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The Shot Peener

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

Dual Function Cabinet Meets Multiple Customer Needs

Plus:

Human Factors in Non-Destructive Testing

U.S. Drought Brings Flood of Business

Shot Peening Research at Army Research Lab

Shooting at Ceramics

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THE SHOT PEENER

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

Campaigning

CANDIDATES FOR POLITICAL OFFICE in the USA will often visit their constituents while campaigning. Jackie Walorkski and her team visited Electronics Inc. this summer. Ms. Walorski has served as an Indiana State Representative and is running for Congress in the fall 2012 election. Our visitors were impressed that over 50% of our products are shipped outside of North America. It's important to EI to have legislators that understand U.S. domestic and foreign trade policy and are willing to support efforts to improve international trade. We were able to share many ideas and concerns with Ms. Walorski.

JACK CHAMPAIGNE

Campaigning for Shot Peening

SAE is considering a new committee for Lightweight Materials for Automotive Applications. When I heard about their mission to review new lighter and stronger materials, I campaigned for a sub-committee to consider the fatigue life properties of these new materials. The most important feature of any component is its surface. The condition of its surface will virtually always determine its fatigue load carrying capability and fatigue lifetime. As Chairman of the Surface Enhancement Committee, I suspect that I will also be on this new committee. I look forward to sharing shot peening's benefits to the fatigue life of lightweight materials with my fellow committee members. While Ms. Walorski would like to make a difference in Washington, D.C., I'd be happy to be part of a group that makes a difference in Detroit. I'll keep you posted on the developments through *The Shot Peener* magazine.

Jackie Walorski, a candidate for the U.S. Congress, and Jack Champaigne tour the Electronics Inc. facility.

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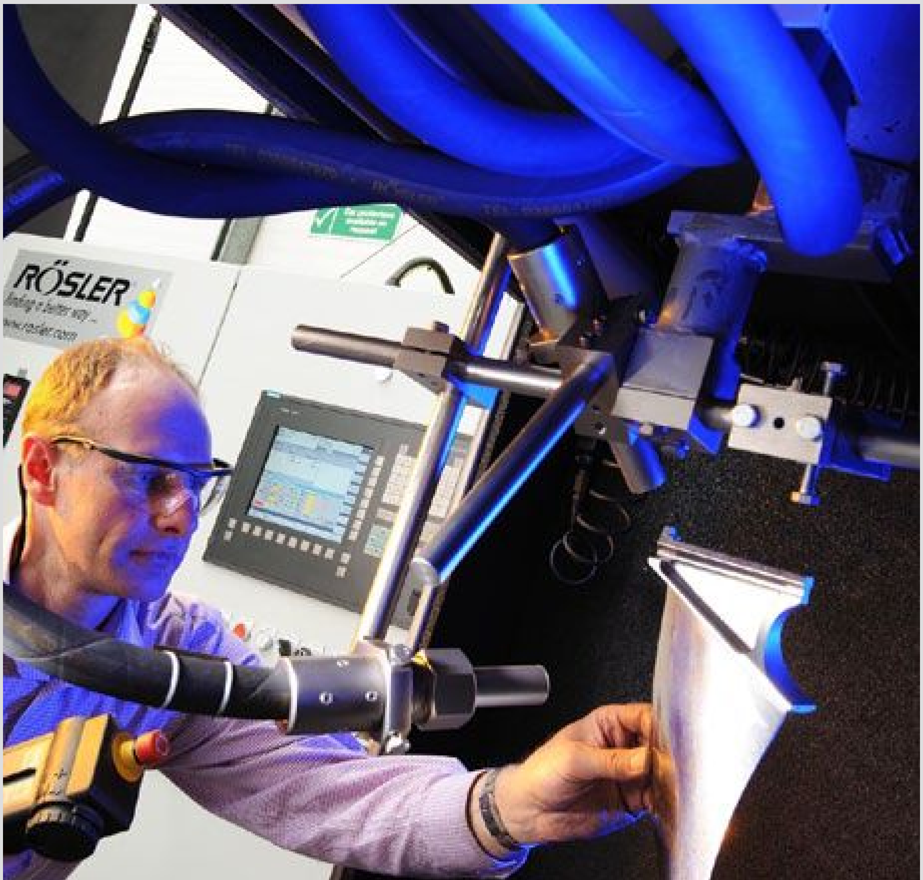

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Dual Function Cabinet Meets Multiple Customer Needs

SPECIFICATIONS REQUIRING PRESSURE and suction blast capabilities within the same cabinet system are rare, to say the least, for simple reasons. Pressure systems work faster than suction systems, consume less energy, operate over a wider pressure range, provide more control at both high and low pressures, and tackle jobs suction systems can't handle. So once the higher initial cost for a pressure system has been paid, switching to suction normally represents a step backward — *unless the system is destined for R&D as well as future production*. (See "Roles of Suction and Pressure" on page 10.)

Such was the case with a company involved in the development of various products, some used in air-blast equipment and others requiring shot peening and/or blast finishing. The firm wanted to use pressure and suction blasting for research and development in addition to production of prototype and finished products. Consequently, the company's specification required equipment that provided room to explore, produce and accept modifications at the same time.

"Typically this flexibility would require two to four pieces of equipment," reported one of the firm's lead engineers. "Empire met our needs with one system."

Concerning modifications, the firm wanted to minimize hardware by enabling the system's pressure vessel, normally a component in the pressure chain only, to operate as a storage hopper for media supplied to the suction system as well. In addition, the customer wanted a MagnaValve® beneath the pressure vessel/media hopper. (See Figure 1.) "Empire is one of the few cabinet makers that extends the legs on the media hopper so that we will have plenty of access to the valve," said the engineer. "We're currently running ferrous shot but if we switch to non-ferrous media, we can easily change the valve," he added. Given the modular design of our Pro-Finish® cabinets and our ability to adapt standard equipment, giving the customer this level of versatility presented no problem.

In fact, we operate an entire division devoted to modifying our extensive line of cabinets — over 100 standard configurations are available in our Pro-Finish® line alone — to meet specialized finishing needs with a minimum of custom engineering and its associated high cost. Drawing on our expertise in automated air blasting, in-house fabricating skills, and an array of standard factory options, we have developed hundreds of cost-effective equipment solutions ranging

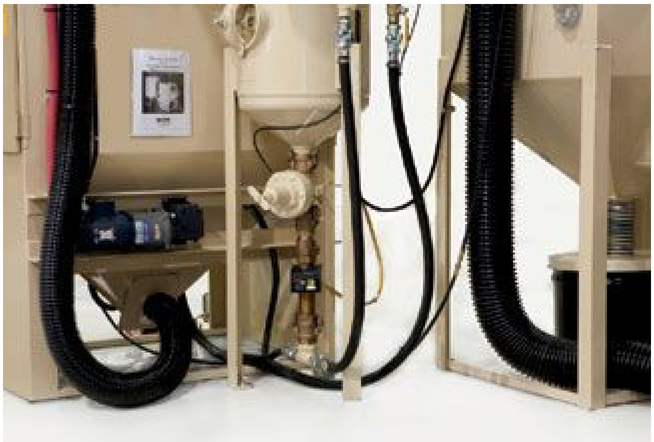

Figure 1. Extended legs supporting the system's 3.5 cubic foot pressure vessel provided sufficient clearance for mounting of a MagnaValve® media flow valve.

from straightforward, such as connecting two blast cabinets with an expander to contain long work pieces, to sophisticated, such as partial automation involving programmable controls.

In the case of the firm needing a single blast system for production plus R&D, the availability of items as standard factory options as opposed to custom equipment played an important role in their buying decision. For example, the 480 volt, 60 hertz, three-phase electrical package required by the customer is just one of five optional electrical packages offered with our Pro-Finish® cabinets. Likewise, the inside rubber curtains specified are a standard factory option, available in white or black, sized to fit the cabinet ordered, and include rubber coated mounting knobs. (See Figure 2.) Sound attenuators ordered for the system's fan motor outlet and blast cabinet inlet are, again, standard factory options.

Figure 2. Rubber curtains extend cabinet life by protecting interior walls from blast media.

For production purposes, the customer wanted to add equipment designed to reduce labor requirements and enhance quality. From our list of standard

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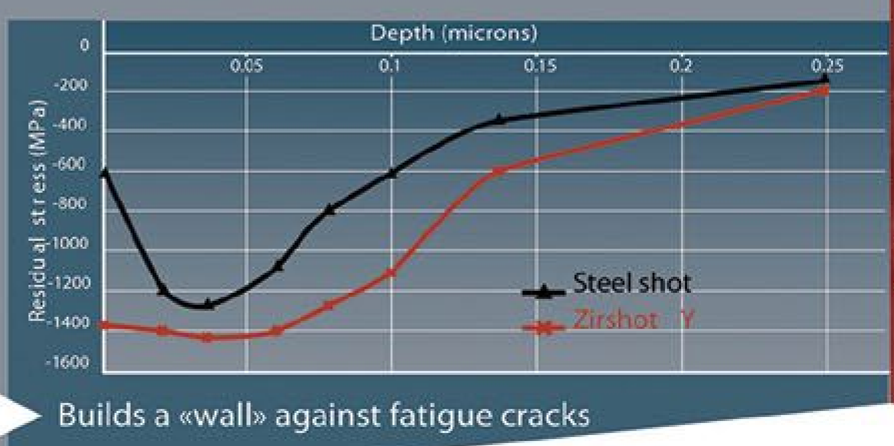

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factory options, the firm selected a fixed nozzle holder for the pressure-blast nozzle, a fixed gun holder for the suction-blast gun, a 24" diameter stationary turntable with a perforated top and variable speed control from 3 to 12 revolutions per minute, and an electric timer to control blast cycle duration.

The system's control package (See Figure 3), mounted on the left front of the blast cabinet next to the viewing window, includes on and off buttons for lights and blast, start and stop buttons for timed blast cycles, selector switches for automatic or manual blasting in either the pressure or suction mode, and controls for turntable rotation speed and blast cycle duration as well as MagnaValve media flow controls and a flow monitor installed by the customer. "Our production and R&D work require precise control of the media flow rate and repeatability of the process." said the engineer. "The MagnaValve and the system's control package give us both." All controls are electric to simplify data logging.

Figure 3. A selector dial for "PRESS" or "SUCT" on the system's control panel permits the operator to select pressure or suction blasting.

The automatic blast feature, which teams part movement via the powered turntable with timed blast cycles, not only eliminates the complication of operator involvement when evaluating results related to the adjustment of various blast parameters, it also contributes to repeatable production.

Because the system uses a wide range of relatively fine media consisting of beads and grit, our cyclonic reclaimer equipped with a magnetic separator and tuning band has the flexibility to recycle them all. Before flowing ferrous media, such as steel shot and grit, the magnetic separator is easily removed. When flowing non-ferrous media such as glass and ceramic bead, plastics and aluminum oxide, the separator plays an important role in extracting ferrous debris carried over from blasted surfaces. By adjusting the tuning band on the reclaimer, the amount of air introduced into the system can be controlled to assure precise separation of functional media from dust and other unwanted debris. (See Figure 4.)

As another goal, the customer wanted to maximize the length of production cycles by increasing the volume of the system's pressure vessel and decreasing maintenance on the dust collector. In response, we substituted an optional three-and one-half cubic foot pressure vessel — with optional sight glasses for easy level checks—for our standard one cubic foot vessel, and supplied our 600 CFM cartridge dust collector rather than a bag-type collector with equal capacity.

