicator lights. Control systems not only display various process parameters in real-time, but also permit the operator to create 'recipes/techniques' containing relevant process parameters.

Such recipes identified by their unique part number can be stored and retrieved for use at a later date.

In order to assist maintenance personnel with troubleshooting the machine during times of breakdown, control systems now provide a map of all inputs and outputs in the machine along with their individual status. This helps isolate the location of the problem and thereby leading to faster correction.

Modern controls systems also recognize the need for security and permit up to four levels of the same. Systems Administrator, Engineer, Maintenance personnel and finally the Operator all have different accesses to the machine controls.

In summary

Spring peening has evolved over the years into a monitored and controlled operation. Modern day spring peening equipment suppliers recognize the need for repeatability, consistency and quality of operation and design equipment to offer such exacting features as found in other precision production equipment.

Evolution of this technology has not been restricted to the mechanical aspects of equipment alone. Trials are underway to study the effects of supplementary blast techniques to enhance the effectiveness of the peening operation. Also gaining prominence is the sophistication of controls systems to monitor, display and report on the entire peening operation thereby providing trailing evidence about various operating parameters.

Kumar Balan is a Product Engineer with Wheelabrator Group Equipment/Process Design & Specification Conformance.

The Tenth International Conference on Shot Peening

Tokyo, Japan
September 15 - 18, 2008

Important Dates:

July 31, 2007	Deadline for Abstracts
January 31, 2008	Deadline for submission of Manuscript
July 31, 2008	Deadline for Registration

Conference Chairman:
Prof. Katsuji Tosha (Meiji University)

Conference Secretary:
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Submission of Abstracts:
Deadline, 31, July, 2007
Both oral (15+5 mins) and poster presentations are welcome. Those wishing to present a paper should submit abstracts, preferably in electornic format, as an e-mail attachment to icsp10@isc.meiji.ac.jp The abstract should not exceed one type-written page of about 1,500 characters. Please use standard symbols and abbreviations only.

Proceedings:
Deadline for submission of manuscript, 31, January, 2008. Papers presented will be published in the Proceedings and will be available at the Conference if the paper is accepted by the ISCSP. Manuscript generally should not exceed 6 pages. Authors who are present at the Conference for either oral or poster presentations and wish to publish their papers in the Proceedings are welcome to submit an abstract.

Conference Language: English

Registration fee (estimated):
JPY 80,000, including administrative costs, Proceedings, lunches, break refreshments, welcome party, banquet, and plant tour.

Plant Tour:
16, Sept., 2008 at NHK Spring or Nissan Motor

Exhibition:
There will be an exhibition of products and services related to the topics of the Conference. Companies and organizations will have an opportunity to exhibit their products on the appropriation floor. For more information, please contact conference secretary.

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Manual Versus Automated?

Sample Processing Provides the Answer by Herb Tobben

Many customers ask what criteria I use to determine if an application could benefit from sample processing. Customers surprise me all the time with unique applications, but a few common characteristics usually indicate a need for sample processing.

Any blast equipment Distributor worth his ALOX has a manual cabinet set up for basic sample processing. This first-line sample processing demonstrates that manual blasting can safely clean or finish a part.

For automation applications, most Distributors send sample parts to the ZERO lab in Washington, Missouri, for evaluation and processing. ZERO's sample processing technicians test blast or shot peen these representative parts, while modifying the variables. These variables include:

- suction or pressure blasting
- type, number, and size of nozzles or guns
- position of nozzles or guns (distance, angle, spacing)
- blast pressure
- dwell
- nozzle oscillation speed
- part movement
- media composition and size

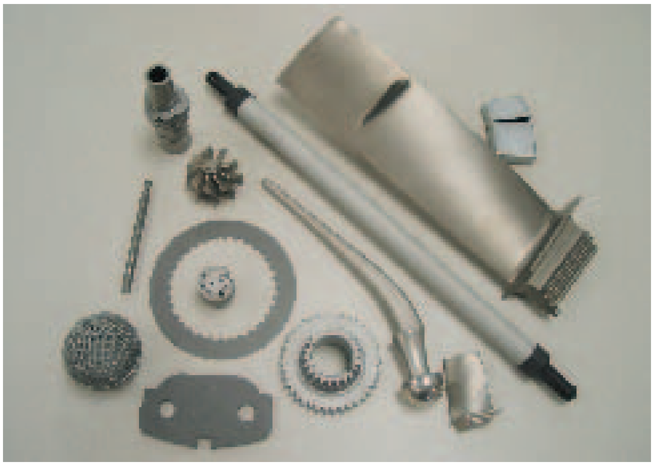
ZERO's technicians maintain painstaking records of each process run, and mark each part. These parts are returned, along with the test results, so the customer can make an informed decision.

The goal of sample processing—design an automated system to get the desired finish, consistently, and economically.
The simplest automation applications take parts of relatively consistent size, shape and condition, and apply a predetermined process to produce nearly identical results over a long production run. With the help of quick-change fixtures and programmable controllers, however, ZERO can build machines to handle an assortment of parts over short or long productions runs.

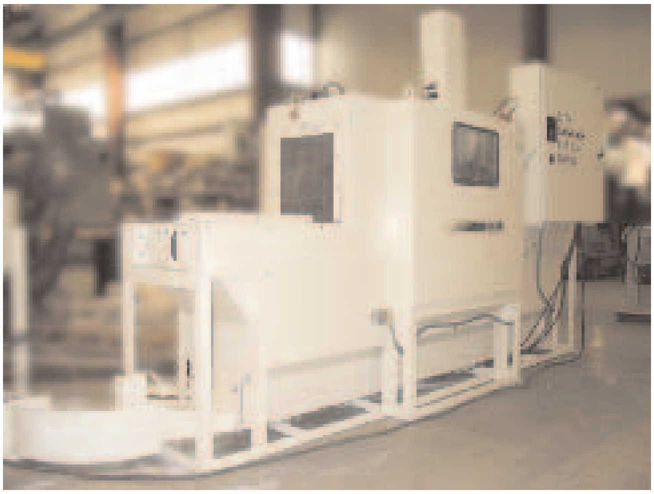
So how do you know if automated blast cleaning will help you? If you have one or more of the following, call your Distributor today.

- Two or more employees spend more than half of each day cleaning parts. (Automation, though expensive, will quickly return its investment by saving labor, speeding production, and reducing rework.)
- Surface preparation - chemical processes, hand sanding, or manual blasting - has become a bottleneck in your production line.
- Your current process takes too long. Or, drying the parts after chemical processing takes too long.
- Your surface preparation involves toxic chemicals. (When your factor in the health and safety issues, environmental compliance requirements, and disposal costs for chemicals, an automated blast system can usually pay for itself in less than a year.
- Your current process produces inconsistent results or causes excessive rework. This is especially true for shot peening, where verifiable and repeatable results are critical to part performance.
- In the past year, you have worn out a manual blast cabinet or have spent more than half the cost of a new manual cabinet keeping your old one running.
- In the past year, you have worn out one or more employees who prep parts.
- You, your mother, your brother, and your children have grown tired of working night and weekends hand prepping parts for the next day's production runs.

