Spring 2025
Volume 39, Issue 2 | ISSN 1069-2010

The Shot Peener

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

A Salute to Professor David Kirk

Plus:

- Ventilation in Blast Machines
- Purdue University Research
- Work-Hardening During Peening

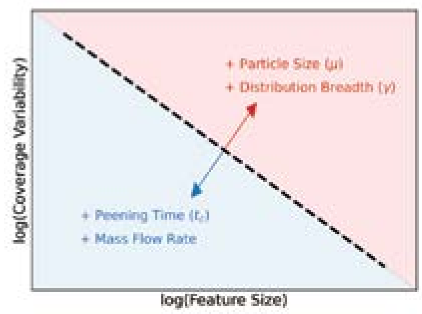


Figure 1 from the article titled "Probabilistic Assessment of Shot Peening Impact Coverage."

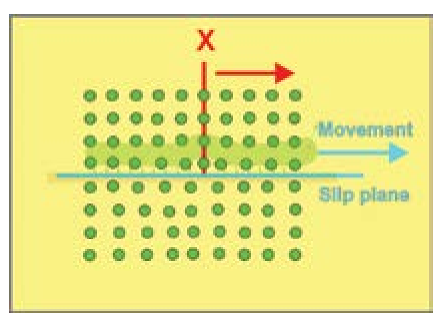
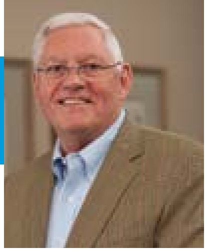


Figure 3 from Professor Kirk's article titled "Work-Hardening During Peening."

THE SHOT PEENER

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



OPENING SHOT
Jack Champaigne | Editor | The Shot Peener

Professor David Kirk's Contribution to My Life

Now that Professor Kirk has announced his retirement from contributing articles to *The Shot Peener* magazine, I am reminiscing about our long relationship. We all have special people in our lives that have made big differences. For me, Professor David Kirk is at the top of my list of special people. I remember meeting him the first time in 1993 at the 5th International Conference on Shot Peening (ICSP5) in Oxford. We stayed in dorm rooms on the Oxford campus—the students were on vacation. The rooms were quite large with very tall ceilings and the bathroom was down the hall. I got the feeling of being a student all over again. (I could now tell my friends that I attended Oxford.) The conference room was nearby and with the students gone we had the campus all to ourselves.

I noticed Dr. Kirk was quite busy and seemed to be doing a one-man show using only a staff member to run the projector. Dr. Kirk performed all the steps needed for a successful conference. He received the manuscripts and assembled them into proper categories and then pre-printed the proceedings for availability at the conference. He then reprinted the final program, eliminating the papers that were not presented by their authors. I purchased a large quantity for re-sale at our website and later converted each document into a PDF for on-line sharing.

Upon meeting David in person at ICSP5, he asked me to serve on the international committee. I was given the honor of sitting at the "High Table" at the conference banquet. That indeed was a high honor. After the dinner, I joined the committee for the triennial meeting and answered questions about venues in the United States. I described several choices since I had experience with planning our annual U.S. shot peening workshops. I thought it was unusual that the questions kept coming back to San Francisco. The committee voted on that site and the following day I visited David at his office. I saw a calendar with photos of San Francisco on his office wall. Mystery solved.

After spending time with Professor Kirk, I was so impressed with his knowledge of the shot peening process that I asked him to write for *The Shot Peener*.

This was the beginning of a long and treasured friendship.

Professor David Kirk and I at the 2018 Shot Peening Seminar in the United Kingdom.

THE SHOT PEENER

Editor
Jack Champaigne

Associate Editor
Kathy Levy

Publisher
Electronics Inc.

For a free subscription of *The Shot Peener,* go to www.theshotpeenermagazine.com

The Shot Peener
56790 Magnetic Drive
Mishawaka, Indiana, 46545 USA
Telephone: 1-574-256-5001
www.theshotpeenermagazine.com

AUTOMATED SHOT PEENING SOLUTIONS

EMPIRE™ ABRASIVE EQUIPMENT

HIGH PRODUCTION

FIXED GUN AND HORIZONAL/VERTICAL LINEAR OPERATIONS

PRECISION PROCESSING

CONSISTENT & UNIFORM BLAST COVERAGE!

GUARANTEED REPEATABILITY!

CUSTOM PEENING SOLUTIONS AVAILABLE

EMPIRE™ ABRASIVE EQUIPMENT

Gibson

MULTIPART PROCESSING

NO MANUAL FLIPPING REQUIRED!

PROCESS LARGE BATCHES OF SMALLER PARTS TOGETHER!

DUAL CHAMBER DESIGN FOR INCREASED PRODUCTION

360° PART COVERAGE!

Empire Abrasive Equipment 2101 W. Cabot Blvd. Langhorne, PA 19047 215-752-8800 airblast@empire-airblast.com www.empire-airblast.com **Gibson Abrasive Equipment** 7988 Centerpoint Drive Suite 400 Indianapolis, Indiana 46256 317- 758-6775 Toll Free: 888-867-1619 gibson@gibson-equipment.com www.gibson-equipment.com

A Salute to Professor David Kirk

While the staff of *The Shot Peener* is very sorry to lose a valued contributor to the magazine, we recognize that Professor Kirk deserves to retire at 92 years of age!

The following are quotes from some of the people that have been influenced by his advancement of our industry.

I am so grateful for the friendship and the mentoring that you have provided. You have been the most influential person in my career. Thank you for all you did for me and the shot peening community.

— Jack Champaigne
Editor of *The Shot Peener*
President of Electronics Inc.

As Associate Editor of The Shot Peener, I have worked with Professor Kirk for almost 30 years. He has been a pleasure to work with as he always sent his articles before the deadline and they were free of typos! Preparing articles of his quality four times a year is no easy feat and I've often wondered how he did it. We will continue to run David's older articles as many of our readers are new and haven't had the benefit of his knowledge.

When you work with someone for as long as I did, you get to know them on a personal level—David's beautiful garden was a favorite topic. The following is a photo of his garden taken in 2019.

— Kathy Levy
Associate Editor of *The Shot Peener*

Professor Kirk's garden at his home in Kenilworth, England

I would like to express my heartfelt respect for Professor Kirk's long-term contributions to The Shot Peener and his great support to those involved in peening.

As a leader of the shot peening society, he has supported international conferences for many years and given advice to many researchers, which has now led to many new findings.

We, as one of your successors, would like to follow your professor's intention and make our efforts to research and public relations in order to perpetuate shot peening technology.

—Yoshihiro Watanabe
TOYO SEIKO CO. LTD.

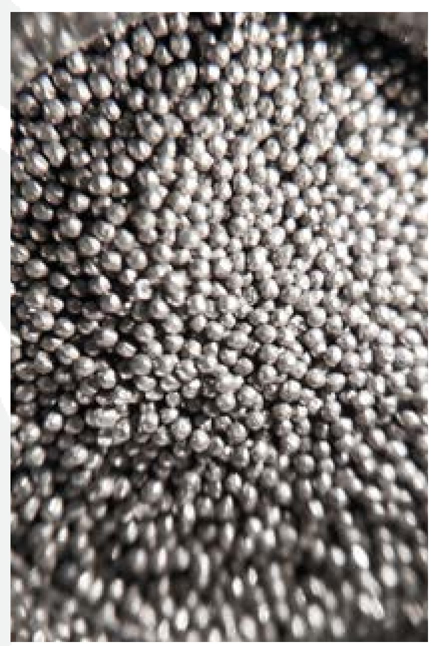
I observed Dr. Kirk's training session at an Electronics Inc. workshop in Warwick, England. Even though he is a renowned academic in the field of shot peening, he was able to relate to Level One and Level Two students on a very basic level. I remember him using tennis balls to demonstrate how shot works. There was no question that the students were engaged and appreciated his class.

—Tom Brickley
Vice President at Electronics Inc.

Professor Kirk has been a gift to the peening world by sharing his knowledge via a catalog of plain-spoken Shot Peener articles.

—Dave Barkley
EI Shot Peening Training Director

David Kirk, Jack Champaigne, and Dave Barkley at the 2018 Shot Peening Seminar in the United Kingdom



ABOUT PROFESSOR DAVID KIRK

Professor David Kirk was born into a multi-generational steel-working family in Rotherham, South Yorkshire, England. His grandfather was the operational head of a rolling mill and his father was an open-hearth steelmaker and a part-time lecturer at Rotherham College of Arts and Technology. David won a scholarship to a local grammar school and his academic success secured three scholarships to the University of Birmingham where he studied Industrial Metallurgy. He was the first member of his family to attend university. Professor Kirk received a Department of Science scholarship after graduation. He then obtained a doctorate for a thesis titled "The Hot Working of Metals."

Professor Kirk's employment as a Research Fellow at the University of Birmingham proceeded a short period as a Senior Research Metallurgist at the International Nickel Company's Research Laboratory in Birmingham. Professor Kirk then joined Coventry University as a Senior Lecturer in Metallurgy. He was promoted to Principal Lecturer in Metallurgy and then Chairman of the School of Materials at Coventry University. His initial research focused on X-ray residual stress measurement. This work prompted him to establish Coventry Science Consultants Ltd. Professor Kirk installed a shot peening research laboratory at the university with active encouragement and advice by the late Jack Plaster.

Upon retirement from the university, Professor Kirk became a Visiting Research Fellow and then was a Visiting Professor of Materials at Coventry University. Following his organization of the 5th International Conference on Shot Peening, he was elected Chairman of the International Scientific Committee for Shot Peening. The International Scientific Committee has since granted him "Life Member" status.

Professor Kirk received the 2001 "Shot Peener of the Year" award for his significant contributions to the advancement of shot peening.