The cartridge collector handles cycle times of almost any length because the air-blast system can continue working while dust is removed from filtration surfaces. A minihelic gauge tells the operator when to initiate reverse jet pulsing, a standard feature that purges dust with the push of a button. (Optional photohelic upgrades move dust from filtration surfaces to a collection drum automatically.) And when cartridge filters wear out, they are easy to replace.

A recap of the customer's specification for a single cabinet system with pressure and suction blast, easy access to the media valve, manual and automated operation, media flow rate control and repeatability, broad media reclamation capability, and extended processing cycles boils down to a central requirement: flexibility. Happily, our Cabinet Division was limber enough to deliver.

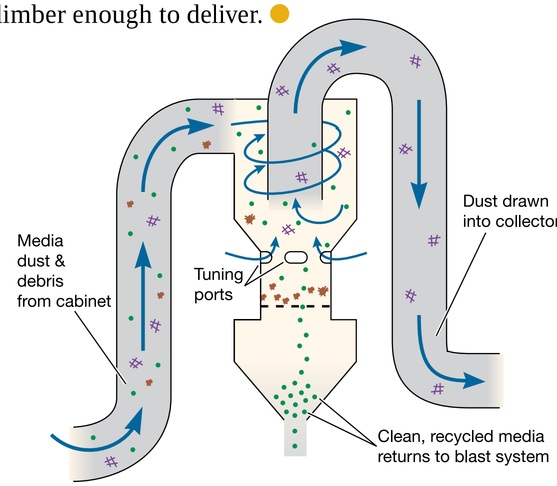


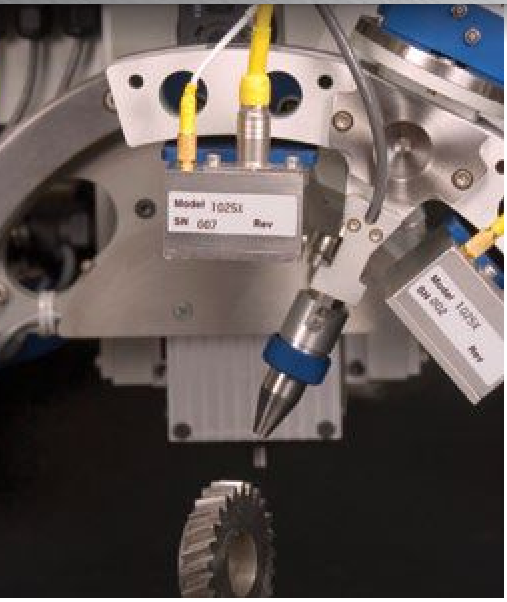
Figure 4. Reclaimer Operating Principles

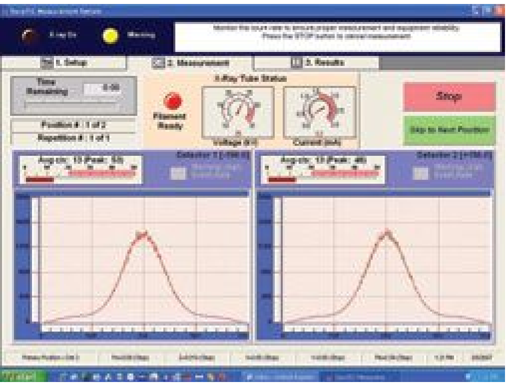
The cyclonic reclaimer diagrammed above includes a movable band (not shown) that can be positioned over the tuning ports to recycle a wide range of abrasives.

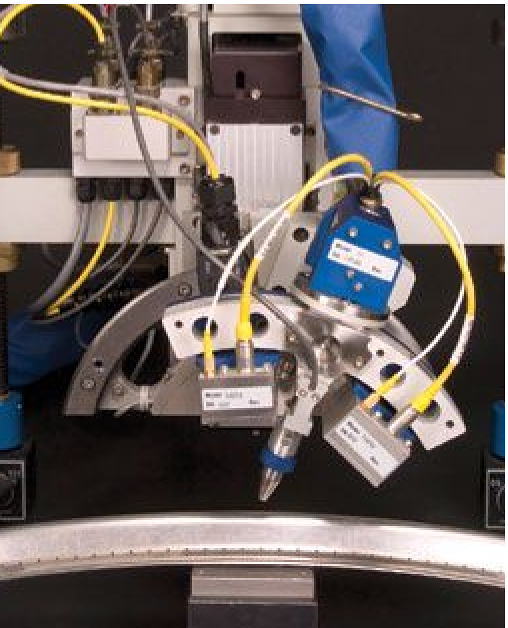
As spent media, dust and debris are pulled by air flow to the reclaimer inlet, incoming air and media spiral in a downward vortex, throwing larger particles against the outer reclaimer wall. An air stream coming through the tuning ports forms an upward counter vortex through the center tube, which carries out dust while heavier particles drop into the storage hopper below for reuse. A screen catches any oversized debris.

Dust and undersized debris are drawn from the reclaimer into the bottom of the dust collector. Sudden expansion forces heavier dust particles to the bottom. Remaining fine dust is pulled to the surface of the dust filters.

Materials Testing Services







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Role of Suction and Pressure

In air-blasting equipment, one of two basic approaches — commonly referred to as suction and pressure (See Figure 1) — "pull" or "push" abrasives (known as media) to desired working speeds. Suction systems rely on compressed air from a supply line to create a venturi effect within a blast gun that draws abrasives through a feed line from a storage hopper operating at atmospheric pressure. When triggered, the blast gun releases compressed air and media to the work surface. The advantages of suction systems include lower capital costs and simplified piping, particularly in applications requiring continuous operation and/or multiple blast outlets. (See Figure 2, 3 and 4.)

In the case of pressure systems, the media-storage vessel operates at the same higher-than-atmospheric pressure as the air supply line (normally between 10 and 120 psi above atmosphere). When actuated, the system releases abrasives from the storage vessel into a blast hose where the difference between system pressure and atmospheric pressure (sometimes more than 100 psi) drives the abrasive particles during their entire trip to a tapered blast nozzle that adds more speed. This continuous "push" pays significant dividends in terms of energy use. On some jobs, pressure systems reduce compressed-air consumption by 75 percent. Moreover, pressure systems control abrasive flow with greater precision at both low and high operating pressures. As a result, they can deploy a broader range of media than suction systems and perform a much wider variety of tasks.

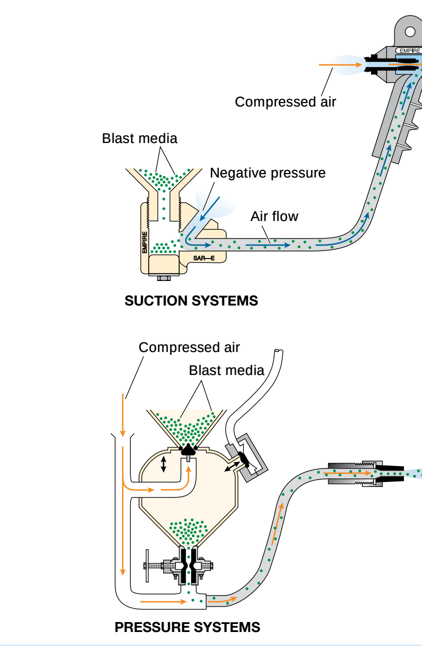
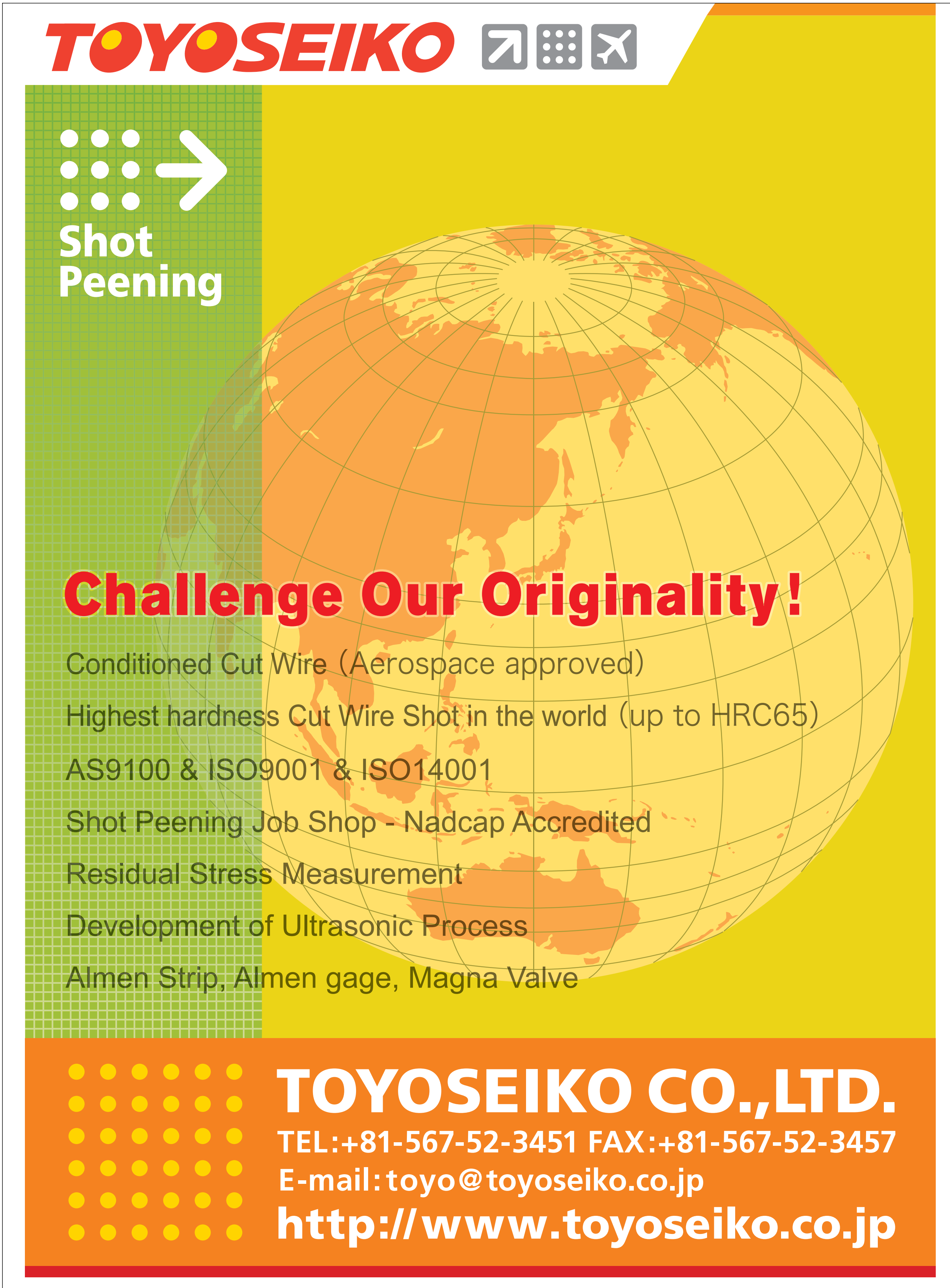


Figure 1. Operating Principles

Figure 2. Besides simplifying piping to multiple blast outlets, suction systems make possible innovations like the rotary blast head. Equipped with six blast guns, the head shown spins to provide even coverage on broad work surfaces.