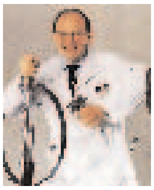
Ask your Distributor to help you evaluate your current process. He or she can arrange free sample processing in the ZERO lab and provide a firm quotation on the equipment you need.



Automated applications



Typical straight line conveyor machine



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.

2006 Shot Peeners of the Year

Congratulations to **Kumar Balan** and **Dr. John Cammett**, our 2006 Shot Peeners of the Year. Mr. Balan was chosen for his considerable training and presentation skills, his thorough understanding of the shot peening process, his facilitation of compliance to specifications and audit criteria through equipment design, and his promotion of the benefits of shot peening by contributing articles to publications including *The Shot Peener* and *Gear Product News*. Mr. Balan is bringing a new level of enthusiasm and energy to our industry.

Dr. John Cammett is one EI's favorite workshop and on-site training presenters. Students enjoy his humorous anecdotes and real-life experiences—his ability to share his expertise in such a enjoyable format is one of the reasons he was elected as a Shot Peener of the Year. Dr. Cammett is one of the greatest minds in the industry and he has been a tremendous asset in the private sector and the military.

Mr. Balan and Dr. Cammett have the rare ability to share their industrial experience with others through teaching, training and writing. The awards were presented at the Shot Peening Workshop and trade show in Indianapolis. The following biographies highlight the accomplishments of these two important contributors to shot peening.

Kumar Balan is employed by the Wheelabrator Group, Burlington, Ontario in Applications, Sales and Marketing. Kumar has a Master of Business Administration degree from York University, Toronto and a Bachelor of Mechanical Engineering, from India. Kumar's initial employment with Wheelabrator Corporation was in 1990 in Bombay, India, where he worked as a Design and Applications Engineer. Kumar directed a team of six engineers at the Wheelabrator Corp. for 'concept to commissioning' of Asia's first automated Rail Car Shot Blasting Plant for the Indian Railways. Kumar has also been employed by the Pangborn Corporation, India as an Applications Manager where he was also responsible for technology transfer. During 1995-2000, Kumar worked for Blastworks Inc., a Canadian company that specialized in Automated Airblast Machinery. After a detour in Industrial Automation relating to robotic material handling systems and CNC Fabrication machinery, in July of 2004 Kumar returned to the Wheelabrator Group in Burlington, Ontario where he now handles Applications, Sales and Marketing of Automated Airblast equipment to the North American market.

Dr. John Cammett has served a total of thirteen years at the Naval Aviation Depot in Cherry Point, NC., and is currently Metals and Ceramics Branch Chief in the Materials Engineering Division. In addition to managerial responsibilities, Dr. Cammett's technical activities with the Navy currently include: Analysis of aircraft component failures, development of repair/rework process methods and technical support of depot manufacturing operations. He is also involved in manufacturing technology investigations to determine feasibility for application to depot activities. Stemming from long time interest and involvement in machining and surface finishing/processing technology, Dr. Cammett is a consultant to and serves as workshop instructor for Electronics, Inc. in the area of shot peening. In a recent sabbatical hiatus from employment with the Navy, he worked with Lambda Research, Inc. on research and development of low plasticity burnishing. Dr. Cammett was employed for 20 years with Metcut Research Associates in fatigue, fracture mechanics, residual stress measurement, metallurgical research and failure analysis. He worked five years at the General Electric Company specializing in fatigue, low cycle fatigue and fracture mechanics properties of aircraft engine materials. He received his BS and MS in Metallurgical Engineering from Ohio State University and his PhD in Metallurgical Engineering from the University of Cincinnati. A Registered Professional Engineer, Dr. Cammett is a fellow of ASTM, past Chairman of Committee E-9 on Fatigue, past Chairman and life member of ASM International and member of the International Committee for Shot Peening.

Dr. John Cammett and Jack Champaigne

Generation of Air-Blast Shot Velocity

by David Kirk

Introduction

Air-blast shot peening is well-established as the principal technique employed for precision peening. Shot particles are accelerated by a stream of compressed air fed into a nozzle. The maximum velocity of the air stream in the nozzle is the speed of sound, which is about 340ms^{-1} at 20˚C. Particles can be introduced into the air stream by any one of three techniques: suction-, gravity- or direct-feeding. Induced shot velocities are normally up to about 100ms^{-1}.

Shot velocity dominates its kinetic energy, ½mv^2, which in turn dominates peening intensity. Effective peening therefore requires that we control, amongst other things, the velocity of the shot particles. That control depends upon regulating the several factors that affect the shot velocity. Air streams and induced particle velocities are aspects of fluid dynamics and ballistics. Rows of textbooks in university libraries bear silent witness to the complexities of those subjects! We have a practical need, however, to consider, quantitatively, the factors that affect the generation of shot velocity.

The generation of air-blast shot velocity is considered in three stages:

1 - Air stream,
2 - Introduction of shot into the air stream and
3 - Acceleration of the shot particles by the air stream.

A general equation is presented that can be used to predict the effects of size, shape, density and nozzle air pressure on shot velocity.

1 AIR STREAM

1.1 Compressed air

Our primary need is to have an adequate supply of compressed air. Nozzle manufacturers publish tables of the compressor capacity requirements for nozzles of different diameters. These give information about the rate at which air has to be compressed in order to maintain a stated range of nozzle pressures. Unfortunately the rate is often quoted using an ambiguous unit – such as "CFM". Industrial examples of unambiguous units are "SCFM" – Standard Cubic Feet per Minute – which is the flow of air corrected to 'standard' conditions - such as 1.0 atm (14.7 psi), 20˚C and 36% humidity - and "ACFM" which means Actual Cubic Feet per Minute – being the actual volume of compressed air put into a pipe per minute, regardless of its compression ratio. As an example: if a compressor takes in 100 CFM of air at 1 atm and compresses it to 5 atm then we have 100 SCFM input and 20 ACFM output.

Pressure gages normally indicate 'relative (to atmospheric)' rather than 'absolute' pressures. That means that without any compression we would have a zero reading. The compression ratio, CR, is given by: CR = (1 + P) to 1 where P is the 'relative' gage reading in atmospheres.

Air at atmospheric pressure has a density of about 1.2kgm^{-3}. If we compress it by applying an outside additional pressure of one atmosphere (14.7 psi) we halve its volume (P = 1 so that CR = 2) and thereby double its density. At a typical peening pressure of seven atmospheres (100 psi) we have multiplied its density by a factor of eight. In general, air density = CR times 1.2kgm^{-3}. It is this 'heavy air' that we force through air supply pipes. Fig.1 illustrates 'heavy air' production.

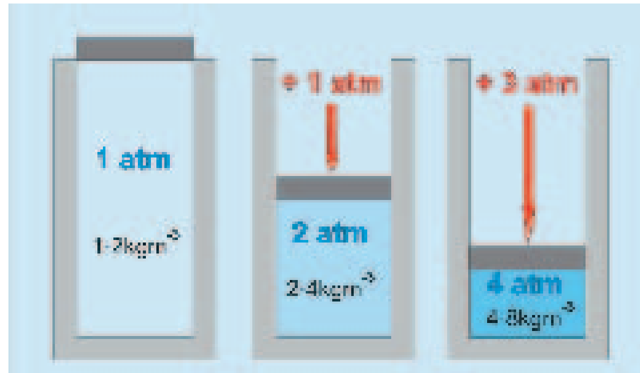


Fig.1 External compression producing 'heavy air'.