IN HIS OWN WORDS

Most of my earlier articles in The Shot Peener were based on research carried out at Coventry University. A few years after I retired, both my X-ray and shot peening laboratories closed down. I was the only person using them and then only for about two hours a week. Small items donated to me personally, such as an Almen Gauge, Almen strips, and shot samples, I took home where I carried out further experimental work.

Years ago I was foolish enough to believe that I knew enough to write a textbook on "The Science of Shot Peening." After a few months I realized that there was a very great deal that I did not understand. Subsequent articles in The Shot Peener were the fruit of my attempts to rectify that situation.

Editor's Note: Professor Kirk is irreplaceable but we wish him the best in his well-deserved retirement from his lengthy and prolific writing career.

ICSP15 Conference Accommodations

September 22 -25, 2025

Purdue University School of Materials Engineering

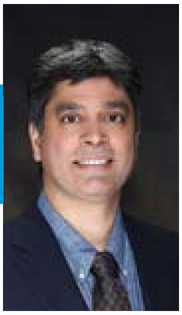
The Purdue campus is home to the iconic Union Club Hotel. Attendees are not required to stay at the Union Club Hotel but it is very convenient to the conference. Attendees should use the website (https://icsp15.org) to register for rooms.

For more information on the hotel—including photos of its spa, restaurants, bars, and rooms designed as a contemporary nod to Purdue University's classic brand—visit www.purdueunionclubhotel.com.

Should you choose to make a reservation: Check-in on Monday, September 22 and check-out on Thursday, September 25. You will be asked to provide a credit card to hold your room, but no charge will be placed on the card until shortly before the conference.


Blasting Nozzles & Liners
Nylon Holders & Couplings
Accessories for Air & Shot Blasting
HMT GmbH
Serge Weydert
General Manager Europe
4, um Bierg
9170 Mertzig
Luxembourg
Tel: 00352 691 968613
Email: weydert.s@hmt-cera.com
URL: http://www.hmt-cera.com

AN INSIDER'S PERSPECTIVE



Kumar Balan | Blast Cleaning and Shot Peening Specialist

Ventilation in Blast Machines

Introduction

Without an exception, every functional blast machine whether cleaning, peening, or performing a similar action, is ventilated by a dust collector and exhaust fan. This collector takes several forms from a simple "sock" in a small manual blast cabinet to a programmable cartridge-type collector or wet collector for special applications. For those of you wondering the relevance of this discussion to shot peening machines, a vast majority of your airblast peening machines use the ventilation volume and exhaust fan static pressure to pneumatically convey the media through the machine. This is commonly referred to as "vacuum reclaim." Before we get into the depth of our discussions, allow me to relate my initiation into ventilation and dust collection as a young engineer in India.

My employer was a company that manufactured dust collection systems to ventilate any dust emanating source including blast machines. This comprised of furnaces for fume extraction, cement plants with its multiple dust sources and so on. My work instructions were simple: (a) drive around until you see brown smoke from a stack, (b) go in and sell your dust collection solution! One such not-so-cold call to an electric arc furnace location put me in contact with a plant manager that was convinced with my pitch of how this marvel of a box with filters was going to solve his pollution control problem. When we started discussing operating costs, I was duly informed that he would only operate the 75 HP exhaust fan connected to the dust collector "as needed".

Further enquiry revealed that my customer's problem was not pollution control, but pollution control authorities! Therefore, the exhaust fan in his power-strapped neighborhood would only be operated in the presence of, and to appease authorities! This anecdote is also to validate that this literary product has been generated without ChatGPT or CoPilot's active assistance!

The need for ventilation

When starting up a blast machine, the sequence commences with powering the motor driving the exhaust fan. As a result, the machine is always under negative pressure. All other motors that power the different reclaim system components in a mechanical reclaim system such as scalping drum, if provided, bucket elevator and screw conveyors are then sequentially energized. Blasting generates dust, the concentration of which is dependent on several factors such as the abrasive/media, contaminant being cleaned, and surface being impacted during shot peening. If not evacuated, this dust will mix with the abrasive/media creating an environment that is not conducive for continued machine operation. I am trying to also gear this discussion to blast cleaning which should explain my use of "abrasive"— a term typically reserved for cleaning applications. Recommended ventilation velocity in cleaning applications is around 3500 FPM. Without adequate ventilation velocity, not only will the parts remain covered by a layer of dust, but will also result in the blast machine operating with dust visually escaping from the cabinet and other areas— neither a desirable nor an acceptable outcome.

A significant percentage of aerospace components are manufactured from aluminum, titanium, magnesium, and such exotic alloys that could potentially generate explosive dust when impacted with media. Therefore, ventilation design in machines processing such components is extremely critical. Ventilation velocity requirement is higher with a minimum 4500 FPM along with several additional requirements to handle explosive dust safely. Dust collectors handling such dust are equipped with explosion vents, fire-retardant cartridges, sprinklers, and rotary airlock valves that continuously discharge the collected dust from the hopper. Ventilation ducting is provided with inspection ports and fitted with a no-return valve to prevent the possibility of the dust collector fire backtracking to the blast machine.

Fire and explosive dust

Proper design of the ventilation system and dust collector for dust with explosive tendencies starts with analyzing the dust for its Kst and Pmax values. The explosion severity is categorized as Pmax (measurement of maximum pressure that the dust could exert when exploding in a closed space). Kst value of a dust indicates the relative severity of a dust explosion when compared to other types of dust. Other

factors that will be revealed during dust analysis are MIE (Minimum Ignition Energy), which is the lowest amount of heat or energy that could cause your dust to ignite, and MEC (Minimum Explosive Concentration), which is the smallest amount of dust in the air that will ignite and cause an explosion.

These are factors that dust collector manufacturers will consider when calculating the deflagration venting area required for your dust. Deflagration or explosion venting is like the rupture disk in a furnace, which releases excessive amounts of energy (generated during an explosion) by rupturing the explosion vent. If your dust collector is located outdoors, you will need to provide a controlled perimeter to prevent pedestrian access around the collector. If your machine happens to be at the center of your facility without easy access to the outside, and the collector can only be located indoors, your explosion/deflagration vent needs to be further protected by flameless venting which allows for the controlled explosion to take place inside the flameless vent.
In addition to all the above, your insurance company will likely stipulate the make and type of components to be used along with an approval requirement on the final design. In summary, ventilating dust that could catch fire or explode requires careful attention.

Ventilation and media reclaim
Our discussion above mainly referenced ventilation for the primary purpose of dust evacuation from the cabinet. However, in airblast machines that generate low volumes of metallic media flow or non-metallic media such as glass bead, ceramic, or aluminum oxide (such as in grit blasting applications), media reclaim is accomplished using vacuum reclaim systems.

The exhaust fan (sometimes referred to as the blower) generates the volume and static pressure to evacuate the cabinet and pneumatically transport media from the cabinet reclaim hopper to a cyclone reclaimer that separates usable media from the dust which is finally sent to the dust collector.

The static requirement of this system is dependent on several factor such as (a) type of media being conveyed, with metallic particles requiring more effort to transport, (b) the length through which it needs to be transported, (c) diameter and routing of the duct—with the addition of elbows contributing to the static requirements. Precise calculation of the static pressure is important for power sizing of the exhaust fan motor.

Most cyclone reclaimers are designed with tuning capability that allow pressure balancing inside the unit to cater to different media types and sizes—the goal being the separation of dust to the collector and retention of useful media within the system. The above is true for blast cabinets and automated airblast machines with a finite physical volume in the range of 6'-7' cube.

Manual airblast rooms that are larger in physical volume than specified above follow a different ventilation path. Manual airblast rooms may be designed with a vacuum reclaim system where the operator sweeps up or by some means directs the spent abrasive into a suction point such as in a corner of the room, or along a hopper across the width of the room. The suction required to move this media through the reclaim system components described earlier is provided by a dedicated exhaust fan and dust collector. This is in the tune of no more than 1000 CFM. However, this unit is not responsible, or capable of ventilating the entire blast room.

Room ventilation is governed by ACGIH (American Conference of General Industrial Hygienists). Commonly accepted practices dictate a ventilation velocity of 50 FPM cross draught through the blast room. This means that ventilating a room with a cross-section of 10′ x 10′ will require 10' x 10' x 50 FPM = 5000 CFM of ventilation volume that the exhaust fan should be able to generate. Such rooms are designed with air inlets that will allow the entry of fresh air into the room. Vent plenums, complete with baffles are provided at the end opposite to the air inlets to facilitate ventilation of dirty air after it has picked up dust in its travel across the cross-section of the room. Room ventilation will also include the air volume from ventilating reclaim system components including bucket elevators and airwash separators with fixed volumes based on the manufacturer's design standards.

ACGIH uses a criterion for ventilation requirements of smaller cabinets where the operator accesses the inside through a handhole while stationed outside the cabinet. Due to their reduced physical volume, a minimum air changes per minute model is used to calculate the ventilation volume. For example, a cabinet with a physical volume of 125 cubic feet will be subject to say five air changes per minute which brings the total ventilation volume requirements to 125 x 5 = 625 CFM.

Ventilation in wheelblast machines
Ventilation requirements for wheelblast machines are structured as follows:

1. The first step is to determine the duty condition. Heavy-duty cleaning involves castings (removing sand), forgings (heavy descaling), rust and paint. Medium-duty cleaning consists of cleaning structural steel, prefabricated weldments, and new steel with mill scale. Shot peening is categorized as light-duty. As we know, if you are removing material from the component being peened, you are not doing it right. Peening requires the part to be clean, else you are peening the layer of scale or another contaminant and not the component.