Figure 3. Supplying six blast guns is relatively straight forward as demonstrated by the single air manifold and media hopper, each with six hose outlets.

Figure 4. As shown by a pressure setup with just two outlets, supplying pressure nozzles requires more hardware.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Human Factors in Non-Destructive Testing

Richard Gasset is a Nadcap U.S.-based supplier voting member and a NDT III with Lisi Aerospace, a manufacturer and supplier of aeronautical fasteners, racing fasteners, and assembly and installation tools, headquartered in Paris. While Mr. Gasset's article pertains to non-destructive testing facilities, the human factor is also crucial in MRO facilities.

THE RELIABILITY OF NON-DESTRUCTIVE TESTING (NDT) can be significantly influenced by the environment in which components are processed and inspected. Consideration of human factors is an area that is all too frequently overlooked. Human factors are typically dependent on a large number of influences, and the following may be areas in which you and your company may want to pay special attention when considering the NDT process within your company.

At a recent NDT Task Group meeting, the topic of human factors came up, and it took me back to my previous position as an FAA Repairman. Part of my responsibility was to help develop a Training Manual as a companion to our Repair Station and Quality Control Manual. Handbook Bulletin for Airworthiness Order 8300.10 then required human factors to be included in the training program. Numerous FAA documents had suggested elements on human factors but none that would apply to our small compressor blade repair facility.

Luck struck when our local Flight Standards District Office (FSDO) was having a two-day Aviation Safety Program Workshop and one of the topics was human factors. The facilitator defined human factors as "The discipline of optimizing the relationship between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering." He also defined human error as "Where there is general agreement that a person should have done something other than what they did."

Most important to our facility were the twelve human factors (the Dirty Dozen[1]) that can cause human error:

- Lack of Communication
- Complacency
- Lack of Knowledge
- Distraction
- Lack of Teamwork
- Fatigue
- Lack of Resources
- Pressure
- Lack of Assertiveness
- Stress
- Lack of Awareness
- Norms

The following is a synopsis of each of the human factors described in the presentation.

Lack of Communication is possibly the most important human factor issue that has played a role in aviation accidents. Either someone was assuming that someone else had done his/her job, or was not given proper instructions. Employees need to communicate before, during and at the end of each task and detailed information must be passed along at shift change.

Complacency is lack of sufficient stress. We all know that too much stress can cause confusion and fixation. However, too little stress can cause a person to be bored and complacent. When a person becomes complacent, not only does their stress level for the task decrease, but their performance decreases also. Error or complacency can be lessened by always following written instructions, procedures or specifications. Do not attempt to do work from memory, and never sign off on work if you are not totally sure that you have completed the task.

Lack of Knowledge. Aircraft systems are so complex and integrated today that it is next to impossible to perform the necessary tasks without substantial technical training and reference sources.

It has been suggested that if we make the effort to study one hour a day for a year on the subject of our profession, we will be among the top 15% of knowledgeable persons within our profession.

Make a daily commitment to spend a small part of everyday reading on subjects that affect you in your daily job to avoid falling victim to the lack of knowledge human factor.

Distraction. Psychologists have identified distraction as the number one cause of forgetting. We humans are always thinking ahead, both consciously and subconsciously. If we are distracted to the point of interruption during a task or procedure, when we return to the job, we often think we are further along than we actually are. Errors from distraction can be lessened by always finishing a task or marking the incomplete work, double inspect by another or self, and when

you return to the job always go three steps back and use a detailed check sheet.

Lack of Teamwork. Teamwork does not just happen by mistake; a lot of constructive communication needs to take place by all departments involved in order to produce teamwork. When there is trust and good communication among employees, teamwork develops. A good team member wants everyone to succeed; we can start out by praising the people we work with.

Fatigue is the body's normal reaction to physical or mental stresses of prolonged duration. Acute and operational fatigue is caused by hard work and long hours. Chronic fatigue, however, may be something that requires medical attention. Symptoms of fatigue can be reduced attention, diminished memory, withdrawn mood, and low situational awareness.

The three most important ways of dealing with fatigue are regular sleep, a well-balanced diet and a regular exercise program.

Editor's Note: According to Dr. Mark Rosekind, National Transportation Safety Board Member, 70 to 80 percent of all accidents are "because of human error." In a MRO facility, maintenance errors are foremost a safety issue, but it can be a financial issue, too. Consider for example, that engine problems yield at least half the flight cancellations, which cost an average $66,000 each in the U.S., according to Boeing.

—David Jensen
"An Awakening to MX Personal Fatigue"
Aviation Maintenance magazine, June/July 2012

Lack of Resources. A list of important resources would be money, people, time, tools and data/knowledge to name a few. Making sure that we have correct tools for the job is just as important as having the proper parts. Technical data is another critical resource which can lead to problems. If we cannot find the data, we need to ask a supervisor or technical representative. When we have the proper resources for the task at hand there is a greater chance that we will do a better and more efficient job.

Pressure can affect our judgment during critical moments at work. Pressure to complete the job is part of the stress that motivates us to do the job. Positive stress is the extra stimulation that helps us to perform at our best. Negative stress occurs when pressures layer one on top of the other and become uncomfortable. A few ways to reduce pressure is to put everything into perspective, be sure the pressure is not self-induced, communicate your concerns to someone in a position to make a difference or ask for extra help.

Lack of Assertiveness. Assertiveness can be defined as standing up for rights and expressing feelings in an honest, open, appropriate and direct way which will not violate another person's rights. Assertiveness takes the view that all individuals can pursue their own goals, protect their own rights and achieve results without violating the rights of others. Assertiveness can be said to be the middle ground between aggressiveness and passiveness. One way to practice assertiveness is to refuse to compromise your standards and do what is right, even when no one supports you.

Stress. It's a blessing and a curse: a blessing in that it motivates us to perform and a curse in that it can adversely affect your health, both mental and physical. Stress can be created from many different sources, some can be family changes, work, or personal or financial issues. Knowing the early warning signs can give us a chance to use stress reduction or coping techniques. Some early signs are disruptions in eating patterns and sleep habits, errors in judgment occurring more frequently, poor concentration and memory loss become noticeable, personality changes and stomach distress. Techniques for reducing stress work differently in different people. Some examples are to go with change rather than against it. If job factors are creating stress, talk with your supervisor or someone in your organization in a position to make a difference, establish a balance between work, family and recreation, smile more, and laugh. Laughter is a proven stress-coping mechanism.

Lack of Awareness, or reduced situational awareness, can be an indication that one or more of the other human factors are in action, such as fatigue or distraction or lack of communication. To maintain our awareness level throughout our careers and in our day-to-day job we can rely on our experience and training. Experience creates a mental file of how one interprets and responds to conditions and events. Use your experience to maintain a constant state of awareness.

Norms. A norm in the context of the Dirty Dozen[1] means that our group has a better way to do the job than the written instruction, procedure or specification. It could be considered "Tribal Memory," which are unwritten rules enforced by the group, peer pressure or habit. Always work as per the instructions or have the instructions changed. At least if things go badly, we can say we were following the published procedure. "It's not my fault" is a nice position to hold.

Human factors should be considered in the design and operation of any NDT facility. The consideration of human factors will often lead to an efficient and effective NDT process.

[1] *Due to a spate of maintenance-related aviation incidents and accidents in the late 1980s and early 1990s, Transport Canada, together with the aviation industry, identified 12 human factors and christened them the "dirty dozen." These human factors could degrade people's ability to perform effectively and lead to maintenance errors. (http://aviationknowledge.wikidot.com/aviation:dirty-dozen)*

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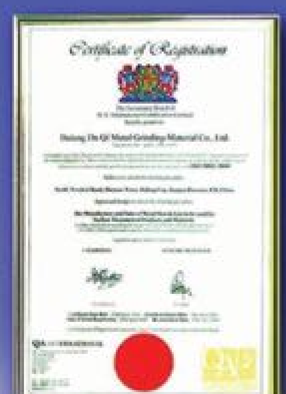

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Kathy Levy | InfoProse

U.S. Drought Brings Flood of Business

IN A DROUGHT, perfectly round soybeans are as valuable as raindrops. That's one reason why sales of Profile Industries' spiral separators to the agriculture market have sprouted this summer. "A 300 percent increase in sales this year would be a conservative estimate," says Steve DeJong, Vice President of Sales and Engineering with Profile Industries. His separators are being snapped up by international seed companies such as Monsanto, Pioneer, Cargill and Syngenta.

The U.S. drought and the resulting losses in corn and soybeans, the nation's two biggest crops, will have a significant impact on seed prices. Soybeans for food consumption are normally around $10 per bushel. Projected prices for this year are $15 to $17 per bushel. Soybeans grown for replanting will have similar price increases.

THE NEED TO CAPTURE EVERY SEED

Spiral separators separate damaged, flat or wrinked seed from the desired round-shaped healthy seed. They also divide round seed, such as mustard, rape, soybeans and peas, from flat seeds and debris. Spiral separation is a straightforward process that is dependent on the laws of physics and a precisely designed piece of equipment. The seed material is discharged onto a banked metal flight, which is spirally wound around a central shaft. As the material flows down the banked surface, its speed increases, and centrifugal force carries it toward the outer edge of the flight. Round materials achieve a velocity sufficient to carry them over the outer edge of the flighting. Non-rounds and less dense material are unable to reach the edge. They continue to travel downward, and ultimately exit separately at the bottom.

While a few desireable seeds will end up in the reject bin with any seed separator, Profile's spiral separators capture more good seed than the older-technology gravity separators. Up to 5% percent of the material in the reject bin of a gravity separator will be good seed. Run the same amount of seed through a Profile rotary spiral separator and only .0025% of the material in the reject bin will be good seed. Throwing away good seed is throwing away money and no one can afford to do that, especially this year. The higher yields quickly pay for the investment in new equipment. Mr. DeJong estimates that his machines pay for themselves within six months.