1.2 Pipe flow

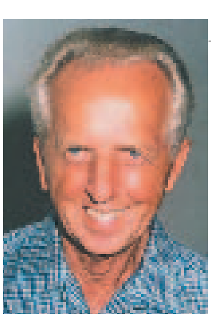
The outlet from an air compressor goes into a ballast tank and thence to an air supply pipe, preferably via a drying unit. The compressed air flows as a stream through the pipe. This can then be connected to a shot feed and nozzle system. Ballast tanks even out pressure fluctuations from the compressor and provide a reservoir of compressed air. One or more pressure control valves, **PCV**, will be present in the air supply line. The compressed air, at a pressure, $\mathbf{p_1}$, is fed into a blast hose of length L, at the other end of which is a nozzle where the pressure will then be $\mathbf{p_2}$, see fig.2.

Fig.2 Schematic representation of air stream component elements, not to scale.

Pressure control valves are our primary control mechanism. As we increase the pressure we expect that the air flow rate through the hose will also increase. An important practical consideration is the capacity rating of the air compressor system. The air compressor must be capable of pumping air into the ballast tank faster than we are taking it out. A simple analogy is an auto's alternator/battery system. If the battery output is continually greater than the alternator's input then we end up with a flat battery!

A useful analogy when considering air flow rates is that of electricity. Just as we need a potential difference between the ends of a wire for electricity to flow so we need a pressure difference between the ends of a pipe for air to flow. For example, $(p_1 – p_2)$ is the pressure difference between the ends of the air supply pipe which induces a corresponding air flow rate, **Q**, through that pipe. $(p_1 – p_2)$ is useful as a process control parameter. Changes in $(p_1 – p_2)$ can be either abrupt or gradual. For example if $(p_1 – p_2) = p_1$ we have a burst pipe! If $(p_1 – p_2)$ approaches zero then the pipe has become blocked with shot at the nozzle. A common example of gradual change is that caused by nozzle wear. As the nozzle diameter increases $(p_1 – p_2)$ increases (assuming that p_1 is maintained at a constant value – which is normal industrial practice).

It is worth noting that the pressure drop $(p_1 – p_2)$ also represents 'wasted energy'. The work, W, being done in pushing air at a constant rate through the air supply pipe is given by **W = p.V** where V is a given volume of air. The 'useful energy' is that being used at the nozzle end of the pipe, p_2.V. The 'wasted energy' is therefore $(p_1 – p_2)$.V.



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.

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GENERATION OF AIR-BLAST SHOT VELOCITY

Continued from page 24

It follows that we can save energy by reducing ($p_1 - p_2$). To a first approximation energy loss increases linearly with pipe length, **L**. Excessive pipe lengths should therefore be avoided. A far more important factor is the internal diameter, **D**, of the supply pipe. The pressure drop for a given flow rate is inversely proportional to D^4 (very approximately). Doubling the pipe diameter will reduce ($p_1 - p_2$) by a factor of about sixteen whereas halving the length only halves the pressure drop.

1.3 Nozzle flow

Our second requirement is to accelerate the air stream at the nozzle. One mechanism for fluid velocity increase is very familiar. A garden hosepipe has low-velocity water flowing through it until it reaches a nozzle. If that nozzle has a cross-sectional area that is a quarter of the cross-section of the hose then the velocity of water would, normally, be increased four-fold at the nozzle. We can apply the same principle to air stream acceleration, up to a certain critical velocity – the speed of sound. Fig.3 illustrates the basic geometry that is involved.

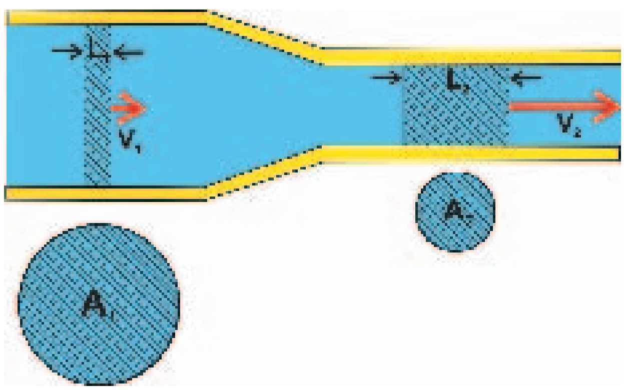

Fig. 3. Velocity change as air in supply pipe reaches nozzle.

Consider an imaginary cylinder of air, shown in fig.3, having a volume $A_1.L_1$ and travelling at a velocity v_1. When this cylinder reaches the nozzle it has the same volume (assuming no density change) but different dimensions, A_2 and L_2 and now has a velocity v_2. Now since $A_1.L_1 = A_2.L_2$ it follows that v_2, must then be A_1/A_2 times greater than v_1. In general: $v_2 = v_1.A_1/A_2$. Now since $v_1.A_1 = Q$ we have the important relationship that:

$$v_2 = Q/A_2 \qquad (1)$$

Using Q as 10 litres per second and a nozzle cross-sectional area of 40mm^2, equation (1) gives us v_2 as 250ms^{-1}. That value is for the average velocity across the nozzle section. In practice the velocity varies across the section.

Equation (1) only applies up to a limiting value of v_2. That is because practical nozzle air pressures are always high enough to produce what is termed “choked flow”. Fig.4 is a simplified schematic representation of how the nozzle air velocity changes with increase of nozzle air pressure (assuming that the nozzle vents to 1 atm pressure in a peening unit). A “sonic barrier” exists at the narrowest part of the nozzle, caused by the difference in pressure in the nozzle as compared with that in the peening unit. This barrier occurs when the air pressure difference is about 1.9 atm. Because all practical peening involves a pressure difference of more than 2 atm (29.4 psi) we have a fixed limited air velocity in the nozzle - regardless of nozzle pressure and nozzle diameter. The only proviso is that an adequate supply of compressed air is maintained.

The constancy of air velocity in the nozzle begs the question: “What effect does air pressure have if it does not affect air velocity?” The answer is that at higher pressures the air is more compressed so that it has a greater density - but has the same velocity. Increasing the nozzle pressure increases the ‘mass flow’ of air. Alternatively we could say **“As we increase nozzle air pressure we are firing heavier air - but at a constant velocity”.**

The *average* ‘fixed limited’ nozzle air velocity depends on the nozzle design and can be inferred from ‘nozzle performance tables’ supplied by manufacturers. For one set of tables, the derived average

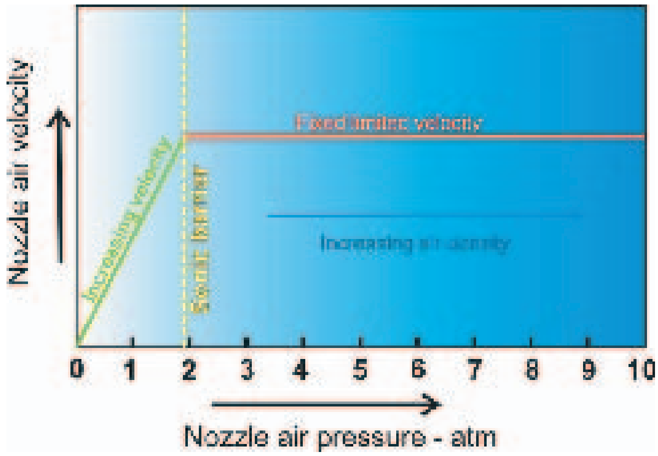

Fig. 4 Schematic representation of velocity variation with air pressure.

nozzle air velocity values were always 207±1 ms^{-1} (678±2 fps) regardless of nozzle pressure or diameter. Average nozzle air velocity estimation simply involves dividing the air flow by both the compression ratio (to give ACFM) and the nozzle cross-sectional area.