2. Step 2 is the volume generated by the type of cabinet such as a batch style car table room, spinner hanger, continuous travel style, etc., with each style presenting its unique ventilation requirements. The calculation for a large car table style room is as described in an earlier section for manual airblast rooms.
3. Step 2a is for cabinet styles such as spinner hangers and those with a pass-through configuration. The blast wheel HP is used as a reference when determining ventilation volume for such designs. For example, the ventilation volume for a pass-through cabinet with 4 x 30 HP wheels for a light-duty application is determined as: First wheel: 1000 CFM (determined and adopted based on field data), second wheel: 600 CFM, followed by 300 CFM for each additional wheel—in our example that would be 2 x 300 = 600 CFM for a total of 1000+600+600 = 2200 CFM. To put this in perspective, the same cabinet would require 2000+1200+1600 = 4800 CFM had this been a heavy-duty cleaning application as in cleaning sand from castings. Multiplying factors are applied for wheel HPs below or above 30 HP. In case you are wondering about the source of these volumes, I have used the example from the design standards of a well-known blast machine manufacturer to help explain the concept. Every manufacturer has their own standards for designing their machine's ventilation requirements.
4. Step 3 is to determine ventilation volumes from reclaim system components such as bucket elevator housings and airwash separators. These requirements are volume-based and directly proportional to the quantity of abrasive being propelled by the blast wheel(s). For example, consider the same machine as used in our earlier illustration. Let us assume that each wheel flows 400 lb/min of media. This adds up to 1600 lb/min. The airwash separator sizing is determined by a conservative recommendation of 40 lb/inch of lip. Therefore, this machine will be best served by a 40" airwash separator. The ventilation requirement for a 40" airwash separator operating light-duty is 500 CFM, which gets added to total ventilation volume.
5. Similarly, other auxiliary units such as the blow-off, touch-up cabinets, etc., contribute to the total volume required to be ventilated from the blast machine.

Issues in ventilation

Some of the common issues I have seen designers and users struggle with over the years:

- Insufficient ventilation volume – this will result in inadequate cabinet ventilation. This could be due to a fundamental mistake in not following norms when calculating ventilation requirements.
- Insufficient static pressure – this could be due to re-location of the dust collector after the initial installation calculations, additional elbows and anything that increases resistance to free flow of ventilation air.
- Not accounting for high dust loading. This leads to diminished life of filter media (cartridges, bags, etc.)
- Inspection of ventilation ductwork – dust and abrasive/media will collect inside the ductwork and should be regularly cleaned out. Inspection ports are required at defined intervals to facilitate this activity. Such accumulations will not only impede air flow but also pose a significant safety hazard to personnel working directly below the ductwork.
- Blast gates (dampers) not inspected regularly—gates could be worn or closed shut due to machine vibration. Insufficient openings or wide-open gates will affect system ventilation.

Conclusion

Our discussion here is a top-level summary of ventilation requirements in a blast machine. Each element identified here deserves its own discussion, such as vent plenum design, use of pre-collectors, velocity tuning using blast gates to retain good media within the machine and so on. I look forward to continuing this discussion at a future date and trust that this provides impetus for you to examine the system with which you are currently working.

PREMIER

PREMIER SHOT COMPANY

1666 Enterprise Parkway Twinsburg, OH 44087

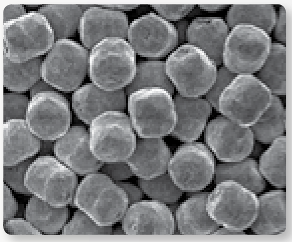
A Cut Above



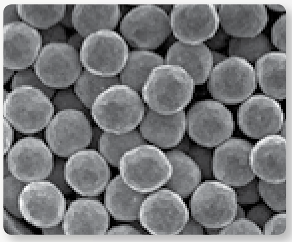

The advantage of Premier Cut Wire Shot

- **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
- **Improved Consistency** Highest consistency from particle to particle in size, shape, hardness and density compared to commonly used metallic media.
- **Highest Resistance to Fracture** Premier Cut Wire Shot media tends to wear down and become smaller in size rather than fracturing into sharp-edged broken particles, which may cause surface damage to the part.
- **Lower Dust Generation** Highest durability equals lowest dust levels.
- **Lower Surface Contamination** Cut Wire Shot doesn't have an Iron Oxide coating or leave Iron Oxide residue — parts are cleaner and brighter.
- **Improved Part Life** Parts exhibit higher and more consistent life than those peened with equivalent size and hardness cast steel shot.
- **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



Normal Conditioning



Special Conditioning

Premier Shot Cut Wire Products for

Automotive • Medical

Aerospace Applications Worldwide

(330) 405-0583

1666 Enterprise Parkway,
Twinsburg, Ohio 44087

premiershot.com

Probabilistic Assessment of Shot Peening Impact Coverage

Langdon Feltner, Paul Mort
Purdue University, School of Materials Engineering, Center for Surface Engineering and Enhancement

Introduction
In shot peening, compressive residual stresses are induced through impact events between media and the surface of a component. When designing a shot peening machine and specifying operational parameters, practitioners often aim to achieve full and even coverage through sufficiently long cycle times and careful positioning of the peening nozzle with respect to the treated surface. Mass flow rate, peening time, and blast pressure are particularly important when considering impact coverage on a component. Over a peening cycle, a discrete number of particles leave the nozzle, each with an associated mass. For a given substrate material, particle mass, and media hardness, the size of the surface dimple left by an impact is determined by the particle's velocity, meaning the distribution of dimple coverage is directly related to the uniformity of particle mass flux.

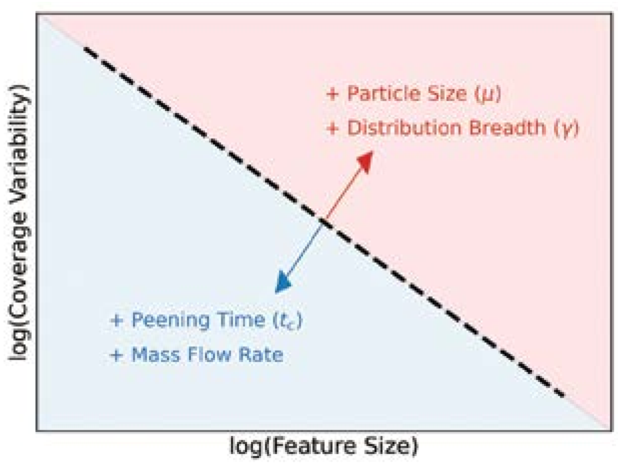


Figure 1. Peening time, mass flow rate, and media size distributions contribute to coverage variability across scales of scrutiny.

Considering shot media as point masses with randomly chosen impact locations upon a component of a fixed area, denoted A_{part}, the average mass flux ($\dot{m}$) is equal to the summation of all particle mass contributions over a cycle, divided by the peening time, t_c, and A_{part}, or equivalently mass flow rate divided by A_{part}. Within control limits, $\dot{m}$ can be considered a constant derived directly from mass flow rate. On the other hand, let M_A be the total mass of media that impacts within an arbitrary region with area A, shown in Equation 1.

Equation 1.

$$M_A = \sum_{i=0}^{n_A} m_p^i$$

M_A depends on two distributed quantities, the number of particles that impinge the region (n_A), and the mass of each particle (m_p^i). The expected, or average, value of a random quantity (denoted E[·]), is the probability-weighted summation of all possible values the variable can take. Wald's identity (Wald, 1944), (Ross, 1996) enables a simplified calculation of $E[M_A]$, separating the contributions of the independent variables n_A and m_p^i. Thus, $E[M_A]$ can be expressed as:

Equation 2.

$$E[M_A] = E[n_A] \cdot E[m_p^i]$$

Variance (denoted *Var*[·]) is a measure of the breadth of a distribution. Like Wald's identity, the Blackwell-Girshick equation (Blackwell & Girshick, 1979) allows for the separation of contributions from n_A and m_p^i with respect to variance. $Var[M_A]$ can then be expressed as:

Equation 3.

$$Var[M_A] = E[n_A] \cdot Var[m_p^i] + Var[n_A] \cdot E[m_p^i]^2$$

Relative standard deviation (denoted *RSD*[·]) is the ratio of standard deviation, or the square root of variance, to average, a dimensionless quantity that expresses the proportional variability of a measure with respect to its mean value. In this context, $RSD[M_A]$ is certainly correlated to the variability in total work imparted onto corresponding features across runs of components. The goal of this report is to apply probabilistic reasoning to characterize a spatial distribution in impact coverage based on cumulative mass over the surface of a component. Specifically, deriving expressions for $E[M_A]$, $Var[M_A]$, and $RSD[M_A]$ to provide perspective on how operational parameters relate to surface treatment uniformity across scales of scrutiny.

Spatial Uniformity of Mass Flux
In a previous Shot Peener report entitled "Characterization of Particle Size and Shape Distributions for Shot Peening Media" (Feltner, Gruninger, Canty, & Mort, 2024), we explored volume weighted distributions in peening media size and shape measured using dynamic image analysis (DIA). This work demonstrated the suitability of a lognormal distribution for describing size in relation to mass sieving. In the current work, DIA is used to

calculate number weighted distributions for probability-based impact coverage modeling.

A lognormal distribution in area equivalent radius (R) implies that $\ln(R)$ is normally distributed with a dimensionless geometric mean (μ) and standard deviation (γ). To be consistent with the notation used in our previous work, $\mu=ln(d_{gN}/2)$, the natural log of half the number weighted geometric mean particle diameter, while $\gamma=ln(\sigma_{gN})$, the natural log of the number weighted geometric standard deviation. The expected value of a particle's radius is $exp(\mu+\gamma^2/2)$. The mass of a particle scales according to its radius cubed, meaning mass is lognormally distributed with mean 3μ and standard deviation 3γ. Assuming a constant density ρ, the expected mass of a particle is:

Equation 4.

$$E[m_p^i] = \frac{4\pi\rho \cdot exp(3\mu + \frac{9\gamma^2}{2})}{3}$$

Shown in Equation 5, the average number flux of impacts ($\dot{n}$) is the mass flux divided by the expected mass per particle. Similar to $\dot{m}$, $\dot{n}$ can be considered constant within control limits. $\dot{n}$ is inversely proportional to the mean radius cubed, with a conspicuous additional inverse dependence on γ.