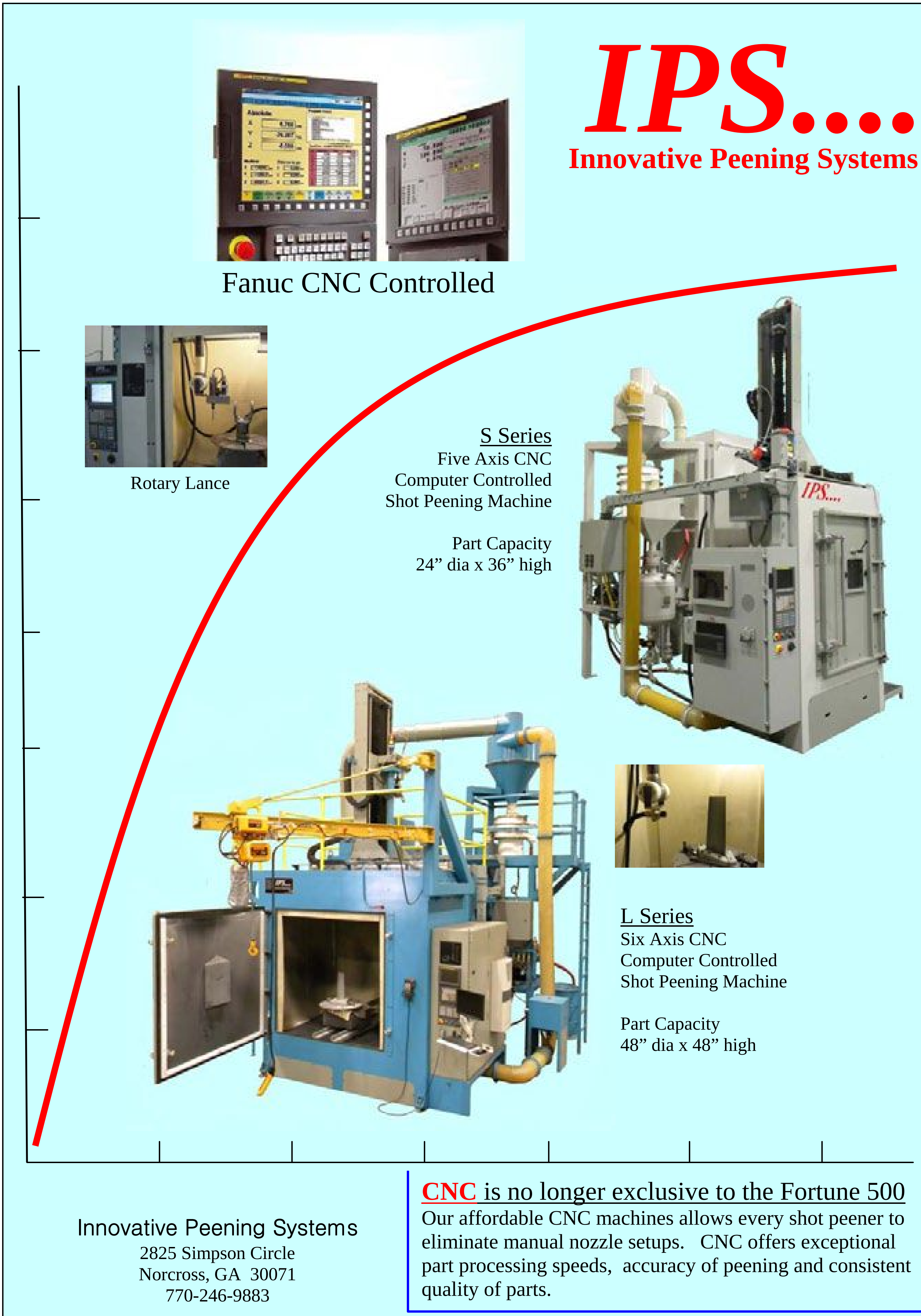
Damaged seeds, like these soybeans, can't achieve enough speed to escape from the inner flight of a separator and they exit the bottom of the machine.

MORE CONTROL EQUALS BETTER YIELDS

Profile recently introduced a motorized rotary spiral separator with a PLC/HMI controller. Machine operators can now quickly and easily adjust motor speed—and thereby the rotation speed of the spiral core—based on differences in the size, weight and shape of the seed material. Since the speed of the material as it moves through the separator is one of most important variables when separating good from undesirable material, the new motorized machines produce higher yields of good product. Most of Profile's sales to seed companies are of the new rotary spiral separator.

Profile is growing their sales to the glass bead market, too, thanks to their new generation of separators. A leading producer of glass beads uses Profile's separators to capture up to 80% more good glass bead than they captured with their

Profile's products for the industrial and agriculture market are the same. The differences between surface finishing media and seeds are easily accomodated by a variety of metal flight sizes and the number of spirals in a separator.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older separators. "The metal finishing industry is slower to appreciate rotary spiral separators than the farming industry but some sectors, like glass bead manufacturers, are definitely catching on," said Mr. DeJong.

Profile's products for industrial and agriculture markets are similar. The differences between surface finishing media and seeds are easily accomodated by a variety of metal flight sizes and the number of spirals in a separator. There are more similarities than differences between seed and media: Seed in a spiral separator is as noisy as metal shot. An estimated 50 percent of Profile's agriculture market sales have been of their enclosed spiral separator that reduces noise and dust.

The machine operator can adjust the variable separation speed of Profile's enclosed Rotary Spiral separator. It's used in industrial and agriculture applications where more control and noise reduction are required.

PLANNING FOR FUTURE GROWTH

The drought isn't the only contributing factor to Profile's success in the agriculture market. Mr. DeJong has aggressively marketed their products to global seed companies at agriculture trade shows in the past year, spreading awareness of the benefits of reduced waste, increased productivity and higher profits of their rotary spiral separators. "There is a natural migration from the old technology in static and spiral separators to rotary spiral separators," said Mr. DeJong. "I wanted to make sure we had top-of-the-mind awareness when buyers were ready to make the change. I think the drought speeded up the buying process."

"It wasn't in our business plan to prosper due to the hardship of others so I like knowing that seed companies are using our products to capture more seeds for food now and for planting in the spring of 2013," added Mr. DeJong.

Soybeans Make the World Go 'Round

Round soybeans are better in agriculture, just like round media is better in shot peening applications. An oval soybean has the same properties has a round bean, but the market—especially the food market—prefers a round bean. China drives this preference and even though most of their soybeans go into tofu where the shape of the soybean is irrelevant, the Chinese buyers prefer round beans, according to Steve DeJong with Profile Industries.

Dave Barkley | Director | Electronics Inc. Education Division

On-Site or Workshop?

I'M OFTEN ASKED to help people evaluate which training program is better for their organization: On-site training or a workshop. Each training format has its own benefits and the determining factors are usually the company's proximity to an upcoming workshop, the number of students, and whether or not they have special training needs. This article will point out the differences between the two types of training; however, our staff is always happy to help you determine the best option for you and your company.

BENEFITS OF AN EI WORKSHOP

- Training topics cover every aspect of quality shot peening and blast cleaning processes for beginning, intermediate and advanced students
- Students have the opportunity to meet their peers from other companies and countries
- Instructors are industry experts that are chosen for their experience, professionalism, expertise and presentation skills
- Most workshops have trade shows with the latest products and services from world-class vendors
- Workshops are located in vacation spots and include social events and tours of local shot peening facilities and other points of interest, when possible
- Attendees are eligible for the Shot Peening and Flapper Peening Certification Exam Programs
- Workshop training is usually more cost-effective than on-site training for groups smaller than five

BENEFITS OF EI ON-SITE TRAINING

- Training can be customized to meet a facility's unique needs
- Employees can be trained on their in-house equipment
- On-site training includes a facility and equipment review to evaluate your organization's ability to accomplish specific procedures or meet specifications
- Instructors are experienced trainers chosen for their expertise in your industry and applications
- No travel time — on-site training is an efficient use of your employees' time
- Training can be done at any time of the year
- Attendees are eligible for the Shot Peening and Flapper Peening Certification Exam Programs
- Very cost-effective for five or more employees

For Managers Only:
Three Reasons to Invest in Shot Peening Training

1 Shot peening training builds real-life skills. Students gain a deeper understanding and appreciation for the process as well as practical knowledge on how to monitor and control every step of the process (media, equipment, intensity, coverage) on the shop floor. The hands-on training segments and exams are effective ways to deliver knowledge that stays with the student once they are back in their own work environments.

2 You say, "Would if I train them and they leave?" We say, "Would if you don't train them and they stay?" If your work environment fosters growth, you are more likely to recruit and retain good employees. And training can improve attitudes. Our training events are upbeat and engaging. Students enjoy meeting peers from other companies and talking about their jobs (this is a great learning opportunity, too). They meet with instructors and trade show vendors and ask questions pertinent to their responsibilities. They come away with a new sense of pride and enthusiasm for their work. As far as the second point, you already know how undeveloped skills and lack of knowledge undermine the integrity of your shot peening program.

3 Buy-in comes from the top in your organization. We offer a group discount to encourage managers and foremen to attend the training programs with their crew. Quality shot peening is a team effort and there is no better way show your commitment to success than to participate with your team. Sharing in the program also enables you to more effectively integrate what your staff has learned into their workflow.

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- The recording of process parameters in real time including date, time, job description, user ID, selected intensity, selected RPM and actual RPM.
- The transfer of reports to a PC using the included 2Gb USB memory key.
- The possibility to input personal "Intensity vs. RPM" curves for up to 5 operators.
- A user-friendly touch screen interface.
- A stopwatch and countdown timer.
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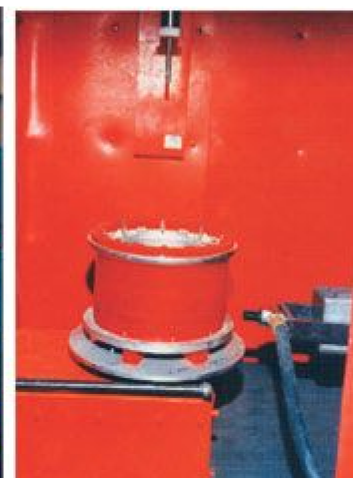

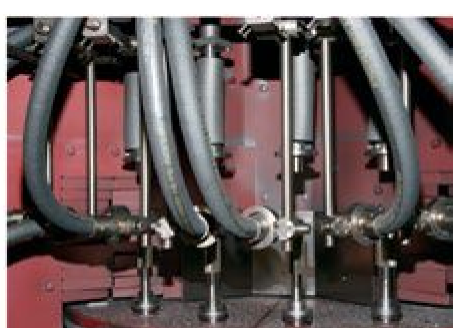

All Fixtures A-2 Tool Steel (62-64 RC)

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Engineered Abrasives manufactures custom and turnkey equipment for high-volume applications. Our machines are used around the world in the most demanding shot peening and blast finishing operations. We specialize in patented rotary index machines for the automotive and aerospace industries. Our index machines aren't just rugged—they are smart, too. Every action is controlled and monitored and our closed-loop systems ensure foolproof and safe operation. No media or energy is wasted at any point in the operation.

We also manufacture industrial blast conveyor systems, abrasive blast table machines, CNC abrasive blast machines, dust collectors, air deburring machines, pressure vessel systems and sand blasting equipment.

We design and fabricate all equipment at our plants in Illinois and ship around the world. We are experts at transporting and installing machines in our customers' facilities and our training and support ensures a fast start-up on the new equipment.

Machine Rebuilds

We take the manufacturing know-how that makes our new equipment a great value and apply the same principles to our rebuild work. Rebuilds are an economical alternative to new equipment and an updated machine will increase efficiency and reduce media, maintenance and energy expenses.

Job Shop Services

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Engineered Abrasives provides shot peening and blast finishing services on the most state-of-the-art equipment on the market today—our own. We will analyze your part and provide competitive pricing with quick turnaround. After we complete the metal treatment, we use high pressure spray washes and ultrasonic wash/rinse and dry systems to clean your parts and assure that they arrive at your facility ready to use.

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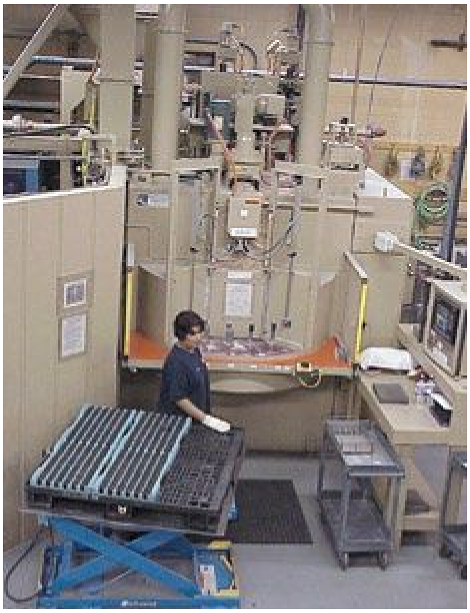

Engineered Abrasives is an ISO/TS16949, ISO 14001 and Ford Q1 certified job shop. We meet SAE and international standards and our patented machines and processes can handle a wide range of parts.

