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The Shot Peener

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

COVID-19 and the Shot Peening Industry

PLUS: ARE YOU STILL USING MIL-S-13165? COIL SPRINGS RESEARCH BACK TO BASICS: SHOT VELOCITY

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OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

In Homage to W. Edwards Deming

(or "My Musings While at Home During the COVID-19 Pandemic)

I READ a pamphlet many years ago about Six Sigma statistical quality control as practiced in Japan. I was thoroughly impressed with the concept and wished I could apply those practices in my business. I started collecting data and reviewing my progress, but it was much later that I started using histogram charts with Six Sigma limits that I really understood process control.

I'm still obsessed with process control and these are quotes I recently found about quality:

Dr. W. Edwards Deming

- Management by results—like driving a car by looking in rear view mirror.
- A company could put a top man at every position and be swallowed by a competitor with people only half as good, but who are working together.
- No one can guess the future loss of business from a dissatisfied customer. The cost to replace a defective item on the production line is fairly easy to estimate, but the cost of a defective item that goes out to a customer defies measure.
- Our system of make-and-inspect, which if applied to making toast would be expressed: "You burn, I'll scrape."
- Every system is perfectly designed to get the results it gets.

These are famous quotes from an esteemed leader in the field of Total Quality Management (TQM) and many people will realize I'm talking about Dr. W. Edwards Deming. Dr. Deming is the internationally respected authority in the field of statistics, especially the sampling theory as well as its practice. Dr. Deming is one of the founders of statistical quality control in the U.S. From 1950 and onward, he provided a considerable contribution to post-war Japan in order to develop and advance the statistical quality control in the country. For his efforts, he was awarded the Second Order of the Sacred Treasure by the Japanese Government.

The Deming Prize was established in 1951 in further recognition of Dr. Deming's contribution to statistical quality control in Japan after World War II. The Deming Prize, given to individuals for their contribution to TQM and businesses that successfully implement TQM, is the oldest and one of the highest TQM awards in the world. The award is so revered in Japan that the awards ceremony is broadcast every year on Japan's national television.

I greatly admire Dr. Deming and even though he was born in 1900 and passed away in 1993, his work is still relevant today.

And speaking of quality, don't miss the article on how shot peening industry leaders navigated their businesses through the COVID-19 pandemic (page six). Most companies in our industry stayed open as essential businesses—defined as manufacturers and distributors of food and beverages, healthcare providers, transporters of essential goods, and businesses that support critical infrastructure—and we had to make adjustments to keep our employees healthy and plan for the future.

THE SHOT PEENER

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COVID-19 and the Shot Peening Industry

I SELDOM WRITE about timely subjects because I begin developing an article four months before the publication of the magazine. And, as we know, a lot can happen in four months. The pandemic will have such a lasting impact on the global economy, however, that I felt an article on our industry's response to the pandemic was a relevant topic. Thank you to everyone that responded to my questions. I greatly appreciate your input.

Tom Brickley, Vice-President, Electronics Inc.
Electronics Inc. (EI) stayed open during the pandemic. "We received letters from three essential businesses requesting that we stay open because we are critical suppliers. We made copies of the letters for employees to keep in their cars if they were pulled over by law enforcement during Indiana's stay-at-home lockdown. Our staff was never questioned but we wanted to be safe," said Tom.

EI let people work from home if their jobs allowed it. EI wants everyone back in the facility once the pandemic is over but has always enabled staff to work from home under special circumstances. For example, when an employee was undergoing chemotherapy, but wanted to continue working, she was able to work from home.

"I worked from home part-time because I have a high-risk family member and I was concerned about exposing her to the virus. Jack (Jack Champaigne, President of EI) worked from home part-time but we both maintained a presence at EI while practicing extreme social distancing. The only downside to working from home is that I gained weight," said Tom.

"We've always had bottles of hand sanitizer around the EI facility and foot-pull door openers on the restroom doors. After the pandemic started, we put foot-pull door openers on every door and hand sanitizer on every desk. We practice social distancing. Workstations and other surfaces are sanitized every day," said Tom. Some EI employees wore masks and gloves and warehouse workers that handle ingoing and outgoing product wear sterile gloves. "Many of us have noticed how much healthier we are. In the past, colds, the flu and stomach viruses would spread through the EI staff. We haven't had any of these illnesses during the pandemic. We will probably continue some of these practices," said Tom.

Before the pandemic, EI held their weekly engineering meetings in a conference room. Because it was impossible to practice social distancing in the meetings, they began to use video conferencing and will continue to use it with customers.

When asked how long he expects our industry to recover from the economic downturn, Tom said, "Good question. I'm hoping we will get back to normal within six months. At the beginning of the pandemic, we were swamped with Almen strip orders because customers were stocking up. We're not sure what sales will be like for the rest of the year but we're maintaining high inventory levels of all our products."

"Ironically, air travel is probably safer than ever because planes are being sterilized. We will be traveling as soon as the demand for training returns," said Tom. In closing, Tom added, "Everyone at EI wants to work."

Dr. Yoshihiro Watanabe, President and CEO, TOYO SEIKO CO., LTD.
We continued to produce cut wire shot media in Japan and Thailand, but not in

Interview Questions

1. Were you able to stay open during the pandemic as an essential business?
2. Did some of your employees work from home? If yes, will you let employees to work from home after the pandemic if their job allows it?
3. If you worked from home, what did you learn from the experience?
4. What precautions did you take to keep your workplace safe?
5. Did you develop new ways of working? For example, using Zoom for company meetings.
6. Did you incorporate new ways of working that will be useful after the pandemic?
7. How long do you anticipate our industry to fully recover from the pandemic?
8. Under what conditions will you and/or your staff resume business air travel?

the U.S. Our sales volume dropped, however, while OEM car manufacturers were shut down around the world.

We changed our work policies and we allowed some of our employees to work from home. This new working style could be acceptable after Corona. All employees in TOYO SEIKO facilities were required to wear masks and their temperatures were taken before each workday. Zoom video conferencing was used for internal meetings and with several of TOYO SEIKO's customers. We might continue to use Zoom meeting.

I think the recovery of the industry depends on the region, but I think it will be completely terminated in 2021. It is more desirable to develop vaccines and specific medicine. We will resume air travel as soon as each country's immigration restrictions are lifted.

Mengxi Wang, Sales in Charge, Jiangsu Daqi Metal Surface Preparation Co., Ltd.

Most businesses in China needed approval to open after the country's Spring Festival Holiday, where the COVID outbreak happened. (Editor's note: The Spring Festival is also known as the Chinese New Year or Lunar New Year. It is celebrated throughout China and it lasts for several days.) We were meant to get back to work on February 8, however, because of the long holiday and the time it took to prepare the documents for approval to open, we didn't start production until February 17.

All of Jiangsu Daqi Metal Surface Preparation's employees were required to work onsite but many precautions were taken. These precautions included:

- Workers back from other cities or towns were required to quarantine at their houses or appointed hotels for 14 days.
- Local workers had to show their travel record before entering the worksite.
- Temperatures were taken from every worker before they entered and left the worksite.
- Employees were required to wear masks.

I don't expect the industry to fully recover before autumn or the end of this year. We will not be attending industrial exhibitions and meetings in 2020 and we will not resume air travel until the health risks are stabilized.

Steve DeJong, President, Profile Industries

Profile Industries supplies agri-food businesses and medical device manufacturers and therefore was an essential business. Our employees in sales, marketing, and administration worked from home. I have always worked from home in the evenings after a day in the office and the manufacturing plant.

As far as employees that continued to work at Profile, items that were touched regularly were sanitized daily and employees practiced social distancing. Our staff used Zoom during the pandemic and will continue to use it.

I hope the industry will recover in three to six months and we will resume air travel as soon as restrictions are lifted.

Keynes Khu, Marketing Director, Dafeng Doshine International Co., Ltd.

The employees of Dafeng Doshine worked during the pandemic and office employees worked from home. We hope all people can work at the office after the pandemic! We took safety precautions including keeping a safe distance from each other, avoiding gatherings, wearing face masks and hand washing.

Dafeng Doshine experienced a downturn in business and I believe it will be two years before the industry recovers. The staff will resume air travel as soon as we see all numbers under control from WHO (World Health Organization) and all public places are opened.

Mike Deakin, President, Pellets LLC

While we didn't apply for essential business status, we received notices from several of our customers that they were essential businesses and they expected us to stay open. We have customers in defense, aerospace and medical industries.

A few of Pellets' employees worked from home but I don't see this as ongoing after we are over this crisis. The staff practiced social distancing and masks were provided for employees that chose to wear them. Work surfaces were sanitized, and hand sanitizer were provided throughout the facility. I have a feeling it will be many months before business will recover to pre-pandemic levels. We don't do a lot of air travel so we will play it by ear.

Mike Wern, President, Engineered Abrasives®

As an essential business, Engineered Abrasives® (EA®) was open during the pandemic. When asked what precautions were taken to keep the workplace safe, Mike replied, "We've always had a very clean operation," but he took extra measures by hiring the services of a company named Pure Maintenance. Pure Maintenance sterilized the EA facility with a dry fog coronavirus treatment that protected the staff from surface-to-human transmission.

Mike anticipates the industry will recover in a few months. "We will fly when we need to but most of our travel is done by driving," wrote Mike.

Scott Nangle, President, Empire Abrasive Equipment Co.

Empire Abrasive Equipment, deemed an essential business, stayed open during the pandemic. However, some employees chose to work from home. To keep the remaining staff safe in the workplace, we practiced social distancing, surfaces were sanitized four times a day, and all meetings were held by conference calls. Everyone got more comfortable with virtual tools. I don't expect the industry to fully recover for 24 to 36 months.

We will resume business travel if the work is essential and if the employee feels comfortable traveling.

Don Wildrick, Sales and Marketing Manager, Quality Engineering Services
Quality Engineering Services is an approved supplier to major aerospace manufacturing companies. Because of our longtime relationship with these companies, we continued to service them during this pandemic. We were fully operational as an essential business while following the recommended CDC guidelines. As an approved source, we provide these major customers with tooling designs for precision fixtures, gauges, fabrications and cast urethane masking tools and components.

Our design and sales personnel were able to work from home, however, in our business communication between design, engineering, manufacturing is more efficient when we are all in the same facility sharing information. Also being able to visit a customer to review a design concept is important because that can answer many questions and starts the whole process off correctly. So working from home can be convenient, but in our business all our departments working in the same facility has many advantages.

Hopefully for everyone, including our industry, we will all recover healthy from this pandemic and find a sense of normalcy again soon.

Joe McGreal, Vice-President Sales and Marketing, Ervin Industries
Ervin remained open as an essential business. To maintain the safety of our employees, we implemented a 100% Wellness Screening program and employees had their temperatures taken and participated in short interviews with a health professional.

Some of our employees worked from home, mostly the administration staff. We have no plans to let employees work from home after the "shelter-in-place" mandate is lifted. We will, however, accommodate anyone with a medical condition that leaves them at risk by working in our offices or plants.

Working from home can be efficient and productive for the tasks that do not require human interaction. This is a time saver when eliminating co-worker distractions and/or non-work related conversations (water cooler). Joe goes on to make this good point, "However, with a drastic reduction in business activity, working from home can give the appearance that it works great and can continue. What has not been tested is how this would work if we were at normal business levels." He added that moving documents from department to department is a burden when you can't share them on paper. Short questions and answers to solve problems take too long and slow down the total work output. Office phone technology is gone and too much time is spent trying to communicate. Ervin used Skype in the past and used it occasionally during the pandemic. "We tended to use voice conference calling so we don't have to see the crazy living conditions of our co-workers," added Joe.

I don't see the changes Ervin made during the pandemic as permanent—they were a way to mend a problem. The majority of our staff (95%) can't wait to get back in the office.

I estimate it will take a year for our industry to return to normal but the Ervin staff and I will resume air travel as soon as our customers, trade associations and other business activities allow. "We are 100% behind getting out into the business work place to promote the good features and benefits of our products. We are not convinced (yet) that commerce will trend away from "live" interactions for the most efficient education of the market place," he concluded.