Equation 5.

$$\dot{n} = \frac{3 \cdot \dot{m}}{4\pi\rho \cdot exp(3\mu + \frac{9\gamma^2}{2})}$$

To illustrate the consequences of this dependence to the relative uncertainty in impact coverage, consider the case where $n \approx \dot{n}\ t_c \cdot A_{part}$ particles are assigned random impact locations within an area of size A_{part}. For a measurement area A that is a subsection of A_{part}, the probability that any particle is contained within is $p_0= A/A_{part}$, and the probability a particle is excluded is $q=1-p_0$. The probability that the measured number of particles within A (n_A) is exactly equal to k is equal to the number of ways to choose k particles from n, multiplied by p_0^k (the probability that all k particles are within A) and q^{n-k}(the probability that all other particles are not within A), shown in Equation 6.

Equation 6.

$$P(n_A = k) = \frac{n!}{k!\,(n-k)!} p_0^k q^{n-k}$$

This is known as the binomial distribution, a fundamental construct in probability theory used to describe the number of successes and failures in experiments with independent and identically distributed trials. When the total number of impacting particles is large, the binomial distribution converges to a Poisson distribution (Ross, 1996):

Equation 7.

$$P(n_A = k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

Where $\lambda = \dot{n}\ At_c$. The Poisson distribution has an expected value and variance of $E[n_A] = Var[n_A]=\lambda$, and is commonly used to model counting processes. Applied to peening, this mathematical formulation provides an exact probability distribution for the number of particles contained within a region based on operational parameters and media size.

Leveraging the equality of expected value and variance of a Poisson distribution, Equation 3 becomes:

$$Var[M_A] = E[n_A] \cdot (Var[m_p^i] + E[m_p^i]^2)$$

The definition of variance states that:

$$Var[M_A] = E[n_A] \cdot (Var[m_p^i] + E[m_p^i]^2)$$

(Ross, 1996), leading to a simplified expression for $Var[M_A]$:

Equation 8.

$$Var[M_A] = E[n_A] \cdot E[{m_p^i}^2]$$

Applying the expected value of the Poisson distribution for N_A and the second moment $E[{m_p^i}^2]$

of the lognormal size distribution leads to:

Equation 9.

$$Var[M_A] = (\dot{n}At_c) \cdot \left(\left(\frac{4\pi\rho}{3}\right)^2 \cdot exp(6\mu + 18\gamma^2)\right)$$

Substituting Equation 5 yields an expression for $Var[M_A]$ in terms of $\dot{m}$:

Equation 10.

$$Var[M_A] = \left(\frac{4\pi\rho\dot{m}At_c \cdot exp(6\mu + 18\gamma^2)}{3 \cdot exp(3\mu + \frac{9\gamma^2}{2})}\right)$$

Simplifying to a final expression for $Var[M_A]$:

Equation 11.

$$Var[M_A] = \left(\frac{4}{3}\pi\rho\dot{m}At_c \cdot exp(3\mu + \frac{27}{2}\gamma^2)\right)$$

$E[M_A]$ is simply equal to $\dot{m}At_c$, leading to a closed form expression for relative standard deviation:

Equation 12.

$$RSD[M_A] = 2\sqrt{\frac{\pi\rho \cdot exp(3\mu + \frac{27}{2}\gamma^2)}{3\dot{m}At_c}}$$

To validate the Poisson distributions application to predicting peening mass flux uniformity, consider three media size distributions for conditioned cut wire 32; 1) idealized monodisperse ($\mu= ln(463),\gamma = ln(1)$), 2) as-manufactured ($\mu$- $ln(463),\gamma$ - $ln(1.071)$), and 3) working mix (μ- $ln(359.2)$, γ - $ln(1.422)$). As-manufactured and working mix media samples were obtained and measured with DIA as part of a previous Purdue University School of Materials Engineering senior capstone project (Kelly, Keuneke, McLaughlin, & Schroader, 2021). Linearized lognormal fits for both are summarized in Figure 2 (page 20). Overall, most working mix particles are smaller than the as-manufactured, though the working mix has a significantly broader distribution.

Using those particle size distributions, a relatively simple Monte Carlo procedure can be performed to simulate impact coverage uniformity numerically. Assuming a constant mass flow rate of 20 *kg/min*, A_{part} is equal to 0.03 m^2, and a t_c of either 10 or 50 *s*, each particle size distribution is repeatedly sampled on a number basis until the cumulative mass of media is greater than or equal to the product of mass flow rate and peening time. The sampled particles are then assigned random (x,y)

WE HAVE THE WORLD COVERED

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

HIGH DURABILITY CUT WIRE SHOT (REDUCTION OF WASTE)
NON-DISTRUCTIVE INSPECTION DEVICE (POSITRON SURFACE ANALYSIS)

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

PEENING PROCESS USING NEEDLE PEENING EQUIPMENT FOR WELDED INFRASTRUCTURE (BRIDGE AND VESSEL)

DUST SOLIDIFYING DEVICE. RECYCLING INDUSTRIAL DUST WASTE.

COMING SOON

TOYO SEIKO CO.,LTD

The World's Leading Company for Shot Peening

Thailand
Tel:+66-324-0046
Fax:+66-2-324-0047
info@toyoseiko.co.th

Japan
Tel:+81-567-52-3451
Fax:+81-567-52-3457
toyo@toyoseiko.co.jp
toyoseiko.co.jp

North America
+1 (574)-288-2000
sales@toyoseiko-na.com
toyoseiko-na.com

TOYO SEIKO SIGNS A PARTNERSHIP DEAL WITH winoa

preparing tomorrow's surfaces

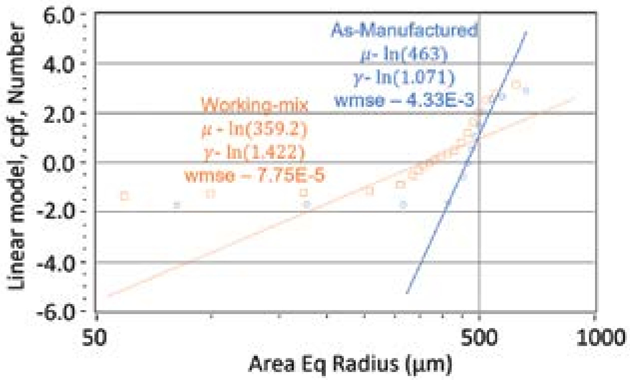


Figure 2. Linearized lognormal fits for area equivalent radius of as-manufactured and working mix CCW32 media.

impact locations within a region of size A_{part}. A_{part} is recursively subdivided into grids of progressively smaller measurement regions, enabling direct calculation of the distribution of M_A at each measurement size. The standard deviation of the set of M_A values divided by its mean yields $RSD[M_A]$ as a function of measurement area. The use of a number-weighted distribution in area equivalent radius is critical to this exercise, ensuring that all particles have the same likelihood of impinging a component, regardless of size.

Shown in Figure 3 is a comparison between Poisson process predictions for $RSD[M_A]$ with Monte Carlo results, demonstrating a clear agreement between the two. In capturing variability in impact coverage, the results of this study suggest that monodisperse is an appropriate approximation for as-manufactured media, while the breadth of the working-mix distribution contributed to a lower number-flux of impacts on average and hence, greater variability in impact coverage across scales of scrutiny.

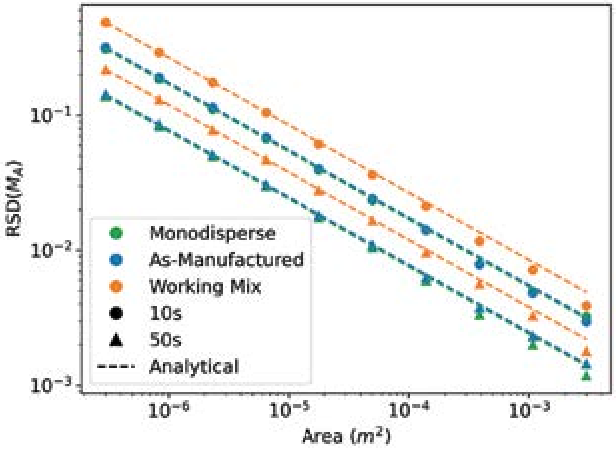


Figure 3. Comparison of analytical prediction with Monte Carlo results for relative variability in cumulative mass as a function of area.

In standard peening processes, with controlled centerlines of air pressure, feed rate, and working mix media size, this model provides insight to the effective impact distribution at relevant scales ranging from slightly larger than the media size up to full parts. It is important to note the limitations of this Poisson process-based model with respect to operational parameters. The Poisson approximation of the binomial distribution relies on a large total number of impacts. Though divergence from the analytical prediction was not observed in this study, processes with especially low average mass fluxes coupled with broad particle size distributions could violate the assumption of independence between the number of impacting particles and the mass of each particle. Additionally, this model assumes that particles are point masses; quantifying a spatial distribution of mass at sub-dimple length scales can be ambiguous.

Conclusions

The Poisson model can provide a starting point for predicting variability in residual stress fields across treated surfaces. Critical features of many peened components, for example axle gear roots and turbine leading edges, fall between the component size and a dimple diameter, the ideal range for Poisson model validity. The Poisson model describes coverage as a counting process; hence it is important to obtain number-based media size distributions, for example using DIA. Results suggest that peening time, mass flow rate, and media size can be used to control uniformity of coverage. We seek to use this model to aid in the design of peening processes that achieve desired stress profiles minimizing variability in critical regions of a component. More broadly, we see this work as a starting point toward the development of advanced statistical tools for linking operational parameters and transient particle size and shape distributions to spatial and temporal uniformity in both surface topography and residual stress fields.

