Summer 2013
Volume 27, Issue 3 | ISSN 1069-2010

The Shot Peener

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

Engineered Abrasives™ Delivers Big

Electronics Inc.'s Training Division Gets a New Identity

12th International Conference on Shot Peening in Goslar, Germany

Two Widely Used Processes: Dual Peening and Ricochet Peening

Measuring the Power and Force of the Shot Stream

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

Collaboration Results in Patent and New Product

JACK CHAMPAIGNE

THE TWO ARTICLES from Curtiss-Wright/Metal Improvement Company in this magazine coincide nicely with the recent notice of a patent approval that was the collaboration between Electronics Inc. (EI) and Metal Improvement Company (MIC). (See MIC articles on pages 18 and 34.) The collaboration started when I was visiting with Dave Francis at MIC several years ago and we were talking about various aspects of shot peening, including specifications, new technology and audits. (Dave is Senior Vice President at MIC and was the 2002 Shot Peener of the Year.) We were both very involved with SAE specs, especially J442 regarding the Test Strip, Holder and Gage for Shot Peening. We talked about the differences between SAE J442 and the now-cancelled MIL-S-13165 military spec for shot peening and we specifically discussed the differences in the placement of the holes in the Almen holders between the two specs. Someone asking for certification of the holders to both documents was going to be disappointed since it was not physically possible. Choose one or the other.

Another issue, the flatness of the Almen holder, was a pretty dull topic at that time but Dave told me that MIC had already addressed that issue with a unique device to ascertain the holder flatness. I told Dave I thought that was a pretty clever device since it could be used with the holder in place. The alternative would require removing the holder from its fixture and placing it onto a granite surface for flatness measurement.

I try to monitor US Patent releases and I saw one assigned to General Electric (US Patent 6,148,532) for measuring the holder flatness. Bob Ellis, whom I had met quite some time ago at GE, was the inventor and I was reminded of the device I saw with Dave Francis. Recognizing some differences in the devices, I contacted Dave in 2011 and asked him to consider revisions to make his version more versatile than the one described by Ellis. We knew we couldn't certify the holder gage to both specs so we certified it to only J442. EI enhanced Dave's design by making the holes elliptical to accommodate the SAE spec hole tolerances. We agreed to file a joint patent application. After several months of negotiating with the patent office, we were informed early this year that our patent for the Almen Holder Flatness Gage has been granted.

I really appreciate our relationship with MIC. They have been a great supporter of our workshops and seminars and they make significant contributions to SAE shot peening technology.

The newly patented Almen Holder Flatness Gage

THE SHOT PEENER

Editor
Jack Champaigne

Associate Editor
Kathy Levy

Publisher
Electronics Inc.

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The Shot Peener
56790 Magnetic Drive
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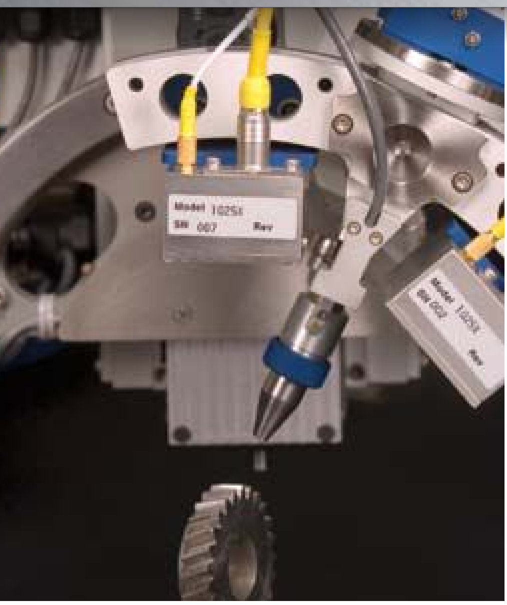

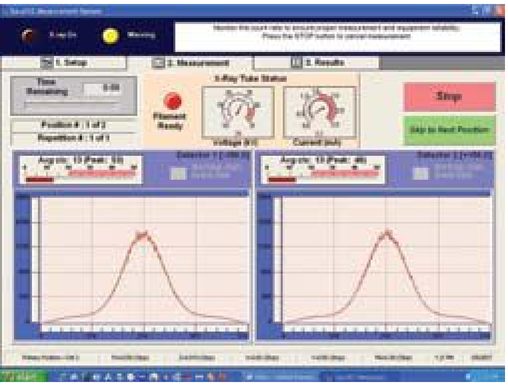

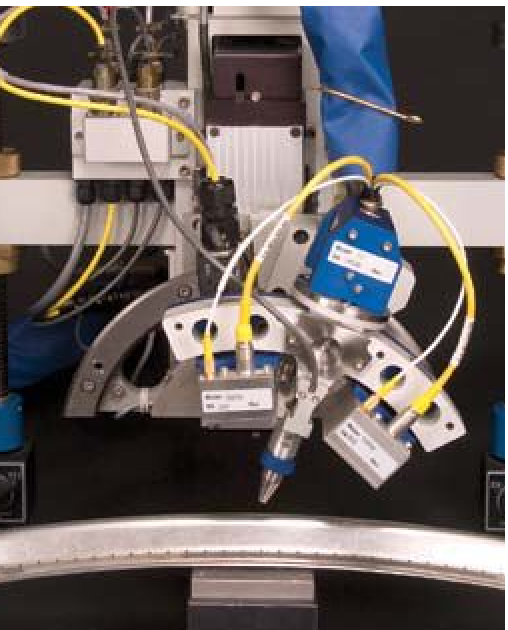

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Big and Built to Last

96" Five-Axis CNC Shot Peen Index Table System by Engineered Abrasives™

WHEN A CUSTOMER needed a new machine, they first reviewed Engineered Abrasives' standard line of machines. The customer liked the robustness of the equipment but needed a bigger version of Engineered Abrasives' largest machines. So began the construction of the "largest Five-Axis CNC Shot Peen Index Table System ever built," said Mike Wern, President of the Illinois-based OEM.

Robust and Versatile

The machine is designed to be a tireless workhorse, able to shot peen large gear sets on a 24/7 schedule and allow changes in component and media sizes.

The high-volume machine will peen the gear root radius and tooth faces of large rack and pinion gear sets (averaging 500 lb.) for bulldozers, excavators and other heavy-duty equipment. In addition to its size, the machine has other unique capabilities and features. The machine was engineered for the quick changeover of gear sets without additional nozzle setup or media changeovers. The 48" Sweco separator for dual medias was elevated and placed in a noise-deadening enclosure for a sound level of less than 80 dB. It screens 100 percent of the media with a five-deck screening system and a lift for quick screen changes. Two continuous-operation pressure vessels move and reclaim two sizes of cut wire shot. Two MagnaValves were installed on each vessel.

The index unit—a precision Camco index drive with overload clutch—has 4-axis on the robot arm (designed by Engineered Abrasives) and 1-axis on the spindles. The OEM's engineering staff developed new servo parameters to accommodate the axis of the large parts.

Three semi-trucks will deliver the machine this summer and Engineered Abrasives will install, test and provide training for the new equipment.

Looking down at the two pressure pots, the two elevators and the Sweco separator. The Sweco is housed in a foam-padded enclosure to reduce noise. Each pressure vessel has two MagnaValve media valves and the Sweco screens 100 percent of the media with a five-deck screening system.

Main Control Panel
Engineered Abrasives designs and builds their control panels.

Pressure pot screenshots on the GE Fanuc control panel.

MagnaValve FC controllers help operators monitor shot flow rates.

The back of the control panel, the dust collector and multiple access doors.

The cabinet was built to withstand high-volume peening. The cabinet roof is 1½" steel plate with 1" polyurethane liner. Cabinet walls are ½" steel plate with 2" foam and ¼" polyurethane liners. The 96" diameter rotary table has 1½" of polyurethane bonded to 1½" aluminum plate and bolted to a 1" precision steel plate.

A New Identity for a Growing Program

ELECTRONICS INC. has changed the name of its Education Division to EI Shot Peening Training, thereby reinforcing the company's commitment to providing comprehensive shot peening and rotary flap peening training.

The name change was prompted by the need for a new website, independent of EI's website. "Enrollment in EI's training programs has grown 132% in the past three years and it was time to launch a more accessible website," said Dave Barkley, Director of Training. "We also wanted a clear differentiation between our shot peening training programs and EI's support of their MagnaValve product line," he added.

The new logo maintains a strong link to EI in name and appearance because Electronics Inc. is the pioneer of shot peening training, holding the first shot peening workshop in 1991. The initial workshops were held in the United States and the events are now hosted in the USA, South America, Europe and Asia. The dates and locations of the seminars/workshops aren't always convenient for groups that need immediate assistance, so EI's on-site training is available worldwide and has been provided in Australia, Canada, Costa Rica, El Salvador, England, France, Germany, United Arab Emirates, and throughout the United States. Training is conducted in English and native languages, including French, German, Japanese, Mandarin Chinese and Spanish.