Table 1 shows specimen calculations obtained using an Excel spreadsheet and manufacturer’s data. The Excel columns are shown as A, B, C and D in the table and the “9” is simply the row number that was being used for entering values.

Table 1 Specimen Calculations of Average Air Velocity in Nozzle.

Nozzle pressure - atm (psi)	Compressor air flow - litres/s (scfm)	Nozzle diameter - mm (inch)	Average air velocity – m.s^{-1} * (feet/second)
6.8 (100)	204 (432.6)	12.7 (0.5)	206 (678)
3.4 (50)	115 (243.6)		206 (676)
6.8 (100)	51 (108.2)	6.35 (0.25)	206 (680)
3.4 (50)	29 (61.2)		208 (680)
A	B	C	D

* - =(B9*1000/((A9+1)*(3.142*C9^2/4)))

The air velocity across the nozzle varies from a maximum of 340 m.s^{-1} (speed of sound in air) to zero at the nozzle wall. An average value of 207 m.s^{-1} reflects this variation.

It is worth noting that in both pipes and blast nozzles we always have what is termed “turbulent flow” – as opposed to “streamline flow” – because the corresponding Reynolds’s numbers are very large. Turbulent flow is illustrated in fig.5. Air moves in three dimensions following sinuous pathlines but with an average forward velocity.

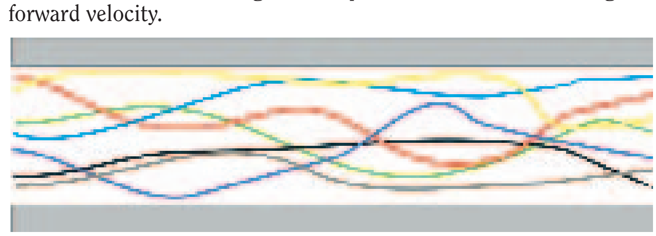

Fig. 5 Pathlines followed by air during turbulent flow through pipes or nozzles.

2 INTRODUCTION OF SHOT INTO THE AIR STREAM

The three common systems for introducing shot into the air stream are suction-, gravity- and direct-feeding.

2.1 Suction feed

This system is illustrated, schematically, in fig.6 on page 28.

Air is sucked up the shot feed tube at a velocity v_1 (which is much lower than the air blast velocity, v_2) hence the term “suction feed”. Because the velocity v_1 is less than v_2 the air pressure in the shot feed tube is higher than that in the nozzle. This phenomenon was explained by Bernoulli (hence “Bernoulli’s Principle”). If p_1 is the pressure in the shot feed tube and p_2 is the pressure in the nozzle then we have that:

$$(p_1 - p_2) = \tfrac{1}{2}.\rho_A.\ (v_2^2 - v_1^2) \qquad (2)$$

where ρ_A is the density of the air.

($v_2^2 - v_1^2$) is very large so that the predicted pressure difference ($p_1 - p_2$) must also be substantial.

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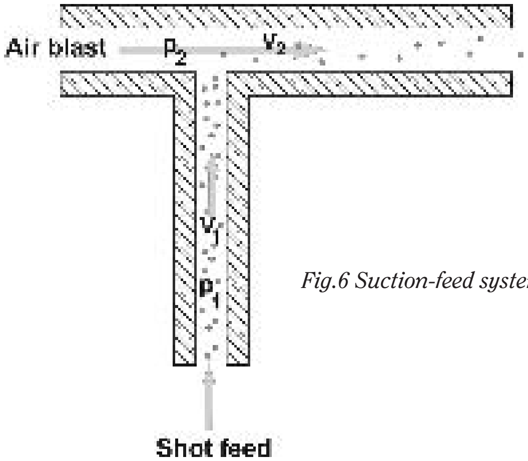

Fig.6 Suction-feed system.

The induced shot feed pipe velocity, v_1, is sufficient to drag shot particles into the nozzle. Turbulent air flow in the nozzle aids mixing of shot and air.

2.2 Gravity feed

Gravity feeding is very similar to suction feeding in that shot is introduced into, or close to, the nozzle. The difference is that the entry point is above the nozzle - so that we have a combination of gravitational and suction forces encouraging the shot particles to enter the nozzle. We would therefore expect that we can achieve higher shot feed rates than with suction feeding. Fig.7 is a schematic representation of a gravity feed nozzle. Shot is shown as entering at a 45° angle, which is found to facilitate air/shot mixing.

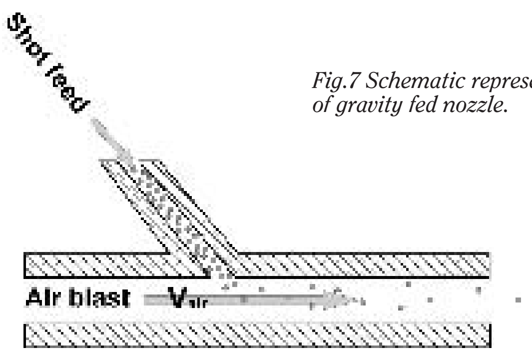

Fig.7 Schematic representation of gravity fed nozzle.

2.3 Direct feed

With direct fed systems, shot and air are mixed before entering the blast hose pipe. The mixture of shot and low velocity compressed air travel together before entering the nozzle. This system is illustrated schematically in fig.8. Turbulent air flow throughout the system aids uniform mixing of air and shot.

3 VELOCITY OF SHOT PARTICLES ACCELERATED BY AN AIR STREAM

3.1 Acceleration

Our fast-flowing air stream exerts a force on each shot particle that has been introduced. Acceleration occurs when we have an imbalance of forces. One form of Newton's Second Law is that "Force is equal to mass times acceleration" or:

$$F = m.a \qquad (3)$$

where **F** is the magnitude of the imbalanced force, **m** is mass and **a** is the consequent acceleration in the direction of **F**.