Walter Beach, Vice-President, Peening Technologies
Peening Technologies received a letter from the Department of Defense that allowed us to stay open during the pandemic.

Many people worked from home and some came into the office one day a week. Regarding working from home, Walter wrote, "It improved life balance—I got to see my kids more than I normally do."

Peening Technologies took multiple steps to keep employees safe in our facilities. An hour separation was added between shifts and employees took an active role in disinfecting commonly touched surfaces before and after their work periods. Masks were provided and were required in areas where employees worked closely together. Tables were removed from the break room and employees ate outside or in their cars. A professional deep-cleaning service came in on weekends.

Peening Technologies used Zoom internally and Webex with most customers. We used Webex to get approval on new processes from customers. I have a feeling that may be a permanent change.

I estimate the aviation industry will take two years to return to where it was in February 2020. As far as flying again, "I'm hopeful that by September, we can resume flying. However, personally I'll be waiting until these planes have been back in the air for a few weeks. Who knows what problems will arise from bringing these planes and crews out from cold storage," he wrote.

Sinto America, Sinto Staff
Sinto America's shot peening service companies—National Peening and Technical Metal Finishing—are considered essential businesses with customers in aerospace, life science/medical, infrastructure and transportation. These businesses remained opened although we were affected by GE's shutdown schedule across a number of plants. Sinto America's Roberts Sinto Corporation, as a automation and services supplier to foundry and general manufacturing businesses, is not

an essential business, but remained open as a critical parts and service supplier to many essential businesses serving aerospace (military), infrastructure, medical and transportation companies. (Michael Halsband, CEO Sinto America)

The majority of office employees across all Sinto America companies, including Mexico, worked from home since the initial shelter-in-place executive orders were announced in March. "With manufacturing and services personnel still performing work at reduced levels, our HR and Executive Management teams have been in regular attendance to ensure the safety of our employees and provide onsite leadership," wrote Michael.

We can say with certainty that this pandemic forced us to do what we otherwise would not have done, allowing the majority of office employees to work from home. The interesting observation is that for certain roles the location at which the work is performed is not important. We increased the frequency of team calls to catch up and share thoughts and ideas as well as progress on projects. These calls, attended by all employees of a department, enabled us to have efficient communication, to continue to work in lock-step with each other and perform at the expected highest levels. Based on this very positive experience we will be open to some level of home office work in the future. Nevertheless, certain positions in engineering or specific people on the leadership team require to interact frequently with others and they will most likely be asked to work in the office again full time once the health risks from the pandemic have been mitigated. (Michael Halsband, CEO Sinto America)

Rachel Lunce, Human Resources Director Sinto America wrote, "During the shelter-in place, I split my time between working from home and working from the office. Since this was my first true experience working from home, I did learn quite a bit from it. The main thing I learned was to be flexible. Working from home causes unforeseen and unplanned occurrences that arise daily. Accepting that our normal routine was changing made the experience easier to accept. I made a "new" normal routine and went with the flow.

Second, communication was key. Not physically being with your co-workers forces you to overly communicate with emails and phone calls because you cannot just walk over to the desk when questions come up. Lastly, I learned to truly appreciate my office at work and my daily interactions with my co-workers. I found myself excited to get ready to go to work and have in-person conversation and interaction.

Sinto America developed a Preparedness and Response Plan Playbook for employees and trained everyone on the content. This plan included our COVID-19 screening process for employees and visitors entering into the facility, our cleaning procedures, social distancing requirements, proper handwashing and required PPE to be worn at work which includes wearing mask inside the facility. We conducted all of our meetings via WebEx and we initiated a weekly newsletter to communicate with all employees on COVID-19 updates, new company policies and positive news on events going on within our organization. (Rachel Lunce, Human Resources Director Sinto America)

Sinto America is taking a very conservative approach to the recovery after the pandemic. We are preparing for a longer term recovery that may take three to four years to come back to pre-pandemic levels. The company is taking a similar attitude toward air travel. Safety is our number one objective and given the current situation it is unlikely that we will allow our employees to utilize air travel any time soon. We will allow air travel as soon as reliable passenger testing prior to boarding a plane is in place. (Michael Halsband, CEO Sinto America)

PROTO Manufacturing, Maria Veinberg, Technical Writer

PROTO was deemed an essential business and was able to stay open during the pandemic. We take customer service very seriously, so we are glad we could continue operating with minimal interruptions while still maintaining strict safety measures.

About half of our employees were able to work from home during the pandemic. Thanks to our advanced cloud-based technology that has been implemented over the last couple of years, working from home was an easy transition for most of our employees. By making use of company Slack, Dropbox, and email platforms, employees could maintain their regular level of communication with coworkers and supervisors.

Working from home during the COVID-19 pandemic showed us that we could accomplish many more tasks remotely than we previously thought. Many employees were new to working from home, but they were able to adapt and remain productive after only a minor learning curve. By using the proper tools, employees could hold meetings, participate in fruitful group conversations, plan and complete projects, and work as a team to solve problems.

In addition, communication became more intentional and, in some cases, more effective while we worked from home. Employees could no longer stop by their coworkers' desks to catch them up on a particular project; instead, they had to make a conscious effort to update them electronically, which often resulted in clearer, more beneficial communication strategies.

In terms of maximizing our productivity from our home offices, we learned a few valuable lessons. Firstly, setting boundaries is important. We realized quickly that we needed to communicate with our family members and let them know when we were working so that everyone was on the same page. We also found that starting and ending at the same time as we normally would, as well as taking our scheduled breaks, helped us transition more easily to working from home. For our employees who were working on site during the pandemic, we prioritized health and safety by putting

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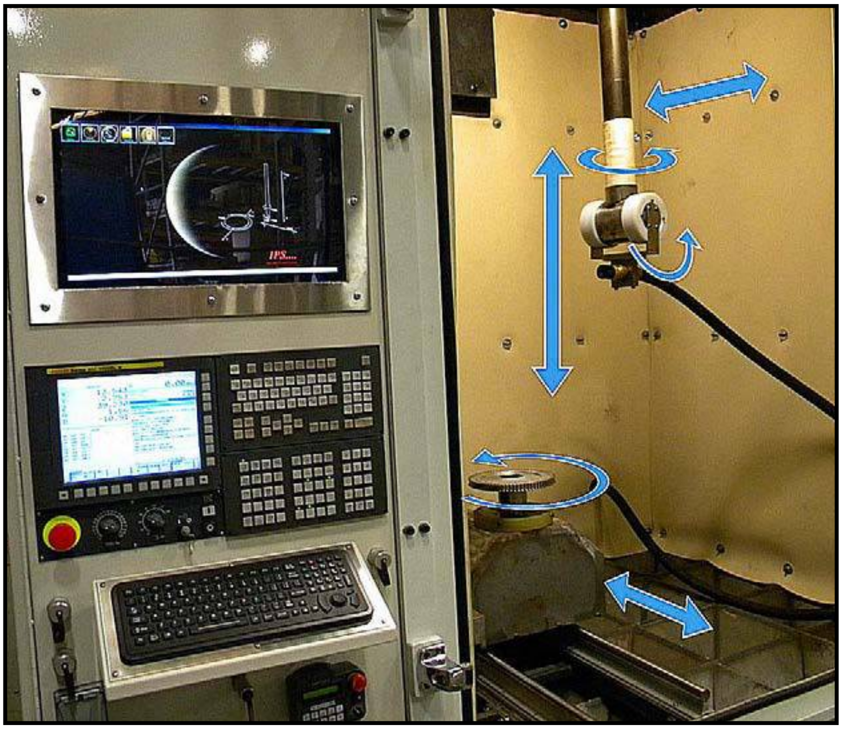


CNC motion allows the nozzle to follow the contour of the part. This motion provides consistent intensities and coverages to occur with optimal speed and precision.

new policies and procedures in place. Most importantly, we limited the number of employees present on site by allowing employees to work from home whenever possible. We closed our workplace off to the public to limit in-person interactions, and we prohibited in-person meetings. Sanitizer was placed at the entrances for employees to use upon entry/exit of the building, and highly touched surfaces were disinfected multiple times each day. Through a series of company memos, we advised employees to clean their workstations regularly, adhere to social distancing and hygiene guidelines, and find ways to keep their immune systems strong. Finally, we had daily health and safety check-ins to assess new information and set guidelines, and we encouraged employees to provide their input via Slack in dedicated health and safety channels.

Although PROTO already used Slack before the pandemic, we started using more advanced features such as voice calling, video conferencing, and screen sharing. We also used Zoom to communicate with customers.

The new methods we incorporated will certainly be useful after the pandemic is resolved. For example, some employees may work from home from time to time. In addition, we will continue voice chatting via Slack, as it makes meetings and communication more efficient between employees at different office locations.

It's tough to say how long it will take for the industry to recover. However, we're hopeful that there will actually be a positive effect on our industry once the pandemic is resolved. Our industry is resilient and hard working, and we imagine that our eagerness to work will only increase once we all return to our on-site jobs. Because of this pandemic, we've definitely learned not to take things for granted, and being able to go to work and see our coworkers is one of them.

Business air travel is prohibited until government officials announce that it is safe to travel again. This will involve isolation/lockdown rules being lifted and a thorough assessment of the safety of all our employees and customers. Until that happens, PROTO employees can drive or assist customers remotely when possible.

Jeff Pruitt, Marketing Coordinator, Magnetic Inspection Laboratory

Magnetic Inspection Laboratory (MIL) remained fully operational as an essential business per Homeland Security and the Department of Defense. We process a variety of medical, defense and other highly essential components on a daily basis. Medical supplies were prioritized and expedited by our production teams in order to ensure necessary equipment for fighting against COVID-19. It was our goal to not only support our customers' efforts, but to provide assistance to those on the frontlines of this pandemic as well. MIL prioritized the following:

- Medical Equipment: Respirators, Ventilators, Oxygen Delivery Systems, Medical Diagnostic Systems (COVID testing), Surgical Instruments
- Defense Equipment: Fighter jets (F-35, F-18, F-16), Military cargo carrier (C-130), missile systems (THAAD, Hellfire, PAC-3), Avionics
- Space Systems: NASA, Spacex

MIL provided the opportunity to work remotely to all employees capable of successfully continuing their daily functions off-site. MIL has invested in the proper equipment and technology to ensure those working from home have all the proper tools at their disposal. For those still working on site, MIL was able to develop a new shift rotation to limit contact between employees.

"Coffee is an essential item when working from home." wrote Jeff. Clear and concise communication is necessary to get high value information to others quickly and accurately. The number of tools at our disposal to collaborate is astounding. The industry should be prepared for an eventual shift into a more digital-based realm. From trade shows to the increase in webinars, we may be in for a drastic change in how we do business.

For those working at MIL, the company was quick to develop an internal response team to coordinate and facilitate urgent action items throughout the company. This team constantly relayed vital information to ensure everyone was aware of the current company status, updated safety protocols, information on COVID-19 symptoms and testing opportunities, etc. We implemented teleconferencing capabilities in order to support our employees working from home. We have physically rearranged departments and communal areas to accommodate social distancing protocols and limit the capacity of each area.

Additional precautions included building-to-building part transport procedures were given enhanced safety measures and procedures, development of new disinfecting protocols and procedures, including an atomizer for disinfecting large areas, new illness and return-to-work procedures and protocols have been implemented. Due to the sudden run on hand sanitizer, our in-house chemist created our own following FDA guidelines.

Prior to the pandemic, MIL upgraded their internal phone system to Dialpad. Dialpad is a cloud-based phone platform that allowed our team to keep in constant contact through phone calls, group video chats, and messages. This system seamlessly integrates with MIL's Microsoft Office programs, such as Microsoft Teams, which has helped improve our collaboration with employees working on and off-site.

Continued on page 44

AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

Are You Still Using MIL-S-13165?