Acknowledgements

The authors would like to express their gratitude to Purdue University's Center for Surface Engineering and Enhancement for their support of this work. In particular, this study was motivated by open-minded discussions with technical staff at American Axle & Manufacturing and Electronics Incorporated.

Bibliography

Blackwell, D. A., & Girshick, M. A. (1979). *Theory of games and statistical decisions*. Courier Corporation.

Feltner, L., & Mort, P. (2023, Summer). Stress Field Modeling in Context of Industrial Shot Peening. *The Shot Peener*, pp. 8-12.

Feltner, L., Gruninger, M., Canty, T., & Mort, P. (2024, Spring). Characterization of Particle Size and Shape Distributions for Shot Peening Media. *The Shot Peener*, pp. 12-16.

Hill, R. (1963). Elastic properties of reinforced solids: some theoretical principles. *Journal of the Mechanics and Physics of Solids*, 357-372.

Kelly, B., Keuneke, B., McLaughlin, G., & Schroader, H. (2021, May). *Shot Media Characterization and Finite Element Modeling of Peening Operations for Automotive Driveline System Components*. Retrieved from Purdue University School of Materials Engineering: https://engineering.purdue.edu/MSE/engagement/Posters/2020-21/AAM

Ross, S. M. (1996). *Stochastic processes*. New York: Wiley.

Wald, A. (1944). On cumulative sums of random variables. *The Annals of Mathematical Statistics*, 283-296.


CURTISS-WRIGHT
SURFACE TECHNOLOGIES
LEADERS IN SURFACE ENGINEERING
Increasing the performance and life of critical components
SHOT PEENING AND RELATED SERVICES:
• Shot, Laser, & Cavitation Peening
• Peen Forming & Distortion Correction
• On-Site Shot & Laser Peening
• Vibratory Superfinishing
• Non-Destructive Testing
• Approvals: AS9100, Nadcap, ISO9000, FAA/EASA & Most OEMs
OTHER SERVICES:
• Solid Film Lubricant & Liquid Coatings
• Thermal Spray Coatings
• Plasma Electrolytic Oxidation
• Parylene Coatings
• Materials Testing
GLOBAL FOOTPRINT
65+ FACILITIES | 16+ COUNTRIES
United States, Mexico, Canada, United Kingdom, Belgium, France, Germany, Ireland, Poland, Portugal, Hungary, Spain, Sweden, Switzerland, China, India and Singapore
CWST.COM | INFO@CWST.COM | 201.518.2979
95
CURTISS-WRIGHT
1929-2024

Engineered Abrasives®

Manufacturers of the Finest Blast Finishing and Shot Peening Systems

(708) 389-9700

Email: mwern@engineeredabrasives.com Web: www.engineeredabrasives.com

IATF 16949
ISO 14001
FORD Q1
Certified
Job Services

All Engineered Abrasives® systems are available with the EA® Knowledge System®. The EA® Knowledge System® features computer animation on machine operation and maintenance, including how to do Almen Strips.

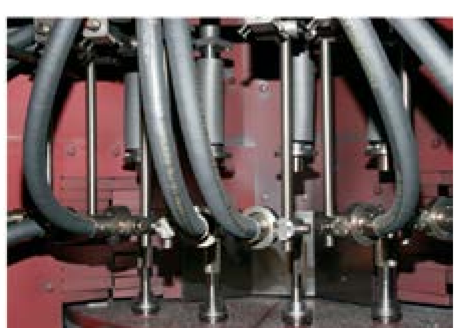
Engineered Abrasives® High-Volume Index Unit with complete Material Handling and Robotic System

60" Index Unit Ring and Pinion Gears for High Volume

8 Pressure Nozzles with MagnaValves®, Buck Elevator, Sweco and Dust Collector

CONTROL by MagnaValve®

All Tooling and Fixtures Tool Steel hardened to 62 RC



Engineered Abrasives® index units are the most durable machines on the market today with all our special features

Patented 72" Index Unit with Shot Flow Controls, Sweco, Bucket Elevator, 8 Nozzles and 16 Spindles. Designed for high-volume shot peening.

Look for RED components and surfaces to be sure you get Engineered Abrasives® quality equipment and OEM parts.

High-volume automotive systems for ring and pinion axle gears

Designed and built by EA®

Two (2) Index Units with complete load and unload Fanuc Robots and Conveyor System

Both machines built and tested on EA® floor

EA® 72" Flex Peener™
4 stations with 4 spindles at each station. Can do different gears on each spindle or all the same for higher volume.

Single Cell Unit, 5 Pressure Nozzles

Bucket Elevator
Sweco System
◀ MagnaValves®

◀ Dual Swing Doors for higher volume

Special safety platforms for easier maintenance ▶

EA® 72" Index Unit

84" Flex Peener Four (4) Spindles at each Station for High-Volume Gears. Can do Eight (8) Different Type Gears with our Patent Pending one pc. Tooling with Robot Load.

72" Flex Peener three (3) Spindles at each Station for High Volume Gears. Can do Eight (8) Different Type Gears with our Patent Pending one pc. Tooling Holders. Shown with Robot Load.

AbrasiveMaterials

Industry Leading Quality Cut Wire Abrasive Media.

QUALITY ABRASIVE PRODUCTS TRUSTED BY THE UNITED STATES MILITARY.

Abrasive Materials has manufactured cut wire products for over 50 years. Our team of experts bring over 60 years of experience in the blasting industry. We are the premier Surface Finishing Specialists.

Carbon Steel Cut Wire

- Available in G1, G2, & G3 Roundness
- Low maintenance
- Manufactured & certified to all peening specifications including AMS.

Stainless Steel Cut Wire

- As-Cut or Conditioned
- Bright Surface Finish
- Maintains size and shape

Contact Abrasive Materials Today! Let us help you develop a process that meets your finish expectations. Take advantage of our free sample processing service.

1(800) 283-7468
info@abrasivematerials.com
abrasivematerials.com

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Work-Hardening During Peening

INTRODUCTION
Shot peening is normally applied in order to improve the fatigue properties of components. This improvement is due to two factors:
(1) Work-hardening of the surface layer and
(2) Compressive residual stress in the surface layer.

This article is about work-hardening and fatigue improvement and is aimed at shot peeners rather than scientists. The key to understanding work-hardening is a crystal defect called a "dislocation." In the early 1900s, scientists were baffled as to why metals started to plastically deform at much smaller stresses than their predicted theoretical strength. About 1934, various scientists proposed that the puzzle could be explained if the metals contained "dislocations". Many metallurgists remained skeptical of this dislocation theory until the development of the transmission electron microscope in the late 1950s. With further research, based on transmission electron microscopy, we can now understand how work-hardening progresses during plastic deformation.

For most components, fatigue life depends upon the applied levels of both static stress and alternating stress. Consider, as an example, a simple railway wagon as illustrated schematically in fig.1. If the wagon was stationary, then a certain level of force, F, would be exerted on the axles inducing a corresponding stress level. The magnitude of F would vary according to the amount of cargo put into the wagon. If now the wagon is being pulled along the track, with a force P, an alternating stress is superimposed on the static stress being applied to the axles. The fatigue life of the axles depends upon the combination of these two stresses. Any increase of either stress will shorten the fatigue life.

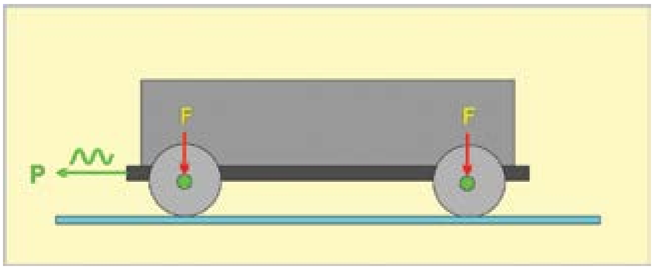


Fig.1. Static and alternating loading of railway axles.

Most shot peeners are familiar with the effect of alternating stress on fatigue life through so-called "S-N" curves (stress versus number of applied stress cycles). Much less familiar is the contribution of the static stress which is often represented by a so-called "Goodman Diagram." A section of the article is devoted to introducing the significance of Goodman Diagrams.

PICTORIAL EXPLANATIONS OF DISLOCATION YIELD STRENGTH REDUCTION
Why does a caterpillar move in the manner illustrated in fig.2? The answer is because it puts much less stress on its system. A small part of the body is progressively moved forward. Only a small fraction of its feet are involved. In the region of the "hump" this fraction is being "dislocated" from the twig.

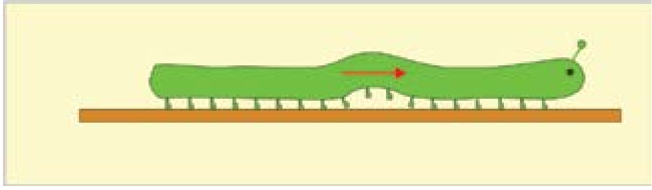


Fig.2. Localized movement of a caterpillar.

Fig.3 (page 28) illustrates the parallel situation for a metal crystal. A background image of the caterpillar has been included to emphasize the analogy. There is an extra half-plane of atoms, X, which, at its intersection with the slip plane, is analogous to one foot of the caterpillar being lifted.

The caterpillar analogy is two-dimensional. A nearer analogy to a crystal dislocation is a ruck in a carpet, as illustrated in fig.4 (page 28). Carpet layers have known for millennia that a relatively small force, F, will make a carpet move in a required direction. The line, AB, is analogous to a dislocation line.

Another analogy is to consider waves hitting a beach. Wind cannot move the whole of the sea's surface all at once. Instead it moves just the amount contained in a wave.

SPEED AND MULTIPLICATION OF DISLOCATIONS
Dislocations have two characteristics that explain work-hardening by shot peening:

(1) **During deformation, dislocations move at the speed of sound** and
(2) **During deformation, dislocations multiply at an astronomical rate.**

Once the yield stress is reached, the only thing stopping initial movement of dislocations on slip planes is the speed of sound in the metal. During movement, dislocation lines multiply at an astronomical rate. As an example, annealed steel containing 10^6 dislocation lines per square centimeter may contain 10^{12} after denting. This equates to a million-fold increase in, say, a thousandth of a second!