Fig.9 represents a model of the air/shot situation in a straight-bore nozzle. On the central axis we have the maximum air velocity with lower velocity as we move towards the bore surface. The average (mean) air velocity is that calculated in section 1.1, being about 200m.s^{-1} (656ft/sec) for a straight nozzle. Shot particles will move about in the nozzle bore, because the air flow is "turbulent". We can

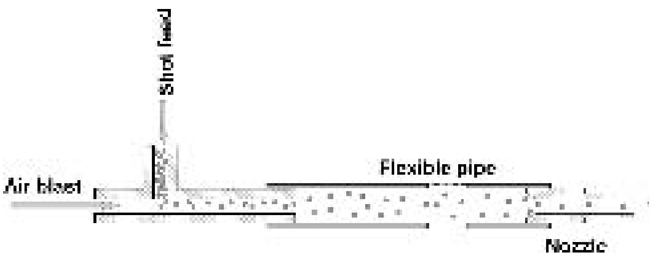

Fig.8 Direct feed system (not to scale).

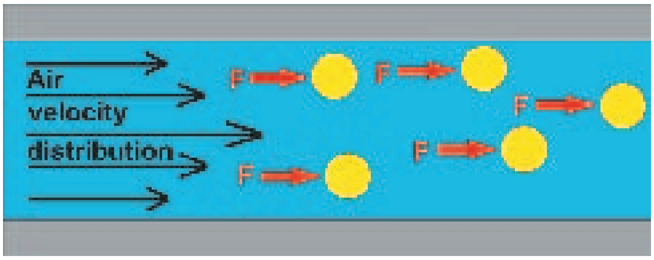

Fig.9 Model of air/shot situation in a straight-bore nozzle.

therefore assume that there is an average axial force, **F**, that is virtually the same for each particle.

With suction- and gravity-feed systems we have a limited distance, **s**, in which to accelerate the particles. Direct-feed gives us much more distance in which to generate shot velocity, v_s. The greatest acceleration will occur within the nozzle (where the air velocity is greatest).

If we assume that the acceleration remains constant then we have a simple relationship between the three parameters **a**, **s** and v_s:

$$v_s^2 = 2.a.s \qquad (4)$$

In order to increase the velocity we can either increase the acceleration or increase the length or both. Shot peening nozzles have a length of the order of 100mm so that the acceleration has to be very high in order to produce velocities in the region of 50m.s^{-1}. Substitution of 0.100m and 50m.s^{-1} into equation (4) gives us that the required acceleration would be 12,500m.s^{-2} or 1,250 times normal gravitational acceleration!

We can re-write equation (3) as **a = F/m** and substituting that into equation (4) gives us:

$$v_s^2 = 2.F.s/m \qquad (5)$$

The force, **F**, on a particle in fast-flowing fluids is given by the equation:

$$F = ½.C_D.A.\rho_A.(v_a – v_s)^2 \qquad (6)$$

where C_D is the "drag coefficient" (a dimensionless number that depends upon the shape of the object and for a smooth sphere $C_D \approx 0.5$), A is the cross-sectional area of the object, ρ_A is the density of the **compressed** air (1.2kgm^{-3} times the compression ratio), v_a is the velocity of the air stream and v_s is the velocity of the shot particle. $(v_a – v_s)$ is termed the "relative velocity" of the particle compared with that of the air stream.

3.2 Shot velocity development

Combining equations (5) and (6) gives that:

$$v_s = (C_D.A.\rho_A.s/m)^{0.5}\ (v_a – v_s) \qquad (7)$$

Equation (7) can be expressed in more familiar terms, for spherical shot, by substituting $\pi.d^2/4$ for **A** and $\rho_s.\pi.d^3/6$ for **m**, where d is shot diameter and ρ_s is the density of the shot. That gives:

$$v_s = (1{\cdot}5.C_D.\rho_A.s/\pi.d.\rho_s)^{0.5}\ (v_a – v_s) \qquad (8)$$

All we have to do now is to solve equation (8) for v_s, using known peening parameters. The simplest approach is to set up an

Continued on page 30


SHOT PEENING
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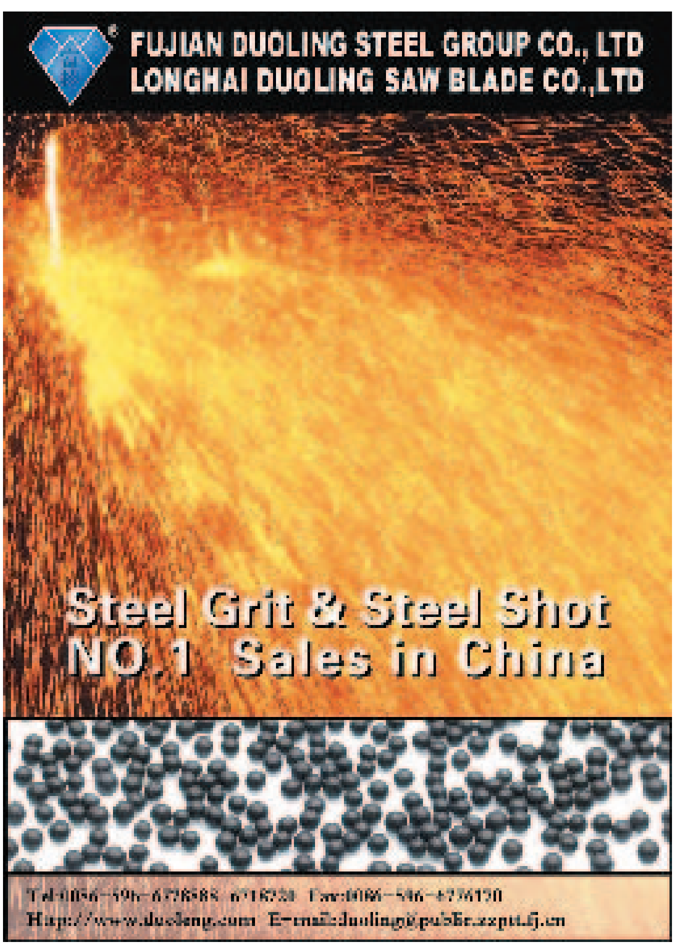
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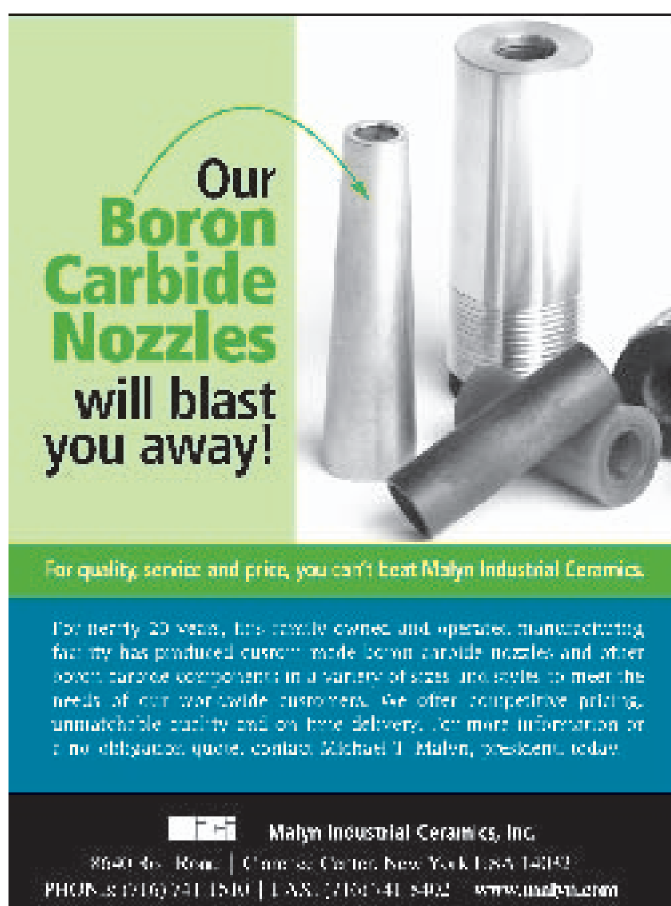
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GENERATION OF AIR-BLAST SHOT VELOCITY