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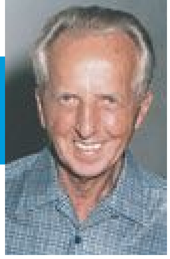
Bringing shot peening or blast cleaning in house can be a big project. However, ordering your equipment from Engineered Abrasives guarantees a partnership that will make your company a successful metal finishing facility. First, we will carefully analyze your needs and goals. Your Engineered Abrasives equipment will be the ideal solution, now and in the future. While we build your shot peening or blast finishing machine, we can process your parts in our job shop so you don't lose production time. Upon delivery of your equipment, we will train your team on your new machine. And, if you have a high-volume run, count on us to help you meet your deadlines at our job shop. We are able to duplicate your production capabilities and this tandem approach assures high-quality and consistent production runs.

Our unique tandem approach ensures the success of your in-house shot peening or blast finishing operation.



ACADEMIC STUDY

Prof. Dr. David Kirk | Coventry University, U.K.

Satisfactory Peening Intensity Curves

INTRODUCTION

Obtaining satisfactory peening intensity curves is a basic priority. Such curves will:

1 Allow acceptable derivation of the peening intensity,

2 Help in determining the time required to achieve specified coverage levels and

3 Indicate the stability of the arc height measurements as a function of time.

Achieving these objectives is assisted by knowing the factors that constitute a satisfactory peening intensity curve. The first objective is very well-documented but the other two are often either overlooked or ignored. As an extreme example consider the situation shown in fig.1. This would be universally classed as being an unsatisfactory peening intensity curve. The data set indicated is not impossible. It could have involved a "pre-bow" of 25μm for a measured unpeened strip together with four strips peened using a rapidly-falling air-blast pressure.

A "best-fitting" curve is shown in fig.1. This was obtained by using a curve-finder program – which revealed a type of "rational function" as having the "best fit". This curve is, however, inappropriate as it does not remotely resemble the shape that a peening intensity curve should have if the shot stream is reasonably stable. Attempts to fit this data set to a more familiarly-shaped curve do, however, generally fail.

It is clear that:

Data should be fitted to a suitable type of curve – rather than the other way round.

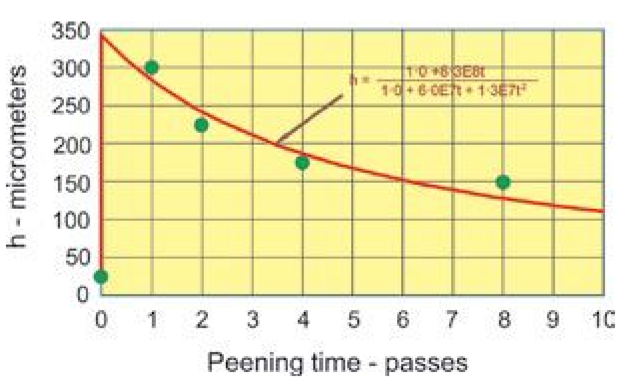


Fig.1 Unsatisfactory Peening Intensity Curve indicating an unstable shot stream.

1 SATISFACTORY DERIVATION OF THE PEENING INTENSITY

Several factors affect whether or not a given peening curve can be classed as "satisfactory" in terms of peening intensity derivation. These include pre-bow, curve shape and choice of curve-fitting program

Pre-Bow

Every Almen strip deviates from flatness to some extent. The most significant deviation is called "pre-bow" which can be measured before any peening is applied. Few, if any, shot peeners would include such measurements on a graph. This does, however, lead to a situation where we can have two different saturation curves produced using the same peened strips. One curve represents "Measured arc heights versus peening time" and the other "Change in arc height versus peening time". The difference is illustrated in fig.2.

The pre-bow of 0.001", used for fig.2, is a pure assumption. It is used to illustrate and quantify the effect of a constant pre-bow (if it had been present). The upper curve has the added assumption that the unpeened specimen's measured arc height has been plotted as being zero (even though it would have been measured as +0.001"). Using Solver EXP2P,

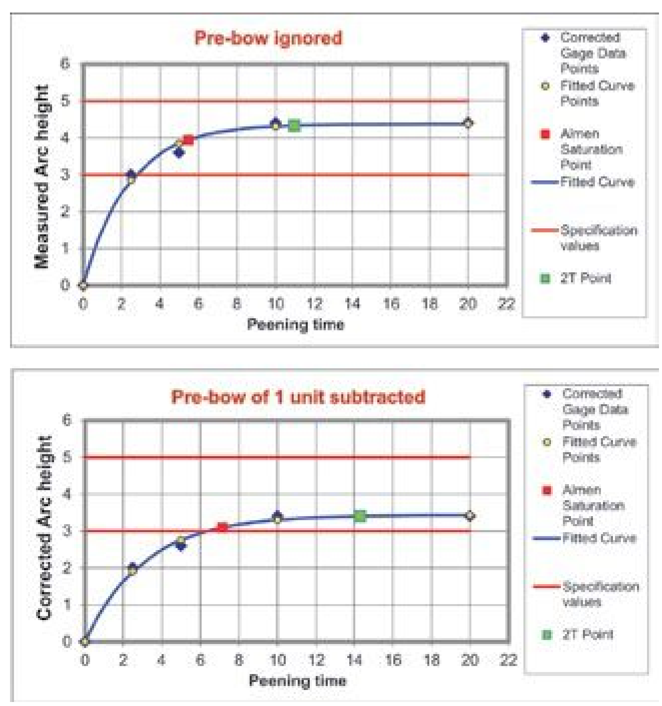


Fig.2 SAE Data set No.2, ignoring and allowing for an assumed constant pre-bow of 0.001".

the upper curve has a derived peening intensity of 3.94 occurring at T = 5.48. This compares with the lower curve's derived values of 3.09 at T = 7.19. Effects of pre-bow can therefore be quantified by using an appropriate peening intensity curve analysis program. J442 specifies a maximum pre-bow of 0.001" for N and A strips and 0.0015" for C strips. This example therefore shows the effect of having a maximum pre-bow. Some specifications, such as the current version of J443, require that any pre-bow be allowed for.

It is generally accepted that every peening intensity curve will pass through the origin (0, 0) of the graph. This general assumption of passing through the origin is useful - it adds an extra point to the number of points that can be employed for estimating the curve's equation.

In practice several strategies are available when faced with the problem of pre-bow:

1 Ignore any pre-bow completely and assume it to be zero.

2 Measure every Almen strip before peening and deduct any detectable pre-bow from subsequent measured arc heights.

3 Use Almen strips for which the pre-bow has been measured and indicated by the manufacturer – again deducting pre-bow from subsequent measured arc heights.

4 Use high-quality Almen strips for which the manufacturer guarantees that the pre-bow will be so small as to be insignificant – therefore assuming it to be zero.

The choice of strategy will depend, to some extent, on the rigors of the peening job involved (low-spec or high-spec) and the attitude adopted by the shot peener.

Satisfactory Shape of Fitted Peening Intensity Curve

Every curve has a corresponding equation that defines its shape. A satisfactory shape (and hence equation) of a peening intensity curve should meet the following criteria:

C1 The curve will pass through the origin of the graph (0,0).

C2 An initial rapid, almost linear, increase in arc height will be followed by a continuous reduction in the rate of increase.

C3 The rate of arc height increase becomes small after considerable peening.

C4 The curve should be capable of yielding the peening intensity values for the sets of data included in J2597 (derived to within the limits prescribed).

A pivotal problem is to decide on an acceptable equation that will represent a satisfactory shape. One approach, used by the French Standards Committee, is to name a single, two-parameter, equation that must be used when working to their specifications. The SAE Sub-Committee on computerized curve fitting has adopted a different approach. This is that any fitting-equation is acceptable provided that it yields derived peening intensity values that lie within prescribed limits of ± 0·001" when applied to its reference data sets, see Table 1.

Table 1
SAE J2597 Data Sets for Peening Intensity Curve Verification

Set 1		Set 2		Set 3		Set 4		Set 5	
Time	Arc height	Time	Arc height	Time	Arc height	Time	Arc height	Time	Arc height
4	0.0060	2.5	0.0030	3	0.0065	1	0.0038	4	0.0062
6	0.0069	5	0.0036	6	0.0081	2	0.0051	6	0.0070
8	0.0070	10	0.0044	12	0.0088	3	0.0052	8	0.0072
12	0.0070	20	0.0044	24	0.0090	4	0.0053	12	0.0072
Intensity	**0.0064**	**Intensity**	**0.0040**	**Intensity**	**0.0080**	**Intensity**	**0.0048**	**Intensity**	**0.0066**

Set 6		Set 7		Set 8		Set 9		Set 10	
Time	Arc height	Time	Arc height	K/Feed	Arc height	K/Feed	Arc height	K/Feed	Arc height
1.1	0.0046	2	0.0055	0.25	0.0081	0.25	0.0108	0.25	0.0045
2.3	0.0087	3	0.0066	0.50	0.0096	0.50	0.0129	0.50	0.0054
4.5	0.0101	4	0.0067	0.75	0.0100	0.75	0.0137	0.75	0.0059
9	0.0107	6	0.0068	1	0.0103	1	0.0144	1	0.0058
Intensity	**0.0098**	**Intensity**	**0.0063**	2	0.0108	2	0.0157	2	0.0062
				4	0.0113		0.0164	4	0.0064
				Intensity	**0.0093**	**Intensity**	**0.0137**	**Intensity**	**0.0054**


EI LOT# 98447/1-03P
EI LOT# 98447/1-03P
EI LOT# 98447/1-03P

These data sets correspond to a wide range of peening conditions. The derived intensity values are the averages of values produced using four different curve-fitting procedures.

Training in the use and selection of a satisfactory equation is provided by the Solver suite of Excel programs available through Electronics Incorporated at www.shotpeener.com/learning/solver.php. This offers a range of equations where user choice is available. A general guide is that:

1 A two-parameter equation should always be used when the data set contains only four points (excluding 0,0).

2 A three-parameter equation offers a better approach to the true shape of a perfect saturation curve but should normally only be used for data sets containing six or more points representing a reasonably stable shot stream. It can also be used for data sets containing five points but with an added proviso. This is that the five-point data set should represent a stable shot stream and therefore be a reasonably good fit to the curve.

Choice of Program for Deriving Peening Intensity Values

Users normally have a variety of programs to choose from, unless working to the French specification. There are a few companies that have their own in-house programs whose use is, presumably, prescribed. Alternatively there are either free programs, such as the Solver Suite, or commercial programs. The Solver Suite has always been intended to be educational – giving users an insight into how curve-fitting is carried out and subsequently analyzed to yield Peening Intensity and T values. It has, however, found extensive commercial application.

An important question is "Do different programs yield different peening intensity values when fed with the same data set?" The answer is "Yes – but the differences are so small as to be insignificant".

The target intensity values in Table 1 were themselves obtained as the averages of four different programs (A to D of Table 2). Table 2 is a compilation of the SAE results together with results obtained using the Solver Suite Programs EXP2P, 2PF and a commercial program shown as "COM 1". All seven programs satisfied the SAE peening intensity criterion for every one of the ten data sets. Seven is just large enough a number to afford statistically-significant standard deviation values – shown as STDEV in Table 2.