"The growth in training is exciting to us for three reasons. Obviously, we're pleased that our endeavor is successful, but also because the demand for training signifies the strength and growth of the entire shot peening industry," said Tom Brickley, Vice President of Electronics Inc. "And it means that more companies are paying attention to the quality and control of their shot peening processes."

EI Shot Peening Training is based in Electronics Inc.'s corporate headquarters in Mishawaka, Indiana. EI manufactures the MagnaValve media valve, controllers, Almen gages and strips. EI also publishes *The Shot Peener* magazine and maintains the world's largest online resource for shot peening and blast cleaning at www.shotpeener.com.

The new website: www.shotpeeningtraining.com

Features of the website include:

- Upcoming seminars and workshops with fees, hotel accommodations, and agenda/training topics
- On-site shot peening and rotary flap peening training information
- A comparison of the benefits of seminars and workshops to the benefits of on-site training
- An online registration form
- A complete list of all training topics, broken down into Core Classes/FAA-Accepted Courses, Specialty Seminar Classes and Customized On-Site Training Topics
- A list of instructors and their biographies
- Information on the Achievement Exam Program
- and much more

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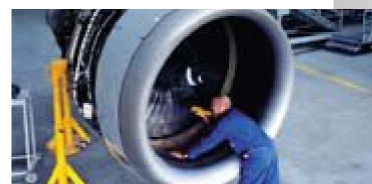
on relevant topics



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The Twelfth International Conference on Shot Peening

The International Scientific Committee for Shot Peening is pleased to share information on the upcoming ICSP-12 in Goslar, Germany on September 15–18, 2014.

IMPORTANT SUBMISSION DATES

Abstract Submission	August 1, 2013
Paper Submission	May 1, 2014

Send abstracts to the Chairperson, Prof. Lothar Wagner, at lothar.wagner@tu-clausthal.de.

PAPER TOPICS

- Mechanical Surface Technologies
- Residual Stress Measurements
- Fatigue Performance
- Case Studies
- Modeling
- Process Parameters
- Corrosion Performance

REGISTRATION FEE

Registration Fee EUR 780
(Reduced student fees have not been announced)

Registration fee includes Proceedings, technical program booklet, luncheons, coffee breaks, receptions, conference banquet, exhibit admission, Brocken-Tour with historical train, and Volkswagen Autostadt Wofsburg.

LOCATION

The conference will be held at the Hotel der Achtermann in Goslar. Recommended hotel accommodations will be available at www.shotpeening.org/ICSP-12.

CHAIRPERSON

Prof. Lothar Wagner, Clausthal University of Technology Institute of Materials Science and Engineering

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The Town Hall in Goslar, Germany. Goslar is a very beautiful city with impressive historical attractions.

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EXHIBITION

Tentatively scheduled to be open three days, from Monday through Wednesday.

Garlan Barnes | USA-Based Auditor | Nadcap

Quality is Everybody's Job

In this interview from Nadcap's May 2013 newsletter, Nadcap Auditor Garlan Barnes answers key questions about the program and gives his perspective on how to have a successful audit.

What would be the key piece of advice you would give to companies preparing for a Nadcap audit?

Prepare for the audit using the checklist. Completely. I have a saying: the amount of preparation reflects directly on the audit results. Suppliers should answer every checklist question with reference to the evidence they will provide to support their response.

In my experience, good audit results are directly proportional to the amount of preparation done. It just makes sense and then the audit is easier for everyone.

We all know that first impressions count. Are there any simple things that a company could do to give a good first impression?

Have all the documentation set up for review and be prepared for the job audits. Basically, be organized. I did an audit recently and the company was so organized, we were able to complete the audit smoothly and in good time. In other cases, I spend a lot of time waiting around for the relevant documentation to be found.

What is your definition of "quality"?

Quality is everybody's job. Every single person. It flows down from management through to the shop floor.

In your experience, describe the impact of Nadcap on the companies you have audited.

Nadcap has had an immense impact on quality improvement in the companies that I have audited. And I'm talking globally. Companies have better control of their systems, better review structures for their activities and measures in place to help them improve their processes. In my experience, attitudes are different too: companies are more organized and I've even heard that some companies refuse merit status so as to be sure to maintain the discipline of Nadcap. That's impressive.

There's an aerospace saying: the highest form of flattery is plagiarism. No one should see Nadcap as an audit that takes place once per year. It's an ongoing cultural change and all participating companies should use the tools that are made available through Nadcap to benefit their organizations.

What attracted you to Nadcap auditing in the first place?

I was working before for a U.S. company that was among the first Nadcap auditees in the early 1990s. A few years after that I was approached to see if I was interested in becoming an auditor. It was the right time in my career to look for a new challenge so I decided to try it!

What has surprised you about being a Nadcap auditor?

Every single audit, I see something that surprises me. There's always something new—processes, ideas… It's really neat to see parts that go on aircraft and know how it's done. I really enjoy that.

What is the best thing about being a Nadcap auditor? And the worst?

The travel, although I enjoy it, can be a pain to organize as most facilities are located in remote areas. But that's more an inconvenience than anything else.

The best thing is that I get to see new shapes and processes and I've seen many changes and improvements since I started in the industry 38 years ago. Although the general process is the same, control is now much better than it used to be.

Please describe a typical audit day.

Well, on the first audit day, I meet the team, verify the scope of the audit, do a site tour and get going on the job audits. On the last day, I make sure I've shown the supplier eAuditNet and the PRI website—both excellent sites containing a lot of useful information. I also review the nonconformances word for word so that I'm sure the supplier understands them and I get them to sign off on them. Now, that doesn't necessarily mean that they agree with them—that's a separate question which is to be determined by others—but they do, at least, understand them.

Each evening, I go back to my hotel room and type up my notes. I estimate that for every hour spent on site, I take another 30 minutes working at the hotel, depending on how organized the paperwork was. There's no hidden agenda, no secret fraternity. There's no quota for Non-Conformance Reports. I have conducted a number of audits and found zero non-conformances. I report what I see and what I don't. That's it.


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Ricochet Peening

We recently received an email from an engineer with an aerospace manufacturer, suggesting more information on ricochet peening in The Shot Peener magazine. "There are many scenarios that require ricochet peening in industry," he wrote.

We shared the following research paper with him, and we agree. Ricochet peening is very common but little research has been done on intensity verification on ricochet-peened surfaces. It would be a great topic for the upcoming Twelfth International Conference on Shot Peening (September, 2014 in Goslar, Germany).

P. Bailey, J. Champaigne, C. Long
Electronics Inc., Mishawaka, Indiana 46545, USA

Abstract

Ricochet peening may be used in cases where it is impossible to obtain complete visual coverage by direct impact. AMS-S-13165 refers to this as reflected shot stream. This study illustrates the influence on the shot stream reflected angle and impact intensity as a function of material hardness.

Keywords

Ricochet Peening, Reflected Shot Stream, Impact Angle, Ricochet Angle, Peening Coverage

Introduction

Ricochet peening, also called reflected shot peening, is a convenient method of providing coverage when the surface to be peened is obstructed. This can be especially useful when the area to be peened is fatigue critical and elaborate methods are either unavailable or cost prohibitive. Figure 1 illustrates a typical application for ricochet peening.

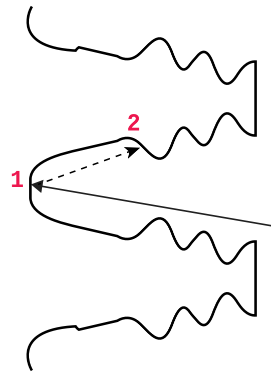


Figure 1. Peening of dovetail slot: 1) First impact 2) Second impact

Method

A direct pressure peening system with MagnaValve shot flow control shown in Figure 2 was used to perform these experiments using size S-110 cast steel shot. A right angle fixture of tool steel was constructed to represent the first and second impacts (see Figure 3). The nozzle was aimed such that the first impact was on the ricochet plate and the impact of the reflected shot was on the target plate. The first task was to evaluate the incident and reflected angles of the shot stream on the ricochet plate.

Figure 2. Peening Cabinet

The surface of the ricochet plate was painted and examined after a brief exposure to the shot stream thus revealing the reflected angle of the shot stream. See Figure 4. If the ricochet plate provided an "ideal" inelastic collision, then the 45° incident angle would result in a 45° reflected angle. However, energy losses at the first impact site reduce the reflected angle as shown in Figure 5 (see page 16).

The second task was to evaluate the intensity of the second impact after the shot stream was reflected from the ricochet plate. The arc height response of an Almen strip placed on the ricochet plate was used as a reference for intensity comparisons (Figure 6). The authors recognize that this is not an accurate evaluation of intensity since full saturation curves were not generated but it was deemed to be sufficient to illustrate a general comparison of intensity levels. The first strike intensity was set at 0.4 mm arc height.

Almen strip arc heights for the second impact were then recorded for each of the three cases of first impact on tool steel, aluminum and mild steel.