INTRODUCTION

We have been shot peeners for a while now. Having fully acknowledged the efficacy of the process, we have advanced it from hammer peening leaf springs in medieval times to today's computerised shot peening of mission-critical aircraft components. Over the years, along with sophisticated machinery, we have also installed processes and specifications that ensure process reliability. We have early adopters in the automotive and aerospace industries, followed by oil & gas, mining, and medical implants embracing our cohort more recently. Though the common goal is to generate compressive stress leading to increased fatigue life, the indentations also create reservoirs that store the lubricant in certain components. Whatever the ultimate goal, clear awareness of the process and the desire to adopt are directly proportional to the user's earnestness in conforming to commonly adopted specifications.

In my involvement with this industry over the last three decades, the most common document cited to me is MIL-S-13165C. For those new to shot peening, MIL stands for Military, and the first version of this specification, "Shot Peening of Ferrous Metal Parts" was published in December 1953. It was intended for use by Departments of Army, Navy, and the Air Force. This specification was cancelled in February 1998 and replaced by AMS-S-13165. AMS-S-13165 was made redundant by AMS 2430 and AMS 2432. We now reference and conform to AMS 2430 and AMS 2432.

Our discussion here is driven by the fact that several end-users continue to use the original MIL specification for their peening operations. To those users, I hope to provide a comparison and plausible reason to progress to a common spec platform.

HISTORY

(Author's note: I received documentation and consultative assistance from Jack Champaigne, Chair of the Surface Enhancement Committee, SAE, on the history of specifications.)

AXS-1272 - General Specification for Shot Peening of Metals was drafted and revised in August 1944 and it is considered the foundation for the MIL spec. This document was created by the Ordnance Department of the US Army and has all the fundamental information required to conduct shot peening, such as intensity, shot size, shot maintenance, coverage, and intensity (saturation curves did not exist during those times, and what we know as "arc height" today was referred to as "intensity" in this specification). The specification also lists the criteria for shot selection. Interestingly, in giving more importance to coverage, the specification suggests plotting a saturation curve with test strips at increasing exposure times and relying on flattening of this curve as a measure of complete coverage. In 1944, Almen strips were sold by Pangborn and Wheelabrator (formerly American Foundry Equipment Company), two of our industry's oldest companies, per this document.

MIL-S-13165 was published and progressed to four updates, starting with MIL-S-13165 (ord) in December 1953, followed by MIL-S-13165A in March 1956, MIL-S-13165B in December 1966 and finally MIL-S-13165C in June 1989. Overall, the MIL spec is an extension or replacement document to AXS-1272. Salient points from each update of the MIL spec are listed here to demonstrate the progression:

- The media types listed in MIL-S-13165A are cast iron, cast steel, and cut wire (conditioned). Arc heights were still an acceptable measure of intensity. These "intensity" values were measured using the A and C strips only; the N strip did not exist. There was no quantifiable number to signify complete coverage (such as 98% or 100% as we know now).
- Though some of the details such as arc height/intensity still prevailed, MIL-S-13165B is a quantum leap from its previous version. Some of the notables include:
    - Type of equipment and requirement of separator for continuous removal of broken or defective shot
    - Introduction of the N strip
    - Listing of minimum shot sizes for a particular intensity target (details were likely not available in part drawings at that time)
    - Better definition of strip limitations for intensity ranges
    - Acceptable and unacceptable shapes of shot (this is the first instance where shape of the shot is given importance in a specification)

Given that the MIL spec remained unaltered for the next 23 years, the final version MIL-S-13165C published in June 1989 had substantial changes. If you read it now, this version might still seem outdated in comparison to AMS 2430 and

2432. However, MIL-S-13165C embodied sound peening practices that were further polished and clarified, with the benefit of experience, in the AMS documents listed above.

MIL-S-13165C was cancelled in February 1998 and replaced with AMS-S-13165. This AMS document, with some editorial changes, signified the transfer of this spec from the Military to AMS (Aerospace Material Specification) administered by SAE (Society of Automotive Engineers). This transformed the specification to an industrial rather than a military standard.

MIL-S-13165C – THE MIL SPEC

During its active life, the MIL spec widely proliferated in the shot peening industry. It is still common for users to seek its conformance in their peening operation. The Aerospace industry, with its multi-tiered structure, has almost entirely switched to AMS 2430 and 2432. Other industries, including part of the Automotive sector, still use MIL-S-13165C. These are some of the features of MIL-S-13165C that keep it relevant to a large group of users:

- **3.2:** Introduction to Automated and Computer controlled shot peening—not only does the specification account for varying levels of sophistication in peening equipment types, it also introduces the user to process control elements, shutdown limits and reporting of process data. These details that are elements of AMS 2430 & 2432 were novel in 1989 when revision C was published.
- **3.3.6:** In addition to suggesting intensity values based on part thickness when the intensity is not listed, the specification provided an allowance of -0, +30%, but in no case less than three intensity units, when only a minimum intensity is specified. This removes the ambiguity in situations where the engineer drafting the peening requirements failed to accommodate for the practical difficulty (and futility) in achieving a fixed intensity value, especially at multiple locations in a component.
    - An interesting comment was made by Walter Beach of Peening Technologies who helped me review this article. He noted that a major aerospace company permits a default tolerance band of -0.002" to +0.005", unless otherwise stated in the drawing. Having a wider range to start with makes it more practical to center the process.
    - When verifying the intensity during regular production (after developing the initial saturation curves), SAE J443 requires that the arc height at each strip location be within 0.0015". However, the resultant arc height does not have to be within the intensity tolerance band for verification time T.
    - AMS 2430 takes this further and attaches another condition to verification: The resulting verification arc height, along with the 0.0015" tolerance, shall stay within the intensity range for the part. MIL-S-13165 does not have this repeatability requirement.
- **3.3.9:** Media maintenance consumes a large part of the text in new and old specifications for shot peening. Notwithstanding the fact that media does play a critical role in the achievement of accurate and repeatable peening results, the different types of media validate the need for this elaboration. As a side note, all versions of the MIL spec included cast iron as a peening media type. Cast iron constitutes alloys with a carbon content greater than 2% and is not considered suitable for shot peening due to the inherent brittleness and reduced durability (i.e., its inability to maintain sphericity due to rapid fracture). Cast steel that is commonly used as a shot peening media has carbon content between 0.8% and 1.2%, thereby providing a working balance between durability and energy transmitting properties.
- **4.2.3:** Generation of a saturation curve is explained in detail in this version of MIL spec. Being the first attempt of this kind in a specification, the language (which was refined in the future AMS documents) resulted in ambiguity among its adopters. To quote, "Saturation is achieved when, as the exposure time for the test strips is doubled, the arc height does not increase by more than 10%." This was tightened to "intensity is defined as the arc height value on the curve that increases by 10% when the exposure time is doubled" in SAE J443. AMS 2430 and 2432 refer to this practice.
- The "Notes" section of this specification is filled with valuable information on the practical aspects of the process such as explaining the effect of process parameters that affect peening results (6.9) and detailed information on inspection of coverage.

It is not surprising that MIL-S-13165C was the definitive document from 1989 to 1998. It was only when the military decided to pass on the responsibility of spec maintenance to industry that the AMS peening specifications gained momentum. The original AMS document on shot peening (AMS 2430) was first issued in 1948 but not as widely used as the MIL spec for peening.

The above historical information will help answer some important questions: Can I continue to use the MIL spec? What are the differences between MIL13165C and AMS 2430/2432? What can I do if my organization insists on staying with MIL-S-13165C? Am I peening my product correctly to derive its benefits in a repeatable fashion? Let us analyze the above in the following paragraphs.

AMS 2430 AND MIL-S-13165C

The MIL spec is a standalone, comprehensive document that incorporates all required information in a single location. The AMS documents refer to multiple J documents, called "Recommended Practices." AMS 2430 is for Shot Peening,

Automatic and AMS 2432 covers Shot Peening, Computer Monitored. Since the immediate correlation to MIL-S-13165C is with AMS 2430, let us compare the contents of the two documents.

- AMS 2430 has a legacy provision, where cancelled documents such as AMS 13165 can be used until such time that AMS develops a document for such processes, such as barrel peening, as long as it is approved by the purchaser.
- Maintenance of peening media is where majority of the changes appear between the documents. The following table lists those differences.

MIL 13165 C dated 7 June 1989 Shot Peening of Metal Parts	AMS 2430, Rev S, issued July 2012 Shot Peening, Automatic
3.1: Shot • (3.1.1): Cast iron is listed as one of the media types. Selection of shot hardness is explained in relation to part tensile strength. J documents are referred to for use of Ceramic and Glass bead 3.1: Shot • (3.1.1): Cast iron is listed as one of the media types. Selection of shot hardness is explained in relation to part tensile strength. J documents are referred to for use of Ceramic and Glass bead • (3.1.2): Size and quality (new or reclassified) of shot at the option of the contractor. The media should conform to: (3.1.3) - Table 1: Shape classification table • Maximum allowable unacceptable particles (shape) are greater (signified by sketches of 'acceptable' and 'unacceptable'. No definition for 'marginal' as in AMS 2430 (new and in-process)	3.1: Peening Media • Split into 3.1.1: New media and 3.1.2: In-process media • New media to conform to AMS 2431, which in turn references AMS 2431/1 to /8 for different media types and SAE/ASTM documents related to media classification and testing. These documents list the requirements for screening, acceptable shapes, chemistry etc. • In-process media (3.1.2) has screening tolerance (Table 1), acceptable shape notification (Figure 1) and shape tolerance for metallic and non-metallic media (tables 2A and 2B) • Screening (size) tolerance is identical in both specifications. • Provision for 'Marginal' shapes in specifications. Tolerance is tighter than MIL for unacceptable particles.

	Max. Unacceptable		**AMS (new)**	
	MIL-S-13165	AMS (in process)	Marginal	Unacceptable
S230	32	14	14	5
S280	23	9	20	4
S330	16	7	14	3
S390	45	22	39	7
S460	32	16	28	5
S550	22	9	20	4
S660	16	7	16	3

In order to conform to the stringent media quality requirements, AMS 2430 emphasizes the need for process control components such as inline classifiers and spiral separators (3.2.1.2). Though the language in the document could be interpreted as if the user is offered a choice (Equipment "may" include a media separator to mechanically control size and shape…………inclined belt), experience would have already confirmed to you that a shot peening operation can not produce repeatable results in the absence of such devices in your machine. That said, 4.2.2, Table 6 in AMS 2430 lists the frequency requirements of in-process media size and shape inspection with and without a separator.

AMS 2430 continues with other aspects of the peening process such as low air pressure alarm (3.2.1.3) for compressed air machines. Overall, AMS 2430 describes all aspects of process control and inspection in greater detail than MIL, whether it be in the main body of the specification or the comprehensive notes section of the specification.

The requirement governing an analogous parameter to air pressure, in a centrifugal wheel machine, the wheel speed, is listed in AMS 2432.

When compared to AMS 2430, AMS 2432 is extremely process-control oriented with shut-down limits imposed on critical process parameters, including the material handling equipment presenting the component to the blast nozzles or wheels. A review of AMS 2432 will require a separate discussion, outside the purview of this one.

SUMMARY

When you have a well-established peening process that conforms to MIL-S-13165C, is there a reason to adopt a different specification? The response depends on your peening equipment. If your end-customer stipulates this requirement, you could make a case with the above comparison/equivalence data. If your peening machine is built with process control components that allow meeting the requirements of AMS 2430, it might just be a matter of conducting an audit to 2430 and see how you fare. It might be as simple as making slight modifications to your process to achieve conformance. Will such conformance change the quality of your product? The answer to that question is highly subjective. There is no doubt that a tighter process will result in greater repeatability and less rejections and failures. However, that does not diminish the fact that your process can be fine-tuned by conscious choice and not necessarily dictated by a specification.