Continued from page 28

Excel spreadsheet that includes a formula that is a re-arranged form of equation (8). Table 2 shows how the required shot velocity (cell C11) is evaluated using the following (in Excel format):

=C9*((1.5*C3*C5*C4*C8)/(C6*C7))^0.5/(1+((1.5*C3*C5*C4*C8)/(C6*C7))^0.5)

With a spreadsheet it is a simple task to enter specific values for the variables. A range for a given variable can also be used to plot a graph of that variable against induced velocity.

Table 2 Specimen calculation of nozzle-induced shot velocity using Excel.

1	B	C	D
2	Parameter	Value	Units
3	Cd	0.5	
4	Air density	1.2	kgm^{-3}
5	Air pressure	9	atm
6	Shot density	7860	kgm^{-3}
7	Shot diameter	0.25	mm
8	Length	50	mm
9	Air velocity	200	$m.s^{-1}$
10			
11	Shot v elocit y	48.6	$m.s^{-1}$

Fig.10 is an example of curves produced using equation (8).

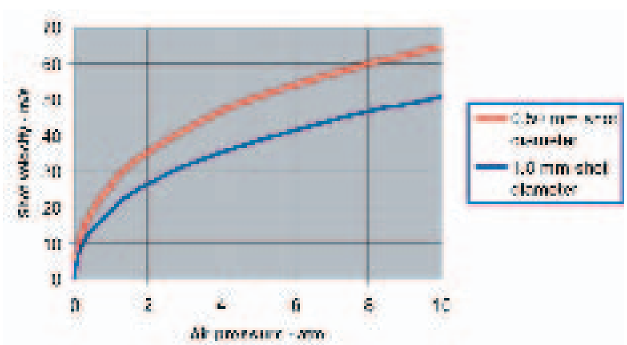

Fig.10 Curves of nozzle-induced shot velocity versus nozzle air pressure.

There are, however, three stages in which shot particles can increase their velocity. These are in the:

(i) feed pipe,
(ii) nozzle and
(iii) post-nozzle air/shot cone.

Feed pipe velocity increase only occurs with direct-feed systems.

(i) feed pipe
The direct-feed pipe length is huge compared with that of the nozzle. Air velocity in the pipe is, however, much smaller than that in the nozzle. The air velocity is estimated by dividing the compressor air input by the product of compression ratio and pipe cross-sectional area. For example, using the Table 1 spreadsheet and substituting 6.8 atm (100psi) and 204 litres/s (432.6 scfm) for a 25.4mm (1") I.D. pipe gives 51.5 $m.s^{-1}$ (170 feet/second) for feed pipe air velocity. Substituting a length of 4000mm for Length, 6.8 atm (100psi) for Air pressure and 51.5 $m.s^{-1}$ for Air velocity into the Excel spreadsheet used for Table 2 gives an induced shot velocity of 11.2 $m.s^{-1}$. That can be regarded as a 'pre-nozzle velocity increase' - to be added to subsequent nozzle acceleration. This pre-nozzle velocity increase is attractive when we have large shot and/or a requirement to maximise shot velocity.

(ii) nozzle
Equation (8) was used to predict the variation of nozzle-induced shot velocity with air pressure for two shot sizes - as shown in fig.10. The advantage of pre-nozzle velocity increase for large shot becomes apparent. The equation can also be used to predict the effects of nozzle length and shot material (through change of shot density).

(iii) post-nozzle air/shot cone
As the shot particles exit from the nozzle they are travelling much more slowly than the air stream – as evidenced by the examples in the preceding section. Fig.11 illustrates the situation where shot acceleration occurs in the nozzle from A to B with a constant air velocity. A rapid reduction of air pressure occurs at B. From B to C the relative air velocity reduces, so that at C both air and shot are travelling at the same speed. Thereafter the shot is travelling faster than the air stream so that a reduction in shot velocity occurs.

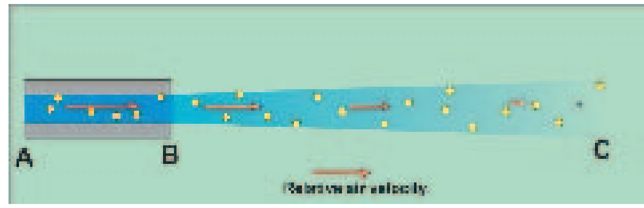

Fig.11 Combined acceleration within nozzle, A-B, and after leaving nozzle, B-C.

Theoretical analysis of shot velocity changes in the expanding cone, BC, is very, very complicated. There is some experimental evidence that the maximum shot velocity occurs at about 200mm from the nozzle. As a rough example, substitution of 200mm for Length,100$m.s^{-1}$ for Air velocity (as an average value) and 1 atmosphere for Air pressure would indicate a post-nozzle shot velocity increase of 17.6$m.s^{-1}$. Nozzle type will also be a factor, convergent-divergent nozzles, for example, have a larger air velocity at exit than have straight nozzles.

3.3 Final shot velocity
Shot velocity at the nozzle exit will be the sum of (i) and (ii) for direct feed systems and just (ii) for suction and gravity feed systems. Post-nozzle shot velocity will depend upon the distance from the nozzle – being a maximum at some distance from the nozzle (of the order of 200mm).

DISCUSSION and CONCLUSIONS
This article is based on a simple model of air flow and shot acceleration. The small effects of temperature and humidity have been ignored. Very accurate values for predicted shot velocities cannot, therefore, be expected. On the other hand the equations presented can be used to explain experimentally-observed variations.
Several significant conclusions can be drawn from the analyses contained in the article. These include:

- An adequate air supply will induce a virtually-constant nozzle air velocity that is a large fraction of the speed of sound and is independent of both nozzle air pressure and diameter.
- Increasing the nozzle air pressure increases induced shot velocity because of the corresponding increase in air density.
- A general equation has been presented that allows quantitative prediction of induced shot velocity and the effects of shot size, shot density, nozzle length and nozzle pressure.

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The Paris Museum National d'Histoire Naturelle staff freed this 45 million-year-old shell, the Chama punctata, from its sandstone bed with a blast cleaning process. Photograph used with permission by the museum. (Specimen MNHN A25732. The speciman was cleaned by Renaud Vacant, a lithopreparator at the museum.)

Blast Cleaning the World's Oldest Parts

by Michel Cardon

When Tilghman published the very first patents covering sand blasting in 1870, he listed many potential applications for the process from castings to etching tombstones, glass decorating to cleaning ship hulls.

Through Roger Brickwood, a good friend and work associate of many years, I now have a blast cleaning application for some of the world's oldest parts that Tilghman never considered.