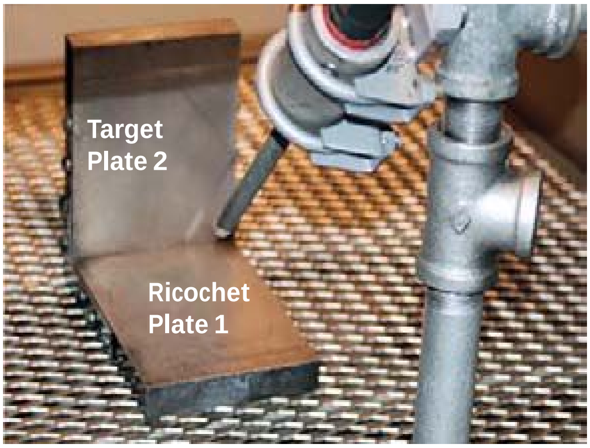


Figure 3. Nozzle aimed at Ricochet Plate (1)

Figure 4. Tool steel, aluminum and mild steel ricochet surfaces.

Results

The higher hardness material produced a larger reflected angle for the shot stream (Figure 8) and also a higher intensity for the second impact (Figure 9).

Table 1. Experimental Data

Impact Material	Hardness BHN	Impact Angle	Impact Arc Height	Ricochet Angle	Ricochet Arc Height	Incident Angle
Tool Steel	650	45	0.38 mm	33	0.43 mm	57
Mild Steel	110	45	0.38 mm	24	0.38 mm	66
Al 6061	86	45	0.38 mm	22	0.32 mm	68

Discussion

The numerical results are shown only for illustration and should not be applied directly to other applications. Complete saturation curves should be developed to ascertain the actual intensities achieved on each peened surface.

Conclusions and Implications

Ricochet peening, impacts with reflected shot, may be an effective method to provide coverage in certain applications, such as dovetail slots in aircraft turbine engines or other materials. The shot stream reflected angle is affected by the material hardness.

The test results show that the softest material, the Aluminum, absorbed more energy at the point of reflection and delivered a higher angle of incident (68°). There is a reduction in arc height measured at the incident site (0.32 mm) than at the reflection site (0.38 mm) despite the higher impact angle of 68°. This is due to the loss of energy during the reflection collision. The test on the Mild Steel showed no difference in measured arc height between the point of reflection and the point of incident. Although the incident angle (66°) was greater than the reflection angle (45°), energy was again lost in the reflection collision. The Tool Steel, the hardest material, had the least amount of energy absorbed at the reflection site and delivered the lowest angle of incident (57°). However, the measured arc height at the incident site (0.43 mm) was greater than the measured arc height at the point of reflection (0.38 mm). The natural conclusion would be that the intensity projected by the reflected shot stream might actually be higher than the intensity at the impact surface.

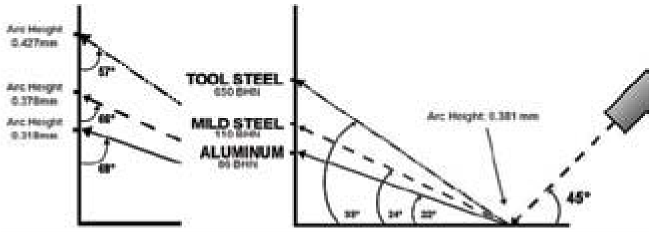


Figure 5. Angle of incidence and reflection for three hardness targets.

Figure 6. Technique to establish arc height of 0.38 mm at 45° impact.

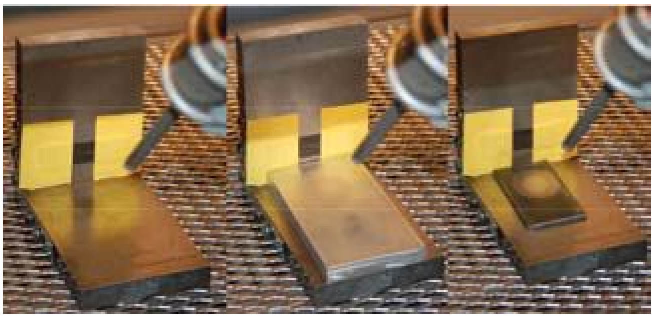


Figure 7. Almen strips used to measure second impact intensity after first impact on tool steel, aluminum and mild steel.

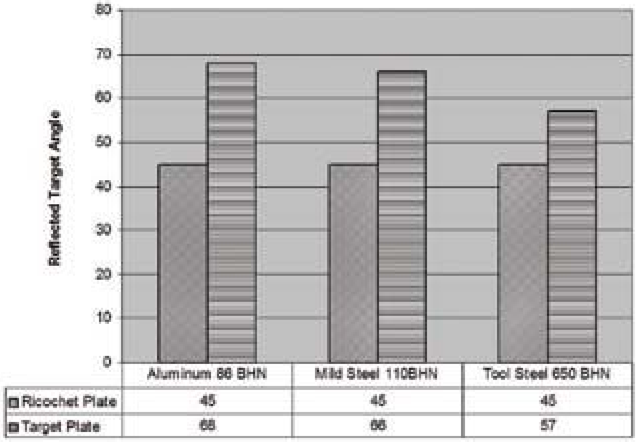


Figure 8. ***Ricochet reflection angles****. Shot stream reflected angle after first impact (1) at 45°*

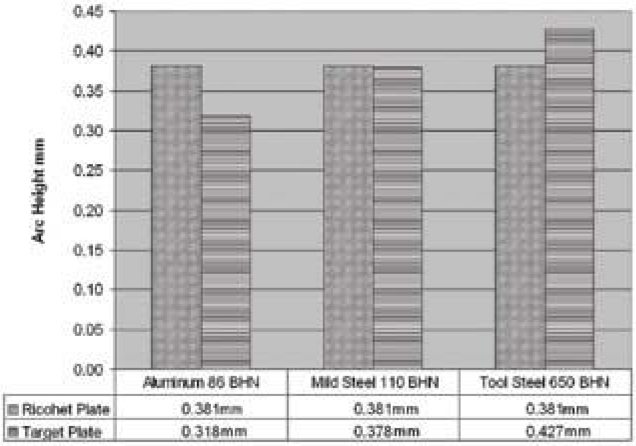


Figure 9. ***Ricochet impact intensity****. Intensity of second impact (2) with first impact set at 0.381 mm.*

Dual Peening

DUAL PEENING is used to further enhance the performance of traditional shot peening. Whereas traditional shot peening uses one shot media at a specified intensity range, dual peening adds a secondary shot peening operation. The second peening operation usually uses a smaller diameter media that is peened at a lower intensity than the first peening operation. When the secondary peening is performed, the smaller media is able to pound the high points from the first shot peen into the surface. This has the effect of driving additional residual compressive stress at the outer surface.

Figure 1 shows a magnified view of a single peen using 230H shot media.

Figure 2 shows the same magnification of a dual peen of the same surface. The original 230H shot peening operation has been followed by a 110H shot peening operation. This surface shows a better surface finish as a result of the peaks from the 230H shot peening being pounded in the surface.

Figure 3 shows the effect of greater residual compressive stress at the surface of a carburized gear from the dual peen (solid line).

Since almost all fatigue cracks initiate at a component's surface, the residual compressive stress in the near-surface region (up to 0.002" depth) is very important. Readers of *The Shot Peener* magazine are aware that applications that operate in higher cycle (lower stress) fatigue regimes respond better to shot peening. Therefore, if a single peen operation moves the component into a higher cycle fatigue regime, the second peen is able to further expand the benefits of first peen.

There are two common reasons to dual peen. In some industries, such as Formula One or NASCAR racing and medical implant manufacturing, it is common to 'pay up' for performance. Therefore, design engineers in these industries will often ask for the best peening process with less concern about cost.

The second reason is increased performance demands to existing parts. It is not unusual for either loads to be increased or life requirements to be lengthened. When the fatigue performance demands outgrow the initial peening requirements, it is likely that the lowest cost improvement to the part is to add a dual peen to the part in the assembly that fails (providing that it is already shot peened). For example, an engine manufacturer had recently uprated the horsepower output going to the transmission. Accelerated engine load testing was failing on a carburized and shot peened transmission gear at 19 hours of testing. The design engineers required 50 hours of testing to validate the engine and transmission for release. By changing the original shot