James Pineault and Mohammed Belassel | *PROTO Manufacturing*

Quantifying Residual Stress in Shot-Peened Springs

RESIDUAL STRESSES in manufactured components, assemblies, and structures can improve or diminish their service life, and this is especially true for coil springs. Because fabrication and forming operations often produce surface conditions that debit the fatigue life of production springs, peening processes are often performed to improve the surface condition and fatigue resistance of coil springs. As there are several different types of coil springs, it follows that each type may experience failure at different locations based on how they are manufactured and used. In compression springs, tensile residual stress at the inner diameter (ID) is the most common source of failure. On the other hand, torsion springs tend to fail at the outer diameter (OD), and tension springs typically fail at the inner radius of their hook. These variation in failure locations make it important to understand the residual stress present in a particular spring before and after shot peening.

When a spring wire is formed into a coil (see Figure 1) and then heat treated or heat set to obtain specific performance characteristics, a complex residual stress field is generated in the spring. Even if the spring wire is stress free prior to formation of the coil, significant tensile stresses typically reside on the ID of the set coil. As shown in Figure 2, when a stress-free wire (shown in green) is bent elastically (blue), the ID is in compression, and the OD is in tension. If the bending load is then removed from the wire, it returns to the stress-free state (green). However, if the wire is bent elasto-plastically (shown in red) beyond the yield strength of the material to form a permanent spring coil set, the wire will only partially spring back when the applied bending load is removed and will remain with the intended spring coil set. In this case, the resultant stress introduced into the part will be tensile on the ID and compressive on the OD (shown in black). Moreover, as Figure 2 demonstrates, the tensile residual stresses will also be a maximum on the ID. Since total stress is equal to residual stress plus applied stress, the compressive loading of a spring in service creates the perfect conditions for its premature failure under fatigue loading (i.e., adding tensile applied stresses to an already tensile residual stress state).

To mitigate this condition, shot peening is often applied since it is a convenient, cost-effective, and potent method of imparting compressive residual stresses near the surface of a spring. As shown in Figure 3, when an as-formed coil (black) is shot peened, a compressive residual stress layer is imparted near the surface around the circumference of the spring wire (purple). These residual stresses are redistributed, generating additional balancing tensile residual stresses below the surface, where they are more benign. This is an example of how a component's tensile stress can be redistributed into areas that will not be detrimental to the part. The compressive cold worked layer will enhance fatigue resistance through

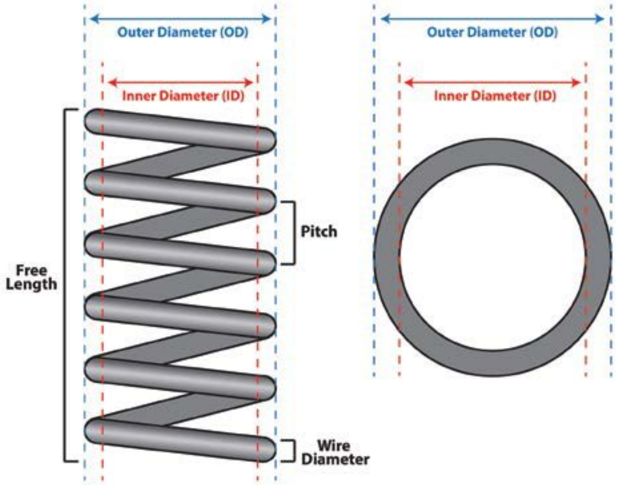


Figure 1

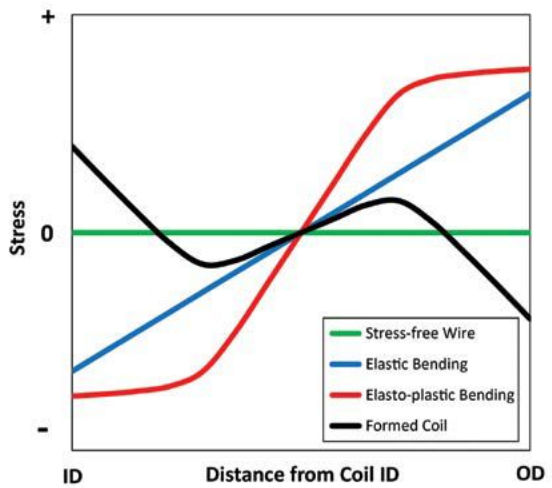


Figure 2

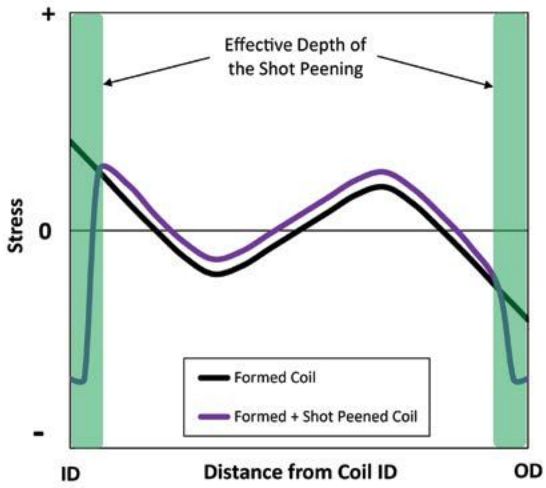


Figure 3

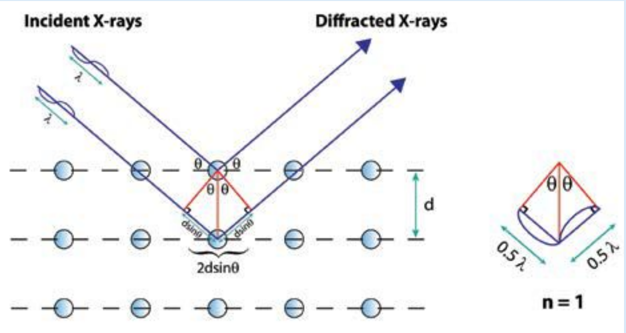
the effective depth of the shot peening (shown in green). Moreover, the effective depth, as well as the magnitude of the compressive layer imparted, varies with the material's properties and can be controlled via the applied peening pressure, the hardness of the shot relative to the coil wire, the coverage, the peening nozzle angle, etc.

The resultant peening intensity for a given set of peening parameters is normally characterized by the deflection of a suitable Almen strip—a time-tested and reliable metric for qualifying and monitoring whether a given peening process has been applied to specification. An Almen strip is a thin strip of steel that is placed in the shot peening chamber. Through a measurement of the Almen strip's deflection after peening, it can be used to quantify the intensity of the shot peening process. However, an Almen strip is unable to quantify the resulting residual stress state of the component. This direct information can only be obtained by measuring the residual stress in the component itself after the peening process. Many different residual stress fields may result from the same peening intensity measured by the Almen strip: the peened part may react differently to a given peening process as a result of its material properties, its shape, its residual stress field prior to peening, and other factors such as the peening equipment setup, nozzle angles, percent coverage, etc. Thus, the only way to understand the precise residual stress field is to measure it experimentally. Industry has long recognized that x-ray diffraction (XRD) is the method of choice for the characterization of residual stresses in shot-peened components due to its high spatial resolution and its ability to capture the often steep gradients resulting from peening at and near the surface, where it matters most (i.e., where cracks tend to initiate). XRD-based residual stress measurements have been applied to quantitatively characterize and evaluate numerous peening processes in a wide variety of applications and industries, both in the laboratory and in the field (using portable equipment). As such, XRD has been a very flexible and invaluable tool for process development and optimization where the best peening parameters for a given component must be characterized quantitatively. Components treated with conventional peening/blasting media such as cast shot, cut wire, and glass bead, as well as those treated with more unconventional treatments, such as laser shock peening, have been successfully characterized using XRD. Since peening is a value-added process, its effects can be optimized using XRD analysis to obtain a better return on investment, improve product quality, minimize the effects of fatigue and stress corrosion, decrease development and production costs, reduce component weight, and/or enhance component performance. Conditions such as over-peening or unnecessary peening time can also be minimized with great economic benefit.

Advances in technology have enabled the creation of XRD instruments that are very robust and capable of measuring on almost any component geometry. The inner diameter of coil springs (and other components with small ID) can often be measured without the need for sectioning or destroying the component when the appropriate equipment configuration is used (see Figure 4 on page 22). However, for springs that are too small to be measured directly, they can be measured by simply sectioning first to gain access to the inside of the spring.

To better understand the effects and resultant residual stress fields obtained from the application of various peening parameters, residual-stress-versus-depth profiles are typically collected using XRD measurements from the surface through the effective depth of the peening process (i.e., through the peening cold worked layer and below). To

X-rays are diffracted by atoms arranged periodically in crystalline materials such as metals and ceramics. The angle of a diffracted x-ray beam, θ is related to the atomic lattice spacing, d, via Bragg's law: $n\lambda= 2d\sin\theta$ where λ is the wavelength of the incident x-ray beam and n is an integer multiple of the wavelength. By measuring the diffraction angle for a given wavelength, the d-spacing, and thus the strain, can be calculated for the sampled volume. The stress can then easily be calculated using elasticity theory.



confirm the precise effect of the peening process, a baseline residual-stress-versus-depth profile may also be collected on an un-peened part. As shown in Figure 5, an as-formed coil spring has significantly different residual stress on the ID versus the OD. The ID profile, shown in red, is characterized by tensile residual stress, while the OD (blue) is compressive. Because measurements on the ID revealed tensile residual stress, further testing was performed on the ID to examine the effectiveness of shot peening on reducing harmful stresses at this location. Identically formed springs were peened using a 230R shot single peening process and a 460H/230R dual peening process (shown in black and green, respectively). The depth to which the peening process has affected the material can be seen in Figure 5 where the residual stress levels of the peened springs (black and green lines) meet the baseline curve (red line). Quantitative data sets can be used with fracture mechanics software to make predictions about fatigue life and damage tolerance, or data sets can be used in conjunction with fatigue testing to establish the correct level of residual stress needed to achieve the required fatigue life. Moreover, the data can be used to create a specification once the results have been verified for consistency by testing a sufficient number of samples (e.g., five) to account for part-to-part variance due to the peening process. Results can be

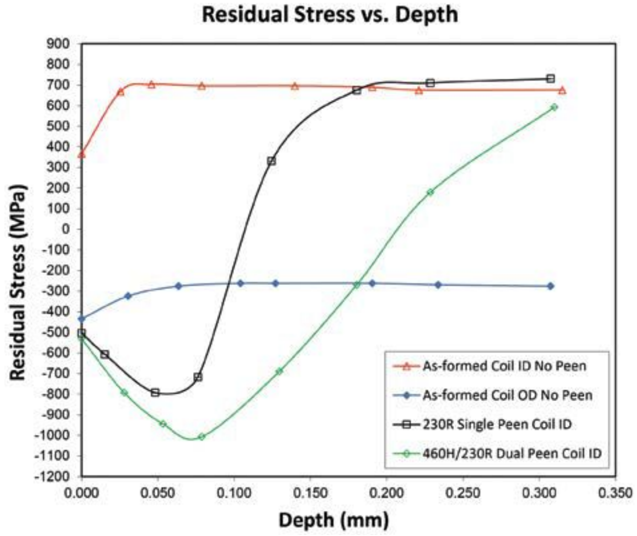


Figure 5

used to establish a residual stress level at which a component's fatigue life will be increased, thus allowing the identification of a minimum threshold for peening. It may even be possible to reduce the peening specification to a single depth and residual stress value, thereby simplifying quality control processes. For example, in the profiles shown above, the specification may be to peen all springs to at least -1000 MPa at a depth of 0.075 mm. For future tests, this one depth can be tested rather than measuring at the surface, as it will be indicative of whether peening was performed adequately.

As illustrated above, XRD residual stress measurements provide the quantitative data necessary to fine-tune shot peening processes. Because concrete numbers can be attained, specifications can be accurately defined and peening processes can be optimized. For anyone who designs components that will be shot peened, obtaining a residual stress specification is necessary to ensure proper quality control.