The values shown in Table 2 are very encouraging with respect to derivation of peening intensity, generally showing very close agreement for the different programs. The average percentage standard deviation is only 1.78 ("% Dev" being 100*STDEV/Average). It should be noted, however, that all of the ten SAE data sets represent 'good data'.

2 INDICATION OF PEENING INTENSITY TIMES

Another important question is "Do different programs yield the same peening intensity times when fed with the same data set?" The answer is "No – the differences are not large but they are significant".

The time, T, at which any given peening intensity value occurs is an indication of the rate of coverage that could be achieved using the corresponding shot stream. It is, therefore, of some interest to examine the effect of different programs on derived T values. Table 3 on page 30 gives these times for the seven programs shown in Table 2 applied to the ten SAE data sets. It is apparent that there is a much greater fluctuation of intensity times than for the intensity arc heights shown in Table 2. The average percentage standard deviation value again quantifies this difference – 11.27% for T compared with only 1.78% for arc height, H, at T. It can be concluded that different programs predict peening intensity times that can be significantly different from one another.

Table 2
Summary of Peening Intensities derived by applying different programs to SAE Data Sets

Program	Peening Intensities for different SAE Sets - inch x 1000									
	1	2	3	4	5	6	7	8	9	10
A	6.4	4.0	8.0	4.8	6.6	9.8	6.2	9.9	13.5	5.4
B	6.3	4.0	8.0	4.8	6.5	9.7	6.2	9.4	13.7	5.4
C	6.5	4.0	7.9	4.9	6.7	9.8	6.4	9.2	13.9	5.3
D	6.4	4.0	8.0	4.9	6.6	9.9	6.3	9.3	13.7	5.4
EXP2P	6.4	3.9	8.0	4.8	6.6	9.8	6.3	9.6	13.8	5.5
2PF	6.4	4.0	7.9	5.1	6.6	10.7	6.4	9.4	13.7	5.4
COM1	6.4	4.0	8.0	4.8	6.6	9.9	6.2	9.0	12.9	5.2
Average	6.40	3.99	7.97	4.87	6.60	9.94	6.29	9.40	13.60	5.37
STDEV	0.06	0.04	0.05	0.11	0.06	0.34	0.09	0.29	0.33	0.10
% Dev	0.90	0.95	0.61	2.28	0.87	3.43	1.43	3.07	2.44	1.77

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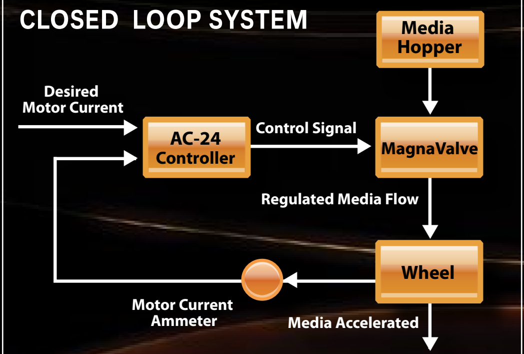

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Table 3
Summary of Peening Intensity times, T, derived by applying different programs to SAE Data Sets

Program	Derived peening Intensity times, T, for different SAE Sets									
	1	2	3	4	5	6	7	8	9	10
A	4.64	6.73	6.30	1.90	4.80	4.49	2.74	0.44	0.63	0.51
B	4.43	5.92	5.38	1.73	4.50	3.76	2.59	0.42	0.63	0.47
C	5.42	6.64	5.29	1.95	5.27	4.03	3.07	0.39	0.69	0.40
D	4.72	6.70	5.63	1.89	4.70	4.19	2.80	0.44	0.71	0.50
EXP2P	4.75	5.48	5.38	1.81	4.73	3.92	2.76	0.43	0.55	0.46
2PF	4.75	7.05	6.17	2.62	4.71	6.93	3.36	0.47	0.66	0.50
COM1	4.70	6.72	6.21	1.87	4.81	4.42	2.72	0.3	0.45	0.39
Average	4.77	6.46	5.77	1.97	4.79	4.53	2.86	0.42	0.62	0.46
STDEV	0.31	0.55	0.45	0.30	0.24	1.09	0.26	0.05	0.09	0.05
% Dev	6.42	8.55	7.72	15.07	4.92	24.00	9.18	11.69	14.57	10.57

It may be hypothesized that all of the seven programs indicated in Tables 2 and 3 involve two-parameter equations that are exponential to some maximum value. EXP2P and 2PF programs have equations showing the variation of arc height, h, with peening time, t:

EXP2PF $\quad$ **h = a[1 – exp(- b*t)]**

2PF $\quad$ **h = a[t/(1-b*t)].**

These equations both have "a" outside a bracket. The bracket contains the second parameter "b" as a function of the peening time "t". The unique peening intensity arc height, H, and time, T, are derived from the two equations as follows:

EXP2P $\quad$ **H = 9*a/10 @ T = 2.303/b**

2PF $\quad$ **H = 9*a/11 @ T = 4.5*b**

Applying the equations to the SAE Data Set No.2 gives the results illustrated in fig.3. Fitting EXP2P to the four data points yields a = 4.38 and b = 0.42. 2PF yields a = 4.86 and b = 1.57. Substituting these values predicts that for EXP2P: H = 3.94 at T = 5.48 and for 2PF: H = 3.98 at T = 7.05. The difference in peening intensity predictions (0.04 thousandths of an inch) is tiny when compared with the difference in T-value predictions (1.57).

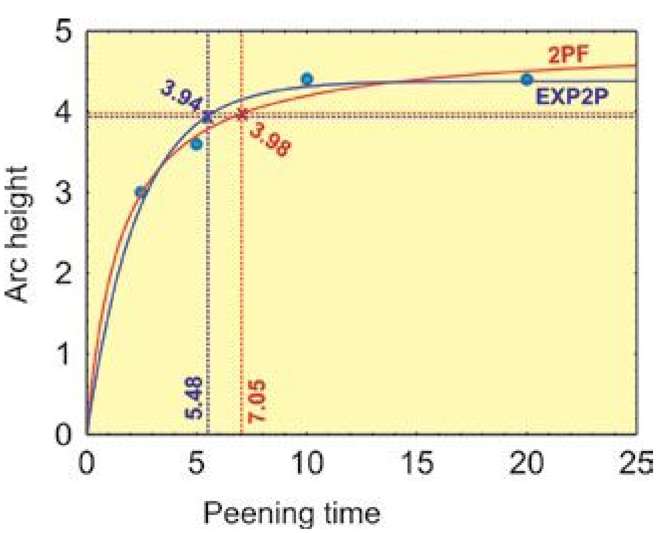

Fig.3 Two different programs applied to SAE Data Set No.2

Special Cases

The current version of J443 allows for "Special Cases". These are declared to be those when a single pass imposes such intensive coverage that it exceeds a corresponding T value. Fig.4 shows the idealized graph and 'virtual' data points that demonstrate a "Type II Saturation Curve". This is unsatisfactory insofar as the 'unique point' at one pass depends on the particular data and the time, T, is vague.

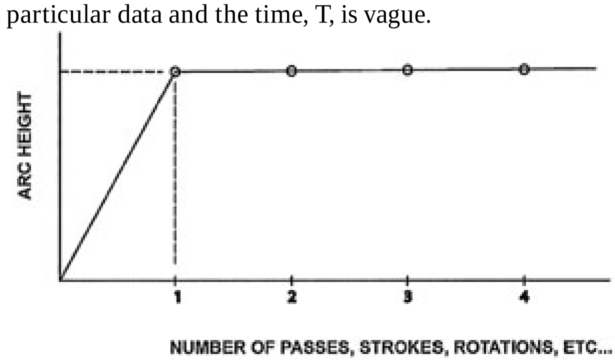

Fig.4 Type II Saturation Curve for Special Cases

A conventional shape of saturation curve could, however, be generated for Special Case situations. This would necessitate modification of the J442 strip holder requirements. Possible modifications range from simple to complex. One simple modification would involve a set of hardened steel masks with holes drilled to different area percentages. Different masks would expose the strip to different percentages of the shot

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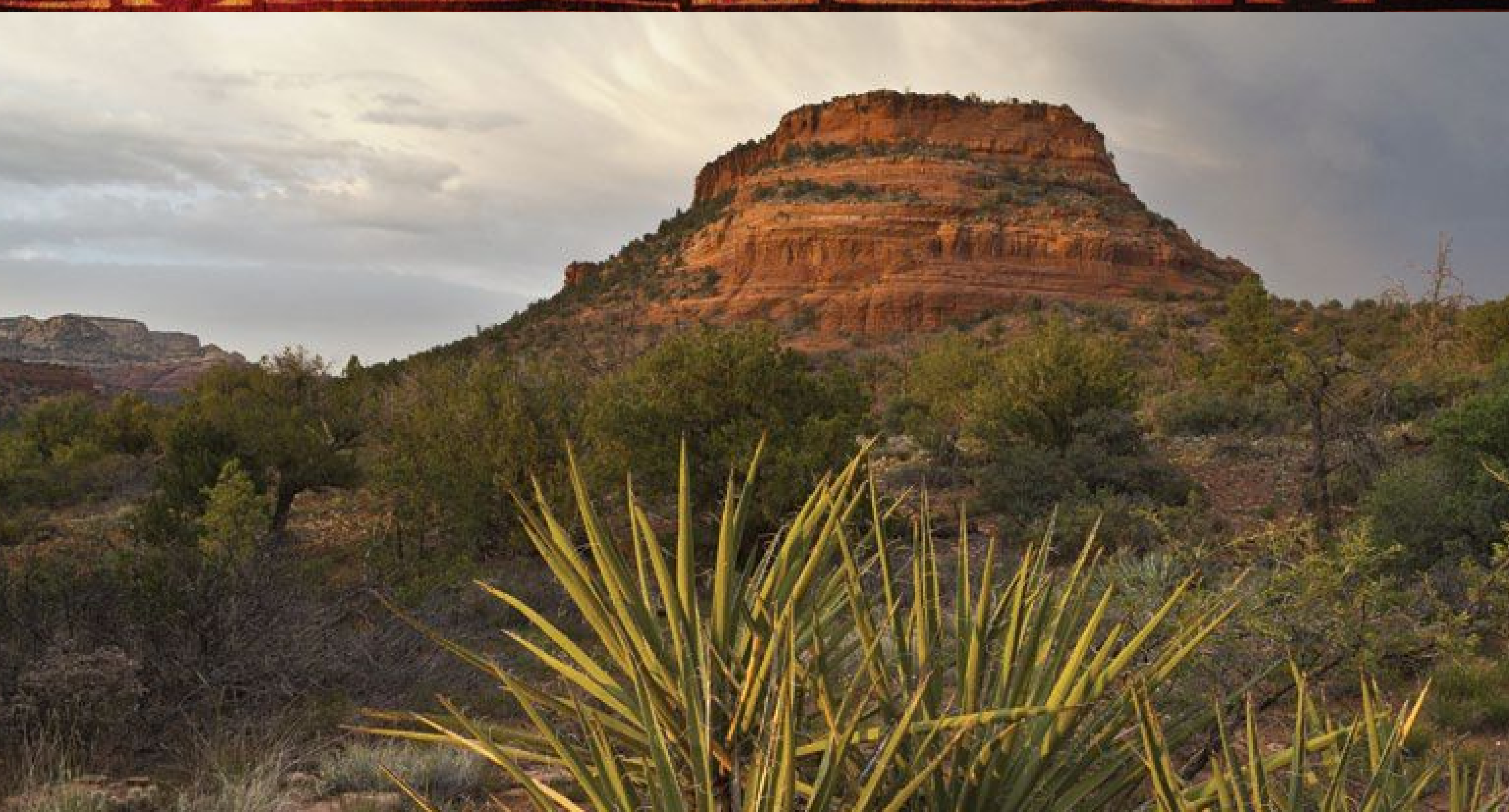

Shot Peening and Blast Cleaning Workshop

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stream. A complex modification would involve a motorized strip holder with variable movement speeds triggered by an incoming shot stream. The movement speeds, in the opposite direction to that of the shot stream, could be percentages of the shot stream travel speed. This would reduce the exposure time to fractions of the stream speed. With either modification a given strip's exposure could be reduced by controlled amounts.