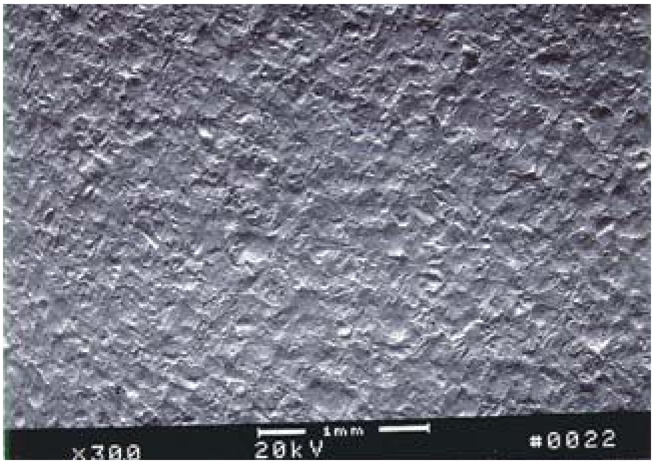


Figure 1. Single peen using 230H shot media

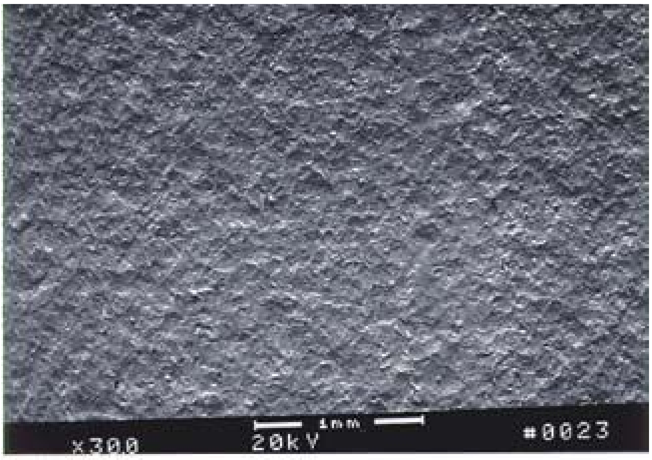


Figure 2. Dual peen using 230 H media, followed by 110H peen

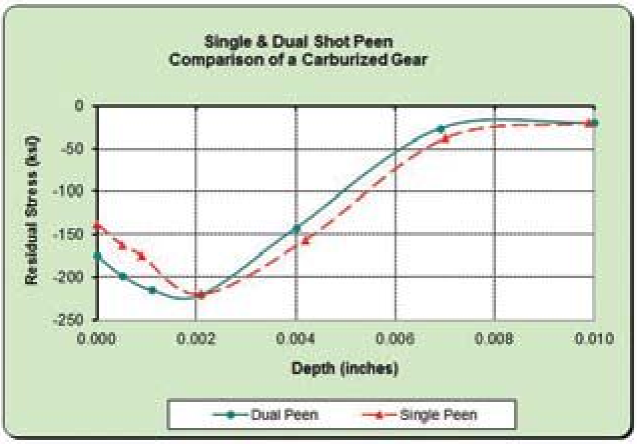


Figure 3. Single and Dual Shot Peen Comparison of a Carburized Gear

peen operation to a dual peen, the engine and transmission reached 50 hours of accelerated testing thus allowing the engine design for release.

The most common dual peening callouts usually have a larger steel shot followed by a smaller steel shot. An example is the following 330H-110H dual peen callout.

1st shot peen: 330H @ 0.016-0.020" A, 125% coverage
2nd shot peen: 110H @ 0.005-0.008" A, 125 % coverage

Some variations of a dual peen use a different media material for the second peen. It could be non-ferrous such as glass bead or ceramic media. When shot peening case-carburized gears, the benefit of using glass or ceramic is both medias are harder than traditional hard shot peening media (55-62 HRc) and the case-carburized surface (58-63 HRc).

Two benefits happen when using this type of dual peen on carburized gears, especially those that have the tooth flanks ground.

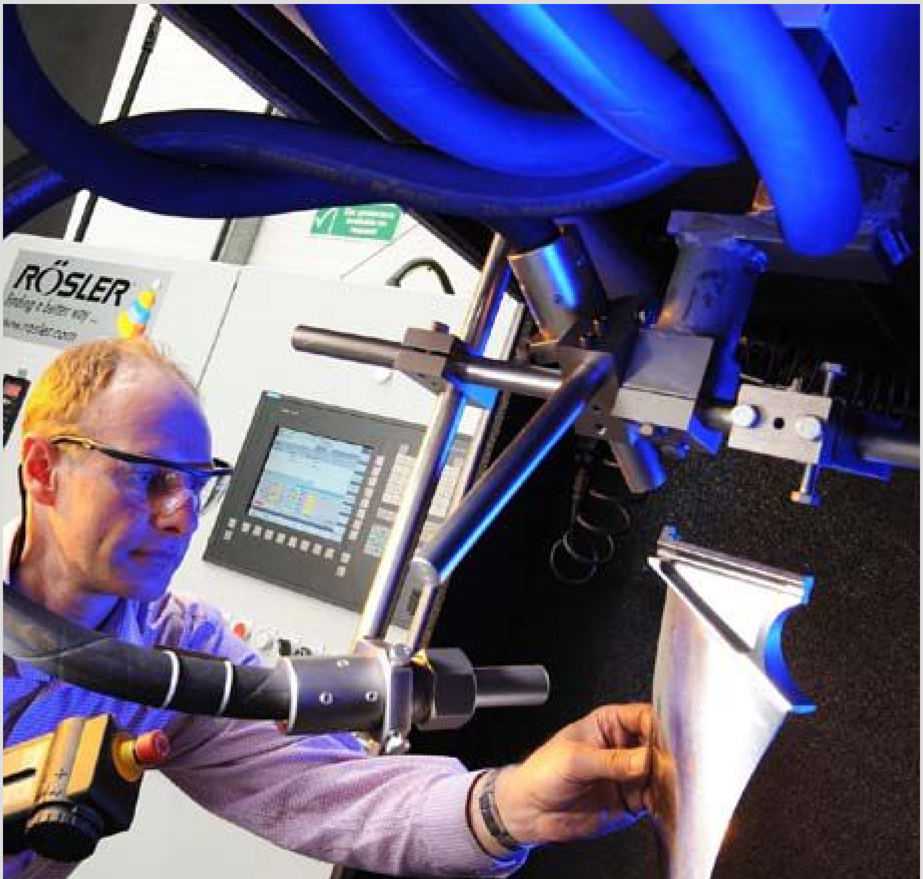
- The residual compressive stress and maximum compressive stress (from the first shot peen) is increased from the surface to about 0.002" depth. This happens because the glass/ceramic media is harder than the carburized surface (as opposed to being about the same hardness of the steel media). Higher values of residual compressive stress are produced thus offering better fatigue performance as this is where fatigue cracks initiate.
- The surface finish achieved from the first shot peen is improved resulting in a more refined surface finish. This reduces localized contact stresses from the rolling and sliding forces on mating gear tooth faces. Tooth flank failures from these mechanisms are a major cause of concern for gear engineers. It is accepted that a better surface finish on gear tooth flanks generally results in improved gear life.

Figure 4

Figure 4 shows the improvement in surface finish on a (35 HRc) steel component that was first shot peened with a 230H media around the face of the bore. Half of the bore face was then masked and the other portion had a secondary glass bead peen applied with a 0.006" Ø glass bead. Residual stress analysis was not performed on these surfaces but it is a safe assumption that the dual peened surface would have additional residual compressive stress at the surface.

When evaluating options to address fatigue failures, shot peening is usually considered along with changing materials, geometry and heat treatment. When evaluating options on a fatigue failure of a shot peened component, a dual peen should always be considered. No additional vendors have to be added to the manufacturing and some of the shot peening process steps (i.e., masking) do not have to be duplicated. This makes dual peening an attractive option from both a cost and manufacturing standpoint.

About the Author: Dave Breuer has worked with Metal Improvement Company (MIC), a business unit of Curtiss-Wright Surface Technologies, for over sixteen years. Mr. Breuer is the primary author of MIC's "Shot Peening Applications-Ninth Edition," a widely distributed international publication.



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Shot Stream Power and Force

INTRODUCTION

Shot peening is achieved by directing a powerful shot stream at components. The stream's power depends upon the velocity, flow rate and density of the shot and carrier fluid (normally either air or water). Much of the power of the shot stream is absorbed when it strikes a component causing dents, compressive residual stress and surface work-hardening. The force exerted on components is rarely considered – but is very important. This force can easily be measured, giving an insight into the relative contributions of shot and carrier fluid.

This article presents equations that allow reasonably accurate estimates to be made of a shot stream's power and the force that it can exert. The mathematical background to these equations is necessarily included - in order to justify the practical implications that are considered. A separate section summarizes the equations as an Excel worksheet - which can be used directly to estimate power and force for any shot stream situation. The equations show that air-blast shot streams normally have several hundred watts of power whereas wheel-blast streams have several kilowatts of power. The force that a shot stream applies (to reasonably flat surfaces) varies from tens of Newtons to hundreds of Newtons. Air, on its own, will exert a higher force than will an air/shot mixture – because of the drag-effect slowing down the air's velocity. For the rest of this article, air is assumed to be the carrier fluid. Calculations can readily be modified to accommodate a different fluid.

SHOT STREAM POWER

Shot streams are a mixture of shot particles and a carrier fluid – assumed hereafter to be air - moving at a high velocity. Shot stream power, **P**, therefore has two components; shot power, **S**, and air power, **L**. Hence: **P = S + L**. Shot power is the sum of the kinetic energies of those shot particles that cross a defined plane, AB, per second – see fig.1. Air power, **L**, is the kinetic energy contained by the volume of air that crosses the corresponding area, **A**, of that defined plane per second.