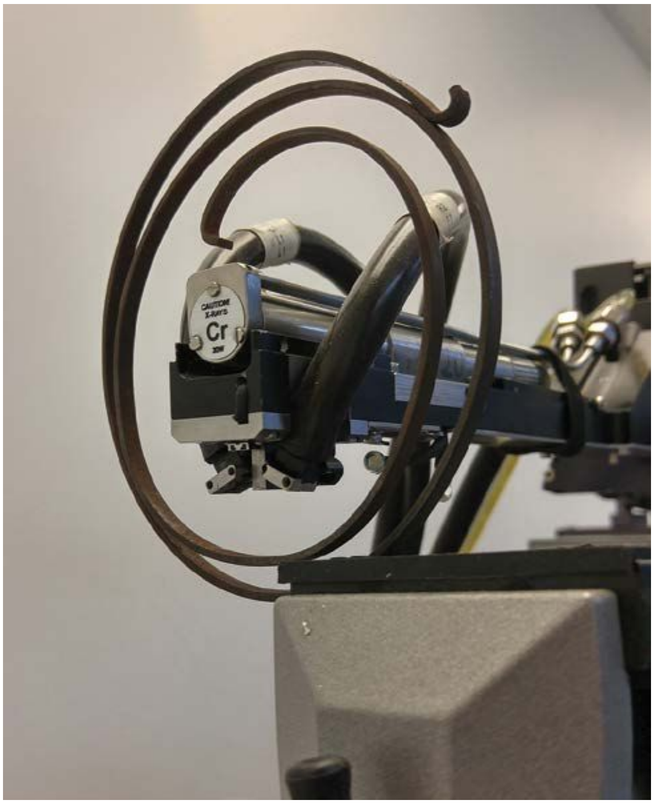


Figure 4

About PROTO Manufacturing
PROTO is a world leader in the measurement of residual stress using XRD and has been helping companies for over 35 years with the measurement of residual stresses in the laboratory, on the shop floor, and in the field. PROTO produces off-the-shelf instruments and custom solutions, and their team also offers residual stress measurement services in their laboratories.

Some examples of structures/components characterized include suspension bridges, ships, submarines, natural gas pipelines, automotive components, medical implants, power generation structures, and aerospace components.

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

High-volume automotive systems for transmission gears

Designed and built by EA®

Three (3) Index Units with complete load and unload automation

All three machines built and tested on EA® floor

Single Cell Unit, 5 Pressure Nozzles

Bucket Elevator
Sweco System
MagnaValves®

6 Spindles each station for high volume

Dual Swing Doors for higher volume

Large 84" Index Unit, 12 Pressure Nozzles

ACADEMIC STUDY
Dr. David Kirk | Coventry University

Back to Basics: Shot Velocity

INTRODUCTION

The aim of this mini-series is to cover the basic scientific principles of shot peening. Fundamental principles are presented together with relevant theoretical explanations. Shot particles themselves, together with the velocity that we give them, are the two essential factors needed to carry out shot peening. Quoting from the song made famous by Frank Sinatra: "They go together like a horse and carriage—you can't have one without the other." This synergy is also encapsulated by the formula, ½mv^2, that represents the kinetic energy for each accelerated shot particle (m being mass and v being velocity).

Shot is accelerated to its required velocity by applying either pneumatic or mechanical force. Pneumatic acceleration is normally achieved using high-velocity air as the fluid or alternatively water. Mechanical force acceleration is normally achieved using a bladed rotating wheel. Unlike shot particles, velocity is not covered by specifications. The Almen strip test can be used to prove, indirectly, that the required velocity has been achieved.

Equations are necessary to show how shot velocity is influenced quantitatively by shot peening variables. We do not need to know how they were derived just as we can use Pythagoras' Theorem without being able to derive it.

GENERATION OF AIR-BLAST SHOT VELOCITY

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

1 - Air stream,

2 - Introduction of shot into the air stream and

3 - Acceleration of the shot particles by the air stream.

A general equation is available that can be used to predict shot velocity based on the effects of shot size and density together with nozzle air pressure and nozzle length.

1 - AIR STREAM

1.1 Compressed air

Our primary need is to have an adequate supply of compressed air. The outlet from an air compressor goes into a ballast tank and thence to an air supply pipe, preferably via a drying unit. The compressed air flows as a stream through the pipe. This can then be connected to a shot feed and nozzle system. Ballast tanks even out pressure fluctuations from the compressor and provide a reservoir of compressed air. One or more pressure control valves, **PCV**, will be present in the air supply line. The compressed air, at a pressure, **p_1**, is fed into a blast hose of length **L**, at the other end of which is a nozzle where the pressure will then be **p_2**, see fig. 1. It is the nozzle pressure that is the key factor affecting induced shot velocity.

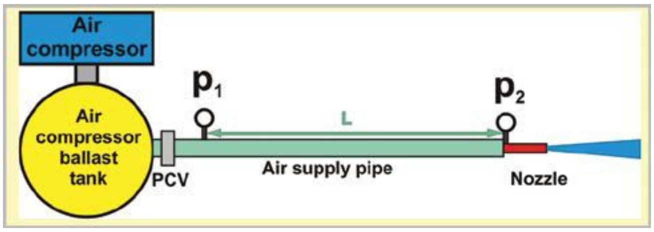


Fig. 1. Air stream generation and supply to nozzle.

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

Air at atmospheric pressure has a density of about 1.2 kgm^{-3}. If we compress it by applying an outside additional pressure of one atmosphere (14.7 psi) we halve its volume (P = 1 so that CR = 2) and thereby double its density. At a typical applied peening pressure of seven atmospheres (100 psi) we have multiplied its density by a factor of eight to about 100 kgm^{-3} which compares with 1000 kgm^{-3} for water. Air density = CR times 1.2 kgm^{-3}. It is this "heavy air" that we force through air supply pipes. Fig. 2 (page 30) illustrates heavy air production.

We must note that the air pressure at the nozzle is not constant. The air compressor ballast tank, see fig. 1, reduces but does not eliminate the air compressor's set pressure range. Air density is a prime factor in accelerating shot particles. Compare, as an analogy, standing in a street with a wind blowing at 10 klmh^{-1} with standing in a river that is also flowing at 10 klmh^{-1}. We would not be blown over by the wind but we would be pushed over by the water's flow.

Background image courtesy of Progressive Surface.

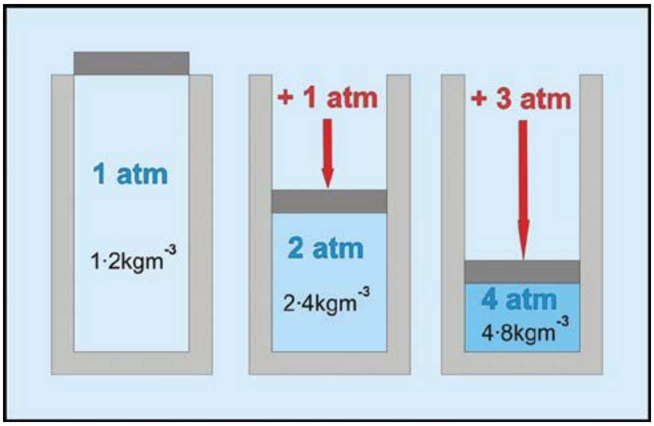


Fig. 2. "Heavy air" production by compression.

The reason lies in the relative densities of the two fluids—1.2 kgm^{-3} for air compared with 1000 kgm^{-3} for water.

1.2 Pipe flow

A useful analogy when considering pipe flow rates is that of electricity. Just as we need a potential difference between the ends of a wire for electricity to flow so we need a pressure difference between the ends of a pipe for air to flow. In fig. 1 (**$p_1 - p_2$**) represents the pressure difference between the ends of the air supply pipe. This pressure difference induces a corresponding air flow rate, **Q**, through that pipe. (**$p_1 - p_2$**) is useful as a process control parameter. Changes in (**$p_1 - p_2$**) can be either abrupt or gradual. For example, if (**$p_1 - p_2$**) = **p_1** we have a burst pipe! If (**$p_1 - p_2$**) approaches zero then the pipe has become blocked with shot at the nozzle. A common example of gradual change is that caused by nozzle wear. As the nozzle diameter increases (**$p_1 - p_2$**) increases (assuming that **p_1** is maintained at a constant value which is normal industrial practice).

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

1.3 Nozzle flow

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

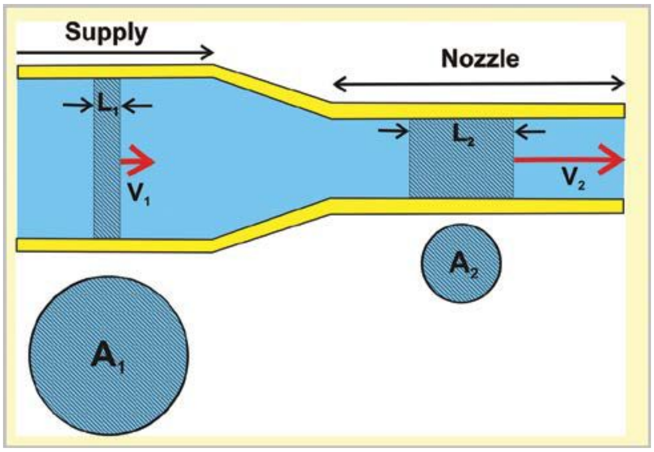


Fig. 3. Acceleration of air stream velocity by peening nozzle.

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

Practical nozzle air pressures are always high enough to produce what is termed "choked flow". Fig. 4 is a simplified schematic representation of how the nozzle air velocity changes with increase of nozzle air pressure. A "sonic barrier" exists at the narrowest part of the nozzle, caused by the difference in pressure in the nozzle as compared with that in the peening unit. This barrier occurs when the air pressure difference is about 1.9 atm. Because all practical peening involves a pressure difference of more than 2 atm (29.4 psi) we have a fixed limited air velocity in the nozzle regardless

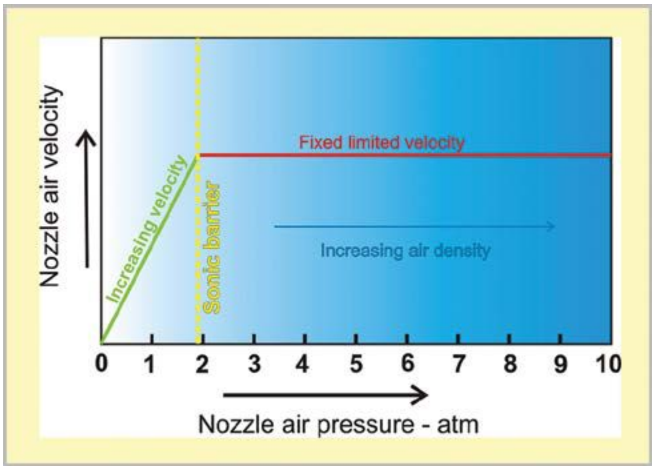


Fig. 4. Schematic representation of velocity variation with air pressure.

of nozzle pressure and nozzle diameter. This fixed limited air velocity is commonly the speed of sound but may vary slightly with nozzle design. The air velocity across the nozzle varies from a maximum of 340 $m.s^{-1}$ (speed of sound in air) to zero at the nozzle wall. An average value of 207 $m.s^{-1}$ within the nozzle reflects this variation.

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

2 - INTRODUCTION OF SHOT INTO THE AIR STREAM

The three common systems for introducing shot into the air stream are suction-, gravity- and direct-feeding. These are illustrated, schematically, in fig. 5. More detail is available in a previous TSP article ("Generation of Air-blast Shot Velocity", Winter, 2007).