DISTRIBUTION OF DISLOCATIONS IN WORK-HARDENED METALS
As dislocations ferociously multiply, they meet with various obstacles such as grain boundaries and intersecting slip systems. Enormous pile-ups occur leaving each metal grain with a dislocation substructure. This substructure (a.k.a. nanostructure) has been described as "Regions of high dislocation density surrounding regions of low dislocation density." Figs.5 and 6 are purely pictorial representations. Fig.5 represents the low dislocation content of annealed metals within a structure of grain boundaries. Fig.6 indicates the difference in dislocation content and distribution for just one grain, A, if it had a cold-worked structure. The blue lines indicate the boundaries of the sub-grains.

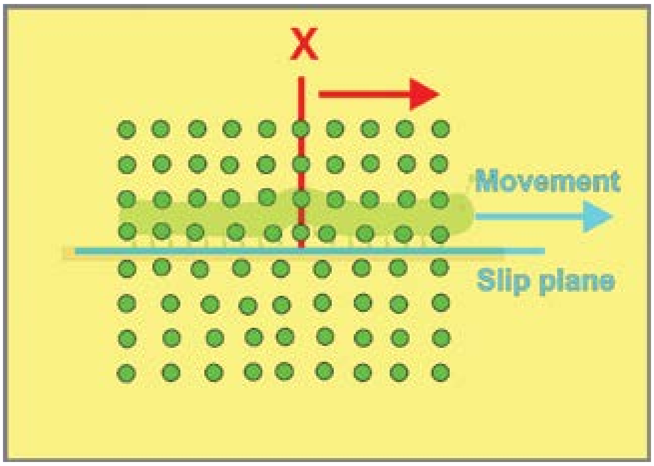


Fig.3. Progressive movement of 'extra half-plane', X, along its 'slip plane'.

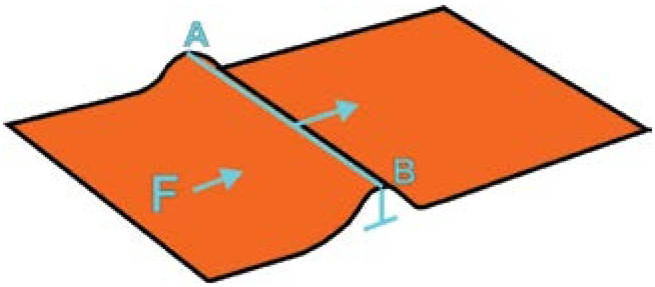


Fig.4. Ruck-in-carpet analogy of a dislocation line, AB.

HARDNESS CHANGE WITH INCREASING AMOUNTS OF PEENING DEFORMATION
Hardness is proportional to the stress that is needed to start dislocations moving. It is also proportional to the yield strength of the material. Fig.7 illustrates how yield strength

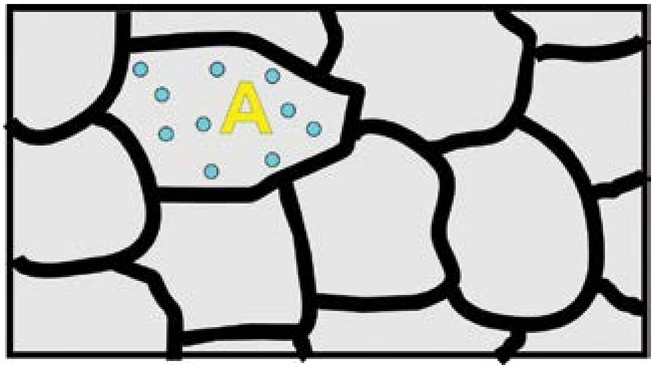


Fig.5. Schematic representation of an annealed structure with individual grains having low dislocation content.

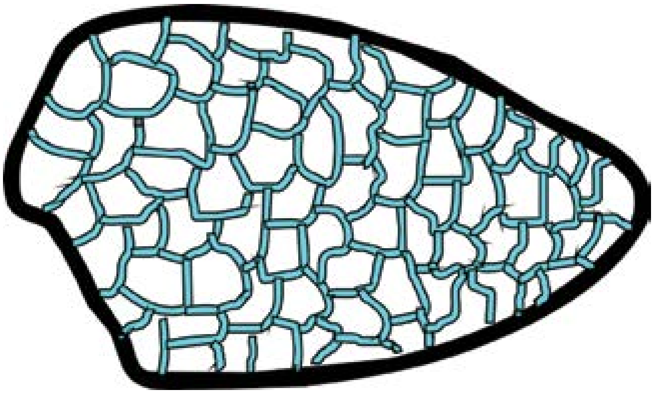


Fig.6. Schematic representation of an individual grain's dislocation sub-structure.

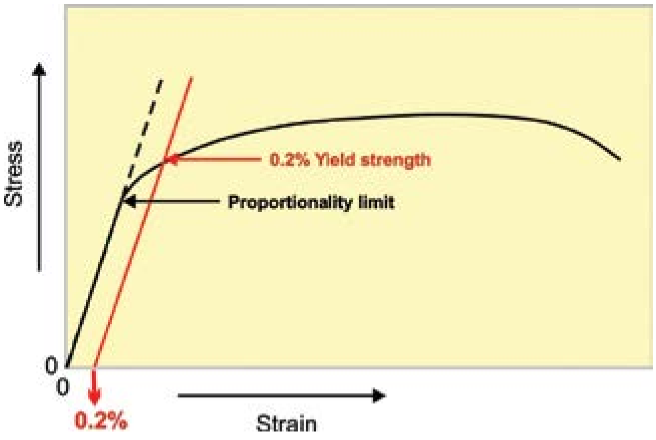


Fig.7. Yield strength estimation from a tensile test stress/strain curve.

is commonly deduced from a tensile test stress/strain curve. Because it is difficult to accurately determine the point at which strain is linearly proportional to stress, yield strength is usually quoted for the point of intersection of the curve with a parallel straight line.

The difficulty of denting metals increases with the yield strength of the metal. It should be noted, however, that:

(1) The quoted yield strength values derived using tensile testing are not the same as the stresses required to indent using flying shot particles. That is because yield strength increases with strain rate. The very high strain rates occurring during denting mean that the stress is several times greater than that predicted by a slow tensile test.

(2) The increase in yield strength with increasing strain is much higher when denting than would be predicted from a simple tensile test. That is because a compressive stress system is set up as described in a previous article (TSP Spring, 2013, "Peening Impressions (Dents)")

Fig. 8 compares the progressive resistance to denting that occurs during shot peening.

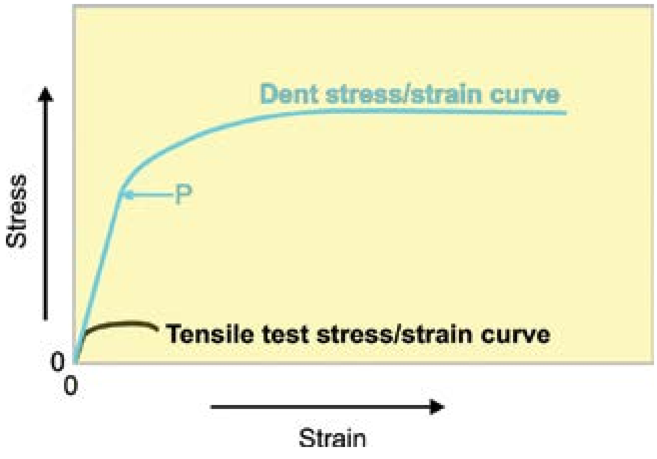


Fig.8. Schematic comparison of tensile and dent stress/strain curves.

The limit of proportionality, P, is much higher for denting than for tensile testing. Maximum hardening and ductility are also much greater.

Fig.9 shows the zone of work-hardening (cross-hatched) that accompanies dent formation. An important feature is that the work-hardening is not uniform. As the moving shot particle reaches its maximum depth, the deformation zone has two strain boundaries. Maximum plastic strain occurs at the contact area between particle and dent—marked as a red line. Zero plastic strain occurs where the applied stress is only equal to the proportionality limit stress, P, and is marked as a blue line. Below that line the component is only elastically stressed.

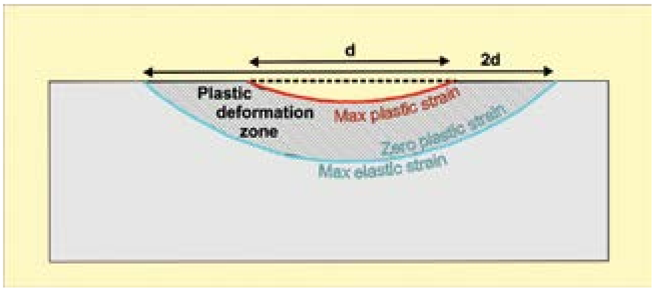


Fig.9. Plastic deformation zone beneath a peening dent.

EFFECT OF MULTIPLE DENTING

As coverage increases, the peened surface is subjected to multiple impacts. Progressively a continuous work-hardened surface layer is produced. The amount of plastic deformation is far higher than that encountered in a tensile test. A pertinent question is "Why doesn't cracking occur during peening?" The answer lies in the different type of stress system that is being applied. Fig.10 (taken from TSP Spring, 2013, "Peening Impressions (Dents)") shows that a three-dimensional compressive stress system is operating. In effect, the metal is being squeezed together during deformation. This is the same as when we make snowballs. Squeezing using cupped hands applies a three-dimensional stress system. Compare that with what would happen if we press using flat hands.