Shot Power, S

Shot power is kinetic energy per second summed for all of the particles crossing a defined area. Each shot particle crossing the area contributes its individual kinetic energy, $\frac{1}{2}mv_s^2$. Particles are striking the surface at a very high frequency. Coupled with the relatively high moment of inertia of a component that means that particle impact can be treated as if it was continuous. The shot feed rate, **M**, sums the mass of all of the particles fed during one minute. Hence we have, when using metric units, that:

$$\mathbf{S = M^*v_s^2/120} \qquad (1)$$

where **S** is in watts, **M** is in kg/minute and $\mathbf{v_s}$ is in meters per second.

As a typical air-blast example:
if **M** = 10 kg/minute and $\mathbf{v_s}$ = 50 ms^{-1} then **S** = 208 watts.

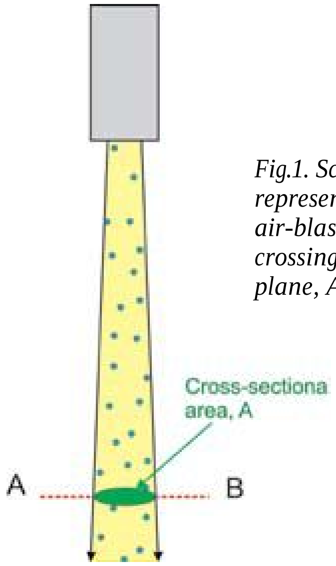


Fig.1. Schematic representation of an air-blast shot stream crossing a defined plane, AB.

Equation (1) is based on the familiar expression for individual particle kinetic energy, $\mathbf{\frac{1}{2}mv^2}$, summed for the total mass of particles fed during one second.

Use of imperial units requires a different divisor from that given in equation (1). Hence:

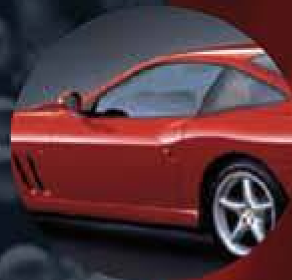
$$\mathbf{S = M^*v_s^2/2848} \qquad (2)$$

where **S** is still in watts but **M** is now in lb/minute and $\mathbf{v_s}$ is in ft/second.

Converting the values used for the metric example gives that M = 22 lb/minute and v_s = 164 ft/second. Substituting these values into equation (2) again gives that **S** = 208watts.

The feed rates for wheel-blast shot streams are an order of magnitude greater than those for air-blast machines. It follows that the corresponding shot power will usually be several kilowatts.



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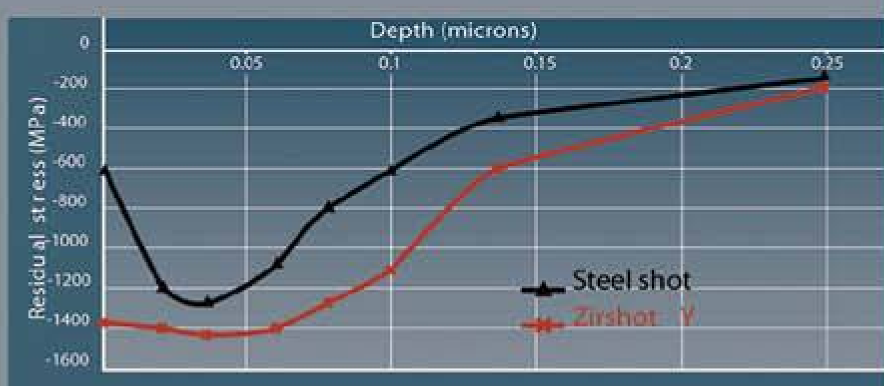

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Air Power, L

Air power, **L**, is the kinetic energy contained by the volume of fluid that crosses the defined plane per second. The volume of air passing across the plane per second, **V**, depends upon its velocity, $\mathbf{v_A}$, and the area of intersection, **A** (see fig.1). Now $\mathbf{V = v_A{*}A}$. The mass of any object is its density, **ρ**, multiplied by its volume. Hence: Air mass flow per second is given by $\boldsymbol{\rho}{*}\mathbf{v_A{*}A}$. Air power, **L**, is its kinetic energy, $\mathbf{½mv_A^2}$ summed for the mass of air crossing the plane per second. Therefore:

$$\mathbf{L = ½\ \rho{*}v_A{}^{3}{*}A} \tag{3}$$

where **L** is in watts, **ρ** is in $kg.m^{-3}$, $\mathbf{v_A}$ is in meters per second and **A** is in square meters.

The density, **ρ**, of air at atmospheric pressure, is 1.225 kgm^{-3}. For a stream of air passing through a standard area, A, of 0.001 m^2 (1000 mm^2) at a velocity, v_A, of 50 ms^{-1} equation (3) indicates that its power is 77 watts.

If, however, the fluid was water, with its density of 1000 kgm^{-3}, then for the same area and velocity used for the preceding example, the fluid stream power becomes 62.5 kilowatts!

Combined Shot Stream Power, P

The combined shot stream power, **P**, is the sum of shot power, **S**, and air power, L, as shown pictorially in fig.2. If we assume that shot and air velocities are almost equal we get, as a very close approximation, that:

$$\mathbf{P = M{*}v^2/120 + ½{*}\rho{*}v^{3}{*}A} \tag{4}$$

where **v** is the shared shot and air velocity.

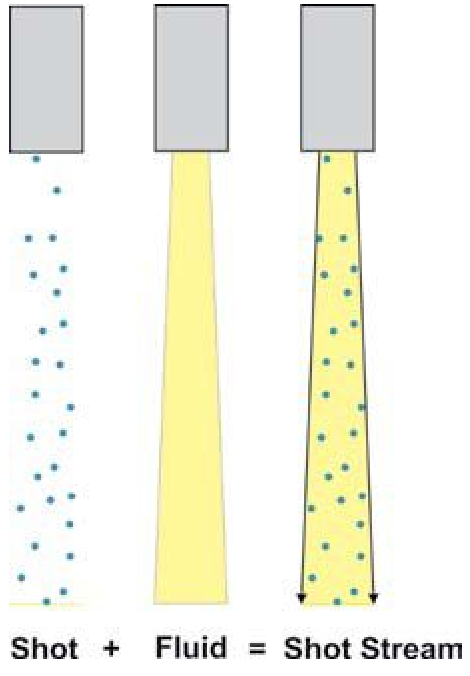

Fig.2. Constituents of a shot stream.

Shot and air velocities are equal at a 'neutral point distance' from a nozzle, i.e., when $\mathbf{v_S = v_A}$. This has also been termed the "sweet point" – which corresponds to a maximum in the peening intensity potential of a shot stream. Fig.3 represents schematically, the neutral point distance, **NP**. From the nozzle to the neutral point the air is travelling faster than the shot so that the shot particles are being accelerated. After the neutral point the shot is being decelerated.

If no shot has been added to a given air stream then its velocity must be greater at any given distance from the nozzle – as indicated in fig.3. The presence of shot particles means that the high-velocity air has to do work in order to accelerate the particles. Airflow patterns are also being disturbed as the air molecules have to find a way around the particles.

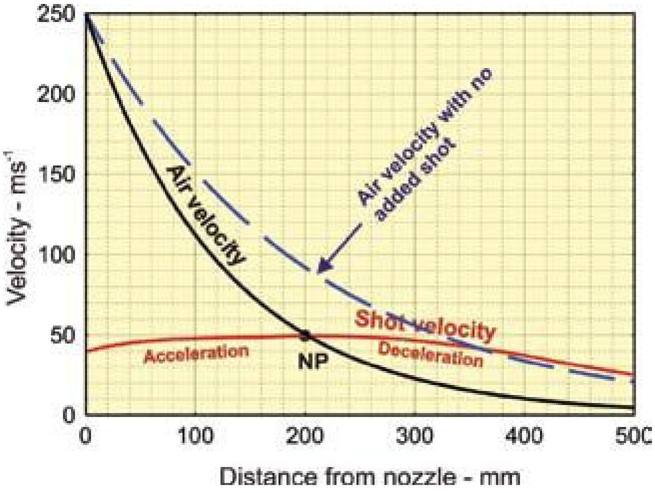

Fig.3. Neutral point, NP, when air and shot have equal velocities.

FORCE EXERTED BY SHOT STREAMS

Shot streams exert a force when they strike components. This force increases with increased power of the shot stream. Reasonable estimates of the forces involved can readily be obtained by invoking Newton's 2nd Law of Motion. This law can be written as:

The force exerted by a fluid stream is equal to the rate of change of momentum encountered on striking an object.

Momentum is mass multiplied by velocity. Rate of change of momentum is, therefore, mass times velocity divided by time. This leads to two 'textbook' equations that are relevant to shot stream force estimation:

Shot force, $\mathbf{F_s}$ = Mass x Velocity/Time or

$$\mathbf{F_s = M{*}v_s/60} \tag{5}$$

Where **M** is the feed rate in kg/minute and $\mathbf{v_s}$ is the shot velocity in ms^{-1}.

$$\textbf{Air force, } \mathbf{F_A = \rho{*}A{*}v_A{}^2} \tag{6}$$

Where **ρ** is the air density in kg/m3, and $\mathbf{v_A}$ is the air velocity in ms^{-1}.