3 STABILITY OF THE ARC HEIGHT MEASUREMENTS AS A FUNCTION OF TIME

The stability of arc height measurements can be quantified using a "Goodness of Fit" analysis. "Goodness of fit" is simply a measure of how closely data points are to a given fitted equation. If every data point lies exactly on the curve then we have a perfect fit. In practice there are always some deviations from the curve. These deviations are termed "residuals" and are the numerical difference between the data point value and the corresponding curve value. If, for example, the arc height measurement is 10.8 and the corresponding value on the fitted curve is 10.881 then the "residual" is 0.081. Table 4 is an extract from the worksheet of Solver Suite Program 2PF applied to SAE Data Set No.8. The data point values in the "Corrected" column have been highlighted to show the distribution of positive and negative residuals.

Table 4
Extract showing distribution of Residuals arising from curve fitting 2PF

Time	Arc Height	Pre-bow	Corrected	Calc. Y	Residuals
0	0	0	0	0	0
0.25	8.1	0	8.1	8.10238	0.0023759
0.5	9.6	0	9.6	9.49129	-0.108713
0.75	10	0	10	10.0665	0.0664861
1	10.3	0	10.3	10.381	0.081047
2	10.8	0	10.8	10.8916	0.0915615
4	11.3	0	11.3	11.1661	-0.133877

The commonest parameter used for estimating all data point/curve deviation situations is called "R-Square". This very powerful parameter is defined as:

R-Square = 1 – SSE/SST

where **SSE** is the **Sum of Squares due to Error**

and **SST** is the **Sum of Squares Total**

SSE appears as "**SUM**" in all of the Solver Suite of programs. It is simply the sum of the squares of the residuals' values. For the example shown in Table 4 "**SUM**" = 0.04912. **SST** is again a sum of squared values. Each value is that of the difference between the measured value and the average of the measured values. For example the average of the six corrected values in Table 4 is 10.02 so that the first squared value is $(8.1 – 10.02)^2$. Adding up the six squared values gives **SST** = 6.1884. R-Square is therefore given by:

1 – 0.04912/6.1884 so that **R-Square = 0.9921**.

0.9921 is more than 99% of the possible maximum value for R-Square (which is 1.0000). Hence we can say, quantitatively and objectively, that the 'Goodness of Fit' is 0.9921.

The requisite calculations for SST and R-Square were made automatically - using a simple modification to the corresponding Solver Suite program – illustrated by the pasted extract shown as Table 5. Calculated values of R-Square can also be compared automatically with a fixed minimum allowable value. If the set minimum value is not achieved then a "Warning" can be flagged-up automatically.

Table 5
R-Square calculation using the same Data Set as for Table 4

-1.91667	3.673611
-0.41667	0.173611
-0.01667	0.000278
0.283333	0.080278
0.783333	0.613611
1.283333	1.646944
SSE	0.04912
SST	6.188333
R-Square	0.992062

CONCLUSIONS

The production of computer-generated peening intensity curves is rapidly becoming standard practice. Increasing awareness of computer techniques will encourage a more detailed knowledge and understanding of the possibilities that computer programs can offer. That is certainly true when it comes to deciding whether or not a satisfactory peening intensity curve has been generated for a particular data set. Some of the factors that define 'satisfactory' have been discussed in this article. With a satisfactory peening intensity curve the three main uses (acceptable intensity derivation, help in determining time required to achieve specified coverage levels and indication of stability of arc height measurements) can be employed.

Visual examination for factors such as goodness of fit can be employed but that is a very subjective process. Objective quantification, based on computerized curve analysis, is a characteristic feature of the factors discussed in this article.


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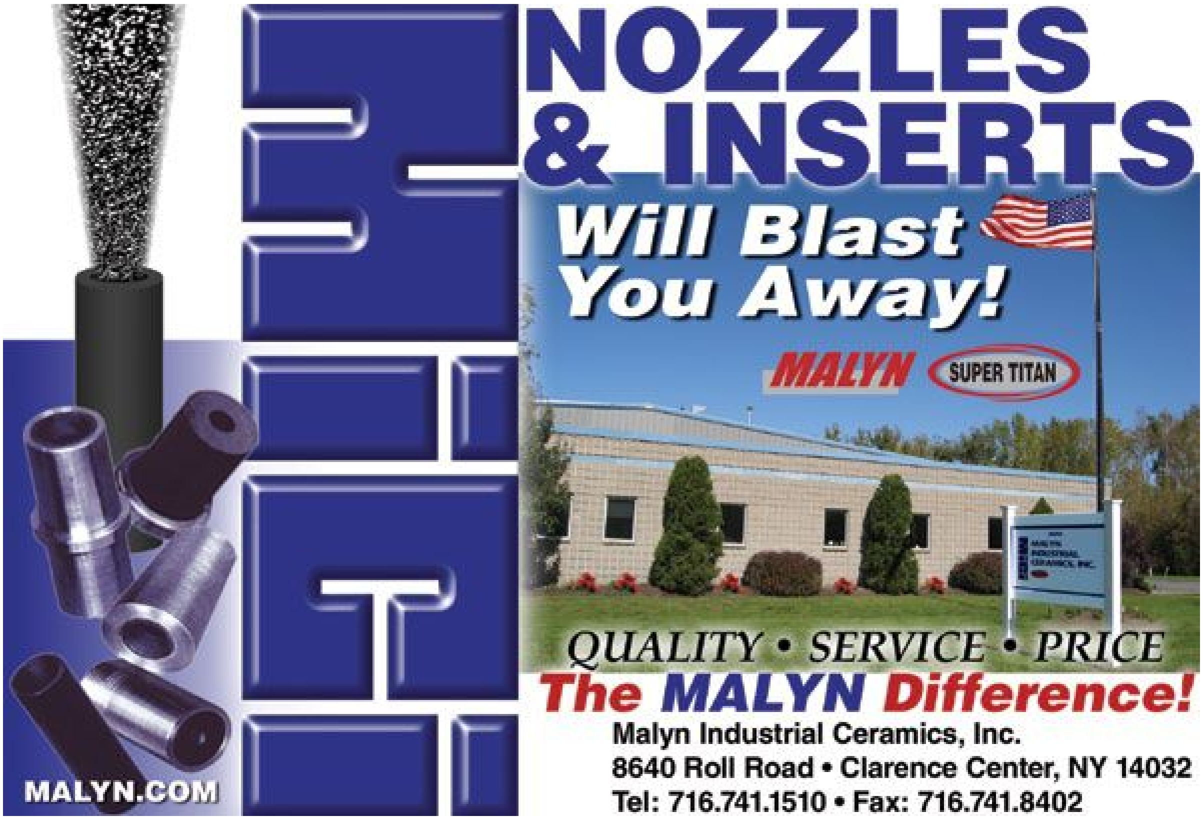
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Army Research Lab Uses XRD to Evaluate Shot-Peened Aerospace Materials

THE U.S. MILITARY is in fat-trimming mode and is cutting aerospace budgets through aircraft sustainment and the implementation of lighter, stronger aerospace materials that will reduce aircraft weight without sacrificing strength. Since shot peening is a useful tool for accomplishing both of these goals, the ability to evaluate shot peening's results is just as important.

The Army Research Lab (ARL) in the Aberdeen Proving Ground in Maryland was commissioned by the U.S. Army Aviation and Missile Research Development and Engineering Command to evaluate variations of shot peening intensity on several aerospace materials with x-ray diffraction (XRD).

The results were published in a paper titled, "Using XRD Elastic and Plastic Strain Data to Evaluate the Effectiveness of Different Cold-Working Techniques in Aerospace Materials." The paper was written by Beth S. Matlock with TEC, and Daniel Snoha and Scott Grendahl, both with the U.S. Army Research Laboratory. The following is a synopsis of the paper; the paper in its entirety is available at www.shotpeener.com/library. (The paper also reviews a cold-worked hole study from the U.S. Air Force.)

Shot peening is a widely used surface treatment in OEM and MRO facilities because it imparts compressive residual stresses that enhance fatigue life. These residual stresses are elastic and develop or change as a result of the plastic flow of a material. XRD is an excellent tool for measuring elastic and plastic strains in shot-peened materials. It is a direct method for measuring elastic strains and plastic strain can be determined by measuring the diffraction peak width at half the maximum intensity (FWHM). See Figure 1.

Elastic Strain
A form of strain in which the distorted body returns to its original shape and size when the deforming force is removed.

Plastic Strain
Strain in which the distorted body does not return to its original size and shape after the deforming force has been removed.

Procedure

Titanium 6Al-4V (Ti-6-4), 4340 and 9310 steels and 7075-T73 aluminum were chosen for this study. An Almen strip intensity study of variations in impingement angle, air pressure, media flow rate and stand off/nozzle distance was used to establish desired shot peening parameters for the disks and fatigue specimens used in this study. The ARL staff used TEC 1610 and 4000 systems for the x-ray diffraction work.

Results

The residual stress (RS) and full width-half maximum (FWHM) data are shown in Figures 2-6. This data represents the average of six separate measurements. V1 and V2 are different vendors while 4A - 12A and 3N - 14N represent A- and N-scale shot peening intensities, respectively.

The 4340 steel surface residual stresses ranged from 488.2 MPa (-70.8 ksi) for V2-12A to -593.0 MPa (-86.0 ksi) for V1-4A. For these samples, the maximum compressive stress occurred at the 0.025 mm (0.001″) and 0.051 mm (0.002″) depths and ranged from -576.4 MPa (-84.6 ksi) to -610.2 MPa (-88.5 ksi) for the V2-12A and V2-8A intensities.

Peak Width-Full Width at Half Maximum (FWHM)

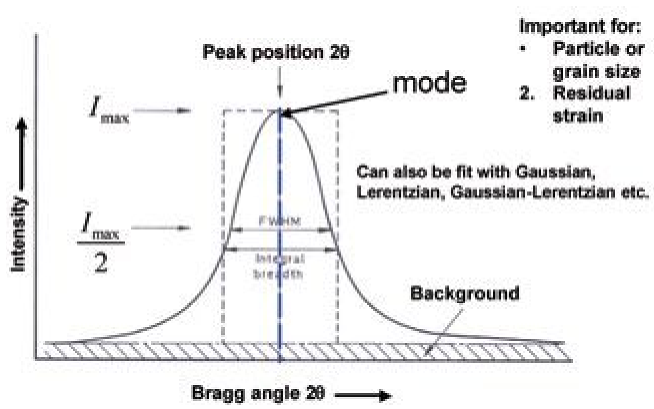

Figure 1. FWHM is the width of the diffraction peak, in radians, at a height half-way between background and the peak maximum.