In 1983, an amateur fossil hunter, William Walker, found an enormous claw, 12 inches/31 cm long, sticking out of the side of a clay pit in Surrey, England. About 70% of the Dinosaur skeleton was later recovered. It was named "Baryonix Walkerii" in his honour (Baryonix means "Heavy claw").

The fossil went to the Natural History Museum in London. When considering that the living dinosaur was about 40 feet/12 meters long, and weighed about 4 tons/3600 kg, it's easy to imagine the enormous amount of fossilized remains that the museum had to collect, protect, transport, study and prepare for display.

Vacu-Blast in Slough, United Kingdom, had sold machines to the Natural History Museum, and several other museums, while Roger Brickwood was Sales and Marketing Director at Vacu-Blast. "We gave the museums 'educational' discounts which was quite progressive at that time," said Brickwood. "These relationships gave us great PR. When the Natural History Museum received the Baryonix Walkerii from Walker, they came to us and asked for help."

Tests undertaken at Vacu-Blast proved that dry blast cabinets used with fine abrasive can assist the cleaning process without damaging the specimens. As work progresses, the operator can control precisely the degree of removal before risking touching the actual part. Cracks are often found on the surface of the fossil and this brings another concern—the cleaning process must not stress the part or add to the danger of catastrophic fracture. Carefully controlled blasting achieves this result.

"Rather than make the museum staff bring us samples, we installed the machine in the museum and let the staff play with it. Their results were so good that we gave them the machine," said Brickwood.

The Paris Museum National d'Histoire Naturelle also blast cleans fossils and Philippe Richir, Lithopreparator, explained to me the difficulty of fossil preparation. "In their original sediments, fossils are found in hugely variable conservation conditions. A specimen can be large and heavy from 2 meters and 30 kg down to small, very small and thin, just a few millimetres and grams. Bigger specimens are easier to handle but bring additional challenges in their preparation. In addition, each natural site offers different working difficulties. The sediments can be limestone, clay, sand or sandstone with big differences in hardness and adhesion."

"Parts are often protected on-site by applying plaster jackets to enable the safe extraction and transport of the specimens. Then, back at the museum, careful experimentation is necessary for each specimen before selecting the best methods to remove the unwanted material. We use needles, micro tools, acid, and blasting and micro blasting cabinets. The most frequently used blasting abrasives so far are soda carbonate or bicarbonate, dolomite and crushed walnut shell, with fine to very fine mesh sizes. We try to test first with each specimen to gauge the hardness differences between the fossil and its sedimentary debris; sometimes the differences are very small and the precious fossil might be cracked or damaged if we do not understand these differences," continued Richir.

Often a painted-on rubber masking material is used to protect the surface of the fossil from the blast stream. This can be applied, stripped and replaced many times during the process. As an example of a very delicate job, Didier Merle, head of the museum's fossil shells collection conservation, shared with us the photograph of a "Chama punctata" shell, a tropical mollusk which lived about 45 millions years ago and was discovered in the Paris area. The very fine and delicate mollusk spines were freed from the surrounding sandstone bed by blast cleaning.

Philippe Richir adds, "We always try to combine efficiency and time-savings, but keeping the specimen in the very best possible condition is a must."

While time is money when blast cleaning today's products, to these creatures that lived millions of years ago, what is a little more time to make sure that they are treated respectfully and carefully preserved?

Michel Cardon is retired from the vacu-blast industry and resides in Paris, France. During his career, he was the manager of the vacu-blast department of his family business, Satem. He formed Matrasur which was later purchased and became Wheelabrator. Some of his career highlights include being a guest of the U.S. Capitol in 1982 and a meeting with Jacques Chirac.

Industry News

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

Acquisition of Baiker Maschinenbau AG by RÖSLER Oberflächentechnik GmbH

Untermerzbach, Germany. The RÖSLER Group has announced that contrary to the announcement from August this year, the company Baiker Maschinenbau AG now will be acquired by the Rösler Oberflächentechnik GmbH effective January 1, 2007.

The RÖSLER Group is worldwide acknowledged market leader in the field of vibratory finishing and shot blasting.

The RÖSLER Group and the Baiker Maschinenbau AG have more than 25 years active experience in the Aerospace industry and therefore they complement one another as a result of experience, competence and innovation.

Through the long history of both companies operating successfully in the same market sector, this acquisition provides important advantages:

- The know-how of the company Baiker Maschinenbau AG will be secured long-term
- The care of the Baiker customer base as well as the service and spare parts supply for existing equipment will be assured for the future

Furthermore, Mr. Erwin Baiker has confirmed his support for at least the transitional period. The development, design and production of Baiker equipment will be integrated into the RÖSLER Organisation. The Baiker location in Switzerland will be closed and the aerospace side of the business will be moved to RÖSLER France and the automotive side will be moved to RÖSLER Germany.

Cym Materiales Receives ISO 9001

Soldini, Argentina. Cym Materiales S.A., an established manufacturer of shotblasting machinery serving a number of industries, is pleased to announce having successfully fulfilled the established requirements leading to the award of ISO 9001by the TUV Rheinland Group.

The ISO 9001 certification further establishes Cym as a premier manufacturer of shot blasting systems. Manufacturing shotblasting machinery since 1984, Cym Materiales has grown to deliver to a variety of industries including wire rod, plate and strip, tube, structural forms and foundries and forge.

Located in Soldini, Argentina, Cym Materiales maintains a staff of 11 administrative, 10 engineering and 30 hourly employees operating within a 1500 square meter manufacturing facility. A second operating division is also located in Campinas, Brazil.

Please contact Cym Materiales to speak with a sales professional about your surface preparation needs. For Information, send email to: infocym@cym.com.ar.

Vapormatt Wet Blast Surface Preparation Process Proves a Winner at Motor Racing Carbon Fibre Specialist

Global Technologies Racing Ltd (GTR), the Fontwell, West Sussex, UK, based specialist designer and manufacturer of high specification carbon fibre components for Formula 1, Indycar and other state-of-the-art racing and performance cars, has recently installed its second Vapormatt wet blast machine.

The new machine – a 'Vapormate 3', with a 995mm x 700mm x 700mm processing enclosure – is used for the surface preparation of post-cured parts prior to painting or coating.

Global Technologies Racing opted for the wet blast surface treatment process following thorough trials by Vapormatt, which established its superiority over comparable systems for the surface preparation of carbon fibre and other composite materials such as glass reinforced polyester (GRP).

When working with composite materials used in safety-critical applications in the motor racing and aerospace industries, precise and dependable surface preparation for bonding and coating is obviously of paramount importance. Both carbon fibre and GRP are notoriously difficult to bond, due to the presence of resinous material on the normally smooth surface. Grease and dust also compromise effective adhesion.

The Vapormatt wet blast process utilizes water and fine abrasives in suspension, delivered by a slurry pump and accelerated by compressed air to the process nozzle, which is normally manually operated (automatic nozzle manipulation is also available for dedicated, repetitive tasks). The action of the slurry scours the surface to create a thoroughly clean and lightly abraded result. The water can be heated and mild detergent added to ensure the effective removal of grease or oil.