During tensile testing we are simply trying to pull the metal apart. Cold-rolling involves an element of three-dimensional squeezing. Steel that cracks apart at, say, 10% elongation can easily be cold-rolled to hundreds of percentage elongation without cracking. Extrusion has the largest three-dimensional compressive component of any metalworking operation. The same steel can be extruded, without cracking, to thousands of percentage elongation.

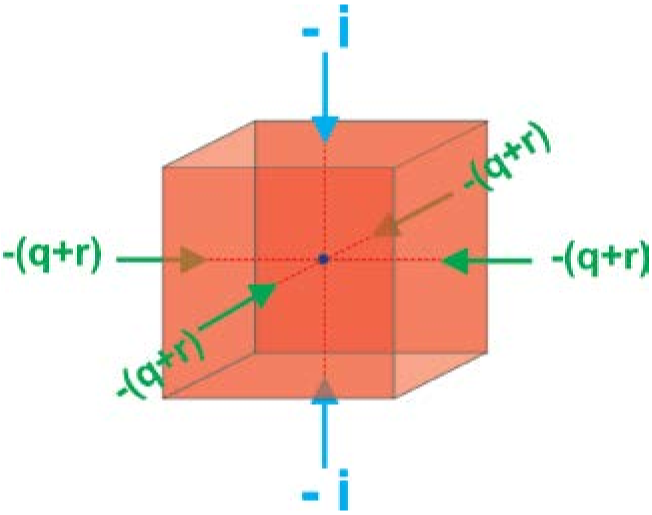


Fig.10. Three-dimensional stress system during denting.

When coverage is approaching 100%, work-hardening reaches a maximum. Excessive peening only runs the risk of exceeding the metal's ductility limit.

EFFECT OF WORK-HARDENING ON FATIGUE STRENGTH

It is well-established that shot peening improves fatigue strength. This improvement is generally represented in the form of so-called "S-N curves." Fig.11 is a schematic pair of S-N curves for ferritic steels. **S** is the maximum stress applied during cyclic loading and **N** is the number of applied loading cycles—necessarily plotted on a logarithmic scale.

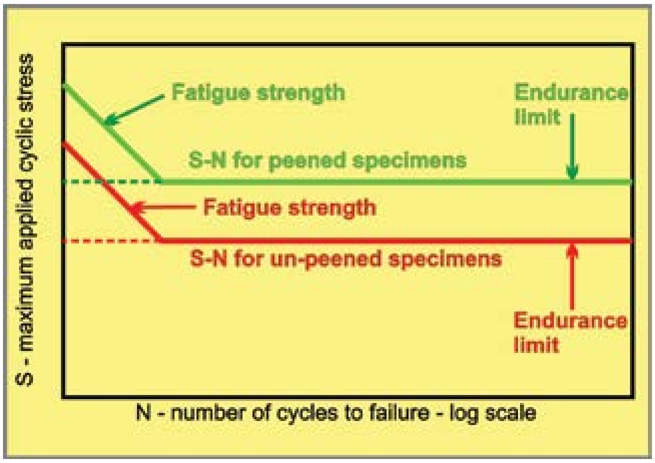


Fig.11. S-N curves for comparing peened and un-peened fatigue.

Fatigue strength is the applied cyclic stress that will cause failure in a specified number of cycles. Endurance limit is the applied cyclic stress below which fatigue failure will never occur. Shot peening normally raises both the fatigue strength and the endurance limit simultaneously. The respective contributions of work-hardening and surface residual stress cannot be simply deduced from S-N curves. Separating the magnitude of the two contributions is an important consideration. The following is one method that has been employed successfully. It is based on what is known as a "Goodman Diagram".

Constant versus alternating applied stresses

Goodman diagrams are normally used to represent the combined effects of constant and alternating applied stresses. Fig.12 shows the difference between constant and alternating applied stress.

Imagine pushing steadily down on the end of the strip. The maximum stress induced in the strip's surface, σ_{max}, is where it is clamped at one end. If we push hard enough, the maximum applied stress will reach the ultimate tensile strength, U.T.S., of the strip and it will break. Hence the maximum value of an applied constant stress (shown black

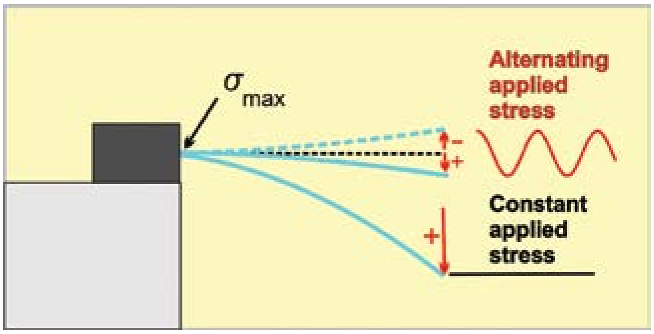


Fig.12. Constant and alternating applied stresses.

in fig.12) is the U.T.S. If, on the other hand, we only push up and down by the same amount on the end of the strip the maximum applied stress alternates about zero (shown red in fig.12).

Goodman diagram for unpeened material

A basic Goodman diagram for unpeened material is shown as fig.13. This assumes that the surface contains neither residual stress nor work-hardening.

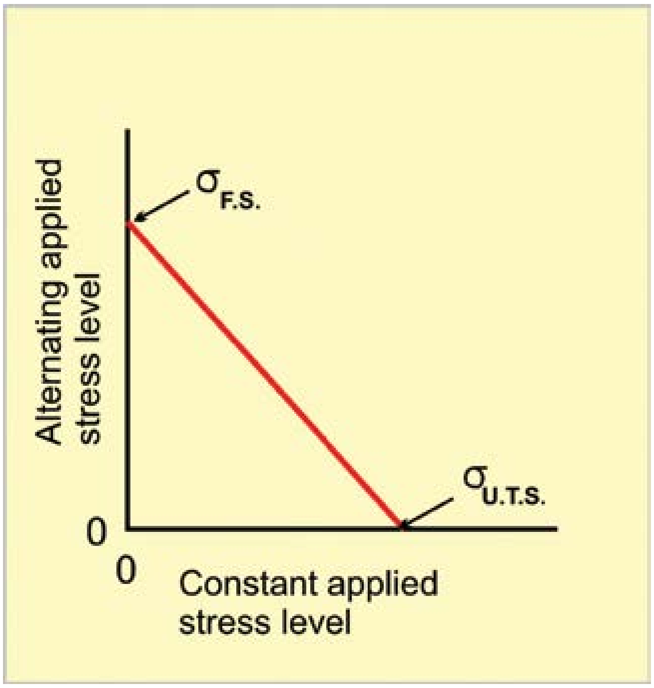


Fig.13. Goodman diagram.

Goodman diagram for peened material

Fig.14 (Page 34) shows how a Goodman diagram can be employed to estimate separate contributions to fatigue strength.

Point A in fig.14 corresponds to the maximum constant bending stress (with no alternating applied stress) that can be applied to un-peened material without exceeding its U.T.S.


赛普优特
Superior Shot
专注 CONCENTRATE 专业 PROFESSIONAL
只为更好 ONLY FOR BEST CUT WIRE SHOT
ACCORDING TO：
SAE J441
VDFI8001
MIL-S-13265-C
AMS2431/3
AMS2431/4
AMS2431/8
• 喷（抛）丸磨料
Shot Peening (Blasting) Media
• 喷（抛）丸设备
Shot Peening (Blasting) Equipment
• 喷（抛）丸服务
Shot Peening (Blasting) Accessories & Service
YANCHENG SAIPU METAL PRODUCTS CO.,LTD
ADD：A-13 Minhao Industrial Park 224300
Yancheng Jiangsu China
E-Mail：nabrasive@vip.163.com
www.superiorcutwireshot.com
PARTNER
DOSHINE
DAFENG DOSHINE INTERNATIONAL CO.,LTD
ADD：No.1 Wuyi Ave 224100 Dafeng City Jiangsu China
Tel：0086-139-0141-2688
E-Mail：keyneskhu@vip.163.com
www.doshineinternational.com


NOZZLES & INSERTS
Will Blast You Away!
MALYN
SUPER TITAN
QUALITY • SERVICE • PRICE
The MALYN Difference!
Malyn Industrial Ceramics, Inc.
8640 Roll Road • Clarence Center, NY 14032
Tel: 716.741.1510 • Fax: 716.741.8402
MALYN.COM

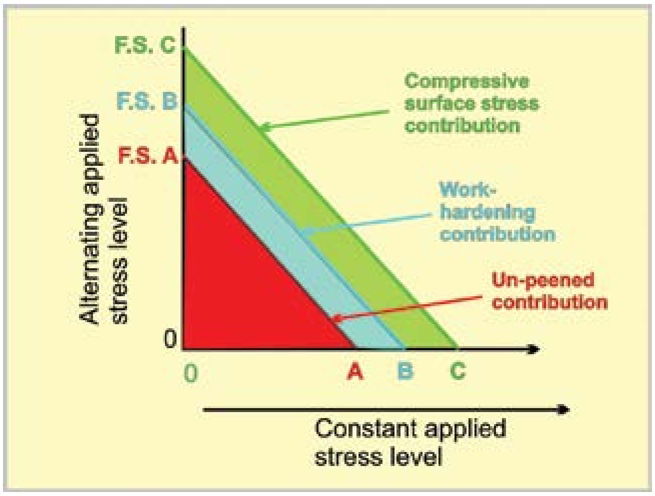


Fig.14. Goodman diagram modified to show separate contributions.

Point C corresponds to the maximum bending stress (again with no alternating applied stress) that can be applied to peened material without exceeding its U.T.S. This raising is due to a combination of work-hardening (which raises the U.T.S.) and compressive surface residual stress (which subtracts from any constant applied stress). The compressive surface residual stress is equal to B – C and is often measured. Hence, AB corresponds to the work-hardening contribution and BC to the compressive surface residual stress contribution. Corresponding fatigue strength values are shown as F.S. A, F.S. B and F.S. C.