The depth of compression from maximum to minimum for the different shot peening conditions was V2-12A, V1-8A, V2-8A, V2-4A, and V1-4A.

The diffraction peak widths (FWHM) ranged from 2.84° to 3.17°. For all cases, the maximum FWHM was at the surface. The largest to smallest FWHM values for the different shot peening intensities were V2-12A, V1 and V2-8A, V2-4A, and V1-4A. See Figure 2.

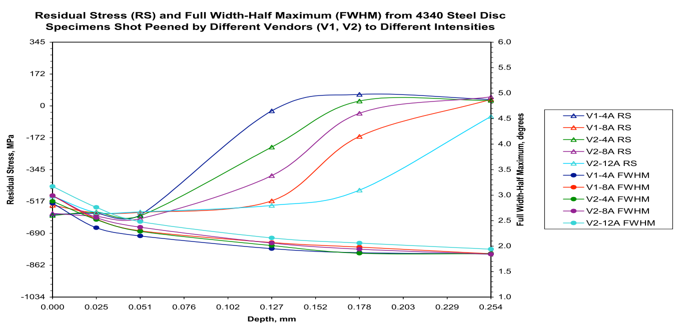

Figure 2. Residual Stress and Peak Width Profile for 4340 Steel

Trends for the 9310 steel followed the pattern for the 4340 steel; however, the compressive stresses were higher. The depth of compression from maximum to minimum was V2-12A, V1-8A, V2-8A, V2-4A and V1-8A. The maximum to minimum FWHM order was V2-12A, V2-8A, V1-8A, V2-4A, and V1-4A. Allowing for slight differences in vendor processing, the trend still followed the maximum to minimum shot peening intensities. See Figure 3.

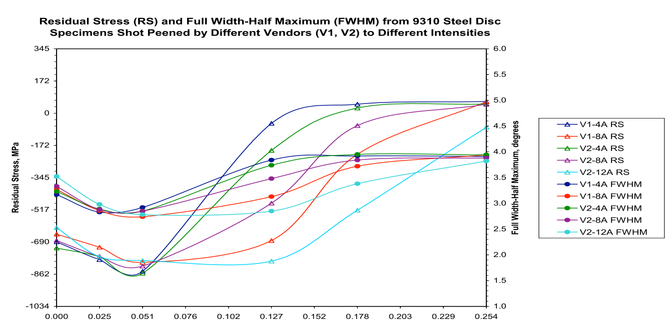

Figure 3. Residual Stress and Peak Width Profile for 9310 Steel

The Ti 6-4 samples were shot peened to both A- and N-scale intensities. The A-scale intensities resulted in deeper levels of compression with the maximum to minimum depth of compression order being V1-11.5A, V2-14A, V1-8A, and V1-4A. For these samples, the FWHM order was V2-14A, V1-11.5A and V1-8A, and V1-4A. There was a slight variation in depth of compression and FWHM trends that again can be attributed to vendor shot peen processing differences. See Figure 4.

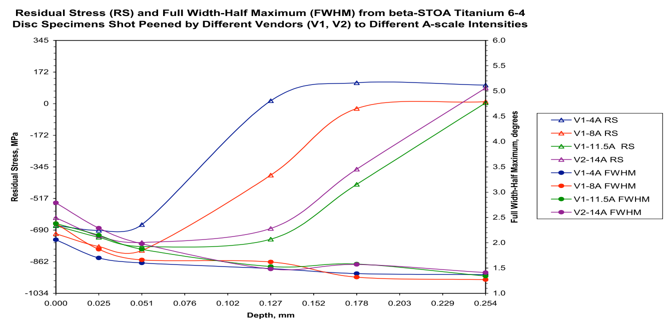

Figure 4. Residual Stress and Peak Width Profile for Ti-6-4, A-Scale

For the Ti 6-4 N-scale intensities data, the compressive stresses approached neutral between 0.025 mm (0.001″) and 0.051 mm (0.002″) for the lower intensity shot peening and prior to the 0.127 mm (0.005″) depth for the higher intensity. The maximum to minimum compression level was V1-14N, V1-11N, V1-5N, and V1-3N. The FWHM data exhibited the same trend as the stress data. See Figure 5.

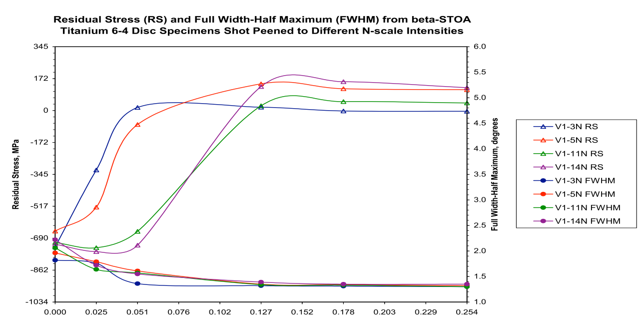

Figure 5. Residual Stress and Peak Width Profile for Ti-6-4, N-Scale

The 7075-T73 aluminum samples remained in compression to 0.254 mm (0.010″). At that depth, the residual stresses for the 10A, 12A, and 14A intensities ranged from -218.6 MPa (-31.7 ksi) to -295.8 (-42.9 ksi). The order of maximum to minimum compressive stresses was V1-14A, V1-12A, V2-10A, V2-12A, V1-10A, and V1-4A. Here the surface FWHM was V1-14A, V1-12A, V1-10A, V2-12A and V2-10A, and V1-4A. Since there was no significant difference in the subsurface stresses for V1-12A, V2-10A and V2-12A, the trend of larger surface FWHM for more compressive depth holds. See Figure 6 on page 40.

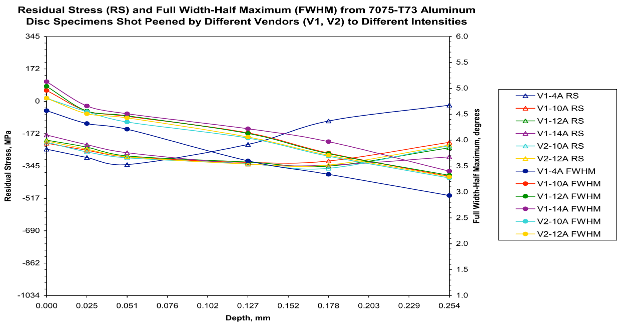

Figure 6. Residual Stress and Peak Width Profile for 7075-T73 Al

Although it is outside the scope of this paper, it is interesting to note that the best fatigue response in most cases did not come from the samples with the highest intensity shot peening. In many cases, the best fatigue performance was associated with the minimum intensity shot peening.

Discussion

X-ray diffraction can non-destructively measure surface stresses. This technique, however, effectively measures stresses in the top few atomic layers of a material. Residual stresses, by definition, are calculated from the elastic strains measured. The diffraction peak width indicates the amount of plastic strain in the part. Coupling surface residual stresses and diffraction peak width can provide information about the effective layer of compressive stresses.

The shot peening study showed that deeper compressive stresses were regularly associated with the higher intensity shot peening. The exceptions were on the Ti 6-4 A-scale intensity samples and the 7075-T73 aluminum samples. For the Ti 6-4 samples, the V1-11.5A shot peening intensity produced a slightly greater residual compressive stress with depth than the V2-14A intensity. And for the 7075-T73 aluminum, the compressive stress in the V2-12A intensity sample was similar but not greater than the V2-10A sample. Although the number of samples tested was small, vendor shot peen processing differences may be the reason these particular samples did not follow the general trend.

Conclusion

Shot peening a sample imparts compressive stresses in the sample. These plastic deformation processes increase the diffraction peak width relative to the amount of the plastic deformation. The XRD technique non-destructively measures elastic (residual stress) and plastic (diffraction peak width) strains at the surface of a sample. When the level of residual stress is compared to the peak width, the depth of compressive stresses can be qualified.

Shooting at Ceramics

IN CORROSIVE, high-temperature environments, metals quickly lose their elasticity. Beyond certain temperatures the material fails and its properties are compromised; metallic springs stop working if heated above 500 degrees Celsius, for example. But what to do if these are exactly the conditions a production process requires? One way of avoiding the problem has been to make components out of ceramic, a material that is lightweight, rigid, corrosion-resistant and able to withstand high temperatures. Yet this only offers a partial solution, as producing thin ceramics for parts such as leaf springs, lightweight mirrors for optical and extraterrestrial use, or membranes for sensors and fuel cells, is both time-consuming and expensive. This is because ceramics can only be machined using costly diamond tools, and the process itself creates tensions within the surface of the material which cause the finished part to distort as soon as it is removed from the machine. Reshaping the components after manufacture has never been a viable option before as the material is too brittle, and so the large amounts of waste that are generated push the costs up.

Precisely Calculated Paths Guide the Way

Researchers at the Fraunhofer Institutes for Mechanics of Materials IWM in Freiburg and for Production Systems and Design Technology IPK in Berlin have now found a way to straighten out distorted ceramics using shot peening, a process by which small pellets, known as shot, are fired at the surface of a component with a blasting gun. The shot strikes the surface and alters the shape of the thin, outermost layer of material. By moving the gun over the ceramic part along a precisely calculated path, scientists are able to counteract any undesired warping or create lightly curved mirrors out of thin, even ceramic plates. "Shot peening is common practice for working metals," says Dr. Wulf Pfeiffer, who manages this business unit at the IWM, "but the technique has never been used on ceramics because they are so brittle – they could shatter, like a china plate being hit with a hammer. This meant that we had to adapt the method to the material with great precision." The researchers began by analyzing which size of shot would be suitable for use on ceramics, as the surface could be destroyed by pellets that were too big. Cemented carbide balls in the range of 90 µm up to 700 µm were chosen. Pellet speed is another critical factor: hitting the material too fast causes damage; too slow and the shape of the surface is not altered enough. They also discovered that it is important not to bombard the same spot too often with too much shot. Before producing a new component, the scientists first conduct experimental analysis to determine what can be expected of the particular ceramic involved. They fire a beam of shot at it and then measure the resultant stresses to see what sort of deformation is possible and how the beam should be directed.

The experts have already produced various prototypes, including a ceramic leaf spring and a concave mirror. For manufacturing simple components, the technique is now advanced enough to be used in series production. The IWM scientists have recently gone one step further and are developing a computer simulation that will allow components to be worked in multiple axes. Meanwhile their colleagues at the IPK are working on automating the process using a robot.

Shot is fired from a blasting gun at a ceramic leaf spring to correct its shape or cause specific warping as desired. (© Fraunhofer IWM, Felicitas Gemetz)

Editor's Note:

Dr. Wulf Pfeiffer will present his paper, "Shaping of Ceramics Using Residual Stresses," at the 9th International Conference on Residual Stresses (ICRS9) in October 2012. He wrote the paper in conjunction with Heiko Höpfel, a fellow researcher at Fraunhofer Institute for Mechanics of Materials IWM. Here is an excerpt from the paper's abstract:

> This paper describes the first successful experiments aimed at shaping ceramic specimens using shot peening. Strips of different thicknesses, made of silicon nitride ceramic, were shot-peened using different shot sizes, peening pressures and coverage. The residual stress-depth distributions were determined using X-ray diffraction. Based on the experimentally-determined stress states, the curvatures of the strips were determined analytically and using Finite Element calculations (FEM).

You may contact Dr. Pfeiffer at wulf.pfeiffer@iwm.fraunhofer.de.