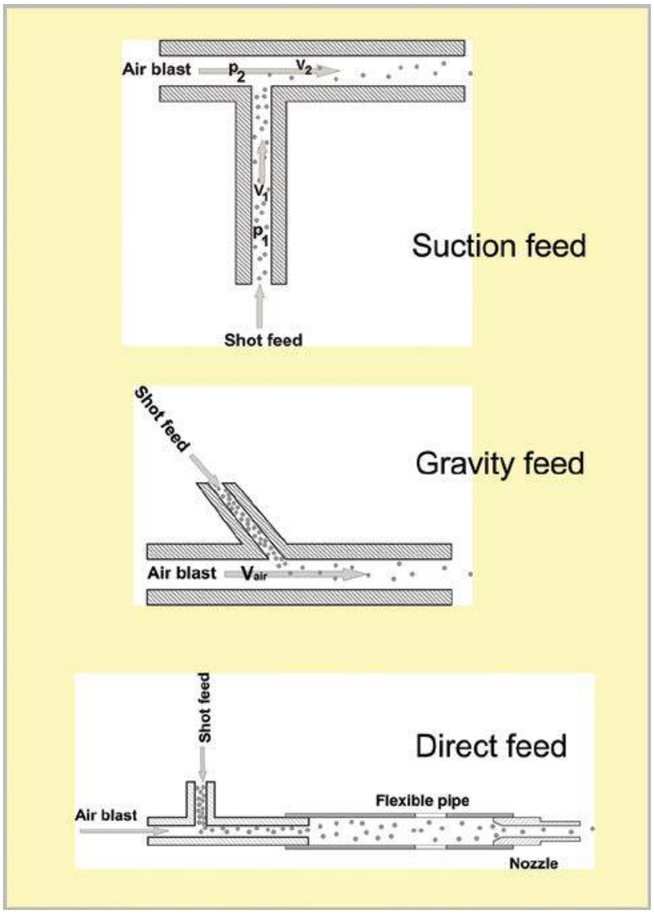


Fig. 5. Shot feed systems.

3 - ACCELERATION OF THE SHOT PARTICLES BY THE AIR STREAM.

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

$$\mathbf{F = m.a} \tag{1}$$

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

Fig. 6 represents a model of the air/shot situation in a straight-bore nozzle. On the central axis we have the maximum air velocity. The velocity lowers as we move towards the bore surface. The average air velocity is therefore about 200 ms^{-1} (656 ft/sec) for a straight nozzle.

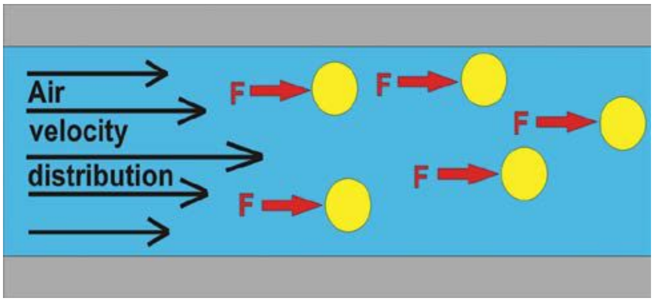


Fig. 6 Model of air/shot situation in a straight-bore nozzle.

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

For nozzle acceleration we have a simple relationship between the three parameters **a**, **s** and $\mathbf{v_s}$:

$$\mathbf{v_s^2 = 2.a.s} \tag{2}$$

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

An equation for shot velocity was developed and presented in a previous article ("Generation of Air-blast Shot Velocity", Winter, 2007). Fig. 7 (page 34) is an example of curves produced using that equation. Other parameters such as nozzle length, shot size and shot density can be inputted.

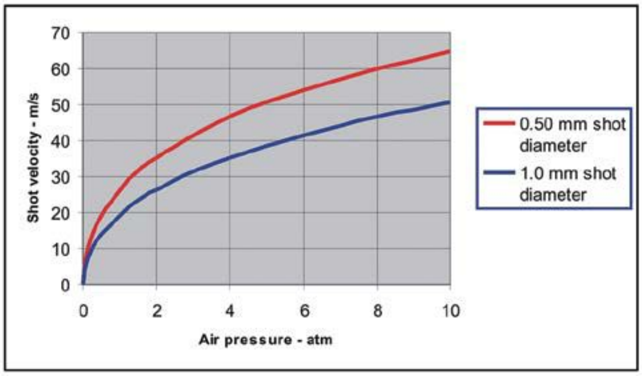


Fig. 7. Curves of nozzle-induced shot velocity versus nozzle air pressure.

GENERATION OF WHEEL-BLAST SHOT VELOCITY

The generation of wheel-blast shot velocity has many of the principles that are embodied in the Bible's story of David and Goliath as illustrated in fig.8. David accelerates a round pebble by rotating a sling. The velocity imparted depended upon the length of the sling and the speed of its rotation. Wheel-blast shot velocity depends on the length of the blades and the speed of the wheel's rotation.

Fig. 8. Image of David slaying Goliath.

Wheel-blast shot velocity is achieved in two stages: accelerator drum and throwing blades.

1 ACCELERATOR DRUM

Shot particles are fed into peripheral slots formed between the rotating accelerator and a stationary control cage. Centrifugal force keeps the particles pressed into the slots as the accelerator drum rotates. At this stage the shot particles have the rotational velocity of the drum. When a slot reaches the outlet slot in the control cage shot particles escape onto a throwing blade for the second stage of acceleration, see fig. 9.

Shot particles trapped in a slot, immediately achieve the drum's peripheral velocity. They are then being acted upon by two forces: centrifugal and gravitational. The centrifugal force, $\mathbf{F_C}$, is given by:

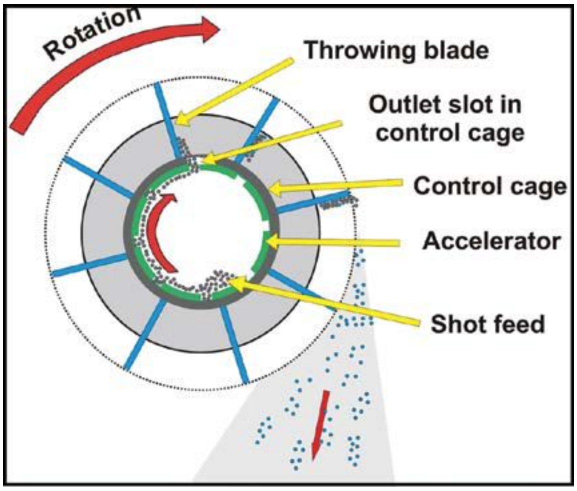


Fig. 9. Principal parts of a Wheel-blast system.

$$\mathbf{F_C = m.V_D^2/S} \qquad (3)$$

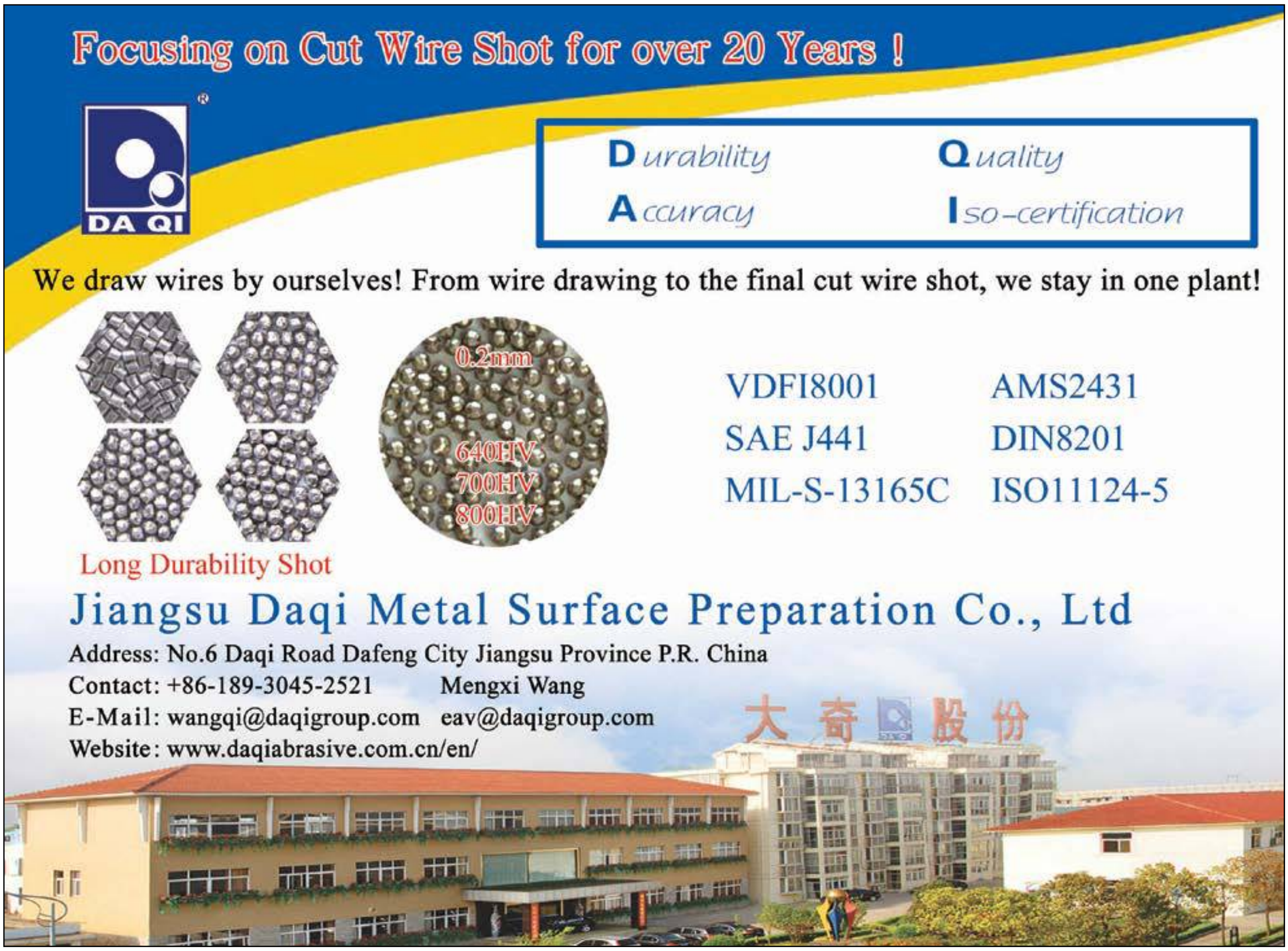
where $\mathbf{V_D}$ is the tangential velocity of the drum and $\mathbf{S}$ is the distance of the slot from the axis of drum rotation.

Gravitational force can be ignored as it is about 0.1% of the centrifugal force. We must note, however, that the shot particles are being pressed against the control cage surface with an enormous centrifugal force. They are also being scraped along that surface at high speed. This combination of high force and high speed imposes very severe wear regimes on both particles and drum surface. Finally, when the particles reach an exit slot, they burst out with an acceleration about a thousand times that of normal gravity.

2 THROWING BLADE

When a shot-filled slot reaches the outlet slot of the static control cage some of the shot particles exit onto a throwing blade carried on a rotating drum. This "cohort" of shot particles now immediately adopts the inner tangential velocity of the throwing blade. The cohort of particles is now under immense centrifugal radial acceleration, forcing it along the blade. When the particles reach the tip of the blade, they are flung off to form a shot stream. At the tip of the blade each particle being flung off will have two velocity components, $\mathbf{V_T}$ and $\mathbf{V_R}$. These are vectors which combine to give the shot particle its velocity, V_S, as illustrated in fig. 10 (page 36). $\mathbf{V_R}$ is the radial velocity induced by the centrifugal acceleration and $\mathbf{V_T}$ is the tangential velocity (which is equal to the rotational velocity of the blade tip).

Vectors are anathema to many shot peeners but they needn't be. Professional soccer players, not noted for their mathematical skills, employ vectors intuitively. Imagine one receiving a pass from a teammate. Ordinary players generally stop the ball before kicking it (hopefully to a teammate). This means that they only have to generate a single vector of speed and direction of ball travel. Star players, on the other



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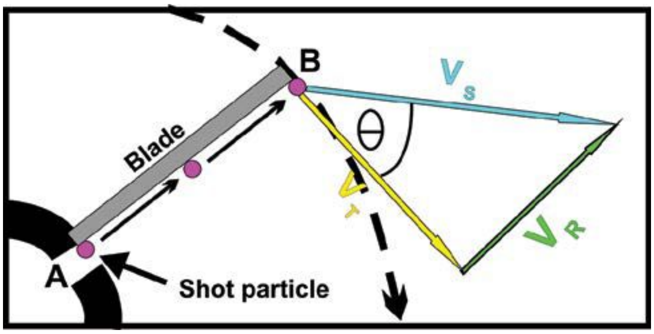

Fig. 10. Shot velocity induced by wheel blasting.

hand, employ what is termed a "one-touch pass". The received pass is not stopped but is immediately kicked. This requires two vectors to be accommodated—speed and direction of received pass and speed and direction imparted by the kick.