Equation (5) shows that the force exerted, by just the shot particles, is a linear function of both feed rate and shot velocity. Equation (6) shows that the force exerted by the air alone is a linear function of the cross-sectional area, A, but increases with the square of the air velocity. Fig.4 illustrates the velocity-variation of the two force components over practicable ranges of shot feed rates and stream cross-sectional area. It is noteworthy that at high velocities the examples show that air tends to exert a much higher force than does the shot.

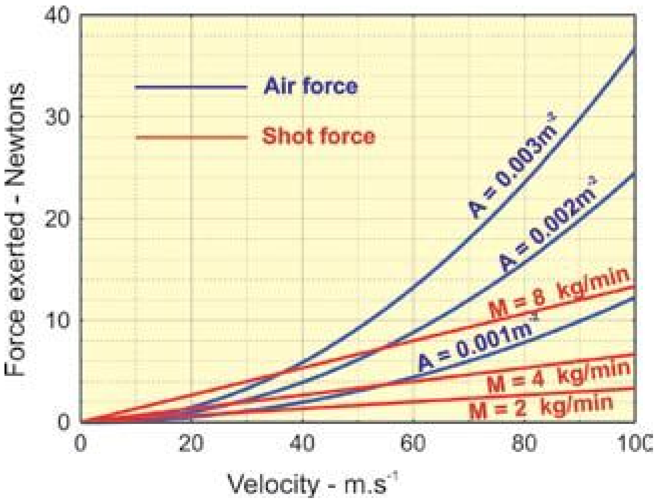

Fig.4. Force variation for separate air and shot components of a shot stream.

Shot stream force, **F**, is estimated by adding the shot and fluid force components so that:

$$\textbf{Shot stream force, } F = M^*v_S/60 + \rho^*A^*v_A^2 \qquad (7)$$

Even if we know **F**, **M**, **ρ** and **A**, equation (7) still contains two 'unknown quantities': $\mathbf{v_S}$ and $\mathbf{v_A}$. Fortunately, most shot peening is carried out at, or near to, **NP**, the 'neutral point distance' when $\mathbf{v_S}$ and $\mathbf{v_A}$ equal one another. The addition of forces for equal air and shot velocities is illustrated in fig.5. This uses an example when M = 4 kg/minute and A = 0.002 m^2.

For point X in fig.5, it can be seen that air contributes 6.25 N and the shot contributes 3.75 N to the total of 10 N. The common shot and air velocity at the point X is 52 m.s^{-1}.

FORCE MEASUREMENTS

Shot stream forces can easily be measured directly. Fig.6 shows a schematic representation of a direct force measurement device.

Force can be indicated by several types of instrument – from a dedicated load cell to a simple household weighing scale. The type of facility indicated in fig.6 is readily portable and can be inserted into various locations in a shot peening machine: - for example to assess a multi-nozzle arrangement.

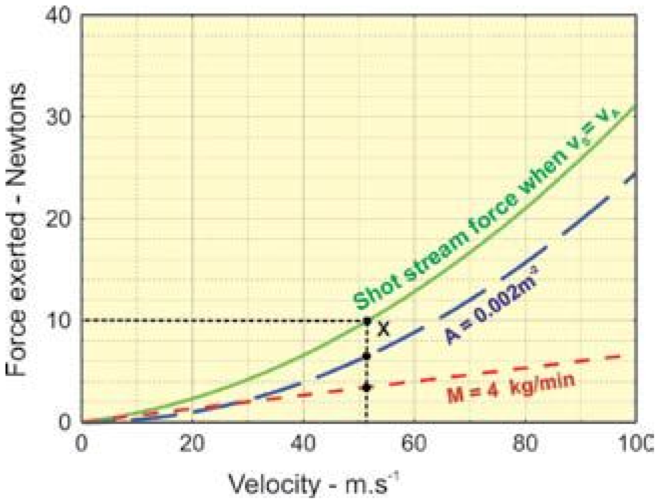

Fig.5. Shot stream force when air and shot velocities are equal to one another.

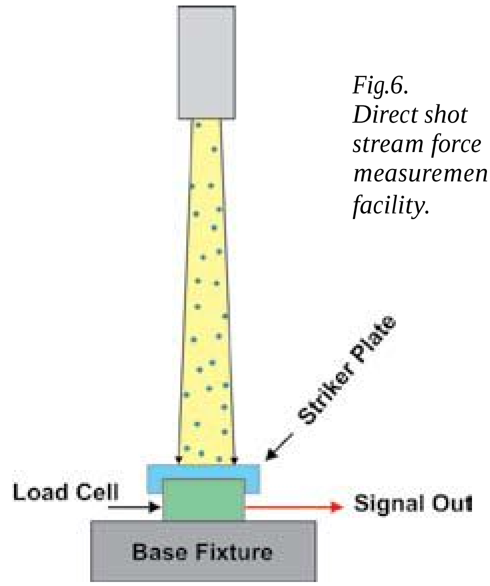

Fig.6. Direct shot stream force measurement facility.

FORCE MEASUREMENT STUDIES

Measurements have been made involving different air pressures and shot feed rates. These measurements were carried out at Electronics Inc. under the supervision of Jeff Derda. The setup involved the use of a highly controlled air-blast cabinet, S230 shot, 8 mm nozzle at 150 mm from a target steel plate on a protected digital weighing scale. Shot indentations on the steel plate indicated a circular impact region having a diameter of 49.5 mm. That translates to a target area, A, of 1924 mm^2. Table 1 on page 30 details the twelve measurements obtained (converted from Imperial to S.I. units). Analysis of the data in Table 1 can be carried out using graphical representations.

Table 1. Force Measurement Data Obtained by Electronics Inc.

Air pressure	Measured forces - Newtons			
	Air-only	Air + 2.2kg/min	Air + 4.5kg/min	Air + 7.0kg/min
20 psi (1.4 atm)	7.6	5.8	4.9	4.0
40 psi (2.7 atm)	14.7	12.9	11.1	10.5
60 psi (4.1 atm)	22.7	18.7	17.8	17.4

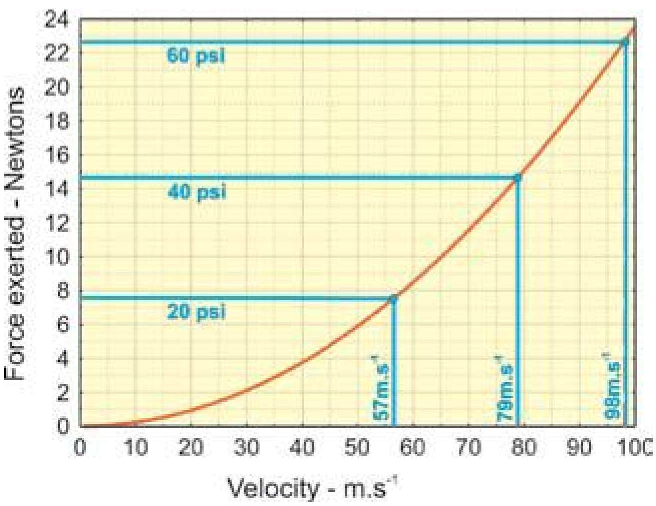

Fig.7. Force predicted with air-only stream striking a circular area of 1924 mm^2.

Fig.7.represents the 'Air-only' data, indicating: (1) that the force exerted increases directly with the air pressure and (2) that the inferred air-only velocities are 57, 79 and 98 m.s^{-1} for 20, 40 and 60 psi pressures respectively.

Before analyzing the air-plus-shot data it is important to bear in mind that:

Shot added to an air stream must slow it down.

The amount of air velocity reduction will increase with the proportion of shot in the mixture.

Fig.8 represents the shot feed rate of 4.5 kg/min accelerated by an air pressure of 40 psi. The measured value of force being exerted by this combination was 11.1 Newtons (see Table 1). A force of 11.1 Newtons intersects the air-plus-shot line at point X in fig.5. The common velocity for the air and shot will, therefore, be 54 ms^{-1}. The air velocity for air flow on its own at 40 psi is 79 ms^{-1}. Hence it can be deduced that the shot, when fed at 4.5 kg/min, has slowed down the air velocity of the shot/air stream from 79 to 54 ms^{-1}. Such a reduction, 25 ms^{-1}, is perfectly reasonable. It should be noted that air on its own at 79 ms^{-1} exerts a force of 14.7 Newtons – significantly greater than the 11.1 Newtons for air-plus-shot at the same nozzle pressure.

Similar analysis can be applied to each of the nine air-plus-shot values. Graphical analysis is unnecessary if the required calculations are incorporated into, say, an Excel worksheet. Table 2 presents the results of a worksheet analysis of the Table 1 data.