The ratio between the water pressure and air pressure in the process nozzle is variable, to enable a "water buffer" to be maintained between the abrasive media and the surface being processed. This water buffer effect has a number of major benefits. It lubricates the action of the media, eliminates static build-up and washes the surface continuously during processing. Added to this, it prevents impregnation of hard abrasive particles into the soft resin surface and prevents fibre damage.

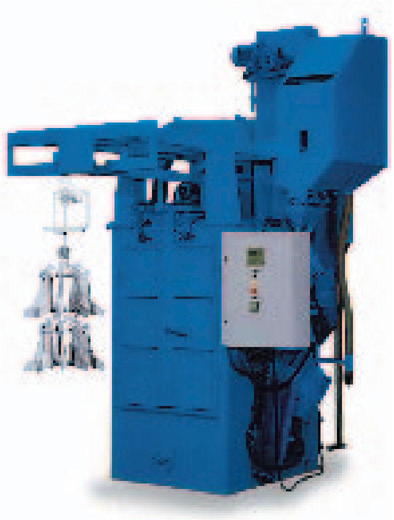
Because of its inherent advantages, the Vapormatt wet blast process has superseded the use of hand abrading in many composite surface preparation applications – overcoming the inconsistencies of the latter and also eliminating the need for further chemical cleaning. The Vapormatt process is also highly effective for preparation of the complex automotive components manufactured by Global Technologies Racing, which are difficult and time-consuming to prepare with conventional manual methods. No solvents or other potentially hazardous chemicals are used by the wet blast process, so it is not subject to stringent EU solvent emission, VOC or dust emission legislation.

For further information, send email to Robin Ashworth at robin.ashworth@vapormatt.com.

Continued from page 36

Wheelabrator Smartline "Y" Track Spinner Hanger Machine

LaGrange, GA. The newly designed Wheelabrator Smartline™ "Y" Track Spinner Hanger Machine cleans and prepares odd-shaped work pieces that do not lend themselves well to table or tumble blasting machines. The Smartline "Y" Track Spinner Hanger Machine is self-contained including ducting hoses to the dust collector. The unique in/out hook spinner drive reduces operator fatigue permitting parts to enter and exit the blast cabinet with ease. The "Y" Track overhead rail permits one work fixture to be unloaded while the loaded work fixture is in the machine being blasted, virtually doubling productivity. The Smartline "Y" Track Spinner Hanger Machine features a PLC equipped control panel for easy operation.



The Smartline "Y" Track Spinner Hanger Machine is pre-assembled and tested at the Wheelabrator factory, and the user will assemble the components according to a supplied instruction manual. The machine consists of a blast cabinet built from a welded steel frame with internal lining of one-fourth inch Manganese steel plating on the blast side and opposing wall.

The cabinet doors are built from steel plating, and the door closure forms a labyrinth seal for shot retention while allowing air to intake ventilation. A vertical bucket elevator, driven by a 1.5 HP gear motor, transfers the abrasive media from the lower hopper. The "Y" configuration features a trolley monorail system that is detached from the main machine for easy shipping. Two trolley hangers, which can each handle loads of 1,100 pounds, allow for one trolley to load outside the machine while the other is used in the blasting cycle.

The Spinner Hanger's spinner drive engages with a work hanger sprocket which pulls the hanger and work piece into the cabinet. The spinner drive rotates the work piece in front of the wheel blast once inside the cabinet. The abrasive separator receives the contaminated abrasive media from the bucket elevator, and this is screened for large impurities and tramp metals.

The abrasive media falls downward as the separator air washes the media, drawing the small particles to the ventilation system. The clean media cascades to the abrasive storage hopper and directs itself to the wheel via the abrasive control valves.

For more information on Wheelabrator visit the web site at www.wheelabratorgroup.com.

Shot Peen Masks

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Straton also provides design and building of molds for grommets, boots, gaskets, seals and O-rings. Areas of other mold building specialties encompass compression, injection and transfer molds as well as mold repair.

Straton Industries, founded in 1961, is a small yet progressive, veteran-owned machining facility with extensive experience in the aircraft repair marketplace. Straton is ISO 9001:2000 certified and is an FAA repair station (# XTRR859K). Straton can be found on the internet at www.straton.com.Please contact us at molds@straton.com or call (203) 375-4488 and ask for Dave Cremin.

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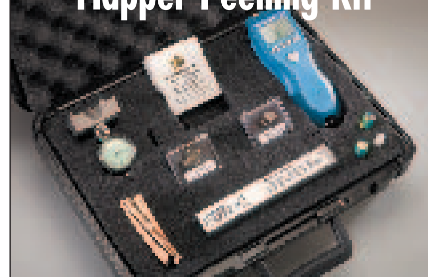

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The Parting Shot
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A Proud Tradition

Prior to the start of the 16th annual U.S. Shot Peening and Blast Cleaning Workshop in Indianapolis this fall, Electronics Inc. sponsored a tour of the Indianapolis 500 Speedway. The tour included the Speedway museum, race facilities, a movie, and even a ride around the 2.5 mile track in a bus.

The Speedway is filled with the rich 100-year history and traditions of the race. The tour guides took every opportunity to point out the facts and milestones in speed, safety and design. They provided a real education to the true scope of racing—we knew that racing was more than just crossing the finish line but we were impressed with the tremendous amount of technology and skill that must come together to make the finish line possible. Even on race day, teams will make adjustments based on things like tire wear, driver feedback and the weather. Most of us in the shot peening industry have an engineering or mechanical background and that made us appreciate the tour even more.

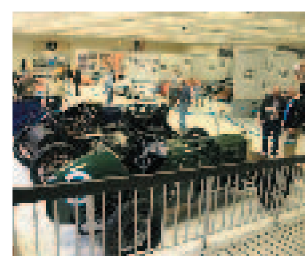
Shot peening and blast cleaning, like racing, is a progressive field. Machine design, media development, training, screening and sensing are continually evolving. These innovations have led us to a practice that is controllable and repeatable. It can be confirmed on a day-to-day basis through monitoring, measuring and analysis. And while a shot peening or blast cleaning job isn't as glamorous a career as a race car driver, let's give ourselves credit for our place in the automotive industry. The improvements we're implementing in our processes are making a big contribution to safer, faster, and stronger vehicles—Indy, Formula One and NASCAR race teams are using our shot peened components for these very reasons.

Since 1991, the EI Shot Peening and Blast Cleaning workshops have been not only a educational forum for new technologies but a networking venue for people from around the world. Out of 163 attendees, 96 were students, 35 were exhibitors and 32 were speakers. Even though it was our U.S. workshop, we had 26 students from South America, Canada, Europe and Asia and many first-time students that are new to the industry. We all continue to learn from each other.

The students, exhibitors and presenters of the 2006 USA Shot Peening and Blast Cleaning Workshop

Dave Beherns, President of a precision machining facility, summed up his workshop experience nicely: "At one point during the conference I thought to myself that I was proud to be part of this group."

More workshop photos are online at www.shotpeener.com



Hall of Fame Museum

Ed Richerme, Engineered Abrasives, takes a photo opportunity in an Indy car

Kissing the bricks is an Indianapolis tradition