SUMMARY

The whole point of shot peening is to improve service properties of components, especially their fatigue strength. Improvement is achieved by a combination of work-hardening and induced surface compressive residual stress. These two factors are of similar importance.

Work-hardening centers on the role of crystal dislocations. These are line defects that multiply at astronomical rates and travel at the speed of sound during work-hardening. They form massive pile-ups—particularly at grain boundaries. The vast dislocation content of cold-worked material is arrayed as a sub-structure.

Goodman diagrams are a convenient method of indicating the relative contributions of work-hardening and induced surface compressive residual stress to fatigue strength. They are, arguably, as important as the more familiar S-N fatigue curves.

Editor's Note: This is article is reprinted from the Summer 2017 Shot Peener magazine.

Are you looking for an earlier article by Professor David Kirk?

The library at www.shotpeener.com has all of Professor Kirk's articles from The Shot Peener and his conference papers going back to 1981.

Visit https://www.shotpeener.com/library/kirk_articles.php?pn=1 to access the articles or scan the QR code.

The following are just a few of the over 125 topics Dr. Kirk has covered for *The Shot Peener* magazine.

- Estimating Peening Intensity
- Questions for Shot Peeners
- ELASTICITY: The Missing Link
- Hardness Testing
- Shot Peeners' Magic Steel MANGALLOY
- Shot Peening Statistics
- Shot Peening Materials Science
- Shot Peening Mathematics
- Back to Basics: Energy Controls Shot Peening Efficiency
- Back to Basics: Accuracy of Shot Peening Measurements
- Back to Basics - Advances in Shot Peening
- Back to Basics - Shot Peening in a Nutshell
- Back to Basics Shot Peening Calculations
- Back to Basics: Coverage
- The Appliance of Science
- Coverage Science
- Hardness Matters
- The Solver Story: An Autobiography
- Metals are Alive!
- The Curvature of Peened Almen Strips
- Almen Strip Quality
- Component Distortion An Overview
- Decarburization: The Silent Enemy
- Variations on the Almen Technique
- Work-Hardening During Peening
- The Importance of Work
- Coverage Variability
- Shot Stream Generation
- Intensity: True Meaning and Measurement Strategy
- Optimization of Shot Peening Coverage
- Wear and Its Reduction
- Verification of Peening Intensity
- Principles of Peening Intensity Selection
- Essential Elements of Shot Peening
- Quantification of Shot Peening Intensity Rating
- Quantification of Shot Peening Coverage
- Water-Jet Peening and Water-Jet Shot Peening
- "Peenability" of Steel Components
- Shot Stream Force Affects Thin Components
- Shot Stream Power and Force
- Peening Impressions (Dents)
- Satisfactory Peening Intensity Curves
- Shot Peening Coverage Requirements

New Semi-Automatic Roller Type Shot Blasting Machine

Designed for Fold-Away Trays Made of Sheet Molding Compound

The "Fold-Away Tray" made of Sheet Molding Compound (SMC) used in Railway/Aircraft/Automotive Passenger seats requires the removal of stress and roughness before the coating process.

MEC SHOT has successfully engineered and supplied a Suction-Induction Type Special Semi-Automatic Shot Blasting Machine to meet this need.

The machine is simple to operate with minimum maintenance. In order to blast the tray on both sides, there are two sets of blast guns provided inside cabinet (Upper and Lower Side) with reciprocation system for uniform blasting. The job is loaded on roller at one side of cabinet and unloaded at another side of cabinet. A cartridge-type dust collection system is incorporated to keep the dust emission level within permissible limit with a fire-resistant feature.

The abrasive recycling is automatic through reclaimer and usable media is recycled while dust generated during shot blasting is separated and collected in dust bags. This machine is meant for high-productivity at lower cost.

MACHINE FEATURES:

- Machine works on suction principle of abrasive blasting
- Acoustic Cabinet and Dust Collector sound proofing
- Multiple Nozzles (6) with Reciprocation system
- Air Pressure Regulator
- Level Sensor
- Dust Collector Fire resistant
- Cartridge Dust Collector for better filtration of air
- Inside PU Lining for wear resistance
- Special Leather Bellow on Pneumatic Cylinder for long-term protection
- Roller PU Coated for after blasting to eliminate marks and dots on job
- Eco Friendly and Operator Friendly
- Simple Operation Method
- White Aluminum Oxide used
- Multiple media can be used as per required Ra Value
- Pit-less Design - No Civil Works required, provide vibrator shock absorber

Fold-Away Tray in aircraft

Semi-Automatic Roller-Type Shot Blasting Machine

For more information, please feel free to contact:
Ummed Singh, Head-Marketing
Mobile: +91 7014731363

Q & A

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

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

Tolerances of Holes After Shot Peening

Questioner: We have an issue with some holes which are too large after shot peening.

We do shot peening with an intensity of 0.007A inch on titanium parts. Some of the holes (38.1-38.125 mm) have to be shot peened.

We have seen that after they come back from the shot peening operation (done externally), and after a flash etch in nitric acid as decontamination (0-2.5 Âµm taken off), that the shot-peened holes are way out of tolerance (15 and 41Âµm to be precise).

When shot peening these holes:

- How much deformation can we attribute to the shot peening? I know the compressive residual stress depth can be up to 200 Âµm, but how much would this be visible in the measurement after shot peening? Is it possible to be 41Âµm out of tolerance due to the shot peening alone or do we have to look elsewhere?
- After machining the dimensional control was okay. After machining we do a first etch before penetrant testing. We have measured these holes as well after the first etch, and they were still within tolerance. After, the part is sent to the shot peener. We will measure the holes again when the part returns shot peened (before the decontamination which is done in-house).
- Is it possible at all to take the deformation of the shot peening into account when machining such tight tolerances?

It's a very interesting, yet complicated matter!

Answerer #1: Is it possible at all to take the deformation of the shot peening into account when machining such tight tolerances?"

This is done all the time when parts are sent to us for shot peen. You need to determine which process is changing the hole size (peening or cleaning), not always but most of the time peened holes get smaller not larger. Is it possible the holes could be being peened well beyond 100% coverage? If so, this would likely be the cause. I would suggest manufacturing one part and measuring it to sure it's within tolerance:

1) Then send it to the shot peen source for peening. However, DO NOT perform acid cleaning yet.
2) Once peening is complete re-measure the part.
3) If the part is within tolerance return the part for acid cleaning then measure again.
4) If the part is NOT within tolerance after peening then adjust your pre-peen dimension accordingly to factor in the changes caused by peening.
5) Manufacture another part with the new pre-peen dimensions then repeat the steps above.

Hope that helps.

Questioner: Thanks for the great reply. We were planning on doing these measurements.

As we don't do the shot peening in-house we don't actually know what they are doing. I will ask for the saturation curves.

The drawing asks for a coverage of 2.0, what they actually apply is unknown for the moment for me. Could this be the cause of being out of dimension (hole becoming too big)?

We will need to analyze further, but knowing we might have to look at their coverage would already help us a great deal.

Answerer #1: One other thing to check. Are you sure the diameter of these holes are a post-peening requirement? Often dimensions are prior to peen, and the designer realizes there will be some dimensional changes. If you tell me what specification you are working to perhaps I could help more.

Questioner: That's also something I've been looking at and will further look into. Spec is Bac5730.

For those interested: we have done an analysis on six parts. Though lots of questions remain, we have seen that the shot peening decreases the hole diameter for these parts.

What we do see is that the diameter change is not consistent. For the same program and part, we can have a difference of up to 11Âµm in diameter change purely because of shot peening (some parts show a 2 Âµm decrease of diameter, others 13, for the same part number, diameter and shot peen program!).

We are also looking at the etching bath, but there the differences are less pronounced. Still analyzing all the available data, but I'm sure we will get there!

SHOT PEENING AND BLAST CLEANING FORUM

Continued

Answerer #2: Thank you for the report. Curious about your results showing the difference in resulting diameter. You stated that it's the same part and the same diameter, but is it the same hole?

If in different locations, the amount of pre-peening stress may be different and cause varying amounts of resistance to deformation.

I am curious about your continued trials.

Questioner: Of the six parts, two are always the same PN. They were sent out together for shot peening (one of the problems: black box, we don't know what our subcontractor is doing and with COVID we can't visit them).

We see for example for the same hole on the same PN (but different part):
part 1 : -5Âµm diameter change because of shot peening
part 2: -16Âµm diameter change because of shot peening

The other PN are very similar (minor thickness change of non-holes), and there it's not consistent either. With tight tolerances, such big difference after shot peening between parts is difficult, as we don't know how to adapt our machining to take into account the shot peening.

Answerer #1: Something else to consider. In your original post you stated the intensity is .007A. Boeing generally allows a wide tolerance range. -0.002 to +0.005. So the allowed range would be .005-.011A. You might want to find out what the "intensity" is of the process. If it's at the high end of the range target the process to the lower limit. Perhaps impose your own tighter limit say .005-.008 A. If that doesn't work, you may want to peen the parts a second time at a substantially lower intensity but cutting the air pressure 50%. This will help to knock down the "high points" of the peening dimples. I suspect when you're measuring your picking up these points.

Think of it as a peak of a wave but not the level of the sea.

Questioner: I wanted to give a short update:
In the meantime we have analyzed around 12 parts and 192 holes at each operation (after machining - after first etch - after shot peening - after 2nd etch).

What we see now is that the shot-peened holes get a little bit smaller (around 5Âµm) because of the shot peening, but this is almost always cancelled out with the 2nd etch (increase in diameter with 5Âµm).

Now we always end up with diameters which are too small, so where the problem was on the first parts, we don't know. I'm suspecting the first etch process, but this is only speculation.

We will in the future probably soon adapt our machining program and keep analyzing for X parts like this to assure our changes are giving us the desired diameters.


Progressive
SURFACE