Table 2. Analysis of Data Showing Estimated Velocities and Retardation Effect

Air pressure - psi	Parameter	Air only	Air + 2.2kg/min	Air + 4.5kg/min	Air + 7.0kg/min
20 (1.4 atm)	Force - Newtons	7.6	5.8	4.9	4.0
	Retardation – Newtons	-	1.8	2.7	3.6
	Velocity - ms^{-1}	56.8	42.4	32.4	23.3
	Retardation – ms^{-1}	-	14.4	24.4	33.5
40 (2.7 atm)	Force - Newtons	14.7	12.9	11.1	10.5
	Retardation - Newtons	-	1.8	3.6	4.2
	Velocity - ms^{-1}	79.0	66.6	54.5	46.4
	Retardation – ms^{-1}	-	12.4	24.4	32.5
60 (4.1 atm)	Force - Newtons	22.7	18.7	17.8	17.4
	Retardation - Newtons	-	4.0	4.9	5.3
	Velocity - ms^{-1}	96.1	81.6	72.4	64.7
	Retardation – ms^{-1}	-	16.5	25.7	33.5

"Retardation" is the difference between the estimated 'air only' values and the values when shot is being fed into the stream. For example: at 20 psi applied pressure the air velocity is 56.8 ms^{-1} with no added shot. This is reduced to 42.4 ms^{-1} when 2.2 kg/min of shot is added. The difference (56.8 minus 42.4) is the retardation value of 14.4 ms^{-1}. Retardation increases with shot feed rate for each of the force and air velocities. Retardation is, however, very similar for different air pressures but a constant feed rate. For example: with a feed rate of 4.5 kg/min the retardation is 24.4, 24.4 and 25.7 ms^{-1} for 20, 40 and 60 psi air pressures respectively.

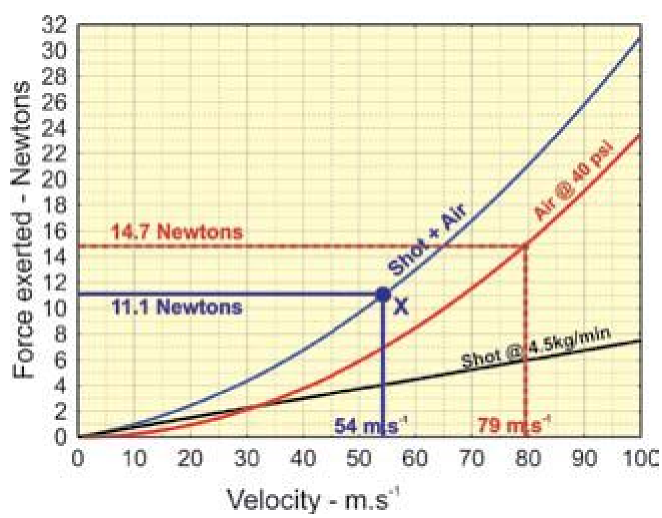

Fig.8. Force exerted with a feed rate of 4.5 kg/min and an air pressure of 40 psi.

POWER AND FORCE ESTIMATION

The equations presented for estimating power and force can easily be fed into an Excel worksheet. One example is presented as Table 3 (page 32), where the column heading letters correspond to those in an Excel table as do the row numbers.

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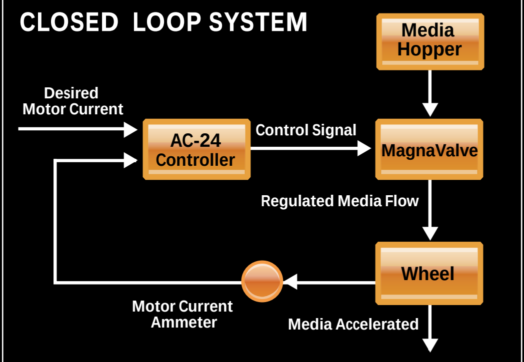

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Table 3. Excel Worksheet for Estimating Shot Stream Power and Force

A	B	C	D	E
3	Feed rate	M	5	kg/minute
4	Shot velocity	v – shot	50	m/second
5	Fluid velocity	v – fluid	50	m/second
6	Fluid density	ρ	1.225	kg/cubic meter
7	Cross-sectional area of shot stream	A	0.001	meters squared
10	Shot power	S	104	watts
11	Fluid power	L	77	watts
13	Shot stream power	P	181	watts
15	Shot force	F_S	4	Newtons
16	Air force	F_A	3	Newtons
17	Force applied on flat surface	F (F_S+F_A)	7.2	Newtons

Values of variables are entered into rows 3 to 7 of column D to yield the required estimates (given in red). Table 4 gives a number of examples, illustrating the range of power and force that can be encountered for different shot streams, obtained using the worksheet.

Table 4. Estimates of Shot Stream Power and Force Exerted on a Flat Surface

M – kg/minute	5	10	20	10	100
V_s –m.s^{-1}	100	100	100	50	50
V_L –m.s^{-1}	100	100	100	50	50
ρ	1.225	1.225	1.225	1.225	1.225
A	0.001	0.001	0.001	0.001	0.01
Power, P - watts	1029	1446	2279	208	2849
Force, F - Newtons	20.6	28.9	45.6	11.4	114

DISCUSSION

Shot stream force and power can be regarded as useful complements to established parameters: such as peening intensity, coverage and residual stress profile. They enable different aspects of the process to be controlled.

The force required to propel a shot-plus-air stream has been the subject of previous studies by Robert A. Thompson of the General Electric Company. His 1989 patent (U.S. Patent Number 4,848,123) included the incorporation of a force sensor behind the peening gun to monitor the reaction force of the shot peening gun. Hence the force required to propel the shot stream out of the nozzle was being measured. That is different from the force that a shot stream imparts onto a workpiece – which varies with distance from the nozzle. The device recommended in this article monitors shot streams directly and has the advantage of being removable from the peening cabinet.

Assessment of force due to the air flow alone can be used as a check on air supply from the nozzle. Force variation is a direct function of the air pressure being supplied to the actual nozzle. Hence it would be possible to confirm the validity of any air pressure meters - they must, of necessity, be back stream of the nozzle.

Assessment of force due to a given shot stream (air-plus-shot) will indicate (a) the potential for component distortion during the actual peening process and (b) if previous assessments using the same peening parameters are being maintained. Component distortion due to the force applied by a shot stream will be the theme for the next article in this series.

The power and force equations presented in this article are based on fundamental laws of physics. They do not have to be understood in order for them to be utilized. Excel worksheets can be devised or obtained from the author via email at shotpeener@btinternet.com.

Force measurements can be made using quite simple equipment. The force equations have enabled the effect of shot on slowing down air stream velocity to be quantified. The measurements also allow an estimate to be made of the common air and shot velocities that reign at the neutral distance ("sweet point") from the nozzle. The force equations presented in this article can be modified to accommodate different anticipated velocity differences.

Shot peening should normally be carried out with a nozzle-to-workpiece distance at, or close to, the neutral distance. That is where the shot particles have their maximum velocity and hence their maximum peening intensity potential. The neutral distance can be established by experimentation. Two techniques that have been used are (a) to produce saturation curves for various nozzle-to-workpiece distances and (b) to peen polished mild steel strips at various nozzle-to-strip distances using a low coverage regime. The average diameter of indentations is a direct measure of the shot stream intensity. Mild steel is recommended because it is relatively photogenic, facilitating indent diameter measurements.

The potential for applying large forces can readily be quantified using the equations presented in this article. Very large forces can plastically distort thin sheet metals. For example: Waterjet streams have been utilized as a shaping process for annealed, 0.3 mm thick, aluminum sheet. Steel shot had to be added to the water stream to generate large-enough forces to plastically form stainless steel sheet (Iseki et al, Key Engineering Materials, p. 575, vol. 344, 2007). The use of water underlines the significance of carrier fluid density incorporated into this article's equations.


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Curtiss-Wright Surface Technologies to Open Third Asian Operating Facility

IN ORDER TO SUPPORT the fast emerging aerospace, defence, power generation and general industrial markets within the region, Curtiss-Wright Surface Technologies (CWST) is delighted to announce the opening of an operating facility in the Bangalore area of India. Our initial services in Bangalore will include the same high quality controlled shot peening as CWST currently supplies to North American and European OEM's and their subtier machining vendors; and will be expanded as requirements dictate to encompass shot peen forming, engineered coatings, thermal spray and analytical services.

Our new Indian operating facility will be an important and critical addition to the local supply chain within India and will also provide a platform for further expansion of CWST's locations and services throughout Asia.

CWST opened its first Asian operating facility in 2009 providing controlled shot peening and engineered coatings within the Suzhou area of China, close to Shanghai. This was closely followed by a second Chinese facility based in the Tianjin region, close to Beijing, supporting the local aerospace and automotive manufacturing supply chain business. Tianjin is fast becoming one of the largest evolving vehicle production centres within the region. CWST has already seen an increasing demand for its range of critical treatments and services in other areas of Asia and has recently added laser peening technology to the list of available processes to its operations centre based in Singapore.

The Indian aerospace industry is one of the fastest-growing aerospace markets in the world, including civil and military aviation and space and this has attracted major global aerospace companies to the area. There is also a significant planned expansion of India's power plants over the next five years in order to meet the greater demands for energy as manufacturing expands within the region. Boeing has projected a demand for 1,450 new commercial aircraft worth $175 billion over the next 20 years. In the near term, India's defence budget has been set at $40 billion for the 2013 -2014 financial year, with a large proportion of this specifically earmarked to modernise their forces by acquiring new assets, including combat aircraft and Boeing helicopters. In addition, commercial aviation expenditure, assuming current demand remains unaffected, is expected to be in the region of $25 billion. These factors will drive more growth in this area.