The values of $\mathbf{V_T}$ and $\mathbf{V_R}$ combine to form both the velocity, $\mathbf{V_S}$, and movement direction, $\boldsymbol{\theta}$, of the thrown shot particles. Tangential velocity, $\mathbf{V_T}$, is quite easy to estimate, whereas the radial velocity, $\mathbf{V_R}$, requires the application of physical principles (and some simplifying assumptions). Equations (3), (4) and (5) were presented in a previous TSP article (Spring, 2007, "Generation of Wheel-blast Shot Velocity").

$$\mathbf{V_T = 2.\pi.N.R} \tag{3}$$

where **R** is the radius of the blade and **N** is the number of revolutions per second.

2.π.R is the circumference of the circle traced out by the tip of the blade. If, for example, the circumference was 1 m and the wheel was rotating at 50 s^{-1} then the tangential velocity would be 50 ms^{-1}.

$$\mathbf{V_R = 2.\pi.N(2RL - L^2)^{0.5}} \tag{4}$$

where **L** is the length of the blade itself.

A combination of (3) and (4) gives us:

$$\mathbf{V_S = 2.\pi.N(R^2 + 2RL - L^2)^{0.5}} \tag{5}$$

Equation (5) looks complicated, but can easily be employed. The radius of the wheel, **R**, and the length of the blade are fixed so that **N**, the speed of rotation, is the only variable. Hence, for example, when **R** = 0.4 m and **L** = 0.2 m, equation (5) simplifies to $\mathbf{V_S = 2.\pi.N.0.529}$ or $\mathbf{V_S = 0.324N}$.

The **direction** of $\mathbf{V_S}$, $\boldsymbol{\theta}$, is obtained by knowing that:

$$\mathbf{\tan\theta = V_R/V_T} \tag{6}$$

For example, when $\mathbf{V_R = V_T}$, tanθ =1, so that $\boldsymbol{\theta = 45^\circ}$. If $\mathbf{V_R}$ is $\mathbf{0.87V_T}$ then $\mathbf{\tan\theta = 0.87}$ so that $\boldsymbol{\theta = 41^\circ}$.

COHORT MOVEMENT

The forgoing account is based on the movement of a single particle along a rotating, open-ended blade. Each blade is slinging, however, a cohort of particles. Cohorts of particles escaping out of the aperture of the control cage have group features that are important.

Cohort mass is a simple function of the number of blades, speed of wheel rotation and mass thrown per second. For example: an eight-bladed wheel rotating at 50 r.p.s. throws 400 cohorts per second. If we are throwing 120 kg per minute that is 2 kg per second. Dividing 2000 g equally between 400 cohorts gives 5 g per cohort.

Cohort number depends on the shot size. S230 shot has an average mass of 1.48 mg per particle. Dividing 5 g by 1.48 mg gives 3380 particles per cohort.

These estimates of the mass and number and volume of each cohort allow us to envisage the shot stream generation.

Fig. 11 is a schematic representation of the several significant positions of a shot cohort. The shot particles exit onto the throwing blade at slightly different times. The time taken for the first particle to travel from the exit slot to the blade tip determines the position of the head stream and that for the last particle determines the position of the tail stream.

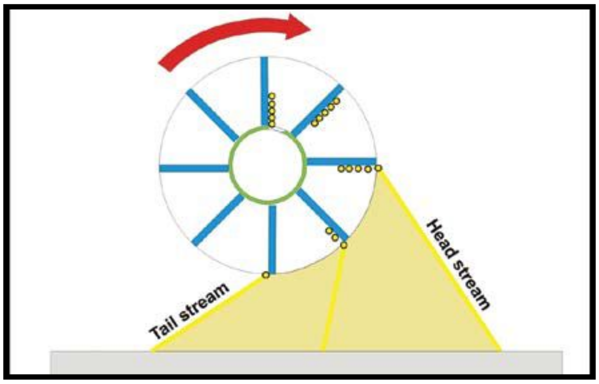

Fig. 11 Schematic representation of shot cohort movement positions.

The time difference (between first and last thrown particles) determines the angular range over which the cohort is thrown for a given wheel speed.

DISCUSSION

Shot velocity is one of the prime factors that need to be controlled if peening is to attain required levels of intensity. This article has only considered the velocity generated at either the peening nozzle's exit or the tip of wheel-blast blades. The velocity will, however, change slightly before reaching a component. Such changes will be explained in a future article in this series.

The velocity control measure for air-blast peening is air pressure whose effect is to vary its density. With wheel-blast peening the velocity control measured employed by peeners is the wheel speed. For both types of peening the shot flow rate will have a secondary effect.

Nano Peen™ Technology

Peterson Spring: Ronald Check—Vice President of Engineering and Technology
Willard Schultz—Corporate Metallurgist, Chris Osborn—Project Engineering Manager

INTRODUCTION

Peterson Spring has developed and refined a peening technology for highly stressed springs that greatly enhances fatigue life by as much as 35%. Previously it was not possible to shot peen small springs that had outside diameters under 3 mm with wire sizes below 0.5 mm and/or very tight pitch spacing (less than 0.3 mm between the spring coils). Peterson Spring has industrialized a production process and methodology to manufacture small critical springs with a beneficial residual compressive stress. This innovation will allow springs to be made more efficiently (smaller) to carry more load and have higher cycle life for demanding applications such as fuel systems, medical, aerospace, and military uses.

Challenges to proper shot peening of small springs include:

- Presenting springs reliably to the shot stream
- Obtaining complete shot peen coverage at the inside diameter
- Obtaining repeatable shot peen intensity
- Obtaining significant residual compressive stress without significantly distorting the spring
- Media selection to obtain all of the above without requiring passivation (for stainless steel springs)
- Do all of the above with an economical process suitable for production volumes of springs

Solution to these challenges grew out of the Nano Peen™ process technology developed in 2005 for Peterson Spring's high-performance racing valve springs. This process establishes beneficial residual compressive stresses of high magnitude in addition to modifying and smoothing the wire surface. A direct result is superior fatigue strength under high amplitude cyclic stresses. The media size used is appropriate for small wire diameter springs and also for springs with tight coil spacing. For stainless steel springs, modified media prevents a need for a secondary passivation operation. The greatest modifications pertain to spring containment and presentation to the shot stream. This allowed for duplicating the racing benefits of the Nano Peen process for small wire diameters and tight pitch gap stainless steel springs.

Engine valve springs (wire diameters typically between 3 to 6 mm and pitch gaps greater than twice the wire diameter) are peened single or multiple times with shot sizes typically ranging up to 0.8 mm. Smaller diameter fuel injector springs have also been shot peened with cut wire shot sizes of 0.3 or 0.45 mm. Up until now, critical small wire springs ($d < 1$ mm) could not be economically or reliably shot peened with the current technology in the marketplace without distorting or damaging them. Springs with very tight pitch spacing could not be economically or reliably shot peened because peening media cannot get between the coils to provide the beneficial residual stress where it is needed most—at the inside diameter (ID).

A batch process for shot peening is common practice in the industry as it utilizes the law of large numbers to achieve a certain level of uniformity and consistency over time. Other processes, methods, and technology are possible but not economically viable when taking into account part handling, cycle time or controlling and documenting the process parameters to requisite automotive standards. Economic viability limited the options to a batch type process in which hundreds if not thousands of springs could be peened in a single batch. Uniformity is evaluated for a given batch size by conducting such tests as saturation testing, and coverage studies. A batch system with the size and type of media needed for the Nano Peen™ process narrowed the delivery method to an air propelled system. The air pressure and subsequent velocity transports the very small media to the work piece transferring kinetic energy to the spring surface and thereby imparting the beneficial residual compressive stress.

In order for the media to be effectively efficient, it needs to be similar in hardness to the object being peened; otherwise the media will not fully transfer its kinetic energy to the spring in the form of a plastic deformation dimple on the surface of the wire. This resulting dimple can only be imparted if the shot peen media is spherical (or near spherical) in shape; else the resulting impact with the spring wire could create a detrimental surface indentation. Sharp-edged media could potentially scar the spring wire surface and leave a damaging early fatigue stress raiser where crack propagation can initiate. Glass beads have been used in the past on other parts, springs included, to improve the surface residual stress but this media is limited as it is brittle and will shatter when used at higher velocities on high-hardness parts. Shards from the shattered glass beads impart detrimental sharp bottomed indent surface stress raisers.

The targeted industry and customers for this process utilize stainless steel spring wire. This narrowed media selection to a media type that would not require passivation after shot peening. Carbon steel shot was not considered as an option. Several sizes and types of media were evaluated and the one with the best combination of features (shape, size, hardness) was selected.


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When conducting preliminary trials on a production air blast machine, small wire springs escaped the basket and ended up in the shot reclamation system. This would become the most difficult challenge with this process—containing parts without trapping them. The force of the high-pressure media stream blew springs out of the basket and everywhere else in the cabinet. The bulk of development focused on the basket and mating component design to retain parts without trapping parts or restricting shot reclamation. Several iterations and significant creative modifications achieved the goals with a custom basket system solution.

The final steps for the production intent system was to incorporate the necessary failsafe controls for the process variables and to continuously monitor and document these parameters for each batch of parts run through the system. By adding the necessary transducers, sensors and machine code, each batch of parts can be documented that they received the correct recipe and that all parameters are within specification.

RESULTS

Tests used to establish process parameters included saturation tests using Almen strips and coverage evaluation using black light with fluorescent paint. SEM photographs, residual stress measurements and fatigue testing were used to quantify the results.

Two different springs were selected to demonstrate the benefits of the Nano Peening process. Cycle testing was conducted on a special test spring with wire diameter of 0.41 mm and pitch gap of 0.5 mm to demonstrate fatigue strength improvement of Nano Peening. Cycle testing and residual stress testing conducted on a larger spring with wire size of 0.56 mm and pitch gap of 0.32 mm compared Nano Peen with a more conventional shot peen and illustrated benefit for springs with tight pitch gap.

The first spring design tested was a small wire spring (d = 0.3 mm) which previously went un-peened based on the size of the wire relative to the traditional media size. The readily available media size of 0.3 mm propelled at this wire size with enough velocity to impart compressive residual stress would damage and distort the spring. Nano Peen media size was sufficiently smaller than the spring wire size to impart beneficial residual stress to the wire surface; enhancing the fatigue life without any dimensional distortion (bending or bowing of the spring).

Reliable evaluation of shot peen coverage on valve springs only requires low power magnification and an optical microscope is sufficient. With smaller shot, smaller spring wire and lighter intensity shot peening, evaluation of coverage under the optical microscope becomes more challenging. Electron microscopy allows for assessment of the degree of surface texture modification caused by light intensity shot peening. By its very nature, this is a qualitative evaluation.

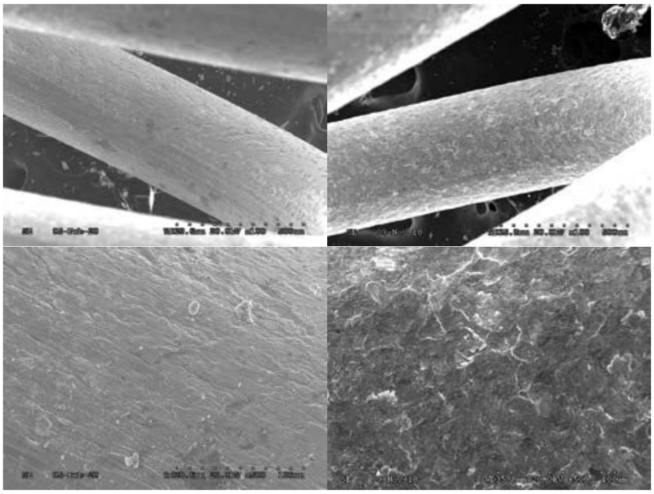


Figure 1 - Comparison views of the inside diameter of a 17-7 PH stainless steel (d = 0.41 mm, pitch gap = 0.5 mm) spring. Images at left show the residual wire drawing surface texture of an unpeened spring, while images at right show inside diameter after Nano Peen.