Many of the West's main OEM's are moving their manufacturing and sub-contract work to India to take advantage of local government support, relatively lower costs, availability of talent, the capabilities of its information technology firms and its location between the major markets in East Asia, the Middle East and Europe.

Our aerospace customer portfolio includes the prime OEM's and R&O's in the West covering airframe, aero-engine, undercarriage and actuator systems. Our other main markets include transportation, power generation, oil and gas, medical and other general industrial industries where pushing component performance to the limit is critical to reducing maintenance costs and downtime.

CWST currently has a network of over 72 facilities in North America, Europe and Asia to meet the logistical requirements of our customers and is a business unit of the Curtiss-Wright Corporation (CW:NYSE) who provide highly engineered products and services to the motion control, flow control and material processing industries.

The history of Curtiss-Wright Corporation started over 100 years ago when the Wright Aeronautical Corporation, founded by Orville and Wilbur Wright, and the Curtiss Aeroplane and Motor Company, founded by Glen Curtiss, merged to form the Curtiss-Wright Corporation. In 1929, it founded the China National Aviation Corporation, based in Shanghai, in partnership with the Chinese government. The China National Aviation Corporation played a significant role in the history of modern India and China by pioneering the famous routes over the Himalaya Mountains (the Hump) between India and China which during World War II became the only source of outside supply for China.

Shot peening equipment in the Metal Improvement Company facility in Suzhou, China.


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Brian Cappallo Promoted to Wheelabrator Plus US Sales and Service Manager

Wheelabrator Plus is pleased to announce that Brian Cappallo has been promoted to USA Sales and Service Manager for Wheelabrator Plus and will work out of the LaGrange, Georgia facility. Brian joined Wheelabrator Plus in 2007 and most recently was Regional Sales Manager based in Texas. Brian has worked in the blast industry since 2004.

Wheelabrator Group is a global provider of surface preparation and finishing solutions. Committed to offering the broadest array of technologies, products, replacement parts, services and technical know how, the Wheelabrator Group works closely with customers to deliver the best solutions for their specific requirements.

For more information, email info@wheelabratorgroup.com or visit www.wheelabratorgroup.com.

COMPANY PROFILE

Quality Engineering | *www.qes1.com* | *(203) 269-5054 or 1-800-637-6809*

Quality Engineering Services: More Than Masking

QUALITY ENGINEERING SERVICES is known in the shot peening industry for its cast-urethane, molded-masking products. The aerospace industry, in particular, appreciates the company's extremely short lead times and competitive pricing. The "soft tooling" aspect of cast-urethane masking also offers the unique characteristics of resistance to abrasive wear, exceptional elongation and rebound, chemical resistance, cut-and-tear resistance and high-tensile strength.

In addition to shot peening applications, Quality Engineering's cast-urethane products are used for turbine blade and vane airflow and water flow testing seals, grit blast masking, cost-efficient prototypes, foreign-object prevention and more.

More than Masking

Cast-urethane masking products are only one component of Quality Engineering Services' offerings: They specialize in the design and fabrication of precision tooling and gaging for the aerospace industry and other industrial manufacturers. The privately owned company is located in Wallingford, Connecticut and employs over 45 people. Their fully integrated management team is capable of handling projects from design conception through tool/gage tryout. Quality Engineering Services is an ISO 9001:2008 registered and AS9100:2009 Certified company. Quality Engineering is an approved tooling supplier to Pratt & Whitney, Sikorsky, GE Aviation, GE Canada, Lockheed Martin, Pratt & Whitney Aviation Canada, and many more.

Fabrication

Quality Engineering Services' tool and gage manufacturing department is capable of producing fixtures and gages to tolerances of ± .0002. They manufacture a wide range of items including Turbine Blade and Vane Tooling, EDM Fixtures, Location Gages, RTM Molds, Preform Tools, Lifting Devices, Vacuum Milling Fixtures, Assembly Tooling, CMM Nests, Tool Fabricating, Grinding Fixtures, Feather Seal Slot Gages, Holding Fixtures, Air Flow Fixtures, and more.

Design

Quality Engineering's design department states that their designs are machine-shop friendly, reducing initial build costs as well as future repair costs. They use Unigraphics NX software, which allows the tools to be designed quickly and efficiently and changes can easily be incorporated. This is especially important when the tools are being designed concurrently with the product for which they are intended.

Composite Tools

Quality Engineering is made up of highly experienced Class A Toolmakers, Unigraphics and Catia designers that have been designing and building composite tools for over 20 years. Their primary focus is on aircraft engine components, aircraft structures and missiles. Quality Engineering designs and builds complex resin transfer molds, autoclave, multi-piece release and compression molds for both the aerospace and commercial sectors. They produce all required secondary tooling, trim tools, and drill jigs.

Prototype Machining

Quality Engineering has the technical capability to manufacture low-volume, high-precision machine components and special machinery within tolerances of ± .0002. The company will custom manufacture special process equipment, integrated systems, semi-automated tools and assembly tools.

Selective Lasering Sintering

Quality Engineering designs and develops low-volume prototype SLS (Selective Laser Sintering) tooling for aerospace and commercial parts for a variety of applications. The SLS process is capable of producing snap fits and moving hinges. The maximum dimensions for a single piece item is: 26" x 14" x 21". Additionally, SLA (Sterolithography) parts are produced for fit, form, and function as well as demonstration and show model pieces. Approximate maximum dimensions for a single piece item is: 20" x 20" x 20". Larger two-piece constructed parts can be produced from both the SLA and SLS processes.

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New Carbon Monoxide Monitor/Alarm for Abrasive Blast Machine Operators

A NEW CMS-3 MONITOR detects carbon monoxide (CO) in the breathing-air supply and triggers audible, visual, and vibratory alarms when CO is detected in concentrations of at least 10 parts per million. The alarms alert the abrasive blast operator to an unsafe condition.

CMS-3 Features
- Digital liquid crystal display (LCD)
- Audible, visual, and vibrating alarms
- Low battery alarm
- Sensor fail alarm
- Replaceable sensor and battery

Advantages
- Blast operator can work independently. No need to rely upon others to warn operator or take action when monitor alarms. No need for remote alarm; each user is individually protected for instant awareness of a hazardous condition.
- Unit is small, lightweight, and conveniently worn inside blast respirator.
- Requires no external connections or hoses.
- Unit can be calibrated in minutes, is easily installed, and easily removed.
- Long-life, economical easy-to-replace sensor with estimated sensor life of two years.
- Unit uses small commonly-available lithium easy-to-replace battery with estimated life of 3000 hours.
- Microprocessor controlled with digital read-out for accurate readings.

Requirements for Operation
- Battery installed in the CMS-3
- 25 ppm calibration gas, calibration cup and connector
- Grade D or ambient-air breathing-air supply for the abrasive blast operator
- Thorough familiarity with the CMS-3 instructions

Description of Operation
OSHA requires Grade D quality breathing air and NIOSH-approved Type CE continuous-flow supplied-air respirators for abrasive blast operators. OSHA regulations call for a maximum exposure limit to carbon monoxide of 10 parts per million (ppm). When the presence of carbon monoxide is detected at this level, the CMS-3 emits an audible alarm, a visible flash, and the unit vibrates. When an alarm occurs, the user should remove the respirator immediately when it is safe to do so. To prolong battery life, turn unit off when not in use; turn unit on and re-install at beginning of work shift.

Introducing the Clemco CMS-3 CO Monitor: Small, portable protection for individual blast operator safety.

Specifications
- Sampling by diffusion
- Operating temperature and humidity range: -4 to 104˚F (-20 to 40˚C); up to 85 percent relative humidity (non-condensing) factory set at 10 ppm
- Accuracy rating: plus or minus 2 ppm
- Powered by 3-volt coin-type lithium battery (CR2450)
- Continuous operation: approximately 1 year of normal use (3000 hours)
- Unit calibrated with 25 ppm test gas; optional impurity-free gas available for fresh-air setting audible, vibratory, and visual alarms
- Low-battery warning given by visual flashing indicator
- Dead battery indicated by audible alarm
- System failure warning given by audible alarm
- Attachment to respirator: VELCRO®
- Warranty: 2 years material and workmanship

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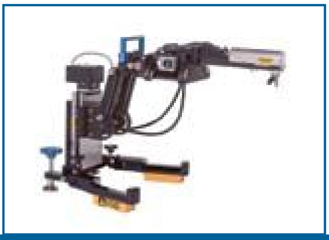

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www.protoxrd.com
1 (800) 965-8378

USA
Proto Manufacturing Inc
313-965-2900
xrdlab@protoxrd.com

Canada
Proto Manufacturing Ltd
519-737-6330
proto@protoxrd.com

Japan
Proto Manufacturing KK
047-402-2703
info@protoxrd.jp