SN fatigue curves are generated by testing springs at various stress amplitudes—in this case, 35 springs at each stress range. A custom fatigue test fixture cycled peened and unpeened springs at the same time. The Nano Peen process increases the 10 million cycle endurance limit by ≈35% over non-peened springs.

Figure 2 – Test fixture capable of cycling 70 springs simultaneously.

Nano Peening can also peen the inside diameter of spring designs with very little space between spring coils. Tight pitch gap restricts access to the inside diameter. A good rule of thumb for media size as it relates to pitch gap is for the media to be 1/3 the size or smaller of the pitch gap to allow comprehensive, full and complete peening at the spring inside diameter, where applied stresses are highest. For the example in Table 1 (next page), cut wire shot of the recommended size is not readily available. Using cut wire shot results in complete shot peen coverage on the outside diameter, but insufficient coverage on the inside diameter. Extending the cycle to obtain full coverage on the inside diameter can result in distortion

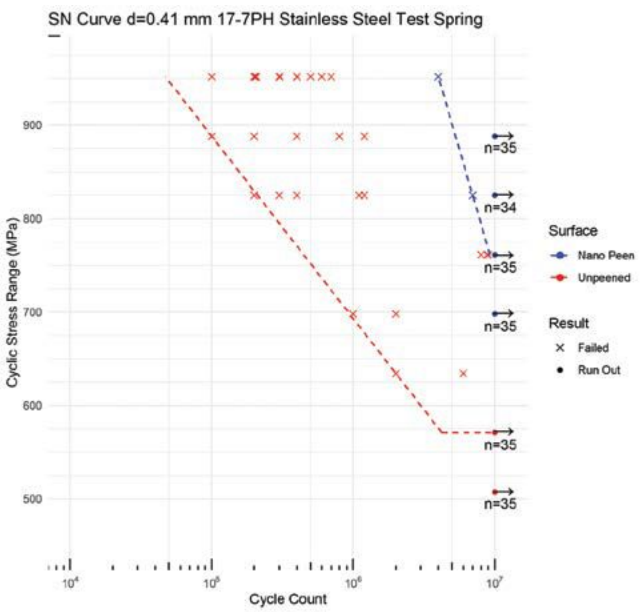


Figure 3 – SN curve for 17-7 PH stainless steel (d = 0.41 mm, pitch gap = 0.5 mm).

of the ground end coil tips and/or uneconomical throughput. Nano Peen achieved complete and full shot peen coverage on inside and outside diameter. Residual stress results (Table 1) demonstrate the improvement of Nano Peen over standard cut wire shot sizes.

Table 1

Residual stress measurements on springs with wire diameter of 0.56 mm and pitch spacing of 0.32 mm. The smaller Nano Peen media results in superior residual compressive stress at the spring inside diameter.

	Residual Stress Measured at Inside Diameter
Unpeened	-28 MPa
Standard Peen (0.3 mm cut wire)	-186, -62, -214 MPa
Nano Peen	-517, -476, -476 MPa

A single multi sample fatigue fixture running both peened versions (standard peen vs. Nano Peen) of the same spring (wire size 0.56 mm, pitch gap 0.32 mm) generated first failures with an order of magnitude difference. First failure for the standard peen was recorded at 600,000 cycles, while first failure for the Nano Peened parts occurred at 6,000,000 cycles.

CONCLUSION

With inspiration from our racing technology and innovation from our engineering group, it is now possible to economically and reliably enhance the fatigue life of high-tensile stainless steel springs with both wire diameters and pitch gaps as small as 0.3 mm.

ICSP14—See You in 2021!

The current emergency due to the COVID-19 virus has suddenly changed everyone's life. Due to the restrictions caused by the need to control, reduce and hopefully annul the infection rate, the complete conference calendar in 2020 has been suppressed. ICSP14 has been postponed to next year considering the pandemic global situation. Now it is time to start thinking ahead to the new ICSP14 to be held in 2021.

It is really sad to write this article after recently making an announcement on the postponement of the 14th International Conference on Shot Peening that was to be held in Milan, Italy in September 2020.

Since that time we have received many high quality abstracts from all over the world and have been contacted by multiple companies interested in exhibiting their products and services at ICSP14. Everything was running fine and an exciting event was expected.

We all know what happened then. A pandemic was announced cause by COVID-19 or Corona virus with a terrible impact in terms of human lives and the global economy—effects that will last for years.

My country, and specifically the region where I live and where ICSP14 was planned to be held, was one of the first regions in Europe to be infected by the virus. Here the people suffered a lock down of over two months long. Indeed from the beginning of the epidemic, we immediately decided to postpone the conference, both to be on the safe side and to leave the calendar of the people free in an uncertain situation.

It was not an easy decision but I am sure it was the right one. And the fact that almost all conferences planned this year have been cancelled thus confirmed the rightness of our timely decision!

What about now? Indeed the situation is not normalized yet and restrictions are not over but step by step, they are being removed. In Italy, shops, barbers, restaurants, and hotels are now opening but they must follow a strict procedure to guarantee their own and their clients' safety. Despite all the restrictions in place, we can see the path back to a normal life and hopefully in some months we will defeat the enemy. A similar situation can be described almost everywhere in the world.

That is to say, it is time to start over the organization of ICSP14 for 2021!

The first aspect is that ICSP14 will be held at the Technical University of Milan (Politecnico di Milano). Indeed emergency measures due to Corona virus have been successfully implemented and now we are preparing for the next semester to guarantee the students can safely attend the lectures and the exams. ICSP14 will take advantage of the improved and well-established communication technologies, including remote connections. In other words, if restrictions to avoid crowded places are still active and necessary next year, we will be able to adopt the actions needed for that. Even if the situation does not impose strict restrictions any longer, we will stay on the safe side by assigning large rooms to the sessions where we can have an appropriate ratio of busy/free seats for the audience and attendees.

Let me say, I know, you could wonder how many presentations will be expected next year. It is probably too early to try to forecast but I can say most of the authors of the abstracts that were submitted for 2020 before the lockdown have confirmed their willingness to present their ongoing research results and share them with the qualified ICSP14 audience in 2021.

I would like to add that, due to the emergency, new subjects and new applications of shot peening and related treatments could come along, increasing the interest of the conference.

The priorities of research and development are changing now due to the need to consider and possibly avoid new virus infections. This is affecting the research priorities and influencing almost every industrial sector, changing the design, the treatments, and the development of the products.

Shot peening can be involved in this process because it is a powerful tool to modify the material surface and then interface with the external environment. Combined with the additive manufacturing processes, shot peening can serve as a post treatment to be successfully implemented for this aim. I expect new contributions in this field, opening new opportunities for shot peening and allied treatments.

Another aspect to keep in mind is that the changed scenario with an increased competition among the players should encourage them to improve their product and shot peening is an attractive tool to this aim. ICSP14 is the best place to learn more about the latest results and achievements in shot peening. This is even more valid for exhibitors and multiple companies have confirmed their interest about ICSP14. We invite companies interested in shot peening to contact us for more details.

And, how about Milan? I am sure that most of you watching the television in the past few months have seen really sad images of Milan and its several attractions, all empty, completely free of people. The Cathedral ("Duomo") and the square around it, generally crowded with enthusiastic people in front of it, has been absolutely empty! And the Sforzesco Castle and the Naviglio channel, with its bars, restaurants and pubs that used to hold a lot of people at sunset drinking aperitifs, have been all closed!

But now we are happy that the situation is changing and they are re-opening following the procedure and the prescriptions given by the authorities. We are confident that in some months the situation will be fully normalized. We are ready to welcome you at the conference and guide you to the many attractions you can visit in Milan.

Finally, let me conclude by highlighting that we are now 100% active in the organization of the next ICSP14 in 2021. My team and I, as well as the International Scientific Committee, are concentrated on the organization of ICSP14 and we are doing our best to offer you a wonderful time in Milan next year.

We are still not able to fix a date but we can anticipate that ICSP14 will be in the summer of 2021. If you want to keep informed, take a look at the www.icsp14.org website.

I am looking forward to meeting you at ICSP14 in Milan next year!

INDUSTRY NEWS

Continued from page 12

MIL is currently renovating a third building to be added to our campus at 1455 Greenleaf Avenue. The new addition will require our team to be able to communicate and work across three different locations. During the pandemic we have restricted/limited access between buildings which has strengthened the skills necessary for us to work effectively and efficiently in such a setting.

Based on the previous downturns in the industry, first in 2001 and then again in 2007/2008, I would estimate several years before the industry is back near 100% capacity and production.

MIL is utilizing the Illinois stay-at-home orders as well as the internally developed response team to coordinate and gauge when our staff will be allowed to travel via air again.

Jesús De la Garza, Equipos de Abrasión, S.A. de C.V.

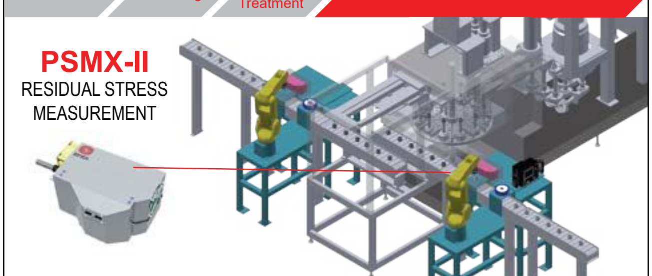
Since some businesses were considered as "critical manufacturing" under prior guidance from Mexican government because their fabrications are used to support utilities, power grids, medical appliances, food services, etc. Some of these business sent us communications that Equipos was a supplier in their critical manufacturing processes and requested our cooperation to continue supplying products if they were needed and urged us to remain open. We therefore made the decision to keep personnel in the office to assist with calls.

Some of our employees worked from home. Maybe once this pandemic ends and if the job allows it, we could continue with this practice creating some savings in some areas. I worked some days from home. It was not easy at the beginning since I do not have an office at home and needed to make some adjustments to have a private area as an office so I could concentrate on what I was doing with no interruptions, no pets, no noises, etc. Not a simple task.

To keep our workplace safe, we reduced the number of employees, keeping half in office and half at home. We took extra precautionary measures to ensure essential operations can continue without sacrificing the health and safety of our employees including social distancing and the use of respirators.

We used Zoom to keep communication with some of our customers, especially taking note of their future activities and dates for reopening facilities. It seems to me that Zoom and Skype will be the most useful tools in the immediate future as new ways of working. Employees began doing two or three tasks not done before, creating some flexibility in the business.

I estimate that industry will fully recover from the pandemic when we have a vaccine or medicine to avoid infection with this disease (approximately 6-12 months) but hopefully before. When we know that air travel and hotel lodging are safe for our employees, we will travel.



PRESS RELEASE

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The Compact Rotary Sorter That's Big on Benefits

THE COMPACT ROTARY SORTER by Profile Industries has all the benefits of its larger version.

"The need for a compact rotary sorter became clear when clients approached us about a rotary sorter for smaller lots such as research facilities, nurseries, and industrial manufacturers," said Steve DeJong, President of Profile Industries.

The Compact Rotary Sorter has the capability to sort vegetable seed, hemp seed, brassicas, and oilseeds along with ceramic beads, steel shot, and glass beads. Its compact design creates a centrifugal force to achieve a precise separation for the commodity from debris, foreign matter, splits, and misshapen items.

"We have been making a variety of sorting equipment for over 40 years. The Compact Sorter offers the same benefits as our larger volume rotary sorters just in a condensed version," added DeJong.

Profile Industries' goal is to manufacture sorting technology that the global agricultural community, agri-foods industry, and global industrial manufacturing can use to improve quality and reduce product loss.

Visit www.profile-ind.com or send an email to info@profile-ind.com for more information on the Compact Sorter or other Profile industries sorting equipment.